Report on productive and behavioural profiles of smallholder farmers (and their segments) linked to socioeconomic and demographic factors

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Short Description
This report presents the work of multiple partners across the FoodLAND project who have prepared research papers, at a cross country and country specific level, to investigate the productive and behavioural profiles of smallholder farmers and link these profiles to their propensity to adopt different types of innovations, which will be proposed in the framework of the project. We start by reminding the objectives of the research dedicated within the FoodLAND project and introducing the working group created for the purpose of data analysis. Part 1 of the report then presents the papers that have based their research at a cross country comparison level. Secondly, partners' research written on a country specific basis, is presented in Part 2. Finally, we present the key conclusions and policy implications based on all the papers and their findings regarding the behaviour, economic conditions and characteristics of our sampled farmers. We recommend polices that can overall aid farmers and support the uptake of innovations. The appendices include Food Hub specific tables with the characterisation of groups of farmers with similar features and their propensity to adopt innovations.

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Introduction

Context and objectives of the report

This report builds up on previous activities and deliverables within WP3 of the FoodLAND project. Protocols were designed, including a survey and lab-in-the-field experiments, to gain insights on **smallholder farmers' preferences and behaviours as well as individual and contextual conditions relevant to innovation-related decision-making**. The experimental protocols are presented in deliverable D3.2 and accessible on Zenodo (Kuhfuss et al., 2022).
Survey data was collected in 12 Food Hubs, with five of the Food Hubs also implementing the lab-in-the-filed experiments on the same sample of smallholders. As explained in D3.3, the data gathered includes:

1. A **baseline, gender-sensitive survey** measuring **smallholder farmers' structural, organizational, environmental** and **productive factors** (e.g., farm and pond size, techniques adopted, varieties, fertilizing and feeding practices, yields, food losses and waste, and farm workload), **including socio-economic conditions** (e.g., family income, migration choices, and remittance use) affecting the local food supply chains and smallholders' choices.

2. Results of **structured behavioural economic experiments** to identify behavioural factors influencing, either as a barrier or as a driver, smallholders' decision-making.

The approach taken for data collection as well as a preliminary analysis are presented in deliverable D3.3. Relevant key elements of the methodology are included in this report, in each chapter, for ease of understanding of the results presented. The dataset used for the analysis is that included in D3.1.

Approach taken for data analysis and preparation of the report

To facilitate collaboration amongst all partners, a working group was formed in May 2022, primarily focusing on the analysis of the survey data (T3.1) and experimental data (T3.2). The group held recurrent meetings every three weeks, where members attended through video conferencing. Each partner involved in WP3 was represented by at least one researcher. The group members shared their research proposals and progress, whilst econometric tips and advice were also exchanged amongst participants. A diverse skillset within the group cultivated a mutually beneficial environment; specialised skillsets were deployed for certain tasks, and the product shared with everyone. This coordination also allowed for the identification of potential overlaps between the analyses planned by each partner and therefore enabled collaborations on these areas, avoiding duplications. It also ensured that the data analysis, while split between partners, still covered all relevant research questions for the FoodLAND project. Recommendations on how to account for gender-related dynamics in the data analysis and reporting were provided by Elhuyar for each single report. A Teams discussion channel was created to provide

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support and exchange tips for data analysis between meetings of the data analysis working group.

At the last meeting in August 2022, and after five meetings, all research questions and associated data analysis strategy had been identified. Each of these now constitutes one chapter of the current report. Collaborations and co-authorship for each chapter were agreed upon. Smaller working groups were established to progress on each chapter in parallel. Each sub working group prepared a chapter, all chapters were then compiled and homogenised in a single report, after being reviewed by JHI and Elhuyar. Each of these chapters will in the future be developed into a manuscript to be submitted for publication in peer-reviewed academic journals.

Overview of content

Technology acts as a significant driver towards raising well-being and prosperity of smallholder farmers. The efficient and effective production of primary commodities is vital for farmers both to ensure food and nutrition security conditions and to make profits whilst also protecting themselves from vulnerabilities and market volatilities. The papers presented within this report will be illustrating how smallholder farmers in the five FoodLAND African countries perceive innovation, their level of engagement within it, and specific technological areas they are interested in. Whilst also indicating which preferences and socio-economic characteristics significantly influence farmers' uptake of innovation. The data analysed within this report is primarily exploring interests in yield enhancing and limitation overcoming process innovations, in tandem with the introduction of new nutritious and profitable crop/fish products. The impact of innovation adoption can be profound, as explained by Mukasa (2018) on their analysis of smallholder farmers in Uganda and Tanzania. Accordingly, the presented analyses are based on survey and experimental data, thus combining situational conditions and stated preferences with revealed preferences with the aim to consolidate knowledge of farmers' innovation-focused decision-making. Given that this will not necessarily result in uptake of innovation, actual decisions will be monitored in three Food Hubs where randomised controlled trials will be implemented in the framework of T5.9 of the FoodLAND project.

We structure this report in two main parts, each containing a series of chapters. Each chapter can be read as an independent piece of work, but all complement each other. The first part includes 8 chapters providing cross-country analyses of innovation adoption and its links to farmers' behavioural and socio-economic profiles. To complement this analysis, the second part provides additional in-depth analysis of country or Food Hub-specific challenges identified by the working group.

In the first part, Chapter 1 aims, through a cluster analysis, at identifying groups of smallholder farmers with similar productive and behavioural profiles, and linking such profiles to smallholders' stated propensity to adopt different types of innovations, within each of the 12 Food Hubs, thus providing information to orient and better tailor FoodLAND R&I activities and communication in WP4 and WP5. After this first overview chapter, the following chapters investigate with more depth specific factors influencing the uptake of innovations. Chapter 2 looks at the role of time preferences, and how these are influenced by experience of adverse events by farmers, which may affect their ability to adopt

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innovations. Chapter 3 analyses gender differences in the intention to adopt innovations. In order to further define how the characteristics of farmers within the 12 Food Hubs relate to each other and to innovation adoption, chapters 4.1 to 4.3 investigate respectively the determinants of income levels within the Food Hubs, and the broader determinants (beyond gender) of adoption of a nutrient-dense or a more profitable crop, and of a yield enhancing or a limitation-overcoming technology. Chapter 5 investigates how the allocation of household labour to either farming or migration in the single countries relates to household food security. Chapter 6 provides an understanding of the role of farmers' associations and cooperatives in innovation adoption, while Chapter 7 uses experimental results to investigate conditions that may affect farmers' collaboration in the joint adoption of innovations. Chapter 8 investigates inconsistencies in farmers' behaviour during the risk elicitation experiment.

Part 2 includes in depth analysis of country-specific research questions to support the adoption of FoodLAND innovations. It starts with a focus on the Tanzanian Food Hubs (Kilombero and Mvomero), with an investigation of the effect of farm size on propensity to adopt innovations (Chapter 1). Chapter 2 investigates the role of farmers' cooperatives in Tanzania in household livelihoods' improvement. Chapters 3 to 5 focus on the Ugandan Food Hubs, with Chapter 3 investigating the role of associations and cooperation in promoting farmers' welfare as well as the profile of farmers belonging to these groups. Chapter 4 focusses on the Kamuli and Nakaseke Food Hubs (UG), and how the diversity of crops currently grown by farmers affects their ability to meet their food needs. This is followed by an analysis in Chapter 5, of the reasons behind farmers' decision to rotate crops over the years. Chapter 6 turns to the analysis of the likelihood to adopt nutrient dense crops by Kenyan farmers. Finally, Chapter 7 investigates the factors affecting farmers' willingness to be early adopters of agricultural innovation in Tunisia, and outlines future directions of research. Chapter 8 provide a typology of smallholder farmers in the region of Ait Ouallal Bittit, Morocco, their operational systems and constraints for the adoption of technological adoption.

In each chapter, we build on the results obtained to reflect on key implications and recommendations to support the adoption of FoodLAND innovations in different countries and Food Hubs, as well as more general policy recommendations. These are summarized in the conclusion of this report.

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Part 1: Cross country analysis

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Chapter 1: Behavioural and productive profiles of smallholder farmers: Evidence from FoodLAND Food Hubs in five African countries

Authors: Simone Piras (JHI), Gurneet Kapour (JHI)

Introduction

FoodLAND aims at boosting adoption of innovations by smallholder farmers, including both crop and fish farmers, in 13 Food Hubs from five countries in Northern (Morocco and Tunisia) and Eastern Africa (Kenya, Tanzania and Uganda). By improving the quality of agricultural production including conservation and storage, these innovations are expected to enhance local supply chains linking the FoodLAND Food Hubs with local cities, thus promoting agricultural and nutritional diversity.

However, adoption of innovation is not a straightforward process, and faces a number of barriers related to individual resources and preferences, which can result in non-linear adoption from early adopters to latecomers, while some smallholders can decide not to adopt at all. For this purpose, in the framework of T3.1 “Consolidating knowledge of Pan-African crop and fish supply chains” and T3.2 “Behavioural economics research on producers’ preferences and choices,” surveys and incentivised economic experiments have been implemented, aimed to outline smallholders’ productive and behavioural profiles, linked to socioeconomic and demographics characteristics. This chapter aims at addressing the multidimensional complexity of these profiles by identifying a smaller number of groups of farmers with similar productive and behavioural profiles, and linking such profiles to smallholders’ stated willingness to adopt different types of innovations. The results will first feed into T5.9 “Innovation and validation across the network,” which aims at implementing randomised controlled trials in three Food Hubs from Morocco, Tanzania and Uganda, respectively. Second, they will benefit innovators across the full network of Food Hubs by providing an overview of the productive and behavioural characteristics of local smallholders that can be used to define more tailored guidelines to promote the adoption of FoodLAND innovations locally.

Methodology

To identify productive and behavioural profiles of smallholder farmers linked to socioeconomic and demographic factors, we implemented a cluster analysis at the level of the single Food Hubs. While other levels (cluster, country, crop farmers, fish farmers) were considered, this is the level that allows us to use the largest number of variables without losing too many observations (e.g., the behavioural experiments were only run in five Food Hubs, thus a higher- Level analysis would require to exclude the resulting variables; and variables such as land size and irrigation are specific of crop farmers). In addition, the Food Hub level is the most appropriate to support the adoption of FoodLAND innovations, since these areas have been chosen to have farmers that may benefit from specific innovations (e.g., because of the locally grown crops).

As a first step, relevant variables describing the smallholders’ productive and behavioural characteristics were identified. All the categorical variables were turned into series of dummies (e.g., if the smallholders have been growing the same crop, and if they have been doing it in the same field) and skewed continuous or count variables were

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transformed by taking the logarithm, to ensure that they were normally distributed. Then all the variables were standardised by subtracting the median and dividing by the range (highest value minus the lowest value), apart from the dummies, which assume values zero (0) or one (1). Compared to the calculation of z- Scores, this approach allows "consistently superior recovery of the underlying cluster structure" (Milligan and Cooper, 1998: 181). The variables are listed in Table 1.

The variables were checked for pairwise correlation, which was low apart from land and production-related variables, leading to the removal of some of them (not shown in Table 1). We tried to reduce the dimensionality of the data by applying a principal component analysis, but no significant reduction in the number of dimensions could be achieved apart from the Kilombero (fish farmers) Food Hub, which only includes 16 farmers. Hence, in all cases apart from this, we used in the cluster analysis all the variables as they are.

We applied the Ward's linkage clustering algorithm because the objective function considers all observations in each group, and is thus less affected by extreme values, resulting in more equilibrated groups sizes. More precisely, this algorithm minimises within-group variance, and the objective function is an error- Sum-of- Squares (Ward, 1963). To define the optimal number of groups we looked at both the Calinski-Harabasz pseudo-F and Duda-Hart index stopping rules. In some instances, these provided different outcomes, and the optimal number of groups was identified with a view to obtaining more equilibrated group sizes. Very few observations were lost as a result of this procedure: 58 in Chbika, 21 in Kitui, between zero and eight in the other Food Hubs.[1] The number of groups ranges between two and four depending on the Food Hub.

For each Food Hub, we tested if the cluster variables differed significantly between the groups by using Kruskal-Wallis' equality-of-populations rank tests for count and ordered categorical variables, Fisher's exact tests for dummies, and Bonferroni multiple-comparison tests for continuous variables. The groups were then labelled by observing the average and median values of the variables which differed significantly between them.

The variables measuring smallholders' propensity to adopt innovation were not used in the cluster analysis because we consider them an "outcome" of the productive and behavioural profiles of the smallholders. Therefore, their difference across groups was tested ex post, allowing to draw conclusions on whether the smallholders in each group are potential early adopters or rather latecomers, and how to better promote innovation among them.

[1] In the following pages, the discrepancy between the total number of farmers in each Food Hub, and the sum of the numbers of farmers belonging to each group is due to these observations lost or, in the case of Mvomero and Kajjansi- Masaka, to some farmers who only took part in the experiments or in the survey, and therefore are not included in the cluster analysis. This is also the reason why the percentages of farmers belonging to all the groups in a Food Hub (reported in the Appendix's tables) do not sum up to 100%.

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Table 1. Variables used in the cluster analysis or whose difference was tested afterwards.

Typology	Variable	Variable description	Notes
Household (respondent)	age	Farmer's age (years)	
	gender	Farmer's gender (male)	
	educ	Farmer's level of education (1 to 5)	
Household (size)	adult4plus	Number of adults (14+) in the household (log)[1]	
	child0to2	Number of children (0 to 2) in the household (log)[1]	
	child3to3	Number of children (3 to 13) in the household (log)[1]	
Household (migration)	emig	Household with emigrants (dummy)	
	emig_remitt	Household receiving remittances (dummy)	
Household (wellbeing)	foodneed	Extent to which the farmer was able to meet their household's food needs (1 to 5)	
	income_avg	Average monthly household income (1 to 5)	
	income_cost	Share of the farmer's household income used to cover farm costs (1 to 5)	
	income_food	Share of the farmer's household income spent on purchased food (1 to 5)	
Farm (production)	log_product_value_total	Total value of farm production in USD PPP (log)[1]	
Farm (sales)	log_sales_value_total	Total value of farm sales in USD PPP (log)[1]	
	share_sold	Share of production which is sold (0 to 1)	
Farm (prices)	log_single_price	Average price faced by the farmer in USD PPP (log)[1]	
Farm (land/pond)	log_land_totsz	Total land size in hectares (log)[1]	Not available for fish farmers
	used_land	Farmer farming all of their land (dummy)	
	log_system_tot	Total pond/tank/cage size in cubic meters (log)[1]	Not available for crop farmers
	used_pond	Farmer using all of their ponds/tanks/cages (dummy)	
	own_land_pond	Farmer owning at least part of their used land (dummy)	
Farm (labour)	farm_labour_employ	Number of hired farm workers (log)[1]	
	farm_labour_hh	Number of household members working on farm (log)[1]	
Farm (practices)	irrigate	Farmer irrigating their crops (dummy)[1]	Not available for fish farmers
	same_crop	Farmer growing the same crops in different years (dummy)	
	same_field	Farmer growing the same crops in the same fields (dummy)	
Farm (cooperation)	assistcoop	Importance of assistance from cooperatives/institutions/organizations (1 to 5)	
	cmnres	Farmer using any productive means/resources in common with other farmers (dummy)	
	memassc	Membership of local farmers' association/organization/cooperative (dummy)	
Farm (financing)	credit	Farmer receiving informal credit in the last year (dummy)	

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Typology	Variable	Variable description	Notes
	loan	Farmer taking formal loans in the last year (dummy)	
Behaviour (stated)	explain_new	Openness to innovation in farm production (1 to 5)	
	explain_risk	Risk avoidance when managing farm interests (1 to 5)	
	explain_trust	Trust towards organisations promoting innovations in agriculture/aquaculture (1 to 5)	
	other_advt	Opinion on trustworthiness of most farmers in the village (1 to 3)	
	other_help	Opinion on whether most farmers in their village would try to take advantage of them (1 to 3)	
	other_trust	Opinion on whether most farmers in their village try to be helpful most of the time (1 to 3)	
Behaviour (experiments)	impatience	Switching point in the time preference game (0 to 10)	Only available in the Meknes, Jendouba, Mvomero, Mukurweini, and Kajjansi Masaka Food Hubs
	pgg_std_contr	Sum donated in the standard public good game (0 to 150)	
	risk_aversion	Switching point in the risk preference game (0 to 10)	
Innovation adoption	joincrop	Extent to which the farmer is interested in selling their production jointly with other farmers for a higher unit price, but aligning their variety (seeding and harvesting time) with others	Not used in the clustering; differences tested ex post
	nutricrop	Extent to which the farmer is interested in introducing a new crop / fish species with higher nutritional content at parity of selling price and costs (1 to 5)	
	profcrop	Extent to which the farmer is interested in introducing a new crop / fish species with higher selling price at parity of costs (1 to 5)	
	tech_adopt_imit	Extent to which the farmer is interested in introducing a new technology to their farm, such as an irrigation system that raises their crop yield / a water cleaning system (1 to 5)[2]	
	tech_adopt_interest	Extent to which the farmer is interested in adopting a technological innovation such as a new fertilizer /other, that allows them to overcome the limitations faced (1 to 5)	
	tech_avsb	Choice between keeping the current technology (1) or opting for the introduction of a new technology such as equipment or monitoring tool which can reduce crop / fish losses after three years (0) (dummy)	

[1] To facilitate the interpretation of the results, the variables which were subject to logarithmic transformation before implementing the cluster analysis were re-transformed into linear variables before calculating the average and median values shown in the Appendix. Therefore, the values provided in the Appendix are in USD PPP for farm production and sales, hectares for land, cubic meters for ponds/tanks/ages, and number of people for household members and farm labour. [2] Differently from the variables joincrop, nutricrop, profcrop and tech_adopt_interest, whose values indicate interests (from “not at all interested” to “extremely interested”), the values of this variable indicate the timing of adoption compared to peers (“not interested”, “if more than half adopt”, …, “would volunteer to be one of the first in the village”).

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Results

In the **Beni-Mellal** Food Hub (Morocco) 400 farmers were involved in the FoodLAND survey. The clustering algorithm divided them into two groups that compared to other Food Hubs, show more limited differences. The larger group includes 232 farmers and was labelled "Risk-Averse farmers engaged in crop rotation, poorer but more food secure", the smaller one includes 163 farmers and was labelled "Risk-taking farmers with limited crop variation, less poor, but more food insecure". Women are more represented in the second group (4.3% vs 1.3%) while other socio-demographic characteristics do not differ significantly. The second group are more food insecure, the average answer being 2.89 vs 2.56 (*p* 0.002) but also earn higher cash income (2.06 vs 1.68, *p* 0.000) and spend a larger share on food (1.75 vs 1.58, *p* 0.096). "Risk-taking farmers" employ less labour on average, are much more likely to grow the same crop across years (98% vs 36%, *p* 0.000) and to do it in the same field (89% vs 4%, *p* 0.000). For them, assistance of cooperative is less important, and they are also less likely to put resources in common with other farmers. They declared to be less risk averse (as suggested by their group's name), and have slightly more trust in other farmers. The two groups do not differ significantly in their stated willingness to adopt the proposed innovations, except for the innovation that can help them overcome the limitations they face (for which they had to state their preferred timing of adoption compared to peers): interestingly, in this case "Risk-Averse farmers" are more likely to be early adopters (median of 5 vs 4).

Table 2. Summary of group characteristics for the Beni Mellal Food Hub.

Group 1 "Risk-Averse farmers engaged in crop rotation, poorer but more food secure"	**Group 2 "Risk-taking farmers with limited crop variation, less poor but more food insecure"**
232 farmers (58%)	**163 farmers (42%)**
- Less likely to be women. - Less food insecure. - Earning lower income. - Spending less on farm costs. - Employing more farm labour. - Much less likely to grow the same crop. - Much more likely to rotate crops. - More likely to be assisted by organisations. - More likely to put resources in common. - More risk averse (stated preferences). - More likely to think others take advantage.	- More likely to be women. - More food insecure. - Earning higher income. - Spending more on farm costs. - Employing less farm labour. - Much more likely to grow the same crop. - Much less likely to rotate crops. - Less likely to be assisted by organisations. - Less likely to put resources in common. - Less risk averse (stated preferences). - Less likely to think others take advantage.
- More likely to adopt an innovation to overcome their limitations.	- Less likely to adopt an innovation to overcome their limitations.

In the **Meknes** Food Hub (Morocco), 500 farmers were involved in the FoodLAND survey and experiments. The clustering algorithm divided them into three groups that differ significantly across many dimensions. The largest group includes 245 farmers, and was labelled "Farmers with mid-to-big farms relying on employed labour, more likely to be association members, and risk- Averse"; the second group of 211 farmers was labelled "Farmers with smaller farms and farm production, less likely to be cooperative members and to share resources"; and the smaller one of 37 farmers, "Farmers with big farms and

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farm production, more likely to put resources in common, risk-taking, and trustful". The "Farmers with big farms" have by far the largest household (5.8 members), are the most food insecure despite having the highest income, and spend the smallest share of income on farm cost and food. The three groups show significantly different willingness to adopt any type of innovation. The "Farmers with mid-to-big farms" are the least likely to adopt a crop to be grown jointly, a nutritious crop and a more profitable crop, and the least likely to adopt an innovation which could help them overcome their limitations (median 4 in all these variables). The "Farmers with smaller farms" are the least likely to adopt a yield-enhancing technology based on other farmers' decisions (median 4), and the most likely to adopt a technology to reduce losses (6.1% vs 7.3% for "Mid-to-big farms"). The "Farmers with big farms" are the most likely to adopt all the innovations (median of 5), apart from the innovation against losses (10.8%).

Table 3. Summary of group characteristics for the Meknes Food Hub.

Group 2 "Farmers with smaller farms and farm production, less likely to be cooperative members and to share resources"	**Group 3 "Farmers with big farms and farm production, more likely to put resources in common, risk-taking, and trustful"**	**Group 1 "Farmers with mid-to-big farms relying on employed labour, more likely to be association members, and risk-averse"**
211 farmers (42.8%)	**37 farmers (7.5%)**	**245 farmers (49.7%)**
- Average likelihood to be male. - Average level of education. - Average number of adults in the household. - Least likely to have a family member migrated. - Somewhat food insecure. - Average levels of income. - Spend average shares of income on farm costs. - Spend average levels of income on food. - Lowest value of farm sales. - Least share sold of product. - Least likely to have the highest amount of land. - Average number of family members working on farm. - Average likelihood to be growing the same crop. - Least likely to be sharing resources in common. - Least likely to be a member of an association. - Average likelihood to have taken a loan. - Average likelihood to trust farmers in their village.	- Least likely to be male. - Lowest level of education. - Greatest number of adults in the household. - Average likelihood to have a family member migrated. - Least food insecure. - Lowest levels of income. - Spend the most on farm costs. - Spend the most on food. - Highest value of farm sales. - Most share sold of product. - Average likelihood to have the highest amount of land. - Largest number of family members working on farm. - Most likely to be growing the same crop. - Most likely to be sharing resources in common. - Average likelihood to be a member of an association. - Least likely to have taken a loan. - Most likely to trust farmers in their village. - Least likely to believe other farmers may take advantage of them.	- Most likely to be male. - Highest level of education. - Smallest number of adults in the household. - Most likely to have a family member migrated. - Most food insecure. - Highest level of income. - Spend the least on farm costs. - Spend the least on food. - Average value of farm sales. - Somewhat average share of produce sold. - Most likely to have the highest amount of land. - Smallest number of family members working on farm. - Least likely to be growing the same crop. - Average likelihood to be sharing resources in common. - Most likely to be a member of an association. - Most likely to have taken a loan. - Least likely to trust farmers in their village.

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Group 2 "Farmers with smaller farms and farm production, less likely to be cooperative members and to share resources"	Group 3 "Farmers with big farms and farm production, more likely to put resources in common, risk-taking, and trustful"	Group 1 "Farmers with mid-to-big farms relying on employed labour, more likely to be association members, and risk-averse"
211 farmers (42.8%)	**37 farmers (7.5%)**	**245 farmers (49.7%)**
- Most likely to believe other farmers may take advantage of them. - Average likelihood to be risk takers.	- Least likely to be risk takers.	- Average likelihood to believe other farmers may take advantage of them. - Most likely to be risk takers.
- Average likelihood to adopt a crop to be sold jointly. - Average likelihood to adopt a nutritious crop. - Average likelihood to adopt a more profitable crop. - Least likely to be early adopter of a yield raising irrigation system. - Average likelihood to adopt an innovation to overcome their limitations. - Most likely to adopt a loss-reducing technology.	- Most likely to adopt a crop to be sold jointly. - Most likely to adopt a nutritious crop. - Most likely to adopt a more profitable crop. - Most likely to be early adopter of a yield raising irrigation system. - Most likely to be early adopters an innovation to overcome their limitations. - Least likely to adopt a loss-reducing technology.	- Least likely to adopt a crop to be sold jointly. - Least likely to adopt a nutritious crop. - Least likely to adopt a more profitable crop. - Average likelihood to be early adopter of a yield raising irrigation system. - Least likely to be early adopters an innovation to overcome their limitations. - Average likelihood to adopt a loss-reducing technology.

In the **Chbika** Food Hub (Tunisia) 431 farmers were involved in the FoodLAND survey only. The clustering algorithm divided them into two groups showing an average level of differentiation. The larger group includes 287 farmers and was labelled "Higher-income, more food secure farmers with larger farms and production but less trustful, less willing to try new things and more risk averse", while the smaller one (86 farmers) was labelled "Low-income, food insecure farmers with smaller farms and production but more trustful, more willing to try new things and more risk-taking". Besides income, food security and farm size, the groups differ in terms of gender (7% of women in the larger one and 19% in the smaller one) and household size (3.9 vs 5.5 members). Interestingly, "Low-income farmers" sell a larger share of production on average (93% vs 82%), employing much more family labour (3.1 vs 1.5 members). However, they irrigate less (53% vs 87%) and always grow the same crop, often in the same field (92% vs 58%). Being significantly more trustful, they are also more likely to put resources in common (33% vs 15%). In terms of innovation adoption, in line with their behavioural characteristics (but not with income), "Low-income farmers" are more likely to sell a crop jointly, adopt a more profitable crop, be early adopters of an irrigation system, and switch to low-loss technology. Other responses do not differ significantly.

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Table 4. Summary of group characteristics for the Chbika Food Hub.

Group 1 "Higher-income, more food secure farmers with larger farms and production but less trustful, less willing to try new things and more risk averse"	**Group 2 "Low-income, food insecure farmers with smaller farms and production but more trustful, more willing to try new things and more risk-taking"**
287 farmers (76.9%)	**86 farmers (23.1%)**
- Less likely to be women. - Less adult members in the household. - Less children aged 3 to 13 in the household. - More likely to have emigrant household members and to receive remittances. - Less food insecure. - Higher income levels. - Spending a smaller share of income on farm costs. - Selling a smaller share of their production. - Facing lower selling prices. - Less family members working on farm. - More likely to irrigate. - More likely to engage in farm rotations. - More likely to be assisted by cooperatives. - More likely to be association members. - Less open to farm innovations. - More risk averse. - Less likely to trust other farmers. - More likely to think that others would take advantage of them, do not want to help, and would look after themselves.	- More likely to be women. - More adult members in the household. - More children aged 3 to 13 in the household. - Less likely to have emigrant household members and to receive remittances. - More food insecure. - Lower income levels. - Spending a larger share of income on farm costs. - Selling a larger share of their production. - Facing higher selling prices, - More family members working on farm. - Less likely to irrigate. - Less likely to engage in farm rotations. - Less likely to be assisted by cooperatives. - Less likely to be association members. - More open to farm innovations. - Less risk averse. - More likely to trust other farmers. - Less likely to think that others would take advantage of them, do not want to help, and would look after themselves.
- Less likely to adopt a crop to be sold jointly. - Less likely to adopt a more profitable crop. - Less likely to be early adopters an innovation to overcome their limitations. - Less likely to adopt a loss-reducing technology.	- More likely to adopt a crop to be sold jointly. - More likely to adopt a more profitable crop. - More likely to adopt an innovation to overcome their limitations. - More likely to adopt a loss-reducing technology.

In the **Jendouba** Food Hub (Tunisia), 500 farmers were involved in both the FoodLAND survey and experiments. The clustering algorithm divided them into four groups that differ significantly across most of the variables considered. The largest group includes 217 farmers and was labelled "Young farmers with larger farms and larger farm production and sales, employing more labour and more impatient"; the second group, of 167 farmers, was labelled "Average- Age farmers with mid- Sized farms and moderate productive and behavioural characteristics"; the third one (60 farmers), "Low-educated farmers with low incomes and more food insecure, engaged in crop rotation and often association members"; whilst the smallest group (48 farmers) was labelled: "Older farmers with small farm sales, not engaged in cooperatives, less open to new things but more trustful and less impatient". Besides the characteristics that provide their names, the groups differ in terms of gender, with male farmers by far more represented in the largest group (79%), while they are a minority in the other ones, especially among "Low-educated farmers".

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The household size does not differ, but “Young farmers” hire more farm labour. Emigration and remittance inflow is most prevalent among “Average- Age farmers” (59% and 22%), and least among “low-educated” ones (13% and 3%). “Young farmers” are by far more likely to sell their production (52% of it on average), while in all the other groups more than half of the farmers sell nothing. “Older farmers” are less likely to irrigate their crops (4%), while “Low-educated farmers” are often members of associations (62%), compared to none among “Older farmers”. Interestingly, “Younger farmers” are the most likely to receive credit (46%), “Low-educated farmers”, formal loans (27%). In terms of stated willingness to adopt innovations, the groups differ significantly across all of the questions but in a counterintuitive direction: “Young farmers” are the least likely to grow a crop jointly, adopt a nutritious crop, or a more profitable crop, while “Low-educated farmers” are the most likely to adopt a profitable crop, an irrigation system based on others’ decisions or a technology to overcome their limitations. “Older farmers” are the most likely to grow a crop jointly but the least likely to adopt an irrigation system based on imitation, a technology to overcome their limitations, and one to reduce losses (21%), while 71% of the “Young farmers” would adopt the latter.

Table 5. Summary of group characteristics for the Jendouba Food Hub.

Group 1 “Low-educated farmers with low incomes and more food insecure, engaged in crop rotation and often association members”	**Group 2 “Average-age farmers with mid-sized farms and moderate productive and behavioural characteristics”**	**Group 3 “Older farmers with small farm sales, not engaged in cooperatives, less open to new things but more trustful and less impatient”**	**Group 4 “Young farmers with larger farms and larger farm production and sales, employing more labour and more impatient”**
60 farmers (12.2%)	**167 farmers (33.9%)**	**48 farmers (9.8%)**	**217 farmers (44.1%)**
- Youngest age. - Lowest level of education. - Least likely to have a household member migrated. - Second least likely to receive remittances. - Most likely to spend a higher proportion of income on food. - Most likely to be food secure. - Least likely to have the highest income. - Most likely to resemble higher levels in stated behaviour. - Second least likely to have the highest level of impatience.	- Second oldest age. - Second highest level of education. - Most likely to have a household member migrated. - Most likely to receive remittances. - Second least likely to spend a higher proportion of income on food. - Second least likely to be food secure. - Second most likely to have the highest income. - Second most likely to resemble higher levels in stated behaviour.	- Oldest age. - Second lowest level of education. - Second most likely to have a household member migrated. - Least likely to receive remittances. - Second most likely to spend a higher proportion of income on food. - Second most likely to be food secure. - Second least likely to have the highest income. - Least likely to resemble higher levels in stated behaviour. - Least likely to have the highest level of impatience.	- Second youngest age. - Highest level of education. - Second least likely to have a household member migrated. - Second most likely to receive remittances. - Least likely to spend a higher proportion of income on food. - Least likely to be food secure. - Most likely to have the highest income. - Second least likely to resemble higher levels in stated behaviour.

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Group 1 "Low-educated farmers with low incomes and more food insecure, engaged in crop rotation and often association members"	Group 2 "Average-age farmers with mid-sized farms and moderate productive and behavioural characteristics"	Group 3 "Older farmers with small farm sales, not engaged in cooperatives, less open to new things but more trustful and less impatient"	Group 4 "Young farmers with larger farms and larger farm production and sales, employing more labour and more impatient"
60 farmers (12.2%)	**167 farmers (33.9%)**	**48 farmers (9.8%)**	**217 farmers (44.1%)**
- Most likely to have a positive attitude towards innovation adoption. - Least likely to be growing the same crop. - Second most likely to irrigate.	- Second most likely to have the highest level of impatience. - Second most likely to have a positive attitude towards innovation adoption. - Second most likely to be growing the same crop. - Second least likely to irrigate.	- Second least likely to have a positive attitude towards innovation adoption. - Most likely to be growing the same crop. - Least likely to irrigate.	- Most likely to have the highest level of impatience. - Least likely to have a positive attitude towards innovation adoption. - Second least likely to be growing the same crop. - Most likely to irrigate.
- Second least likely to adopt a crop to be sold jointly. - Second most likely to adopt a nutritious crop. - Most likely to adopt a more profitable crop. - Most likely to be early adopter of a yield raising irrigation system. - Most likely to adopt an innovation to overcome limitations. - Second most likely to adopt a loss-reducing technology.	- Second most likely to adopt a crop to be sold jointly. - Most likely to adopt a nutritious crop. - Second most likely to adopt a more profitable crop. - Second most likely to be early adopter of a yield raising irrigation system. - Second most likely to adopt an innovation to overcome limitations. - Second least likely to adopt a loss-reducing technology.	- Most likely to adopt a crop to be sold jointly. - Second least likely to adopt a nutritious crop. - Second least likely to adopt a more profitable crop. - Least likely to be early adopter of a yield raising irrigation system. - Least likely to adopt an innovation to overcome limitations. - Least likely to adopt a loss-reducing technology.	- Least likely to adopt a crop to be sold jointly. - Least likely to adopt a nutritious crop. - Least likely to adopt a more profitable crop. - Second least likely to be early adopter of a yield raising irrigation system. - Second least likely to adopt an innovation to overcome limitations. - Most likely to adopt a loss-reducing technology.

In the **Mukurweini** Food Hub (Kenya), 505 farmers were involved in both the FoodLAND survey and experiments. The clustering algorithm divided them into three groups that do not show many differences. The largest group includes 347 farmers and was labelled "Older farmers with migrant household members, less likely to irrigate, very engaged in associations and resource sharing"; the second group (77 farmers), "Younger farmers with smaller farm production, less engaged in associations and resource sharing but stronger co-operators"; whilst the smallest group (73 farmers), "Farmers with larger farm production and sales, facing high selling prices, more likely to get credit and loans". The farmers with larger farm production are more often female (55%), and less likely to have

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migrant household members (22%); they also spend less of their incomes on food. The significantly higher price they face suggests that they produce more profitable crops; they are also more likely to irrigate (77% vs an average of 37%). In terms of willingness to adopt, surprisingly, “Older farmers” are the most likely to be early adopter of a new irrigation system, to adopt a technology to address their limitations, and one to reduce losses (96%), while farmers with larger farms (who are also more likely to obtain financing) are the last likely in all these instances.

Table 6. Summary of group characteristics for the Mukurweini Food Hub.

Group 1 “Older farmers with migrant household members, less likely to irrigate, very engaged in associations and resource sharing”	**Group 2 “Younger farmers with smaller farm production, less engaged in associations and resource sharing but stronger co-operators”**	**Group 3 “Farmers with larger farm production and sales, facing high selling prices, more likely to get credit and loans”**
347 farmers (69.8%)	**77 farmers (15.5%)**	**73 farmers (14.7%)**
- Oldest age. - Most likely to have a household member migrated. - Most likely to spend a higher proportion of income on food. - On average likely of having the highest product value and sales. - Most likely of utilising the most land. - Most likely to own the most land. - Least likely to irrigate. - Most likely to being a member of farm cooperatives/associations. - Average likelihood to taking up a loan. - Average likelihood to trust other farmers. - Least likely in believing that other farmers are helpful - Somewhat likely to being the highest contributors in the public good game.	- Youngest age. - Somewhat likely to have a household member migrated. - Average likelihood to spend a higher proportion of income on food. - Least likely of having the highest product value and sales - On average likely of utilising the most land. - Least likely to own the most land. - Somewhat likely to irrigate. - Least likely to being a member of farm cooperatives/associations. - Least likely to taking up a loan. - Least likely to trust other farmers. - Most likely in believing that other farmers are helpful. - Most likely to being the highest contributors in the public good game.	- Average age. - Least likely to have a household member migrated. - Least likely to spend a higher proportion of income on food. - Most likely of having the highest product value and sales. - Least likely of utilising the most land. - Average likelihood to own the most land. - Most likely to irrigate. - Average likelihood to being a member of farm cooperatives/associations. - Most likely to taking up a loan. - Most likely to trust other farmers. -On average likely in believing that other farmers are helpful. - Least likely to being the highest contributors in the public good game.
- Most likely to be early adopter of a yield raising irrigation system. - Most likely to adopt an innovation to overcome limitations - Most likely to adopt a loss-reducing technology.	- Average likelihood to be early adopter of a yield raising irrigation system - Average likelihood to adopt an innovation to overcome limitations. - Average likelihood to adopt a loss-reducing technology.	- Least likely to be early adopter of a yield raising irrigation system. - Least likely to adopt an innovation to overcome limitations. - Least likely to adopt a loss-reducing technology.

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In the **Kisumu** Food Hub (Kenya), 403 fish farmers were involved in the FoodLAND survey. The algorithm divided them into four groups that differ significantly along all the dimensions. The largest group includes 193 farmers and was labelled "Younger farmers with higher education, less food insecure, employing limited labour, growing different fish species"; the second one (108 farmers), "Older farmers with many migrant household members, and higher income, who spend more on food, more risk-taking"; the third one (52 farmers), "Farmers with larger households and larger farm production, unlikely to get loans or credit, more risk averse"; and the smallest one (49 farmers), "More food insecure farmers, less engaged in sales, putting resources in common and likely to obtain credit." "Younger farmers" have the highest level of education (3.4 on average) and the lowest number of children aged 0 to 2 and 3 to 13. The groups show significantly different willingness to adopt any types of innovation apart from the one against losses, which all the farmers in Kisumu are willing to adopt. "Younger farmers" are the most willing to adopt a nutritious crop, a more profitable crop, a technology to overcome their limitations (alongside the "Farmers with larger households") and to be early adopters of a new irrigation system. The "Farmers with larger households" are the most likely to sell a crop jointly and to adopt a technology to overcome their limitations (alongside "young farmers"). "More food insecure farmers" are the least willing to adopt any of the technologies proposed, apart from selling crops jointly, for which "Young farmers" are slightly less likely to adopt.

Table 7. Summary of group characteristics for the Kisumu Food Hub.

Group 1 "Older farmers with many migrant household members and higher income, who spend more on food, more risk-taking"	**Group 2 "Farmers with larger households and larger farm production, unlikely to get loans or credit, more risk averse"**	**Group 3 "More food insecure farmers, less engaged in sales, putting resources in common and likely to obtain credit"**	**Group 4 "Younger farmers with higher education, less food insecure, employing limited labour, growing different fish species"**
108 farmers (28.1%)	**52 farmers (12.4%)**	**49 farmers (12.2%)**	**193 farmers (47.3%)**
- Oldest age. - Most likely to be male. - Second highest level of education. - Second most likely to have the largest household size. - Most likely to have a household member migrated. - Most likely to receive remittances. - Second least likely to have a higher	- Second youngest age. - Second least likely to being male. - Lowest level of education. - Most likely to have the largest household size. - Least likely to have a household member migrated. - Least likely to receive remittances. - Second most likely to have a higher level	- Second oldest age. - Least likely to being male. - Second lowest level of education. - Least likely to have the largest household size. - Second least likely to have a household member migrated. - Second least likely to receive remittances.	- Youngest age. - Second most likely to being male. - Highest level of education. - Second least likely to have the largest household size. - Second most likely to have a household member migrated. - Second most likely to receive remittances.

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Group 1 "Older farmers with many migrant household members and higher income, who spend more on food, more risk-taking"	Group 2 "Farmers with larger households and larger farm production, unlikely to get loans or credit, more risk averse"	Group 3 "More food insecure farmers, less engaged in sales, putting resources in common and likely to obtain credit"	Group 4 "Younger farmers with higher education, less food insecure, employing limited labour, growing different fish species"
108 farmers (28.1%)	**52 farmers (12.4%)**	**49 farmers (12.2%)**	**193 farmers (47.3%)**
level of household wellbeing. - Second most likely of having the highest product value and sales. - Second most likely to have the highest farm labour. - Second least likely to have farm labour from the household. - Second most likely to be a part of farm cooperatives/associations. - Least likely to resemble higher levels in stated behaviour.	of household wellbeing. - Most likely of having the highest product value and sales - Second least likely to have the highest farm labour. - Most likely to have farm labour from the household. - Second most likely to use same farm practices. - Least likely to be a part of farm cooperatives/associations. - Most likely to resemble higher levels in stated behaviour.	- Most likely to have a higher level of household wellbeing. - Least likely of having the highest product value and sales. - Most likely to have the highest farm labour employed. - Least likely to have farm labour from the household. - Most likely to use same farm practices. - Most likely to be a part of farm cooperatives/associations. - Second least likely to resemble higher levels in stated behaviour	- Least likely to have a higher level of household wellbeing. - Second least likely of having the highest product value and sales. - Least likely to have the highest farm labour employed. - Second most likely to have farm labour from the household. - Least likely to use same farm practices - Second least likely to be a part of farm cooperatives/associations. - Second most likely to resemble higher levels in stated behaviour.
- Second most likely to adopt a fish species to be sold jointly. - Second most likely to adopt a nutritious fish species. - Second least likely to adopt a more profitable fish species. - Second least likely to be early adopter of a water cleaning system. - Second least likely to adopt an innovation to overcome limitations.	- Most likely to adopt a fish species to be sold jointly. - Second least likely to adopt a nutritious fish species. - Second most likely to adopt a more profitable fish species. - Second most likely to be early adopter of a water cleaning system. - Equally most likely to adopt an innovation to overcome limitations.	- Second least likely to adopt a fish species to be sold jointly. - Least likely to adopt a nutritious fish species. - Least likely to adopt a more profitable fish species. - Least likely to be early adopter of a water cleaning system. - Least likely to adopt an innovation to overcome limitations.	- Least likely to adopt a fish species to be sold jointly. - Most likely to adopt a nutritious fish species. - Most likely to adopt a more profitable fish species. - Most likely to be early adopter of a water cleaning system. - Equally most likely to adopt an innovation to overcome limitations.

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In the **Kitui** Food Hub (Kenya), 482 farmers were involved in the FoodLAND survey. The clustering algorithm divided them into four groups that differ significantly across several dimensions. The largest group includes 140 farmers and was labelled “Young farmers with slightly larger farms and highest farm sales, unlikely to share resources and to engage with associations”; the second one (134 farmers), “Farmers with larger farm production and farm sales, likely to put resources in common and to receive credit and loans”; the third one (113 farmers), “Farmers with smaller farms, less likely to engage in rotations, and more likely to trust others”; and the smallest one (74 farmers), “Older farmers with limited farm sales, relying on assistance from associations, risk averse, and less likely to trust others”. The characteristics that differentiate each group compared to the others are highlighted in their names. “Farmers with larger farms” also have the largest households (4.3 adults compared to an average of 4.0). Membership of associations, the importance of their assistance, and sharing of resources, are much more prevalent among “Farmers with larger farms” and “Older farmers.” In terms of willingness to adopt, the groups only differ for what concerns technologies that would help them overcome their limitations or reduce their losses, with “Farmers with smaller farms” most likely to adopt both, and “Farmers with larger farm” least likely to adopt both.

Table 8. Summary of group characteristics for the Kitui Food Hub.

Group 1 “Farmers with larger farm production and farm sales, likely to put resources in common and to receive credit and loans”	**Group 2 “Young farmers with slightly larger farms and highest farm sales, unlikely to share resources and to engage with associations”**	**Group 3 “Farmers with smaller farms, less likely to engage in rotations and more likely to trust others”**	**Group 4 “Older farmers with limited farm sales, relying on assistance from associations, risk averse and less likely to trust others”**
134 farmers (27.8%)	**140 farmers (29.0%)**	**113 farmers (23.4%)**	**74 farmers (15.4%)**
- Second oldest age. -Joint least likely to be male. - Most likely to have the most adults in the household. - Least likely to have a household member migrated. - Most likely of having the highest product value. - Second most likely of having the highest sales. - Second least likely to spend the highest proportion of income on food. - Most likely of having the highest amount of land.	- Youngest age. - Most likely to be male. - Second least likely to have the most adults in the household. - Second least likely to have a household member migrated. - Second most likely of having the highest product value. - Most likely of having the highest sales. - Second most likely to spend the highest proportion of income on food. - Second most likely of having the highest amount of land.	- Second youngest age. - Second most likely to be male. - Least likely to have the most adults in the household. - Second most likely to have a household member migrated. - Second least likely of having the highest product value. - Second Least likely of having the highest sales. - Most likely to spend the highest proportion of income on food.	- Oldest age. -Joint least likely to be male. - Second most likely to have the most adults in the household. - Most likely to have a household member migrated. - Least likely of having the highest product value. - Least likely of having the highest sales. - Least likely to spend the highest proportion of income on food. - Second least likely of having the highest amount of land.

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Group 1 "Farmers with larger farm production and farm sales, likely to put resources in common and to receive credit and loans"	Group 2 "Young farmers with slightly larger farms and highest farm sales, unlikely to share resources and to engage with associations"	Group 3 "Farmers with smaller farms, less likely to engage in rotations and more likely to trust others"	Group 4 "Older farmers with limited farm sales, relying on assistance from associations, risk averse and less likely to trust others"
134 farmers (27.8%)	**140 farmers (29.0%)**	**113 farmers (23.4%)**	**74 farmers (15.4%)**
- Least likely to be using the same field. - Second most likely to be a part of farm cooperatives/associations. - Most likely to have received credit. - Most likely to have taken a loan. - Second least likely to resemble higher levels in stated behaviour.	- Second most likely to be using the same field. - Least likely to be a part of farm cooperatives/associations. - Least likely to have received credit. - Least likely to have taken a loan. - Second Most likely to resemble higher levels in stated behaviour.	- Least likely of having the highest amount of land. - Most likely to be using the same field. - Second least likely to be a part of farm cooperatives/associations. - Second least likely to have received credit. - Second least likely to have taken a loan. - Least likely to resemble higher levels in stated behaviour.	- Second least likely to be using the same field. - Most likely to be a part of farm cooperatives/associations. - Second most likely to have received credit. - Second most likely to have taken a loan. - Most likely to resemble higher levels in stated behaviour
- Least likely to adopt an innovation to overcome limitations. - Least likely to adopt a loss-reducing technology.	- Second least likely to adopt an innovation to overcome limitations. - Second most likely to adopt a loss-reducing technology.	- Most likely to adopt an innovation to overcome limitations. - Most likely to adopt a loss-reducing technology.	- Second most likely to adopt an innovation to overcome limitations. - Second least likely to adopt a loss-reducing technology.

In the **Kilombero** Food Hub (Tanzania) 407 farmers were involved in the FoodLAND survey only. The clustering algorithm divided them into two groups that show limited differences. The larger group includes 286 farmers and was labelled "Younger farmers with smaller households and few migrant members, slightly smaller farms, less likely to receive credit", whilst the smaller one (115 farmers) was labelled "Older farmers with larger households and many migrant members, slightly larger farms, more likely to receive credit." The age of the farmers differs significantly between the groups (44.0 vs 54.3, *p* 0.000), like the household size (3.7 vs 2.8 adult members). The second group, with more adult members, are also likelier to have a family member emigrated (100% vs 7%), and to receive remittances (99% vs 3%). Additionally, the farmers with more adults in their households have more family members working on farm (2.5 vs 2.1), are more often members of associations (25% vs 15%), and are significantly more likely to uptake credit (45% vs 22%). In terms of innovation adoption, "Older farmers" are significantly more likely to sell crops jointly with others (at 10% level), adopt a more profitable crop (at 5%), and to be early adopters of an irrigation system (at 5%); other responses do not differ significantly.

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Table 9. Summary of group characteristics for the Kilombero Food Hub.

Group 1 "Younger farmers with smaller households and few migrant members, slightly smaller farms, less likely to receive credit"	**Group 2 "Older farmers with larger households and many migrant members, slightly larger farms, more likely to receive credit"**
286 farmers (70.3%)	**115 farmers (28.3%)**
- Younger age. - Smaller number of adults in the household. - More children from 0 to 2 in the household. - Less likely to have a household member migrated and receive remittances. - Less likely to have a higher area of land. - Less likely to use a higher level of land. - Less family members working on farm. - Less likely to be a member of an association. - Less likely to have received credit.	- Older age. - Larger number of adults in the household. - Less children from 0 to 2 in the household. - More likely to have a household member migrated and receive remittances. - More likely to have a higher area of land. - More likely to use a higher level of land. - More family members working on farm. - More likely to be a member of an association. - More likely to have received credit.
- Less likely to adopt a more profitable crop. - Less likely to adopt an innovation to overcome limitations.	- More likely to adopt a more profitable crop. - More likely to adopt an innovation to overcome limitations

In the **Kilombero (fish)** Food Hub (Tanzania) 16 farmers were involved in the FoodLAND survey. The clustering algorithm divided them into two groups that show limited differences. The larger group includes 9 farmers and was labelled "Farmers with higher average income who do not rely on organisation and are less likely to trust other farmers", whilst the smaller one includes 4 farmers and was labelled "Farmers with lower average income who rely on organisations and are more likely to trust other farmers." There are no significant demographic differences among the groups. The average income of the farmers in the groups differs significantly, with the farmers who are more likely to trust agricultural partners on average having a lower income (4.00 vs 5.00, *p* 0.001). Additionally, the farmer who are more likely to trust agricultural partners also consider assistance from cooperatives more importance (4.00 vs 1.44, *p* 0.008). Finally, farmers who have lower trust levels with their agricultural partners are significantly less likely to receive informal credit (median of 0 vs 1, *p* 0.001). In terms of innovation, the two groups only differ for their willingness to sell crops jointly with other farmers which differently from what expected is significantly higher for less trustful farmers (5.00 vs 4.00, *p* 0.023).

Table 10. Summary of group characteristics for the Kilombero (fish) Food Hub.

Group 1 "Farmers with lower average income who rely on organisations and are more likely to trust other farmers"	**Group 2 "Farmers with higher average income who do not rely on organisation and are less likely to trust other farmers"**
4 farmers (25%)	**9 farmers (56.3%)**
- Less likely to have higher household income. - Employing more labour on farm.	- More likely to have higher household income. - Employing less labour on the farm.

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Group 1 "Farmers with lower average income who rely on organisations and are more likely to trust other farmers"	Group 2 "Farmers with higher average income who do not rely on organisation and are less likely to trust other farmers"
4 farmers (25%)	**9 farmers (56.3%)**
- More family members working on farm. - More likely to be assisted by cooperatives. - More likely to have received credit. - Less likely to take risks in farming. - Less likely to trust agricultural partners. - Less likely to trust other farmers in the village.	- Less family members working on farm. - Less likely to be assisted by cooperatives. - Less likely to have received credit. - Less likely to take risks in farming. - More likely to trust agricultural partners. - More likely to trust other farmers in the village.
- Less likely to adopt a fish species to be sold jointly.	- More likely to adopt a fish species to be sold jointly.

In the **Mvomero** Food Hub (Tanzania), 504 farmers were involved both the FoodLAND survey and experiments. The clustering algorithm divided them into three groups that differ significantly across some dimensions. The largest group includes 276 farmers and was labelled "Farmers with no migrant household members, not high incomes, smaller farm sales, and less engaged in crop rotation". The second one (129 farmers) was labelled "Young farmers with larger farm sales, hiring more labour, irrigating and engaged in rotations", and the smallest one (67 farmers), "Older farmers with migrant household members, higher incomes, larger farm production, not irrigating." Besides the characteristics from which their names derive, older farmers present the largest households (4.1 adult members), younger farmers, the smallest (2.7), but the opposite is true if considering the number of children. The differences in terms of number of migrants is strong, as highlighted. "Young farmers" are much less likely to own their land (67% vs 88% in the other groups), but they employ more farm labour. The higher propensity to irrigate their crops (57%), and to change the crops grown and to rotate them, suggests that they have a more modern approach to farming. Despite being more trustful toward organisations, they rely less on their assistance; they are also more impatient. Mvomero farmers differ significantly in terms of willingness to adopt innovations: young farmers are the most likely to sell a crop jointly (p 0.002), adopt a more profitable crop (p 0.004), be early adopters of an irrigation system (p 0.000), and adopt an innovation to overcome their limitations (p 0.002). In turn, they are the least likely to adopt a nutritious crop (p 0.012). The farmers with no migrant household members are the least likely to implement all of these actions, with the exception of adopting a profitable crop, which is least attractive to older farmers.

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Table 11. Summary of group characteristics for the Mvomero Food Hub.

Group 1 "Young farmers with larger farm sales, hiring more labour, irrigating and engaged in rotations"	**Group 2 "Farmers with no migrant household members, not high incomes, smaller farm sales and less engaged in crop rotation"**	**Group 3 "Older farmers with migrant household members, higher incomes, larger farm production, not irrigating"**
129 farmers (25.6%)	**276 farmers (54.8%)**	**67 farmers (13.3%)**
- Youngest age. - Most likely to be male. - Least likely to have more adult household members. - Most likely to have more children in the household. - Average likelihood to have a household member migrated and to receive remittances. - Average household income. - Average product value. - Largest share sold of product. - Most likely to have more labour employed on their farm. - Most likely to use irrigation. - Least likely to be growing the same crop. - Least likely to be growing crops on the same field. - Least likely to have assistance from cooperatives. - Most likely to trust farmers from their village. - Most likely to believe other farmers would take advantage of them.	-Average age. - Least likely to be male. - Average likelihood to have more adult household members. - Average likelihood to have more children in the household. - Least likely to have a household member migrated and to receive remittances. - Lowest household income. - Lowest product value. - Lowest share sold of product. - Average likelihood to have more labour employed on their farm. - Average likelihood to use irrigation. - Most likely to be growing the same crop. - Most likely to be growing crops on the same field. - Average likelihood to have assistance from cooperatives. - Least likely to trust farmers from their village. - Average likelihood to believe other farmers would take advantage of them.	- Oldest age. -On average most likely to be male. - Most likely to have more adult household members. - Least likely to have more children in the household. - Most likely to have a household member migrated and to receive remittances. - Highest household income. - Highest product value. - Average share sold of product. - Least likely to have more labour employed on their farm. - Least likely to use irrigation. - Average likelihood to be growing the same crop. - Average likelihood to be growing crops on the same field. - Most likely to have assistance from cooperatives. - Average likelihood to trust farmers from their village. - Least likely to believe other farmers would take advantage of them.
- Most likely to adopt a crop to be sold jointly. - Least likely to adopt a nutritious crop. - Most likely to adopt a more profitable crop. - Most likely to be early adopter of a yield raising irrigation system. - Most likely to adopt an innovation to overcome limitations.	- Least likely to adopt a crop to be sold jointly. - Average likelihood to adopt a nutritious crop. - Average likelihood to adopt a more profitable crop. - Least likely to be early adopter of a yield raising irrigation system. - Least likely to adopt an innovation to overcome limitations.	- Average likelihood to adopt a crop to be sold jointly. - Most likely to adopt a nutritious crop. - Least likely to adopt a more profitable crop. - Average likelihood to be early adopter of a yield raising irrigation system. - Average likelihood to adopt an innovation to overcome limitations.

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In the **Kamuli** Food Hub (Uganda), 400 farmers took part in the FoodLAND survey. The clustering algorithm divided them into three groups that differ mostly in terms of household characteristics and cooperation. The largest group included 259 farmers and was labelled “Older farmers with larger farm sizes and farm production, engaged in cooperatives and cooperation”; the second one by size includes 79 farmers and was labelled “Mid- Aged farmers with mid- Sized farms and production, engaged in cooperatives and cooperation, and with no migrant household members”; the smallest one (51 farmers) was labelled “Younger farmers with a smaller farm and smaller production, less involved in cooperatives and less likely to cooperate”. Besides the characteristics which provide the names to the groups, these differ in terms of gender and education, with “mid- Sized farms” more often led by women (65.8%) and by farmers with lower levels of education. These are also less likely to have migrant family members (11.4%) and thus to receive remittances (5.1%). The smaller the farm, the more food insecure, and the larger the share of income spent on food; equally, the larger the farm, the larger the number of household members working on it. “Younger farmers” are by far less likely to benefit from organisational assistance, of being members of associations (18%), and of putting resources in common (6%). This is in line with their significantly lower level of trust towards farmers and organisations. They are also the most likely to receive informal credit (46%) but the least likely to receive formal loans (4%), highlighting the difference between these instruments also in terms of access. As for innovation adoption, the groups differ in terms of their willingness to sell crops jointly with other farmers (mid- Sized farmers being the most willing, small farmers the least); and to adopt an innovation that can help them overcome their limits (mid- Sized farms the most willing, larger farms the least).

In the **Nakaseke** Food Hub (Uganda), 400 farmers participated in the FoodLAND survey. The clustering algorithm divided them into two groups that show limited differences. The largest group includes 262 farmers and was labelled “Younger farmers with smaller households and smaller farms”, whilst the smaller one includes 138 farmers and was labelled “Older farmers with larger households and larger farms.” The “Farmers with the larger households” were likelier, on average, to have a household member migrated (83% vs 16%, *p* 0.001), and, as expected, they were also significantly more likely to have been provided with remittances (74% vs 4%). The “Older farmers” had, on average, significantly larger households (4.46 vs 3.64 members 14+, *p* 0.000). Additionally, they were significantly more likely to have been sharing resources with other farmers (59% vs 25%). In line with this, we observed that the “Younger farmers” were significantly less likely to be members of an agricultural association (53% vs 81%). Another significant observation was the uptake of loans, as “Older farmers with larger farm sizes” were, on average, likelier to be taking up these (49% vs 29%, *p* 0.000). In terms of innovation adoption, the two groups differ significantly only in terms of their likelihood to adopt a nutritious crop, with an average assessment of 4.72 by older farmers and 4.42 by younger ones (*p* 0.002).

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Table 12. Summary of group characteristics for the Kamuli Food Hub.

Group 1 "Older farmers with larger farm sizes and farm production, engaged in cooperatives and cooperation"	**Group 2 "Mid-aged farmers with mid-sized farms and production, engaged in cooperatives and cooperation, and with no migrant household members"**	**Group 3 "Younger farmers with a smaller farm and smaller production, less involved in cooperatives and less likely to cooperate"**
259 farmers (64.8%)	**79 farmers (19.8%)**	**51 farmers (12.8%)**
- Oldest age. - Average likelihood to be male. - Average likelihood to be higher educated. - Most likely to have more adult household members. - Least likely to have more children aged 0 to 2 in the household. - Most likely to have a household member migrated and to receive remittances. - Average household income. - Least food secure. - Least likely to spend the highest proportion of income on food. - Average likelihood to have the most land in use. - Average likelihood to have more labour employed on their farm. - Most likely to have a household member as labour on the farm. - Least likely to be growing crops on the same field. - Average likelihood to have assistance from cooperatives. - Average likelihood to be member of an association. - Average likelihood to use common resources. - Most likely to have taken up a loan. - Average likelihood to trust farmers from their village.	- Average age. - Least likely to be male. - Least likely to be higher educated. - Average likelihood to have more adult household members. - Most likely to have more children aged 0 to 2 in the household. - Least likely to have a household member migrated and to receive remittances. - Average food security. - Average likelihood to spend the highest proportion of income on food. - Most likely to have the most land in use. - Least likely to have more labour employed on their farm. - Average likelihood to be growing crops on the same field. - Most likely to have assistance from cooperatives. - Most likely to be member of an association. - Most likely to use common resources with other farmers. - Average likelihood to have taken up a loan. - Least likely to trust farmers from their village.	- Youngest age. - Most likely to be male. - Most likely to be higher educated. - Least likely to have more adult household members. - Average likelihood to have more children aged 0 to 2 in the household. - Average likelihood to have a household member migrated and to receive remittances. - Most food secure. - Most likely to spend the highest proportion of income on food. - Least likely to have the most land in use. - Most likely to have more labour employed on their farm. - Least likely to have a household member as labour on the farm. - Most likely to be growing crops on the same field. - Least likely to have assistance from cooperatives. - Least likely to be member of an association. - Least likely to use common resources with other farmers. - Least likely to have taken up a loan. - Least likely to trust farmers from their village. - Most likely to trust farmers in their village.
- Average likelihood to adopt a crop to be sold jointly. - Most likely to adopt a loss-reducing technology.	- Most likely to adopt a crop to be sold jointly. - Least likely to adopt a loss-reducing technology.	- Least likely to adopt a crop to be sold jointly. - Average likelihood to adopt a loss-reducing technology.

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Table 13. Summary of group characteristics for the Nakaseke Food Hub.

Group 1 "Older farmers with larger households and larger farms, more likely to share resources and to take loans"	**Group 2 "Younger farmers with smaller household, smaller farms, less likely to share resources and to take loans"**
138 farmers (34.5%)	**262 farmers (65.5%)**
- Older age. - More likely to have more adult household members. - More likely to have a household member migrated. - More likely to receive remittances. - Less likely to spend a higher proportion of income on food. - More likely to use more land. - More household farm workers. - More likely to use common resources with other farmers. - More likely to be a member of an association. - More likely to have taken up a loan.	- Younger age. - Less likely to have more adult household members. - Less likely to have a household member migrated. - Less likely to receive remittances. - More likely to spend a higher proportion of income on food. - Less likely to use more land. - Fewer household farm workers. - Less likely to use common resources with other farmers. - Less likely to be a member of an association. - Less likely to have taken up a loan.
- More likely to adopt a nutritious crop.	- Less likely to adopt a nutritious crop.

In the **Kajjansi-Masaka** Food Hub (Uganda), 508 fish farmers took part in both the FoodLAND survey and the experiments. This is the only Food Hub where fish farmers engaged in experiments. The clustering algorithm divided them into four groups with an average level of differentiation compared to other Food Hubs. The largest group (160 farmers) was labelled "More risk- Averse farmers, likelier to receive assistance from organisations but less willing to cooperate"; the second one (124 farmers), "Risk averse farmers likely to receive assistance from organisations but less willing to cooperate"; the third one (39 farmers), "Risk averse farmers likely to receive assistance from organisations and more willing to cooperate"; and the smallest one (36 farmers), "Risk-taking farmers, unlikely to use resources in common but very willing to cooperate". Apart from the differences highlighted in their names, they differ in terms of age, with the smallest group made up of older farmers (54.4 years on average), and the other three similar (40 to 44). Women are by far more represented in the largest group (37%), while the second one is characterised by the largest households (6.5 members). Farmers from the largest group are also very unlikely to have migrants (17%), compared to the second one where all households have some migrants; understandably, remittances follow a similar path. Farmers from the second largest group are less likely to grow the same crop (73%) and to do it in the same field (35%). In terms of innovation adoption, the groups differ for their willingness to sell their product jointly (the third group is the least likely, the fourth group the most); to adopt a nutritious fish species (same ranking); and to adopt a more profitable crop (the second group being the most likely, the third group the least).

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Table 14. Summary of group characteristics for the Kajjansi-Masaka Food Hub.

Risk averse farmers, likely to receive assistance from organisations but less willing to cooperate	**Risk-taking farmers, unlikely to use resources in common but very willing to cooperate**	**Risk averse farmers likely to receive assistance from organisations and more willing to cooperate**	**More risk- Averse farmers, likelier to receive assistance from organisations but less willing to cooperate**
124 farmers (24.4%)	**36 farmers (7.1%)**	**39 farmers (7.8%)**	**160 farmers (31.5%)**
- Second oldest age. - Second most likely of being male. - Most adult members in the household. - Most likely to have a household member migrated and to receive remittances. - Second least likely to own a pond. - Most likely to have a household member employed on their farm. - Least likely to grow the same fish. - Most likely to have assistance from a cooperation. - Most likely to use resources in common with others. - Second most likely to have taken up a loan. - Most likely to be risk takers. - Most likely to trust aquacultural organisations. - Most likely to trust. - Second least likely to trust other farmers in their village.	- Oldest age. - Most likely of being male. - Second most adult members in the household. - Second most likely to have a household member migrated and to receive remittances. - Most likely to own a pond. - Least likely to have a household member employed on their farm. - Most likely to grow the same fish. - Least likely to have assistance from a cooperation. - Least likely to use resources in common with others. - Second least likely to have taken up a loan. - Least likely to be risk takers. - Least likely to trust other farmers in their village.	- Youngest age. - Second least likely of being male. - Second least likely to have more adult members in the household. - Second least likely to have a household member migrated and to receive remittances. - Second most likely to own a pond. - Second least likely to have a household member employed on their farm. - Second least likely to grow the same fish. - Second least likely to have assistance from a cooperation. - Second least likely to use resources in common with others. - Least likely to have taken up a loan. - Second most likely to be risk takers. - Second most likely to trust aquaculture organisations. - Most likely to trust other farmers in their village.	- Second youngest age. - Least likely of being male. - Least likely to have more adult members in the household. - Least likely to have a household member migrated and to receive remittances. - Least likely to own a pond. - Second most likely to have a household member employed on their farm. - Second most likely to grow the same fish. - Second most likely to have assistance from a cooperation. - Second most likely to use resources in common with others. - Most likely to have taken up a loan. - Second least likely to be risk takers - Second least likely to trust aquaculture organisations. - Second most likely to trust other farmers in their village.
- Second most likely to adopt a fish species to be sold jointly. - Second most likely to adopt a nutritious fish.	- Most likely to adopt a fish species to be sold jointly. - Most likely to adopt a nutritious fish. - Second most likely to adopt a more profitable fish.	- Least likely to adopt a fish species to be sold jointly. - Least likely to adopt a nutritious fish. - Least likely to adopt a more profitable fish.	- Second least likely to adopt a fish species to be sold jointly. - Second least likely to adopt a nutritious fish.

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Risk averse farmers, likely to receive assistance from organisations but less willing to cooperate	Risk-taking farmers, unlikely to use resources in common but very willing to cooperate	Risk averse farmers likely to receive assistance from organisations and more willing to cooperate	More risk- Averse farmers, likelier to receive assistance from organisations but less willing to cooperate
124 farmers (24.4%)	**36 farmers (7.1%)**	**39 farmers (7.8%)**	**160 farmers (31.5%)**
- Most likely to adopt a more profitable fish.			- Second least likely to adopt a more profitable fish.

Conclusions

Although the cluster analysis made the classification of smallholders simpler by reducing the number of dimensions along which they differ, the results highlighted the diversity of behavioural and productive profiles across the FoodLAND Food Hubs. As a result of this diversity, the clusters also show different effectiveness in explaining the farmers' stated propensity to adopt innovations. In three Food Hubs, namely Meknes, Jendouba and Kisumu, the groups' willingness to adopt differs significantly for all the six innovations considered; in Mvomero for all but one; and in Chbika for all but two. Instead, in Kajjansi-Masaka and Mukurweini the difference is significant for only three of the variables; in Kamuli, Kilombero and Kitui, for two; and in Nakaseke, Kilombero (fish) and Beni Mellal, for only one. Across Food Hubs, the groups are more effective in explaining the farmers' interest in adopting a technology that can help them overcome their limitations, or their willingness to sell crops jointly with other farmers; they are less effective in explaining responses to the question used to test the farmers' interest in being early adopters in their village.

The cluster analysis revealed a (qualitative) association between behavioural factors and propensity to adopt; however, this association does not always go in the expected direction (for example, impatience is related to either higher or lower propensity to adopt the proposed innovations depending on the Food Hub). This point to the importance of linking experimental and survey data, and complement stated preferences with adoption data.

We would expect farmers that trust organisations and their peers more to be more inclined to adopt innovations (especially to sell crops jointly) and *vice versa*. On the contrary, trust in (and thus reliance on) organisations and peers could indicate smallholders' search for security and certainty that innovations could instead undermine. We would expect higher propensity toward innovation of farmers used to deal with new products, and of those who are less risk averse, less impatient, and larger contributors in the public good game (especially if the innovation implies some joint activity with other farmers). Rather, the results suggest the existence of a gap between stated intentions to innovate and revealed preferences, suggesting that the stated propensity to adopt innovations can indeed conceal a bias towards default choices (status quo). These findings far from our initial hypotheses call for more specific and in depth analyses (see next chapters), and for the use of framed field experiments, preferably randomised controlled trials, that indeed will be implemented in Meknes, Mvomero, and Kajjansi-Masaka within T5.9. In Meknes and Kajjansi- Masaka, for example, the behavioural factors align with stated willingness to innovate (if the ranking of the groups in terms of these variables is considered), but in Mvomero it is less the

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case, with impatient farmers more willing to adopt in most instances. In general, the results of the cluster analysis show that the results of behavioural experiments do not differ significantly across farmers' groups in the Food Hubs where they were implemented, and that, exactly like *stated* trust and risk preferences, they do not align as expected with stated willingness to adopt, thus revealing unforeseen gaps.

Despite the criticalities and need for further research discussed above, the results of the cluster analysis shed light on the composition of the farmers' populations in the Food Hubs in terms of productive and behavioural characteristics linked to socio-demographics (individual respondent and their household). Each group was assigned a name that describes the main characteristics of the farmers belonging to it, relative to the others, and the size of each group is also reported in the description. Researchers and organisations that deal with agricultural innovation in the Food Hub areas could use this information to **tailor technological solutions and dissemination activities** and assess uptake ex post. For example, general policy implications include prioritising **low-risk, time-saving innovations** when dealing with farmers who have a low propensity to adopt, **enhancing the role of intermediate bodies** (extensions services, NGOs), and supporting existing **social structures and social innovations**. Furthermore, the allocation of farmers to each treatment in the Food Hubs where randomised controlled trials are foreseen could be based on the clusters identified, i.e., the composition of the treatment groups could be similar in terms of shares of farmers belonging to each of the clusters. Then, after actual adoption is assessed, it will be possible to test whether this is correlated with stated (survey) and revealed (experiments) preferences, drawing recommendations also in terms of future measurement of behavioural factors.

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Chapter 2: Adverse events' influence on smallholder farmers' time preferences: evidence from 5 African countries

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Introduction

Farmers' behaviours and innovation uptake can be influenced by the way they manage their patience for receiving rewards (Le Cotty et al., 2018). This is an important issue in contexts highly exposed to economic and climate events and where the adoption of innovation can contribute to preventing/reducing their impact while enhancing farmers' livelihood. In turn, farmers' patience is influenced by several situational and individual factors that might range from demographic to personal experience and risk attitude. Shocks and adverse events such as floods, droughts, and pest invasion can modify farmers' wealth and time preferences thus affecting their decision to invest on their business (Cassar et al., 2017). Literature reports an overconfident approach to risk for those farmers who have experienced adverse events (Barsbai et al., 2022; Finger et al., 2022). Even though there is literature on farmers' risk aversion and its determinants, precise measurements on how farmers' experiences are affecting their time preferences and thus their propensity to innovate is particularly lacking.

Literature reports that an impatience behaviour might be the result of past negative experience (Cassar et al., 2017). Barnett & Breakwell, (2001) found that individuals' negative experiences weaken the risk propensity but, on the other hand, individuals facing experience of certain setbacks repeated in the long term might be less sensitive to future adverse events and show more patience (Barnett & Breakwell, 2001): demographic factors combined with occurrences, influence individuals' patience and time preferences (Coletta et al., 2019).

This research aims at investigating to which extent individuals' characteristics and past experiences are influencing farmers' time preferences. Our research questions are: (i) how farmers differentiate themselves in terms of experienced setbacks and worries towards the future? (ii) To which extent these differences affect farmers' time preferences?

Methodology

Data from 5,329 fish and crop small-scale farmers in 5 African countries (12 rural Food Hubs) have been collected in 2021. The survey investigated farmers' habits, levels of trust, innovation propensity, risk perception, past experiences, and demographic as well as contextual aspects. Linked to this set of data, a dataset of structured behavioural economic experiments to identify behavioural factors influencing, either as a barrier or as a driver, farmer's decision-making was also gathered from 5 Food Hubs within the 5 African countries. In these Food Hubs, incentivized lab-in-the-filed experiments were done involving the same farmers engaged in the survey activities so to compare farmers stated and revealed preferences. 2,393 valid observations were collected.

A list of setbacks has been derived and farmers were asked to assess, using a 1-5 Likert scale, to which extent they experienced a series of economic, social, and environmental setbacks during the last year (see Table 15).

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Table 15: list of setbacks identified, mean values and standard deviations

Setbacks	Category	Mean Value	Standard deviation
Food shortage	SOCIAL	2.65	1.64
Health	SOCIAL	2.98	1.56
Drought	ENVIRONMENTAL	3.04	1.66
Flood	ENVIRONMENTAL	1.78	1.37
Infestation	ENVIRONMENTAL	3.13	1.63
Dispossession	ECONOMIC	1.60	1.26
Cost increase (price of fertilizer and seed)	ECONOMIC	3.75	1.45
Job loss	ECONOMIC	2.14	1.56
Income reduction	ECONOMIC	3.54	1.50
Social problems (violence or crime)	SOCIAL	1.95	1.48

As for the setbacks, a list of the farmers' worries towards the future was measured through 1-5 Likert scales assessing to which extent they were concerned of experiencing a list of potential economic, social and environmental distresses (Table 16).

Table 16: list of worries identified, mean values and standard deviations

Worries	Category	Mean Value	Standard deviation
Food shortage	SOCIAL	3.24	1.65
Health	SOCIAL	3.07	1.62
Drought	ENVIRONMENTAL	3.27	1.62
Flood	ENVIRONMENTAL	2.19	1.57
Infestation	ENVIRONMENTAL	3.24	1.62
Dispossession	ECONOMIC	2.22	1.67
Cost increase (price of fertilizer and seed)	ECONOMIC	3.60	1.55
Job loss	ECONOMIC	2.53	1.69
Income reduction	ECONOMIC	3.29	1.60
Social problems (violence or crime)	SOCIAL	2.30	1.64

Setbacks were aggregated into the social, economic, and environmental macro classes presented in Table 15 using the arithmetic mean. Mean values were rounded to the nearest integer so to approximate the original 1-5 Likert scale. An econometric model was employed to test their influence on the farmers' time preferences, combining behavioural experiment data with the information collected from the survey. Tobit regression was used to account for the two-side censored nature of the time preferences data.

The complete model is reported in the following equation:

$$\boldsymbol{Y}^{*}_{\boldsymbol{i(c,s)}} = \alpha + \boldsymbol{S'}_{\boldsymbol{i(c,s)}}\boldsymbol{\beta} + \boldsymbol{W'}_{\boldsymbol{i(c,s)}}\boldsymbol{\gamma} + X'_{i(c,s)}\delta + P'_{i(c,s)}\vartheta + \mu\, risk_{i(c,s)} + \rho_{c,s} + \partial_{s} + \epsilon_{i(c,s)}$$

Where Y^{*}_{ics} is the uncensored latent variable behind the observed switching point of the farmer's time preferences. This score is based on the switching point from which farmers

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start choosing to wait for 2 more weeks (they choose the payment in 4 weeks rather than in 2 weeks), to get a higher payment. Y_{ic} is measured on a 1 to 11 impatience score, where 1 indicates farmers with highest levels of patience, whereas 11 indicates the highest levels of impatience. Inconsistent choices (with more than one switching point) were removed. The regressors of interest are mean social, economic, and environmental setbacks (S'_{ics}) and worries (W'_{ics},). The model also considers a series of socio-demographic controls X'_{ics} (farmer's age, education, gender, and income), farmer's stated preferences towards innovation, risk, and trust (P'_{ics}), as well as a measurement of the farmer's revealed preferences on risk ($risk_{ics}$). Farmers' attitudes to risk are measured using a 1 to 10 score, with 1 showing a high willingness to take risks (risk lovers) and 10 a low willingness to take risks (risk averse profiles). These scores correspond to the switching point at which farmers start choosing the high stakes lottery in the series of 10 choices, rather than the low stakes lottery. Similar to the time preferences, inconsistent choices of risk were removed from the dataset. Finally, the models include a country fixed effect ($\rho_{c,s}$ and an experimental session fixed effect (∂_s) to control for time invariant country and session heterogeneity. All models were tested for multicollinearity.

Results

Figure 1 and Figure 2 show the most common setbacks and worries concerning the near future for small-scale crop and fish farmers, as reported in D3.3. These concerns include the shortage/quality/cost of available fingerlings (fish farmers), pesticides and seed feeds (crop farmers).

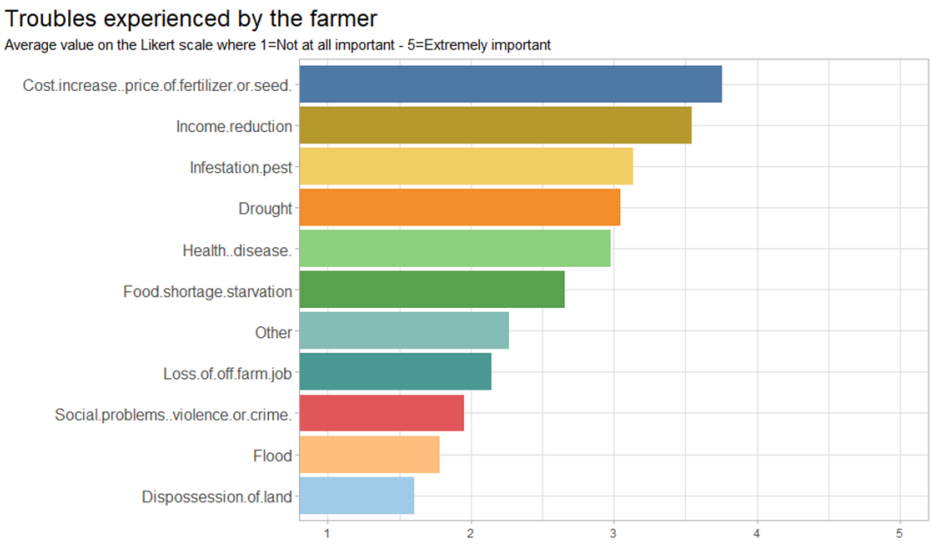

Figure 1. Most common answers to the question: Did you experience any of the following setbacks during the last year? (Q32).

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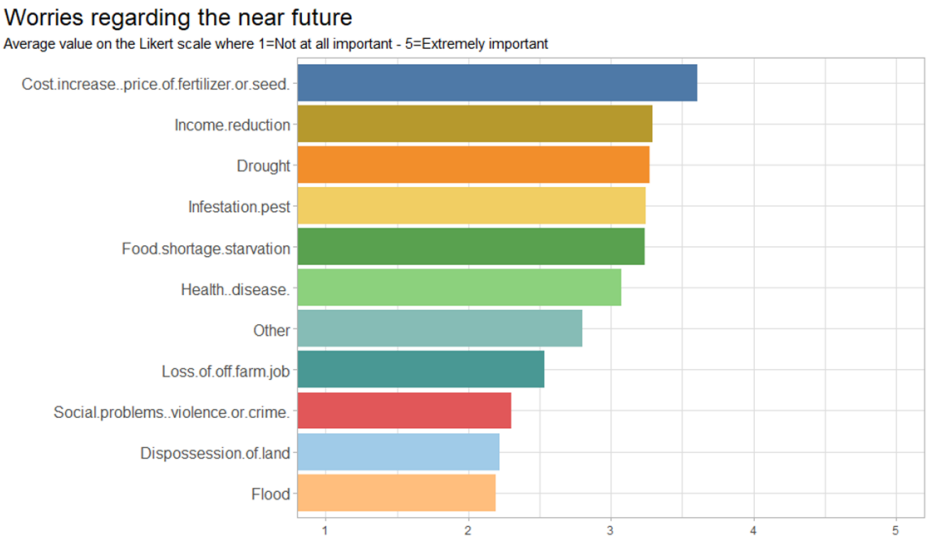

Figure 2. Most common answers to the question: Regarding your near future, are you worried about any of the reasons below? (Q33).

Table 17 reports the results from the econometric analysis. In all specifications, results show the extent to which farmers faced social setbacks in the last year significantly predicted farmers' time preferences. In the most completed model (4), a marginal increase in social setbacks corresponds to a 0.48 reduction in farmer's impatience. Farmer's gender and farmer's revealed risk preferences also contribute to predict farmers' time preferences. Male farmers are more likely to be impatient, while a marginal increase in farmers' risk aversity corresponds to a 0.18 increase in farmers' impatience. The outcomes of this analysis suggest that farmers who have experienced social setbacks during the last year, female farmers, and risk lover farmers are more likely to be patients.

Table 17. Tobit results coefficients (SE in parentheses)

VARIABLES				
Social setbacks	-0.552** (0.222)	-0.424* (0.218)	-0.474** (0.224)	-0.478** (0.230)
Economic setbacks	0.374 (0.266)	0.233 (0.266)	0.569** (0.282)	0.419 (0.281)
Environmental setbacks	-0.716*** (0.228)	-0.261 (0.226)	-0.068 (0.224)	-0.038 (0.227)
Social worries	-0.040 (0.226)	0.037 (0.221)	-0.104 (0.230)	0.036 (0.238)
Economic worries	0.319 (0.262)	0.083 (0.256)	-0.106 (0.272)	-0.182 (0.273)
Environmental worries	-0.371* (0.218)	-0.332 (0.215)	0.029 (0.218)	-0.005 (0.222)
Age			0.006 (0.014)	0.013 (0.014)
Educational level			0.211 (0.159)	0.074 (0.160)
Gender			-1.246*** (0.431)	-1.245*** (0.479)
Income spent on food			0.022 (0.139)	-0.134 (0.149)

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VARIABLES				
Farmer's risk aversion			0.152 (0.126)	0.126 (0.130)
Farmer's trust			-0.108 (0.143)	-0.271* (0.145)
Farmer's innovation			0.186 (0.168)	0.221 (0.170)
Risk switch point (experiments)			0.241*** (0.080)	0.178** (0.080)
Constant	4.592*** (0.688)	0.676 (0.842)	-0.300 (2.050)	-23.831 (815.950)
Observations	1,938	1,938	1,181	1,181
Country FE	NO	YES	YES	YES
Session FE	NO	NO	NO	YES
McFadden's pseudo R2	0.005	0.025	0.028	0.06
Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1				

Conclusions

Research implications

Results show that experiences of social setbacks positively influence farmers' patience. This partially confirms what emerged from Barnett & Breakwell (2001) when they report that individuals facing a constant setback experience might be less sensitive to future adverse events, thus more likely to wait for a future reward. This interpretation, however, cannot be fully confirmed since the measurement of the setbacks did not measure how long they have been experienced. The experience of adverse social conditions such as health problems, food shortage and crime can be considered good predictors of farmers' behaviours in terms of patience towards rewards. This represents a significant novelty in the debate on time preferences since the relation between farmers' experiences and their patience has not been sufficiently explored. Moreover, gender emerged as a driver of farmers' time preferences since female respondents seem to be more patient, in line with the literature that additionally includes age and social conditions, among the determinants (Schechter & Francis, 2010). Furthermore, the results confirm that there is a cause-effect relationship between risks and time preferences. In particular, farmers with a high propensity to take risks are also more prone to bet on a long-term remunerating investment. This is only partially confirmed by the literature, since the relation between risks and time preferences is still a debated topic in the literature as their relationships seem to depend on the contextual elements, thus confirming the importance of investigating the role of experienced setbacks (Andreoni & Sprenger, 2012; Coletta et al., 2019; Tanaka et al., 2010).

Policy recommendations

Our results can be useful for stakeholders and decision makers in interpreting how farmers' might behave when experiencing social setbacks and negative experiences. Understanding which factors influence time preferences is then crucial for policy makers in order to prevent and tackle the negative events that might affect farmers' patience. From the results, we can suggest that policy actions responding swiftly to farmers' social distresses (e.g., introduction of agricultural innovations as a response to famines) could have better chances in being effective in the long-term. Furthermore, long-term

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innovations are especially accepted (and needed) in the areas and by farmers affected by social setbacks, even though benefits are delayed. Policy makers should introduce adequate measures fighting social insecurities (e.g., food shortage, health distresses, violence and crime) and, in parallel, sustaining R&I generating timely benefits and promoting innovation knowledge (e.g., support to extension services and NGOs, implementation of knowledge raising campaigns) in the targeted areas,

Recommendations for FoodLAND project

The results from this work are reflected in the FoodLAND project in terms of a better understanding of farmers' time preferences and choices. This will help those actors establishing long-term relationships with farmers. Agricultural decisions involve options that offer a choice between immediate small payoffs or delayed large payoffs (farming cycles, adopting innovations, farm investments, etc.). With our work we can conclude that the different typologies of technologies that will be introduced in the Food Hubs would have different success rate among farmers, according to their capacity of guaranteeing long vs short-term rewards, this depending, among other, by their exposure to social setbacks. Based on the results emerging from this work, we can assume that technologies with a long-term impact will be those preferred by female farmers and farmers with a higher risk propensity (possible pioneers to be involved in testing the prototypes). Furthermore, the results help the assessment of those areas that have been more vulnerable to social setbacks, thus supporting the development and deployment of innovations addressing food shortage and (nutritional) health issues in those areas even though time-demanding. These elements will be useful when meeting farmers' needs in the Food Hubs and in finding the key elements for encouraging their participation in the bottom-up decision-making processes, which is a crucial aspect of the FoodLAND project.

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Chapter 3: Gender differences in adopting agricultural innovations: The case of five African countries.

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Introduction

Agricultural innovation could increase the productivity of the sector and improve rural household livelihood (Feder et al., 1985; Alston, 2010). However, in most developing countries, a low adoption rate of agricultural technologies has been a persistent concern. Moreover, the adoption rate of a specific innovation could vary across different social groups. For instance, evidence shows that males and females could adopt a specific innovation at a different rate (Obisesan, 2014; Shibata et al., 2020). This highlights that if a certain group of society is not adopting or is adopting the innovation at a lower rate than others, it is crucial to understand the reasons to design effective intervention that increases the diffusion rate of the innovation for all groups of society. Specifically, women who represent a considerable share of the agricultural and rural economy through their role as farmers, laborers, and entrepreneurs in developing countries face several challenges that may constrain them to adopt innovations. Among other reasons, attributes of technologies could affect the two genders' interest in adopting at different rates (Feder and Umali, 1993). For instance, some types of innovation could be more appealing and could have significant implications for females than males and vice versa. Moreover, social norms or gender norms could limit women's social learning opportunities, such as the availability and benefit of adopting innovations, and significantly affect women's adoption decisions (Smith, 2000; Katungi et al., 2008; Beaman and Dillon 2018).

This study uses primary data collected from the five Foodland African countries (Morocco, Tunisia, Kenya, Tanzania and Uganda) in 2021 to address two main research questions. ***First***, we aim to examine the role of gender in adopting different agricultural innovations. The gender-linked differences in adopting technologies could exist due to many reasons. For instance, crop variety preferences of the two genders can vary due to their perception of the crop. Specifically, in a conservative society, females are responsible for preparing food for their household members, and female farmers may grow crops primarily for home consumption. Thus, females are more likely to be interested in adopting a crop/innovation that directly benefits the well-being of the household, such as a crop that improves their family nutrition. On the contrary, evidence shows that male farmers are market-oriented and are more likely to be interested in adopting technology with high economic returns. ***Second***, we further test a hypothesis whether this difference in adopting innovations could associate with behavioural attributes and contextual factors such as altruism and gender norms. Culturally, females are expected to care for their children and family; we therefore expect that they display more altruistic attitudes than males, which might affect their decision to adopt a specific innovation. Moreover, in a conservative society, females may have limited social-relation due to strong gender norms that may limit their social learning about the benefit of high economic-return innovation (Shibata, R. et al., 2020). Thus, gender norms could also explain the two genders' differences in adopting a specific innovation.

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Methodology

The study relies on the FOODLAND datasets collected using both survey and experiment, covering five African countries i.e., Kenya, Morocco, Tanzania, Tunisia, and Uganda. The survey was conducted in 10 food hubs from the five countries, while the experiment was based on one food hub from each country. The dataset contains rich information about farmers' profiles, behavioural and contextual factors, and their interest in adopting different technologies such as risk-minimizing technologies, yield-maximizing technologies, high-profit crops, and nutrient-dense crops. Farmers' interest in adopting the four types of innovation is evaluated using the ordinal scale ranging from 1 to 5 ("not at all interested" to "extremely interested").

To empirically test the hypotheses mentioned in section 1, two regression models are developed. The first model identifies the gender-based difference in adopting the four types of agricultural innovations. The second model analyses whether this gender difference in adopting the innovations is related to their individual behavioural difference (altruism) and contextual factors (gender norms).

Gender and adoption decisions

In general, we expect female farmers in developing countries to have limited resource access and face adverse social norms that affect their decision to adopt agricultural technologies (Aduwo, O. E., et al., 2017). Moreover, women in rural developing countries are responsible for all the household tasks, including feeding their family members, and they are more likely to understand the health benefit of improved nutrition-dense crops. Thus, unlike other agricultural technologies, we expect female farmers to have a higher interest in adopting a nutritional-dense crop than males. This first hypothesis is tested by using the following specification:

$$Y_{ji} = \alpha + \beta\, Female_i + \theta X_i + \delta FE_c + \epsilon_{ij} \qquad (1)$$

Where the dependent variable, Y_{ji} is farmer i 's interest in adopting j type of innovation. Farmers intention to adopt the four types of agricultural innovation, j, i.e., risk-minimizing technologies, yield maximizing technologies, a high profit crop, and a nutrient-dense crop, are introduced in specification (1), separately. The variable $Female_i$ identifies female farmers. The variable X_i and FE_c represent set of individual and contextual factors and country fixed effects, respectively. These explanatory variables allow us to control for possible association between individual and contextual factors and farmers' intention to adopt the innovations. For example, male farmers could have better resource access such as access to financial resource, land and education, that may positively affect their decision to adopt the innovation. Moreover, country characteristics, such as social norms, may affect male and females' farmers interest in adopting the innovation differently, thus country fixed effect also included, to control both observable and unobservable country characteristics.

Altruism and gender differences in adopting the nutrition-dense crop

As mentioned above, in developing countries, both naturally and culturally, females are expected to care for their children and their families. This indicates that females and males may have behavioural differences affecting their decision-making process. Specifically, females may be more altruistic and give more weight to the well-being of their families than males (Aguiar et al., 2009; Marianne, 2011; Falk and Hermle, 2018), which affects their intention to adopt a nutrition-dense crop. We test this hypothesis by

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introducing an interaction term between farmers' gender and their altruism level, as specified in the following regression form:

$$Y_i = \alpha + \beta_1 Female_i + \beta_2 Altruim_i + \beta_3 Female_i * Altruim_i + \theta X_i + \delta FE_c + \epsilon_i \quad (2)$$

Where, Y_i represents farmer i 's interest in adopting a nutrition dense crop. The variable $Altruim_i$ is farmer i 's altruism level which is measured by his/her contribution during the public good games. The other variables are the same as specification (1). The coefficient B_2 identifies the association between altruism level and male farmers' intention to adopt the innovation after controlling all other factors. B_3 identifies the association between altruism and female farmers' intention to adopt the innovation, compared to male farmers, assuming all other factors are the same. For example, a positive B_3 indicates that female farmers who are altruists are even more likely to adopt the innovation than similarly altruistic male farmers and other females with lower levels of altruism.

The coefficients in specifications 1 and 2, are identified using the ordered logit estimation techniques as the dependent variable is defined on ordinal terms.

Results

Gender and intention to adopt the innovations

The results achieved through the ordered logit models are based on 4,529 farmers who produce crops. Female farmers account for 33 percent of the total respondents. Table 18 shows the statistical summary of respondents' characteristics of by gender. With reference to the agricultural innovations, female farmers have significantly higher interest in adopting the four types of innovation than males, while the magnitude is significantly higher when the innovation is nutrition-dense crops *Figure 3*). All personal and contextual factors of farmers show differences between gender, except access to financial institutions. Specifically, male farmers are more educated and have better resource access, such as land and labour, than females. Moreover, the public good game results show that male farmers contribute more than females. On the contrary, farmers interested in producing and selling their crops jointly with other farmers[2] indicates female farmers have higher stated others-regarding preference than males. Female farmers are also less risk takers and have lower trust in others than males.

Table 18. Statistical summary of main characteristics by gender

Variables	Mean (Male)	Mean (Female)	Diff.	p-value	Obs.
Intention to adopt					
Risk-minimizing innovation	4.450	4.524	-0.073**	0.017	4529
Yield increasing Innovation	4.424	4.464	-0.040	0.255	4529
High economic-return crop	4.329	4.446	-0.116***	0.001	4529
Nutrition-dense crop	3.931	4.211	-0.280***	0.000	4529
Individual / contextual characteristics					
Age	46.856	44.499	2.356***	0.000	4529

[2] Farmers willingness to produce and sell their production jointly with other farmers is used as a proxy to measure stated other-regarding preference. We considered thus

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Variables	Mean (Male)	Mean (Female)	Diff.	p-value	Obs.
Education	3.089	2.850	0.239***	0.000	4529
Income	2.718	2.546	0.173***	0.000	4529
Loan	1.847	1.842	0.004	0.709	4529
Credit	1.703	1.701	0.001	0.932	4529
Land size	3.895	1.378	2.516***	0.000	4529
Labor (Nb of adult family member)	4.007	3.692	0.315***	0.000	4529
Behavioural Attributes					
Altruism (pgg2_contrib)	68.629	64.903	3.726*	0.063	1927
Altruism (joint crop)	4.009	4.114	-0.105**	0.013	4529
Risk attitude	3.256	3.450	-0.194***	0.000	4529
Innovativeness	4.460	4.483	-0.023	0.492	4529
Trust to others	3.955	4.058	-0.103**	0.010	4529

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

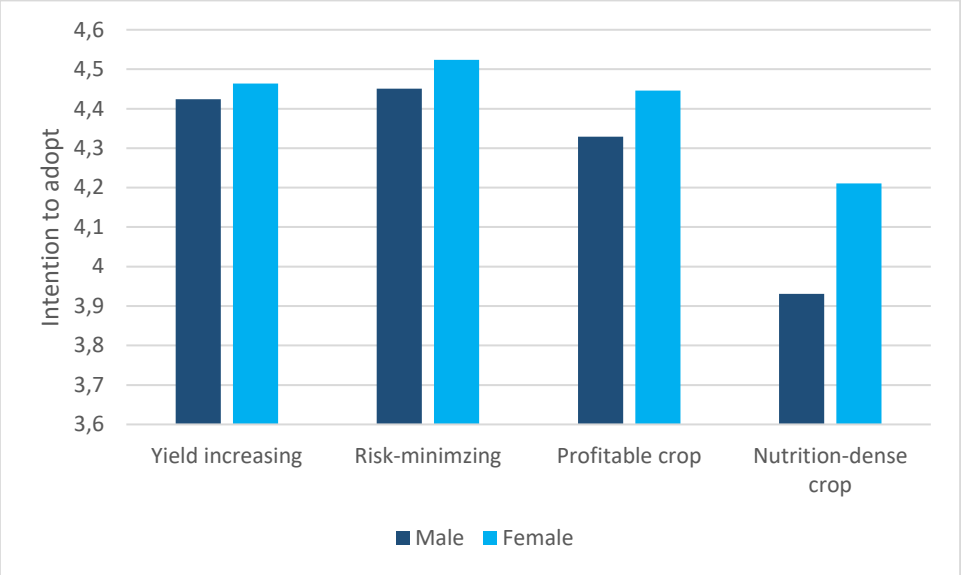

Figure 3: Farmers' intention to adopt the agricultural innovations by gender.

Figure 4 shows the association between altruism and farmers' intention to adopt nutrition-dense crops across genders. In general, in contrast to our expectation, farmers' altruism is not positively correlated with their intention to adopt the innovation for the two genders. Thus, it may indicate that intention to adopt the innovation may not be characterized by a relatively higher altruism level. Rather other factors may contribute to farmers' intention to adopt the innovation.

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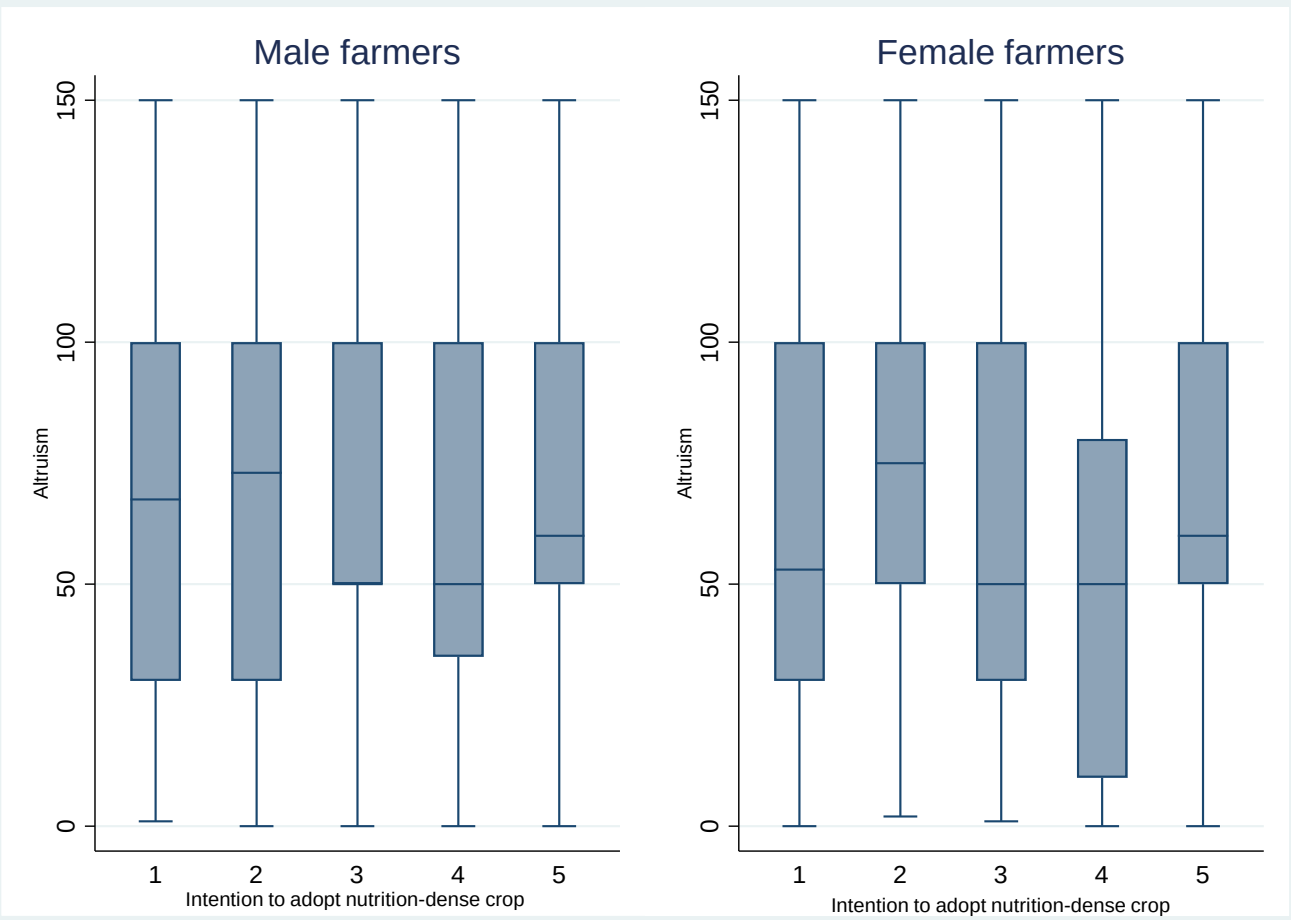

Figure 4: The association between altruism and intention to adopt nutrition-dense by across gender.

Estimation results

Gender and intention to adopt the innovations

The results, derived from regression specification (1), in Table 19 identify the role of gender in adopting the three agricultural innovations, i.e., columns 1 and 2 focus on technologies that minimize risk, columns 3 and 4 focus on new crops with high profit, and columns 5 and 6 focus on new crops improve nutrition. Consistent with our hypothesis, in columns 5 and 6, the coefficient of the female variable shows that females are more interested in adopting a new crop that improves nutrition before and after controlling all other factors, respectively compared to their male counterparts. However, columns 1-4 show that we have not found evidence of gender difference in adopting the other two types of innovations. It suggests that females are more concerned about their family's well-being and are more likely to be aware of the benefit of adopting such nutrition-dense crops than other innovations.

Moreover, other factors also determine farmers' intention to adopt the innovations. For instance, older farmers are less likely to be willing to adopt the three types of innovation. Farmers' economic vulnerability, such as food shortage experience, has a positive

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influence on their decision to adopt technologies that minimize risk and crops that increase profits. Moreover, farmers' risk aversion attitude negatively affects their intention to adopt the three types of innovations. On the contrary, farmers' innovativeness and trust in other farmers positively contribute to their interest in adopting the innovations.

Table 19 Gender difference in adopting different technologies

	(1) Risk_min. technology	(2) Risk_min. technology	(3) Profitable Crop	(4) Profitable crop	(5) Nutrition-dense crop	(6) Nutrition-dense crop
Female	0.012	-0.12	0.066	-0.061	0.30***	0.26***
	(0.88)	(0.17)	(0.37)	(0.43)	(0.00)	(0.00)
Age		-0.0060**		-0.010***		-0.0045*
		(0.03)		(0.00)		(0.06)
Education		0.017		-0.065**		-0.015
		(0.63)		(0.05)		(0.62)
Income		0.012		-0.028		-0.018
		(0.65)		(0.27)		(0.42)
Food need		0.15***		0.12***		0.027
		(0.00)		(0.00)		(0.31)
Cooperation/Association.		-0.26***		-0.022		-0.23***
		(0.00)		(0.78)		(0.00)
Risk aversion		-0.090***		-0.092***		-0.078***
		(0.00)		(0.00)		(0.00)
Innovativeness		0.80***		0.35***		0.21***
		(0.00)		(0.00)		(0.00)
Trust to others		0.34***		0.21***		0.13***
		(0.00)		(0.00)		(0.00)
Loan		-0.077		-0.16		-0.17*
		(0.48)		(0.12)		(0.06)
Credit		-0.073		-0.022		-0.030
		(0.37)		(0.76)		(0.64)
Land size		-0.0037		-0.0033		-0.0025
		(0.44)		(0.49)		(0.57)
Labour		-0.0039		0.041**		-0.0057
		(0.82)		(0.01)		(0.69)
N	4529	4505	4529	4505	4529	4505
pseudo R-sq	0.04	0.16	0.03	0.07	0.05	0.06

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Altruism and gender differences in adopting the nutrition-dense crop

Using regression form (2), Table 20 shows the role altruism on gender difference in adopting nutrition dense crop. In column 1 and 2, farmers contribution in the public good game is used to measure altruism (revealed other regarding preference). While in columns 3 and 4 farmers' willingness to produce and sell crops is a proxy for altruism (stated other-regarding preference). In column (2), the results show that both the Altruism and the interaction term (Female*Altruism) variables are not statistically significant. Our results indicate no evidence of the association between altruism and both genders' intention to adopt the innovation. In column 4, although there is positive association between altruism (stated other-regarding preference) and intention to adopt the innovation, we have not found evidence of gender differences.

In general, the results suggest that females' intention to adopt nutritional-dense crops is not characterized by relatively higher altruism. Column 5 replicates the analysis for gender norms[3], the results show that no evidence of the relation between gender norms and the two genders difference in adoption decision.

Table 20: Factors explaining the adoption of nutrient dense crops (gender and altruism).

	(1)	(2)	(3)	(4)	(5)
Female	0.42**	0.42**	0.097	0.029	
	(0.02)	(0.02)	(0.63)	(0.89)	
Altruism (PGG)	-0.00003	0.00003			
	(0.98)	(0.98)			
Female*Altruism	-0.002	-0.002			
	(0.42)	(0.44)			
Altruism(jointly)			0.61***	0.58***	
			(0.00)	(0.00)	
Female*Altruism			0.064	0.076	
			(0.18)	(0.12)	
GenderNorm					0.008*** (0.00)
Female*GenderNorm					0. 002 (0.34)
Age		-0.0042		-0.0026	
		(0.24)		(0.28)	
Education		0.056		-0.012	
		(0.22)		(0.69)	
Income		-0.081**		0.0087	
		(0.02)		(0.70)	
Cooperation/Association		-0.22*		-0.21***	
		(0.07)		(0.00)	
Risk attitude		-0.090***		-0.049**	

[3] Gender norm is the difference between the stated other-regarding preference (jointly) and the revealed other regarding preference (pgg_contrib),

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	(1)	(2)	(3)	(4)	(5)
		(0.00)		(0.02)	
Innovativeness		0.083**		0.14***	
		(0.04)		(0.00)	
Trust to others		0.20***		0.071***	
		(0.00)		(0.00)	
Loan		-0.097		-0.20**	
		(0.49)		(0.03)	
Credit		0.10		0.045	
		(0.33)		(0.51)	
Land size		-0.0051		-0.0028	
		(0.43)		(0.54)	
Labor		-0.0059		-0.014	
		(0.78)		(0.33)	
N	1927	1907	4529	4505	
pseudo R-sq	0.04	0.06	0.11	0.12	

Conclusions

Agricultural innovation can increase the productivity and sustainability of the sector and improve rural household livelihood, yet adoption rate among developing countries is still very low. Thus, understanding factors determining farmers' propensity to innovate among different demographic has a paramount relevance.

Using primary data collected from five African countries, this study tests if the adoption of specific agricultural innovations (i.e., risk-minimizing technologies, yield maximizing technologies, a high profit crop, and a nutrient-dense crop) vary across genders. We further examine a whether gender difference in adopting a specific innovation could be explained by behavioural attributes and contextual factors.

Our findings show that gender differences emerge when innovation directly improves the well-being of the family. Specifically, female farmers are more interested in adopting new products that improve nutrition than males. However, we have not found evidence of the association between farmers' behavioural attributes and the gender difference in adopting nutritional-dense crops. This could be because this study used farmers' outdoor altruism level instead of indoor altruism.[4]

The results suggest the importance of targeting a certain social group to design effective intervention that increases the diffusion rate of specific agricultural innovations. Specifically, innovations aimed at improving the nutrition security are more likely to be adopted by female farmers to whom it is therefore crucial to provide relevant information and tailored assistance.

[4] Since this study aims to show the effect of females' altruistic manner toward their family on their adoption decision, it is more relevant to use indoor altruism level than outdoor altruism.

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Chapter 4.1: Detecting contextual, production, behavioural factors of farmers' household income and deriving anti-poverty policies.

Author: Gurneet Kapour (JHI)

Research question

We are exploring here factors determining a farmer's household income, and draw policy recommendation to negate the prevalence of poverty. The present research highlights how important socio-economic characteristics are in determining farmers' income. Increasing income is imperative in smallholder farming economies as a mechanism to tackle nutritional poverty traps (Debraj, 1998). Once we have established which variables are statistically significant, these areas can then be taken ahead by policy makers to tackle poverty. However, these predictors need to be observed with caution, due to possible endogeneity as, for instance, educated farmer may already come from ancestorial wealth (Olayiwola 2022). Hence, them being in the high-income group is not a product of their education, but their education emanates from their previous privilege of having the resources to accumulate human capital, alluding to the fact that correlation does not mean causation.

Method

To find factors that determine farmers' income, we have chosen a few explanatory variables, as shown in Table 22. Every farmer in our survey was asked to select their average household income level, which was in, from 1 to 5, 1 being the lowest and 5 was for the higher income groups (shown below **Errore. L'autoriferimento non è valido per un segnalibro.**). The average income groups were specifically tailored for each country in our questionnaire, providing farmers with representative income levels relevant to their country.

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Table 21: income thresholds, from 1 to 5, of all countries

Income thresholds from 1 to 5	1	2	3	4	5
Kenya	1001 to 10,000 KES	10,001 to 20,000 KES	20,001 to 40,000 KES	40,001 to 50,000 KES	40,001 to 50,000 KES
Morocco	<1000 DHS	1000 to 2000 DHS	2000 to 4000 DHS	4000 to 7000 DHS	4000 to 7000 DHS
Tanzania	<270,000 TZS	270,001 to 520,000 TZS	520,001 to 760,000 TZS	760,001 to 1,000,000 TZS	760,001 to 1,000,000 TZS
Tunisia	<200 TND	200 to 300 TND	300 to 350 TND	300 to 350 TND	350 to 430 TND
Uganda	<100,000 UGX	100,000 to 790,000 UGX	800,000 to 1,490,000 UGX	800,000 to 1,490,000 UGX	1,500,000 to 2,000,000 UGX

We set a binary variable that identifies high-income farmers. Farmers are categorised into high- or low-income groups, which takes the value 1 if the stated income range is "4" or "5", and 0 if the state income range was "1", "2", "3".

Once this binary is set, we include education (five levels from low to high), migration (dummy for the presence of migrants in the households), number of children and agricultural land tenure-ship (size of land owned, rented, and in other forms of possession) as predictors. Through a Probit regression model, we analyse the effect each of these explanatories has on the probability of a farmers' household income to be high rather than low. We applied a logarithmic transformation to some of our variables within our model. We apply this transformation by first testing the variables for skewness, and those that depict significant levels of skewness are applied a logarithm to make the distribution of the variable less distorted.

Results and policy implications

From Table 22 below we can see the impact each explanatory variable has on the probability that a household has a high level of income, rather than low. Education and size of land rented/inherited for cultivation are statistically significant, at the 5% level of significance, and positively related to a family being in the high-income bracket. Whilst farmers who receive remittances from emigrated household members have a significant impact on their household income levels, however in this case it is negatively associated reducing the likelihood of a farmer's household to be in the high-income group. These four variables are the only ones that have a statistically significant *p*-value at the 5% confidence level, therefore entailing an impact on farmers' income.

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Table 22: Probit regression explaining high levels of income of the farmers.

Probability of belonging to a high-income household	Coefficient	P-value
Education (1-5)	0.236***	0.000
Land size via rent (log)	0.315**	0.019
Land size owned via family (log)	0.244**	0.024
Land possession size (log)	0.374*	0.070
Children 3 to 13 (log)	0.304*	0.052
Children 0 to 2 (log)	-0.513	0.127
Number of emigrants (log)	0.162	0.454
Remittances (dummy)	-1.080***	0.000
Interest in adopting technology (1-5)	0.028	0.751
Risk taking behaviour (0-10)	-0.019	0.493
Pseudo R-Squared Value		0.173

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

Constructing binary variable: High income level 1 allocated if income level is “4” or “5” whilst the lower income level 0 is allocated if income selected by the farmer is “1”, “2” or “3”. The income levels, for each country, are reported above.

To further of understanding of the income levels of farmers and how they range within our dataset we have shown the distribution of farmers by income, respective of their country, from FoodLand’s report **D3.3** below.

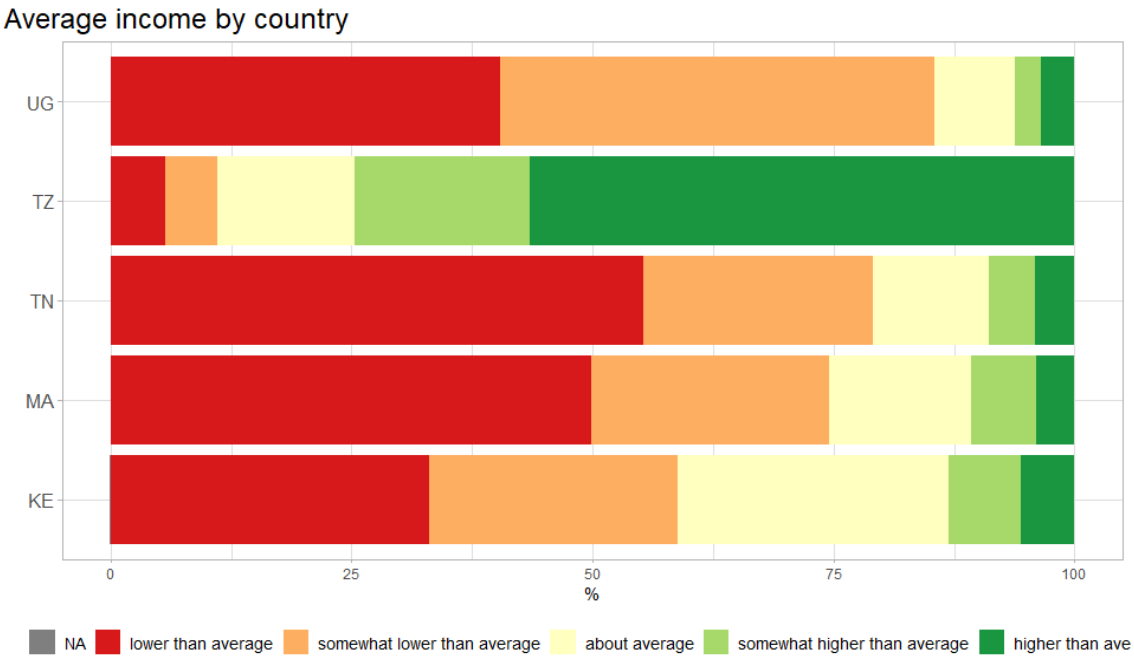

Figure 5.(Marini Govigli V., Kuhfuss, L., Piras, S., Kapour, G., Alboni, F., Setti, M. 2022. “Inception report on the socio-economic, demographic, and technological characteristics of each relevant supply chain and location, and on first experimental results”. 2022. Foodland. Figure 4).

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Thus, factors/variables that have a positive impact on a farmer's probability to be in the higher income group should be an area of focus for policymakers. In our results (Table 22) these positive effects emanate from greater land ownership (rented or ancestorial) alongside higher levels of education, which both allow a farmer to achieve a higher level of income. The positive impact of these explanatories is simple, the more land a farmer has, the greater his/her productive capacity and cultivation. Whilst higher levels of education lead to farmers making better decisions and incorporating new production methodologies or technological practices within agriculture to break away from subsistence level farming.

However, correlation does not suggest causation, since higher levels of education alongside more land tenure-ship may not be factors that led to high levels of income but were products of higher income households. Hence, these richer farming households may have been able to accumulate land and human capital due to their ancestorial wealth.

Finally, the opposite can be inferenced for our predictor encapsulating whether a household is a recipient of remittances, as this is negatively correlated with farmers' average income. However, one should understand that correlation does not imply causation and this correlation may be due to prevalent financial burdens on the family, and underlying poverty may force household members to emigrate to provide multiple sources of income to meet needs. The entailing literature, Olayiwola (2022) and Bryceson (2002), on smallholder farmers mentions that emigration within farming households in Africa is triggered by the lack of income generated through agriculture and the urban sector is a substitute. Therefore, policies supporting the development and adoption of yield enhancing solutions, such as those developed within Foodland, or direct payments provided to smallholder farmers could contribute to an increasing in farmers' revenues from agricultural activities or elevating their income directly. Additionally, the policies should also focus on developing farmers' human capital. Hence, facilitating educational programs or lifelong training service, and ensuring the availability of extension services for farmers can significantly impact their ability to increase their income generating streams as they can apply new/technologically oriented practices within their production practices.

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Chapter 4.2: Analysing drivers of intention to introduce a nutrient-dense or more profitable crop/fish product.

Author: Gurneet Kapour (JHI)

Research question

Many crop/fish products are susceptible to disease and price fluctuations, all impacting a farmer's wellbeing. Introduction of innovative nutritious and profitable products can lead to farmer's making diverse choices and minimising their exposure to these risks. However, the introduction of change requires openness to technology, training, and trust from the farmers, all which we have gauged through socio-economic questionnaires and experiments. We want to investigate which economic conditions, demographic patterns or behavioural traits enhance or negate a farmer's tendency to adopting innovative crop types / fish species.

Method and data

Our dependent variables measure the extent to which the farmer is interested in introducing a new product with a higher profit or nutrient level, with their choices ranging from 1 to 5, with "1" representing no interest in adoption and "5" showing very interested and willing to be the first in the village to uptake. We selected multiple predictors: factors the farmers are worried about, factors they are affected by and their household migration position. The dataset used for this analysis is that included in **D3.1**, whilst the approach taken for data collection are presented in deliverable **D3.3**. The factors the farmers are affected by take a range from "1" to "5", with "5" representing that the factor is a serious problem and "1" showing it is not a problem. Whilst for worries the ranges are same, 1 to 5, with "1" highlighting the factor in contention is not important whilst "5" suggests it is of upmost important. Additionally, the predictor indicating a households migration position, is a dummy variable here, where the farmers answers "yes" or "no" to being the recipient of remittances. Finally, we used variables from the experimental dataset, measuring the farmers' willingness to collaborate, proxied by their contribution to Public Good Game and how much they kept, ranging from 0 to 150.

We determine through two ordered regression models the drivers of various predictors in explaining if a farmer has the intention to introduce a nutrient dense product and a more profitable product. The statistical implication of an ordered regression model follows two criteria's: one being that the dependent variable has a meaningful order and that they have more than two groups of choices. We believe an ordered regression model fits our analysis well, since our dependent variables are in intervals or categories.

Results and policy implications

The extent to which a farmer is worried about their health and if they invest remittances received from emigrated household members are both statistically significant and act as deterrents in adoption of a profitable crop/fish for farmers (shown in Table 23).

Table 23 shows that the predictors which entail the largest impact on a farmer's likelihood of accepting a **more profitable new product** are: if the farmer is concerned about their

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health and affected by the lack of access to fuel and equipment or has invested their received remittances on their farmland.

The second regression, which results are shown in Table 24, explores the predictors' influence on a farmer' intention of growing a **more nutritious new product**. Worries about health and investment of remittances reduce the likelihood of a farmer's propensity to uptake such an innovation.

Table 23. Ordered regression for farmers propensity to growing a more profitable crop/fish.

Farmers' interest in adopting a more profitable new crop/fish	Coefficient	P-value
Worried about Starvation	-0.137	0.735
Worried about Health	-1.320**	0.020
Worried about Drought	0.202	0.642
Worried about flood	0.035	0.932
Worried about Disease	-0.859	0.101
Worry about Dispossession	0.356	0.450
Affected by Fuel access	0.795*	0.070
Affected by Pesticide access	0.139	0.765
Affected by Fertiliser access	0.395	0.277
Affected by Water access	0.423	0.318
Affected by Equipment access	0.670*	0.068
Affected by Loan access	-0.287	0.398
Investment of Remittances (dummy)	-2.933**	0.046
Contribution in Public Good Game 1	0.020*	0.092
risk taking behaviour (0-10)	0.067	0.584
Pseudo R-Squared Value		0.439

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

Table 24. Ordered regression on farmers' interest in growing a more nutritious crop/fish.

Farmers who said Yes to a more nutritious new crop/fish	Coefficient	P-value
Worried about Starvation	0.016	0.951
Worried about Health	-0.708**	0.042
Worried about Drought	-0.289	0.314
Worried about flood	-0.085	0.727
Worried about Disease	-0.263	0.332
Worry about Dispossession	0.250	0.396
Affected by Fuel access	0.321	0.163
Affected by Pesticide access	0.077	0.794
Affected by Fertiliser access	0.274	0.299
Affected by Water access	0.180	0.495
Affected by Equipment access	0.253	0.328
Affected by Loan access	0.047	0.843
Investment of Remittances (dummy)	-1.378*	0.086
Contribution in Public Good Game 1	0.000	0.956
risk taking behaviour (0-10)	0.025	0.792
Pseudo R-Squared Value		0.213

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

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Recommendations for FoodLAND

We can observe from our findings parallels amongst adoption of profitable or nutrient dense crop/fish by farmers. These predictors are statistically significant and act as deterrents for farmers, pushing them away from diversification. Primarily it is the farmers' concern on their health. FoodLAND should ensure to make policymakers understanding the importance of tackling health concerns of smallholder farmers to empower them in their adoption of innovations. Additionally, priority to health enhancing innovations should be facilitated and local actors such as NGOs and cooperative alongside farming associations should work in tandem to encourage health driven campaigns. These campaigns need to entail direct health implications, such as encouraging the adoption of nutritious products and spread the awareness across their respective communities of the advantages of such diets. Finally, the introduction of direct payment schemes or subsidies may encourage farmers to diversify production, as it would reduce the need for farmers to invest remittances on their farm, which negatively affects their ability to grow more profitable or nutritious crops/fish.

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Chapter 4.3: Detecting determinants (socio-economic conditions and preferences) of smallholder farmers' propensity to adopt a yield-enhancing or limitation-overcoming technological innovation.

Author: Gurneet Kapour (JHI)

Research question

The present research indicates how certain socio-economic conditions and behavioural traits impact on farmers' attitudes towards innovation. The willingness or attitudes towards the adoption of new technologies in agriculture is paramount and related to farmers' wellbeing, as their primary commodities in the agricultural market need to yield profits and avoid setbacks such as droughts, pests and diseases. These issues can be countered by technological progress and enhance the economic stability of smallholder farmers, which has witnessed by economists Mukasa (2018) among other scholars. However, the optimal provision and dissemination of a new technology is imperative as certain factors can discourage their farmers' uptake of innovations. We will assess two technological innovation frameworks: farmers' interest in yield enhancing and limitation overcoming technology.

Method

To analyse determinants that impact smallholder farmers' propensity to adopt a yield enhancing or limitation overcoming crop/fish production, we ran two regression models. The explanatory variables for our regression models will be used to determine farmers' attitudes towards technological changes. Our first dependent variable, seen in Table 25, is the extent to which farmers are interested in adopting technological innovations that can increase their yield, such as a fertilizer. The choices for this variable ranged from 1 to 5, with "1" stating the farmer is not interested at all whilst "5" represented them willing to be the first person to uptake the innovation in their village. Additionally, our second dependent variable, depicted in **Errore. L'origine riferimento non è stata trovata.**, is the importance that farmer's associate towards technology that can help them in overcoming limitations to farming, such as the introduction of an irrigation system, which they face in production. This variable also ranges from 1 to 5, and the farmers depicted their interest for this technology by selecting "1" if they not interested and "5" if they are extremely interested in its adoption. The mentioned variables are derived from the dataset included in **D3.1**, and the approach taken for data collection are presented in deliverable **D3.3**.

We use a dummy variable called "high income", representing if a farmer is in the high-income threshold group or not. We assign a value of 1 to all farmers who have an average income greater than the third income range. Whilst those farmers who were in categories 3 or below, were assigned with a 0. The generation of this categorical approach arises from the average income variable in our dataset, where the local coordinators decided not to directly ask farmers in the survey their income, as this may lead to irregular answers. Therefore, categories were displaced for them to select; with 1 being the lowest group of income and 5 being the highest. The income groups are proportional to average levels of income of smallholder farmers in their respective countries, given in local currency valuations. Hence, this dummy variable approach is efficient to determine

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high income farmers within our dataset and gauge their attitudes/interests towards technology. We have also taken the statistical approach of transformation of the variable representing the number of emigrants within a household, utilising a logarithm approach, as this variable was skewed. Hence, its transformation fits our regression model adequately. We then ran two regression models with these various predictors seen in Table 25 and **Errore. L'origine riferimento non è stata trovata.**.

Results and policy implications

Table 25. Regression exploring farmers' interest in adopting yield enhancing technology.

Interest in yield enhancing new technology	Coefficient	P-value
Education (1-5)	0.093***	0.000
Number of emigrants (log)	0.144**	0.026
Remittances (dummy)	-0.138***	0.009
High income farmers (dummy)	-0.061	0.342
R-Squared Value		0.022

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

Table 26. Regression exploring farmers' interest in adopting limitation overcoming technology

Interest in limitation overcoming new technology	Coefficient	P-value
Education (1-5)	0.117***	0.000
Number of emigrants (log)	0.042	0.577
Remittances (dummy)	-0.016	0.797
High income farmers (dummy)	-0.026	0.731
R-Squared Value		0.015

Note: p-values *** p<0.01, ** p<0.05, * p<0.1

We can see from Table 25 and **Errore. L'origine riferimento non è stata trovata.** that education has a positive impact on farmers adopting technology in both instances, with the bigger impact on limitation-overcoming innovation. We can see from Table 25 that there is a significant effect on the propensity to adopt a yield enhancing technology when there is emigration within a farmer's household. Interestingly, we can see that remittances received from emigrated members of a farmer's household has a negative impact on their interest towards adopting yield enhancing technology. This may suggest that smallholder farming households have established different sources of income streams, in this instance via remittances, since present literature shows how smallholder farmers tailor their farming activity primarily for subsistence income generation.

Our results signify how education is important for farmers to show interest in technology. This may be due to educated farmers being aware of the benefits of technology available to them and are willing to apply technological practices within agriculture. We can also view that emigration within smallholder farming households can act as a deterrent towards technological change for farmers. Finally, we should not forget here that we observe correlations and not causation.

The policies that should be encouraged to drive farmers' interest in technology should be aimed at education within communities. Educating farming communities on consumer needs and demands, and how the supply chain overall may value technology driven

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products that entail nutritional benefits may increase farmers' willingness to adopt innovations. Again, the negative effect of investment of remittances in farm, suggests that direct payments to farmers could reduce the reliance of the farm functioning on remittances and facilitate adoption of yield enhancing technologies.

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Chapter 5: Smallholder livelihoods between farming and migration: Food security outcomes in five countries from Northern and Eastern Africa.

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Introduction to research paper

The relationships between migration, agriculture, and food security in rural areas of developing countries are complex, and understanding them is challenging (FAO et al., 2018). On the one hand, people's migration can be driven by food insecurity; on the other hand, household members are more likely to engage in migration if they are richer in assets, and thus relatively more food secure. In turn, migration of one of more household members results in a reduction of food demand and an inflow of remittances, which can help overcome the shocks that characterise the agricultural sector. Therefore, we observe reverse causality links and endogeneity. Despite the recognised existence of strong interrelationships between these phenomena, the issue of food security tends to be neglected in the debates between migration and development (Crush, 2013). We aim to contribute to this strand of literature by investigating the implications for smallholders' food security of different labour allocation choices between farming and migration, and of the resulting inflow of remittances. We compare five countries from Northern Africa (Morocco, Tunisia) and Eastern Africa (Kenya, Tanzania, Uganda).

Farming households in developing countries are both units of production and consumption; differently from countries with well-functioning markets, the decisions related to the two sides are non-separable. This is usually illustrated through farm household models (Singh, Squire & Strauss, 1986). The households are assumed to maximise utility (which is a function of an agricultural good, a market purchased good, and free time) subject to a cash income constraint, a time constraint, and a farm production function (constraint). If we assume that other production factors, primarily land, are fixed in the short-term, the key decision that the households face is how to allocate their labour between farm activities and off-farm activities, including migration. In turn, their farm output can be self-consumed or sold, and the cash earned through farm sales or off-farm labour can be used to purchase goods on the market, including food that can contribute to increase their food security.

To investigate our topic of interest, we start from the above premises but deviate from the standard models by assuming that the households maximise their food security instead of a more general utility function, and by restricting labour allocation options to either farm or migration (since the number of present adults is larger than the number of farm workers, we assume these to be inactive household members). Hence, the theoretical form of the model, adapted from Wouterse (2012) is as follows:

1) Food security (utility) function: $F = f(Q_c, Y, T - L_m)$;
2) Farm production function: $Q = f(A, L, I)$;

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3) Cash constraint: $Y = \pi_f + \pi_m$, which includes farm profit $\pi_f = pQ_s - w(L_h)$, and a remittance function $\pi_m = \pi(L_m, \boldsymbol{l}, \boldsymbol{d})$;
4) Time constraint: $T = L_f + L_m + H$;

F is (self-assessed) food security; $Q = Q_c + Q_s$ is total farm production, which can be either self-consumed Q_c or sold Q_s. Y is cash income, which is the sum of farm profit π_f and remittances π_m; farm profit is the difference between the quantity sold Q_s at price p, and hired farm labour L_h paid at the wage w; remittances are a function of the labour allocated to migration L_m, the places of migration $\boldsymbol{l}$ and the duration of migration $\boldsymbol{d}$. A is the land endowment of the household; $L = L_f + L_h$ is labour used on farm, which includes labour provided by the household L_f and hired labour L_h; I are farm inputs. Finally, T is the total household size including migrants and H, inactive members.

We face several data constraints. First, farm and migrant labour is only available as number of household members who have engaged in either activity during the year; therefore, the related coefficient for farm labour can be interpreted as a "yearly shadow wage." Second, we lack information about purchased goods; hence, we replace them with cash income (as already done in the theoretical model), assuming that it is all spent. Second, we lack the expenditure on farm inputs; hence, we only include hired farm labour. The most challenging element are remittances, since the dataset only includes a dummy indicating whether the household have received them, and a five-point assessment of how much these contribute to welfare: accordingly, we estimate two versions of the model. Since our cash income and remittance variables are categorical (or dummy), an identity cannot be verified and we turn the cash constraint into a behavioural equation; remittances are already expressed as a function of a behavioural equation rather than as an identity in the theoretical model, because the place and duration of migration increase variability in the sums earned. As a result of these considerations, the empirical model assumes the following form:

1) Food security (utility) function: $F = \beta_0 + \beta_1(Q - Q_s) + \beta_2 Y + \beta_3(T - L_m) + \boldsymbol{\beta_5 Z} + \boldsymbol{\beta_6 j_p} + \boldsymbol{\beta_7 P} + \varepsilon_1$
2) Cash income function: $Y = \gamma_0 + \gamma_1 p + \gamma_2 Q_s + \gamma_3 L_h + \gamma_4 \pi_m + \boldsymbol{\gamma_5 s_i} + \boldsymbol{\gamma_6 P} + \varepsilon_2$;
3) Remittance function: $\pi_m = \alpha_0 + \alpha_1 L_m + \boldsymbol{\alpha_2 l} + \boldsymbol{\alpha_3 d} + \boldsymbol{\alpha_4 Z} + \boldsymbol{\alpha_5 P} + \varepsilon_3$;
4) Farm production function: $Q = \delta_0 + \delta_1 A + \delta_2(L_f + L_h) + \delta_3 I + \boldsymbol{\delta_4 Z} + \boldsymbol{\delta_5 j_f} + \boldsymbol{\delta_6 s_f} + \boldsymbol{\delta_7 P} + \varepsilon_4$.

In (1), the coefficients for quantity (total and sold) and for household members (total adults and migrants) are restricted to have the same value but opposite sign,[5] while in (4) the coefficient for farm labour (household and hired) are restricted to be the same, implying perfect substitutability and thus the same productivity. Apart from the standard variables, we include in the empirical model a vector of household characteristics $\boldsymbol{Z}$ (number of adults, number of children, age, gender, education); indicators of setbacks s related to income or farm activities; indicators of product losses j, on field or post-harvest; and a vector $\boldsymbol{P}$ of controls for the Food Hub and, where available, the locality (region, village, or settlement).

[5] This is equivalent to having a single coefficient for self-consumption and a single coefficient for the number of adults that are present.

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From our theoretical model and its empirical specification, we can derive the following hypotheses:
H1. Food security is positively related to the quantity of farm production which is self-consumed.
H2. Food security is positively related to the number of migrants and negatively to household size.
H3. Food security is positively related to the income level, which in turn is positively related to (**a**) farm sales and (**b**) remittances, and negatively to (**c**) hired farm labour.
H4. Food security and farm production are negatively related to the quantity of food losses.
H5. Setbacks are negatively related to income and farm production, respectively.
H6. Households with more children are more likely to receive remittances.

We do not make specific hypotheses on the relation between remittances and the place and duration of migration. However, we will discuss the coefficients for different countries comparatively.

Besides the allocation of labour as a productive factor and the use of remittances to cover consumption expenditures, the latter can be used for farm investments which are low-risk because they entail no interest rate (Piras et al., 2018). These sums can be complemented with formal loans or informal credit, which is particularly common in a developing country context (Junior et al., 2021). These investments are expected to improve efficiency and the quantity produced. In turn, the additional production can be self-consumed, thus improving food security directly, or commercialised, and the cash income obtained can be used to purchase food products that can improve food security indirectly (Ibid). Whether these distinct types of investments act one way or the other, i.e., increase market integration of the farms and/or food security, is worth being investigated. To compare investors with non-investors in the absence of counterfactuals, we apply a propensity score matching (PSM) approach to each country sample in turn, considering different investment mixes as separate treatments, in line with Guerzoni & Raiteri, 2015). As a robustness check, we also use PSM to assess the impact on food security of having at least one household member engaging in migration.

Methodology

We use the FoodLAND survey dataset of about 5,500 crop and fish farmers (smallholders) from five countries. The estimates are implemented at country level, and for crop and fish farmers separately in Kenya and Uganda. The key dependent variable, “food security,” is assessed on a 5-point scale, while labour allocation choices are identified through the number of migrants and the number of household members who have worked on farm during the year. Other important variables are the household’s cash income (5 income brackets), remittances (a dummy for receiving them; and a 5-point assessment of their contribution to the household’s welfare), the place of migration (nation, out of Africa) and the duration of migration (seasonal, permanent). All the dummy variables are coded as 0-1, and continuous variables (e.g., land size) are transformed by taking the logarithm to ensure that they are normally distributed; this is also applied to count variables characterised by skewness (e.g., the number of children). All the models are preliminary checked for collinearity between the independent variables, and when issues are identified, these are solved (primarily by reviewing the locality controls).

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As a first step, the relationship between food security and the numbers of migrants and farm workers, and between food security and the income level and the availability of remittances, is assessed for each country using ANOVA and ordered logit models with Food Hub controls. Then, the equations of the farm household model are estimated separately with OLS and ordered logit (or logit) models. With the exception of farm production, our dependent variables are either ordered categorical (food security, income, welfare contribution of remittances) or dummy (remittances), therefore the (ordered) logit models are more appropriate, and are used to check the robustness of the simultaneous estimates described below. It should be noted that the proportional odds assumption is only verified for 7 out of 28 models across the various samples, in which cases OLS are still preferable to an ordered logit despite the categorical nature of the variable. To overcome the endogeneity issue (confirmed through statistical tests), an instrumental variable (IV) approach was also trialled, but was abandoned due to the lack of good instruments in the dataset. The standard tests indicated that the many instruments tested were weak, and increasing their number to achieve decent explanatory power would worsen the bias and lead to overidentification issues. The OLS and ordered logit (or logit) models are not reported, and should be considered carefully and jointly with the simultaneous estimations discussed below.

As a second step, the full model is estimated simultaneously using three-stage least squares (3SLS) until convergence (which is achieved for all the samples apart from Morocco, and Kenyan fish farmers). This approach is similar to IV, but does not allow separate estimation of the equations, and requires specifying the functional form of the first stage equations. Furthermore, it allows to include constraints, and to define more endogenous variables in addition to the dependent variables of the various equations. Besides food security, cash income, remittances (or their welfare contribution) and farm production, we set as endogenous the quantity of farm sales, hired farm labour (number of people), and the two labour variables (number of farm workers and of emigrants). We estimated two versions of the overall model: one with remittances (dummy) and one with remittances' contribution to welfare. Since remittances can only be observed for the households with migrants, inverse Mills ratios for the probability of migrating are computed and included as dependent variables in the first model; in the second model, inverse Mills ratios for the probability of receiving remittances are used instead, since their welfare consequences can only be observed among recipients.

As a third step, we apply PSM (Rosenbaum & Rubin, 1983). First, we test whether investing remittances on farm (treatment) has an impact on two outcomes: food security, and the share of farm product sold (as a proxy of commercial orientation). However, since the smallholders have also access to formal loans and informal credit, these options and their mixes with remittances should also be considered, resulting in seven treatments (each investment type in turn, three combinations of two types, and all types together) whose impact on food security and commercialisation is tested separately against a baseline of no investments (following Guerzoni & Raiteri, 2015). Finally, we also test the impact of participating in migration (treatment) on food security (outcome). Each of the models is replicated using kernel, nearest-neighbour and radius matching in turn. After calculating the average treatment effect on the treated (ATT), its statistical significance is assessed by generating 100 bootstrap replicates. Then, the sensitiveness of the ATT to unobserved variables is tested using the Rosenbaum bound test (DiPrete & Gangl, 2004); this test generates an index Γ representing the minimum odd ratio

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associated to a unitary change in unobserved variables that makes the matching unreliable: the higher this index, the smaller the sensitivity.

Results

The preliminary ANOVA and ordered logit models suggest that food security is significantly and positively related to the number of emigrants in Morocco and Uganda as well as in the pooled sample, and to the number of family farm workers in Morocco and (marginally) in Uganda. Instead, it is significantly and negatively related to the number of family farm workers in Tunisia. The coefficients are not significant in other countries. Equally, food security is significantly and positively related to the level of income in all the countries and in the pooled sample, and to the fact of receiving remittances only in Morocco, Uganda and in the pooled sample.

Table 27 reports the estimates of the simultaneous models for each country (and for crop and fish farmers separately). The estimates confirm the significant and positive relationship between cash income (which includes remittances) and food security, particularly in Tanzania. In Tunisia, Tanzania and Kenya there is also a positive and significant relationship between food security and the number of emigrants. Since the coefficient is constrained to be equal but opposite to the coefficient for the number of adults, this result suggests that by reducing the number of household members to be fed, migration increases food security; indeed, the coefficients associated to the number of children are negative. In turn, the quantity of farm production is significantly and positively related to food security in Tunisia and Tanzania, negatively for Ugandan crop farmers. This coefficient is constrained to be equal but opposite to the coefficient for the quantity sold, which should instead benefit food security indirectly, though income. This suggests that, differently from Tunisia and Tanzania, where there is a direct benefit from self-consumption, Ugandan crop farmers achieve more security if they sell their product. We also observe that men-led households are significantly more food secure in Morocco, but significantly less among Ugandan crop farmers.

In all countries apart from Morocco, farm sales are likely to benefit food security via cash income, as it can be noticed from the significant and positive coefficients in the second equation. In turn, remittances are significantly and negatively related to income in Tanzania and among Kenyan crop farmers, which contradicts our hypothesis and can be explained with the fact that poorer households are more likely to receive remittances in these samples. Looking at the model for remittances, Ugandan crop farmers are more likely to receive them in case of a larger number of emigrants, but this is not the case elsewhere. Furthermore, the relative benefit in terms of remittances of national and international migration and of permanent and seasonal migration varies consistently across countries. It should also be noted that men-led households are significantly less likely to receive remittances in Morocco, Tunisia, Tanzania and among Ugandan crop farmers, which suggests that more remittances are sent home when the male head of the household migrates.

Finally, concerning the agricultural production function, the number of family farm workers (whose coefficient is constrained to be equal to the coefficient for hired workers, assuming equal productivity and perfect substitutability), is significantly and positively related to total farm production in Morocco, Tunisia, Tanzania, and among Kenyan crop

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farmers, but not in other samples. In the same samples, and among Ugandan crop farmers, the total farm product *ceteris paribus* is significantly larger for male-led households, suggesting higher productivity of male labour.

Table 27. Simultaneous (3SLS) model for food security, income, farm production and receiving remittances (by country, with Food Hub / locality controls).

Variable	Morocco	Tunisia	Tanzania	Kenya (crop)	Kenya (fish)	Uganda (crop)	Uganda (fish)
Food security:							
Quantity produced (log)	*0.021*	*0.094**	*0.807****	*-0.062*	*-0.888*	*-0.311***	*0.087*
Quantity sold (log)	*-0.021*	*-0.094**	*-0.807****	*0.062*	*0.888*	*0.311***	*-0.087*
Post-harvest losses (1-5)	*-0.082****	*0.145****	*-0.119***	*-0.065**		*-0.057**	
Fish losses (1-5)					0.095		-0.058*
Income level (1-5)	0.686***	1.099***	4.007***	0.468***	1.583***	0.257**	0.286**
Adults over 14 (log)	-0.051	-0.223***	-0.211*	-0.246***	-0.199*	-0.108	-0.077
Number of emigrants (log)	0.051	0.223***	0.211*	0.246***	0.199*	0.108	0.077
Children 3 to 13 (log)	-0.053	0.062	-0.229**	-0.253***	0.009	-0.062	-0.136
Children 0 to 2 (log)	-0.003	-0.301**	0.078	-0.119	-0.233	-0.185**	0.066
Age	-0.014	-0.026	-0.047**	-0.030**	-0.047*	-0.006	0.012
Age (squared)	0.000	0.000	0.000**	0.000**	0.000	0.000	0.000
Gender (male)	*0.748****	*0.131*	*0.052*	*0.109*	*-0.102*	*-0.304****	*-0.007*
Constant term	1.495***	1.869***	-16.824***	3.278**	0.718	4.007***	2.622***
Cash income:							
Mean farm price (USD PPP)	0.340	-0.125	-0.005	0.458**	0.355	-0.130	-0.085
Quantity sold (log)	0.021	0.079**	0.171***	0.368***	0.434***	0.335***	0.141*
Employed farm workers (log)	*0.471****	*0.475****	*-0.185**	*-0.327*	*-0.591****	*0.046*	*0.078*
Remittances (dummy)	0.183	-0.304	-0.087**	-0.302*	0.022	-0.035	0.252
Affected by job loss (1-5)	*-0.047*	*0.061****	*-0.044****	*-0.016*	*-0.019*	*0.003*	*-0.081***
Affected by income loss (1-5)	-0.024	-0.346***	-0.035***	-0.135***	-0.149***	-0.044	0.038
Constant term	1.389***	2.059***	4.415***	0.666	0.334	0.266	2.192***
Farm product:							
Land size (log)	0.878***	1.156***	1.025***	0.654***		1.128***	
Pond/cage/tank size (log)					0.321***		0.592***
Employed farm workers (log)	0.261**	0.354*	0.347**	0.315***	0.121	0.071	0.006
Family farm workers (log)	0.261**	0.354*	0.347**	0.315***	0.121	0.071	0.006
Field losses (1-5)	-0.011	0.008	-0.082***	-0.071**		-0.085***	
Fish losses (1-5)					-0.034		-0.004
Irrigation (dummy)	0.698***	0.062	0.280***	0.091		0.457***	
Age	0.028	0.014	0.026*	0.027**	-0.011	0.037**	-0.003
Age (squared)	0.000	0.000	0.000**	0.000**	0.000	0.000***	0.000
Gender (male)	0.805***	0.258***	0.378***	0.287***	0.037	0.648***	0.071
Education (1-5)	0.069**	-0.003	0.202***	0.066*	-0.042	0.024	0.122**
Setback drought (1-5)	*-0.077***	*0.013*	*0.000*	*-0.005*	*0.081****	*0.012*	*0.003*
Setback flood (1-5)	0.055	-0.020	-0.052**	0.007	0.014	-0.072***	0.004
Setback infestation (1-5)	0.015	0.087***	-0.091***	-0.020	0.023	-0.025	-0.001
Constant term	4.499***	6.108***	5.559***	6.192***	3.189***	5.518***	1.502**
Remittances:							
Emigration (inverse Mills ratio)	0.113	-0.003	0.057	-0.132	-0.007	-0.005	-0.120
Number of emigrants (log)	0.122	0.090	0.149	-0.179	0.112	0.492***	0.334
National emigrants (dummy)	-0.013	0.216	0.830***	0.147	0.442**	0.084	0.155
Out of Africa (dummy)	0.190***	0.134	(omitted)	0.142*	(omitted)	0.181**	0.025

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Variable	Morocco	Tunisia	Tanzania	Kenya (crop)	Kenya (fish)	Uganda (crop)	Uganda (fish)
Permanent migrants (dummy)	0.233***	0.000	-0.044	0.724***	0.198	0.016	0.055
Seasonal migrants (dummy)	*0.179***	*0.144***	*0.040*	*(omitted)*	*-0.147***	*0.118***	*0.116*
Adults over 14 (log)	0.144	0.018	0.127	-0.137*	-0.030	-0.004	-0.169
Children 3 to 13 (log)	-0.044	0.022	-0.009	-0.009	-0.049*	0.012	0.044
Children 0 to 2 (log)	*0.012*	*0.006*	*-0.033***	*0.055**	*0.043*	*-0.020*	*0.030*
Age	-0.012***	-0.002	-0.002	-0.003	-0.002	-0.016***	-0.005
Age (squared)	0.000**	0.000	0.000	0.000	0.000	0.000***	0.000
Gender (male)	-0.069**	-0.067***	-0.021*	0.030	-0.017	-0.042*	0.009
Education (1-5)	-0.003	0.004	0.004	-0.007	0.029	0.004	0.005
Constant term	0.132	0.127	-0.157	1.010	-0.023	0.350***	0.487
Sample size	888	865	900	959	402	798	508

Notes: Green: significant and positive coefficients; red: significant and negative coefficients; *italics*: variables where the sign of the coefficient changes depending on the sample; bold: coefficients whose sign is in the opposite direction than expected.

The PSM analysis suggests that migration increases food security in Kenya among both crop and fish farmers, and in Morocco, while the impact is not significant in other countries. With the variable being measured on a 1-5 scale, the significant bootstrapped values of the ATT are 0.30***, 0.29** and 0.31** among Kenyan crop farmers (depending on the matching method), 0.37** and 0.41* for fish farmers, and 0.19* and 0.19* among Moroccan crop farmers. After considering the quality of the matching and its sensitivity to unobservable variables ($\Gamma > 1.4$), the mix of informal credit and formal loans has a significant positive impact on commercialisation in Morocco (0.14*** and 0.13**) and Tunisia (0.14***), informal credit alone has a significant and negative impact among Kenyan fish farmers (-0.08*** and -0.07***)., and the mix of credit and remittances has a negative impact among crop farmers in Kenya (-0.15**) and Uganda (-0.12**). In turn, food security is negatively impacted by credit alone in Morocco (-0.25*** and -0.24***) and positively impacted by the mix of loans and remittances in Morocco (1.01**) and the mix of informal credit and loans in Tanzania (0.75*** and 0.98**). The effects of other mixes in other countries are either non-significant or too sensitive to unobservable variables to be considered reliable.

Conclusion

We have analysed the impact of migration on food security by estimating an adapted version of a classical farming household model, which allowed us to assess the implication of allocating household labour to either farm activities or migration. Then, we adopted a PSM approach to measure the counterfactual effect of migration on food security and remittances (and other types of farm investments) on farm commercialisation and food security.

H1 is verified for Tunisia and Tanzania, where crop farmers achieve higher food security via higher self-consumption, while the opposite is true for Ugandan crop farmers, and no significant effect is detected in other countries. **H2** (household size and food security) is verified for Tunisia, Tanzania and Kenya (both crop and fish farmers), while no significant effect is observed for Morocco and Uganda. This is reinforced by the significant positive impact of migration on food security detected for Kenya (crop and fish farmers) and Morocco using PSM.

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The positive relationship between food security and cash income (**H3**) is verified in all the countries, being particularly strong in Tanzania; equally, farm sales (**a**) are positively related to cash income in all countries apart from Morocco (no effect). Instead, remittances (**b**) are negatively related to income in Tanzania and among Kenyan crop farmers and unrelated to it in other countries. Accordingly, the PSM analysis showed that the mix of credit and remittances reduces commercialisation (and thus cash income) in Kenya and Uganda, besides the weak impact of remittances on food security (significant and positive only in Morocco). Equally surprisingly, hired farm labour (**c**) is positively related to income in Morocco and Tunisia, but negatively as expected for Tanzania and Kenyan fish farmers.

The negative impact of post-harvest losses (crop) or fish losses on food security (**H4**) is confirmed for all groups apart from Tunisia (where a significant positive effect is detected) and Kenyan fish farmers (no effect); field losses negatively impact farm production in Tanzania, Kenya and Uganda. In line with **H5**, the relationship between income and setbacks (job loss, income reduction), when significant, is mostly negative; the same is true for the relationship between drought, floods and infestation and farm product; two positive coefficients are observed for job loss in Tunisia and drought among Kenyan fish farmers. Finally, there is limited evidence in support of **H6**, when not against it.

These results suggest that the relationship between migration and food security is complex and country dependent. The reduction of household members via migration seems to improve food security in most countries (Tunisia, Tanzania, Kenya), calling for efforts to improve farm productivity that could free labour for off-farm employment. However, the investment of remittance on farm does not seem to be an effective strategy to improve food security and market integration of the farms unless combined with other types of financing, calling for promotion of a balanced mix of instruments. Indeed, when the farmer is more engaged in farm sales, there are clear income benefits; and in turn this income has a clear positive impact on food security. However, field losses and post-harvest losses should be addressed as there is robust evidence that they reduce farm product and food security in turn.

Therefore, **FoodLAND** innovations should aim at **increasing labour productivity** to free household members that could look for employment in the off-farm sector. Second, despite the benefits of self-consumption for food security in Tunisia and Tanzania, **cash** rather than subsistence **crops** should be targeted due to the clearer impact of farm sales and resulting income on food security. Third, in a resource-saving perspective, **loss reduction** (on field and post-harvest) should be prioritised compared to intensification or upscale of production, e.g. though better planning, storage and conservation. Finally, if innovation adoption requires **investments**, a balanced mix that spreads risk by combining formal loan, informal credit, and the investment of remittances should be encouraged.

This is an exploratory analysis that suffers from considerable data constraints (primarily the lack of continuous income variables, including remittances, but also data on farm input and costs); therefore, the results should be considered carefully, and confirmed by further analysis implemented on larger survey datasets. Furthermore, the results cannot necessarily be extended to other areas of the countries beyond the FoodLAND Food Hubs.

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Chapter 6: Farmers' participation in cooperatives as a driver of their propensity to innovate

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Introduction to research paper

Many authors include membership in associations and cooperatives among drivers that foster innovation in the farming sector (Adnan et al., 2017). Several empirical papers based on African case studies have found positive correlation between this variable and innovation acceptance (Abawiera Wongnaa et al., 2018; Mansaray et al., 2019; Nkegbe & Shankar, 2014; Oladipo et al., 2020; Olowa et al., 2019; Tefera et al., 2020), but a few have not identified any significant relationship (Mabah Tene et al., 2013; Mantey et al., 2020; Obiero et al., 2019; Takam-fongang et al., 2019; Zeng et al., 2018). Some reviews, focused on specific typologies of farming innovation, can be found for geographic areas beyond African boundaries. Prokopy et al. (2008) reviewed 25 studies on the adoption of best management practices in agriculture in the USA and assessed that participation in organizations was positively correlated with adoption in seven studies, negatively correlated in one study, and not correlated in eight studies. Knowler & Bradshaw (2007) reviewed 23 studies of conservation agriculture around the world and assessed that participation in organizations was positively correlated with adoption in two studies and not correlated in one study.

A clear motivation for why membership in associations and cooperatives should provide a positive environment for innovation is rarely explained or discussed. In most of the empirical studies, the role of membership in groups is neither the only nor the main variable that is considered. On the contrary, empirical papers adopt methodologies derived by the random utility approach, where several factors potentially affecting innovation adoption are included all together.

Only a few papers provide some justification to this relationship, sometimes very simplistic. For example, for Adnan, Nordin, Rahman, et al., (2017, p.45) "production practice used by the majority of members is likely to be adopted by other members". However, "associations" and "cooperatives" constitute a very general set of institutions, very variable from country to country, and even inside the same nation, each farmers' group can serve different needs of their members, including production, purchasing, marketing, socialization, and information-exchange services (Adnan, Nordin, Rahman, et al., 2017). In every specific situation, associations and cooperatives can work well or bad, and maybe can have a different effect on the propensity of members to accept innovations.

In this framework, this paper has the following objectives:

- To test if membership to associations and cooperatives has a positive correlation with innovation acceptance across five African countries.
- To test whether the correlation depends on specific associations and cooperatives.

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- To verify if this positive correlation can be explained by the influence of memberships in associations and cooperatives on the attitude of their members in three ways:
  - Increasing the interest in new ways of production
  - Changing the attitude toward risk
  - Increasing the trust towards organizations promoting innovations.

- To discuss which kind of associations and cooperatives have more effects on these behaviours.

Methodology

Most of the studies on the adoption of innovations in agriculture are usually based on a random utility framework (Adnan, Nordin, & bin Abu Bakar, 2017), indicating that decision to adopt or not a specific technology is affected by the variables that may influence the expected utility (Métouolé Méda et al., 2018). In this framework, factors influencing adoption can be classified as (a) characteristics of the farmer, (b) characteristics of the external environment, and (c) characteristics of the innovation (Meijer et al., 2015). Prokopy et al. (2008) reviewed 25 years of literature on the adoption of best management practices in the USA and assessed that variables more often positively correlated with adoption are education level, capital, income, farm size, access to information, social network access. However, for Knowler & Bradshaw (2007), there are "*few, if any, universal variables that regularly explain the adoption of conservation agriculture across past analyses*", and the attention should be moved on the particular conditions of individual locales.

Discontent in traditional models has led to an increase in the interest in socio-psychological methods in farming studies, sometimes known as behavioural approach (Burton, 2004). These methods include, among others, Theory of Planned Behavior (TPB) (Ajzen, 1991), Reasoned Action Approach (RAA) and Technology Acceptance Model (TAM) (Davis, 1989). Empirical studies frequently adopt methods that mix assumptions and tools derived from both the random utility approach and the behavioural approach, however without a rigorous theoretical framework that is able to integrate these two traditions (Burton, 2004).

Adnan, Nordin, Rahman, et al. (2017, p.45) suggests a link between economic factors and the thinking processes, opening "*a window for building an integrative theoretical framework in this study bridging the gaps between theories*". Similarly, Meijer et al., (2015) indicate that extrinsic factors should affect intrinsic factors but warns that "*there is little understanding of how the perceptions and attitudes are shaped*". Beedelland (2000) highlights that it is essential to theorize how a factor has an influence on adoption.

According to Adnan, Nordin, Rahman, et al. (2017b) and Meijer et al. (2015), we assume that background factors influence the farmer's perspective, beliefs and attitudes, which positively or negatively affect propensity to accept innovation (*Figure 6*).

Thus, a two-stage procedure is proposed. At a first stage, memberships to farmers organization is used as an independent variable to explain three attitudes of farmers: "Interest in new ways of production", "Trust in organizations promoting innovations",

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"Preference to avoid risks". Since these attitudes have been measured in the survey using 5-point Likert scale, an ordered logit is used for estimation. Other variables included in the model are "Use of productive means or resources in common with other farmers or with their organization" (which is another variable assessing the function of farmers associations and cooperatives), land size, credit, use of irrigation, use of mobile, age, gender, education, number of adults in the family and share of the farmer's household income spent on purchased food. Local dummies for every Food Hub are included. Finally, twenty farmers organizations have been selected, choosing those with a higher number of members among the participants to the survey.

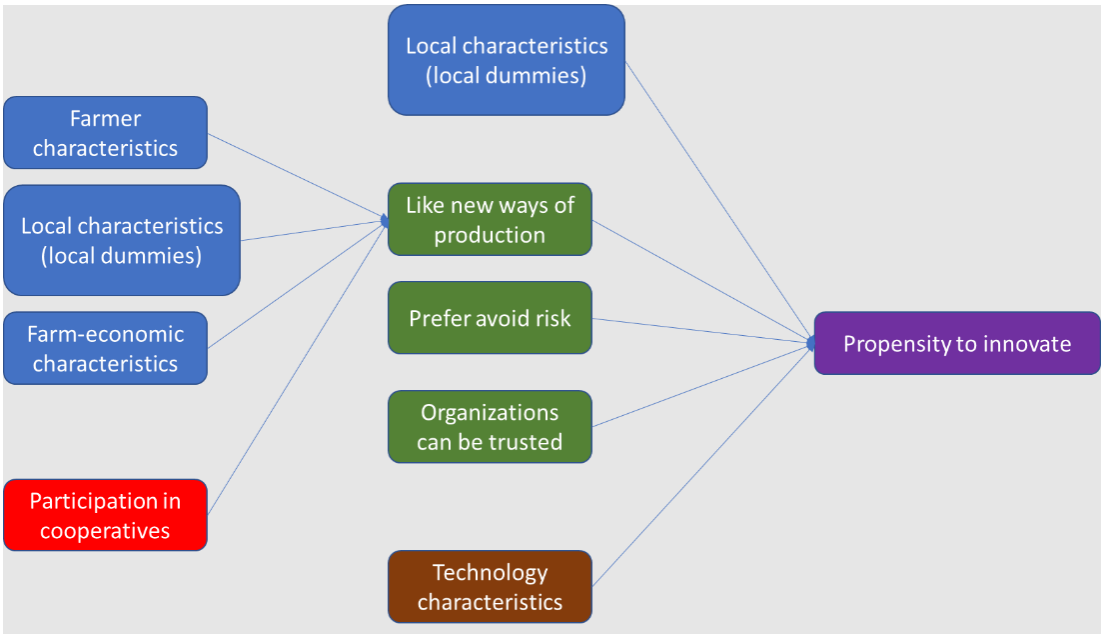

Figure 6. Map of relationships assumed by the paper.

At a second stage, the three attitudes are used as variables to explain, in a panel data framework, the propensity to use five different innovations: a) a new irrigation system, b) a technological innovation overcoming the existing limitations, c) selling production jointly, d) a new crop with a higher selling price, e) a new crop with a higher nutritional content.

Results

Preliminary results indicate that membership to a farmer organization has a strong correlation with the three attitudes of farmers considered in this study (Table 28 and Table 29). In fact, being member of a farmer association or cooperative is positively (and significantly) correlated with "Interest in new ways of production", with "Preference to avoid risks" and with "Trust towards organizations promoting innovations". Furthermore, the use of productive means or resources in common is positively correlated with "Trust towards organizations promoting innovations". Finally, the estimates indicate (data not shown in the table) that a specific organization can positively or negatively alter this basic

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relationship. For seven of the twenty farmers organizations included in the analysis, membership has a negative correlation with “Interest in new ways of production”; for “preference to avoid risk”, while there is a positive correlation with three organizations, and a negative correlation with other two; for “trust in organizations”, there is a positive correlation with three organizations and a negative correlation with other five. Other co-variates with a significant relationship with attitudes are age, gender, education, number of adults in the family and share of the farmer's household income spent on purchased food.

Table 28. Factors affecting attitudes of farmers

Variables	Interest in new ways of production	Preference to avoid risks	Trust in organizations
Organization member	0,198** (0,094)	0,338*** (0,075)	0,285*** (0,075)
Use of productive means in common	−0,065 (0,091)	−0,044 (0,073)	0,280*** (0,074)
Land size	−0,001 (0,006)	−0,003 (0,005)	−0,008 (0,005)
Irrigation	−0,085 (0,080)	−0,071 (0,066)	0,023 (0,067)
Credit	0,033 (0,074)	−0,112 (0,061)	−0,092 (0,060)
Age	−0,013*** (0,003)	−0,007*** (0,002)	−0,002 (0,002)
Gender	−0,108 (0,081)	−0,137** (0,066)	0,028 (0,066)
Education	0,065* (0,035)	0,025 (0,029)	−0,013 (0,029)
Number adults	0,054*** (0,018)	−0,007 (0,014)	0,038*** (0,014)
Mobile	−0,102 (0,152)	−0,062 (0,130)	0,030 (0,130)
Food/Income	0,075 (0,027)	−0,050** (0,022)	0,020 (0,023)

Note: Standard errors in parenthesis. ***p<1%; **p<5%; *p<10%

In the second step of the analysis all three attitudes have shown to be significantly correlated with the propensity toward innovation, either in a positive (“Interest in new ways of production” and “Trust in organizations”), or negative (“Preference to avoid risks”) way. Propensity to innovation is strongly affected also by the technology characteristics. Innovations that are more probable to be accepted are “New crop with a higher selling price” and “Technological innovation overcoming the limitations”, while innovations that are less probable to be accepted result to be “New crop with a higher nutritional content” and “Selling production jointly”.

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Table 29. Factors affecting propensity towards innovation of farmers

Variables	Propensity to innovation
Interest in new ways of production	0,402 (0,014)***
Preference to avoid risks	−0,092 (0,010)***
Trust in organizations	0,198 (0,011)***
Technological innovation overcoming the limitations	0,157 (0,046)***
Selling production jointly	−0,538 (0,045)***
New crop with a higher nutritional content	−0,690 (0,043)***
New crop with a higher selling price	0,229 (0,048)***

Standard errors in parenthesis. ***p<1%; **p<5%; *p<10%

These preliminary results indicate that membership in farmers associations and cooperatives is strongly correlated with attitudes of farmers and, indirectly, to propensity toward innovation. However, the exact nature of this correlation has to be analysed more deeply, since the nature of the organization, its functions and results, can affect this relationship. Furthermore, endogeneity of memberships to organizations has to be considered.

Conclusion

The role of associations and cooperatives for the success of FoodLAND innovations, and for the acceptance of technological innovations in general has to be considered for further developments. Members of some specific organizations can be readier than others (i.e., non-members, and members of other organizations) to test innovations and to spread them. These differences must be understood in order to see which cooperatives can be really used as a tool for innovation diffusion, and which represent, on the contrary, an obstacle.

Other elements should also be taken into consideration. Age, as expected, affects attitudes of people. Thus, different approaches should be tailored to demonstrate the benefits of innovation to elder people, which normally are less interested in changes. For them, accurate training, trials and/or visits to experimental parcels are more necessary than for young people. Young and educated people, on the contrary, can be used as pioneers that should persuade other people to test new technologies.

The positive effect (on innovation propensity) associated to the number of adults in the household is probably to be put in relation with the higher number of income opportunities that these families have; in other words, these families feel surer and accept innovation more easily. If this intuition is confirmed, this would mean that assurance strategies (or maybe specific incentives) should be tailored to persuade more marginal families.

The analysis also showed differences in propensity as an effect of the specific typology of innovation proposed. Market oriented crops and innovations tailored to the specific problems of the household (i.e., problems that have been subjectively considered as the main ones to be resolved) should spread more quickly. On the other hand, if the objective of policy makers and institutions is to spread other kinds of innovations, such as nutritional crops for a healthier alimentation or producer organizations that trade together, these more “top-down” ideas can be less appreciated and would need more efforts (e.g., facilities, public support, incentives, educational programs) to be accepted.

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Chapter 7: How do design elements affect contribution in public good games? Evidence on rate of return, group size, endowment inequality and repetition among African smallholders

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Introduction to research paper

Public Good Games (PGGs) are a well-established typology of experiments where participants face a dilemma between individual reward and the generation of public good of which everyone benefit in the same measure. They are used to elicit participants' willingness to cooperate or equally, their care for the public good. When the decision is implemented more than once and the participants are informed about the aggregated decisions of their peers in the previous round, then the outcome can also provide information about the evolution of cooperation, and whether this cooperation is sustainable.

In FoodLAND, two-round PGGs were implemented among smallholders from five Food Hubs in North Africa (Morocco and Tunisia) and Eastern Africa (Kenya, Tanzania, Uganda). Indeed, some of the FoodLAND innovations (e.g., storage drying equipment) require cooperation between smallholders in terms of setting up the innovation and sharing the costs. The PGG results inform the researchers of how difficult the adoption and management of such innovations would be. In addition, specific treatments were introduced in some countries; this report focuses on the impact of these treatments.

In a standard PGG, the payoff of an individual participant i is as follows:

$$P_i = (e_i - c_i) + m\frac{\sum_{j=1}^{n} c_j}{n}, \qquad (1)$$

where e_i is the initial endowment (150 $\forall i$ in our standard PGG treatment), c_i the individual contribution to the public good, $m > 1$ the multiplication factor[6] (2 in our standard PGG treatment), and n is the number of participants in a group, who share the public good (10 smallholders in our standard PGG). Under standard economic assumptions, people would maximise their own payoff by setting $c_i = 0$, and would expect everyone else to do the same, so no public good is generated. However, the behavioural economic literature has shown that people deviate significantly from this assumption, meaning that they are driven by non-material rewards (warm glow, altruism, inequality aversion, etc.). If we indicate with $a_i \geq 0$ and $s_i \geq 0$ i's relative care for public good and for individual reward, with $a_i + s_i = 1$, i's utility function becomes

$$U_i = s_i\left[(e_i - c_i) + m\left(\frac{c_i}{n} + \frac{\sum_{j\neq i} c_j}{n}\right)\right] + a_i m\left(c_i + \sum_{j\neq i} c_j\right). \qquad (2)$$

We cannot know the relative sizes of a_i and s_i before running the experiment, and single participants have no control over $\sum_{j\neq i} c_j$, which can thus be ignored. The public good

[6] The Marginal Per Capita Return (MPCR) to the public good is m/n, i.e. 0.5 in our standard setting.

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term (relevant if $a_i > 0$) is always increasing in m; while in the payoff term (relevant if $s_i > 0$), the share of public good generated from i's contribution is decreasing in n, making marginally more convenient to retain a larger share of e_i. Based on such considerations, in one of the treatments, implemented in Mvomero (Tanzania), we vary the rate of return to public good between rounds, setting it either at 2 (100% return for each unit invested) or at 1.5 (50%) and randomising the order, and we test:

Hypothesis 1: When the rate of return is lower, farmers contribute less to the public good.

Most of the literature on the rate of return has focused on the impact of uncertainty in this parameter (see for instance, Freundt & Lange, 2021; Aksoy & Krasteva, 2020). However, there is experimental evidence suggesting that higher MPCR results in larger public good contributions (Bruttel & Friehe, 2014; Isaac & Walker, 1988; Isaac et al., 1984; Kim & Walker, 1984).

We vary m between 1 and 2 in Tanzania, where $n = 10$ for all groups and hence also the MPCR assume only two values. However, due to no-shows or to differences in the catchment areas of the villages where the experiments were run, in Uganda and Morocco (less frequently in other countries[7]), this group size varies randomly between 4 and 25 members, allowing us to test the following:

Hypothesis 2: A larger group size results in smaller individual contributions.

While there is consensus in the literature that group size affects cooperation levels, there is no consensus on the direction of this effect. Some studies (e.g., Feltovich & Grossman, 2015; Isaac & Walker, 1998) showed that it is more difficult for larger groups to achieve efficient cooperation, others (Pereda et al., 2019; Diederich et al., 2016; Isaac et al., 1994) found the opposite. Additionally, Weimann et al. (2019) detected almost no effect for large groups, and Capraro and Barcelo (2015) detect a curvilinear effect, where the level of cooperation improves up to a certain size and then declines. Given such contradictory results, we have derived our hypothesis mathematically from the PGG formula above.

Besides the above elements, we introduced another treatment in Mukurweini (Kenya), where one of the two rounds started with unequal endowment, i.e., $e_i = 100$ for half of the participants and $e_i = 200$ for the other half, while the second round used an equal endowment $e_i = 150$ for all. This approach ensures that the total endowment at group level is the same of the rounds with equal endowment. Unfortunately, the order of the treatments was not randomised, thus the treatment is collinear with the first round and we cannot disentangle the effect of inequality from the effect of learning and of the previous group contribution. The public good term in (2) increases linearly with c_i, i.e., for the same value of a_i, the marginal benefit associated to one unit is the same regardless of e_i, while participants with $e_i = 100$ obviously have less availability. Equally, the payoff term is increasing in $e_i - c_i$, which combined with the "endowment effect" for $e_i = 200$,

[7] In Tunisia, the size of the groups was constant at 10, while the session size varies for some sessions; therefore, in the Tunisia-specific models only, the coefficients for group size refer to session size.

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and a feeling of relative deprivation for $e_i = 100$, could reduce the overall willingness to contribute to public good. Therefore, we test the following:

Hypothesis 3.1: With endowment inequality, the total contribution to public good is smaller.

Hypothesis 3.2: Farmers with lower endowment contribute more in relative terms but less in absolute terms compared to farmers with higher endowment.

Most of the extant literature includes more than two endowment levels and combines this treatment with others, such as voting on the redistribution rule (Colasante & Russo, 2017), or earning of the endowment through individual effort (Bjorvatn & Coniglio, 2020). Nevertheless, these two hypotheses are in line with the findings of past experiments conducted in western countries or China. In particular, **H3.1** aligns with Bjorvatn and Coniglio (2020), Colasante and Russo (2017), Paetzel and Traub (2017), Filippin and Raimondi (2016), Cao et al. (2015), and Cherry et al. (2005). Noteworthy, a study by Gueye et al. (2020) found instead that coordination outcomes are more likely in the case of inequality; however, these authors consider inequality in the payoffs rather than in the endowment, and increase the total group payoff when inequality increases. **H3.2** is in line with what found by Bjorvatn and Coniglio (2020), Cao et al. (2015), and Martinangeli (2021).

Finally, farmers have no prior information about others' decisions apart from their expectations, but at the end of the first round they receive their share of the public good, which informs them of the average contribution of their peers $\frac{\sum_{j \neq i} c_j}{n}$. We assume that in the second round they update their expectations accordingly, and modify their contribution to be in line with others, e.g. contribute less if others have contributed little. This result in the following hypothesis:

Hypothesis 4: In repeated games, farmers who had received a larger public good share in the previous round contribute more, and *vice versa*.

The bulk of the literature focuses on group-level rather than individual contributions, and there is a consensus that cooperation (i.e., total group contribution) tends to decline over time (e.g., Buttel & Friehe, 2014; Greiff & Paetzel, 2016; Bigoni & Suetens, 2012), although this result is based on much more than two rounds. Bigoni and Suetens (2012), who provide players with feedback about individual contributions, observe that those with higher propensity to cooperate tend to imitate the highest contributor. Finally, if punishment is allowed, cooperation can be more stable along time (Salahshour et al., 2021).

As anticipated above, the result of our analysis are relevant for innovations requiring collective set up or management. In particular, farmers' reaction to different rates of return provides information about likely real-life reactions to lower than expected (or decreasing) gains; the impact of group size, on the optimal number of farmers to achieve efficient cooperation; farmers' potential aversion to inequality, on whether cooperation may be undermined by involving groups with diverse resource endowment, despite richer farmers being better placed to become early adopters of costly innovations. Finally, the repeated implementation allows to detect if farmers adopt an 'anti-cyclical' behaviour

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(contributing less if they have already received more), or cooperation is 'self-reinforcing' and thus sustainable in the long-run. Our insights are particularly relevant because most of the literature cited studies samples from developing countries, either students or the general population, rather than smallholders in developing countries.

Methodology

Our analysis is based on a dataset of 2,392 crop or fish farmers, of which 500 in Jendouba (Tunisia), 500 in Meknes (Morocco), 504 in Mukurweini (Kenya), 482 in Mvomero (Tanzania), and 406 in Kajjansi-Masaka (Uganda), who are the only fish farmers. Contributions in the PGG (our dependent variable) are assumed to be influenced by three typologies of factors: (a) the PGG design (with design elements being the focus of our hypotheses); (b) situational factors; and (c) individual smallholder characteristics.

PGG design elements include the farmers' relative endowment, the rate of return (or multiplication factor), group size, and the round order in repeated games. Inequality of endowment, low rate of return, and repetition were implemented as within treatments in either the first or the second round; group size (count variable) is constant across rounds. **Situational factors** include the macro-region (North or East Africa), the country, the session (a proxy for enumerators, weather, and other time-specific events), understanding of the games, and the number of participants known. In some instances, the country is collinear with the treatments above, and cannot be included (e.g., fish farmers are collinear with Uganda). In Kenya, the identity of the enumerator is available, while in turn the 'number of people known' is not. 'Understanding' is measured differently in different countries and is not available in Tunisia and Kenya. Finally, **individual characteristics** include age, gender, level of education, income, trust for other farmers, risk aversion, time preferences, and farm commercialisation. 47 observations from Uganda, and 53 from Tanzania are lost because the farmers did not fill the survey and the variables are missing. Since income levels are not reliable, and there are complex purchasing power considerations, we use two proxies: the share of income spent on food and the assessment of food security. Risk aversion and time preferences are elicited using the other games; trust is measured using two questions from the survey; farm commercialisation – share of product sold (value) – is used as a proxy of entrepreneurial mindset.

The estimation strategy consists of the following steps:

- Regressions of PGG contributions on treatment variable(s), without controls.
- Regression of PGG contributions on treatment variable(s) with controls (other design elements, situational factors, individual farmer characteristics).
- Regression of change in contributions between rounds on treatment(s), without controls.
- Regression of PGG contributions on treatment variable(s) with controls (other design elements, situational factors, individual farmer characteristics).

Each of the above models is estimated for each country in turn, and then using a pooled cross-country sample. Models 3 and 4 cannot be estimated for countries with a single round (Morocco and Uganda, since the first round used a non-standard protocol with no feedback provided afterwards). Given the continuous nature of the dependent variable, all models are estimated using OLS, while models 1 and 2 are also estimated using fixed- and random-effect panel models (the fixed-effect model causes all the variables that are

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constant across rounds to be omitted). In line with most of the literature, standard errors are clustered at group level in all models (see, for instance, Hambulo et al., 2020; Bchir, 2014; Gätcher & Herrmann, 2011).

Each of the models are estimated first for individual contributions (with farmers as observations) and then for group-levels contributions (with groups as observations). The groups are 371 overall – 98 in Kenya, 96 in Tanzania, 32 in Uganda, 45 in Morocco and 100 in Tunisia. In the second set of models, the same variables are included as average values for one group, when their nature allows (e.g., we cannot include an identifier of the individual endowment in Kenya).

For each model, we test different specifications of the dependent variable. For individual-level models, we use the absolute contribution (c_i), and contribution as a share of endowment (c_i/e_i). These specifications are equivalent in all the countries net of a scale effect but not in Kenya and the pooled sample, where absolute contributions can be censored at 100, 150 or 200 depending on the treatment. In the models for change in individual contributions between rounds, we consider both absolute ($c_2 - c_1$), and relative change ($c_2/e_2 - c_1/e_1$, equivalent to $(c_2 - c_1)/e_1$ when Kenya is not included). In group-level models, we test as dependent variables the average contribution per participant $(\sum_j c_j)/n$, and the groups' contribution relative to their total endowment, $\sum_j c_j \,/\, \sum_j e_j$. The group-level models for change between round use the difference in these two variables between the first and the second round (inequality is not an issue in this case).

Each model is preliminarily tested for collinearity, and critical variables are removed, with the exception of age and its squared value (as we assume that its impact is non-linear). After estimating each model, the power of a sample of that size in detecting the effects is assessed. With the exception of group-level models for Uganda and Morocco (where a single round took place and thus the sample size is small), the power is satisfactory (above 80%).

Results

In the following, we report the estimates of the OLS models explaining the absolute and relative contribution of individuals (Table 30) and groups (Table 31), while providing additional insights on the models for change in contributions across rounds. The results of fixed- and random-effect models are in line with those presented.

H1 is **only partially verified**: contributions do not differ significantly depending on the multiplication factor. A significant and negative impact on the absolute and relative individual contributions is detected for those who faced the lower multiplication factor in the second round, but only when the analysis is implemented on the pooled sample. However, when the *change* in contributions between rounds is considered, we observe a significant and negatively impact on contributions of facing a lower multiplication factor in the second round; this is valid for both the Tanzanian and the pooled sample when individual contributions are considered, but only for the pooled sample when looking at group contributions. Our result confirms the finding of Bruttel and Friehe (2014), who in repeated PGG found that individuals who had previously experienced high marginal returns contribute less once the return is decreased.

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H2 is **not verified**: group size is significantly and positively associated with absolute and relative individual contributions in Uganda, and with absolute and relative group contributions if the analysis is implemented on the pooled sample. If considering *change* between rounds, we observe a significant and positive correlation with group size in Tanzania but a significant and negative correlation in Tunisia, in both cases only for individual, not group contributions. Hence, with the exception of this last finding about Tunisia, our findings align with Pereda et al. (2019), Diederich et al. (2016), and Isaac et al. (1994), who ran their experiments in developing countries.

The impact of endowment inequality is more complex. **H3.1** is **not verified**: in the Kenyan and pooled sample, endowment inequality *per se* is significantly and positively associated with the levels of the absolute and relative contribution at both individual and group level, which is in line with Gueye et al. (2020). Accordingly, the *change* in (individual or group) contributions between rounds is significantly and *negatively* associated with having faced inequality in the previous round, but only in the pooled sample. This second result contradicts the literature on endowment inequality, including Gueye et al. (2020), who found that reduction in inequality facilitates coordination, and might be explained with the fact that Kenyan farmers faced unequal endowment in the first round, and the decline of cooperation across rounds is well-established. **H3.2** is only **partially verified** as farmers with lower endowment contribute *less* in both absolute and relative terms, and this effect is significant in both the Kenyan and the pooled sample. However, the farmers who had previously received a lower endowment show significantly negative *change* in their relative contributions between rounds, i.e., in the round with inequality they contributed more in relative terms. In absolute terms, the change is significantly positive for the farmers who had received 100 tokens, and significantly negative for those who had received 200, in both the Kenyan and the pooled sample. Our finding about relative contributions is in line with Martinangeli (2021) and Bjorvatn and Coniglio (2020). Obviously, H3.2 cannot be tested with group-level contributions.

H4 is **verified** at group level in all the countries where more than one round was implemented (Kenya, Tanzania, and Tunisia) as well as in the pooled sample: in the groups that contributed a larger share of their total endowment, the subsequent contribution is significantly higher.[8] However, this is not true for individual contributions, which increase in groups with larger group-level contributions in Kenya, decrease in Tanzania, and do not vary significantly in Tunisia and in the pooled sample. We also found that the farmers who contribute more in the first round contribute significantly more in the second round too, in both absolute and relative terms and in all models – a hypothesis which seems to align with Bigoni and Suetens (2012) but cannot be tested for group-level contributions. *Ceteris paribus*, the round order effect is significantly negative for both absolute and relative contributions, and at both individual and group level, in Tunisia and in the pooled sample, and also in Tanzania for individual contributions, confirming the findings in the literature (Buttel & Friehe, 2014; Greiff & Paetzel, 2016; Bigoni & Suetens, 2012). It is important to highlight that since we run only two rounds, further experiments with larger numbers of repetitions are needed to confirm this last category of findings.

[8] To avoid losing observations, this variable as well as the farmers' previous individual contribution are set equal to zero in the first round.

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Concerning socio-demographic variables, age is significantly related, but not linearly, to individual contributions in Kenya and Tanzania; male farmers contribute significantly less in Tanzania and in the pooled sample, and groups with a larger share of male farmers show lower per capita contribution in Kenya; more educated farmers contribute less in Kenya but more in Tanzania. In terms of other behaviours, risk-averse farmers contribute more in Uganda, and groups with more risk-averse farmers show higher contribution in the pooled sample, those with more impatient farmers, lower contributions. Unexpectedly, farmers trusting others less contribute more in Kenya, and the same is true at group level in Kenya and Tunisia, while groups with farmers who declare more trust contribute less in Morocco. The belief that other farmers are fair has a positive impact on contributions in Tunisia at both individual and group level. Finally, in Uganda, farmers contribute more or less depending on their belief about the share of participants who contributed more or less.

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Table 30. OLS models for absolute contribution (0 to 150; 0 to 100 or 200 with endowment inequality) and relative contribution (0 to 1) of individual smallholders, by country and overall.

Relative contribution (0-1)	**Kenya (abs)**	**Kenya (rel)**	**Tanzania (abs)**	**Tanzania (rel)**	**Uganda (abs)**	**Uganda (rel)**	**Morocco (abs)**	**Morocco (rel)**	**Tunisia (abs)**	**Tunisia (rel)**	**Pooled (abs)**	**Pooled (rel)**
Round with inequality (dummy)	**80.340*** **	**0.367*** **									**40.309*** **	**0.100*** **
Endowment of 100 (dummy)	-53.742***	**-0.035***									-54.355***	**-0.040** **
Group size (session size in Tunisia)	-0.042	-0.001	-6.348	-0.042	**2.110** **	**0.014** **	0.278	0.002	0.527	0.004	-0.057	-0.001
Round with lower return (dummy)			0.779	0.005							3.305	0.022
2nd round (dummy)			-9.928	-0.066					-20.162***	-0.134***	-23.323***	-0.155***
Round with lower return # 2nd round			13.992	0.093							-9.298**	-0.062**
Average contribution in previous round	*0.477****	*0.003****	***-0.542****	***-0.004****					*0.076*	*0.001*	*0.037*	*0.000*
Own contribution in previous round	0.278***	0.002***	0.648***	0.004***					0.397***	0.003***	0.485***	0.003***
Age (years)	*-1.546****	*-0.010****	*1.694****	*0.011****	*0.398*	*0.003*	*-0.834*	*-0.006*	*0.386*	*0.003*	*0.230*	*0.001*
Age (years) (squared)	*0.014****	*0.000****	*-0.017****	*0.000****	*-0.005*	*0.000*	*0.007*	*0.000*	*0.000*	*0.000*	*-0.002*	*0.000*
Gender (male)	-0.149	-0.006	-7.547**	-0.050**	-4.817	-0.032	1.793	0.012	-7.023	-0.047	-3.954**	-0.028**
Education (1-5)	*-2.087***	*-0.015***	*3.448**	*0.023**	*1.749*	*0.012*	*-0.588*	*-0.004*	*-1.009*	*-0.007*	*-0.367*	*-0.003*
Income spent on food (1-5)	-0.823	-0.008	-1.015	-0.007	-0.567	-0.004	0.561	0.004	-0.503	-0.003	-0.475	-0.004
Difficult to meet food needs (dummy)	0.081	-0.001	-1.062	-0.007	-4.242	-0.028	-1.573	-0.010	2.595	0.017	0.656	0.003
Food needs fully met (dummy)	-1.281	-0.005	-0.014	0.000	9.270	0.062	3.764	0.025	8.317*	0.055*	2.842*	0.020*
Share of production sold (0-1)	4.281	0.024	2.602	0.017	24.541*	0.164*	6.891*	0.046*	-2.683	-0.018	3.455	0.022
Trusting other farmers (dummy)	0.867	-0.001	-2.875	-0.019	4.044	0.027	-2.162	-0.014	1.480	0.010	-0.974	-0.008
Not trusting other farmers (dummy)	10.950**	0.062**	-1.653	-0.011	5.992	0.040	-7.331	-0.049	0.662	0.004	0.811	0.004
Believe others are fair (dummy)	-0.910	0.000	1.334	0.009	-5.238	-0.035	4.796	0.032	5.588*	0.037*	1.560	0.011
Believe others are unfair (dummy)	0.711	0.015	-3.037	-0.020	2.109	0.014	-0.958	-0.006	2.456	0.016	0.677	0.006
Risk aversion, experiments (0-10)	0.168	0.001	-0.357	-0.002	2.720*	0.018*	0.655	0.004	-0.010	0.000	0.136	0.001
Impatience, experiments (0-10)	0.024	0.001	-0.325	-0.002	-0.859	-0.006	-0.511	-0.003	-0.291	-0.002	-0.171	-0.001
Share of participants known (0-1)			*9.702***	*0.065***	*-10.246*	*-0.068*	*-6.783*	*-0.045*	*-11.607**	*-0.077**		
Understood the PGG (dummy)			3.077	0.021								
Understand the PGG (1-5)					-2.438	-0.016	1.410	0.009				
Share of selfish participants (0-1)					-17.731*	-0.118*						
Share of altruist participants (0-1)					78.223***	0.521***						
"Richer should contribute less" (1-3)					-3.603	-0.024						
"Others will find out" (1-3)					-4.034	-0.027						
North African country (dummy)											12.125**	0.079**
Tanzania (dummy)											-13.669**	-0.093**
Morocco (dummy)											-17.784*	-0.118*
Constant term	58.920***	0.395***	81.997	0.547	28.202	0.188	78.432**	0.523**	45.741*	0.305*	55.683***	0.380***
Sample size	1008	1008	954	954	359	359	500	500	1000	1000	3821	3821
R^2	0.388	0.211	0.269	0.269	0.263	0.263	0.168	0.168	0.222	0.222	0.257	0.222
Log likelihood	-4.9e+03	211.613	-5.0e+03	-200.401	-1.8e+03	-31.422	-2.4e+03	99.711	-5.1e+03	-90.785	-1.9e+04	-226.147
AIC	9835.987	-353.226	1.0e+04	490.802	3722.481	124.845	4871.213	-139.422	1.0e+04	265.571	3.9e+04	660.295
BIC	1.0e+04	-181.176	1.0e+04	709.531	3842.864	245.228	4997.651	-12.984	1.0e+04	471.697	4.0e+04	1310.115
Power	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9987	0.9987	1.0000	1.0000	1.0000	1.0000

Notes: All the models include section fixed effects (not reported). Standard errors clustered at group level. Green: significant and positive coefficients; red: significant and negative coefficients; *italics*: variables where the signs of the coefficients change depending on the sample; **bold**: coefficients whose signs are in the opposite direction than expected.

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Table 31. OLS models for contribution per participant (0 to 150) and relative contribution (total group contribution / total group endowment) at group level, by country and overall.

Group-level contribution	**Kenya (abs)**	**Kenya (rel)**	**Tanzania (abs)**	**Tanzania (rel)**	**Uganda (abs)**	**Uganda (rel)**	**Morocco (abs)**	**Morocco (rel)**	**Tunisia (abs)**	**Tunisia (rel)**	**Pooled (abs)**	**Pooled (rel)**
Round with inequality (dummy)	**50.497*** **	**0.338*** **									**10.455*** **	**0.072*** **
Group size (session size in Tunisia)	-0.171	-0.001	4.791	0.032	0.995	0.007	-0.625	-0.004	0.008	0.000	**0.814** **	**0.005** **
Round with lower return (dummy)			-1.878	-0.013							1.067	0.007
2nd round (dummy)			-28.591***	-0.191***					-36.350***	-0.242***	-40.699***	-0.271***
Round with lower return # 2nd round			2.318	0.015							-2.816	-0.019
Relative contribution (previous round)	105.763***	0.704***	77.218***	0.515***					109.276***	0.729***	111.855***	0.746***
Average age (years)	-0.287	-0.002	-0.083	-0.001	1.806	0.012	-0.555	-0.004	0.519	0.003	-0.148	-0.001
Male farmers (share, 0-1)	-12.940*	-0.088*	3.621	0.024	28.257	0.188	13.160	0.088	-6.213	-0.041	-2.860	-0.019
Average education (1-5)	-3.776	-0.024	0.377	0.003	7.383	0.049	-8.893	-0.059	0.126	0.001	-1.233	-0.008
Average income spent on food (1-5)	*-4.633*	*-0.035*	*-8.412**	*-0.056**	*-1.612*	*-0.011*	*2.905*	*0.019*	*6.703***	*0.045***	*-2.721*	*-0.019**
Farmers not meeting food needs (share, 0-1)	10.065	0.078	-10.862	-0.072	-24.459	-0.163	-28.003	-0.187	0.884	0.006	1.956	0.013
Farmers with food needs fully met (share, 0-1)	2.632	0.011	-0.367	-0.002	14.972	0.100	-0.333	-0.002	1.667	0.011	9.062	0.058
Average share of production sold (0-1)	25.261*	0.163*	-1.548	-0.010	-44.325	-0.296	49.978	0.333	3.981	0.027	17.782**	0.119**
Farmers trusting others (share, 0-1)	4.328	0.019	7.233	0.048	54.765	0.365	-49.357*	-0.329*	13.477	0.090	-4.122	-0.029
Farmers not trusting others (share, 0-1)	47.047**	0.294*	-8.057	-0.054	45.068	0.300	-26.033	-0.174	13.906*	0.093*	8.331	0.055
Farmers believing others are fair (share, 0-1)	-8.722	-0.044	-13.463	-0.090	2.264	0.015	1.491	0.010	34.022***	0.227***	4.708	0.032
Farmers believing others are unfair (share, 0-1)	-4.454	-0.010	-4.872	-0.032	-33.644	-0.224	-21.195	-0.141	3.568	0.024	7.654	0.052
Average risk aversion, experiments (0-10)	-4.299	-0.027	-2.481	-0.017	-3.647	-0.024	1.882	0.013	-2.353	-0.016	1.959**	0.013**
Average impatience, experiments (0-10)	-2.148	-0.013	-2.283	-0.015	-7.513	-0.050	-0.966	-0.006	-2.334	-0.016	-1.389**	-0.009**
Average share of known farmers (0-1)			8.500	0.057	24.372	0.162	4.925	0.033	-6.457	-0.043		
Farmers who understood the PGG (share, 0-1)			6.293	0.042								
Average understanding of the PGG (1-5)					20.501	0.137	-7.953	-0.053				
Average declared share of selfish farmers (0-1)					76.954	0.513						
Average declared share of altruist farmers (0-1)					92.372	0.616						
Average of “richer should contribute less” (1-3)					20.569	0.137						
Average of “others will find out” (1-3)					-27.353	-0.182						
Tanzania (dummy)											-11.347***	-0.075***
Morocco (dummy)											-13.201***	-0.088***
Constant term	53.340*	0.359*	58.433	0.390	-52.030	-0.347	118.704	0.791	18.258	0.122	59.741***	0.398***
Sample size	98	98	96	96	32	32	45	45	100	100	371	371
R^2	0.410	0.412	0.281	0.281	0.726	0.726	0.295	0.295	0.582	0.582	0.376	0.377
Log likelihood	-382.337	109.627	-381.745	99.276	-126.040	34.300	-187.926	37.553	-394.141	106.922	-1.5e+03	322.658
AIC	798.675	-185.253	805.490	-156.552	294.081	-26.600	409.851	-41.106	824.282	-177.845	3117.687	-601.315
BIC	842.619	-141.309	859.342	-102.700	324.861	4.181	440.564	-10.393	871.175	-130.952	3203.843	-515.159
Power	0.9986	0.9988	0.8342	0.8342	0.7402	0.7402	0.2287	0.2287	1.0000	1.0000	1.0000	1.0000

Notes: Standard errors clustered at group level in the countries where more than one round took place. Green: significant and positive coefficients; red: significant and negative coefficients; *italics*: variables where the signs of the coefficients change depending on the sample; **bold**: coefficients whose signs are in the opposite direction than expected.

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Conclusion

We have investigated the impact of design elements on individual and group-level contributions in PGGs implemented with smallholder farmers in five African countries. We found that some of these elements matter, although not always in the expected way, while others do not. Namely, the rate of return to the public good, tested in Tanzania, has no significant impact except that the farmers who experience a subsequent drop in this rate reduce their contribution, which only partially confirms our **H1**. Second, opposite to our **H2**, results from Morocco and Uganda show that cooperation is more efficient if the group size is larger. Third, opposite to **H3.1**, inequality increased absolute contributions of Kenyan farmers at both individual and group levels, but in line with **H3.2**, less endowed farmers contributed more in relative terms. Finally, contributions drop when the decision is repeated a second time but in line with **H4**, the groups experiencing higher cooperation first, see larger subsequent individual and group contributions.

The above findings allow us to draw recommendations in terms of policies to promote the uptake of innovations by farmers, including FoodLAND innovations that may require collective management through farmers' associations or cooperatives. These are, among others, olive oil centrifugation, filtration and clarification systems; systems for precision irrigation/fertigation, protection and harvesting requiring a small group of local farmers to install sensors in their fields; osmotic dehydration and solar drying systems; and smart storage systems (e.g., zero energy cool chamber in Tanzania). First, **we advise against advertising sizeable returns to investments** as a strategy to promote wider uptake: it is preferable to adopt a cautious approach and make the risks clear, rather than disappointing farmers with lower than expected (or decreasing) returns. Second, the involvement of **large groups of farmers** is likely to be beneficial, since it spreads risk (including the damage potentially caused by free riders), facilitating cooperation. Third, the involvement of farmers endowed with **different amounts of resources**, particularly rich farmers, is unlikely to represent a challenge either. It rather increases the group's investment in innovations, and ensures the presence of potential early adopters, where needed. However, it is necessary to develop **mechanisms to safeguard poorer farmers**, who are otherwise likely to invest relatively more time and resources, increasing their vulnerability. Finally, the efficiency of cooperation is likely to deteriorate with time, especially in the Food Hubs that are initially less successful. To avoid the gap between different Hubs from widening progressively, **constant support by local organisations** (cooperatives, farmers' groups, public bodies) is required. These must have been established previously: the Food Hubs, even if legally recognised, are unlikely to achieve sustainability without the support of pre-existing local structures, especially in the short and mid-term after the conclusion of the FoodLAND project.

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Chapter 8: Understanding inconsistencies in risk attitude elicitation games: Evidence from crop and fish farmers in five African countries

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Introduction to research paper

Understanding individual farmers' risk preferences in developing countries has both research and policy relevance. The adoption of technological breakthroughs that increase agricultural output is indeed influenced by behavioural factors like risk preference (Wong et al., 2020; Holden, 2015; Love et al., 2014; Karlan et al., 2014; Cole et al., 2013; and Ross, 2012). Due to the risk associated with technology adoption, risk-averse farmers typically choose not to adopt new technologies (Holden, 2015; Ross, 2012).

As risk preferences play a vital role in agricultural investment decisions, several experimental studies have used different methods to elicit risk preferences.[9] Existing experimental and behavioural studies employ complex lottery games to test attitudes towards risk (Louis et al., 2012; Booth and Katic, 2012; Sarah and Ragan, 2007; Holt and Laury, 2002). Economic theory tells us that in such lottery experiments an individual with a concave utility function should switch between options with different level of risk at some point and are not expected to switch back again (Pan et al., 2018; Sarah and Ragan, 2007; Laurent et al., 2007; Holt and Laury, 2002). For an extremely risk-loving individual, the case could be different. If an individual is extremely risk-loving, he may choose not to switch at all (may choose monotonously or only risky choices).

However, in practice, evidence shows that individuals who take part in such experiments either switch multiple times or make other choices that are found to be inconsistent with the theory (Brunette and Ngouhouo, 2021; Gary et al., 2018; Sarah and Ragan, 2007). In most of the extant studies, a significant portion of the sample provided inconsistent responses to risk preference (Burns et al., 2022; Douglas et al., 2021; Marielle and Jonas, 2019; Pan et al., 2018; Gary et al., 2018; Bejarano and Galarza, 2016; Ihli et al., 2016; Norbert et al., 2014; Sarah and Ragan, 2009).

Beyond the elicitation of risk preference, researchers have also been investigating the following related research themes. First, the relationship between cognitive skills and risk aversion: recent experimental studies show mixed results on this relationship (Lau, 2019; Hernan and Francisco, 2016). Cognitive skills have an impact on risk aversion (Dohmen et al., 2018). Individuals with high cognitive skills have a higher risk tolerance compared to individuals with lower cognitive ability (Farago et al., 2021; Dohmen et al., 2010; Sarah and Karl, 2006). On the other hand, there are also studies that indicate no relationship between cognitive skills and risk aversion (Ola et al., 2016; Booth and Katic, 2012).

Understanding whether and how far females differ from males in a variety of decision-making processes is another vital research theme (Alison et al., 2018; Frederick, 2005).

[9] Multiple Price List (MPL) and the Ordered Lottery Selection (OLS) methods are the most common procedures used to elicit individual risk preferences in experimental economics.

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Previous research has shown that there are considerable risk preference differences between women and men. On average, women are found to be more risk averse (Booth, et al., 2013; Booth and Katic, 2012).

A third related research agenda, to which this paper would like to contribute, is on investigating inconsistent responses in risk attitude elicitation games. Although there is strong evidence of inconsistent responses to risk preferences, few studies have examined what explains these inconsistencies and how these can be reduced or prevented (Burns et al., 2022; Bejarano and Galarza, 2016). Furthermore, existing studies present several criticalities. First, most of the studies are conducted either in developed countries or with students and are typically conducted in a computer laboratory setting (Bejarano and Galarza, 2016). There are concerns about the external validity of results obtained in such settings (Gary et al., 2020). Second, although there are some field-experimental studies conducted with farmers in developing countries to investigate this issue (Burns et al. 2022), most of them focus on a single country case and use small samples.

Our contribution fills these gaps, by conducting incentivized field experiments with 2,371 small-scale farmers from three Eastern (Kenya, Uganda, Tanzania) and two Northern African countries (Tunisia, and Morocco). This has given us the advantage of a large sample and allows us to undertake a comparative analysis. We have three research goals. First, we want to investigate the existence of inconsistency in responses in a risk attitude elicitation game. Second, we want to examine determinants of these inconsistencies. Third, we want to understand from an operative perspective how these inconsistencies could be reduced, to improve the validity of incentivized field experiments. These gaps led us to establish two main initial hypotheses. First, persons with low levels of education may not grasp complex lottery tasks well, which could lead to more random answers and an inconsistent reaction to risk preference. On the other hand, educated people are predicted to have better cognitive abilities to comprehend complex lotteries, which lowers the likelihood of obtaining inconsistent responses to risk preference. Therefore, our first hypothesis is that the level of literacy is a significant negative predictor of inconsistency. However, people may not only be ignorant, but also unfocused (Bruns et al., 2022). Stress affects poor people more, and they are more likely to become distracted by the difficult job of surviving. Poor people are less likely to make logical decisions when faced with economic alternatives because of the stress caused by poverty (Banerjee and Duflo, 2011; Spears, 2011). Thus, we also hypothesize that poverty might account for erratic reactions to risk preference and be a cause of inconsistencies.

Our sample farmers exhibit a high level of inconsistent behaviour in the risk elicitation game. Depending on the circumstances of each country, we find that poverty, gender, and the interaction of gender and level of education statistically explain risk inconsistencies. Further, we obtain interesting results on the effect of the sessions (i.e., the specific data collection occurrences). Indeed, in all the country cases, and also in the pooled data, some session fixed effects significantly explain inconsistencies, pointing to the role of the context (which could result in different levels of attention) and of the enumerators in properly explaining the experiment.

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Methodology

Sampling strategy

In the framework of an international project,[10] rural regions were identified in five African countries to establish so called 'Food Hubs', where farmers and their associations were involved in the creation of local supply chains and in the demonstration and adoption of innovations. As a preliminary step, surveys and economic experiments were run with samples of farmers to assess their socio-demographic, economic (farm), and behavioural characteristics which could impact their willingness to uptake innovations. In each Food Hub, the sample consisted of crop farmers, except for Uganda, where fish farmers were involved instead.

Each Food Hub has different geographical characteristics, with one consisting of a single village (Ndole, Mvomero district, Tanzania); three of different villages of a single region (Meknes, Morocco; Mukurweini, Kenya; Jendouba, Tunisia); and one of villages from different districts (Kajjansi, Masaka, and nearby districts, Uganda). Local researchers obtained lists of farming household operating in the areas, and used stratified sampling, with strata based on age (young/old), gender (male/female), and farm sizes (large/small). Where more than one village was involved, a two-stage sampling strategy was adopted, by randomly selecting the villages first, and then the farmers. Where either of the genders represented less than one third of the sample, the underrepresented gender was oversampled to obtain a better overview of gender-specific conditions, in line with the requirements of the funder.

Farmers were invited in the locality where the survey and the experimental sessions would take place. Each session consisted of about 20 farmers to allow the creation of groups for a public good game, and lasted for half a day (around 3 hours). Transport and refreshment were provided. The target sample size was 500 in each Food Hub. The final sample size is 500 in both Morocco and Tunisia, 504 in Kenya, 482 in Tanzania, and 406 in Uganda, for a total of 2,392 (after removing 22 observations with a level of education of other, which makes it difficult to categorized them as either illiterate or literate people, the number was reduced to 2,371).

Experimental interventions

The data collection took place between Mach and July 2021, depending on the Food Hub, with only the Ugandan fieldwork lasting until December. Each experimental sessions consisted of three behavioural games: a two-round public good game with country-specific treatments; a lottery game to elicit risk attitudes; and a game to elicit time preferences. The farmers received a show up fee, and a payoff whose amount depended on the results of the games. During the sessions, the payoffs were expressed in tokens, which were converted at the end of the full session at a rate that ensured the same

[10] FoodLAND "Food and Local, Agricultural and Nutritional Diversity", funded by the European Commission's Horizon 2020 Framework Programme.

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average payoff at purchasing power parity across the Food Hubs. The focus of this article is on the lottery game only.[11]

The risk elicitation game is based on a multiple price elicitation task à la Holt and Laury (2022). This games requires players to make ten choices between pairs of lotteries (A and B) with different odds of winning the higher stake. In lottery A, the lower stake is 0.8 times the higher one; in lottery B, the ratio is 0.026, making it riskier. The odds of winning the higher stake increase for each choice (from 0.1 to 1.0). A rational, risk-indifferent player would always choose the lottery that maximises the expected payoff, i.e., A in choices 1 to 4, and B in choices 5 to 10. Because in lottery 10 the winning of the higher stake is certain, all players are expected to choose lottery B, thus allowing us to test their understanding of the game. The choice at which the players switch from lottery A to lottery B is a proxy of their appetite for risk. Risk-averse farmers would keep preferring lottery A beyond choice 4, while risk-taking farmers would switch to B before that.

While in the original version of the lottery (Holt & Laury, 2022) they payoffs are expressed in USD, we expressed them in experimental tokens while preserving the same ratios between and within lotteries and ensuring that the average payoff was salient enough compared to the payoffs in the other games. We also included drawings of white and red balls to visualise the stakes in each lottery to win the lower or higher payoff. Since a large share of farmers were expected to be illiterate or with very low level of education, the concept was illustrated by performing two ball extractions, and an enumerator-to-player ratio close to one was maintained in all the sessions. The choices were recorded using pen and paper.

Among the farmers who do not commit inconsistencies, a plurality (21.6%) switch from A to B at choice 5, as expected from rational players; and relevant numbers show slight risk aversion (18.7%, who switch at choice 4), or are slight risk takers (16.4%, who switch at choice 6). The fourth largest group (12.9%) always choose the riskier lottery.

Statistical approach

We use both descriptive and logit regression analysis in order to investigate the inconsistent responses. Inconsistent responses are observed over one and zero, thus we created dummy variables for the various forms of inconsistencies. Logit regression models are used to estimate the effects of educational attainment, gender, and poverty on inconsistent responses. We also take into account interaction effects to investigate if the impact of educational achievement varies by gender and age.

Our risk attitude elicitation games allow us to identify various kind of inconsistencies. Considering this, we have created variables for three basic types of inconsistencies. The first one identifies multiple switches. This variable takes one (1) if the farmer switches to the alternative option in the game more than once, and zero for a consistent switch (switch once, or monotonous B). The second one is a dummy variable for monotonous choice A, which takes one (1) if the farmers choses A in all the options, and zero (0) for a consistent switch. The third dependent variable is a dummy for “primitive choice”. In

[11] The full experimental protocol (Kuhfuss et al., 2022) is available at this link: https://zenodo.org/record/6341926#.Y00mCNfMKUk [retrieved 17 October 2022].

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our lottery game, the lottery task 10 asks to choose between lottery A, which entails 100% probability to get 100 tokens, and lottery B, which provides 100% probability to get 190 tokens. This task was included exactly to detect inconsistent participants. A choice of lottery A over lottery B is primitive. The primitive dummy takes one (1) if the participant chooses alternative A for the lottery task 10, and zero (0) for a consistent switch.

Three main explanatory variables are proposed in this study. Education level is the first. we create a dummy variable for education that takes one (1) if education is equal to or more than primary level (literate) and zero (0) if it is below primary (i.e., illiterate, or literate with no qualification). Second, poverty might potentially be a factor in people's uneven reactions to risk preference. We define poor households as those that spend a large percentage of their income on food. As a result, the indicator variable for poverty takes one (1) if a large percentage of the farmer's household income is spent on food, and zero (0) if a low percentage.

The third explanatory variable is the session. A session is an event in the same day when a group of farmers participate simultaneously in the experimental games under the guidance of the same facilitators. Accordingly, we created a dummy variable for each session in each country to control for session fixed effects. Indeed, session specific effects would be expected, especially in the context of lab-in-the-field experiments, due to the time- and location-specific circumstances of a session that cannot be controlled by the experimenter (location of the session, weather, enumerator effects, etc.), even when protocols are strictly followed.

Results

Descriptive statistics

Table 1 provides summary statistics of our sample farmers.

Table 1 Descriptive statistics (N=2,371)

	Variable type	Mean	S.D.	Min	Max
Level of education	ordered categorical[a]	2.9	1.2	1	5
Literate	dummy[b]	0.69	0.46	0	1
Age	Count	47	15	18	92
Gender	dummy[c]	0.34	0.47	0	1
Income spent on purchased food	ordered categorical[d]	2.83	1.39	1	5
No. of switching & switching patterns in the lottery task					
Number of switches	count[e]	2.3	2.3	0	9
Consistent switch	dummy[f]	0.52	0.50	0	1
Inconsistent switch	dummy[g]	0.48	0.50	0	1
Monotonous (A)	dummy[h]	0.17	0.37	0	1
Primitive choice	dummy[i]	0.34	0.48	0	1
BA single switch	dummy[j]	0.05	0.36	0	1
ABA single switch	dummy[k]	0.22	0.41	0	1
Multiple switch	dummy[l]	0.42	0.49	0	1

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[a](=1 illiterate, =2 no qualification but literate, =3 elementary, =4 high school, =5 high school& above); [b]=1 if education is equal to or greater than primary; [c]=1 if female; [d]=share of the farmer's household income spent on purchased food: 1 = A very limited part (less than 25%), 2 = Less than half (from 25% to 50%), 3 = About half (50%), 4 = More than half (from 50% to 75%), 5 = Almost all (from 75% to 100%); [e]= number of switches (takes 0 to 9); [f]= 1 if switched exactly once or monotonous switch only (B); [g]=1 if monotonous switch only (A) or switched more than once; [h]=1 if monotonous switch only (A) and =0 if consistent switch; [i]=1 if choice A in lottery task 10 and =0 if consistent switch; [j]=1 for BA single switch and =0 if consistent switch; [k]=1 for ABA single switch and =0 if consistent switch; [l]=1 if multiple switched and =0 if consistent switch;. Monotonous (A), Primitive choice, BA single switch, ABA single switch and Multiple Switch sum up to more than Inconsistent switch because several farmers committed more than one inconsistency.

Our sample includes 2,371 farmers from five different African countries. The average age of the farmers is roughly 47 years, and 34% of them are women. Farmers typically completed their primary education (close to 70% of them). The typical respondent spends almost 50% of their income on food. The summary statistics also show that there is a high level of inconsistent choice to risk preference: over 48% of farmers exhibit inconsistent risk preference behavior.

Figure 7 shows the switching pattern of respondents who participated in the experiment.

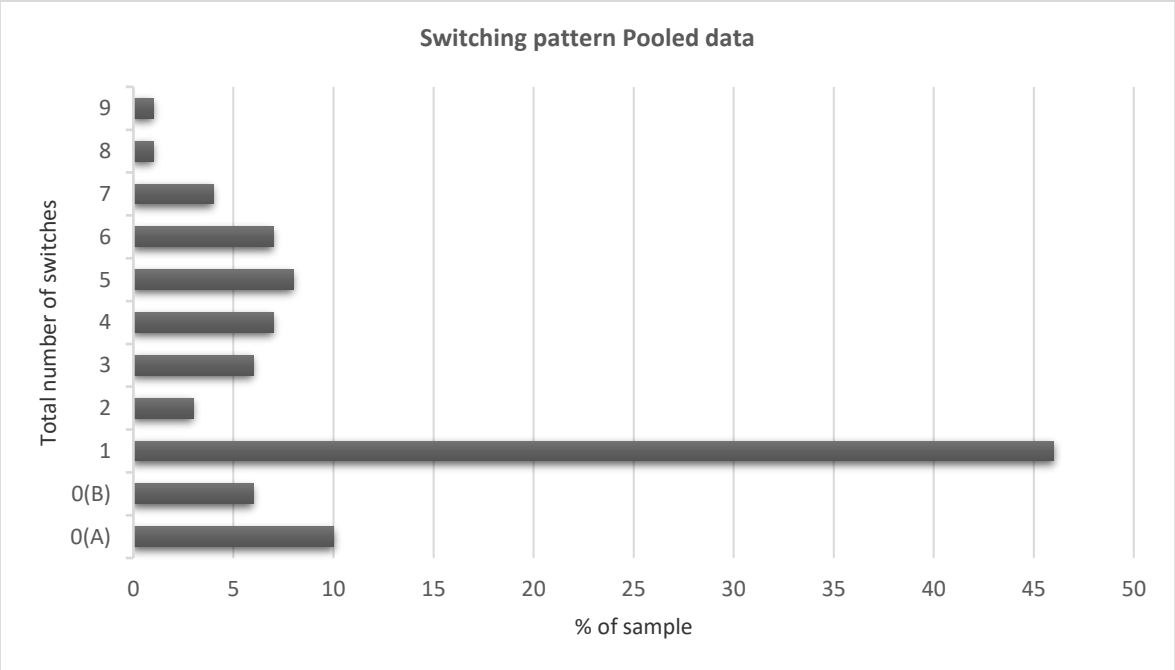

Figure 7. Switching pattern within the lottery task (pooled data, n=2,371).

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Table 3 Results of logit regression for the inconsistency ''multiple switch''

	Pooled data	KE	UG	TZ	TN	MO
=1 if education is equal to or greater than primary (literate)	0.593	1.460	0.702	-0.470	1.434	2.509
	(0.586)	(1.203)	(1.488)	(1.075)	(1.759)	(2.422)
food_share	0.165	0.895**	0.479	-0.156	0.601**	-1.137**
	(0.150)	(0.426)	(0.418)	(0.294)	(0.298)	(0.489)
Age	0.005	-0.001	0.015	-0.009	0.004	0.026
	(0.009)	(0.016)	(0.028)	(0.017)	(0.025)	(0.036)
=1 if female	0.518*	0.822	0.998	0.834	0.544	0.812
	(0.271)	(0.660)	(0.848)	(0.612)	(0.694)	(0.746)
interaction of literate and gender	-0.393	-1.183	-0.828	-0.527	-0.178	-0.799
	(0.308)	(0.741)	(0.901)	(0.678)	(0.728)	(1.285)
interaction of literate and age	-0.004	-0.024	-0.001	0.011	-0.006	-0.046
	(0.010)	(0.021)	(0.030)	(0.020)	(0.030)	(0.043)
Country fixed effect	Yes	No	No	No	No	No
Session fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1861	426	320	374	404	337
Pseudo R^2	0.39	0.06	0.08	0.23	0.14	0.13

*Note: Robust standard errors are in parentheses * p < 0.1, **p < 0.05, *** p < 0.01*

Table 3 reports the results of logit regressions for the inconsistency “multiple switches”, and we observe that only gender significantly explains this inconsistency in the pooled data (Column 1). The coefficient for gender is positive and statistically significant, confirming that women in our sample are more likely to be risk inconsistent. Considering country-specific regressions, the coefficient for poverty is positive and statistically significant in the cases of Kenya and Tunisia (Columns 2 & 5). This indicates that poor people in these countries are more likely to be risk inconsistent. On the other hand, the effect of poverty on inconsistency is negative and significant for Morocco (Column 6), which goes in the opposite direction from our hypothesis.

In many instances, the sessions’ impact on inconsistencies is statistically significant in both the pooled data and the country-specific sample. In the five countries, there are around 82 different sessions. It would take few pages to report the entire table for session effect. We have therefore omitted reporting the entire regression table for the session impact in the interest of conciseness; however, these can be found in the Supplementary Material. We perform a follow-up Chi2 test using all of the session’s dummy variables following the logit regression. The outcome demonstrates that sessions explain inconsistencies significantly (chi2 (72) = 552.23, Prob > chi2 = 0.000).

Tables 4 and 5 present logit regression result for monotonous and primitive types of inconsistencies, respectively.

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Table 4 Results of logit regression on Monotonous A

	Pooled data	KE	UG	TZ	TN	MO
=1 if education is equal to or greater than primary (literate)	0.527	0.940	-5.083	0.299	-0.968	0.320
	(0.743)	(2.513)	(3.311)	(1.503)	(2.257)	(1.405)
food_share	0.152	1.534***	0.529	-0.065	-0.261	0.005
	(0.191)	(0.525)	(0.956)	(0.418)	(0.458)	(0.330)
Age	0.020*	-0.001	-0.164**	0.010	0.039	0.030*
	(0.011)	(0.036)	(0.080)	(0.024)	(0.027)	(0.018)
=1 if female	-0.412	1.632**	2.383*	-0.614	-1.365	-1.956**
	(0.340)	(0.823)	(1.295)	(1.010)	(0.885)	(0.928)
interaction of literate and gender	0.462	-2.335**	-1.884	0.772	2.392**	0.000
	(0.399)	(0.939)	(1.470)	(1.094)	(1.059)	(.)
interaction of literate and age	-0.015	-0.006	0.138*	-0.009	0.003	-0.010
	(0.013)	(0.040)	(0.080)	(0.027)	(0.040)	(0.025)
Country fixed effect	Yes	No	No	No	No	No
Session fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1133	127	98	269	217	400
Pseudo R2	0.19	0.16	0.19	0.11	0.12	0.09

*Note: Robust standard errors are in parentheses * p < 0.1, **p < 0.05, *** p < 0.01*

Table 5 Results of logit regression on primitive choice

	Pooled data	KE	UG	TZ	TN	MO
=1 if education is equal to or greater than primary (literate)	0.449	1.185	-1.043	-0.219	0.839	1.219
	(0.582)	(1.534)	(1.732)	(1.072)	(1.745)	(1.282)
food_share	0.144	0.926**	0.356	0.065	0.087	-0.130
	(0.150)	(0.431)	(0.477)	(0.306)	(0.382)	(0.297)
Age	0.014	-0.003	-0.026	-0.010	0.050**	0.033*
	(0.009)	(0.022)	(0.033)	(0.017)	(0.023)	(0.018)
=1 if female	-0.177	0.827	1.820**	0.227	-0.759	-1.972**
	(0.276)	(0.682)	(0.843)	(0.684)	(0.751)	(0.891)
interaction of literate and gender	0.248	-1.367*	-1.549*	0.076	1.515*	0.000
	(0.314)	(0.773)	(0.915)	(0.752)	(0.847)	(.)
interaction of literate and age	-0.011	-0.017	0.039	-0.000	-0.022	-0.025
	(0.011)	(0.026)	(0.035)	(0.020)	(0.030)	(0.023)
Country fixed effect	Yes	No	No	No	No	No
Session fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1631	314	223	340	316	416
Pseudo R^2	0.32	0.06	0.11	0.19	0.15	0.06

*Note: Robust standard errors are in parentheses * p < 0.1, **p < 0.05, *** p < 0.01*

Our estimates for monotonous and primitive choices show that gender matters even if it plays a mixed role. According to country-specific estimates, gender (female) and risk inconsistency have a strong positive and significant relationship in Kenya and Uganda (Column 2 and 3, Table 4). This suggests that women are more likely to be risk

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inconsistent in these country samples. Additionally, we investigate if gender interacts with education in causing inconsistency. For both countries, the interaction coefficient between gender and education is negative and significant. This shows that inconsistent choices are less frequent among more educated females comparted to less educated ones. The situation is different, though, when we consider the regression results for Tunisia and Morocco. Women are significantly less likely to commit inconsistencies in Morocco, while the decline in inconsistency is less pronounced for educated females in Tunisia (Column 4 and 5, Table 4). This suggests that country-specific gender effects exist. The estimates in Tables 4 and 5 further shows that the poverty coefficient is positive and statistically significant for Kenya, suggesting a growth in inconsistency with poverty in that country sample, but not in other countries. Finally, we find no evidence in any of our regression estimates that the level of education alone influences inconsistencies in risk attitude elicitation games.

Conclusion

This study is among the first in the literature to evaluate inconsistencies in risk attitudes elicitation games, and the first to investigate the effects of poverty and situational characteristics (identified by the session) on inconsistent responses to risk preference using data from five African nations comparatively. Overall, our sample of farmers exhibit a high level of inconsistent behaviour in risk elicitation games. Depending on the circumstances of each country, we also find that poverty, gender, and the interaction of gender and education explain risk inconsistencies.

Further, we obtained an interesting result on the effects of the sessions. Session effects considerably explain inconsistencies in all the specific country cases as well as in the pooled data. Therefore, in addition to explanatory variables such as cognitive skills, poverty and gender, risk elicitation studies should pay attention to situational factors such as the location and the specific enumerators and provide proper training to the enumerators in order to address the issue of inconsistency.

Overall, our findings can help researchers and policymakers better tailor risk elicitation methods and help explain why farmers in poor countries give inconsistent answers to risk elicitation tasks. Due to the high degree of inconsistency displayed by farmers in developing countries when answering to experiments, the use of the resulting risk attitude parameter as a determinant of, e.g., the adoption of technology without considering the existence and the cause of inconsistency may lead to unreliable results and it should be given serious consideration.

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Part 2: Country specific analysis

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Chapter 1: Does farm size drive the willingness to adopt farm technology in the rural areas in the Kilombero and Mvomero districts of the Morogoro region, Tanzania

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Introduction

Technology in agriculture, generally means a new, often scientifically derived factor, information or practice which if adopted, positively affects agricultural production (Feder and Umali, 1993). It ranges from seed varieties improvements, soil and water conservation, irrigation, pest and disease management, mechanization, soil fertility management, storage, to processing and marketing. The importance of improved technology and their adoption to agriculture in livelihood improvement cannot be overemphasized. Adoption of the right technology is associated with high productivity, low production costs and less drudgery (Wordofa *et al.,* 2021)

Though improved technologies in agriculture is advantageous, farmers' willingness to adopt, is still low (Yahaya *et al.,* 2022; Muzari *et al.,* 2012). The choice of farmers to adopt a certain technology depends on several factors: farm size, access to technology, income level, risk exposure to bear risk and capacity, human capital, labour availability, credit constraints, tenure, utility obtained from the technology adopted, and access to commodity markets (Adesina and Baidu-Forson, 1995; Moser and Barrett, 2003; Muzari *et al.,* 2012; Kinyangi, 2014; Kaliba *et al.,* 2018)

Studies suggest that farm size is among the most important factors influencing adoption of technology in agriculture, directly and indirectly (Brown et al., 2020). Growth of farm size has been observed to be central to rural development in many countries including those of Europe and America (Timmer, 2014). Kaliba *et al,* (2018) defined farm size as the summation of all land/farm cultivated in a given farming season. A study by Kithome *et al,* (2022) reported that farmers with a large farm size were more likely to adapt irrigation technology so as to increase farm yield compared to farmers with a small farm size. Adoption of irrigation technology for small scale farmers was only possible after earning more income from non-farm activities. This indicates that the financial capability of the farmers is important for the adoption of improved agricultural technologies. A study by Atinafu *et al.,* (2022) reported that ownership of a large farm size can influence technology adoption as it allows farmers to grow varieties of food crops (diversification) that enable farmers to earn more income and use it for technology investment. According to Hu et al. (2022), farmers with large farms are more willing to adopt new technology, spend more time and money in pursuit for agriculture knowledge and pay more attention in productive technology.

A study done by Udimali *et al,* (2017) in Ghana also suggested a positive relationship between farm size and technology adaptation that is the larger the farm size, the more farmers are willing to adapt a new technology. According to the study, farmers with larger farm sizes were wealthier, and thus could afford to purchase new technology when compared to farmers with smaller farm sizes. Similar findings were reported by other researchers (Dhraief *et al.,* 2018, Kaliba et al 2018)

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However, a study done by Siyum *et al.* (2022) in Ethiopia suggested a different scenario as ownership of land was found to reduce the intensity of a farmer's adaptation to improved bread wheat technologies. This was mainly because farmers did not want to take the risk of trying something new that they were not used to and are not sure how it will affect productivity in their farms therefore, land size was not a factor.

In some cases, lack of access and cost limit the willingness and use of improved technologies by farmers. For example, Fisher et al. (2015) found that unavailability of seed and unaffordability of seeds due to high prices were the main factors preventing the adaptation of new maize varieties in Tanzania. In Ethiopia, unavailability of improved seeds and resources such as land, cash and inputs were identified. In Uganda, poor access to information on new seed varieties and unavailability of seeds. Malawi, high seed price and storage as majority of farmers believe the new varieties cannot sustain the storage condition compared to the local. In Zambia, inadequate information and unavailability of seeds, while in Zimbabwe the main barrier is inadequate information.

Since the factors that influence choice and adoption of technology could differ from one place to another depending on major agricultural activities in the area and other factors mentioned above, it is important to determine if farm size is one of the influencing factors in the case of the rural areas in Tanzania. This information will be important when designing the technologies to be introduced in the rural so that farmers can be clustered according to farm sizes and appropriate technologies be introduced in those clusters. Therefore, the objective of the study is to determine if farm size influences the adoption (willingness to adopt) of improved technologies in rural areas of Tanzania and establish the level of influence that farm size has as compared to other factors that are influencing the choice of technologies.

H1: Farm size influences the proclivity to adopt farm technologies in rural areas positively.

H2: Technology adoption/willingness for technology adoption is influenced by farm size, age, family labour, gender, membership in a local association, access to loans, access to credit, and level of education

H3: Farm size has a relationship with other factors influencing adoption

Methodology

Sampling and data collection

The study was conducted in the Kilombero and Mvomero districts of the Morogoro region, Tanzania. A two- stage sampling procedure was adopted.

Firstly, the selection of villages was done in both districts where crops of interest i.e., beans and vegetables are grown. In addition, fish farming was a criteria for Kilombero district. A list of households in the selected villages was prepared, indicating the sex of the household head, age and size of the farm they use to grow crops. This list was later used to make eight strata, from a combination of age, sex, and farm size. People aged below 50 years were grouped as young and those with aged 50 years and above were

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grouped as old. Farm sizes were grouped into two categories; small (below 3 acres) and large (from 3 acres and above) for Kilombero, and small (from 4.9 acres and below) and large (above 4.9 acres) for Mvomero. The cut-offs for farm size categories differed between the two districts, because they followed the perceptions of the farmers and extension officers in the two districts as gathered separately during the pre-survey.

Secondly, a random selection was done to get around 500 respondents in Mvomero district and 400 respondents in Kilombero district. During sampling, female household leaders were set not to be less than 33.3% of the sample size for each district. The final sample size in Mvomero was 504 while that of Kilombero was 407 making a total of 911 respondents for the whole study. Questionnaire was administered to household heads by trained enumerators through a one by one, face to face interviews. Tablets were used to administer the questionnaire in an ODK environment.

Data analysis

In order to analyse factors influencing technology adaptation, a logit model was used as the dependent variable is binary. Hence from the model *P* represents the probability of adapting (1) while 1-*P* stands for farmer's probability not willing to adapt technology (0).

$$\Pr(Yi = y|x_{G\ldots\ldots RE.}) = P_i \;\; if \; y = 1 \qquad 1 - P_i \; if \; y = Otherwise(0)$$

Thus: $Log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_G X_G + \beta_{MA} X_{MA} + \beta_{LR} X_{LR} + \beta_A X_A + \beta_{FZ} X_{FZ} + \beta_{FL} X_{FL} + \beta_L X_L + \beta_C X_C + \beta_{PE} X_{PE} + \beta_{SEA} X_{SEA} + \beta_{MO} X_{MO} + \beta_{RE} X_{RE} + \mathcal{E}$

$$\beta_{0\ldots\ldots RE} = Coefficients \quad X_{G\ldots\ldots RE} = Independent\ variables$$

G=Gender; MA= Membership of local association; LR= Land rent; A= Age; FZ= Farm size; FL=Family Labour; L= Access to Loan; C= Access to Credit; PE=Primary Education; SEA=Secondary education and above; RE= Remittance used for farm investment; MO=Mobile ownership

In order to analyse how farm size is related to factors of technology adoption, a Multiple Linear Regression model was used.

$$Y = \beta_0 + \beta_G X_G + \beta_{MA} X_{MA} + \beta_A X_A + \beta_{TA} X_{TA} + \beta_{FL} X_{FL} + \beta_L X_L + \beta_C X_C + \beta_{PE} X_{PE} + \beta_{SEA} X_{SEA} + \beta_{MO} X_{MO} + \beta_{RE} X_{RE} + \mathcal{E}$$

$$Y = Dependent\ variable \quad \beta_{0\ldots\ldots RE} = Coefficients \quad X_{G\ldots\ldots RE} = Independent\ variables$$

G=Gender; MA= Membership of local association; A= Age; TA= Technology Adaption FL=Family Labour; L= Access to Loan; C= Access to Credit; PE=Primary Education SEA=Secondary education and above; RE= Remittance used for farm investment; MO=Mobile ownership

Results

When willingness to technology adoption was regressed to some possible factors of adoption, including farm size, using the logit model, results in Table 32 show that

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adoption of the technologies is significantly and positively related to farm size, indicating adoption of technologies by farmers depend on the size of the farm, suggesting that farmers with bigger farms have a higher propensity to adopt than those with smaller ones. The adoption of new technologies is also significantly and positively related to credit access, implying that for most of the introduced technologies, including irrigation, adequate funds are needed for their adoption and one source of funding is through access of credit from various sources. Primary and secondary education also have a significant and positive relationship with adoption, meaning when farmers are knowledgeable through education, they are more capable of learning new things and making decisions to adopt new technologies than when they are not educated. Gender and family labour also have a significant and positive relationships with technology adoption. The results indicate that males are more willing to adopt new technologies than females. On the other hand, age seems to be significantly and negatively related to adoption of the technologies indicating that older people are more hesitant to adopt new technologies than younger ones. Strangely, access to loans is highly significant and negatively related to the adoption of technology. This result could be attributed to the very small number of farmers indicating access to loans therefore, it does not provide a good implication.

Table 32: Factors influencing technology adaption Kilombero and Mvomero in Tanzania.

Variable (Technology Adoption)	Coefficient	SE	P>Z
Age	-0.0167	0.0080	0.038**
Farm size	0.3794	0.1708	0.026**
Family labour	0.2003	0.1208	0.097*
Gender	0.4561	0.2447	0.062*
Membership of Local Associations	0.2107	0.4631	0.649
Loan	-1.4548	0.4719	0.002***
Credit	0.8067	0.3347	0.016**
Land rent	-0.4827	0.2243	0.031**
Primary education	0.6460	0.2897	0.026**
Secondary education	0.9107	0.5065	0.072**
Mobile Ownership	-0.1184	0.3427	0.730
Remittance used to cover farm costs	-0.2117	0.3020	0.483

*** Significant at 1%, ** Significant at 5% and * Significant at 10%.

The results of the multiple regression analysis in Table 33 show that farm size is significantly and positively related to age, family labour, and adoption of technology, suggesting that older people have more access to land than younger ones and perhaps also households with a high number of people who at working age tend to acquire more land so that the family can be utilized. The results also suggest that people who adopt new technologies have more land in ownership than non-adopters. Similarly, the findings show that farm size is highly significantly and positively related to gender, membership in a local association, access to loans, and land rent (Table 33). These results mean that male have more access to larger land than females. Also, people with larger land sizes tend to join the local associations more than their counterparts. The findings also suggest that people with larger land holdings may be able to obtain loans more easily than those

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with smaller holdings, particularly where collateral agreements are required in order to obtain loans and land can be used as a collateral item for such agreements. Because some farmers acquire more land by renting, the results suggest that farm size may be related to land rent.

Table 33: Relationship between Land size and other factors of technology adoption

Variables (Land Size)	Coefficients	Standard Error	P>z
Age	0.0115	0.0039	0.003**
Family labour	0.0912	0.0481	0.058*
Gender	0.3616	0.1119	0.001***
Membership of Local Association	0.9208	0.1791	0.000***
Loan	1.1786	0.2753	0.000***
Credit	-0.0591	0.1240	0.634
Primary education	0.5543	0.1540	0.719
Secondary education	0.0296	0.2209	0.893
Mobile Ownership	0.2192	0.1667	0.189
Remittance used to cover farm costs	-0.0580	0.1395	0.677
Land rent	0.9152	0.0728	0.000***
Technology adaption	0.3224	0.1898	0.090*

*** Significant at 1%, ** Significant at 5% and * Significant at 10%.

Conclusion

The results have confirmed that farm size influences the adoption of technology in the rural areas (H1). The analysis has shown that farmers with larger land sizes are more likely to adopt new and improved technologies than those with small land sizes, and this could also be indirectly related to other factors like family labour and gender. The analysis has also revealed that adoption of technology is a complex aspect where there are factors other than the land size that influence it in different ways (+/-). For example, factors like age, family labour, education level and others have been shown to influence willingness to adopt farm technology (H2). We have also been able to establish that land size is also related to other factors that are influencing technology adoption in different ways. For example, age, family labour, gender, membership in a local associations and land rent are positively related to land size making some of these factors indirectly influence the propensity to adopt farm technologies.

Since it appears older people have more access to larger land sizes than the younger ones, but since the older ones are not very keen on adopting new farming technologies, the government should try to find ways to make land available to younger people, are according to the results, are more willing to adopt farm technologies. In addition, the government should find ways of facilitating these young farmers to access credit through loans from banks or other credit organisations. This is because access to credit seems to be important for technology adoption.

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Chapter 2: Farmers' involvement in cooperatives in Tanzania: Does it help to improve livelihoods?

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Introduction

Cooperatives are a global phenomenon. Besides, they are found in almost all sectors including agriculture, food, finance, health care, marketing, insurance and credit (Kumar et al., 2015). Consequently, cooperative enterprises are the largest organization in the world, wherein 2.6 million cooperative societies employ over 1 billion members both directly or indirectly (Grace 2014). And as the global community works towards achieving the Sustainable Development Goals (SDGs) by the year 2030, cooperatives have been found highly relevant and well positioned to contribute to realizing the same (Wanyama, 2016). Similarly, many actors including the United Nations (UN), the International Labour Organization (ILO), and the International Co-operative Alliance (ICA) are agreed that the cooperative enterprise is the type of organization that is most suited to addressing dimensions of reducing poverty and exclusion (Wanyama, 2016). Moreover, cooperatives are increasingly being advocated as a means to improve incomes, livelihoods and the sustainability of smallholder farmers (Ofori et al., 2019).

There exists empirical literature on cooperatives, in general, which has focused on the role of cooperative membership in improving livelihoods or welfare covering various aspects such as household income, food security, and adoption of improved practices. Some studies have reported on the impact of cooperative membership on both household food security and income (Ofori et al., 2019); food security (Oluwatoyo, 2009; Nugusse et al., 2013; Ayele, 2014; Gebremichael, 2014; Ofori et al., 2019; Kehinde and Kehinde, 2020; Zeweld et al., 2015); and household income (Wanglin, 2016; Meena et al., 2009; Mojo et al., 2017; Ofori et al., 2019). However, some studies though limited, show that the cooperatives have had minimal impacts on rural livelihoods (Churk, 2015). In the same vein, a study by Shumeta and D'Haese (2018) could not confirm the effect of membership of cooperatives on income. Thus there is need for further examination of whether involvement in cooperatives has had any significant impacts on rural livelihoods. More specifically, the research question that this study seeks to answer is: Does membership of cooperatives help to improve livelihoods with respect to household income and food security?

Objective and Hypothesis of Research question

The objective of the research question is to determine the relationship between membership of cooperatives and improved livelihoods in terms of household food security and income. The hypothesis of the research question is: Membership of cooperatives has no significant relationship with household income and food security

Methodology

Data for this study are based on the household survey which was done using a questionnaire.

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Results

Socio-economic profile of the sample

Majority of the respondents (61.1%) were men; majority (72.4%) of them had attained secondary level of education (Table 34). However, only the smallest proportion (11.3%) of the respondents had membership in associations (Table 34).

Table 34: Socio-economic profile of the sample

Gender	N	%
Men	557	61.1
Women	354	38.9
Total	911	100.0
Level of education	n	%
Illiterate	68	7.5
No qualification, literate	78	8.6
Primary	660	72.4
Secondary	660	72.4
More than secondary	87	9.5
Other specify	18	2.0
Total	911	100.0
Membership in association	n	%
Yes	103	11.3
No	808	88.7
Total	911	100.0

Moreover, majority of them (67.1%) indicated the assistance obtained from being members of associations not important at all (Table 35). On the other hand, those who considered it very important accounted for only 17.2% of the respondents and the rest considered the assistance to be from slightly to moderately important (Table 36).

Table 35: Perceived importance of received assistance for self and own farm

Whether received any assistance	n	%
Not at all important	611	67.1
Slightly important	43	4.7
Somewhat important	46	5.0
Moderately important	54	5.9
Extremely important	157	17.2
Total	911	100.0

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Table 36: Membership in association by perceived importance of received assistance

Membership in the association	Whether received any assistance					Total
	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important	
Yes	32 (5.2)	13(30.2)	14(30.4)	19(35.2)	25(15.9)	103(11.3)
No	579 (94.8)	30(69.8)	32(69.6)	35(64.8)	132(84.1)	808(88.7)
Total	611 (100.0)	43 (100.0)	46 (100.0)	54(100.0)	157(100.0)	911(100.0)

The chi-square test (Table 37), shows that membership in association significantly influence farmers' perception regarding the importance of technical assistance/services received from cooperatives or from some other institution/organization (Pearson Chi-squire = 88.629, $P < 0.01$).

Table 37: Chi-square test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	88.629[a]	4	.000
Likelihood Ratio	74.936	4	.000
Linear-by-Linear Association	38.030	1	.000
N of Valid Cases	911		
a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.86.			

Status of household food security

The largest proportion of the respondents indicated that experience of food shortage was slightly important (35%) followed by those who felt it was moderately important (32.5%) (Table 38).

Table 38: Experience of food shortage/Starvation

Food need	Frequency	Percent
Not at all important	123	13.5
Slightly important	319	35.0
Somewhat important	134	14.7
Moderately important	296	32.5
Extremely important	39	4.3
Total	911	100.0

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Membership in association and experience of food shortage

Generally, the study shows that the respondents who had no membership in associations experienced food shortage than those who were members of associations (Table 39).

Table 39: Experience of food shortage by membership in association

Experience of food shortage/starvation	Membership in the association		
	Yes	No	Total
Not at all important	27 (26.2)	96(11.9)	123(13.5)
Slightly important	41(39.8)	278(34.4)	319(35.0)
Somewhat important	12(11.7)	122(15.1)	134(14.7)
Moderately important	20(19.4)	276(34.2)	296(32.5)
Extremely important	3(2.9)	36(4.5)	39(4.3)
Total	103(100.0)	808(100.0)	911(100.0)

Experience of food shortage

Table 40 shows that about 19% of farmers who are not members of association experienced food shortage. On the other hand, the findings show that about only 9% of farmers who were members of associations experienced food shortage. The positive correlation ($r = 0.12$) indicates that experience of food shortage is higher among non-members as compared to members. The chi square findings ($\chi 2 = 15.190$; $df = 4$; $p = 0.000$) further show that there is a significant association between membership and experience of food shortage. Besides, the findings show that membership in farmer associations was significant ($p<0.01$) and negatively related with experience of food shortage (beta coefficient = -0.645). In additional, the odds ratio indicates that members of farmer organization were 0.52 less likely to experience food shortage.

Table 40: Experience of food shortage

Experience of food shortage	Membership in association		
	Yes	No	Total
Not at all important	46(44.7)	256(31.7)	302(33.2)
Slightly important	25(24.3)	140(17.3)	165(18.1)
Somewhat important	10(9.7)	121(15.0)	131(14.4)
Moderate important	13(12.6)	140(17.3)	153(16.8)
Extremely important	9(8.7)	151(18.7)	160(17.6)
Total	103(100.0)	808(100.0)	911(100.0)

$\chi 2=15.190, df=4, P=0.000; r= 0.12;\ \ p = 0.000$

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Table 41: Ordinal logistic regression on influence farmers group on experience of food shortage

Factors	**Food shortage/starvation**		
	Estimate	Sig.	OR
Age	.008	.025	1.01
Education	-.156	.013	0.86
Household size	-.018	.650	0.98
Membership(being a member)	-.645	.001	0.52
Gender=Male	-.423	.001	0.66

Food shortage: Cox and Snell=.0.036; Nagelkerke=.038; McFadden=0.01

Household income

Table 42 below shows that membership in association significantly influenced the average household income (Pearson Chi-squire = 20.004, P < 0.01).

Table 42: Chi-square test

Chi-square test			
	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.004[a]	4	.000
Likelihood Ratio	23.181	4	.000
Linear-by-Linear Association	17.929	1	.000
N of Valid Cases	911		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.54.			

Experience of income reduction

Table 43 shows that about 19.4% of respondents who were members of associations did not experience income reduction. On the other hand, the study shows that about 30.9% of farmers who were not members of the associations experienced income reduction. The positive correlation (r = 0.072) indicates that experience of income reduction is higher among non-members as compared to members. However, according to Table 42, the chi square findings show that there is no significant association between membership and experience in income reduction ($\chi 2=5.470, df=4, P=0.242$). Also, the odds ratio was 0.68 implying that members of farmer organization were 0.68 less likely to experience income reduction (Table 44).

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Table 43: Income reduction and membership in association (Cross-tabulation)

Experience of income reduction	Membership in association		Total
	Yes	No	
Not at all important	20(19.4)	108(13.4)	128(14.1)
Slightly important	19(18.4)	110(13.6)	129(14.2)
Somewhat important	15(14.6)	131(16.2)	146(16.0)
moderately important	23(22.3)	209(25.9)	232(25.5)
Extremely important	26(25.2)	250(30.9)	276(30.3)
Total	103(100.0)	808(100.0)	911(100)

$\chi 2=5.470, df=4, P=0.242; r= 0.072;\quad p = 0.030$

Table 44: Ordinal logistic regression on influence farmers group on income reduction

Factors	**Income reduction**		
	Estimate	Sig.	OR
Age	.001	.770	1.00
Education	-.031	.620	0.97
Household size	-.007	.868	0.99
Membership(being a member)	-.385	.044	0.68
Gender=Male	-.030	.803	0.97

Income reduction: Cox and Snell=.0.005; Nagelkerke=.005 ; McFadden=0.02

Conclusion

Generally, drawing on the study's findings it is concluded that membership of cooperatives help to improve rural livelihoods in terms of household income and food security.

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Chapter 3: Does trust influence crop and fish farmers' decision to join group membership in Uganda? An instrumental variable modelling of the associated welfare gains

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Introduction to research paper

Agriculture remains a source of livelihood in sub-Saharan Africa, contributing approximately 80% of the food supply (Donkor et al., 2021). The Food and Agricultural Organisation underscores the importance of farmer organisation in spearheading the agricultural development agenda (Rokhani et al., 2021).

Trust has an influence on creating positive synergies in terms of collaboration, cooperation and healthy interaction in groups (Molina et al., 2021). It is note-worthy that trust is directly proportional to the degree of positive attitude about a given event or phenomenon (Turyahikayo & Kamagara, 2016). Specifically, trust is enhanced by efficient feedback and effective communication between the parties that are involved and yet pivotal for improved performance of the nodes of a value chain (Rugema et al., 2017). On the other hand, membership in farmer group is important in generating collective effort in undertaking activities such as marketing at a minimised transaction cost, enables credit access and reduces risk (Funmilayo et al., 2016). In addition, smallholder farmers also benefit through enhanced access to extension support, advisory services, farm inputs, savings and a strengthened social capital (Dendup & Aditto, 2021). A robust market information system is necessary to curtail any prevailing socioeconomic hiccups (Sebuliba-Mutumba et al., 2017).

A number of studies have been done on drivers of group membership for example; Sebuliba-Mutumba et al. (2017) which focused on collective action and adoption of poultry in Wakiso, Rokhani et al. (2021) investigated the determinants of participation among Sugarcane and Tobacco farmers in Indonesia and Mwaura (2014) studied the effect of group membership on agricultural adoption and productivity. At another trajectory, Lwezaura & Ngaruko (2013) investigated the determinants of group participation and proceeded to assess the impact of participation in farmer group in Mbozi district in Tanzania. To fully comprehend the trust-farmer membership-welfare relationship, two research questions can be posed; i) What is the effect of trust on the membership of fish and crop farmers in groups and ii) Do farmers who group members attain better welfare gains (income) compared to non-group members? This study seeks to build on the already existing empirical evidence by assessing the effect of trust on membership among crop and fish farmer groups and then will model the impact of membership and non-membership on welfare of farmers. The findings will also be useful in designing policy interventions in the smallholder farmer domain along dimensions of both production and food systems.

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Conceptual framework of the study

The study is done in two stages (Figure 8), first, the effect of trust on decision to join farmer groups is assessed. However, the decision to join group membership is endogenous and hence an instrumental value (common resource use) was used to solve the endogeneity problem. In the second stage, the effect of membership on welfare of farmers was assessed. Income inform of sales value and product value was used as a proxy for welfare. In both models' covariates.

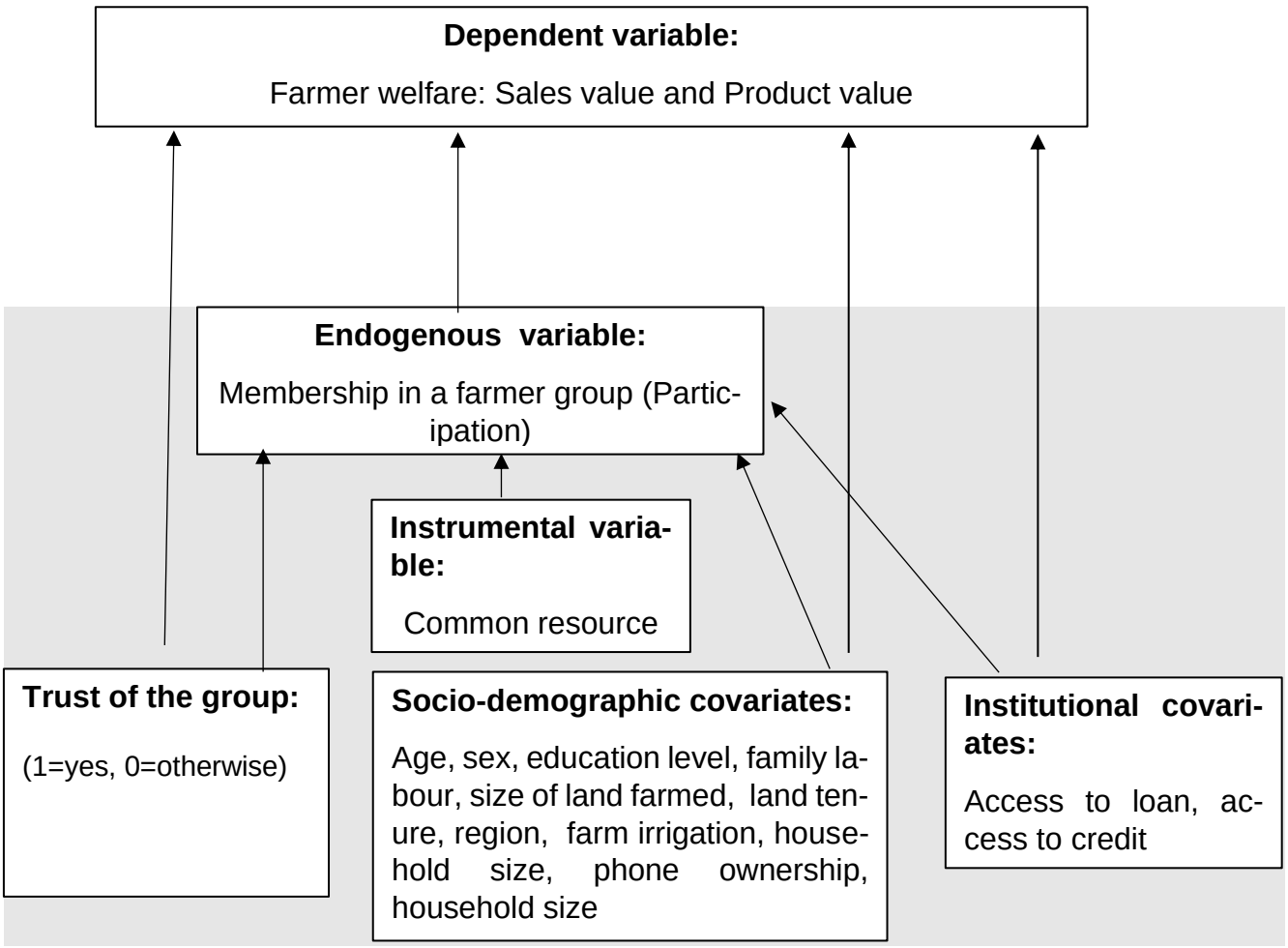

Figure 8. Conceptual framework showing relationship between the variables

Methodology

We follow, Lwezaura & Ngaruko (2013) to model the two stages of the research problem; i) to assess the effect of trust on decision to join groups and ii) effect of group membership on the welfare of the participants and non-participants.

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$Ln\left(\frac{D_i}{1-D_i}\right) = \beta_0 + \beta_1 Fc_i + \beta_2 E_i + \epsilon$.....(1)

With D_i is the probability of joining a group, F_{ci} internal factors, E_i external factors,

Prob (*MEMBOR = 1*) = $\frac{1}{1+e}$ - Z_j.....(2)

$Z_j = \beta_0 + \sum_{j=1}^{n} x_j \beta + \mu_{1j}$.....(3)

With: MEMBOR = dichotomous dependent variable, X_i = vector of variables in the model, B_i = Parameters to be estimated and μ_{1j} = Error term

$y_i = \alpha + \beta x_i + \lambda Z_i + \epsilon_i$.....*(4)*

$y_i = \alpha + \beta x_i + \epsilon_i$.....*(5)*

With: Y_i = Impact or continuous outcome; x_i = Independent variables such as trust, age, education, gender, land size, ownership of phones, access to credit; Z = dummy variable indicating whether one is a member of a group or not; A, β and λ are parameters and ϵ Error term

Results

Comparing the main characteristics of between participants and non-participants to farmers groups

A t-test was run to compare participants and non-participants along socioeconomic characteristics. The results showed a significant difference between participants and non-participants in terms of; age (*P*=0.000), family labour (*P*=0.000), land size (*P*=0.031), household size(*P*=0.000), sales value (*P*=0.000) and product value (P=0.0001. The results are indicated in Table 45.

Table 45. Results of the t-tests between participants and non-participants

Variable	Overall Mean	Participants	Non-participants	P-value
Age (year)	42	43	40	0.000
Family labour (person)	3	3	2	0.000
Hired labour (person)	2	2	3	0.862
Land_rented (acre)	0.3	0.4	0.4	0.253
land_family (acre)	1.3	1.4	1.0	0.031
Household size (count)	8	9	7	0.000
Sales_value(UGx)	5320387	4095010	7549306	0.000
Product value(UGX)	6109350	4719883	8636742	0.000

A chi square analysis of categorical and dummy variables between participants and non-participants revealed a significant difference by gender (*P*=0.019), loan (P=0.000) and by enterprise (0.000). It is noteworthy that, there was no significant difference between participants and non-participants by education, credit and ownership of mobile.

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Table 46. Results of Chi-square estimations (Percentages are row percentages)

Variable	Participants (%)	Non Participants (%)	Chi-square statistic	P-value
Gender			5.4686	0.019
Male	62.31	37.69		
Female	68.85	31.15		
Education			0.2597	0.610
No qualification	69.57	30.43		
Literate	64.44	35.56		
Credit			1.5945	0.207
Yes	66.81	33.19		
No	63.31	36.69		
Loan			16.6297	0.000
Yes	74.27	25.73		
No	61.54	38.46		
Mobile			2.4190	0.120
Yes	64.88	35.12		
No	52.63	47.37		
Enterprise			17.0204	0.000
Fish	42.00	58.00		
Crop	69.00	31.00		

3.2 Assessing the effect of trust on group membership by fish and crop farmers.

A probit and logit model were run and the results compared. There was no statistical difference in the outputs, by parameter. Therefore the results of the logit model will be discussed because of the robust nature of the logistic distribution of errors.

The results revealed that trust has a significant effect on the decision to participate or join groups by fish and crop farmers.

Covariates that were significant (with a positive coefficient) in determining the decision to join groups included; age, access to loan, use of common resource and districts (dummies for Kamuli, Masaka, Mukono and Nakaseke). Interestingly, the variable fish farmer was significant at 5% but with a negative sign

Results are presented in *Table 47* and Table 48. The chi-square test result indicates that the logit model is significant improvement in fit compared to an intercept only model, LR Chi2(14)= 277.19, p<.001.

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Table 47. Results of probit and logit regression effect of trust on group membership by fish and crop farmers.

	Probit results		**Logit results**		
	Marginal effect	**se**	**Marginal effect**	**se**	**Odds ratio**
Membership(Yes=1)					
Trust (Yes=1)	0.230**	0.087	0.378**	0.147	1.459
Household size	0.008	0.01	0.012	0.018	1.012
Age (Year)	0.015***	0.003	0.026***	0.005	1.026
Gender (Male=1)	-0.091	0.083	-0.158	0.14	0.854
Education(Literacy=1)	-0.458	0.319	-0.769	0.536	0.463
Loan (Yes=1)	0.381***	0.098	0.652***	0.168	1.919
Credit (Yes=1)	0.076	0.083	0.116	0.139	1.123
Use Common resource (Yes=1)	0.779***	0.081	1.301***	0.138	3.673
farm_labour_hh	0.041	0.025	0.069	0.043	1.072
farm_labour_employed	0.011	0.014	0.016	0.024	1.016
Fishfarmer (Yes=1)	-0.331**	0.135	-0.528**	0.229	0.590
d_kamuli	1.133***	0.195	1.922***	0.338	6.834
d_lwengo	0.381	0.325	0.628	0.56	1.874
d_masaka	1.400***	0.19	2.376***	0.332	10.767
d_mukono	1.059***	0.2	1.804***	0.344	6.071
d_nakaseke	0.888***	0.203	1.532***	0.35	4.628
d_wakiso	0	(.)	0	(.)	1
Constant	-1.296**	(0.403	-2.214**	0.681	0.109
Number of observations	1,308		1,308		
LR Chi2(14)	278.64		277.19		
Prob>Chi2	0.0000		0.0000		
Log likelihood	-711.31283		-712.03678		
Pseudo R2	0.1638		0.1629		
Number of observations	1,308		1,308		

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Evaluation of Methodology:
Post regression diagnostics:

i) Predictive accuracy rate

The overall percentage of joined specificity and sensitivity is 69.72%. This is the degree of correctness of the percentage of cases with an observed outcome that were correctly predicted by the model.

Assessing whether there is a difference in welfare gains between group members and non-members.
A two-stage least square instrumental variable procedure was undertaken; Stage 1 assessed the effect of trust on decision to join groups and stage ii) assessed the effect of group membership on the welfare of the participants and non-participants.

Table 48. Results of logit regression effect of group membership by fish and crop farmers on

	Sales value		**Product value**	
	Marginal effect	**se**	**Marginal effect**	**se**
Membership(Yes=1)	0.177	0.307	0.183	0.275
Trust (Yes=1)	0.026	0.082	0.017	0.075
Household size	-0.019**	0.009	-0.015*	0.009
Age (Year)	0.001	0.003	0.003	0.003
Gender (Male=1)	0.708***	0.079	0.599***	0.072
Education(Literacy=1)	0.272	0.282	0.435*	0.26
Loan (Yes=1)	0.461***	0.097	0.418***	0.088
Credit (Yes=1)	-0.055	0.077	-0.037	0.071
farm_labour_hh	0.075***	0.022	0.057**	0.02
farm_labour_employed	0.069***	0.012	0.071***	0.011
Fish farmer(Yes=1; 0=crop)	0.488***	0.127	0.235**	0.117
d_kamuli (dummy)	-1.678***	0.231	-1.596***	0.211
d_lwengo (dummy)	-1.480***	0.322	-1.535***	0.298
d_masaka (dummy)	-1.161***	0.239	-1.152***	0.217
d_mukono (dummy)	-0.992***	0.224	-0.947***	0.205
d_nakaseke (dummy)	-1.012***	0.219	-1.137***	0.201
d_wakiso (base)	0	(.)	0	(.)
Constant	13.861***	0.366	14.077***	0.337
Number of observations	1,287		1,308	
Wald chi2(17)	713.85		675.01	
Prob > chi2	0.0000		0.0000	
R-squared	0.3562		0.3402	
Root MSE	1.2828		1.1855	

The instrumental variable selected was the use of common resource and the dependent variables were sales value and product value. Similar results were obtained. For

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instance, there was no difference between group members and non-members by both dependent variables, implying that group membership did not have a significant effect on welfare which was measured by a proxy of income in the form of sales value and product value. Other covariates that were significant included are: household size, age, gender, access to loan, household farm labour, hired labour, used land, fish farmer and region. By product value, education was significantly different.

Conclusion

Conclusion of Research question

Trust has a significant influence on decision to join groups by crop and fish farmers

Group membership has no significant effect on welfare gains; sales value and product value.

Policy recommendations

There is need to strengthen the quality of extension message that is delivered to farmers. Specifically on agribusiness topics so that their farm incomes and level of production is increased. This would be a clear pathway in enhancing food security through increased access.

More attention should be accorded to fish farming in terms of extension and budgetary allocation since the results showed significant effect of fish farming on welfare.

There is need to introduce farmer-friendly interest rates for loans since results were significant. The borrowing procedures should be smoothened and made less bureaucratic for the farming communities.

Recommendations for Foodland project

Focus should be on a fish-crop integrated scenarios to fully comprehend the synergies that accrue in terms of food security and income security to the farmers.

Areas of further research in the thematic areas should be considered for example: How do the group members and non-members differ in terms of food security indicators of HFIES (Household Food Insecurity Experience Scale).

A possibility of panel data could be explored to cater for individual time difference, deals with omitted variable bias, more accurate tests behavioural phenomena that are complex, generates individual outcomes more accurately and among others.

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Chapter 4: Current and future farm household food needs: Does crop variety matter? Evidence from the Kamuli and Nakaseke Food Hubs, Uganda.

Authors: Johnny Mugisha (MAK), Josephine Kisakye (MAK), Brian Ogenrwoth (MAK)

Introduction

Growing multiple crops concurrently is part and parcel of Ugandan cropping systems. Crop diversification is closely associated with positive welfare effects in terms of food stability in space and time at various levels such as individual, household and national (Makate, Angelsen, Terje & Tveitereid, 2022). There has been an increasing adoption of diversification of crops cultivated as a deliberate risk management strategy as attributed to high efficiencies in small landholdings, soil amendment and enhanced yields, among others (Mubiru et al., 2018). Rural households that are prone to risk of food insecurity often manage the risk by diversifying on-farm production hence attain satisfactory levels of food availability and income (Wichern et al., 2017).

Makate et al., (2016) defined crop diversification as a crop husbandry practice of growing more than one crop variety in either space (as an intercrop) or time (following a clear rotation schedule). It is note-worthy that crop diversification is affordable and a good catalyst for poverty reduction (Feliciano, 2019). Diversification can be conducted in form of; intercropping, livestock-crop integration, introducing new varieties of crops and planting of fruit trees (Mubiru et al., 2018). Diversification may also be carried out inform of substituting low value commodities with high value ones, agri-silvicultural practices which involve integrating crops and trees on the same land as well as production of perennial cash crops such as coffee (Feliciano, 2019). A study by Mengistu et al., (2021) revealed that household food security is positively associated with number of crops grown by a farmer. However, it remains hypothetical that the lack of crop diversification, or dominance of one or few crops smallholder farmers grow have a negative implication on adequacy of their household food needs. In some parts of Uganda, maize tends to traditionally dominate the farming systems of the smallholder farmers, considering it as a food security and income crop. This provides a good case to examine the relationship between crop diversification and the ability of farmer households to meet their food needs, determine the influence of crop diversification on farmers' perceived risk of food shortages or starvation, and test the hypothesis that lack of diversity curtails household food needs and makes a farmer worried about future food shortages/starvation.

Conceptual framework

The dependent variable used in this study was food needs. This was categorised into current consumption needs and future consumption needs or food stability. The key independent variable was crop diversity which was measured by a crop diversity score and crop categorisation. Other covariates that were used in this study included; socioeconomic variables such as; age, sex/ gender, household labour, size of land farmed, irrigation, household size, remittance, total annual income, occupation of farmer, membership in associations and phone ownership. In addition, the institutional covariates that were used in this study included; access to loan and membership in associations. The independent variables affect both current needs and future needs as illustrated in Figure

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9. For robustness, the variables were selected in line with existing theory and previous related studies .

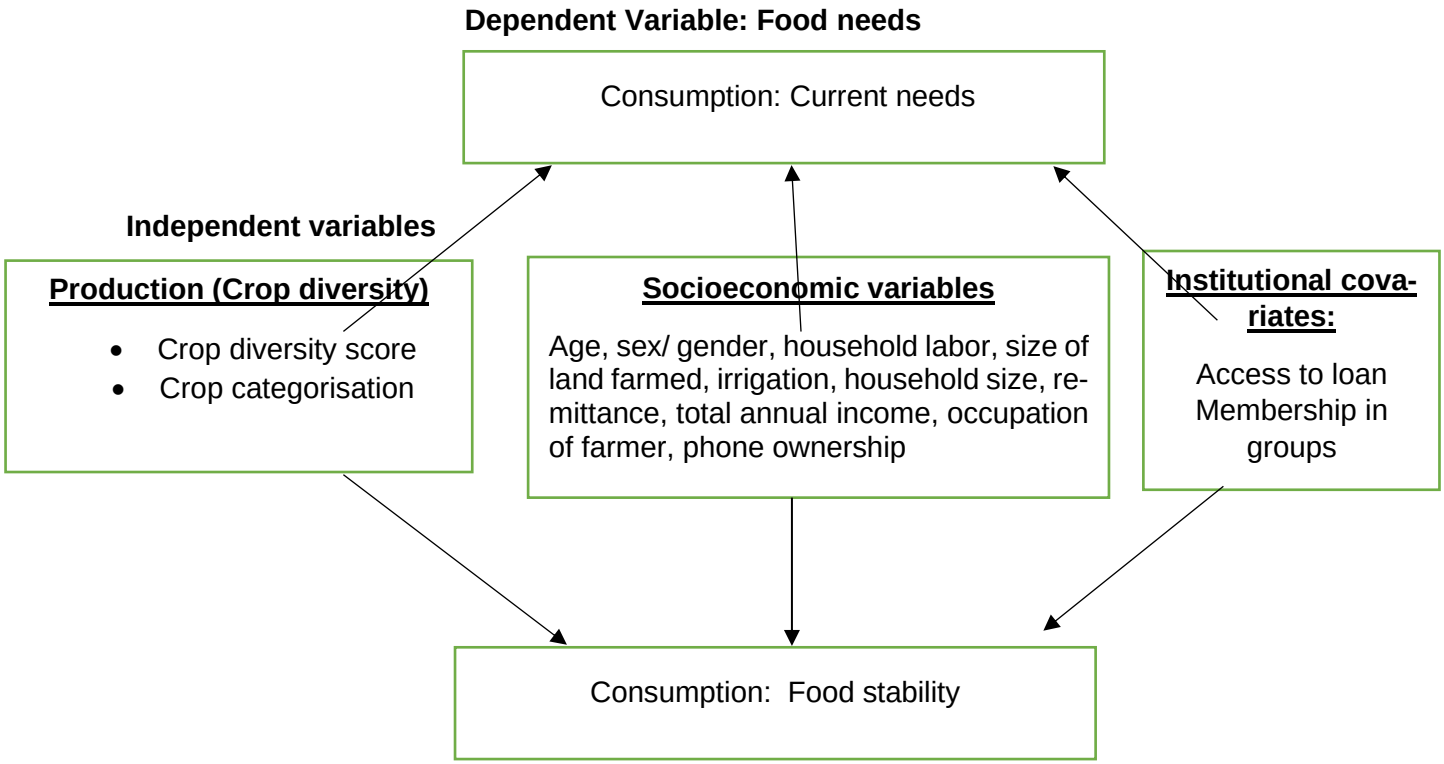

Figure 9. Conceptual framework showing the relationship between dependent variables and independent variables

Methodology

To estimate the influence of crop diversity on the ability of farmer households to meet their food needs, we used the FoodLAND crop survey dataset from Nakaseke and Kamuli districts, Uganda. The data were collected from 610 maize crop farmers (354 from Kamuli and 256 from Nakaseke). Previous studies indicate that there are various ways that researchers have measured crop diversification. Approaches such as use of Herfindahl-Hirschman Index (HHI) (Adjimoti and Kwadzo, 2018), Simpson diversity Index and Shannon Index are commonly applied. The HHI index would be appropriate however, it would not give a correct estimate because in this study, respondents were limited to a maximum of 3 major crops (rather than the total) that they had grown on the farm. Therefore, we measured crop diversity as a count of the number of crops grown by the farmer and registered a categorical variable where 1=farmer grew maize only, 2=farmer grew maize and one other crop, 3=farmer grew maize and two other crops.

The dependent variable is the household's ability to meet their food needs categorically ranked 1-5 where 1= farmer is able to have more than enough food for the household and 5= farmer faces serious food shortages.

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Table 49. Crop categorization of selected crops that were grown by maize farmers

Category	Crop
Cereals	Maize, rice, millet
Legumes	Beans, soybean, groundnut
Tubers	Cassava
Vegeta-bles/fruits	Amaranth, aubergine, eggplant, tomatoes, nakati, matooke, watermelon, cabbage
Cash crop	coffee

Results

Chi-square tests and multinomial regression results showed that the extent of crop diversification did not significantly affect farmer's ability to meet household needs regardless of whether the farmer grew sole maize or maize with 2 other major crops. This could be due to poor farming technologies that may not be necessarily leading to increased farm production. It is also likely that the farmers' understanding of the phrase "major crops" varies and may not necessarily be in terms of food but rather income or other terms, implying that their worry about food emanates from elsewhere other than the food they grow.

However, further analysis revealed that more diverse farmers (with 2 or 3 major crops) are less worried of future food shortages (Table 50). Results indicated that farmers in Kamuli are less likely to slightly worry and more so less likely to perceive extreme worry of future food shortages. Farmers that indicated that they were extremely worried of facing starvation and food shortage spend larger shares of their income on food purchases. Results also showed selling maize at a higher price slightly reduces the likelihood of extremely worrying about future food needs. Farmers that extremely worry about food shortages grow different crops every season and face serious storage problems.

Farmers that diversify into vegetables and or fruits are more likely to meet their household food needs (Table 51). Other food groupings were not significant to explain farmers' ability to meet their household food needs. Results also suggest that farmers that are able to have more food than they need have higher farm labour and grow different crops per season. Similarly, increase in total farm labour (both hired and family) reduces the probability of a farmer facing serious food shortage.

Results also indicate that farmers that have larger proportion of farmland under maize crop, have faced health setbacks and spend almost all their income on food, are less likely to meet their food needs. This could be explained by the fact that such farmers will have faced a setback drought as shown in the results.

Results also show that farmers that have experienced health setbacks are less likely to produce more food than they need, however, also some farmers that report facing some difficulties in meeting food needs are less faced some serious health setbacks. This is an unexpected finding that could be further investigated, however, the time the data was collected it was still COVID period. People that had off-farm jobs faced difficulties in accessing their workstations whereas farmers could still access their farms. Therefore, in

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that case a health setback would result in a positive outcome as farmers spend more at their farm and saving on labour.

Table 50. Results of the multinomial regression showing the influence of crop diversity on worry about meeting future food needs (reference group is the first category "not worried at all")

	Slightly worry(n=53)		Somewhat worry (n=37)		Moderately worry (n=76)		Extremely worry (n=271)	
Variables	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Diversity score	-0.568*	0.324	-0.675*	0.375	-0.285	0.301	0.069	0.231
Foodhub (1=Kamuli)	-0.644*	0.389	-0.393	0.432	-0.368	0.340	-0.927***	0.252
Income setback (1=extremely important)	-0.093	0.355	0.209	0.404	-0.151	0.320	-0.757***	0.245
Infestation setback (1=extremely important)	0.201	0.359	0.805*	0.432	-0.489	0.330	-0.355	0.243
Drought setback (1=extremely important)	0.565	0.353	0.725*	0.409	1.044***	0.314	0.077	0.241
Health setback(1=extremely important)	0.444	0.354	0.289	0.409	-0.324	0.315	-0.354	0.234
% of income spent on food	0.051	0.390	0.548	0.423	0.431	0.328	0.464*	0.251
Age of the farmer	-0.008	0.013	0.008	0.015	0.002	0.012	0.003	0.009
Gender of the farmer	0.022	0.368	0.409	0.411	-0.335	0.340	0.164	0.242
Farm labour (family +hired)	-0.004	0.058	-0.062	0.074	-0.134**	0.062	-0.003	0.038
Land Proportion maize	0.379	0.705	-0.304	0.936	0.137	0.658	0.822*	0.479
Commercialization Index of maize	-0.006	0.008	-0.002	0.006	-0.008	0.008	-0.004	0.005
Maize average price sold (per kg)	0.000	0.001	0.000	0.001	-0.001	0.001	-0.002**	0.001
Grow Same crop every year(1=yes)	0.670	0.409	0.500	0.458	0.6308	0.360	1.061***	0.266
Loan(1=yes)	0.054	0.408	-0.618	0.434	-0.204	0.338	0.437*	0.263
Affected by storage (1=extremely important)	0.101	0.105	0.083	0.122	0.1598	0.094	0.251***	0.069
Constant term	-0.748	2.059	-2.719	2.362	1.277	1.849	0.953	1.369
Number of obs		547						
LR chi2(64)	=	165.66						
Prob > chi2	=	0.000						
Pseudo R2	=	0.1106						
Log likelihood	=	-666.22835						

**=P<0.10, **=P<0.05, ***=P<0.01*

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Table 51. Multinomial regression results of influence of crop type on household ability to meet food needs (Reference category "we have what we need")

	More that need		Just about		Some difficulty		Serious short-age	
Food need	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err
Vegetables/fruits	0.926**	0.379	0.513	1.000	0.490	0.570	0.180	1.163
Foodhub(1=Kamuli)	-0.167	0.236	0.306	0.498	-0.052	0.341	-0.454	0.661
Income set back(1=ex-tremely important)	-0.041	0.230	-0.336	0.286	-0.155	0.335	-0.771	0.757
Pest infestation(1=extremely important)	0.223	0.228	-0.391	0.292	-0.297	0.334	-0.452	0.711
Drought setback(1=ex-tremely important)	-0.017	0.227	0.156	0.281	0.561*	0.312	1.343*	0.674
Health setback(1=extremely important)	-0.647***	0.225	0.225	0.273	-0.538*	0.323	-0.364	0.655
Propostion of income spent on_food	-0.633**	0.250	-0.160	0.274	0.660**	0.315	0.625	0.645
Age of the farmer	0.006	0.008	0.523*	0.274	-0.007	0.012	-0.045	0.032
Gender of the farmer	-0.027	0.226	0.002	0.010	-0.138	0.327	-1.077	0.846
Farm labour (family +hired labour)	0.065*	0.037	-0.332	0.286	-0.094	0.067	-0.336**	0.169
Proportion of land allocated to_maize	-1.159**	0.488	-0.032	0.052	-0.130	0.531	0.935**	0.482
Commercialization Index of maize	-0.002	0.004	0.058	0.419	-0.012	0.007	0.003	0.003
Maize average price sold (per kg)	0.001	0.001	-0.001	0.004	-0.001	0.001	-0.001	0.003
Grow Same crop every year(1=yes)	0.601*	0.263	-0.001	0.001	0.502	0.390	0.503	0.830
Constant term	0.513	1.000	0.026	0.299	0.397	1.495	0.697	2.928
Number of obs. =	547							
LR chi2(56) =	114.29							
Prob > chi2 =	0.0000							
Pseudo R2 =	0.0775							
Log likelihood =	-679.940							

**=P<0.10, **=P<0.05, ***=P<0.01*

Conclusion

Conclusion of Research question

This study investigates the influence of growing more than one crop on the ability a farmer household to meet their food needs. Results of the analysis reveal that crop diversification (number of crops grown by a maize farmer) in Kamuli and Nakaseke districts, significantly affects farmers perception of likelihood of facing future food shortages but not their ability to meet their current food needs. Growing different crops every season and facing storage problems have a strong influence on farmer perception of likelihood of facing food shortages in future. In addition, land allocated to maize production,

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therefore decreasing land available for diversification, has an effect on both current and future food need.

The hypothesis that growing food crops increases the household ability to meet food needs is partly true as the study reveals that maize farmers that diversify into vegetables and fruits are more likely to meet their food needs other food categories: cash crops, legumes, tubers and cereals are less likely to have a significant impact on farmers' ability to meet food needs of maize farmers Kamuli and Nakaseke.

Recommendations for Foodland project

First, most of the farmers in the two food hubs grow more than one crop but that strategy is less likely to have an effect on their food security. Therefore, the FoodLAND project could focus on vegetables/fruits as these are positively associated with ability to meet food needs. Farmers could be argued to convert more of the land under maize and to vegetable growing.

Secondly, the project could consider promoting drought resistant varieties (maize and other crops) plus other technologies that can reduce the impact of drought on farm production.

Lastly, the results of the study suggest that farmers that report serious food shortages are likely facing some labour constraints, either availability or high cost of labour therefore FoodLAND could promote labour saving technologies among maize farmers.

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Chapter 5: Does perception of crop loss influence farmers' decision to rotate crops in Uganda?

Authors: Josephine Kisakye (MAK), Brian Ogenrwoth (MAK), Johnny Mugisha (MAK)

Introduction

Understanding the decisions of farmers on crop practices is important in promoting agricultural innovations especially those that comprise new crops. Research shows that the decision to grow crops is largely driven by expected economic gains (Ouédraogo et al., 2017). Farmers tend to opt for a certain crop if the market is available and that they are likely to profit from selling it. However, other studies find that farmers make decisions to change to another crop if the risks associated with growing it are lower than for the current crop (Kijima, 2019).

Farmers that have specialized farms or grow the same crops every season, are more susceptible to recurrent losses due to pest attacks and diseases rendering them less resilient (Seo, 2010).Crop losses should act as a disincentive to continue growing a specific crop, therefore consideration of farmers' perception of the loss is important as it is indicative of their awareness of the constraints associated with the farm environment or the enterprise. If a new technology reduces farm losses and yet a farmer does not consider losses when choosing a crop then the likelihood of adopting this new technology may be low. When reduction of crop losses involves the use of equipment, introduction of a new variety or other technology that does not require change of crop, one can assume that a farmer might consider the option in comparison to completely moving to producing another crop.

Several studies have explored how crop rotation impacts yield (Naab et al., 2017), soil health (Dang & Hung, 2021; Shah et al., 2021) and the factors that influence the crop choices (TEFERRA, 2019), however, the preceding decision that questions as to why a farmer may engage in a crop rotation practice in the first place has been overlooked. The influence of different factors, including environmental, farmer characteristics, and in particular farmers' perceptions of crop losses on the decision to keep their previous crop or change, needs to be considered as this has a bearing on their willingness to introduce a new crop on their farm.

The primary goal of this study is to determine whether farmers' perception of maize crop loss influences their decision to rotate crops or not. Specifically, the study purposes to establish farmers' perception of maize crop loss at the farm and post-harvest stages of the maize crop and examine the influence on farmers' decision to rotate crops.

Methodology

The study utilizes data that was collected from a survey of 800 crop farmers from Kamuli (400) and Nakaseke (400) in central Uganda. Of the total sample, 610 respondents were maize farmers that hailed from 16 sub-counties (11 in Kamuli and 5 in Nakaseke). Results of the question: ***Have you been growing the same crop(s) over the years?*** give an indication whether the farmer practices crop rotation or not. Perception of crop loss is captured categorically at both farm level and post-harvest at a scale of 1-5. Frequencies

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and percentages were used to analyse reported reasons for rotating crops and estimate the influence crop loss perception on farmers' decision to practice crop rotation using the binary logit model.

Results

Out of 610 maize farmers, 22.46% have not grown the same crops over the years, while 77.54% have indeed grown the same crops over the years, regardless of whether it was the same or different fields.

Results show that the major reason farmers in Nakaseke and Kamuli grow the same crop(s) every year is availability of market for their produce. Poor yield of other crops was cited as one of the reasons farmers do not change crop(s) every season. About 35 percent of farmers reported that the fact that the resources they had such as seeds and equipment, favoured them to grow just the same crops. Only 21.8 percent of maize farmers practiced grew the same crops primarily to keep traditions.

Table 52. Farmers' reported reasons for growing the same crop(s) every year

Reason	Frequency(n=473)	Percentage of farmers
Because there is a demand for my product	304	64.3
Because other crops I grew did not yield the results I expected	213	45.0
Because I have the resources to do so (seed, soil quality, water, equipment, …)	165	34.9
Because I want to avoid any risk or trouble in my activity due to a change	148	31.3
Because it's a perennial crop	138	29.2
That's the tradition of our community	127	26.8
Because I don't know about any alternative	111	23.5
Because it's what the other farmers produce	110	23.3
That's what my parents / our ancestors did	103	21.8

Logistic regression results show that farmers' perception of crop loss at farm level significantly influences their decision to maintain the same or grow different crops every season. Farmers that perceive that maize crop loss at farm level to not be important were less likely to grow the same crop every year. Perception of high crop losses are associated with growing of the same crops every year. The results suggest that farmers in Kamuli are more likely to practice crop rotation than those from Nakaseke. This can be confirmed with the cross-tabulation results that showed that farmers that perceived not important maize crop losses were more in Kamuli than Nakaseke. Farmers perception of post-harvest losses did not significantly influence farmers decision. Farmers that have membership in farmer groups/ associations are less likely to grow the same crops every year. Farmer associations are sources of knowledge and information therefore, farmers can learn from each other on how to overcome farm production constraints through various ways such as change of crop. Results show that age of a farmers was significantly and positively associated with growing the same crop. Older farmers are more likely to

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grow the same crop every season compared to their younger counterparts. Farmers that irrigate their crops are likely to grow same crops every season compared to those that do not.

Table 53. Estimates of the logit model showing influence of perception of crop losses on farmers' decision to practice crop rotation

Grow same crop(1=yes)	Marginal effects	Std. Err.
Farm Loss maize not important (1=yes)	-0.132***	0.046
Post-harvest loss maize not important(1=yes)	0.038	0.038
Foodhub (1=Nakaseke)	0.064*	0.037
Association membership (1=yes)	-0.069*	0.038
Age	0.019***	0.007
Age squared	-0.000***	0.000
Gender	-0.045	0.037
Affected by extension(1=yes)	-0.055	0.035
Maize Monocrop(1=yes)	0.031	0.121
Total Product value(log)	-0.019	0.019
Irrigate(1=yes)	0.093**	0.041
Total farm size(log)	0.003	0.026
loan(1=yes)	0.043	0.039
Household size(log)	-0.032	0.034
Constant	0.099	2.106
Number of observations = 610		
LR chi2(14) = 32.52		
Prob > chi2 = 0.0034		
Pseudo R2 = 0.0500		
Log likelihood = -308.66237		

***p<0.01 **p<0.05 *p<0.1

Conclusion

Our analysis reveals that farmers' perception of maize crop losses at farm level contributes significantly to their decision to practice crop rotation. Although not significant, farmers' perception of post-harvest losses was positively associated with growing the same crops every year. That means that farmers in Kamuli and Nakaseke do not respond to incidences of post-harvest losses by rotating crops or they do not think that the practice can reduce their losses. The results also show that the decision to change crops every season is location-specific implying that promotion of technologies that require change of crop should take into consideration the environmental and socioeconomic characteristics of the area.

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Recommendations for Foodland project

This study illustrates that the majority of the maize farmers in Nakaseke and Kamuli will grow same crops every year if the demand of the crop they are growing is high. Therefore, the FoodLAND project must consider market availability of novel crops that the project intends to promote. Also, at farm level, farmers can be supported with seeds and equipment in addition to prioritization of technologies that reduce crop loss and increase yields that way farmers are likely to adopt and keep such crops.

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Chapter 6: Are farmers willing to adopt nutrient-dense crops? Gendered evidence from Kenya

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Introduction to research paper

Rationale of Research question

Propensity or intention to adopt nutrient-dense products has been of increasing interest to economists in the understanding of adoption of new technologies. It is often suggested that a farmer's willingness to adopt a technological innovation geared towards improving nutrients in the products produced may influence propensity or intention to adopt new technologies. However, empirical evidence for or against this view has been relatively scarce and weak. The study attempted to address the missing link between farmers' socioeconomic factors and the drivers for adoption of new innovations. The study also answered questions on the gender dynamics influencing adopting a nutrient-dense and profitable product and the relationship between farmers' socioeconomic factors and propensity to adopt new crops/fish with high nutrient content in Kenya. A total of 1,390 crop and fish farmers in Kisumu, Mukurwe-ini and Kitui food hubs in Kenya were sampled. Ordinal regression model was employed to empirically analyze the data.

Objectives and Hypothesis of Research question

The objective of this chapter is to address the following 2 research questions:

- What are the gender dynamics of adopting a nutrient-dense and profitable product in Kenya?

- What is the relationship between farmers' socioeconomic factors and propensity to adopt new nutrient-dense food products in Kenya?

Methodology

Methodology applied for sampling, data collection and analysis

Data for this study was collected through a survey of farm households in central, western and eastern regions of Kenya. Farming households were sampled using a multistage sampling procedure. In the first stage, three counties – Nyeri, Kitui and Kisumu – were selected purposively because they are from different economic zones Nyeri and Kitui were selected because they are agro-ecologically suitable for agricultural diversification while Kisumu was selected because of its suitability for fish farming given its proximity to Lake Victoria. One sub-county - a food hub was selected from each county. In Nyeri County, Mukurweini sub-County was selected due to high involvement in agricultural activities by the residents. Kitui Central sub-County in Kitui County was selected due to its engagement agricultural farming despite being a semi-arid region while Kisumu sub-County from Kisumu County was selected due to its households' involvement in fish farming. The scoping of the boundaries for each food hub was done with assistance of

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a County Agricultural Officers from the Ministry of Agriculture. Then randomly selected four wards from each sub-county, using a sampling frame from the respective sub-county offices. Farming households were randomly selected, ending up with a sample size of 1,390. Finally, a probability proportionate to size sampling was used to distribute the sample across the three sites (Kisumu – 403, Kitui – 482 and Mukurweini – 505).

The three study areas are part of the ongoing Food and Local, Agricultural and Nutritional Diversity (FoodLAND) project. The intent of the project is to develop, implement and validate innovative, scalable and sustainable technologies aimed at supporting the nutrition performance of local food systems in Africa, while strengthening agro-biodiversity and food diversity, to promote healthy diets.

Background, Evaluation and Effectiveness of the Methodology

To gauge the propensity or intention to adopt nutrient-dense products, a Likert scale was used. It gauged the extent of a farmer's willingness to adopt a technological innovation geared towards improving nutrients level in the products produced. The farmers were expected to rank their choices on a scale of 1 to 5 with 1 indicating "not at all interested" and 5 showing "would volunteer to be one of the first in the village."

Socioeconomic characteristics. Some of the socioeconomic factors captured included age, gender, education level (measured as a categorical variable), membership in associations, access to credit (both formal and informal), household size, migration status of some household members and labor supply (both family and hired). Income is an important and challenging concept to measure in household surveys (Davern et al., 2005; Carletto et al., 2022). When presenting the income question, the respondents were allowed to choose from a range of income bandings. The list was kept short to avoid respondent fatigue and to make sure the numbers did not overlap, as this could lead to confusion.

Face to face interviews were conducted in the local languages using structured questionnaires. The data were collected with the help of enumerators using android tablets. To enhance validity and reliability of the data collection, pretesting of the questionnaire preceded. Questions on agriculture, other economic activities of the household, and the broader socioeconomic context were answered by the household head, either a male or a female.

Empirical framework. An ordinal logistic regression was used to determine the relationship between propensity or intention to adopt nutrient-dense products and explanatory variables. In the model the dependent variable (y) took one of j ordered outcomes (i.e. y ϵ [{1, 2, . . . ,j}) where j denoted the number of distinct categories. In our case j denoted values of 1-5 with 1 representing "Not interested in adopting" 2 Interested in adopting if more than half of the farmers adopt" 3 Interested in adopting if at least half of the farmers adopt" 4 Interested in adopting if at least some of the farmers adopt" and 5 "Would volunteer to be one of the first in the village".

The study applied two models, one for the study sites (food hubs) and another that took account of gender (men and women). For our case, propensity to adopt nutrient-dense products is related to a range of independent variables, such that:

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$$〖PND〗_{ij}=\alpha+\gamma_1 X_i^H+\gamma_2 H_i^F+\gamma_3 X_i^{SA}+\varepsilon_i \quad (1)$$

where 〖PND〗_i refers to the propensity to adopt nutrient-dense by household i, X_i^H is a vector of household related characteristics, H_i^F is a vector of farm-related characteristics, X_i^{SA} is a vector of support access characteristics such as credit and extension, the error term is represented by ε_i and γ represent the coefficients.

We employed the Maximum Likelihood method to estimate the model in a context that the observations were assumed to be independent. Considering that both logit and probit models produce similar results, thus using one or the other is a matter of habit or preference (Liao, 1994), we opted to use the Logit model as compared to Probit model it is easier to interpret.

Results

Farmers' preferences are very heterogeneous between Food Hubs, with a majority of farmers willing to pioneer the adoption of these new crops / fish species, while in Kisumu, a majority of farmers seems to prefer to wait until a majority of other farmers has already adopted the new crop. In Kitui, a majority of farmers would also be willing to volunteer to be the first to adopt the new crop.

A higher percentage of farmers in Kitui in comparison to Kisumu, would volunteer to be one of the first to adopt a newer crop with a higher nutritional content and, of these farmers, a higher percentage are women. More farmers in Kitui than Kisumu would adopt the newer crop with a higher nutritional content if at least some adopt it as well if at least half adopt it. A higher number of farmers in Kitui would adopt a newer crop with a higher nutritional content if more than half adopt (Figure 10).

In Mukurweini, in both male and female farmers camps, majority would volunteer to be one of the pioneers. Although among female farmers the least percentage would adopt if more than half have adopted (Figure 11).

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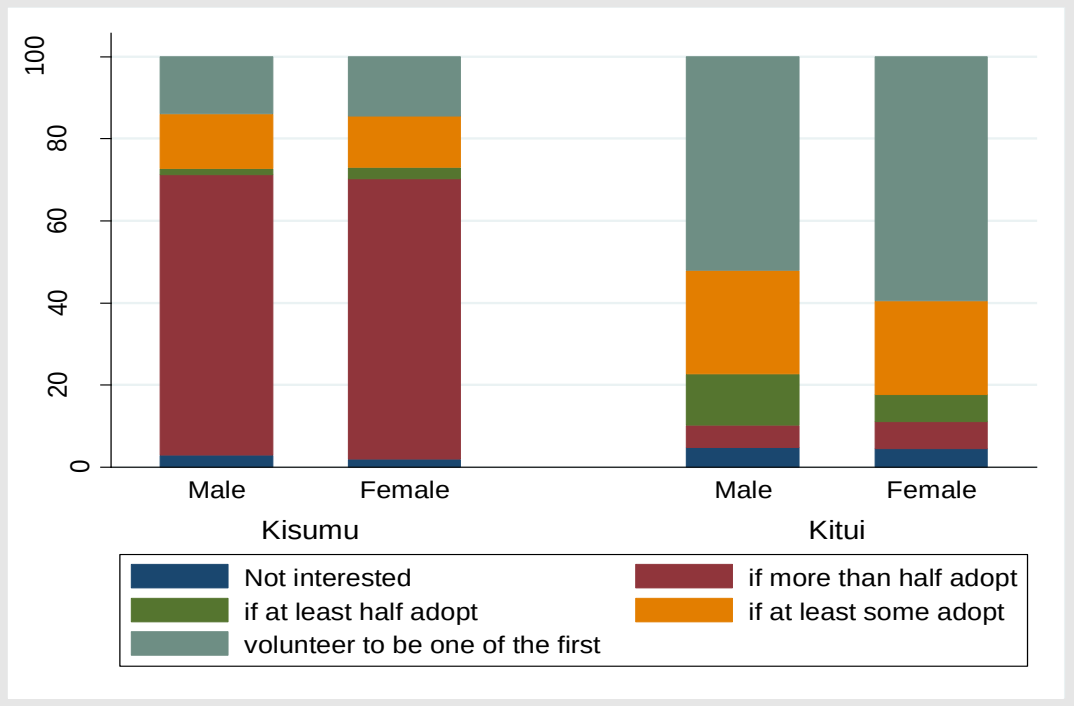

Figure 10. *Extent to which the farmer is interested in introducing a newer crop and fish with a higher nutritional content in Kitui and Kisumu respectively*

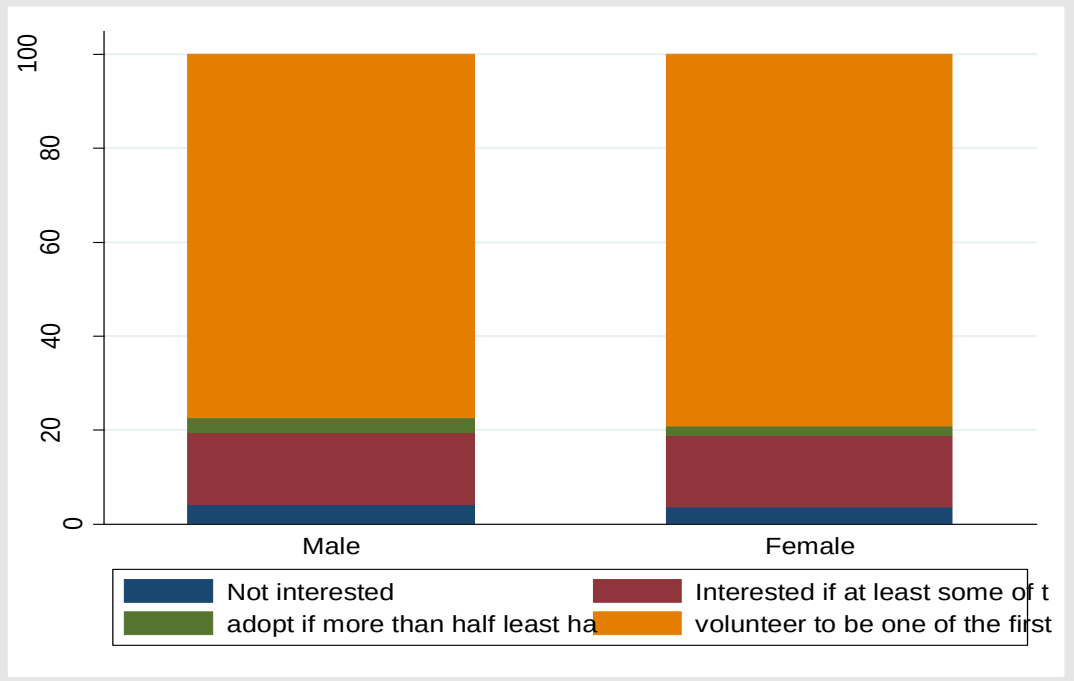

Figure 11. Extent to which the farmer is interested in introducing a newer crop with a higher nutritional content in Mukurweini, Kenya

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Among farmers in Kisumu, age and household size had a significant effect on the decision and extent to which a farmer would adopt a crop/fish of higher nutritional content. Gender and education had a significant effect on the farmer's willingness in Kitui and Mukurweini (Table 54).

On gender-based analysis, at pooled level, age, education and household size had a significant effect on the extent to which the farmer is interested in introducing a newer crop/fish with a higher nutritional content. Among the female farmers education had a significant effect on which the farmer is interested in introducing a newer crop/fish with a higher nutritional content. In both male and female categories age had a significant effect (Table 55).

Table 54. Distribution of drivers of the extent to which the farmer is interested in introducing a newer crop/fish with a higher nutritional content by food hub

Socio-demographic characterisitics		(1) Kisumu	(2) Kitui	(3) Mukurweini
Gender	Female	-0.33	0.85**	0.20
		(0.47)	(0.28)	(0.39)
Age		-0.02*	-0.016	0.0019
		(0.02)	(0.011)	(0.018)
Education (Reference: Illeterate)	No qualification	3.13	0.53	4.30***
		(2.43)	(0.72)	(1.35)
	Primary	2.91	0.17	4.40***
		(2.34)	(0.74)	(1.38)
	Secondary	3.0	0.37	4.39***
		(2.38)	(0.77)	(1.46)
	More than secondary	1.77	1.35	6.17***
		(2.49)	(0.89)	(1.78)
Loan (Reference: Yes)	No	2.16	-0.22	0.27
		(1.32)	(0.044)	(0.41)
Group membership (Reference: Yes)	No	0.51	-0.37	0.68
		(0.48)	(0.29)	0.72
Household size		-0.21**	-0-0016	-0.076
		(0.11)	(0.044)	(0.071)
Income (Kshs.) (Reference: 1001-10000)	10001 – 20000	-0.048	0.14	0.30
		(0.69)	(0.43)	(0.54)
	20001 – 40000	-1.04	0.78	0.10
		(0.78)	(0.59)	(0.44)
	40001 – 50000	0.92	-0.39	0.60
		(1.38)	(0.52)	(0.77)
	Above 50000	-1.47	-0.15	
		(1.17)	(0.44)	
Migration of household		-0.11	-0.03	0.17
		(0.21)	(0.08)	(0.13)

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Socio-demographic characterisitics	(1) Kisumu	(2) Kitui	(3) Mukurweini
members (Number)			
Number of observations	403	482	505

Notes: * Significant at 10% level. ** Significant at 5% level. ***Significant at 1% level. Standard errors are in parenthesis

Empirical findings based on gender

Table 55. Distribution of drivers of the extent to which the farmer is interested in introducing a newer crop/fish with a higher nutritional content by gender

Socio-demographic characteristics		(1) Pooled	(2) Female	(3) Male
Age		-0.018***	-0.024**	-0.016*
		(0.0071)	(0.011)	(0.01)
Education	No qualification	1.63***	2.19***	0.48
		(0.56)	(0.74)	(0.83)
	Primary	1.35**	2.06***	0.069
		(0.56)	(0.76)	(0.81)
	Secondary	1.29**	2.29***	-010
		(0.58)	(0.81)	(0.83)
	More than secondary	2.01***	2.97***	0.72
		(0.64)	(0.92)	(0.92)
Loan	No	-0.034	-032	0.38
		(0.24)	(0.35)	0.35
Group membership	No	-0.11	0.067	-0.32
		(0.20)	(0.28)	(0.32)
Household size		-0.064**	-0.053	-0.051
		(0.031)	(0.049)	(0.043)
Income (Kshs.)	10001 – 20000	0.23	0.026	0.43
		(0.26)	(0.40)	(0.37)
	20001 – 40000	0.043	-0.09	0.21
		(0.27)	(0.42)	(0.36)
	40001 – 50000	0.017	-0.25	0.46
		(0.38)	(0.58)	(0.52)
	Above 50000	-0.35	-039	-0.083
		(0.36)	(0.58)	(0.049)
Migration of household members (Number)		0.027	0.066	-0.038
		(0.057)	(0.082)	(0.089)
Food hub	Kitui	1.78***	1.90***	1.63***
		(0.26)	(0.42)	(0.35)
	Mukurweini	2.58***	2.58***	2.85***
		(0.28)	(0.44)	0.37
Number of observations		1390	601	

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Notes: * Significant at 10% level. ** Significant at 5% level. ***Significant at 1% level. Standard errors are in parenthesis

Conclusion

Conclusion of Research question

In conclusion; age, gender, household leadership, education level and household size are the drivers for adopting nutrient-dense and profitable products.

Policy recommendations

To alleviate the challenges of undernutrition, income generation and food insecurity, we recommend female-headed households-based investments through capacity building towards production and value addition practices for producing nutrient-dense agricultural products.

Recommendations for Foodland project

We recommend public and private investments in education to bring better benefits for households in terms of improvement in human nutrition

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Supplementary material

A. Approximate likelihood-ratio test of proportionality of odds

```
                                          LR chi2(8)      =      23.49
                                          Prob > chi2     =     0.0028
Log likelihood = -664.39821               Pseudo R2       =     0.0174

------------------------------------------------------------------------------
   nutricrop |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      gender |   .3490367   .1728445     2.02   0.043     .0102676    .6878057
         age |  -.0153173   .0065679    -2.33   0.020    -.0281901   -.0024445
        educ |  -.0073677   .0921308    -0.08   0.936    -.1879407    .1732052
        loan |  -.4380158   .2281454    -1.92   0.055    -.8851725    .0091409
     memassc |  -.4308762   .1908093    -2.26   0.024    -.8048556   -.0568968
 totalhhsize |  -.0635419    .030102    -2.11   0.035    -.1225408   -.0045431
  income_avg |   -.030336    .072043    -0.42   0.674    -.1715377    .1108656
    emig_num |   .0899151   .0551652     1.63   0.103    -.0182066    .1980368
-------------+----------------------------------------------------------------
       _cut1 |  -5.064114   .9050759          (Ancillary parameters)
       _cut2 |  -3.042758   .8790568
       _cut3 |  -2.696046   .8766885
       _cut4 |  -2.081204   .8741421
------------------------------------------------------------------------------

Approximate likelihood-ratio test of proportionality of odds
across response categories:
         chi2(24) =     35.62
       Prob > chi2 =    0.1
```

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Chapter 7: Farmers' willingness to early adopt new agricultural technologies in Tunisia: an empirical analysis and future research.

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Other authors: Tunisian Team

Introduction

Innovation is one of the largest contributors to economic growth over time. Adoption rate and speed to adopt agricultural innovation determine the ultimate impact on productivity growth, food security, conservation of natural resources and poverty alleviation. Innovations spread within temporal involves different states and types of adopters (innovators, early adopters, early majority, late majority, and laggards). Innovation adoption decision is a process which includes knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). In fact, farmers do not accept innovation immediately, they need time to think things over before making decision. In Tunisia, some studies were carried out to analyse the adoption decisions of agricultural innovation (Aziza 2009 ; Chiboub et al.,2016; Fouzai et al, 2018 ; Dhraief et al., 2019 ; Dhehibi et al., 2020). The majority of these studies showed that agricultural innovation is characterized by low adoption. However, to our knowledge, no studies tackled the speed of adoption of agricultural innovation in Tunisia. The main objective of this paper is to identify the factors influencing the farmers' willingness to early adopt agricultural innovation in Northern and Central Tunisia. At this regards, the following research questions are proposed:

- Are Tunisian farmers early, later or no adopters of new technologies?
- Which are the drivers of farmer's willingness to early adopt new technologies?

Conceptual framework of adoption of an agricultural innovation

The assumption of utility maximisation of is generally used to explain farmers' adoption decisions of new technology (Adesina et Zinnah, 1993; Alcon et al, 2011). Under this assumption, a farmer would adopt a given technology if the utility obtained from the new technology exceeds that of the old one. For example, farmers will adopt cover crops if their expected utility, subject to their preferences and constraints (e.g., time and climate), is maximized by doing so. Utility is a function of various factors including expected benefits and costs of adopting a practice versus not adopting. Several factors that condition farmers' adoption decisions have been discussed (Feder et al.,1985; Daberkow and Mcbride, 1998; Alcon et al., 2011; Kassie et al., 2015) and can be divided into five categories: (1) Farming systems, (2) farm resources, (3) Farmers' characteristics, (4) Institutional and communication factors and (5) Technology characteristics. These categories and explanatory variables are based on the literature related to adoption studies of agricultural technologies (Alcon et al. 2011).

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Methodology

Study area and data collection

The data used for the empirical analysis was obtained from a farm survey conducted in 2022 by the food land Team in collaboration with extension services. The survey covered one village in the North (Fernana) and another village in the Centre of Tunisia (Chebika). Data was obtained from a random sample of 631 farmers based on a questionnaire which includes questions about the context of farm, resources and technology, farm production, and farmers' characteristics. We have used the question « what extent would you consider introducing innovation in your farm » to define the types of adopters (dependent variable).

Empirical model, variables used and hypotheses

Since the dependent variable represents the speed of innovation adoption (early, late and no adoption) has an ordinal categorical nature, a multinomial ordered model will be used to identify the factors influencing farmers' willingness to early adopt new agricultural technologies.

The ordered logit model is based on the following specification. We suppose that unobservable variable exists, related with the explanatory variable and affects the result of observable variable Y_i as follows:

$$Z_i = x_i'\beta + \varepsilon_i$$

$$Y_i = j \ \ if \quad \mu_{j-1} < Z_i < \mu_j \qquad (1)$$

We define the multinomial ordered model in the following way:

$$P(Y_i = j) = F(\mu_j - x_i'\beta) - F(\mu_{j-1} - x_i'\beta) \qquad (2)$$

i=1 ,2,……n

j=0,1,…..m

The functional form of F most frequently used in application is logistic:

$$Logit \quad F(Z) = \frac{e^Z}{1+e^Z}$$

$$Z = x'\beta \qquad -\infty < Z < +\infty$$

Where the explanatory variables included in the model are farm location, farm size, age of farmer, education level of household head, risk attitudes and trust to farmers, access

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to extension services, land tenure, access to credit, market access, and off-farm income. The definitions of the variables and hypotheses are presented in Table 56.

Since we have only three groups in our example, the model (1) is simplified and presented as follows:

$$Y_i = 0 \quad if \quad Z_i \le \mu_0$$
$$Y_i = 1 \quad if \quad \mu_0 \le Z_i \le \mu_1$$
$$Y_i = 2 \quad if \quad Z_i \ge \mu_1$$

Where: U_i unobserved thresholds defining the group

$$Z_i = x_i' \beta + \varepsilon_i$$

$Z_i = B_0 + B_1 Location + B_2 Size + B_3 Tenure + B_4 Extension + B_5 Risk + B_6 Trust + B_7 Age + B_8 Gender + B_9 EL + B_{10} Credit + B_{11} Market + B_{12} Off\text{-}farm + \varepsilon i$

Table 56. Variables used in the ordered logit model and hypothesized sign

Variable	Description	Nature of quantification	Hypothesized sign
Dependent variable	Types of adopters	O not interested in adopting, 1 interested to be late adopters, 2 interested to be early adopters	
Independent variable			
Location	Chebika/Fernana	1 chebika/O fernan	+/-
Size	Farm Size	Number of ha	+
Tenure	Land tenure	1 Property, 0 otherwise	-
Extension	Assistance from extension services	1 yes/0 No	+
Risk	Risk attitudes	Likert scale 1-5	-
Trust	Trust in farmers	Likert scale 1-5	+
Age	Age of farmer	Number of years	-
EL	Education level	1 higher than primary level, O otherwise	+
Credit	Credit access	1 yes/O No	+
Market	Market access	Likert scale 1-5	-
Off-farm	Off-farm income	1 yes, 0 No	+

1. Likert scale for risk attitude: avoid risk 1 = Completely disagree, 2 = Somehow disagree, 3 = Neither agree nor disagree, 4 = Somehow agree, 5 = Completely agree.

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2.Likert scale for trust: innovations in agriculture can be trusted 1 = Completely disagree, 2 = Somehow disagree, 3 = Neither agree nor disagree, 4 = Somehow agree, 5 = Completely agree.

3. Market access, 1 = Not at a problem, 2 = Minor problem, 3 = Neutral, 4 = Moderate problem, 5 = Serious problem.

Preliminary results

The test of endogeneity rejected the hypotheses that risk and trust are endogenous variables in the model.

The coefficients of the two thresholds (u_0 and u_1) are statistically significant at 1% level.

Regression results of multinomial logit model reveal that early adoption is positively influenced by extension service, trust, and off-farm income. However, it is negatively affected by land tenure (property), risk, age (Table 57).

Table 57. Maximum likelihood estimates of the ordered logit model of farmers' willingness to early adopt agricultural innovation

```
Ordered logistic regression                     Number of obs     =        931
                                                LR chi2(12)       =     267.75
                                                Prob > chi2       =     0.0000
Log likelihood = -480.20978                     Pseudo R2         =     0.2180
```

adopt	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Location	-.0082743	.2731976	-0.03	0.976	-.5437318	.5271832
size	-.0124358	.0118391	-1.05	0.294	-.0356399	.0107683
Tenure	-.7868063	.3197968	-2.46	0.014	-1.413597	-.1600161
Extension	.165797	.0742337	2.23	0.026	.0203016	.3112923
risk	-.5785074	.0580933	-9.96	0.000	-.6923681	-.4646467
trust	.4887359	.0641421	7.62	0.000	.3630197	.6144521
age	-.0147957	.0075884	-1.95	0.051	-.0296686	.0000773
gender	.0008443	.2267138	0.00	0.997	-.4435065	.4451951
EL	-.2734559	.203393	-1.34	0.179	-.6720988	.1251869
Credit	.1673184	.2187819	0.76	0.444	-.2614862	.5961231
accemarket	-.0618584	.0534471	-1.16	0.247	-.1666128	.0428959
offarm	.5092586	.2245456	2.27	0.023	.0691573	.94936
/cut1	-3.305401	.7245227			-4.725439	-1.885362
/cut2	-1.818984	.7159425			-3.222205	-.4157625

Conclusion and policy implications

Our research shows that in the Tunisian Food Hubs, Improved varieties (resistance to salt and drought), Precision agriculture, Integrated pest management, Organic farming

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and Soil and water conservation technologies are innovations that are most likely to be adopted.

We find that young farmers, who trust agricultural extension and farmers' associations, who are risk taker, with off-farm income availability and farming rented land or share-cropping, are more likely to adopt these innovations.

To conclude, we identify the following key strategies which can support the spread of FoodLAND innovations:

- Understanding of farmers' needs and problems

- Need for farmers and extension officers to be trained

- Farmers should be provided with the requested financial support

- Strengthening the material and human resources of extension agents

- Strengthening advisory services and technology transfer activities

- Participatory approach implementation including all stakeholders (innovative platforms) during technology generation and transfer. Technology trials should be observable by farmers.

- Encouragement of farmers' associations
- Policy maker would have to provide incentives to adopt innovation

Future Research: Farmer's involvement in the cooperatives: Does it help to improve livelihood?

A cooperative society is an organization of a group of people with collective responsibilities and thoughts for the development of needy, especially under privileged. "A cooperative is an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise." The concept of cooperatives is based on the values of the development of agriculture, forestry, banking, credit, agro-processing, storage, marketing, dairy, fishing and housing and around 85 per cent of rural households belong to a form of cooperative (Virandra and al, 2015). Cooperatives have inherent advantages in tackling the problems of poverty alleviation, food security and employment generation. It is considered to have immense potential to deliver goods and services in areas where both the public and private sector have failed.

The existing literature on agricultural cooperatives has produced mixed conclusions. Some studies provide evidence of positive impacts attributed to cooperative membership on the welfare of smallholder farmers (e.g., Wollni and Zeller, 2007; Spielman et al., 2008; Ito et al., 2012; Abebaw and Haile, 2013; Chagwiza et al., 2016; Ma and Abdulai, 2016; Mojo et al., 2017). Yet, there is also evidence of cooperatives generating a mix of positive and adverse impacts for its members, depending on which indicators are considered (e.g., Bernard et al., 2008; Mujawamariya et al., 2013; Vandeplas et al., 2013; Addai et al., 2014; Ragasa and Golan, 2014; Hun et al., 2018). Studies across different

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regions of the world show varying degrees of successes and challenges of agricultural cooperatives. For instance, producer cooperatives in Africa have been characterized by inappropriate political interference, financial irregularities and poor management (De Janvry et al., 1993; Akwabi-Ameyaw, 1997; Holloway et al., 2000). Similarly, cooperatives in the Asia-Pacific region have been challenged by socioeconomic constraints and poor management (Karami and Rezaei-Moghaddam, 2005).

In China, cooperatives cover a large part of the agricultural sectors, and could therefore play a role in the improvement of farm sustainability. Through their close relationships with farmers, agricultural cooperatives may be key actors in supply chains to help farmers change their agricultural practices and to favour the adoption of more sustainable practices (Candemir and Duvaleix; 2021)

The objective of this research is to analyse the importance of coops in rural societies. Often time government and other agencies are advocating for the farmers to join into groups. The question then is whether there is any empirical evidence of such move in the improvement of farmer's livelihood.

The objective of the research is to understand whether membership of cooperatives have any impact on rural livelihoods with particular focus on incomes and food security.

We will test the relationship between membership in an association and farmers' income, access to food and satisfaction of their household needs.

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Chapter 8: Assessment of the diversity of small farms and their constraints for the adoption of technological innovations: Case of small irrigated agricultural area in Morocco

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Introduction to research paper

Morocco is essentially a rural country, with 40% of the population engaged in agriculture. The majority of farmers cultivate small and often fragmented areas, but are responsible for the bulk of agricultural production, indicating the importance of this small-scale farming sector in the country's agriculture.

A farming system is defined as the set of resources organised and managed according to the totality of production and consumption decisions made by a farm household, including crop choice, livestock structure and size. Smallholder farming systems are seen to share a number of characteristics that differentiate them from large, profit-oriented farms. These include limited access to land and inputs, average levels of crop productivity and yield (less intensive multi-objective system), low availability of financial resources and the important role of family labour in the agricultural production system.

Typology and statistical clustering methods are often used to address farm heterogeneity. This is done by assigning farms into homogeneous groups with common and specific profiles. Generally, these typologies aim at understanding farm behaviour in order to implement a more appropriate approach to agricultural development. This paper aims to assess the diversity of farming systems in an agricultural area in Morocco (Ait Ouallal), characterised by mixed agriculture (irrigated and dry), through the classification of 300 small farms. The data used are from surveys conducted in 2021 and allowed the construction of a typology based on multidimensional data analysis through principal component analysis and non-hierarchical classification. The variables used concern the size of the farm in terms of area used for different crop categories, levels of land use (intensification), household characteristics, subjective assessment of problems, risks and concerns by farmers.

Limited access to land, financial capital and inputs, high levels of economic and social vulnerability and low market integration can support the introduction and adoption of technological innovations provided that the specific modes of operation and their interactions with the social and biophysical context are well understood. This implies a great diversity of farming systems and their dynamics with a diversity of decision-making strategies in terms of production and consumption.

Basic information on the land capital used, household composition and level of education, modes of land use, production orientation, main crops, sources of income and farmers' perceived concerns and problems as well as their subjective or hypothetical evaluation of new technological innovations were collected.

This work aims at understanding the heterogeneity and diversity of smallholder farms in the irrigated area of Ait Ouallal Bittit and the constraints related to the adoption of different

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types of innovations proposed in the framework of the FoodLAND project. The work uses a subset of data collected in the Meknes area and aims to produce a typology of smallholder farms considering the above-mentioned objectives.

Methodology

Study area

Three social communities were studied and distributed in the rural commune of Ait Ouallal Bittit. The basic unit of social organisation in the area is the agricultural household. The head of the household is generally a man with an extended or nuclear family in which resources and work are organised around several agricultural activities. Livelihoods are often based on mixed farming where resources are divided between cash and subsistence crops with low input use.

Staple food crops include cereals (soft and hard wheat) (which can also be used as a cash crop), with onions, potatoes, olives, pulses and rarely Rosaceae being the main cash crops. Yields are generally medium to high due to the widespread use of localised irrigation. Food crops are grown on non-irrigated plots and yields are low to mediocre due to low and irregular rainfall. Farmers tend to lose interest in food crops when irrigation opportunities are available, given the economic interest of these crops in terms of economic profitability. In this sense, the pressure on the already very limited water resources is very high, especially in times of drought.

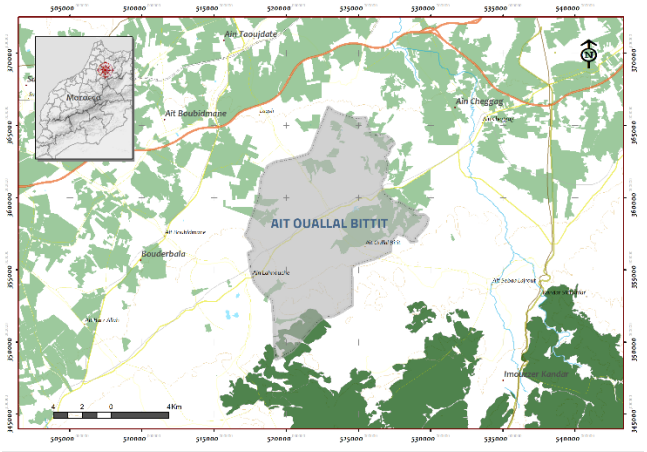

Figure 12: Map of the Northern of Morocco (inset) showing the location of Ait Ouallal Bittit zone

Typology

Two multivariate statistical techniques were used sequentially to generate a typology of the surveyed farm households: PCA to reduce the dataset into uncorrelated principal components and CA to partition the PCA results into clusters. This approach has been used in many studies to categorise farming systems. All analyses were run in R version 4.2.2 with the FactoMineR version 2.6 and Cluster version 1.15.2 packages (available at: https://cran.r-project.org/web/packages/index.html).

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Cluster Analysis

The result of the PCA, in the form of an orthogonal subset of the data called principal components, was submitted to the CA. This is an approach to a hierarchical clustering algorithm using Ward's method to define the number of clusters. It is based on a random seeding of clusters based on individuals (observations) as first clusters that will be successively joined by other individuals of the same profile until there are no more possibilities to further refine the clusters without decreasing the inter-cluster heterogeneity. A compromise is therefore always sought between the number of clusters and the level of dissimilarity between clusters, with the aim of maximising both intra-cluster homogeneity and inter-cluster heterogeneity.

The number of clusters retained by Ward's method was used as a starting value by the non-hierarchical algorithm, which was performed to improve the robustness of the classification by opting for a distribution of farms among the clusters in such a way as to minimise the sum of the distances of each observation from its cluster centre.

The characterisation of farm groups at the level of each cluster was examined in terms of consistency (average value of each variable in the cluster). Finally, each farm type was reviewed and validated in relation to the knowledge of the reality of local farming systems. The patterns of farm functioning and the relationships between the different clusters were analysed considering their specific characteristics and the possibilities of adaptation of the targeted innovations were examined.

Prior to the actual analysis, the dataset on the 12 variables under study was carefully examined by assessing missing data and potential outliers in order to avoid anomalies in the statistical analysis. Boxplots were used to detect outliers to be ignored in order to improve the multivariate analysis while limiting its generalisation to the whole population. In this sense, farmers with land areas of 8ha or more or with land areas of more than 3.5ha under other tenure arrangements were excluded from the analysis as they could not be considered as small farmers and were statistically judged as outliers, a total of 54 farmers.

Of the 300 farm households sampled by the survey, 246 were retained for statistical analysis (i.e. 54 farm households were identified as containing extreme data in relation to area farmed). The number of principal components (PCs) to be retained in the analysis was made on the basis of three criteria: (i) according to the Kaiser criterion, all PCs exceeding an eigenvalue of 1.00 were initially retained. This decision was checked by examining (ii) the minimum cumulative percentage of variance retained. The last criterion (iii), related to interpretability, was used to assess the actual significance of the PCs.

The additional variables concern the evaluation of the interest of 6 types of technological innovations by farmers through the subjective appreciation of their potential interest on a scale of 1 to 5 (not at all interested to extremely interested) or on a binary scale in yes/no (acceptance/refusal).

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Table 58: ***: Description of the variables used to construct the farm typology***

Variable	Unit	Mean	STD	Min.	Max
LANDS					
Owned Area	Ha	1,73	1,82	0	7
Other Area	Ha	0,44	0,74	0	3
Intensification L.	%	92,78	16,93	14,29	120
Irrigated Area	Ha	0,98	0,94	0	6,5
LANDUSE					
% arboriculture	%	3	15,29	0	100
% cereals	%	42	35,05	0	100
% Vegetables	%	46,43	35,06	0	100
% Olives	%	7,96	23,54	0	100
HOUSEHOLD					
Age of the farmer	Y	48,74	12,96	20	90
Consumption units	FCU	5,49	3,54	1	20,50
SUPPLEMENTARY VARIABLES					
Variable		**Mean**	**STD**	**Min.**	**Max**
Agri. Problems valuation		2,84	0,93	1	4,77
Risk & Worries valuation		2,50	0,74	1,25	4,65
Irrigation innovation interest (0-5)		4,11	1,21	1	5
Technological innovation interest (0-5)		4,32	1,00	1	5
Reducing Losses Tech. interest (0-1)		0,07	0,26	0	1
Selling production jointly interest (0-5)		4,10	1,23	1	5
High nutritional new crops interest (0-5)		3,83	1,15	1	5
Higher selling price crops interest (0-5)		4,16	1,10	1	5

Results

Characterisation of farm groups

The PCA allowed the extraction of the first five components explaining about 77% of the variability of the data (**Errore. L'origine riferimento non è stata trovata.**). The first principal component (PC1) seems to be explained by variables related to the importance of irrigation in the farm and contrasts farms with irrigated crops (vegetables) (%MARA) with rainfed crops (%CERE and % OLIV) and is less related to household characteristics (age and FCU).

The second component (PC2) is strongly correlated with land use status; it contrasts owned land (MELK) with other forms of tenure (AUTT). The correlation analysis on the diagram of variables shows that the degree of intensification (NIVINT) is also a factor related to the form of land tenure and it seems that land use intensification tends to be higher on land not owned by farmers (AUTT). Indeed, farmers tend to occupy more land with crops in the case of a lease or association than when the land is owned by the farmer, in order to make a return on the investment made. The correlation between the other land variables (AUTT) and the level of intensification (NIVINT) (Figure 15) confirms this situation.

The third component (CP3) contrasts perennial crops (%OLIV, %ARBO) with cereal crops (%CERE). Market gardening seems to be uncorrelated with this component because it can be grown throughout the year in relation to the cycles of the different market gardening crops grown (Figure 16).

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The fourth component (CP4) seems to be linked mainly to the age of the farmer. It indicates that households with older heads of farms are generally composed of higher family consumption units and are more interested in olive growing than younger farmers. These older farmers are less intensive in terms of land use and are more interested in innovations related to loss reduction than other innovations aimed at increasing profits or improving production technologies.

Finally, the fifth component (PC 5) represents the axis of the importance of irrigated arboriculture in relation to the olive tree and seems to give an idea of the independence of arboriculture as a perennial crop requiring high investment from other annual crops and even from the olive tree whose investment and production strategies are different. In general, arboriculture requires a higher working capital and therefore implies a higher degree of risk-taking.

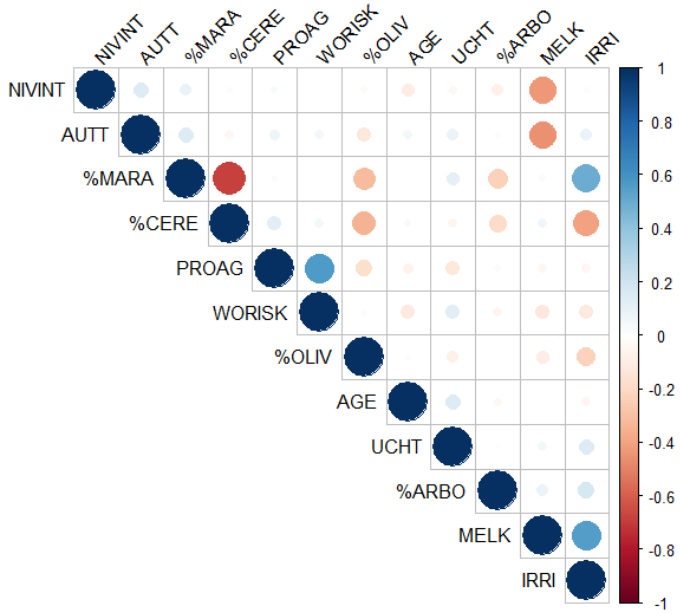

Figure 13: Partial correlation diagram between the different variables

PC	Eigenvalue	Variance (%)	Cumulative Variance (%)
1	2,192	21,92	21,92
2	1,847	18,47	40,40
3	1,399	13,99	54,39
4	1,155	11,55	65,95
5	1,095	10,95	76,90
6	0,839	8,39	85,29

Table 59: Eigenvalues and percentage variance explained by six principal components (PC's)

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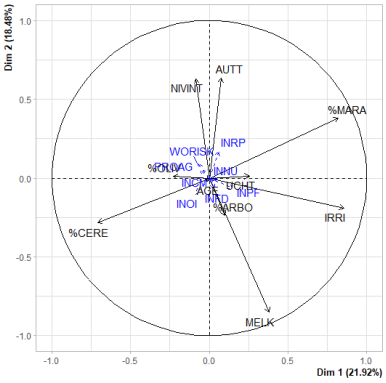

Figure 14

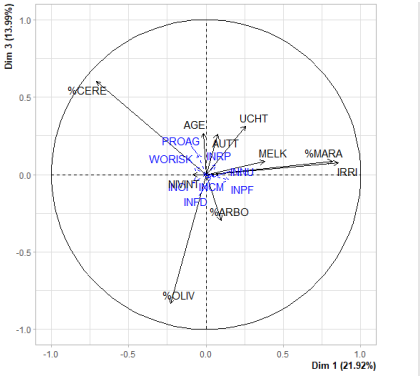

Figure 15

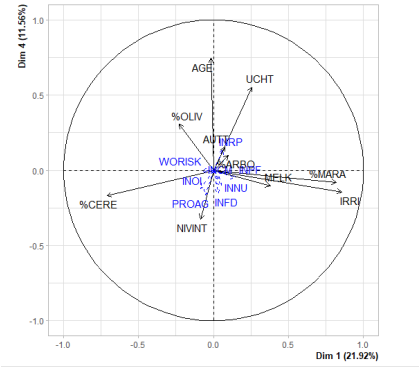

Figure 16

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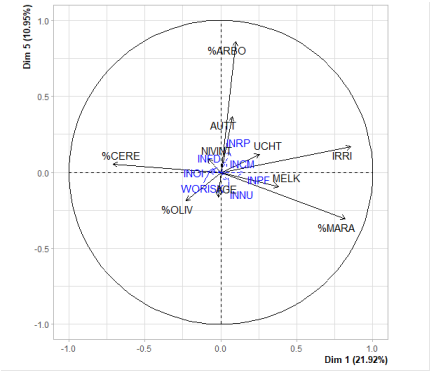

Figure 17

The results of the hierarchical clustering algorithm suggested a five-cluster grouping (Fig. 3) and assigned farms to the identified clusters. Thus, it appeared that households in the study area could be grouped into five main farm types, characterised by their structural (resource endowment) and functional (production objectives/livelihood strategies) characteristics (Figure 18)

Type 1. Type 1, with a medium level of resources, with areas mainly cultivated with dry cereals, a cultivation system based on cereals and rarely on olives (25% of the farms in the sample), has been dissociated from the others because of the strong discriminating power of the variables linked to the importance of cereals in relation to the size of the farm. Considering the low income from agricultural activity, the household is essentially engaged in non-agricultural activities. This group of farmers is more interested in innovations related to irrigation technologies because they can better valorise the available areas currently occupied by cereals. Thus, Type 1 comprises mainly medium-sized households (around 4-5 people) providing the majority of farm labor. The cultivated area tends to be devoted to cereal production (69%).

Type 2. Poorly resourced, with smaller farm areas, a cereal and market gardening based cropping system, market oriented (19% of the sample farms), type 2 is characterized by small farm areas owned (1.7 ha on average), with just over half of the area cultivated in cereals and the other third in market gardening. Type 2 relies, to a greater extent than type 1, on renting and combining land to increase the area under cultivation and a large part of the production is sold on the market. This group of farmers has more financial means to invest in irrigated agriculture to improve income. Some of the labor used is solicited on the market. The household size is relatively medium and provides part of the agricultural labor force (low proportion of hired labor).

Type 3. These are farmers who do not own large areas of land (1.1ha on average) but are more willing to rent or partner with other farmers to cultivate land under irrigation, especially for market gardening. The levels of intensification are higher and the resources mobilized for agricultural activity are significant. Due to its characteristics, farmers in this group are earlier oriented towards crops with high economic potential (market gardening) and engage in higher labor-intensive investments on the farm (28% of the sampled farms). For type 3, the main distinguishing characteristics are the composition,

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the level of intensification and the importance of land cultivated in renting or in association. With an average of 1.9 ha, this group cultivates the second largest area, of which one third is devoted to market gardening.

Because of the importance of production for the market, types 2 and 3 are more interested in innovations that concern improved production technologies, loss reduction and high economic or nutritional potential (improved profits/ better nutritional value) than all the other groups. The assessment of innovations through their introduction as additional variables highlights the interest of each innovation by farmer group (clusters).

Type 4. Group 4 has the smallest agricultural area (about 0.8 ha), mainly dominated by olive trees and the lowest proportion of market gardening compared to the other groups (only 8%). This group is mainly made up of farmers with a high share of off-farm income. These farmers were earlier limited by agricultural financing and engaged in olive cultivation on dry land due to the lack of means to develop the land through irrigation. Generally, this group consists of older farmers (54 years old on average) with a large family size (7.2 FCU). (Figure 18)

Type 5. With medium to large areas (1.9 ha), a large labor force and farm income mainly from the sale of produce from market gardening (36% of the sample farms), type 4 is the largest group. It differs from the other types of farms mainly by the ratio of market gardening to total area (70%), which makes it possible to make better use of the available family labor, but the share of salaried labor is also important because of the area cultivated under irrigation. The cultivated area, dominated by market gardening, provides most of the household's income through the sale of agricultural products (nearly 75% of agricultural products are marketed).

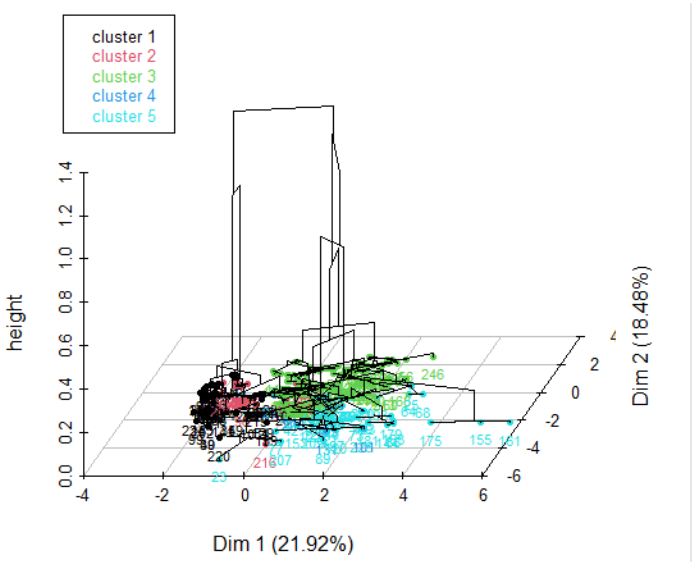

Figure 18: Hierarchical clustering on the factor map

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Conclusion

The typology of farms at the area level revealed the heterogeneity of agricultural production systems, the complexity of farm household dynamics and objectives in relation to their specific constraints and production potential.

The results obtained show a differentiated behaviour towards the different types of agricultural innovation for the five groups of farms identified on the basis of the variables farm size in terms of area used and household size and other functional variables explaining the structural and functional differences between the farming systems.

Types 1 and 4 are characterised by relatively low levels of resource endowment and oriented towards non-agricultural activities respectively. Types 2, 3 and 5 are moderately resource endowed, with income mainly from agricultural activities. Type 4 is resource-poor, with production mainly oriented towards subsistence. The most striking differences between the types of farms concern the type of land use, dry or irrigated, the degree of integration of market gardening and the level of intensification (greatest for types 2 and 3). It seems that the financing capacity of agriculture in the region is a determining factor in the way farms operate. In the absence of land in their own possession, some farmers have been able to find the means to finance the rental or holding in association of irrigated land, which has led to a significant change in the traditional modes of operation of agriculture in the area. Land is no longer a limiting factor for farmers who have significant means of financing due to the emergence of a forward market in land rental.

The typology of farms reveals various operating models whose viability and modes of operation are marked by complex development trajectories stemming from a system that favours direct investment in agricultural production through the financing of agricultural activities for farmers with significant equity capital, especially in equipment and means of access to land. The analysis of business models across the zone has identified the most promising ways of targeting improvements in the conditions of farm households through the adaptation of technological innovations to the specific needs of small-scale farmers. The adoption of a more integrated and equitable approach to the distribution and sharing of resources among different users may be a more interesting way to reduce disparities in the means of financing agriculture with a view to implementing development actions that aim to sustainably improve agricultural production and the well-being of target communities. This should take into account the opportunities and constraints across the different modes of operation identified and adapt development and intervention strategies accordingly.

The results of this typological analysis will be used in the FoodLAND project for a more in-depth analysis of the relevance of technological and organisational innovations. For each type of farm, the innovations proposed by the project will be evaluated in terms of productive, socio-economic and environmental performance in participatory studies based on models and farmer experiments (RTC). One can already imagine the possibilities of synergies between the specific objectives of the project validated through a quantitative approach based on the typology of farms

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General conclusion: summary of key results

Using data from surveys and lab-in-the-field experiments from 12 Food Hubs in five African countries FoodLAND targets, this report illustrated the productive and behavioural profiles of smallholder farmers (and their segments), linking them to socioeconomic and demographic factors, and to smallholders' propensity to adopt different types of innovations that are being developed in the FoodLAND project. Both cross-country and country-specific recommendations were derived.

In line with the overarching goal of the deliverable, the cluster analysis presented in Chapter 1 provides information on the main socio-economic, productive and behavioural profiles of farmers in the 13 Food Hubs. These profiles do not seem to be consistently correlated with stated intentions to adopt innovations, though they provide insights on possible biases to be further investigated as well as a good description of smallholder farmers' characteristics in the Food Hub areas, of potential use for better tailoring of future project activities within the project. This characterisation of the farmers is complemented by Chapter 4.1, which shows that farmers with higher income levels in the Food Hubs tend to own more land and have higher levels of education, while poorer farmers rely more on the receipt of remittances from emigrated household members. Chapter 5 confirms this finding in the case of Tanzania and Kenya. Chapter 4.2 shows that worries about health hinders farmers' intention to adopt more profitable of more nutritious crops – thus suggesting that there could be vicious cycles of malnutrition –, while chapter 4.3 suggests that highly educated farmers are more interested in adopting yield enhancing and limitation overcoming technologies.

Chapter 6 helps understand the role of associations and cooperatives for smallholders' farming activities, and identifies specific associations and cooperatives in which farmers tend to have attitudes (trust, risk taking, and interest in innovations) that make them more willing to adopt innovations. Interestingly, it shows that innovations presented as a "New crop with a higher selling price" or a "Technological innovation to overcome limitations", are more likely to be accepted than a "New crop with a higher nutritional content" or the practice of "Selling production jointly" in exchange for a higher selling price. However, results from Chapter 7 shows that the returns on investments advertised in communications about innovations should be thought through carefully, as farmers are likely to be less willing to cooperate in the future if they receive lower than anticipated returns (according to the results of lab-in-the-field economic experiments).

In the second chapter, we find that farmers having experienced setbacks (in health, food shortages, or social), tend to be more patient, which signals propensity for longer term planning. This result provides support to the idea that the deployment of innovations addressing food shortage and (nutritional) health issues is likely to be well received in areas that have experienced setbacks in these domains, as a solution to avoid the occurrence of, and enhance the resilience of farmers to potential future adverse events. In addition, the chapter notes that technologies with a long-term impact are more likely to be adopted by female farmers and farmers with a higher risk-taking propensity. The later groups represent these potential earlier adopters with whom the project team may want to start the initial diffusion of innovations, ahead of broader dissemination.

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Gender differences in innovation adoption are further investigated in Chapter 3, which confirms that females declare in higher proportions that they are willing to adopt innovations, and that this is particularly true when it comes to the adoption of nutrition-dense crops. This result is also confirmed at the country level in Kenya (Part 2, chapter 6). In turn, that males are better equipped to adopt innovations (better educated and more access to resources) in the FoodLAND Food Hubs. While this shows that it is crucial to provide support to female farmers for the adoption of innovations, especially when the innovation can directly improve the well-being of the whole household (nutritious crops), it also shows that male farmers should be made more aware of the benefits of nutritional dense foods, for them to be able to also contribute to their households' wellbeing in terms of nutrition.

Chapters 4.2 and 4.3 show that emigration and the receipt of remittances by farmers' households is correlated with their willingness to adopt innovations, but with mixed results. Chapter 5 goes further in the analysis of migration and how it affects smallholders' livelihoods and food security in the 12 FoodLAND Food Hubs. It shows that migration seems to enhance food security in Morocco and Kenya, and that this happens not only because of remittances, but also because of reduced food needs of remaining members. Chapter 5 provides useful recommendations for the development and deployment of FoodLAND innovations. The negative effect of production losses (on field, post-harvest or fish) on food security, shows that storage innovations have the potential to increase food security in the Food Hubs. Increasing labour productivity, would help free household members from farm work and increase their ability to engage in off-farm employment, which was shown to lead to higher food security as well. Cash crops should be targeted by FoodLAND innovations given the consistent link between farm sales, cash income and food security across all Food Hubs. Supporting the adoption of innovations through the provision of formal funding, would complement the funding sources beyond the investment of remittances and informal loans.

Chapter 7 looks at the factors that favour farmers' collaboration to produce a public good, collaboration that would be required for the joint adoption of certain FoodLAND innovations, such as olive oil centrifugation, filtration and clarification systems; systems for precision irrigation/fertigation, protection and harvesting requiring a small group of local farmers to install sensors in their fields; osmotic dehydration and solar drying systems; and smart storage systems (e.g., zero energy cool chamber in Tanzania). Working with large groups of farmers could help spread risks. Having farmers with different levels of resources in the same group is unlikely to hinder collaboration, but poorer farmers should be provided with supports/compensations or they risk over-contributing, relatively to wealthier farmers. Finally, to avoid the weakening of collaboration around innovations, support from pre-existing local organisation beyond the remits of the FoodLAND project will be key.

We now turn to country-specific analysis, and the key conclusions and recommendations brought forward for Specific Food Hubs.

In Chapter 1, Part 2, we learn that in the Kilombero and Mvomero Food Hubs, Tanzania, everything else being equal, farmers with larger farms are more likely to adopt new technologies. Farmers with larger farms tend to be male, older, members of local associations. However, with similar resources, younger farmers, and farmers with access to credit tend to be more willing and/or able to adopt new technologies. Hence, policy

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mechanisms that ensure access to land and loans to younger farmers would favour the adoption of new technologies being developed in these Food Hubs.

Chapters 3, 4 and 5 focus on the Ugandan Food Hubs. Chapter 3 shows that membership of farmers' groups does not seem to be associated with welfare gains, measured by sales value and production value, but point towards a relationship between membership and access to loan. Trust is a significant factor in the decision to join such a group. The large production values and sales values associates with fish farming point towards the interest of integrated fish-crop systems – an innovation being developed in FoodLAND – to increase farmers' food and income security. In the Kamuli and Nakaseke Food Hubs, the positive effect on maize farmers' future ability to meet their household's food needs of crop diversity, of growing vegetables and fruits, and of access to storage, points towards the need to focus innovation development on vegetables and fruits associated with farmers' household food needs. Drought resistant varieties and labour-saving technologies would also enhance households' food security. However, Chapter 5 shows that currently most maize farmers do not rotate the crops they grow over the years, even when experiencing post-harvest losses. The decision to rotate crop, instead of keeping the same crops year after year, seems to be mostly positively influenced by the existence of a strong demand for these crops, suggesting that marketability of the new crops being developed within FoodLAND will be crucial for their adoption by farmers.

Results from the analysis of Tunisian farmers' willingness to adopt new technology (Chapter 7) aligns with previous finding: younger farmers, risk takers, farmers with off-farm income, and farmers renting farmland are more willing to adopt innovations at an early phase. The study also highlights the role of extension services, and in particular the level of trust farmers have towards these, in promoting adoption of innovations.

The typology of small-holder farmers in Ait Ouallal Bittit, Morocco (Chapter 8) will support the adaptation of interventions and technological and organisational innovations to suit the needs small holder farmers which have a variety of operating models in the area and face a range of opportunities and constraints (access to land and irrigation in particular).

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Appendices

Table 60. Farmers' clusters in the Beni- Mellal Food Hub (Morocco).

Typology	Variable	Risk- Averse farmers engaged in crop rotation, poorer but more food secure		Risk-taking farmers with limited crop variation, less poor but more food insecure		Overall		*p*-values
		232 farmers (58%)		163 farmers (42%)		400 farmers		
		Average	Median	Average	Median	Average	Median	
Household (respondent)	age	50.5	50	48.32	49	49.62	50	0.210
	gender	0.99	1	0.96	1	0.98	1	0.100
	educ	2.72	3	2.88	3	2.78	3	0.216
Household (size)	adult14plus	4.04	4	3.77	4	3.92	4	0.300
	child0to2	0.12	0	0.09	0	0.11	0	0.436
	child3to13	0.72	0	0.60	0	0.67	0	0.315
Household (migration)	emig	0.44	0	0.38	0	0.41	0	0.300
	emig_remitt	0.17	0	0.18	0	0.17	0	0.894
Household (wellbeing)	foodneed	2.56	2	2.89	3	2.69	2.5	0.002
	income_avg	1.68	1	2.06	2	1.83	1	0.000
	income_cost	1.58	1	1.75	1	1.64	1	0.096
	income_food	3.66	4	3.69	4	3.68	4	0.675
Farm (production)	log_product_value_total	13676.94	7513.77	17315.29	6995.58	14988.61	7060.35	0.984
Farm (sales)	log_sales_value_total	9844.76	4663.72	13981.7	4197.34	11407.51	4197.34	0.814
	share_sold	0.60	0.69	0.60	0.71	0.59	0.68	0.920
Farm (prices)	log_single_price	1.64	1.48	1.65	1.49	1.64	1.49	0.655
Farm (land/pond)	log_land_totsz	6.95	4	7.23	4	6.52	4	0.936
	used_land	0.34	0	0.35	0	0.35	0	0.830
	own_land_pond	0.91	1	0.94	1	0.92	1	0.442
Farm (labour)	farm_labour_employ	2.94	2	2.18	1	2.62	2	0.000
	farm_labour_hh	0.63	0	0.58	0	0.62	0	0.456
Farm (practices)	irrigate	0.82	1	0.75	1	0.79	1	0.131

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Typology	Variable	Risk- Averse farmers engaged in crop rotation, poorer but more food secure		Risk-taking farmers with limited crop variation, less poor but more food insecure		Overall		*p*-values
		232 farmers (58%)		163 farmers (42%)		400 farmers		
		Average	Median	Average	Median	Average	Median	
	same_crop	0.36	0	0.98	1	0.49	1	0.000
	same_field	0.04	0	0.89	1	0.40	0	0.000
Farm (cooperation)	assistcoop	2.49	2	1.87	1	2.23	1.5	0.000
	cmnres	0.30	0	0.21	0	0.27	0	0.064
	memassc	0.37	0	0.33	0	0.35	0	0.521
Farm (financing)	credit	0.22	0	0.28	0	0.25	0	0.195
	loan	0.10	0	0.1	0	0.10	0	1.000
Behaviour (stated)	explain_new	4.25	5	4.47	5	4.35	5	0.209
	explain_risk	3.14	4	2.14	1	2.72	3	0.000
	explain_trust	3.93	5	4.09	5	4.00	5	0.508
	other_advt	2.17	2	2.07	2	2.13	2	0.045
	other_help	2.20	2	2.22	2	2.21	2	0.584
	other_trust	1.86	2	1.87	2	1.87	2	0.973
Innovation adoption	joincrop	3.46	4	3.39	4	3.44	4	0.634
	nutricrop	3.83	4	3.64	4	3.75	4	0.077
	profcrop	4.12	4	4.19	4	4.15	4	0.468
	tech_adopt_imit	4.34	5	4.35	5	4.36	5	0.604
	tech_adopt_interest	4.38	5	4.08	4	4.26	4	0.001
	tech_avsb	0.12	0	0.18	0	0.14	0	0.107

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Table 61. Farmers' clusters in the Meknes Food Hub (Morocco).

Typology	Variable	Farmers with smaller farms and farm production, less likely to be association members and to share resources		Farmers with big farms and farm production, more likely to put resources in common, risk-taking and trustful		Farmers with mid- Sized farms, relying on employed labour, more likely to be association members and risk-Averse		Overall		p-values
		211 farmers (42.2%)		37 farmers (7.4%)		245 farmers (49%)		500 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	48.09	47.00	48.16	43.00	48.47	48.00	48.22	47.00	0.976
	gender	0.84	1.00	0.73	1.00	0.90	1.00	0.86	1.00	0.010
	educ	2.47	3.00	2.11	1.00	2.72	3.00	2.57	3.00	0.013
Household (size)	adult14plus	4.11	4.00	5.84	5.00	3.93	3.00	4.14	4.00	0.000
	child0to2	0.18	0.00	0.30	0.00	0.20	0.00	0.20	0.00	0.279
	child3to13	1.00	1.00	1.27	1.00	0.94	1.00	0.99	1.00	0.417
Household (migration)	emig	0.21	0.00	0.27	0.00	0.31	0.00	0.27	0.00	0.049
	emig_remitt	0.06	0.00	0.19	0.00	0.09	0.00	0.08	0.00	0.027
Household (wellbeing)	foodneed	3.04	3.00	3.43	4.00	2.90	3.00	3.00	3.00	0.003
	income_avg	2.09	2.00	2.78	3.00	2.18	2.00	2.17	2.00	0.000
	income_cost	2.63	3.00	1.89	2.00	2.34	2.00	2.43	2.00	0.004
	income_food	3.15	3.00	2.00	2.00	3.03	3.00	3.01	3.00	0.000
Farm (production)	log_product_value_total	34760.82	20209.44	49150.91	40159.77	40851.52	20209.44	38323.48	20416.71	0.006
Farm (sales)	log_sales_value_total	31326.90	16789.38	47677.57	36895.18	36432.65	15027.53	34600.09	16073.63	0.000
	share_sold	0.75	0.94	0.96	1.00	0.80	0.94	0.78	0.94	0.001
Farm (prices)	log_single_price	1.08	1.04	1.00	0.99	1.31	1.10	1.19	1.04	0.000
Farm (land/pond)	log_land_totsz	4.36	2.50	7.51	7.50	7.56	6.00	6.15	4.75	0.000
	used_land	0.30	0.00	0.43	0.00	0.52	1.00	0.42	0.00	0.000
	own_land_pond	0.75	1.00	0.11	0.00	0.87	1.00	0.76	1.00	0.000
Farm (labour)	farm_labour_employ	5.87	2.00	4.62	2.00	7.13	2.00	6.36	2.00	0.719
	farm_labour_hh	1.29	1.00	2.51	2.00	1.02	1.00	1.25	1.00	0.000
Farm (practices)	irrigate	0.64	1.00	0.65	1.00	0.61	1.00	0.62	1.00	0.814
	same_crop	0.98	1.00	1.00	1.00	0.62	1.00	0.80	1.00	0.000
	same_field	0.85	1.00	1.00	1.00	0.16	0.00	0.52	1.00	0.000

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Typology	Variable	Farmers with smaller farms and farm production, less likely to be association members and to share resources		Farmers with big farms and farm production, more likely to put resources in common, risk-taking and trustful		Farmers with mid- Sized farms, relying on employed labour, more likely to be association members and risk-Averse		Overall		p-values
		211 farmers (42.2%)		37 farmers (7.4%)		245 farmers (49%)		500 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Farm (cooperation)	assistcoop	1.63	1.00	1.24	1.00	1.84	1.00	1.71	1.00	0.001
	cmnres	0.15	0.00	0.89	1.00	0.31	0.00	0.28	0.00	0.000
	memassc	0.09	0.00	0.11	0.00	0.37	0.00	0.23	0.00	0.000
Farm (financing)	credit	0.35	0.00	0.08	0.00	0.32	0.00	0.31	0.00	0.003
	loan	0.13	0.00	0.03	0.00	0.19	0.00	0.15	0.00	0.015
Behaviour (stated)	explain_new	4.51	5.00	4.97	5.00	4.50	5.00	4.54	5.00	0.002
	explain_risk	2.78	3.00	1.27	1.00	3.07	3.00	2.82	3.00	0.000
	explain_trust	4.00	4.00	4.08	4.00	3.31	4.00	3.67	4.00	0.000
	other_advt	2.00	2.00	1.08	1.00	1.91	2.00	1.88	2.00	0.000
	other_help	2.17	2.00	1.14	1.00	1.98	2.00	1.99	2.00	0.000
	other_trust	1.84	2.00	1.08	1.00	1.73	2.00	1.73	2.00	0.000
Behaviour (experiments)	impatience	4.49	5.00	4.70	4.00	4.62	4.00	4.56	4.00	0.877
	pgg_std_contr	57.94	50.00	62.30	50.00	59.44	50.00	59.13	50.00	0.789
	risk_aversion	4.90	5.00	5.16	5.00	5.07	5.00	5.01	5.00	0.681
Innovation adoption	joincrop	3.87	4.00	4.73	5.00	3.75	4.00	3.88	4.00	0.000
	nutricrop	3.74	4.00	4.70	5.00	3.58	4.00	3.73	4.00	0.000
	profcrop	4.16	4.00	5.00	5.00	3.93	4.00	4.10	4.00	0.000
	tech_adopt_imit	3.97	4.00	4.84	5.00	4.23	5.00	4.16	5.00	0.000
	tech_adopt_interest	4.30	5.00	4.95	5.00	4.10	4.00	4.24	5.00	0.000
	tech_avsb	0.06	0.00	0.89	1.00	0.07	0.00	0.13	0.00	0.000

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Table 62. Farmers' clusters in the Chbika Food Hub (Tunisia).

Typology	Variable	Higher-income, more food secure farmers with larger farms and production, but less trustful, less willing to try new things and more risk averse		Low-income, food insecure farmers with smaller farms and production, but more trustful, more willing to try new things and more risk-taking		Overall		p-values
		287 farmers (66.6%)		86 farmers (20%)		431 farmers		
		Average	Median	Average	Median	Average	Median	
Household (respondent)	age	48.39	48.00	48.34	46.50	48.86	48.00	0.927
	gender	0.93	1.00	0.81	1.00	0.89	1.00	0.004
	educ	3.40	3.00	3.28	3.00	3.36	3.00	0.375
Household (size)	adult14plus	3.89	3.00	5.49	5.00	4.36	4.00	0.000
	child0to2	0.16	0.00	0.17	0.00	0.16	0.00	0.683
	child3to13	0.91	0.00	1.20	1.00	0.98	0.00	0.040
Household (migration)	emig	0.13	0.00	0.04	0.00	0.11	0.00	0.016
	emig_remitt	0.05	0.00	0.00	0.00	0.04	0.00	0.027
Household (wellbeing)	foodneed	2.45	2.00	4.11	4.00	2.98	3.00	0.000
	income_avg	1.83	2.00	1.12	1.00	1.58	1.00	0.000
	income_cost	2.87	3.00	3.36	3.00	2.84	3.00	0.005
	income_food	2.78	2.00	2.63	3.00	2.91	3.00	0.429
Farm (production)	log_product_value_total	29535.00	11707.71	17884.19	7400.95	23235.69	7400.95	0.152
Farm (sales)	log_sales_value_total	27519.09	10572.78	17179.63	6343.67	21752.73	6343.67	0.780
	share_sold	0.82	0.95	0.93	1.00	0.73	0.94	0.001
Farm (prices)	log_single_price	1.00	1.06	1.08	1.06	1.02	1.06	0.033
Farm (land/pond)	log_land_totsz	7.38	4.00	5.83	4.00	6.74	4.00	0.051
	used_land	0.16	0.00	0.15	0.00	0.15	0.00	0.868
	own_land_pond	0.95	1.00	0.99	1.00	0.97	1.00	0.207
Farm (labour)	farm_labour_employ	3.85	2.00	3.93	2.00	3.50	2.00	0.216
	farm_labour_hh	1.47	1.00	3.07	2.00	1.80	1.00	0.000
Farm (practices)	irrigate	0.87	1.00	0.53	1.00	0.73	1.00	0.000
	same_crop	0.96	1.00	1.00	1.00	0.97	1.00	0.076
	same_field	0.58	1.00	0.92	1.00	0.70	1.00	0.000

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Typology	Variable	Higher-income, more food secure farmers with larger farms and production, but less trustful, less willing to try new things and more risk averse		Low-income, food insecure farmers with smaller farms and production, but more trustful, more willing to try new things and more risk-taking		Overall		p-values
		287 farmers (66.6%)		86 farmers (20%)		431 farmers		
		Average	Median	Average	Median	Average	Median	
Farm (cooperation)	assistcoop	1.57	1.00	1.23	1.00	1.46	1.00	0.005
	cmnres	0.15	0.00	0.33	0.00	0.20	0.00	0.001
	memassc	0.37	0.00	0.22	0.00	0.31	0.00	0.013
Farm (financing)	credit	0.34	0.00	0.37	0.00	0.35	0.00	0.608
	loan	0.12	0.00	0.13	0.00	0.11	0.00	0.851
Behaviour (stated)	explain_new	3.82	4.00	4.93	5.00	4.11	5.00	0.000
	explain_risk	2.49	2.00	1.08	1.00	2.12	1.00	0.000
	explain_trust	3.56	4.00	4.84	5.00	3.86	4.00	0.000
	other_advt	1.66	2.00	1.20	1.00	1.55	1.00	0.000
	other_help	1.78	2.00	1.20	1.00	1.63	2.00	0.000
	other_trust	1.71	2.00	1.19	1.00	1.58	1.00	0.000
Innovation adoption	joincrop	3.64	4.00	4.67	5.00	3.84	5.00	0.000
	nutricrop	3.42	3.00	3.76	4.00	3.43	4.00	0.137
	profcrop	3.81	5.00	4.80	5.00	4.01	5.00	0.000
	tech_adopt_imit	4.08	5.00	4.99	5.00	4.27	5.00	0.000
	tech_adopt_interest	3.84	5.00	4.97	5.00	4.13	5.00	0.000
	tech_avsb	0.32	0.00	0.03	0.00	0.26	0.00	0.000

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Table 63. Farmers' clusters in the Jendouba Food Hub (Tunisia).

Typology	Variable	Low-educated farmers with low incomes and more food insecure, engaged in crop rotation and often association members		Average- Age farmers with mid- Sized farms and moderate productive and behavioural characteristics		Older farmers with small farm sales, not engaged in cooperatives, less open to new things but more trustful and less impatient		Young farmers with larger farms and larger farm production and sales, employing more labour and more impatient		Overall		p-values
		60 farmers (12%)		167 farmers (33.4%)		48 farmers (9.6%)		217 farmers (43.4%)		500 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	45.07	45.50	46.69	46.00	51.92	50.00	43.46	43.00	45.51	46.00	0.000
	gender	0.17	0.00	0.38	0.00	0.38	0.00	0.79	1.00	0.53	1.00	0.000
	educ	1.80	1.00	2.59	3.00	1.90	1.00	3.25	3.00	2.71	3.00	0.000
Household (size)	adult14plus	3.93	3.00	4.00	4.00	3.98	4.00	3.99	4.00	3.99	4.00	0.853
	child0to2	0.13	0.00	0.09	0.00	0.04	0.00	0.18	0.00	0.13	0.00	0.248
	child3to13	0.78	0.00	0.85	0.00	0.54	0.00	1.00	0.00	0.88	0.00	0.065
Household (migration)	emig	0.13	0.00	0.59	1.00	0.35	0.00	0.33	0.00	0.39	0.00	0.000
	emig_remitt	0.03	0.00	0.22	0.00	0.00	0.00	0.09	0.00	0.12	0.00	0.000
Household (well-being)	foodneed	4.63	5.00	4.13	4.00	4.50	5.00	3.38	3.00	3.90	4.00	0.000
	income_avg	1.35	1.00	1.84	1.00	1.54	1.00	2.40	2.00	1.99	1.00	0.000
	income_cost	2.03	1.00	1.86	2.00	1.96	2.00	2.12	2.00	2.00	2.00	0.060
	income_food	4.68	5.00	2.98	3.00	3.15	3.00	3.27	3.00	3.33	3.00	0.000
Farm (production)	log_product_value_total	2681.46	1720.07	3038.69	1987.44	2656.70	1677.45	6875.42	4440.57	4575.67	2743.96	0.000
Farm (sales)	log_sales_value_total	1129.51	0.00	922.60	0.00	727.25	0.00	4659.83	2061.69	2535.87	634.37	0.000
	share_sold	0.20	0.00	0.18	0.00	0.12	0.00	0.52	0.55	0.32	0.28	0.000
Farm (prices)	log_single_price	0.68	0.69	0.76	0.79	0.62	0.64	0.81	0.80	0.76	0.79	0.000
Farm (land/pond)	log_land_totsz	2.17	2.00	2.17	2.00	2.78	2.00	4.50	4.00	3.42	3.00	0.000
	used_land	0.00	0.00	0.19	0.00	0.25	0.00	0.23	0.00	0.19	0.00	0.000
	own_land_pond	0.92	1.00	0.99	1.00	0.94	1.00	0.90	1.00	0.93	1.00	0.001
Farm (labour)	farm_labour_employ	0.32	0.00	0.37	0.00	0.25	0.00	1.72	0.00	0.93	0.00	0.000
	farm_labour_hh	2.07	2.00	1.90	2.00	1.90	2.00	2.20	2.00	2.05	2.00	0.053
Farm (practices)	irrigate	0.17	0.00	0.11	0.00	0.04	0.00	0.23	0.00	0.16	0.00	0.001
	same_crop	0.13	0.00	0.92	1.00	0.98	1.00	0.86	1.00	0.80	1.00	0.000

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Typology	Variable	Low-educated farmers with low incomes and more food insecure, engaged in crop rotation and often association members		Average- Age farmers with mid- Sized farms and moderate productive and behavioural characteristics		Older farmers with small farm sales, not engaged in cooperatives, less open to new things but more trustful and less impatient		Young farmers with larger farms and larger farm production and sales, employing more labour and more impatient		Overall		p-values
		60 farmers (12%)		167 farmers (33.4%)		48 farmers (9.6%)		217 farmers (43.4%)		500 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
	same_field	0.07	0.00	0.25	0.00	0.31	0.00	0.16	0.00	0.19	0.00	0.001
Farm (cooperation)	assistcoop	2.18	1.00	1.02	1.00	1.00	1.00	1.73	1.00	1.47	1.00	0.000
	cmnres	0.18	0.00	0.03	0.00	0.02	0.00	0.23	0.00	0.13	0.00	0.000
	memassc	0.62	1.00	0.04	0.00	0.00	0.00	0.32	0.00	0.23	0.00	0.000
Farm (financing)	credit	0.10	0.00	0.05	0.00	0.02	0.00	0.46	0.00	0.23	0.00	0.000
	loan	0.27	0.00	0.05	0.00	0.02	0.00	0.16	0.00	0.12	0.00	0.000
Behaviour (stated)	explain_new	4.78	5.00	4.69	5.00	1.06	1.00	4.29	5.00	4.16	5.00	0.000
	explain_risk	1.28	1.00	1.45	1.00	4.94	5.00	2.06	1.00	2.05	1.00	0.000
	explain_trust	4.78	5.00	4.13	5.00	3.44	5.00	3.81	4.00	3.99	5.00	0.000
	other_advt	1.83	2.00	1.78	2.00	2.27	2.00	2.09	2.00	1.97	2.00	0.000
	other_help	2.83	3.00	2.75	3.00	2.81	3.00	2.22	2.00	2.54	3.00	0.000
	other_trust	2.32	2.00	2.04	2.00	1.52	1.00	2.06	2.00	2.02	2.00	0.000
Behaviour (experiments)	impatience	2.32	1.00	2.76	2.00	1.88	0.00	3.27	3.00	2.84	2.00	0.000
	pgg_std_contr	66.43	51.50	67.84	60.00	58.77	50.00	59.49	50.00	63.38	50.00	0.283
	risk_aversion	2.32	1.00	2.76	2.00	1.88	0.00	3.27	3.00	2.84	2.00	0.025
Innovation adoption	joincrop	3.95	5.00	4.01	5.00	4.31	5.00	3.60	4.00	3.85	5.00	0.001
	nutricrop	4.30	5.00	4.33	5.00	4.25	5.00	3.97	5.00	4.16	5.00	0.003
	profcrop	4.78	5.00	4.54	5.00	4.52	5.00	4.28	5.00	4.46	5.00	0.000
	tech_adopt_imit	4.58	5.00	4.35	5.00	3.85	4.50	4.12	5.00	4.24	5.00	0.001
	tech_adopt_interest	4.75	5.00	4.70	5.00	2.58	1.00	4.49	5.00	4.40	5.00	0.000
	tech_avsb	0.42	0.00	0.45	0.00	0.79	1.00	0.29	0.00	0.41	0.00	0.000

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Table 64. Farmers' clusters in the Mukurweini Food Hub (Kenya).

Typology	Variable	Older farmers with migrant household members, less likely to irrigate, very engaged in associations and resource sharing		Younger farmers with smaller farm production, less engaged in associations and resource sharing but stronger co-operators		Farmers with larger farm production and sales, facing high selling prices, more likely to get credit and loans		Overall		p-values
		347 farmers (68.7%)		77 farmers (15.2%)		73 farmers (14.5%)		505 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	53.91	55.00	46.66	46.00	49.81	50.00	52.27	53.00	0.000
	gender	0.59	1.00	0.56	1.00	0.45	0.00	0.57	1.00	0.084
	educ	3.06	3.00	3.18	3.00	3.19	3.00	3.10	3.00	0.423
Household (size)	adult14plus	4.15	4.00	4.17	4.00	3.74	4.00	4.10	4.00	0.218
	child0to2	0.12	0.00	0.26	0.00	0.14	0.00	0.14	0.00	0.074
	child3to13	0.98	0.00	0.84	0.00	0.99	0.00	0.97	0.00	0.695
Household (migration)	emig	0.45	0.00	0.32	0.00	0.22	0.00	0.40	0.00	0.000
	emig_remitt	0.07	0.00	0.01	0.00	0.05	0.00	0.06	0.00	0.149
Household (wellbeing)	foodneed	2.79	3.00	2.96	3.00	2.55	2.00	2.79	3.00	0.060
	income_avg	2.54	3.00	2.65	3.00	2.74	3.00	2.58	3.00	0.340
	income_cost	1.93	1.00	2.09	2.00	1.93	1.00	1.96	1.00	0.477
	income_food	2.67	3.00	2.32	2.00	1.99	1.00	2.53	2.00	0.001
Farm (production)	log_product_value_total	1599.74	860.75	1113.55	510.77	1913.36	1043.40	1576.39	820.57	0.005
Farm (sales)	log_sales_value_total	956.41	472.61	829.23	308.23	1275.65	808.24	991.44	456.63	0.044
	share_sold	0.55	0.61	0.55	0.59	0.63	0.73	0.55	0.64	0.135
Farm (prices)	log_single_price	1.62	1.69	1.62	1.67	2.85	1.94	1.80	1.72	0.002
Farm (land/pond)	log_land_totsz	0.58	0.40	0.50	0.40	0.57	0.40	0.56	0.40	0.405
	used_land	0.65	1.00	0.49	0.00	0.40	0.00	0.59	1.00	0.000
	own_land_pond	0.97	1.00	0.87	1.00	0.95	1.00	0.95	1.00	0.002
Farm (labour)	farm_labour_employ	1.40	1.00	1.09	0.00	1.18	0.00	1.32	1.00	0.240
	farm_labour_hh	1.76	2.00	1.55	1.00	1.33	1.00	1.65	1.00	0.022
Farm (practices)	irrigate	0.25	0.00	0.56	1.00	0.77	1.00	0.37	0.00	0.000
	same_crop	0.94	1.00	0.94	1.00	0.96	1.00	0.94	1.00	0.835
	same_field	0.33	0.00	0.42	0.00	0.40	0.00	0.35	0.00	0.231

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Typology	Variable	Older farmers with migrant household members, less likely to irrigate, very engaged in associations and resource sharing		Younger farmers with smaller farm production, less engaged in associations and resource sharing but stronger co-operators		Farmers with larger farm production and sales, facing high selling prices, more likely to get credit and loans		Overall		p-values
		347 farmers (68.7%)		77 farmers (15.2%)		73 farmers (14.5%)		505 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Farm (cooperation)	assistcoop	4.31	5.00	2.13	1.00	3.56	4.00	3.85	5.00	0.000
	cmnres	0.89	1.00	0.26	0.00	0.79	1.00	0.78	1.00	0.000
	memassc	0.95	1.00	0.21	0.00	0.64	1.00	0.79	1.00	0.000
Farm (financing)	credit	0.18	0.00	0.12	0.00	0.34	0.00	0.20	0.00	0.002
	loan	0.24	0.00	0.17	0.00	0.42	0.00	0.26	0.00	0.001
Behaviour (stated)	explain_new	4.48	5.00	4.61	5.00	4.36	5.00	4.48	5.00	0.711
	explain_risk	3.93	5.00	4.04	5.00	4.27	5.00	4.00	5.00	0.075
	explain_trust	4.03	4.00	3.43	4.00	4.05	5.00	3.94	4.00	0.004
	other_advt	1.60	1.00	1.77	2.00	1.77	2.00	1.65	2.00	0.137
	other_help	1.48	1.00	1.81	2.00	1.77	2.00	1.57	1.00	0.000
	other_trust	1.38	1.00	1.65	1.00	1.34	1.00	1.42	1.00	0.018
Behaviour (experiments)	impatience	1.42	0.00	1.10	0.00	1.33	0.00	1.36	0.00	0.813
	pgg_std_contr	73.86	75.00	84.48	100.00	72.60	75.00	75.34	75.00	0.015
	risk_aversion	0.21	0.00	0.22	0.00	0.00	0.00	0.18	0.00	0.173
Innovation adoption	joincrop	4.33	5.00	4.00	5.00	4.12	5.00	4.26	5.00	0.134
	nutricrop	4.49	5.00	4.22	5.00	4.33	5.00	4.41	5.00	0.193
	profcrop	4.53	5.00	4.43	5.00	4.29	5.00	4.48	5.00	0.319
	tech_adopt_imit	4.78	5.00	4.65	5.00	4.38	5.00	4.70	5.00	0.003
	tech_adopt_interest	4.76	5.00	4.57	5.00	4.34	5.00	4.67	5.00	0.003
	tech_avsb	0.04	0.00	0.12	0.00	0.14	0.00	0.07	0.00	0.001

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Table 65. Farmers' clusters in the Kisumu Food Hub (Kenya).

Typology	Variable	Older farmers with many migrant household members and higher income, who spend more on food, more risk-taking		Farmers with larger households and larger farm production, unlikely to get loans or credit, more risk averse		More food insecure farmers, less engaged in sales, putting resources in common and likely to obtain credit		Younger farmers with higher education, less food insecure, employing limited labour, growing different fish species		Overall		p-values
		108 farmers (26.8%)		52 farmers (12.9%)		49 farmers (12.2%)		193 farmers (47.9%)		403 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	51.05	50.00	48.25	47.50	48.98	48.00	45.55	43.00	47.81	47.00	0.016
	gender	0.83	1.00	0.63	1.00	0.59	1.00	0.73	1.00	0.72	1.00	0.003
	educ	3.26	3.00	2.79	3.00	2.96	3.00	3.36	3.00	3.21	3.00	0.000
Household (size)	adult14plus	3.79	3.00	4.85	5.00	3.10	3.00	3.39	3.00	3.65	3.00	0.000
	child0to2	0.45	0.00	0.62	0.00	0.33	0.00	0.13	0.00	0.30	0.00	0.000
	child3to13	1.65	1.00	2.65	3.00	1.84	2.00	1.48	2.00	1.72	2.00	0.000
Household (migration)	emig	0.36	0.00	0.10	0.00	0.24	0.00	0.30	0.00	0.28	0.00	0.007
	emig_remitt	0.23	0.00	0.02	0.00	0.08	0.00	0.18	0.00	0.16	0.00	0.002
Household (well-being)	foodneed	3.42	4.00	3.73	4.00	3.90	4.00	2.65	3.00	3.15	3.00	0.000
	income_avg	2.51	3.00	2.15	2.00	2.12	2.00	2.18	2.00	2.26	2.00	0.000
	income_cost	1.88	2.00	1.96	1.00	2.35	2.00	2.01	2.00	2.01	2.00	0.001
	income_food	3.08	3.00	2.63	2.00	2.39	2.00	2.69	3.00	2.75	3.00	0.000
Farm (production)	log_product_value_total	1428.87	1186.48	1902.38	1591.64	934.56	844.71	984.53	771.50	0.07	0.06	0.000
Farm (sales)	log_sales_value_total	1315.98	1142.56	1581.00	1349.79	707.26	630.95	930.78	732.08	0.07	0.05	0.000
	share_sold	0.94	0.97	0.85	0.86	0.75	0.79	0.94	0.95	0.90	0.94	0.000
Farm (prices)	log_single_price	6.02	5.95	6.06	6.19	6.19	6.10	5.77	5.63	0.00	0.00	0.000
	log_system_tot	500.11	300.00	530.77	425.00	406.57	400.00	467.31	300.00	476.49	300.00	0.000
	used_pond	0.09	0.00	0.15	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.000
	own_land_pond	0.91	1.00	0.94	1.00	0.37	0.00	0.97	1.00	0.88	1.00	0.000
Farm (labour)	farm_labour_employ	1.71	2.00	1.65	1.50	3.29	3.00	0.81	0.00	1.47	1.00	0.000
	farm_labour_hh	1.68	2.00	2.42	2.00	1.22	1.00	1.85	2.00	1.80	2.00	0.000
	same_crop	0.95	1.00	1.00	1.00	1.00	1.00	0.01	0.00	0.51	1.00	0.000
	same_field	0.63	1.00	0.56	1.00	0.69	1.00	0.00	0.00	0.33	0.00	0.000

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Typology	Variable	Older farmers with many migrant household members and higher income, who spend more on food, more risk-taking		Farmers with larger households and larger farm production, unlikely to get loans or credit, more risk averse		More food insecure farmers, less engaged in sales, putting resources in common and likely to obtain credit		Younger farmers with higher education, less food insecure, employing limited labour, growing different fish species		Overall		p-values
		108 farmers (26.8%)		52 farmers (12.9%)		49 farmers (12.2%)		193 farmers (47.9%)		403 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
Farm (cooperation)	assistcoop	3.91	5.00	2.83	2.00	3.92	4.00	2.74	2.00	3.21	3.00	0.000
	cmnres	0.57	1.00	0.10	0.00	1.00	1.00	0.66	1.00	0.61	1.00	0.000
	memassc	0.66	1.00	0.37	0.00	0.65	1.00	0.60	1.00	0.59	1.00	0.001
Farm (financing)	credit	0.11	0.00	0.06	0.00	0.73	1.00	0.15	0.00	0.20	0.00	0.000
	loan	0.03	0.00	0.00	0.00	0.06	0.00	0.07	0.00	0.05	0.00	0.080
Behaviour (stated)	explain_new	4.25	5.00	4.77	5.00	4.27	4.00	4.56	5.00	4.47	5.00	0.000
	explain_risk	2.79	3.00	4.29	5.00	4.22	4.00	2.85	3.00	3.19	3.00	0.000
	explain_trust	4.19	5.00	4.73	5.00	4.29	4.00	3.08	3.00	3.74	4.00	0.000
	other_advt	1.49	1.00	1.65	2.00	1.80	2.00	1.67	2.00	1.64	2.00	0.011
	other_help	1.42	1.00	1.02	1.00	1.86	2.00	1.64	2.00	1.52	1.00	0.000
	other_trust	1.44	1.00	1.58	1.50	2.06	2.00	1.54	2.00	1.58	2.00	0.000
Innovation adoption	joincrop	3.84	4.00	4.87	5.00	3.57	4.00	3.41	3.00	3.74	4.00	0.000
	nutricrop	2.19	2.00	2.06	2.00	1.94	2.00	3.32	4.00	2.68	2.00	0.000
	profcrop	4.44	5.00	4.75	5.00	4.12	4.00	4.89	5.00	4.66	5.00	0.000
	tech_adopt_imit	4.71	5.00	4.94	5.00	3.90	4.00	5.00	5.00	4.78	5.00	0.000
	tech_adopt_interest	4.69	5.00	4.96	5.00	4.24	5.00	4.96	5.00	4.80	5.00	0.000
	tech_avsb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-

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Table 66. Farmers' clusters in the Kitui Food Hub (Kenya).

Typology	Variable	Farmers with larger farm production and farm sales, likely to put resources in common and to receive credit and loans		Young farmers with slightly larger farms and highest farm sales, unlikely to share resources and to engage with associations		Farmers with smaller farms, less likely to engage in rotations and more likely to trust others		Older farmers with limited farm sales, relying on assistance from associations, risk averse and less likely to trust others		Overall		p-values
		134 farmers (27.8%)		140 farmers (29.0%)		113 farmers (23.4%)		74 farmers (15.4%)		482 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	49.86	49.00	41.67	39.00	43.58	42.00	51.70	52.50	46.04	45.00	0.000
	gender	0.39	0.00	0.54	1.00	0.41	0.00	0.39	0.00	0.43	0.00	0.035
	educ	3.14	3.00	3.24	3.00	3.12	3.00	3.16	3.00	3.17	3.00	0.695
Household (size)	adult14plus	4.31	4.00	3.79	3.50	3.69	3.00	4.20	4.00	3.98	4.00	0.008
	child0to2	0.38	0.00	0.30	0.00	0.26	0.00	0.23	0.00	0.31	0.00	0.196
	child3to13	1.39	1.00	1.44	1.00	1.72	1.00	1.18	1.00	1.45	1.00	0.162
Household (migration)	emig	0.38	0.00	0.43	0.00	0.46	0.00	0.61	1.00	0.45	0.00	0.016
	emig_remitt	0.15	0.00	0.21	0.00	0.16	0.00	0.19	0.00	0.18	0.00	0.595
Household (wellbeing)	foodneed	3.32	4.00	3.29	4.00	3.46	4.00	3.27	3.00	3.37	4.00	0.388
	income_avg	1.93	1.00	2.13	2.00	2.00	1.00	1.77	1.00	1.95	1.00	0.099
	income_cost	1.95	2.00	1.97	2.00	2.28	2.00	1.77	2.00	1.98	2.00	0.042
	income_food	1.95	2.00	1.97	2.00	2.28	2.00	1.77	2.00	1.98	2.00	0.042
Farm (production)	log_product_value_total	2966.74	1141.73	2652.61	1019.48	1980.25	989.18	1492.13	829.49	2288.58	980.09	0.033
Farm (sales)	log_sales_value_total	452.93	19.18	960.41	102.74	369.58	0.00	152.40	38.53	514.92	9.70	0.012
	share_sold	0.16	0.01	0.26	0.09	0.17	0.00	0.17	0.05	0.19	0.01	0.015
Farm (prices)	log_single_price	3.10	3.36	4.65	2.99	4.24	3.31	2.58	2.77	3.77	3.17	0.512
Farm (land/pond)	log_land_totsz	1.28	0.91	1.02	0.81	0.81	0.81	1.07	0.81	1.06	0.81	0.000
	used_land	0.06	0.00	0.06	0.00	0.07	0.00	0.08	0.00	0.07	0.00	0.925
	own_land_pond	0.99	1.00	0.94	1.00	0.97	1.00	1.00	1.00	0.97	1.00	0.042
Farm (labour)	farm_labour_employ	1.85	1.00	1.48	0.00	1.52	1.00	1.61	1.50	1.61	1.00	0.604
	farm_labour_hh	2.13	2.00	2.30	2.00	2.13	2.00	2.04	2.00	2.16	2.00	0.539
Farm (practices)	irrigate	0.19	0.00	0.15	0.00	0.12	0.00	0.11	0.00	0.14	0.00	0.269
	same_crop	0.98	1.00	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	0.430

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Typology	Variable	Farmers with larger farm production and farm sales, likely to put resources in common and to receive credit and loans		Young farmers with slightly larger farms and highest farm sales, unlikely to share resources and to engage with associations		Farmers with smaller farms, less likely to engage in rotations and more likely to trust others		Older farmers with limited farm sales, relying on assistance from associations, risk averse and less likely to trust others		Overall		p-values
		134 farmers (27.8%)		140 farmers (29.0%)		113 farmers (23.4%)		74 farmers (15.4%)		482 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
	same_field	0.54	1.00	0.64	1.00	0.84	1.00	0.55	1.00	0.65	1.00	0.000
Farm (cooperation)	assistcoop	3.92	4.00	2.13	1.00	2.43	2.00	4.14	4.00	3.09	3.00	0.000
	cmnres	0.78	1.00	0.14	0.00	0.22	0.00	0.64	1.00	0.43	0.00	0.000
	memassc	0.95	1.00	0.11	0.00	0.22	0.00	0.95	1.00	0.52	1.00	0.000
Farm (financing)	credit	0.42	0.00	0.22	0.00	0.26	0.00	0.36	0.00	0.32	0.00	0.002
	loan	0.28	0.00	0.06	0.00	0.13	0.00	0.14	0.00	0.16	0.00	0.000
Behaviour (stated)	explain_new	4.57	5.00	4.53	5.00	4.68	5.00	4.73	5.00	4.61	5.00	0.798
	explain_risk	3.32	4.00	3.39	4.00	3.18	3.00	3.95	4.00	3.43	4.00	0.009
	explain_trust	3.97	4.00	3.79	4.00	3.49	3.00	4.07	5.00	3.84	4.00	0.001
	other_advt	1.43	1.00	1.56	1.00	1.65	2.00	1.20	1.00	1.48	1.00	0.000
	other_help	1.43	1.00	1.53	1.00	1.68	2.00	1.19	1.00	1.47	1.00	0.000
	other_trust	1.37	1.00	1.44	1.00	1.59	2.00	1.15	1.00	1.40	1.00	0.000
Innovation adoption	joincrop	4.15	4.00	4.22	5.00	4.35	5.00	4.26	5.00	4.25	5.00	0.216
	nutricrop	4.13	5.00	4.18	5.00	4.35	5.00	4.15	5.00	4.22	5.00	0.295
	profcrop	4.16	4.00	4.10	5.00	4.42	5.00	4.12	4.50	4.22	5.00	0.103
	tech_adopt_imit	4.36	5.00	4.37	5.00	4.54	5.00	4.54	5.00	4.44	5.00	0.163
	tech_adopt_interest	4.20	5.00	4.35	5.00	4.60	5.00	4.55	5.00	4.42	5.00	0.004
	tech_avsb	0.13	0.00	0.07	0.00	0.02	0.00	0.08	0.00	0.08	0.00	0.005

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Table 67. Farmers' clusters in the Kilombero Food Hub (Tanzania).

Typology	Variable	Younger farmers with smaller households and few migrant members, slightly smaller farms, less likely to receive credit		Older farmers with larger households and many migrant members, slightly larger farms, more likely to receive credit		Overall		p-values
		286 farmers (70.3%)		115 farmers (28.3%)		407 farmers		
		Average	Median	Average	Median	Average	Median	
Household (respondent)	age	44.04	42.00	54.29	56.00	47.00	46.00	0.000
	gender	0.64	1.00	0.70	1.00	0.66	1.00	0.203
	educ	3.10	3.00	3.23	3.00	3.14	3.00	0.143
Household (size)	adult14plus	2.79	2.50	3.70	4.00	3.06	3.00	0.000
	child0to2	0.89	1.00	0.61	0.00	0.81	1.00	0.001
	child3to13	1.64	2.00	1.63	1.00	1.66	2.00	0.743
Household (migration)	emig	0.07	0.00	1.00	1.00	0.34	0.00	0.000
	emig_remitt	0.03	0.00	0.99	1.00	0.31	0.00	0.000
Household (well-being)	foodneed	2.50	2.00	2.63	2.00	2.53	2.00	0.363
	income_avg	4.30	5.00	4.19	5.00	4.23	5.00	0.141
	income_cost	2.51	3.00	2.65	3.00	2.55	3.00	0.263
	income_food	2.65	3.00	2.67	3.00	2.66	3.00	0.907
Farm (production)	log_product_value_total	7256.96	1086.03	2501.73	1313.75	5806.36	1127.56	0.817
Farm (sales)	log_sales_value_total	2428.61	356.40	848.62	396.09	1946.37	359.09	0.313
	share_sold	0.44	0.50	0.39	0.39	0.42	0.46	0.142
Farm (prices)	log_single_price	1.89	0.58	0.82	0.57	1.58	0.57	0.436
Farm (land/pond)	log_land_totsz	1.75	0.81	1.96	1.21	1.79	0.81	0.028
	used_land	0.24	0.00	0.37	0.00	0.28	0.00	0.019
	own_land_pond	0.71	1.00	0.79	1.00	0.73	1.00	0.105
Farm (labour)	farm_labour_employ	2.09	1.00	2.21	2.00	2.11	1.00	0.337
	farm_labour_hh	2.06	2.00	2.47	2.00	2.19	2.00	0.002
Farm (practices)	irrigate	0.27	0.00	0.32	0.00	0.28	0.00	0.331
	same_crop	0.97	1.00	0.98	1.00	0.97	1.00	0.736
	same_field	0.64	1.00	0.63	1.00	0.64	1.00	1.000
	assistcoop	1.99	1.00	2.24	1.00	2.05	1.00	0.074

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Typology	Variable	Younger farmers with smaller households and few migrant members, slightly smaller farms, less likely to receive credit		Older farmers with larger households and many migrant members, slightly larger farms, more likely to receive credit		Overall		p-values
		286 farmers (70.3%)		115 farmers (28.3%)		407 farmers		
		Average	Median	Average	Median	Average	Median	
Farm (cooperation)	cmnres	0.03	0.00	0.08	0.00	0.04	0.00	0.059
	memassc	0.15	0.00	0.25	0.00	0.18	0.00	0.021
Farm (financing)	credit	0.22	0.00	0.45	0.00	0.29	0.00	0.000
	loan	0.07	0.00	0.04	0.00	0.06	0.00	0.371
Behaviour (stated)	explain_new	4.36	5.00	4.42	5.00	4.36	5.00	0.103
	explain_risk	3.70	4.00	3.62	4.00	3.66	4.00	0.867
	explain_trust	3.82	4.00	3.48	4.00	3.71	4.00	0.110
	other_advt	1.92	2.00	1.79	2.00	1.88	2.00	0.090
	other_help	1.93	2.00	1.81	2.00	1.89	2.00	0.178
	other_trust	1.69	2.00	1.67	2.00	1.68	2.00	0.737
Innovation adoption	joincrop	3.93	4.00	4.22	5.00	4.02	5.00	0.070
	nutricrop	3.57	4.00	3.83	4.00	3.67	4.00	0.026
	profcrop	4.19	5.00	4.41	5.00	4.26	5.00	0.039
	tech_adopt_imit	4.34	5.00	4.58	5.00	4.37	5.00	0.133
	tech_adopt_interest	4.38	5.00	4.60	5.00	4.40	5.00	0.021
	tech_avsb	0.08	0.00	0.10	0.00	0.09	0.00	0.563

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Table 68. Farmers' clusters in the Kilombero (fish) Food Hub (Tanzania).

Typology	Variable	Farmers with lower average income who rely on organisations and are more likely to trust other farmers		Farmers with higher average income who do not rely on organisation and are less likely to trust other farmers		Overall		p-values
		4 farmers (25%)		9 farmers (56.3%)		16 farmers		
		Average	Median	Average	Median	Average	Median	
Household (respondent)	age	54.25	54.00	51.00	52.00	53.56	54.50	0.535
	gender	1.00	1.00	0.89	1.00	0.88	1.00	1.000
	educ	3.75	4.00	2.56	2.00	3.00	3.00	0.137
Household (size)	adult14plus	3.75	4.00	5.00	5.00	5.00	4.50	0.265
	child0to2	0.25	0.00	0.00	0.00	0.06	0.00	0.134
	child3to13	1.50	1.50	1.56	2.00	1.50	2.00	0.872
Household (migration)	emig	0.50	0.50	0.44	0.00	0.50	0.50	1.000
	emig_remitt	0.50	0.50	0.33	0.00	0.38	0.00	1.000
Household (well-being)	foodneed	2.00	2.00	2.11	2.00	1.88	2.00	0.741
	income_avg	4.00	4.00	5.00	5.00	4.75	5.00	0.001
	income_cost	3.25	3.50	2.33	3.00	2.53	3.00	0.197
	income_food	3.00	3.00	3.22	3.00	3.15	3.00	0.752
Farm (production)	log_product_value_total	1403.58	611.96	984.41	393.00	944.22	364.93	0.814
Farm (sales)	log_sales_value_total	1403.58	611.96	590.16	235.80	682.86	230.19	0.345
	share_sold	1.00	1.00	0.78	1.00	0.69	1.00	0.258
Farm (prices)	log_single_price	4.81	4.57	3.66	3.37	4.06	4.49	0.217
	log_system_tot	290.00	165.00	918.11	400.00	662.44	175.00	0.567
	used_pond	0.00	0.00	0.22	0.00	0.13	0.00	1.000
	own_land_pond	0.75	1.00	0.89	1.00	0.88	1.00	1.000
Farm (labour)	farm_labour_employ	4.00	4.00	1.11	0.00	1.63	0.00	0.041
	farm_labour_hh	3.50	3.50	1.89	2.00	2.44	2.00	0.026
	same_crop	0.75	1.00	0.78	1.00	0.81	1.00	1.000
	same_field	0.75	1.00	0.78	1.00	0.75	1.00	1.000
Farm (cooperation)	assistcoop	4.00	4.50	1.44	1.00	2.00	1.00	0.008
	cmnres	0.25	0.00	0.11	0.00	0.13	0.00	1.000
	memassc	0.25	0.00	0.44	0.00	0.31	0.00	1.000

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Typology	Variable	Farmers with lower average income who rely on organisations and are more likely to trust other farmers		Farmers with higher average income who do not rely on organisation and are less likely to trust other farmers		Overall		p-values
		4 farmers (25%)		9 farmers (56.3%)		16 farmers		
		Average	Median	Average	Median	Average	Median	
Farm (financing)	credit	1.00	1.00	0.00	0.00	0.31	0.00	0.001
	loan	0.50	0.50	0.00	0.00	0.13	0.00	0.077
Behaviour (stated)	explain_new	4.75	5.00	5.00	5.00	4.88	5.00	0.134
	explain_risk	4.00	4.50	5.00	5.00	4.75	5.00	0.027
	explain_trust	3.25	3.00	5.00	5.00	4.56	5.00	0.005
	other_advt	2.00	2.00	2.00	2.00	1.94	2.00	1.000
	other_help	1.50	1.00	2.00	2.00	1.75	1.50	0.320
	other_trust	1.25	1.00	1.89	2.00	1.63	2.00	0.027
Innovation adoption	joincrop	3.50	4.00	4.89	5.00	4.44	5.00	0.023
	nutricrop	4.00	4.00	3.67	5.00	3.38	4.00	0.806
	profcrop	5.00	5.00	4.11	5.00	4.38	5.00	0.325
	tech_adopt_imit	5.00	5.00	5.00	5.00	5.00	5.00	1.000
	tech_adopt_interest	4.75	5.00	4.89	5.00	4.88	5.00	0.538
	tech_avsb	0.00	0.00	0.00	0.00	0.00	0.00	-

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Table 69. Farmers' clusters in the Mvomero Food Hub (Tanzania).

Typology	Variable	Young farmers with larger farm sales, hiring more labour, irrigating and engaged in rotations		Farmers with no migrant household members, not high incomes, smaller farm sales and less engaged in crop rotation		Older farmers with migrant household members, higher incomes, larger farm production, not irrigating		Overall		p-values
		129 farmers (25.6%)		276 farmers (54.8%)		67 farmers (13.3%)		504 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	35.44	35.00	41.50	38.00	50.06	54.00	41.04	38.00	0.000
	gender	0.68	1.00	0.54	1.00	0.60	1.00	0.58	1.00	0.029
	educ	2.73	3.00	2.72	3.00	2.70	3.00	2.71	3.00	0.965
Household (size)	adult14plus	2.68	2.00	2.95	2.00	4.12	4.00	3.02	3.00	0.000
	child0to2	0.73	1.00	0.52	0.00	0.27	0.00	0.56	0.00	0.000
	child3to13	1.83	2.00	1.64	2.00	1.48	1.00	1.70	2.00	0.011
Household (migration)	emig	0.02	0.00	0.00	0.00	1.00	1.00	0.14	0.00	0.000
	emig_remitt	0.01	0.00	0.00	0.00	0.99	1.00	0.14	0.00	0.000
Household (well-being)	foodneed	2.98	3.00	2.97	3.00	3.09	3.00	3.00	3.00	0.692
	income_avg	4.29	5.00	3.92	4.00	4.36	5.00	4.07	5.00	0.000
	income_cost	2.25	2.00	2.55	2.00	2.40	2.00	2.44	2.00	0.111
	income_food	3.12	3.00	2.95	3.00	2.84	3.00	2.98	3.00	0.277
Farm (production)	log_product_value_total	1571.56	745.12	1265.08	529.05	1704.66	745.82	1358.14	613.75	0.008
Farm (sales)	log_sales_value_total	11443.71	392.91	674.03	112.27	790.74	148.55	3421.77	190.87	0.000
	share_sold	0.52	0.58	0.32	0.32	0.33	0.32	0.38	0.38	0.000
Farm (prices)	log_single_price	1.45	1.25	1.64	1.26	2.09	1.26	1.62	1.26	0.730
Farm (land/pond)	log_land_totsz	1.29	1.01	1.24	0.81	1.35	1.21	1.26	0.81	0.106
	used_land	0.45	0.00	0.50	0.50	0.49	0.00	0.49	0.00	0.635
	own_land_pond	0.67	1.00	0.88	1.00	0.88	1.00	0.82	1.00	0.000
Farm (labour)	farm_labour_employ	1.60	1.00	0.95	0.00	0.84	0.00	1.11	0.00	0.021
	farm_labour_hh	2.18	2.00	2.31	2.00	2.54	2.00	2.29	2.00	0.084
Farm (practices)	irrigate	0.57	1.00	0.31	0.00	0.18	0.00	0.37	0.00	0.000
	same_crop	0.49	0.00	0.99	1.00	0.90	1.00	0.83	1.00	0.000
	same_field	0.02	0.00	0.86	1.00	0.61	1.00	0.59	1.00	0.000

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Typology	Variable	Young farmers with larger farm sales, hiring more labour, irrigating and engaged in rotations		Farmers with no migrant household members, not high incomes, smaller farm sales and less engaged in crop rotation		Older farmers with migrant household members, higher incomes, larger farm production, not irrigating		Overall		p-values
		129 farmers (25.6%)		276 farmers (54.8%)		67 farmers (13.3%)		504 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Farm (cooperation)	assistcoop	1.65	1.00	2.11	1.00	2.22	1.00	1.99	1.00	0.008
	cmnres	0.02	0.00	0.02	0.00	0.03	0.00	0.02	0.00	0.909
	memassc	0.09	0.00	0.05	0.00	0.04	0.00	0.06	0.00	0.367
Farm (financing)	credit	0.19	0.00	0.28	0.00	0.28	0.00	0.26	0.00	0.146
	loan	0.05	0.00	0.03	0.00	0.01	0.00	0.03	0.00	0.254
Behaviour (stated)	explain_new	4.50	5.00	4.49	5.00	4.28	5.00	4.46	5.00	0.115
	explain_risk	4.15	5.00	4.17	4.50	4.07	4.00	4.14	5.00	0.398
	explain_trust	4.68	5.00	4.07	4.50	4.46	5.00	4.30	5.00	0.000
	other_advt	1.90	2.00	1.85	2.00	1.66	2.00	1.84	2.00	0.032
	other_help	1.84	2.00	1.87	2.00	1.67	2.00	1.83	2.00	0.189
	other_trust	1.58	2.00	1.57	1.00	1.58	1.00	1.56	1.00	0.892
Behaviour (experiments)	impatience	2.54	0.00	2.01	0.00	1.24	0.00	2.02	0.00	0.073
	pgg_std_contr	61.69	50.00	55.93	50.00	70.75	50.00	59.86	50.00	0.339
	risk_aversion	5.29	6.00	5.49	6.00	4.87	6.00	5.35	6.00	0.114
Innovation adoption	joincrop	4.23	5.00	3.76	5.00	4.00	5.00	3.91	5.00	0.002
	nutricrop	3.53	4.00	3.63	4.00	4.09	5.00	3.66	4.00	0.012
	profcrop	4.74	5.00	4.50	5.00	4.24	5.00	4.51	5.00	0.004
	tech_adopt_imit	4.74	5.00	4.33	5.00	4.37	5.00	4.45	5.00	0.000
	tech_adopt_interest	4.84	5.00	4.49	5.00	4.64	5.00	4.59	5.00	0.002
	tech_avsb	0.07	0.00	0.10	0.00	0.10	0.00	0.09	0.00	0.548

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Table 70. Farmers' clusters in the Kamuli Food Hub (Uganda).

Typology	Variable	Older farmers with larger farm sizes and farm production, engaged in cooperatives and cooperation		Mid- Aged farmers with mid- Sized farms and production, engaged in cooperatives and cooperation, and with no migrant household members		Younger farmers with a smaller farm and smaller production, less involved in cooperatives and less likely to cooperate		Overall		p-values
		259 farmers (64.8%)		79 farmers (19.8%)		51 farmers (12.8%)		400 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	44.06	45.00	38.59	38.00	36.69	32.00	41.67	42.00	0.000
	gender	0.57	1.00	0.34	0.00	0.68	1.00	0.55	1.00	0.000
	educ	3.42	3.00	3.03	3.00	3.90	4.00	3.43	3.00	0.000
Household (size)	adult14plus	5.11	4.00	4.08	4.00	3.44	3.00	4.61	4.00	0.000
	child0to2	0.59	0.00	0.85	1.00	0.63	1.00	0.65	0.00	0.024
	child3to13	3.01	3.00	3.15	3.00	2.30	2.00	2.91	3.00	0.025
Household (migration)	emig	0.51	1.00	0.11	0.00	0.37	0.00	0.41	0.00	0.000
	emig_remitt	0.41	0.00	0.05	0.00	0.27	0.00	0.32	0.00	0.000
Household (well-being)	foodneed	2.02	2.00	2.29	2.00	2.70	2.00	2.19	2.00	0.000
	income_avg	1.67	2.00	1.52	2.00	1.72	2.00	1.65	2.00	0.227
	income_cost	2.20	2.00	2.25	2.00	2.13	2.00	2.20	2.00	0.789
	income_food	1.56	1.00	1.61	1.00	2.13	2.00	1.67	1.00	0.000
Farm (production)	log_product_value_total	1576.55	822.13	1300.29	650.45	1111.31	618.55	1439.41	752.19	0.055
Farm (sales)	log_sales_value_total	1237.09	479.19	865.92	395.69	836.35	358.91	1092.65	452.46	0.178
	share_sold	0.64	0.69	0.60	0.63	0.60	0.67	0.62	0.68	0.303
Farm (prices)	log_single_price	0.67	0.53	0.68	0.56	0.70	0.48	0.67	0.53	0.782
Farm (land/pond)	log_land_totsz	1.73	1.21	1.78	1.21	1.11	0.81	1.63	1.01	0.000
	used_land	0.42	0.00	0.46	0.00	0.24	0.00	0.40	0.00	0.009
	own_land_pond	0.86	1.00	0.84	1.00	0.76	1.00	0.84	1.00	0.163
Farm (labour)	farm_labour_employ	1.71	1.00	1.58	2.00	2.14	2.00	1.76	2.00	0.034
	farm_labour_hh	3.72	3.00	3.32	3.00	2.41	2.00	3.41	3.00	0.000
Farm (practices)	irrigate	0.18	0.00	0.14	0.00	0.08	0.00	0.16	0.00	0.134

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Typology	Variable	Older farmers with larger farm sizes and farm production, engaged in cooperatives and cooperation		Mid- Aged farmers with mid- Sized farms and production, engaged in cooperatives and cooperation, and with no migrant household members		Younger farmers with a smaller farm and smaller production, less involved in cooperatives and less likely to cooperate		Overall		p-values
		259 farmers (64.8%)		79 farmers (19.8%)		51 farmers (12.8%)		400 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	
	same_crop	0.76	1.00	0.76	1.00	0.79	1.00	0.77	1.00	0.914
	same_field	0.21	0.00	0.30	0.00	0.48	0.00	0.28	0.00	0.000
Farm (cooperation)	assistcoop	4.43	5.00	4.63	5.00	1.77	1.00	4.00	5.00	0.000
	cmnres	0.54	1.00	0.68	1.00	0.06	0.00	0.49	0.00	0.000
	memassc	0.86	1.00	0.91	1.00	0.18	0.00	0.75	1.00	0.000
Farm (financing)	credit	0.45	0.00	0.27	0.00	0.46	0.00	0.42	0.00	0.008
	loan	0.26	0.00	0.24	0.00	0.04	0.00	0.22	0.00	0.000
Behaviour (stated)	explain_new	4.90	5.00	4.97	5.00	4.93	5.00	4.92	5.00	0.433
	explain_risk	4.34	5.00	4.08	5.00	4.52	5.00	4.32	5.00	0.476
	explain_trust	4.53	5.00	4.81	5.00	4.39	4.00	4.56	5.00	0.000
	other_advt	2.09	2.00	2.00	2.00	2.03	2.00	2.06	2.00	0.574
	other_help	1.76	2.00	2.00	2.00	2.00	2.00	1.85	2.00	0.014
	other_trust	1.78	2.00	1.57	2.00	1.86	2.00	1.76	2.00	0.002
Innovation adoption	joincrop	4.54	5.00	4.87	5.00	4.42	5.00	4.59	5.00	0.008
	nutricrop	4.78	5.00	4.73	5.00	4.63	5.00	4.75	5.00	0.362
	profcrop	4.80	5.00	4.89	5.00	4.76	5.00	4.81	5.00	0.439
	tech_adopt_imit	4.80	5.00	4.89	5.00	4.65	5.00	4.79	5.00	0.139
	tech_adopt_interest	4.89	5.00	4.92	5.00	4.94	5.00	4.91	5.00	0.517
	tech_avsb	0.02	0.00	0.09	0.00	0.03	0.00	0.04	0.00	0.041

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Table 71. Farmers' clusters in the Nakaseke Food Hub (Uganda).

Typology	Variable	Older farmers with larger households and larger farms		Younger farmers with smaller household, smaller farms.		Overall		p-values
		138 farmers (34.5%)		262 farmers (65.5%)		400 farmers		
		Average	Median	Average	Median	Average	Median	
Household (respondent)	age	44.44	43.00	36.96	35.00	39.54	37.00	0.000
	gender	0.67	1.00	0.70	1.00	0.69	1.00	0.570
	educ	3.14	3.00	3.22	3.00	3.20	3.00	0.330
Household (size)	adult14plus	4.46	4.00	3.64	3.00	3.93	3.00	0.000
	child0to2	0.71	0.00	0.73	1.00	0.72	0.00	0.713
	child3to13	3.08	3.00	2.61	2.00	2.77	3.00	0.056
Household (migration)	emig	0.83	1.00	0.16	0.00	0.39	0.00	0.000
	emig_remitt	0.74	1.00	0.04	0.00	0.28	0.00	0.000
Household (wellbeing)	foodneed	2.00	2.00	2.10	2.00	2.06	2.00	0.898
	income_avg	1.88	2.00	1.90	2.00	1.89	2.00	0.827
	income_cost	2.38	2.00	2.49	2.00	2.45	2.00	0.350
	income_food	1.51	1.00	1.77	1.00	1.68	1.00	0.038
Farm (production)	log_product_value_total	2965.49	1497.31	3383.37	1089.35	3239.20	1239.07	0.231
Farm (sales)	log_sales_value_total	2660.98	1282.93	2903.59	887.48	2819.89	994.46	0.195
	share_sold	0.82	0.91	0.82	0.87	0.82	0.89	0.842
Farm (prices)	log_single_price	0.74	0.62	0.70	0.56	0.71	0.59	0.264
Farm (land/pond)	log_land_totsz	2.03	1.42	1.72	1.01	1.83	1.21	0.004
	used_land	0.62	1.00	0.37	0.00	0.46	0.00	0.000
	own_land_pond	0.76	1.00	0.65	1.00	0.69	1.00	0.023
Farm (labour)	farm_labour_employ	2.32	2.00	2.40	2.00	2.37	2.00	0.317
	farm_labour_hh	3.03	3.00	2.74	2.00	2.84	2.00	0.011
Farm (practices)	irrigate	0.30	0.00	0.29	0.00	0.29	0.00	0.818
	same_crop	0.74	1.00	0.80	1.00	0.78	1.00	0.206
	same_field	0.20	0.00	0.22	0.00	0.21	0.00	0.608
Farm (cooperation)	assistcoop	3.94	5.00	3.64	5.00	3.75	5.00	0.109
	cmnres	0.59	1.00	0.25	0.00	0.37	0.00	0.000
	memassc	0.81	1.00	0.53	1.00	0.63	1.00	0.000

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Farm (financing)	credit	0.41	0.00	0.39	0.00	0.40	0.00	0.748
	loan	0.49	0.00	0.29	0.00	0.36	0.00	0.000
Behaviour (stated)	explain_new	4.78	5.00	4.73	5.00	4.75	5.00	0.927
	explain_risk	4.07	5.00	4.04	5.00	4.05	5.00	0.992
	explain_trust	4.21	5.00	4.00	4.00	4.07	5.00	0.100
	other_advt	2.11	2.00	2.02	2.00	2.05	2.00	0.178
	other_help	1.86	2.00	1.99	2.00	1.94	2.00	0.112
	other_trust	1.74	2.00	1.77	2.00	1.76	2.00	0.683
Innovation adoption	joincrop	4.44	5.00	4.43	5.00	4.44	5.00	0.920
	nutricrop	4.72	5.00	4.42	5.00	4.52	5.00	0.002
	profcrop	4.75	5.00	4.69	5.00	4.72	5.00	0.648
	tech_adopt_imit	4.70	5.00	4.65	5.00	4.67	5.00	0.812
	tech_adopt_interest	4.77	5.00	4.76	5.00	4.77	5.00	0.982
	tech_avsb	0.04	0.00	0.06	0.00	0.05	0.00	0.643

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Table 72. Farmers' clusters in the Kajjansi- Masaka Food Hub (Uganda).

Typology	Variable	Risk averse farmers, likely to receive assistance from organisations but less willing to cooperate		Risk-taking farmers, unlikely to use resources in common but very willing to cooperate		Risk averse farmers likely to receive assistance from organisations and more willing to cooperate		More risk- Averse farmers, likelier to receive assistance from organisations but less willing to cooperate		Overall		p-values
		124 farmers (24.4%)		36 farmers (7.1%)		39 farmers (7.8%)		160 farmers (31.5%)		508 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
Household (respondent)	age	43.64	43.00	54.42	52.50	40.90	36.00	42.31	41.50	44.44	43.00	0.000
	gender	0.76	1.00	0.86	1.00	0.72	1.00	0.63	1.00	0.73	1.00	0.012
	educ	3.77	4.00	3.94	4.00	3.95	4.00	3.81	4.00	3.90	4.00	0.774
Household (size)	adult14plus	6.49	6.00	5.50	5.00	5.18	4.00	5.12	4.00	5.31	4.00	0.047
	child0to2	0.81	0.00	0.47	0.00	0.46	0.00	0.78	0.00	0.70	0.00	0.202
	child3to13	3.24	3.00	2.61	2.00	2.13	2.00	2.92	3.00	2.73	2.00	0.084
Household (migration)	emig	1.00	1.00	0.89	1.00	0.56	1.00	0.17	0.00	0.52	1.00	0.000
	emig_remitt	0.84	1.00	0.58	1.00	0.46	0.00	0.03	0.00	0.36	0.00	0.000
Household (wellbeing)	foodneed	2.40	2.00	1.97	2.00	2.33	2.00	2.46	2.00	2.36	2.00	0.071
	income_avg	1.94	2.00	2.22	2.00	2.10	2.00	2.23	2.00	2.27	2.00	0.105
	income_cost	2.36	2.00	2.14	2.00	2.44	2.00	2.47	2.00	2.23	2.00	0.542
	income_food	2.09	2.00	2.00	1.50	2.21	2.00	2.08	2.00	2.03	2.00	0.789
Farm (production)	log_product_value_total	5189.08	1710.57	3253.90	1546.39	11681.50	2768.22	7630.51	2367.31	8328.51	2596.40	0.460
Farm (sales)	log_sales_value_total	4445.60	1515.08	2749.41	1317.29	6520.64	2481.85	7292.13	1756.39	7380.42	2157.30	0.491
	share_sold	0.90	1.00	0.92	1.00	0.88	0.96	0.91	1.00	0.90	1.00	0.653
Farm (prices)	log_single_price	5.94	5.10	5.05	4.96	6.49	6.43	7.23	5.35	7.50	5.35	0.022
Farm (land/ pond)	log_system_tot	1539.67	771.50	1810.45	688.00	2511.54	1000.00	1821.87	640.00	1968.48	800.00	0.270
	used_pond	0.13	0.00	0.17	0.00	0.69	1.00	0.16	0.00	0.21	0.00	0.000
	own_land_pond	0.58	1.00	0.83	1.00	0.79	1.00	0.55	1.00	0.60	1.00	0.001
Farm (labour)	farm_labour_employ	2.77	2.00	1.94	1.50	2.72	2.00	3.46	2.00	2.88	2.00	0.278
	farm_labour_hh	3.41	3.00	2.39	2.00	2.95	3.00	3.06	3.00	2.98	2.00	0.049
	same_crop	0.73	1.00	1.00	1.00	0.87	1.00	0.89	1.00	0.86	1.00	0.000
	same_field	0.35	0.00	0.64	1.00	0.21	0.00	0.54	1.00	0.48	0.00	0.000
Farm (cooperation)	assistcoop	4.39	5.00	3.33	3.00	4.05	5.00	4.24	5.00	4.20	5.00	0.000
	cmnres	0.77	1.00	0.11	0.00	0.38	0.00	0.49	0.00	0.51	1.00	0.000

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Typology	Variable	Risk averse farmers, likely to receive assistance from organisations but less willing to cooperate		Risk-taking farmers, unlikely to use resources in common but very willing to cooperate		Risk averse farmers likely to receive assistance from organisations and more willing to cooperate		More risk- Averse farmers, likelier to receive assistance from organisations but less willing to cooperate		Overall		p-values
		124 farmers (24.4%)		36 farmers (7.1%)		39 farmers (7.8%)		160 farmers (31.5%)		508 farmers		
		Average	Median	Average	Median	Average	Median	Average	Median	Average	Median	
	memassc	0.83	1.00	0.47	0.00	0.38	0.00	0.65	1.00	0.58	1.00	0.000
Farm (financing)	credit	0.23	0.00	0.22	0.00	0.05	0.00	0.37	0.00	0.25	0.00	0.000
	loan	0.15	0.00	0.11	0.00	0.00	0.00	0.16	0.00	0.15	0.00	0.023
Behaviour (stated)	explain_new	4.75	5.00	4.94	5.00	4.44	5.00	4.76	5.00	4.63	5.00	0.053
	explain_risk	3.69	5.00	1.83	1.00	3.64	5.00	3.28	4.00	3.14	4.00	0.000
	explain_trust	4.40	5.00	3.56	4.00	4.18	5.00	4.04	4.00	3.96	4.00	0.009
	other_advt	2.10	2.00	2.28	2.00	1.95	2.00	2.17	2.00	2.14	2.00	0.143
	other_help	1.65	1.00	1.69	1.00	1.79	2.00	1.84	2.00	1.81	2.00	0.183
	other_trust	1.77	2.00	1.50	1.00	1.85	2.00	1.84	2.00	1.81	2.00	0.007
Behaviour (experiments)	impatience	3.24	3.00	4.08	3.00	3.44	3.00	3.51	3.00	3.47	3.00	0.470
	pgg_std_contr	78.76	73.50	105.56	115.00	95.13	90.00	79.39	75.00	83.51	78.00	0.003
	risk_aversion	2.84	3.00	3.06	3.00	2.74	3.00	3.12	3.00	2.97	3.00	0.531
Innovation adoption	joincrop	4.53	5.00	4.61	5.00	4.10	5.00	4.48	5.00	4.32	5.00	0.048
	nutricrop	4.65	5.00	4.78	5.00	4.36	5.00	4.56	5.00	4.44	5.00	0.015
	profcrop	4.72	5.00	4.69	5.00	4.38	5.00	4.56	5.00	4.48	5.00	0.038
	tech_adopt_imit	4.57	5.00	4.69	5.00	4.56	5.00	4.61	5.00	4.56	5.00	0.720
	tech_adopt_interest	4.73	5.00	4.81	5.00	4.62	5.00	4.82	5.00	4.66	5.00	0.185
	tech_avsb	0.03	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.08	0.00	0.516

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Table 73 Descriptive statistics (N=2,371)

	Variable type	Mean	S.D.	Min	Max
Level of education	ordered categorical[a]	2.9	1.2	1	5
Literate	dummy[b]	0.69	0.46	0	1
Age	Count	47	15	18	92
Gender	dummy[c]	0.34	0.47	0	1
Income spent on purchased food	ordered categorical[d]	2.83	1.39	1	5
No. of switching & switching patterns in the lottery task					
Number of switches	count[e]	2.3	2.3	0	9
Consistent switch	dummy[f]	0.52	0.50	0	1
Inconsistent switch	dummy[g]	0.48	0.50	0	1
Monotonous (A)	dummy[h]	0.17	0.37	0	1
Primitive choice	dummy[i]	0.34	0.48	0	1
BA single switch	dummy[j]	0.05	0.36	0	1
ABA single switch	dummy[k]	0.22	0.41	0	1
Multiple switch	dummy[l]	0.42	0.49	0	1

[a](=1 illiterate, =2 no qualification but literate, =3 elementary, =4 high school, =5 high school& above); [b]=1 if education is equal to or greater than primary; [c]=1 if female; [d]=share of the farmer's household income spent on purchased food: 1 = A very limited part (less than 25%), 2 = Less than half (from 25% to 50%), 3 = About half (50%), 4 = More than half (from 50% to 75%), 5 = Almost all (from 75% to 100%); [e]= number of switches (takes 0 to 9); [f]= 1 if switched exactly once or monotonous switch only (B); [g]=1 if monotonous switch only (A) or switched more than once; [h]=1 if monotonous switch only (A) and =0 if consistent switch; [i]=1 if choice A in lottery task 10 and =0 if consistent switch; [j]=1 for BA single switch and =0 if consistent switch; [k]=1 for ABA single switch and =0 if consistent switch; [l]=1 if multiple switched and =0 if consistent switch;. Monotonous (A), Primitive choice, BA single switch, ABA single switch and Multiple Switch sum up to more than Inconsistent switch because several farmers committed more than one inconsistency.

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