Beyond the fall armyworm

How smallholder farmers adopt crop diversification practices as agroecological pest management strategies in eastern Zambia

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Abstract

This thesis explores farmers' understanding and adoption of crop diversification strategies to manage the fall armyworm (*Spodoptera frugiperda).*The fall armyworm is a crop pest that is increasingly threatening the production of staple crops such as maize (*Zea mays L.*). This study targeted rural smallholder maize farmers in two farming communities in Zambia's Eastern Province, who are affected by this pest. The farmers were participating in a network of on-farm trials that investigated crop diversification strategies to reduce fall armyworm damage, while also increasing food security, nutrition, and income. Previous studies have shown that fall armyworm damage is often lower in diverse cropping systems. By means of crop diversification, farmers can reduce their reliance on chemical pesticides, helping to protect the health of both farmers and the environment. Data was collected through semi-structured interviews and Focus Group Discussions. Farmers' experiences with fall armyworm and crop diversification were analysed as a basis for understanding how they relate to the implemented on-farm trials, and how project organisation and the trials align with farmers' needs. The analysis combined perspectives from Chambers et al. Farmer First theory (1989), Rogers' Attributes of Innovations from the Diffusion of Innovations theory (1983), and Stone's farmer learning typologies (2016). The findings revealed a complex interplay of farmer challenges, next to pests, including labour constraints, climate change, and crop theft. While farmers recognised some advantages to crop diversification in terms of pest damage, farmer learning was limited in the on-farm trials, as they were not provided with sufficient information about the purpose of various activities. This highlights a misalignment between scientific research agendas and farmer realities. Providing fixed 'technology packages', without engaging with farmers' realities, will not provide useful solutions to the farmers. Therefore, it is essential to shift away from a top-down model and advocate for bottom-up research processes. This is essential to create space for truly mutual learning and facilitate useful farmer experimentation, and will help move towards research processes that build effective solutions for and with farmers.

Keywords: Fall armyworm, crop diversification, agroecological pest management, Farmer First, technology adoption

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Abbreviations

CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CP	Conventionally Ploughed
DOI	Diffusion of Innovations
FAW	Fall armyworm (*Spodoptera frugiperda*)
FAO	Food and Agriculture Organization
FF	Farmer First
FFL	Farmers First-and-Last
FGD	Focus Group Discussion
LEG4DEV	Legume-based agroecological intensification of maize and cassava cropping systems in Sub-Saharan Africa for water-food-energy nexus sustainability, nutritional security & livelihood resilience
SIFAZ	The Sustainable Intensification of Smallholder Farming Systems in Zambia
ToT	Transfer of Technology

1. Introduction

Agriculture is a main component of the Zambian people's livelihoods. Over half of the national workforce is employed in the agricultural sector (FAOSTAT, 2022). One of the most important staple crops is maize, providing between 50-90% of the people's caloric intake, making them very reliant on this crop (Silva, et al., 2023). Despite the importance of agriculture to the country's workforce and food security, agricultural productivity has stagnated, or even declined, especially among smallholder farmers.

Among the threats to crop productivity is the fall armyworm (FAW), *Spodoptera frugiperda*, an invasive pest that has increasingly become a problem in agriculture in Africa, especially to maize (*Zea mays L.*). FAW is now described as one of the most damaging pests to some of the most important staple crops such as maize, which millions of people depend on in sub-Saharan Africa (Kumela, et al., 2018). The introduction of FAW came rapidly, which has resulted in farmers extensively applying pesticides. This has led to cases of indiscriminate spraying and overuse of pesticides, which negatively influence human and environmental health. It reduces the population of natural predator insects that feed on FAW, and possibly leads to the FAW developing resistance to certain insecticides (Harrison, et al., 2019). Farmers often rely for a large part on heavy chemical insecticides for FAW management, but the exact management practices differ from farm to farm. A multitude of cultural pest management strategies for FAW management has been cited in the literature surrounding FAW in sub-Saharan Africa. Some farmers spray tobacco extracts, some handpick the larvae of FAW while also spraying insecticide, or some only handpick them, as found in a study by Kumela et.al. (2018) on maize subsistence farmers in Ethiopia and Kenya. In Zambia, common practices for FAW management in maize production are the application of sand, ash, and lime, combined with handpicking and crushing the larvae. Chemical pesticide use as the main FAW control method is reported in varying numbers between 25-60 percent in Zambian smallholder farmer contexts (Kasoma et al., 2021; Durocher-Granger, et al., 2023). However, smallholder farmers can have difficulties accessing pesticides reliably, resulting in the creation of homemade pesticides using different available materials, like laundry detergent, which can cause damage to the plants (Kasoma et.al., 2021). This indicates that there are many factors that influence FAW management.

1.1 Problem statement

Initially, this thesis set out to study Zambian farmers' perceptions and knowledge of FAW, and how crop diversification strategies could offer a solution for sustainable pest management. Previous studies have shown that crop diversification mechanisms show promise to help increase the crop's pest resistance or tolerance, and can make the pest populations less dense (Jaworski et al., 2023).

However, what emerged in the field, was not only stories surrounding pest management, but a gap between the ways farmers and researchers think about, generate, and relate to technological innovations. This disconnect is reflected in literature surrounding agricultural interventions in smallholder farming systems in Africa: studies seem to focus either on technical agronomic solutions, or only on farmers' practices and socio-economic situations. In coming up with technologies to solve issues surrounding pest management, the complexities of social dynamics that shape farmer learning, experimentation, and adoption, are often missed. Rather than analysing both farmer and researcher perspectives symmetrically, this thesis focuses on how farmers themselves understand FAW, evaluate pest-management options, and experiment within the constraints they face**.** The disconnect identified in the literature between technical agronomic solutions and farmers' lived realities, is therefore examined from the farmers' lens**.**

Farmers are not passive recipients of technologies, but they negotiate their characteristics, evaluating them based on their own context and constraints they face (Chambers et al., 1989). Farmers themselves experiment a lot, as it is an intrinsic aspect of farming. It takes work for farmers to translate scientific information into farming methods that are adapted to their local conditions. (Maat & Glover, 2012). Moreover, adoption is often classified in binary terms of adoption or non-adoption, failing to include that there can be different degrees of adoption, as "adopters" can make adaptations to a new technology (Glover et al., 2019). Chambers and Glover both argue that the common agricultural research strategy of providing isolated technical packages - rather than changes to individual management components that can be altered (an all-or-nothing approach) - may have limited results in positively changing an existing production system (Chambers et al., 1989; Glover et al., 2019). The dynamic processes of farmer learning and experimenting are crucial components in understanding effective technology diffusion and adoption (Glover et al., 2019).

The SIFAZ (The Sustainable Intensification of Smallholder Farming Systems in Zambia) project has introduced innovations to farmers in the Southern and Eastern provinces of Zambia, by means of on-farm trials grounded in agro-ecological management. I joined this project in Zambia for this thesis under the CIMMYT (International Maize and Wheat Improvement Center), the body that helped design and implement the SIFAZ trials. This provided an opportunity to study how farmers relate to new cropping techniques, the FAW, as well as exploring the some of the dynamics between farmers,extension officers, and researchers. I worked in the field together with CIMMYT colleagues, I did focus group discussions and interviewed farmers, and assisted with biophysical plant data collection.

There are different types of agro-ecological management strategies included in these on-farm trials, aligning with concepts of sustainable land management. The use of crop diversification strategies provides a variety of mechanisms for pest control. These include the crop rotations and the use of inter-crops (Harrison et al., 2019). While these practices are important and show promise to reduce pest pressure, the effectiveness of these innovations does not only depend on the technical efficiency, but how smallholder farmers understand and relate to these technologies (Chambers et al., 1989). In order to understand how agroecological management strategies can be successfully implemented to reduce heavy insecticide use, it is key to obtain insights into farmers' understanding not only of this FAW pest and agro-ecological innovations, but also what their systemic constraints are, and reflect on the way that innovations are created in relation to local contexts.

1.2 Objective

It is of significant importance that the FAW pest that is threatening Zambia's food security, is managed in both an environmentally friendly way, and a way that fits the farmer's needs. In the literature available surrounding this topic, there appears to be a divide between studies that look at management of FAW grounded in technical solutions, or studies that look from a social science perspective.

The objective of this thesis is to understand how smallholder maize farmers in Eastern Zambia perceive, experience, and manage the fall armyworm, and how this shapes their engagement with agroecological pest management innovations.

This thesis aims to generate insights into this, by interviewing rural smallholder farming communities in Eastern province of Zambia to start grasping how they engage with FAW and its management. Moreover, it aims to understand how farmers relate to agroecological pest management strategies via the implemented on-farm trials, introduced by SIFAZ. Understanding which challenges and constraints they face is key to this. These insights will help to contribute to the long-term impact of innovations for ecological pest management, where the main goal is to ensure that these are tailored to farmer's needs and capabilities.

1.3 Research question

This thesis is guided by the following research questions:

"How do smallholder maize farmers in eastern Zambia perceive and adapt to the threat of the fall armyworm?
How does this shape their engagement with agroecological pest management innovations?"

1.4 Outline

Chapter 2 deepens out the background for the thesis research by providing information on the agricultural sector in Zambia, in particular maize, FAW management, and describes the Sustainable Intensification of Smallholder Farming Systems in Zambia (SIFAZ) - the project in which my thesis research took place. The next chapter dives into the literature surrounding farmer knowledge and technology adoption, laying out the conceptual framework used in the empirical chapters. In chapter 4, the methodology is explained, as well as the research context, design, and data analysis. In chapter 5, the empirical findings explore on the farmer level how these new practices, as presented to them by SIFAZ, were experienced. Chapter 6 reflects on the role of agricultural research in serving the needs of rural smallholder farmers. Lastly, the conclusions and recommendations are discussed in chapters 7 and 8.

2. Literature review/background

2.1 The agricultural sector in Zambia

The share of Zambian peoples' employment in agriculture out of total national employment is 56.1% in 2022 (FAOSTAT, 2022). In terms of crop production, data from 2023 shows that Zambia's primary crops in terms of tonnes produced are in decreasing order: sugar cane; cassava; maize; soybeans; and groundnuts (FAOSTAT, 2023). However, in terms of agricultural production value (gross production value in monetary terms at the farm gate level), the primary crops are cassava, followed by maize, then groundnuts (FAOSTAT, 2023).

Data from 2021 indicate that agriculture contributes to around 2.7% of the Gross Domestic Product (GDP), which has been in decline in the past decade (Mukashov et al., 2024). There are several factors influencing this decline: the growth of the services sector has led to a shift in the labour force from agriculture to services, as well as mining, which seems to be deemed more profitable. Moreover, there are data attributing this decline to poor rural-urban infrastructure, difficulties accessing markets, and a lack of financial investment in the agricultural sector (Phiri et al., 2020). Other literature attributes this to a decline in an agricultural productivity, impacted by climate change, as the country has experienced extreme weather events and high rainfall variability. Since smallholder production is predominantly rain-fed, droughts have caused large-scale crop failures. Many smallholders are not prepared for changes in rainfall, which has had a significantly negative effect on food security (Mulenga et al., 2021).

The Zambian government has been seeking ways to make the agricultural sector more competitive and are promoting agriculture to diversify the economy. Especially since the growth rate of the agricultural sector is declining, and is dominated by smallholder farmers who are vulnerable to shocks, government policies are attributing more programs to attaining food security and smallholder farmers' livelihoods (Phiri et al., 2020). In Zambia, there is a multitude of agronomic management and livelihood strategies. Within the agricultural sector, 1.6 million of its farmers are considered small-scale, making up 70% of farmers with farm sizes smaller than 2 ha, 25% farm sizes between 2-5 ha, and just 5% with farm sizes between 5-20 ha (Silva et al., 2023). It is common for the agricultural landscape to have a mix between large commercial farms and smallholder farms, some more prominent in one place than the other (Silva et al., 2023).

The population in Zambia lives more in rural than in urban areas. The Eastern province is one of its 10 provinces, where the research for this thesis took place. In 2022, the total population of the country was 19,6 million, of which the Eastern province constituted 2,5 million people. The population growth rate in the Eastern province is averaged at 3,1 percent annually (Zambia Statistics Agency, 2022). Zambia is said to have 72 languages, although some are considered dialects, rather than their own language. Nyanja is the language of the capital, Lusaka, but this language is also known as Chewa in the Eastern province. Here, it is also primarily spoken and regarded as somewhat of a Lingua Franca (Zambian Translators International, n.d.).

2.2 Maize

The total amount of maize produced in Zambia in 2023 was 3,3 million tonnes (FAOSTAT, 2023). Maize being one of the most important staple crops for Zambia, especially for smallholder farmers, makes it also a political crop (Kodamaya, 2011). Government incentive programmes within processes of market liberalization, aiming to increase maize output, were seen as a means to boost smallholder agriculture after having been neglected. Government interventions have caused large fluctuation patterns in the amount of maize produced over time, which affects food security (Kodamaya, 2011).

There was a big drought caused by a strong El Niño event in 2024, which has significantly impacted maize production in the Southern and Central regions of Zambia. The damage to the agricultural sector was severe. The Eastern province suffered from a 14 percent crop loss during this year. In total, 2.2 million hectares of maize were planted in this season, of which 1 million hectares were estimated to be lost. This has caused over 1 million households to be food insecure, as maize prices rapidly increased to a record level. The drought has resulted in significant food price inflation, while the country already had a food production deficit. Combined with a weak currency, this has caused a severely negative impact on livelihoods. As a result of the drought events, the government has enforced restrictions on the export of maize, while also attempting to boost maize imports (FAO, 2024). In sum, the impact of the 2024 dry spell had far-reaching consequences on the Zambian people.

2.3 Fall armyworm and crop diversification

The fall armyworm (FAW) is a pest species that has invaded sub-Saharan Africa since 2016. It has the ability to fly long distances, and the fact that it produces many eggs in a batch, has contributed to its rapid spread among its host plants. The pest is native to tropical and subtropical America, and is mainly attacking maize on a large scale, although it also attacks some grain crops and grasses. Since maize is widely grown and a significantly important staple crop in Zambia, the FAW invasion is endangering the country's food security (Baudron et al., 2019).

The FAW are voracious and cause great damage to the maize plant, including defoliation and stem damage. They live in the young leaves that form a leaf whorl, providing them with food as well as protection from the outside world. Hiding in the protected whorl makes them harder to combat with certain pest management strategies, like hand picking or spraying. (Akeme et al., 2021). The visible FAW damage depends on the stage of the crop growth and FAW age, as it feeds on the young vegetative and reproductive structures when the larvae are young, and on the cob when the larvae are mature and still present in the whorls. Thus, it has a twofold damage: the young plants will be stunted in growth, and the matured cobs are significantly windowed, which reduces maize quality and eventual yield (Acharya et al., 2020).

Since this pest came so rapidly and became a widespread issue, the initial response was to quickly start using extensive chemical pesticides as the main management strategy (Baudron et al., 2019). However, this has detrimental effects on the natural environment, as well as the people living in it. Next to being harmful to human health, especially if there is limited access to protective clothing, the pesticides that are used are mostly working on a broad spectrum: meaning that they kill a wide variety of animals and insects, including the natural predators of the FAW (Harrison et al., 2019). Chemical pesticide reduces both the diversity and the abundance of insects, simplifying the agricultural landscape. This loss of biodiversity negatively impacts the functioning of biological control mechanisms, such as natural predators, to control pest populations (Jaworski et al., 2023). It is common for natural predators to be more negatively impacted by chemical pesticides than the pest the chemical means to combat (Harrison et al., 2019). Besides, the uncontrolled and over-application of pesticides exacerbate biodiversity loss. These issues ask for a combination of alternative approaches to manage the FAW (Harrison et al., 2019).

Ideally, chemical pesticides should be used only as a last means, when other strategies have failed to work. Crop diversification is an appealing alternative to regulate pests. These effects are mediated through both top-down and bottom-up mechanisms. Top-down control mechanisms include the predation by natural enemies. Bottom-up control mechanisms such as crop diversification, include the impact on the ability of the pest to select their host by interfering with their signals, increased crop resistance or tolerance, and reducing the cropping field's continuity. This can make the pest populations less dense (Jaworski et al., 2023).

Crop diversification brings other benefits too, such as diversifying the caloric intake away from maize being the sole or dominant food consumption of rural smallholder farmer households, as this can have a negative impact on their nutritional status. Legume-maize intercropping systems already exist throughout Southern Africa, though they are more commonly used on commercial farms than smallholder farms (Thierfelder et al., 2024). Strip cropping is a form of intercropping that arranges plants in a different layout than the more common single-row intercropping. With strip cropping, multiple, uniform rows of the different crops are planted in parallel strips, instead of single, alternating rows. Strip cropping has not been used much in Southern Africa; however, it has the potential to reduce issues concerned with single-row intercropping, such as reduced light interception by the legume. Therefore, it is expected to be better for crop yields of both crops within the strip cropping system (Thierfelder et al., 2024).

2.4 The SIFAZ project

The data collection for this thesis was done in on-farm trials from the Sustainable Intensification of Smallholder Farming Systems in Zambia (SIFAZ) project. SIFAZ is a project implemented by the International Maize and Wheat Improvement Center (CIMMYT), FAO, and the Zambian Ministry of Agriculture. The project is funded by the European Union. Considering issues surrounding agriculture in Zambia described in the previous subchapters, SIFAZ wanted to find suitable options for diversifying maize cropping systems that positively influence yields, and increase Zambian households' nutritional status. Its aim is:

> "to test, promote and enhance the uptake of sustainable intensification practices, including mechanization among smallholder farmers while fostering market linkages and creating an enabling environment for sustainable agriculture growth" (CIMMYT, 2023)

Within SIFAZ, CIMMYT is the body that designs the research components, such as trials, which are then implemented mainly by extension officers who work for the Zambian Ministry of Agriculture.

The crop diversification trials that I focus on in my thesis are one component of the overarching SIFAZ project. The goal of these trials was to see whether certain maize/legume crop diversification systems would lead to higher yields, higher gross benefits, higher energy and protein yield (Thierfelder et al., 2024). Reducing the pressure of FAW was not a specific aim of the SIFAZ project initially, but emerged later on, as the trials provided a good opportunity to study FAW damage in crop diversification.

The trials have been implemented since 2019 at four communities in the Southern and Eastern provinces of Zambia: Chinjala, Nyanje.1, Dumba, and Simaubi.

The trials were all hosted by farmers on their land, and fully managed by farmers during the cropping season. There was some supervision and assistance from extension officers from the Ministry of Agriculture, and CIMMYT staff, mostly during the planting and harvesting stages. CIMMYT staff comes by at a few points during the growing season to collect data on biophysical indicators.

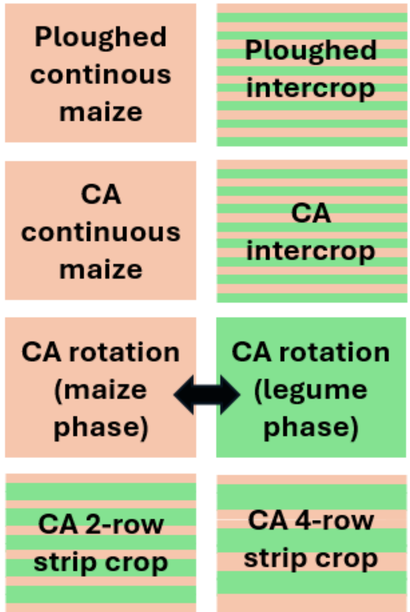

Figure 1: Set-up of the eight different treatments for SIFAZ mother trials hosts. Figure adapted from Chloe MacLaren with permission (2025)

This project used a mother-baby trial set-up, where the mother trial hosts contained one replicate with a setup of all the different cropping systems (eight in total, figure 1). The baby trial hosts selected a subset (two in total) of the eight, as their preferred options. This mother-baby set-up allows for the collection of a wide range of quantitative data regarding different technologies and research hypotheses, to be crosschecked with the baby trials that have different variable circumstances. This is meant to generate new insights among both farmers and researchers. In total there were 29 mother trials among the four communities (figure 3), where each mother had about 20-30 babies that they were overseeing and assisting. The mother farmers would provide knowledge and support for the baby farmers, while the baby farmers would come to the mother farmers to assist with planting, thereby also learning more about the different cropping systems.
People from the Ministry of Agriculture selected host farmers after community meetings where they spoke with a pool of farmers from the community. They then selected the host farmers based on whether they thought they showed a keen interest, and if they would be suitable to manage the trials for the duration of the project. The mother farmer hosts often had some kind of more prestigious role in the community, like chairperson or representatives.

The layout of the eight plots is shown in figure 1. Each plot is 10 by 10 meters, and the legumes are soybeans in the Eastern Province and groundnuts in the Southern Province. One trial replicate consists of a conventionally ploughed (CP) sole maize plot and a ploughed maize/legume intercrop of one alternating row each. In the ploughed plots, the soil preparation was done with a mouldboard plough, and crops were planted into the open lines ripped with the plough. Crop residues were removed after harvest on the CP plots. The other plots were based on Conservation Agriculture principles (CA), in this case CA management included minimum tillage practices. Each year, there was one glyphosate application before planting, and afterwards only manual weeding was done with hand hoes, and they left the maize crop residues to cover the soil after harvest. The sowing patterns included sole maize plot and a CA maize/legume intercrop of one alternating row each. The CA two-row strip crop consists of two rows of maize and three rows of legume, and the CA four-row strip crop consists of four rows of both maize and legume. The CA rotations have their own plot, and are rotated each cropping year (Thierfelder, et al., 2024). See figure 2 for an illustration of the crop diversification treatments.

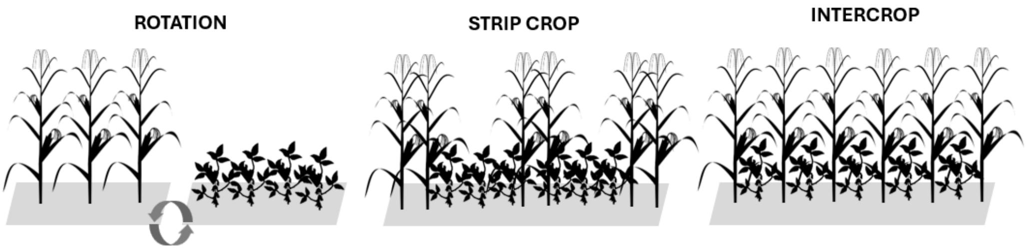

Figure 2: Crop diversification treatments: maize/legume rotation; 2-row strip crop; alternate row intercrop. Figure adapted from Chloe MacLaren with permission (2025)

SIFAZ provided an incentive for the farmers to participate by giving them free inputs for the trials each year, including seeds, fertilizer, glyphosate (to clear weeds in the CA treatment before planting), and pesticide (in limited amounts, to limit overuse). They were given cypermethrin in the first four years of the trials to manage FAW. This year they switched to emamectin benzoate to prevent the FAW developing resistance to the cypermethrin, preventing reducing the pesticide efficiency. The farmers were instructed about application rates and methods during community awareness meetings. Extension officers were also making sure that they are not over-or underapplying, but the farmers are free to use leftover pesticides on their own field, if they had not sprayed all of it on the trials. In terms of fertiliser use, they are given the recommended rates for urea and D-compound from the Zambian government (Thierfelder et al., 2024). This is more than smallholders typically can access and afford, which could lead to the yield from the trials being more than what they yield from the rest of their farm. Similar to the provided pesticides, they are allowed to use leftover fertilizer on their other fields too. The farmers get to keep the harvest themselves to sell or consume.

An important aspect to note of the trials is that they were set up to be precisely consistent among participating farmers. When conducting on-farm trials, the aim is to assess how well a technology works under real-life conditions. As opposed to a research station, on-farm conditions are more variable, considering factors such as soil fertility, water availability, pests, diseases, weeds, as well as labour dynamics (Chambers & Ghildyal, 1985). In order to find variability among participating farmers, it was important for SIFAZ that the experimental set-up was consistent across the trials. The idea is that this should help isolate the effect of the innovation, preventing that the conclusions drawn are based on variables that they do not want to study. In the end, understanding the range of outcomes under real-life conditions, helps understand how these technologies are implemented and can be improved for further research.

I linked up with SIFAZ for this thesis because these trials provided an interesting case study, to explore how farmers relate to these new cropping techniques, the FAW, as well as exploring the dynamics between farmers and extension officers/researchers. The opportunity to spend time working in the field, getting hands-on experience within the farms of the farmers that I collected my data with, was very valuable to my understanding of their context. The data collection for this thesis was funded by LEG4DEV (Legume-based agroecological intensification of maize and cassava cropping systems in Sub-Saharan Africa for water-food-energy nexus sustainability, nutritional security & livelihood resilience), which was acquired through my research colleague from SLU/CIMMYT. For logistical reasons and having access to the field, I joined other researchers associated with the SIFAZ project: a SLU/CIMMYT researcher looking at plant interactions, and a CIMMYT PhD student looking at soil properties. The PhD researcher that was with us during fieldwork, who has worked in this area for a long time, was the link between me and the extension officer. We visited the mother trial farmers during field trips in the four communities together. This means that there were various research needs that needed to be fulfilled during the field trips. I wanted to do interviews and FGDs (Focus Group Discussions), while there was also biophysical data that needed to be collected, such as soil moisture content, and pest damage. During the field trips, I was also assisting the researchers with their biophysical data collection on the fields, providing opportunity for me to really relate to the trials as well, even if only for these moments of data collection. The interviews and FGDs were only executed in the two communities in Eastern province, as marked on figure 3.

Figure 3: Map showing the locations in Zambia of the communities that host the SIFAZ diversification trial sites. Figure adapted from Chloe MacLaren with permission (2025)

This chapter has sketched out the context of Zambian maize farming, the issue FAW poses to maize farmers, and how crop diversification can be a potentially useful mechanism for sustainable pest management. It also discusses the SIFAZ project where the research of this thesis took place. The following chapter elaborates on agricultural development and relevant theories flowing forth from the context as discussed before.

3. Theories and concepts

The body of literature that studies topics surrounding FAW management seems to focus on one of two angles. Studies like the one done by (Waiswa et al., 2025) explore what socio-psychological factors influence the intention to adopt push-and-pull pest management strategies of smallholder farmers in East-Africa. A similar type of study done by Asante et al. (2025) in Ghana about intentions to adopt integrated pest management practices for FAW, using a standardized questionnaire method to describe how farmers' past experiences influence their adoption behaviour. These studies are rooted in deficit knowledge centred approaches such as the Theory of Planned Behaviour. This type of theory perpetuates the narrative that farmers do not adopt things because they lack knowledge. These studies implicate that the solution is to develop new kinds of farmer trainings to generate more positive attitudes towards the solutions developed by scientists. This does not adequately reflect contextual complexities of farmer realities, and does not include broader systemic constraints farmers face. In a similar vein, farmer's perceptions and knowledge of the FAW are studied, such as in the study done by Tabe-Ojong & Nyam (2025) with smallholder maize farmers Kenya, using farm household survey methods. This type of study provides insights into farmers experiences, their knowledge about FAW, and the ways they manage FAW. However, it does not link them back to the previously mentioned complexities and systemic constraints, and again reduces these factors to behaviour only.

On the other hand, there are studies trying to develop technical solutions to manage FAW, such as breeding pest-resistant maize to reduce losses (Kumar et al., 2025), but these miss this context altogether. At most, they might mention that their technical solutions need to be adapted to local contexts, but do not adequately reflect on what that means or what it would look like. This seems to be a commonality in these described studies. What lacks acknowledgement is how research can contextualize and co-develop technologies with the people they are meant to help: the farmers. Technologies that scientists believe to have much potential, do not automatically lead to farmer diffusion and adoption. Their traits and characteristics, combined with the heterogeneity among smallholder farmers, are only some of the characteristics that impact adoption. It is important to think about how complex this technology is, whose constraints are addressed, and how they fit into real-life farmer experiences (Rogers, 1983; Chambers et al., 1989). There are tensions between researchers and farmers with on-farm experiments (Maat & Glover, 2012). Trials done on-farm might not actually give the farmers real insights to evaluate the applicability for them. At the same time, agronomic findings can skew predictions of results away from how the farmer would take up the new technology on their own farm (Macours, 2019). Experimentation is highly important in both farming as well as agronomic science (Maat & Glover, 2012). Agronomic experiments can provide valuable knowledge for scientists on how agricultural treatments work in variable environments (Toffolini & Jeuffroy, 2022; Maat & Glover, 2012). On one hand, the rising movement of on-farm experiments, veering away from the research station, has led to an increased focus on farmer's practices (Toffolini & Jeuffroy, 2022). However, because of the way on-farm experiments are often structured, this leads to dynamics that influence the flow of information, knowledge and technology, in a top-down way (Chambers et al., 1989; Maat & Glover, 2012). Where researchers want to obtain rigorous data, using analytical methods and statistics, farmers want less elaborate, but reliable information that they can use to improve their farming practices. (Maat & Glover, 2012). These aspects must be incorporated in the generation and diffusion of technologies, which means aligning research needs with farmers' needs, and reversing the top-down approach. It is a complicated task to address the complex interplay of challenges that farmers face by coming up with technical solutions (Macours, 2019).

3.1 Diffusion of Innovations theory (Everett Rogers)

The Diffusion of Innovations (DOI) theory by Everett Rogers (1983) provides a foundational lens that helps to explain how and at what rate new ideas and technologies spread within a society or community. Please note that I used the words "innovation" and "technology" to describe similar concepts throughout this thesis. However, they can be distinguished, as "innovation" was used to describe a broader idea or practice that is perceived as new to certain people. While "technology" was used to describe a subset of the innovation, the more tangible and technical part, such as the crop diversification methods. Rogers describes technologies as consisting of a hardware component: the tangible or physical objects of the tool, and the software component: the knowledge or information base of the tool (Rogers, 1983, p. 232). In the context of rural agricultural development, the DOI theory offers insights into how farmers become aware of, evaluate, and potentially adopt new agricultural practices. Rogers grew up on a farm and studied agriculture for his undergraduate degree, and he found that although there were new technologies emerging that could potentially improve their farming system were available, his family was not adopting these. This started his curiosity as to why farmers do not adopt agricultural innovations, despite the potential they have. He researched the characteristics of the diffusion process, which led him to write the first version of his DOI book (McGrath & Zell, 2001).

Rogers defines diffusion as having four main elements: "diffusion is the process by which (1) an *innovation* (2) is *communicated* through certain *channels* (3) *over time* (4) among the members of a *social system*" (Rogers, 1983, p. 10). Diffusion rates depend on many different factors. When the Green Revolution started introducing new crop varieties and fertilizers, and pesticides, extensive diffusion efforts were made, and sometimes succeeded. However, once the detrimental effects of for example pesticides were discovered some years later, the idea to use fewer pesticides diffused much more slowly. At times, diffusion efforts are difficult to undo once initiated, and they can exacerbate or cause new issues (McGrath & Zell, 2001).

As mentioned in Rogers' book (1983), one of the most cited examples of diffusion studies is the study done by Ryan and Gross in 1943 on how hybrid corn has diffused in Iowa. This new variety brought higher yields, had better tolerance to drought, and was more suited for machine harvesting. This adoption comes with a change in behaviour, as previously, farmers would save their seeds each season, but since hybrid seeds lose their vigour after one year, they need to be purchased again. The type of farmers influenced adoption characteristics: initial adopters had larger farms and wealth. Even still, it took about five years for the adoption in the communities to even rise above 10 percent, so why did some farmers take 13 years to start adopting hybrid maize, even though most of their neighbours were doing it? (Rogers, 1983). This illustrated a need for understanding the context of potential adopters and how they relate to an innovation.

Another more recent example of the application of DOI within the African smallholder farmer context, is the adoption of radical terraces in Rwanda, which explores terracing landscaping technology to improve cultivation practices and reduce soil erosion for smallholders. Researchers studied farmers in the Nyamagabe district using individual interviews and field observation techniques. They analysed the data using concepts of the Attributes of Innovations by Rogers (1983), which are characterised as; relative advantage, compatibility, complexity, trialability, observability. These Attributes are used to discuss and explain how the adoption and diffusion of this technology relates to the characteristics of the innovation. They found that there is a complex interplay of factors, positively correlated to farmers' perception of the relative advantage of the new technology, and the compatibility of its characteristics with existing socio-cultural values and beliefs. At the same time, the study advocates for bottom-up participation from the farmers in designing an implementation of new practices, to foster more effective adoption and diffusion (Murwanashyaka et al., 2022).

For my theoretical framework, I will use the first element of diffusion as a theoretical concept, the *innovation* itself. Exploring the innovation element gives the opportunity to analyse what farmers have expressed about the way that they themselves relate to the technologies. It helps to break down how farmers have related to the cropping systems brought to them by SIFAZ, and explores what influences their adoption decision-making processes. The innovation element consists of five attributes: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 1983, p. 211). The relative advantage attribute discusses whether the innovation is better than what it supersedes, and whether it is perceived as advantageous. The compatibility attribute examines whether the innovation is consistent with the existing socio-cultural beliefs and values, previously introduced ideas, and needs of potential adopters. Complexity explores the degree of complexity of an innovation, how difficult to understand and use it is: the more complex it is, the slower the adoption rate will be. The trialability attribute is the extent to which adopters can experiment with an innovation during the trial phase. The last attribute, observability, takes into account in what way the results of an innovation are visible to other potential adopters. When it is easier for observers to see the results of an innovation, it stimulates adoption faster (Rogers, 1983). It is not only these attributes that influence adoption, but they assist in explaining adoption rates (Rogers, 1983).

3.2 Farmer First

To build further on the DOI framework, it is important to not only look at the innovation itself, but reflect on the processes of the trials were designed and implemented, and to contextualize it in the broader scheme of agricultural research with resource-poor farmers. This is where the Farmer First (FF) movement from Chambers (1989) comes in. It challenges the standard "Transfer of Technology (ToT) pipeline model", which is characterised by new technologies being developed only by researchers themselves in controlled conditions, then to diffuse straight to farmers, with no room for bottom-up knowledge. The FF movement advocates for more bottom-up knowledge production and development, asking questions about how scientists see farmers and vice versa, and whether newly developed technologies are stemming from a supply push from research or a demand pull from farmers (Chambers, 1989).

There are different kinds of misalignment between farmers and science. Farmers' research is not necessarily grounded in rigid scientific methodologies, but rather based on context and lessons from the past. Chambers mentions an example from Watts (1983) to illustrate how the ways of thinking are distinct. In this example, farmers in northern Nigeria were observed to make a series of adjustments to their farming system as they were battling the consequences of a drought. As a result, they planted a variety of crop mixes that can adapt better to the circumstances and resources that have changed, using back-up crops as insurance. Here, the scientist likely interpreted that the crop mix was predetermined, as if the farmer has prepared for a risk of drought and therefore selected these crops. But in reality, it is an adaptation, a result of lack of rainfall. Farmer's decision-making is often a result of what has happened to them in the past on their land in a specific time period, rather than trying to implement a general ecological theory of mixing cropping species. This illustrates how researchers, their priorities based in replicating and comparing trials and experiments, can be looking at the wrong things, in this case combinational logic in intercropping. Whereas the farmer's priorities were adapting and adjusting innovations to their conditions based on plant performance (Chambers et al., 1989). Within agricultural research, scientists seem to think that they already know what farmers need, more so than the farmers know themselves. This leads to them not understanding farmers and addressing the wrong problems in their research. It is necessary to identify farmer's needs and agendas, and help to meet these. An important aspect of this is to legitimize their knowledge and facilitate experimentation. Then putting the farmer first will lead to innovations that are actually being adopted (Chambers et al., 1989).

Chambers and Ghildyal (1985) further expand on these issues in contrasting the standard ToT model with the Farmers-First-and-Last (FFL) model. When new technologies are developed in isolated, stable, and controlled conditions, they are assumed to simply diffuse to farmers. Meaning there is a straight, one-way pipeline of knowledge going from research to farmer. However, this often does not fit their needs and social, economic, or cultural conditions. This relates to the compatibility attribute in the DOI. An agricultural technology developed on a research centre, with fertile soils, perhaps irrigated, easy access to seeds and other inputs, little labour constraints, provides a very different environment than the one smallholder farmers face. Moreover, the goals in agricultural research are also often misaligned: where a smallholder farmer prioritizes market prices, food production and sustenance, these needs and socio-economic factors deciding these needs are not comparable to those conditions of the research centre. The needs and environments of smallholder farmers are complex and interrelated with many different factors. Next to that, the ToT model does not stimulate learning from the farmers, who are meant to benefit from these technologies (Chambers & Ghildyal, 1985).

Chambers and Ghildyal (1985) present the FFL model as an approach to start defining research priorities based on systematically understanding the farmers and their farming systems, rather than what the researchers prioritise. The technologies are meant to be developed to serve farmers, starting and ending with the farmer. This can be a mix of several methods, such as rapid appraisal used in the Sondeo method (Chambers & Ghildyal, 1985). Here, a multidisciplinary team, usually including agronomists, socio-economists, anthropologists, and plant scientists, first quickly collect information about agro-socioeconomic situations of the farmers, restrictions they face, and their farming systems. This team visits the area, working in pairs and changing every day, interviewing farmers to collect this information and then discuss every evening to learn what every pair has found. Then, they brainstorm together about what is needed. The input from these appraisals is then used to propose technologies for on-farm and with-farm trials. (Hildebrand, 1981). This gives a more contextualised understanding of what kind of technology should be generated. The last stage in FFL is reflecting on and evaluating whether the technology actually gets adopted in the end. Arguably, this is more likely to be successful once the analysis has started with the farmers, using methods such as rapid appraisals, rather than a top-down ToT (Chambers & Ghildyal, 1985).

Chambers mentions an example from a study that uses participatory methods to validate technologies, having farmers and researcher work together on designing crop trials that work for them. These farmers were situated in the highlands of Peru, and their largest bottleneck was high labour intensity. Members of the community had comparable high labour demands at the same times, their remoteness not providing availability for getting external paid labour. The researchers had group sessions with the farmers in which they together defined the problems that they wanted to tackle, then designed experiments together, implemented them together and evaluated results together. It was important for the researchers to understand factors such as the labour dynamics, as well as labour divisions between gender and age. When these factors were understood, and farmer's objections to earlier versions of the on-farm crop experiments in regards to maximizing land and minimizing labour were heard, it resulted in modifications of the trials until the farmers felt confident in executing the experiments. This example shows that farmers participation is necessary in order to develop technologies that fit the farmer's contextual methods, allowing them to make assessments and evaluations that might be different from science's (Chambers & Ghildyal, 1985).

3.2.1 Social learning (Stone)

In addition to the FF framework, it is important to consider aspects of knowledge and learning, to help better understand farmer's decision-making processes. Stone's (2016) typology of learning discusses environmental, social, and didactic learning. Environmental learning is characterised by learning through experimentation and observation. Stone argues that farmers experiment all the time, but their experimenting realities are not well-understood, as they are characterised as “too complex, dynamic, and uncontrollable for effective experimentation” (Stone, 2016). For example, ecological factors are difficult to control and vary a lot spatially. So are economic factors that drive many decisions, as they are dynamic and change over time. Stone’s arguments are echoed by Chambers & Ghildyal (1985), who advocate for drawing up research priorities by starting off with understanding the farmers and their farming systems. Moreover, experiments conducted on-farm means that the production of knowledge is dependent on farmer’s actual livelihoods. This poses risks to them, as experiments can fail, and they are the ones who have to face the consequences (Stone, 2016).

The second type of learning Stone (2016) describes is social learning. In social learning, farmers base decisions not just on what they observe environmentally, but on social standards: emulating decisions based on the behaviour and status of others, who they perceive as successful or knowledgeable. Lastly, didactic learning refers to learning through instructions that are brought by external parties, such as extension officers or research organisations. This is often driven a different type of agenda, and off-farm interests. When there is less possibility for environmental learning, farmers rely more on social or didactic learning (Stone, 2016). Stone and Chambers ideas both suggest a rethinking of didactic learning, promoting farmer’s own experimentation and adaptation to their context, rather than a one-way ToT, and being sensitive to social and environmental learning dynamics.

3.3 Mobilising the theories

For this study, a combination of the DOI Attributes and FF was chosen to understand how the SIFAZ farmers related to FAW, the new technologies, and how agro-socio-cultural factors and development actors facilitated or hindered the adoption of agroecological crop diversification strategies. I regard these as complementary concepts in this thesis. The DOI framework provides a primary examination of farmers’ experiences with FAW and the cropping systems implemented under SIFAZ. The five key Attributes of Innovations: relative advantage, compatibility, complexity, trialability, and observability, provide a conceptual tool for exploring their experience with FAW, the SIFAZ trials, their challenges, as well as some factors that facilitated or restricted adoption that farmers have described in their experience. Using the Attributes of Innovations as a base framework, lays the foundation for a more critical reflection upon the design of the trials. This includes the role of the SIFAZ project organisation. If only DOI was used, critical mechanisms of organisational dynamics and agricultural research processes would be missed. Therefore, I used FF to offer a meta-perspective on what has been laid out in the Attributes analysis, by shedding light on the complex interplay of dynamics between farmers and researchers. This provided a way of analysing and explaining a more comprehensive and nuanced understanding of the disconnect between farmer's and research's needs. I used FF concepts such as putting the farmer in the light of the experimenter, and analysing systemic constraints, as well as the organisation's dynamics and barriers to learning. To complement this, I use Stone's learning typology as an extension of FF, to unpack how farmers learn in practice. By integrating these three theories, the analysis of my data goes beyond only asking whether how innovations were adopted or rejected, but also whose needs and contexts those innovations serve, and where potential for improvement lies.

4. Methodology

4.1 Research design

This thesis uses qualitative data to critically examine how the experiences surrounding FAW and agroecological pest management is constructed, as well as how farmers adopt these methods, and which barriers and processes there are that influence adoption. The main research questions shaped the research design are: "How do smallholder maize farmers in eastern Zambia perceive and adapt to the threat of the fall armyworm? And how does this shape their engagement with agroecological pest management innovations?In order to answer these questions, data had to be collected on farmers experience with the FAW and its management practices, and their assessment of the on-farm trails, including what they liked, disliked, and which constraints they faced. Next to that, data regarding how the trials align with their culture and values was collected. This data is placed in a critical reflection of how Farmer First participatory approaches can better support the design of innovations to improve FAW management more sustainably. While extension officers and researchers are part of the research setting, in this case they are not treated as primary subjects of analysis. Rather, their role is examined partly through literature by Chambers et al., 1989, as well as through how farmers describe and respond to their advice and interventions.

The data was collected through in-depth, semi-structured interviews, which help in creating a space for clear and direct information exchange (Creswell & Creswell, 2018). I then later conducted two FGDs, which consisted of various drawing and discussion exercises. These are a valuable supplement to individual interviews, since they give different information that emerges from participant-led discussions. The participants give insights by discussing their opinions with each other, coming to collective answers; something that one-on-one interviews do not offer. It also provided the opportunity to dive deeper into topics that were not completely covered in the interviews.

The interviews took place in the first two weeks of February, and the FGDs took place in the last week of March. This is within the cropping season of maize. The interviews took place while the crops were still relatively young, and the FGDs took place closer to harvesting maturity. Within this timeframe, FAW is also very active, therefore simultaneously, data regarding FAW damage was collected, as part of my fieldwork consisted of assisting with colleagues' fieldwork, biophysical data collection on the trials. This provided a good addition to my understanding of the context, and an opportunity for me to relate to the trials in my own way.

I formulated my own questions for the open-ended interviews and FGDs, which I led, with the help of an interpreter. This ensured that I could follow up on specific points or ask more about topics that were not originally included in the interview guide. It was valuable to have an interview guide as a base to make working with the interpreter easier. As mentioned by Creswell & Creswell (2018), the interpreter acts as a 'cultural broker': facilitating, listening, and bridging between me and the farmer in a dynamic way. They help to build trust and to clarify other extra-linguistic cues. Those, we briefly discussed after the interviews and FGDs took place, although I did not quite manage to capture as much insights on these cues as I would have been interested to. There are various aspects to consider regarding the data, as there were be biases towards languages and ease of contact. The language bias went threefold: neither the interpreter nor me spoke our mother tongue, our communal language being English, which increased the risk of misinterpretation. There was also the risk that the interpreter did not always speak the exact language of the farmer either, which adds another layer of potential misinterpretation. I felt like my interpreter and I were to some extent misaligned in the level of detail that was important to capture in the interviews and FGDs. This probably contributed to some simplification of questions and answers, not capturing the full essence, but rather summarized and less nuanced results. Despite my efforts in trying to communicate the importance of catching the more descriptive and colouring answers, more details did not always come forth. Then again, it is not clear whether this was lost in the translating process, or whether the farmers also did not see need to further elaborate on their answers.

4.2 Research context

All farmers for the qualitative studies were either mother or baby trial farmers under SIFAZ. My focus here lies on the farmer's experience of the FAW and the trials themselves. The farmers I did my research with, seemed to be mostly small sized and farm for subsistence as well as sales. The sample size for the interviews was made up of 7 Mother trial hosts in Chinjala and 4 mother trial hosts in Nyanje.1. In total, 4 female and 7 male farmers were interviewed. Chinjala and Nyanje.1 fall within the same climatic region, and have the legume type soybean. Since I was limited by certain circumstances, such as the ease of moving around, budget, and dependence on an interpreter, we had the interpreter present to help me with 11 interviews in both Chinjala and Nyanje.1, in the Eastern Province, and two FGDs in Chinjala. The PhD soil researcher that was with us during fieldwork, who has worked in this area for a long time, was the link between me and the extension officer. He contacted the farmers to see if they were available and arranged the interviews for me. Both these districts were visited twice, with one month between visits, which gave the opportunity to reflect and use the impressions from the first visit as input for the FGDs. Perhaps in the meantime, participants could have also spoken to each other about my research and maybe developed certain ideas themselves. Over which I did not have control, but this could also have influenced the FGDs.

4.3 Study site selection

My interviews happened in tandem with the ongoing SIFAZ project. The research took place on the farms of the farmers from communities in the Eastern Province in Chinjala and Nyanje.1 (See figure 1). Through interviewing farmers in their own surroundings where they exist on a daily basis, where they probably feel more comfortable than in other places, brings the benefit that the I had the opportunity to also include ex-interview queues, notes on the environment (physical and spatial), and non-verbal cues during the interview itself. These notes were included in field notes, which complemented the qualitative data.
As I was doing fieldwork with colleagues from CIMMYT, the selection of the study sites was made with all our different aims and research needs in mind. Important to my data collection, the Eastern province was selected with the characteristic of the languages of interpreter and the farmer were most similar. This is the province where we spent the most time altogether and had the most opportunity to reach enough participants for interviews and FGDs. Next to that, to reduce diversity within the interviews and FGDs and have more relatable understanding of differences and commonalities between farmers, it was also of importance that they were within the same climatic region and grew soybean as the legume.

For the other researchers, it was important that the trials looked good- in terms of factors such as crop stand, and how well they followed the trial's instructions- in order for them to collect reliable biophysical data. Factors like ease of access to the land by road and foot, and memory of last year's visits of whose trials were well managed, played a part in the selection. However, these factors taken into consideration, might have biased my sample group to participants who seem to be comparatively successful, and their socioeconomic context is more suited to benefit from the trials. These farmers are likely wealthier and better connected. The study therefore did not give insights into those who are, for whatever reason, not managing it well. It is important to note that there are two different layers of bias here; first of all, the selection of farmers to participate in SIFAZ, which was not within our control. Secondly, our selection of which farmers to execute the research, likely being the more engaged and better-off farmers. In the Chipata district, all the mother trials in that area were interviewed, who were all relatively accessible. In Nyanje.1, four mother trials were interviewed, who might have had more accessible land than others. The accessibility by vehicle was needed for the other research needs as well, which required equipment to be taken into the fields.

Therefore, overall conclusions that will be drawn about these farmers are limited by these biases.

For the FGDs, there was a mix of mother trial hosts and baby trials, who the extension officer selected. However, some mother trial hosts weren't able to make it to the FGD due to family issues and therefore sent a representative, which also might have biased the discussion in a certain way if they were less involved with the mother trials themselves.

4.4 Reflexivity

Here, I reflect on myself and my values, and how they could have influenced the research process. What I have learned during my university studies in agriculture and rural development will have shaped the way that I saw the farmers, before even meeting them. Being a white, Northern European, female researcher, means I have a position of being an outsider to this research context in rural Zambia. This fieldwork trip was my first time outside of Europe, giving me the opportunity for first impressions, as I did not have many formulated expectations set in mind. But the privileges I carry, including having access to funding and educational institutions, were not equally available to my participants in the same way. This could have influenced how the participants in my data collection have felt comfortable to express themselves to me. Perhaps the male participants felt even less comfortable doing so than the women, because of cultural dynamics. I only got small snippets into their life while visiting them, as we stayed in lodges in nearby towns instead of at the communities, meaning I could not fully immerse myself in their context during this time. However, I still learned a lot by speaking with them, as well as with my interpreter and local colleagues.

I think a major impact on my research is the fact that I came with the CIMMYT colleagues in their car, and helped my colleagues with data collection too, which probably caused the participants to think that I was working for this organisation. This became clear when sometimes participants would ask me to change things in their situation, or bring something for them from CIMMYT, even though I had no influence over this. I tried to make this clear at the start of each session, that I was just a university student, but maybe the message was not completely understood. Next to that, I did not speak the languages of the participants, even though some of them spoke English, the help of an interpreter was still needed. This made our conversations less direct, and will also have contributed to me interpreting certain expressions according to my understanding, which might not have been exactly the same as what they were trying to convey. On the other hand, the benefit of the presence of an interpreter was that the participant and the interpreter could more easily establish some rapport, which could have made them more comfortable in the setting with me.

4.5 Methods

4.5.1 Individual interviews

Before the interview, I made sure that the interviewee knew what my research was about and why I would like to speak to them. I asked if they were okay with the interview taking around one hour, how the data is managed, and how I will anonymize them. I anonymized my participants by creating a pseudonym for each farmer, consisting of the letter "F" for farmer and a number between 1-11. My interpreter spoke Chewa with the interviewees. Some of the interviews were conducted primarily in English, with some help where English was not satisfactory to express ourselves, and a few interviews were completely conducted in Chewa.

The interviews took between 45 minutes to 1 hour and 20 minutes. I recorded the interviews on my phone, for which I made sure to get verbal consent, and later transcribed them on my laptop. The transcribing was initially done perfect verbatim, but as this took a lot of time, I switched to more summarised, but still complete transcribing. I sometimes had to ask the interpreter for clarification on certain things that were said or other non-verbal queues. Next to that, I also kept my notebook with me, as a complement to recording. The field notes were taken based on observations during the interview but also about the farms/fields and dynamics between farmers/researchers/myself. Additionally, as recommended by Creswell & Creswell (2018), I took notes during the interviews, in case of faulty equipment, or the recordings not being audible.

4.5.2 Focus Group Discussions

During my interviews, I gained knowledge on how smallholder maize farmers in the Eastern province of Zambia perceive FAW. However, in order to gain a more comprehensive understanding of other factors that influence their adoption of and contribution to agroecological pest management practices, I wanted to conduct a few activities in FGDs. I led two FGDs, which consisted of a mix of 6-10 participants, both mother and baby farmers, but separated into one male and one female group. This was done to homogenise the groups, to try and provide a space for the participants to share comfortably, with less influence of gender biases and power dynamics that decide whdo speaks and about what. These were conducted partly in English, with my interpreter translating in Chewa. The sessions were recorded on a recording device, which were re-listened to later to give more details to the notes that were taken during the session.

Focus groups provide space for having conversations that are led by the participants, rather than mainly decided by the interviewer. This makes for a process that gives the participants more agency in which topics emerge, giving valuable and wider information on how people think, and their decision-making processes. It stimulates people to discuss with each other, explaining themselves, which produces different kinds of data than semi-structured interviews do, where they only answer the question to the interviewer. In the FGDs, I asked them to discuss, rank, and draw, facilitating interactive discussions. As well as going beyond individual opinions, FGDs facilitate coming up with a sort of collective narrative on the research topics. (Hennink, 2014, p.3). I wanted to find out what prevents farmers from- and drives them to implement these practices from SIFAZ, as well as their knowledge and communication dynamics, and which solutions they see to the challenges they face.

In the first activity, the farmers were asked to rank their challenges on the farm (most to least important, incl. pests, water, soil fertility...), which were then ranked in a top 10 from most (1) to least (10) important. Then, they were asked come up with a selection of their favourite trial systems, as well as a ranking of the positives and negatives about this favourite trial system. The aim of this activity was to find out if their challenges mostly related to pests or which issues are more important, as well as what drives and prevents them from implementing their 'favourite' trial systems.

The second activity consisted of each farmer drawing a map of their whole farm and dividing stickers to divide between fields based on where the FAW damage was most problematic. The aim was to deepen the understanding and perception of the pest and discussing their issues with each other, as well as explaining why they think the damage is worse on some fields compared to others. This activity was omitted in the female FGD due to running overtime.

In the third activity, the farmers were asked about their social network in order to come up with a map of who is involved and how knowledge flows. The aim was to understand how farmers share knowledge and whom they turn to for advice on agroecological pest management, in order to find social and cultural factors that influence their decision-making and adoption.

4.6 Data analysis

I drew on Creswell & Creswell's (2018, p. 267) data analysis procedures to break the analysis down into digestible steps. First, I transcribed the interviews that I recorded on my phone, and included a separate section for field notes. The FGDs were recorded with a recording device, and I took notes during the sessions. My interpreter later went back and revised notes, elaborating on some sections. This data was sorted in separate documents per interview and FGD. The transcripts were named with the pseudonyms I created for each farmer, such as F1, F2, – F11. The transcribed material was then read through in total, to get a sense of what has been said and get first impressions of what the information means. I made notes of direct quotes that were useful for complementing the themes and findings later on.

I used the QDA software ATLAS.ti as a coding tool. Inductive coding was used, because I wanted to see the commonalities between the farmers first, instead of predetermining the narrative, as described in Robson and McCartan (2016). The process for identifying patterns and (sub-)themes is iterative (Robson & McCartan, 2016). I manually went through the transcripts to iteratively edit, add or remove codes, and make sense of the themes that were found. Throughout my study, themes and theories were 'emergent'; they develop and can be defined and re-defined as the data is being collected and analysed. Therefore, the codes and themes I created mostly emerged from data, but were also theoretically informed by the DOI and FF frameworks, cycling back and forth between the coding of data and using theories. The DOI's Attributes of Innovations served as guiding concepts to coding the challenges farmers faced. Some examples of codes are 'labour constraints', 'inputs', or 'droughts'. Concepts from FF were used to find themes related to knowledge, and the dynamics between the research organisation and farmers. I started with a simplified content analysis of the codes, looking at the frequency of certain codes, words and important concepts, that help to see trends in what has been said, and what language is used between the respondents. I then did a thematic analysis, summarizing the codes in code groups, which helped to find themes that keep coming up in the data. This served as a guide for what was important to focus on in the interpretation. To represent the description and themes in the interpretation, I used Everett Rogers' DOI theory, and the Farmer First approach by Robert Chambers, and Stone's learning typology to guide my interpretation and findings. I used DOI as a conceptual tool for exploring farmer's experiences with FAW, the SIFAZ trials, their challenges, as well as factors that facilitated or restricted adoption. I used Farmer First concepts as an analytical lens to explore role of farmers as innovators and experimenters, and how unnoticed farmer constraints and risks lead to limited adoption. The role of SIFAZ and barriers to participatory learning are analysed through the FF model to critique the ToT model. The results based on these theories show that the importance of context-sensitive, participatory forms of agricultural research, which could support more meaningful engagement and learning.

5. Empirical findings and discussion I: Diffusion of innovations

This chapter describes on the farmer level how these new practices, as presented to them by SIFAZ, were experienced. This includes challenges, needs, and what they liked and disliked. After having worked with this system myself, since I was assisting with fieldwork/data collection on the trials, I was able to relate to the technology in my own way, which made me question how the farmers experience these techniques. I use the five Attributes of Innovations from the DOI book by Rogers (1983) to discuss how the farmers perceived these technologies and how their characteristics align with the farmer's values and needs. It explores barriers in terms of compatibility, complexity, trialability, and how they diffuse within the community. Please note that some farmers use the word "demo" when they speak about the "trials", these can be regarded synonymously.

5.1 Relative advantage

The first attribute discusses whether the innovation is better than what it supersedes, and whether it is perceived as advantageous. Relative advantage includes: "the degree of economic profitability, low initial cost, a decrease in discomfort, a savings in time and effort, and the immediacy of the reward" (Rogers, 1983, p. 217). It does not matter if the technology has a great deal of 'objective' advantage, what matters is whether an individual perceives the innovation as advantageous: to which degree this new idea is better than existing practice. (Rogers, 1983, p. 217).

I asked the farmers what their main goal in participating in the trials was, and there were a few topics that kept on returning. Some farmers mentioned that they want to change the community, improve yields and achieve food security for everyone, reduce hunger and poverty. They want others in the community to learn the benefits of crop diversification, so that they have more capital to buy their inputs, like seeds and fertilizer, and other needs like food and their children's school fees.

> "I would want this kind of thing to be applied by everybody, every farmer. Once this is done, then there can be no hunger." (F5)

> "Yield is the most important reason. Because I get soyabeans, and I also even get maize. Legumes I can sell to vendors, maize I can have for food security." (F6)

Another reason for them to participate was wanting to get rid of the FAW, with which they seemed to have varied experiences:

> "Before the armyworm, things were okay, we were having a good yields. Ever since the armyworm came, they're destroying everything." (F10)

> "For the armyworms, they normally come every year, so we spray - we know they'll come. We still spray and we control them. Whether we do intercropping or we do whatever, they still come.." (F7)

> "Armyworms, it is very challenging to avoid them. Yeah, because the only tricky part is the plots where we don't do intercropping. There it's a challenge." (F6)

> "Actually, the armyworm it is able to be controlled. Not with the termites, termites you can't control because it's down in the soil." (F6)

Farmers perceived some benefits in using various intercropping techniques, such as improving yields and reducing pests. Out of these, the four-row strip crop was mentioned most often as the most preferred. In regards to crop rotation, farmers generally did not seem to have strong opinions, a few mentioned that the FAW damage seems to be slightly worse when implementing crop rotation. Many of them have seen that there is more FAW damage where there is sole maize, and less where there is a form of intercropping with soybeans or groundnuts. They expressed that they get better yields, the maize grows better, the soil is enriched with nutrients, and the pest damage is less severe. It is important to bring nuance here, as this is likely also due to the access to fertilisers and pesticides that SIFAZ is providing, and might not only be due to diversification.

> "There are more yields on the demo than other parts of the farm. On just these small plots, yields are better for soyabean and maize. It's a lot that we get compared to the rest of the farm." (F10)

They also expressed the advantage of having a more diverse harvest, yielding two different crops in the same field, which was perceived as beneficial compared to having single crops. Because they produce more yield, some say it's "double profit" as compared to having one crop in the field.

> "We use a small place, but we're harvesting two crops. I like it, because if I can manage to cultivate, let's say one hectare with four lines soyabeans, and four lines maize. Then it will give me less time, less labour, because I will be working on two crops at the same time." (F3)

According to Rogers, incentives can act as one of the initial triggers to increase the rate of adoption, since it increases the innovation's relative advantage (Rogers, 1983). SIFAZ provided an economical incentive for the farmers by giving them inputs such as seeds, fertilizer, and pesticide for these trials for free, in return for the effort they put into maintaining these plots. The farmers therefore get a low initial cost to try out these techniques and they get to keep the harvest, next to a few crops that are taken for sampling. This could have contributed to an increase in their perception as a relative advantage. However, this leaves questions about the sustainability of the innovations later on, since when the SIFAZ project ends, farmers seem to be concerned about the long-term feasibility of continuing crop diversification techniques without the inputs from SIFAZ. The sales of crops from the trial plots gives them money to use to buy fertilizer or seeds for next year, but this will be a lost income after the project ends. Therefore, if the farmers are adopting these technologies partly because they receive free inputs, there might be less motivation to continue using the techniques after the project ends and when they need to purchase their own inputs. Moreover, I got the impression that because they get these inputs that are different from what they use in their regular farming, they cannot really imagine that what they are taught in these trials can be reproduced on other parts of their farm, without the exact replica of inputs. As if it is an isolated system where the inputs are the factor that makes it work, instead of it being techniques that they can adapt to their farming context.

For the sake of the trials, during these five years they also need to maintain plots that don't work well, in terms of plant growth or pest damage. This is because it is important for the researchers to see the variable differences in practice. However, farmers cannot change this, because the trials need to be exact replicas on all the participating farms. This can be discouraging, and it is not enjoyable for the farmers not to have good yields but still have to put in time and labour to maintain those plots.

5.2 Compatibility

The second attribute, compatibility, examines whether the innovation is consistent with the existing socio-cultural beliefs and values, previously introduced ideas, and needs of potential adopters. The more the practice resembles existing methods (e.g., spacing, timing, inputs, cultural values), the easier it is to adopt (Rogers, 1983, p. 225.)

The technology uses crops which the farmers were already familiar with growing, maize is a common staple food, and most of them also had experience growing groundnuts or soybeans. Only two farmers had mentioned that they had done some single-row intercropping before SIFAZ came. However, they were not familiar with the crop spacing in some of the trial plots, presenting a challenge. The four-row strip crop was mentioned by most as being the preferred system, which resembled existing crop spacing more. This resemblance makes it easier to understand. It was said to provide good yields, as well as less FAW damage. In the two-row strip crop however, there were many different spacing measurements which had to be measured precisely, which confused the farmers. It makes sense from a trial point of view that it needs to be replicable and the same amongst all the famers in order to get accurate data, but it was often mentioned as a challenge for the farmers. Some farmers use oxen to rip the lines and said it is difficult to get them to do perfectly straight lines. Especially if there's an extension officer who is perhaps not as available during the planting days, it is prone to cause mistakes in the measurements of the spacing. Consequently, since the farmers are pressured to do all of this perfectly, and being monitored for it, they get discouraged from extending the technologies to other fields. Since the trials are designed in such a rigid way, they feel like they cannot put in the effort of getting such exact spacing on a larger scale, suggesting it is not that compatible with their values and needs, and a lack of prior needs assessment. It is likely that this has slowed down the rate of adoption (chapter 6).

A few farmers mentioned that inputs would sometimes come late for them to plant, causing a negative impact on yields. Normally, they would have planted already when the conditions were right, so they have little autonomy in that way. Additionally, some had expressed that the seeds they receive are maturing too early, so they would rather receive late-maturing varieties. This is due to problems mentioned regarding crop theft, which was brought up during the focus group discussion. When their crops are the first within the area to mature, it is more likely that neighbours can come and steal their crops, as that makes them an easy target. Whereas when their crops are maturing later, it is less likely that they will get stolen. This issue was exacerbated last year due to the drought, when there was a lot of hunger in the area. This illustrates that these kinds of social factors are of great importance for farmer's decision-making processes and needs.

Within the discussion around labour, the issue of weeding came up many times. Many farmers considered weeding a challenge, because they felt like the labour on weeding the trials was more time-consuming than what they usually need to maintain their regular fields. Narrow row spacing makes it more difficult to weed in the lines properly, and increases the risk to damage crops while weeding, especially when the plants are young. Since the herbicides they generally use cannot be sprayed in the intercropping systems, weeding is done manually, multiple times per season.

However, not all farmers viewed weeding in the trials negatively:

> "In terms of working, it is very nice because once I'm weeding for soyabeans, I also weed for maize, I weed at the same time two crops. I don't spread my time between fields." (F3)

I found it interesting that one of the farmers was theorizing about the interactions between weeds and pests, suggesting that the weeds might protect the maize from FAW attacks. Which was something he wanted to investigate himself too:

> “The amount of weeds helps pest damage, because those fall armyworms don’t only feed on maize. If there's this grass, you're going to see fall armyworm there instead on the maize. Yeah, I think these weeds, they're playing another role which we don't know. I’m also a researcher.“ (F2)

This theory could link to scientific literature around push-pull technologies, as certain grasses are found to be effective trap plants for FAW. The trap crop lures pests away from the main crop by providing an alternative host crop, in this case a grass variety, which would reduce the damage on maize (Cheruiyot et al., 2021). In contrast, another farmer suggested the presence of weeds increases pest issues:

> “Sometimes when there are a lot of weeds, the weeds bring the armyworm. But now because there are no weeds here, I’m wondering why the pests are a lot.” (F10)

These contrasting perspectives highlight the complexity of farmer knowledge systems and the need for adaptive agronomic strategies that consider local observations and beliefs.

5.2.1 Use of pesticides

Here, I explore the compatibility of pesticide use with the existing socio-cultural beliefs and values, existing ideas, and needs of the farmers. Pesticides seem to be the most favourable way to manage the FAW among the interviewees. In the past years, literature has shown that chemical pesticides are used as the primary FAW control method in Zambian smallholder farmer contexts (Kasoma et al., 2021; Durocher-Granger, et al., 2023). Since smallholder farmers can have difficulties accessing pesticides reliably, they also come up with alternative solutions by creating their own pesticide. They make pastes using things like washing powder, however, this can be damaging for the plants (Kasoma et al., 2021). The cultural pest control methods used in the Chinjala and Nyanje communities were named as: applying washing powder or ash on the leaves, putting soil in the leaf whorl, spraying a tobacco leaf extract or chili extract, and handpicking the FAW. Next to pesticides and cultural methods, sometimes they just hope for heavy rains to come and wash pests away.

Most of the interviewed farmers find pesticides to be more effective, although it doesn’t get rid of the FAW completely. Cultural methods are said to involve a lot more labour, because it requires scouting all the fields, and this is generally less effective than using pesticides. Spraying pesticides is more seen as a method to rapidly act on FAW early on, whereas with cultural methods the FAW is being treated when it is spotted. This means that there will already be signs of damage on the plant, leading to more damage in the end, compared to when spraying pesticides. The cultural methods are mainly used as a last resort, when farmers don’t have access to pesticides. The farmers in the communities said that they have to share the pesticide spraying equipment among each other. I asked one farmer who expressed a lot of discontentment with waiting for the shared pesticide sprayer, if she uses cultural methods while waiting, but she said she would rather wait for the sprayer than use other methods. The sharing of the equipment makes it more difficult to apply pesticide when it is urgently needed:

> "It's a challenge because we are sharing one machine for spraying. So by the time it reaches your turn, the damage would have been caused already." (F8)

One farmer had even mentioned that when it was his turn to receive the sprayer, unknowingly, somebody had used another chemical in the sprayer, which affected his crops. It was mentioned by a few that SIFAZ doesn't give them enough pesticides to efficiently combat the FAW. Even though they are expressing gratitude that they receive this pesticide for free, it's not enough, especially when sharing the spraying machine. If they run out of pesticide, they need to find other ways of accessing pesticides, either through other government-coordinated initiatives or buy it themselves, which is difficult when they are resource-constrained. I could also imagine that maybe more powerful or prestigious farmers have an easier time to access these pesticides that others have.

It became clear how indispensable pesticides have become to these farmers. When I asked one farmer what he thought would happen if they wouldn't spray pesticide at all, he said:

> "It would be a disaster. Yeah, it would be a disaster. There would be hunger." (F5)

Most of the farmers expressed that they did not have protective clothing. Even though SIFAZ says that the equipment was provided to them, as it is mandatory under the Zambian Environmental Management Agency, it is unclear how the farmers ended up without it. Most farmers could not afford to buy their own gloves, facemasks, gumboots and overalls, since they are expensive. Farmers had mentioned issues with skin burning, lung problems and headaches. Some stressed the importance of following the directions on the bottle, since even there it says protective clothes are needed but they don't have these. Despite these farmers being well aware of health hazards, they are not able to obtain the right protection.

When I asked a farmer if he saw beneficial insects on his farm next to harmful insects like FAW, he mentioned that sometimes when they spray pesticides they see them. He said that because they spray pesticides on all their field, it meant that the beneficial insects are killed as well, which he found was a very bad thing. Some farmers expressed that they saw beneficial insects that come and eat the FAW. A few mentioned that birds come and eat the FAW off the plant that are visible. Someone said he scouts the fields and when he sees a lot of beneficial insects, he won't spray because it would kill the bees that help them. Others mentioned beneficial insects like hoverflies and ants that attack the FAW. When asked whether they think that pesticides also kill these beneficial insects, the responses varied a lot. Some said no, because they can fly and therefore will easily fly away when they smell a pesticide is being sprayed. One farmer said there's beneficial insects that might be helping, but you can only see them under a microscope. Another farmer even said that beneficial insects don't exist at all:

> "No. good insects- all insects are harmful, I don't know. In terms of pollination, I don't have those. Just the ones that are destroying, I have not seen the good ones." (F7)

In sum, not many had an understanding of damaging effects of pesticides for other insects, whereas the downsides of the human health aspect were more commonly mentioned. Again, these contrasting perspectives highlight the complexity of farmer knowledge systems and the need for adaptive agronomic strategies that compatible with local observations and beliefs.

5.3 Complexity

Complexity as an innovation characteristic explores degree of complexity of an innovation, how difficult to understand and use it is. This attribute is the one out of five of which a negative trend shows higher adoption rate. When ideas are perceived as harder, complex, difficult to master, it will slow down rate of adoption (Rogers, 1983, p. 230).

Many of the farmers had expressed that the first year participating in the SIFAZ trials posed a steep learning curve. Initially it was confusing and difficult for them to understand the new methods and to follow the instructions properly and precisely. Moreover, it seems they are not given much information about the *purpose* of different activities, which is significantly limiting to farmer learning and adoption (chapter 6). Some farmers expressed frustration or discouragement due to mistakes. These mistakes can lead to undesirable consequences:

> "The challenge was mostly at the beginning, because after teaching us, they [SIFAZ] gave us seeds. When the extension officers came to check, they found that we did it the wrong way. So we had to remove the seed from the soil because we made mistakes, and replant again. Now the challenge for me mainly was on two-row strip crop. Where I didn't understand the spacing." (F10)

Other farmers encountered different types of unexpected events. For example, one farmer in his first year was forced to prematurely harvest crops due to livestock raiding his field, before he received official authorization to harvest from SIFAZ. Although this was not attributed to difficulties with the trials themselves, it illustrates the vulnerability of the trials to external shocks. It is notable that the first year is a critical adaptation period. This learning phase is expected by the project though, for example, the biophysical data collected from the first year is not used because it is likely unreliable due to mistakes. As the farmers became more used to the trials, most farmers expressed that they had increased confidence and reduced labour intensity in the following years:

> "It's different from the first year when we started, it was difficult. We were spending much time in one plot. But this time because we are used to it now- Ah, no problem." (F3)

This quote shows that familiarity and routine reduces their perceived difficulty over time. Once farmers became more confident with the systems and saw that the results were promising, they were boosted in confidence and motivation. Out of all the challenges discussed with the farmers, the issue of labour was the most frequently mentioned.

> "It's quite involving sometimes because if we get people to remove the weeds, you have to be extra careful [compared to] the way we do the normal fields. [Or else they] end up cutting the plants. So most people avoid working here because they'll take longer time here than the normal fields." (F7)

Especially in the first year, farmers were saying that the labour demand was intense, having to understand new methods, and it requiring concentration to weed properly and to make sure the spacing is correct. Preparing and planting everything on the same day requires an intense concentration of labour. Some farmers rent out parts of their land in return for labour, or pay labourers. This is not always possible for resource-constrained farmers. Others with larger families rely more on family labour, particularly children.

> "So as compared to other areas, within the trials, the only labour involved is on planting That's where I see more labour as compared to other fields. However, I don't feel much impact particularly on the labour because I have many children to help me." (F10)

The trials are designed in such a way that some systems have two crops in close proximity in the same field, causing the use of herbicide to be restricted. This increases labour allocation to weeding:

> "The labour comes on weeding. That's the challenge we're facing, on weeding. The herbicides, the ones that you can put on maize, you cannot put on soyabeans. So the issue is weeding. And then planting as well. Can you go [and plant] according to the specifications? So weeding becomes a big challenge." (F6)

> "There's a lot of labour actually yes, because as I maybe go and remove weeds three times because I cannot spray weed killer. It's the maize that is next to the soyabeans [that can't be sprayed], or else the soyabeans would be damaged." (F11)

5.4 Trialability

The trialability attribute represents the degree to which adopters can experiment with an innovation. The more they can experiment with it, and if it is easy to see results, it makes an innovation less uncertain and can positively influence the rate of adoption (Rogers, 1983, p. 231).

The SIFAZ project provided an environment for doing these trials by offering free inputs during five growing seasons, so that they could experience the different techniques on a small scale, and can compare them to each other. They were able to observe that the four-row strip crop works well. It was commonly mentioned as their favourite, which is why some had tried it out on other fields. Six of the farmers I spoke to had mentioned that they were experimenting with the techniques on their own fields. One farmer was experimenting with lots of projects, for example, he saw on television that putting little dams on his field can stop soil erosion in his fields that are sloped. He also tried some small experiments with fertilizers and leaving more diverse weeds instead of weeding everything. He started this on a small scale, one acre or less. This illustrates that it is key for these farmers to see things with their own eyes before investing a lot in it. He ended his discussion about his experiments by proudly calling himself a researcher and compared himself to researchers from SIFAZ. Some farmers had mentioned that they want to branch out to other crops as well, a few mentioned a wish for having fruit orchards. A few others had experimented with replacing the type of crops, using the intercropping taught by SIFAZ in their fields, outside of the trial boundaries:

> "Because I'm also experimenting, you [SIFAZ] have taught me to do the experimentation. So I'm doing also things on experimental basis. Because we have not done it before. So I'm saying: what if I do this, instead of soybeans, I put the ordinary beans. I want to see the outcome from there." (F5)

In the early stages of adoption, trialability is more important than later on. Late adopters will already have adopters to look to as examples, confirming that it can be worth adopting (Rogers, 1983). Therefore, it is important to stimulate trialability and experimentation. Some want to do that and are capable of doing so, even if it is on a small scale at first. However, these techniques were given in a rigid way with rules to be followed precisely, not leaving space for farmers to experiment more with this themselves with a low risk. There is a tension between scientists' intention to have controlled trials to compare treatments, versus giving farmers space to experiment with the technologies (chapter 6).

Other shocks also prevent farmers from implementing crop diversification on other fields, some farmers had sick family members for which they had to leave the countryside often, limiting the capacity to implement something new.

> "This year, I haven't done it because here I was a bit disturbed, my husband had experienced a stroke. So most of the times, I live in town. So that's why I haven't done it now, but last season, I did [four-row intercrop] in the whole field. But when you are not there, you can't take care of a demo properly." (F3)

Insecurity is also connected to changing weather conditions and reoccurring droughts, where farmers perceive it risky to try out new farming methods.

> "I just started experimenting with intercropping on a field last year. But because of the drought, all the beans died, and we didn't harvest. There is a lot of destruction, and these droughts will continue. It gives us a lot of problems, so we need to adapt" (F5)

Drought and unpredictable rainfall were often mentioned as critical challenges that threatened the viability of the trial plots, as well as their general farming. In 2024 there was a big dry spell, which caused the farmers to lose most, if not all of their harvest. They often don't have access to accurate weather information, so for example if a dry spell comes earlier, the plants will not germinate, which means they would have to plant again. Since their farms are rain-fed, there is no other way for them to get water for their crops. The farmers who had tried to extend parts of the trials, like the four-row intercrop, mentioned that they suffered a lot from the drought.

> "This season I haven't tried it because last season I was affected by the drought, everything that I had planted didn't grow." (F1)

> "When the crops are still very, very tender. That's when the fall armyworm attack. We do spray the chemicals to overcome them. But like last year, I think we had a lot of worms infestation. A *lot* of them. Because there was this drought." (F5)

Farmers mentioned that they particularly had even worse issues with the FAW last year because of the drought. This climate stress caused not only a loss in yield, but also discouraged many farmers from adopting the crop diversification systems on other parts of their fields again this season after experiencing severe yield loss the year before.

5.5 Observability

The last attribute, observability, considers in what way the results of an innovation are visible to other potential adopters. This attribute therefore also connects to the trialability attribute. Some innovations are easier to observe and communicate than others. Rogers characterises technologies consisting of two components: a hardware component: the tangible or physical objects of the tool, and the software component: the knowledge or information base of the tool (Rogers, 1983, p. 232). Applying this metaphor, the software are the principles and knowledge on which these are based. The trial plots themselves are the hardware component. Having trial plots near roads and villages allowed people in the same area to observe physical results easily. They can see how well the crops grow, or how the FAW damage looks. Next to that, the field days organized by the extension officers increased community-wide exposure physical exposure, as even farmers not participating in SIFAZ take part in them.

The observability is a goal of the SIFAZ that the farmers also appreciate. This farmer emphasized how important it was to him that he put the trial on an easily accessible and observable location:

> "I took a central area for the trials. So that anyone can learn. Yes, so many, many people in those who are just passing here. We are teaching them, they ask some questions. Yeah, so if I would have done it near the farm, it would be like I hide it. I want it to be exposed. Because in this demo, I have 25 baby farmers. It's a training school. The class without walls." (F2)

The idea of having a 'class without walls' reflects on the hardware observability providing a space for informal learning by physical visibility. However, only having a good hardware observability component is not enough for accelerating widespread adoption. If other farmers only observe what has been done in terms of planting, they will not understand the knowledge base of this technology simply by observing. The software component seems to be lacking, as even the mother farmers themselves do not really seem to have information on the underlying principles of using strip cropping or CA techniques, and how they would affect FAW damage. This risks that adoption is misinformed, leading to poor understanding and therefore ineffective or limited adoption.

Moreover, the type of farmers that were selected to be mothers, were often the more well-off and more accessible farmers. The farmers who have less resources were not selected because SIFAZ would want to minimize risk not being able to collect the data that they need, reinforcing the thought that they view the farmers more instrumentally. Next to that, the trial mothers are to inspire others to try out these technologies, but this can lead to discrepancies in the applicability for farmers who don't possess these characteristics - who have less resources, more marginal land, more vulnerable to climate change. Learning how this would work out on their own farms only by observing, will be riskier and it won't be an accurate copy-paste from what they observed from the mothers. Especially when the principles are not understood (chapter 6.3).

6. Empirical findings and discussion II: Farmer first

This section reflects on the role of agricultural research in serving the needs of rural smallholder farmers. I would like to preface this by saying that I only interviewed farmers, therefore I only know what they have told me about their experiences, and I am not aware of exactly what research has been done prior to the project implementation. People from the Ministry of Agriculture selected farmers based on whether they thought they would be suitable to manage the trials. Still, the farmer's narratives consistently portrayed that they were 'just picked', implicating they were not explicitly consulted on their priorities or needs, but rather if they would manage to work with the readily designed trials. I asked a farmer how the selection process went:

> "Some questions we were asked: 'Are you going to manage? Have you got enough land? Is your land titled?' Once this project starts, it can stay for four or five years, because they don't need somebody who does not have his own farm. 'If you're going to be selected, it will be there for years and years. So if you think you can't, please tell us, so we can pick another person.' So I fulfilled the criteria so I was picked." (F6)

This illustrates the starting point of why the way the project has interacted with farmers is not facilitating learning or diffusion. As discussed in the Farmers First book by Chambers et al. (1989), farmers often lack secure access to purchased inputs and navigate substantial risks. Under these conditions, there are limits to the extent their needs can be met by conventional research. Non-adoption is not because of ignorance, or farm-level constraints, but because the technology is at fault, which needs to be traced back to the disconnected priorities and processes which generate it. Transfer of technology has been the default model, where priorities are defined by technical scientists, who generate innovations on research stations, then transferring them through extension services. In Farmer First, this process is reversed, where it starts with knowledge, problems, analysis and priorities of farmers – making the farm the main centre of action (Chambers et al., 1989).

6.1 Farmers as innovators and experimenters

Historically, farmers are innovators and experimenters, continuously adapting the crops that they grow and finding better ways to grow them (Chambers et al., 1989; Maat & Glover, 2012). This does not necessarily need to align with the type of criteria that scientists typically use to make decisions, but they are rather contextual. Scientists usually generate packages, while what resource-poor farmers rather need is a "basket of choices", that helps them adapt to their circumstances (Chambers et al., 1989, p.3). As Chambers et al. (1989, p.3) word it: "Farmers are professional specialists in survival, but their skills and knowledge have yet to be recognized. When farmers are seen in this light, as experimenters and innovators, it provides space for them to be seen in a way that their innovation, knowledge and research can be appreciated." The farmers I interviewed have expressed that they take pride in being researchers.

> "Those crops you see, we didn't add any fertilizer, because we wanted to see, if we can harvest without adding any chemicals? We are doing this because we are also researching ourselves. I also want to experiment with using animal manure. However, with SIFAZ we have to follow protocols. So we can't for example add animal manure. That is something I'd like to change, because I am also a researcher." (F2)

Their innovative and experimenting capacity is also illustrated by the multitude of cultural pest management methods that they use. Something I found striking was after an interview, a farmer was asking me "but why do you come here to learn from us? You are the one that has all the knowledge, we are just simple and poor farmers". This illustrates that the narrative that farmers identify with, is that their knowledge is less legitimate than scientists' in creating experiments.

There is a big gap between farmer and scientist as we know them, which is a gap we need to close. Scientists have specific goals in mind and the results of these goals need to be practical and rigid. While farmers have less room for investigation, especially if only driven by personal interest (Chambers et al., 1989).

> "I tried more experiments the past years, but when my husband became sick, we went to town, you know, when you are not there, you can't take care of it properly." (F3)

As a result of experiment's missing farmer's context, the farmer who is supposed to benefit from a new technology and get their problems solved, will still not experience improvements. This disconnect in the common approach will then lead to the conclusions of extension services being poor and farmers being backwards (Chambers et al., 1989).

6.2 Systemic constraints: labour, inputs, and risk

Chambers argues that ignoring farmer constraints (like labour) leads to poor adoption of externally designed innovations. This aligns with Rogers' emphasis on compatibility and complexity affecting diffusion, as described in the previous chapter. Innovations must fit into farmers' *realities*, not idealized ones. By farmers expressing and emphasizing their challenges surrounding labour, they indicate an important point that was overlooked by the scientists: that it is difficult for farmers to keep up with these plots that are so large and complicated, and the high labour demand, mostly regarding weeding.

> "So on the trials there's much labour and we have to be careful- we have to concentrate, we have to make sure the inputs are correct. But on our farms, we don't put that much labour as compared to the labour on the trials." (F1)

> "I used to work with my children, but they've all left. Now, we are only having some tenants who assist us. We have given them portions [of our land] where they can do their farming. In exchange for the labour that they give us." (F5)

Procedures for testing need to be modified to be less extensive when it is resource poor farmers have to do the actual labour and management. Chambers et al. (1989) mention an example of an experiment with selection of new rice varieties, where they involved whole villages to avoid bias in selecting individual, well-off farmers. The villages were all characterised as resource poor. They reduced the labour requirement by dividing the experiment among the whole village, while also giving them freedom to practice the same level of management in the trials as they used to on their own farms with their local varieties. The rationale behind this was, that if a new crop variety can provide better yield under realistic conditions, the farmers would not have to change their management for the sake of the trial. This resulted in a much quicker than usual release of a new and appropriate variety, as it has been tested with resource-poor farmers first, under their own conditions (Chambers et al.,1989). This is a constructive example of a technology that has addressed systemic constraints and fits it into farmer realities. The SIFAZ trials have lacked taking this into account in the trial set-up. Interestingly, these labour constraint issues have indeed become known to the researchers involved in the SIFAZ trials, as they mention it in the Thierfelder et al. paper about the trials (2024). They acknowledge that labour constraints could have influenced farmer preferences and adoption, but only mention that they should therefore implement animal mechanization to reduce labour burdens, rather than critically reflecting on the fact that they were designed with little regard to labour constraints in the first place.

Farmer realities are made up of many interplaying challenges and risks, illustrated by the exercise I did during the FGDs, where I asked them to come up with their main farming challenges. I asked them to come up with challenges not only related to the trials, but surrounding their farming in general. They then ranked them, and explained why they ranked them this way. As illustrated in table 1, they have various challenges they face, next to the threat from pests. The female group emphasised the labour constraints, that having so much manual labour is heavy, next to other tasks they need to keep up with. There is overall a lack of machinery and labour available for them to help with the labour burden. Next to that, they expressed having little capital to buy inputs, and having issues with soil fertility. The male group stressed the threat of droughts and barriers to accessing weather information as a big issue. The issue of crop theft was also brought up, as the community faced significant food insecurity after last year's drought, making theft more common. This illustrates how farmer realities are very complex, and need to be understood to come up with innovations that can target their needs.

Table 1: Overview of farming challenges ranked in male and female FGDs

Ranking	*Male FGD*	*Female FGD*
1	**Irregular rainfall patterns**, impacting yield	**Lack of capital** to buy inputs
2	**Lack of capital** to buy inputs	**FAW** and other pests
3	**Crop theft**, especially after last year's drought	**Little access to machinery,** manual labour is exhausting and slow
4	**Accessing information** about weather, to anticipate planting times	**Irregular rainfall patterns**, impacting yield
5	**FAW** damage has been getting worse	**Soil fertility**, challenges with accessing fertilizer
6	**Land fragmentation**, dividing land between children as the family grows	**Lack of external labour availability**

Another important systemic constraint is that risk and losses are not equally shared but placed on farmers rather than the researchers, such as livestock damage and poor yields. It is important to allocate funds to absorb research risks (Braun, Thiele, & Fernandez, 2000). Farmers should be financially compensated for incurred losses related to the trials.

The project targets smallholder farmers who are already better off than some of their neighbors, and if the project expands, poorer farmers will face even greater risks. One of these significant risks is climate change (chapter 2.2). After the drought of 2024, one million hectares of maize was lost, which caused one million households to be food insecure in Zambia. Combined with the food price inflation, and weak currency, this has caused a severely negative impact on it people's livelihoods (FAO, 2024). This has affected the trade-offs SIFAZ farmers made in trying out the techniques on other fields, and their capacity to experiment.

> "Last year, we had a drought. Soya didn't survive. I emulated some of SIFAZ techniques and nothing survived. Instead of 25 bags, we harvested 12 bags of maize. I would like to do the strip cropping techniques again, but first I have to see that the weather has normalized." (F2)

Resource poor farmers are always wanting to minimize risk in poorly controlled and unfavourable environments. The contrasts between research experiment stations and farmers are big, as the stations have generally more reliable access to seed, credit, labour, than resource-poor farmers. Next to that, farmer's main priorities are food production and minimising risk, not getting good statistical data (Chambers & Ghildyal, 1985). The fact that there is already so much heterogeneity within the group of farmers within the group of mother farmers, illustrates the need for understanding farmers complexities and risks prior to developing and diffusing technologies.

6.3 The role of SIFAZ and barriers to participatory learning

The process of the design of the trials has illustrated a barrier to participatory learning. Innovations were not truly co-produced: they were trialled on farmers' land, but not designed with farmers in decision-making roles. From the organisation's perspective, the intention was that co-development would happen after the on-farm testing of the cropping systems. They expected to then combine feedback from the farmers with findings based on the biophysical data that was collected, to refine the cropping systems for future research. The current treatments were selected as they were considered interesting to test according to the researchers. Even though the research agenda was well-intentioned, undermining farmer's knowledge reflects the standard ToT model. Since farmer's knowledge was not taken into account in the development process, the organisation positioned them as implementers, not collaborators. As farmers are made to follow exact protocols, there is no opportunity to adapt the practices to their own contexts. Moreover, there appear to be limited feedback loops to the farmers, as the results of the data that gets collected by researchers on their farms are not shared with farmers. This may be due to there being an interplay of different actors communicating with the farmers, such as CIMMYT and the extension officers. Therefore, it might not be clear internally who is responsible for this type of communication and feedback, or it is not seen as a priority. Furthermore, the rationale behind the new innovations seem to not be well explained to the farmers, which limits their true understanding of the rationale behind innovations, and therefore also the potential for true learning and long-term adoption. Rather than judging a successful technology diffusion only as adoption or non-adoption, it is more important to foster and understand mechanisms of local modification and adaptation of technologies (Glover et al., 2019)

Many farmers expressed that they want to learn from SIFAZ, and how interesting they would find it to hear their results from the data they come to collect. At the same time, some expressed how much they enjoy and value teaching/learning with others, but this is not facilitated with a top-down approach, giving them the least power in this hierarchy. For example, this cropping year, one researcher decided to stop farmers applying fertilizer on a few rows of each treatment, but did not seem to explain to the farmers why this was, therefore not giving them the opportunity to learn.

> "We were instructed not to use fertilizer on this portion. I don't know what the purpose was, I need to learn from you!" (F5)

This farmer is interested in learning but seems like he cannot ask the questions he would like answered, and this got echoed by other farmers, which leaves to wonder how much has been shared before and during trial implementation. As worded by Chambers et al., (1989, p.18), "Farmers need to know the intentions and reasons for the trials, this gives them a basis to assess them constructively rather than simply either accepting or rejecting the technology". This also gives the opportunity for critique and improvements, leading to trials being designed in a way that is more catered to their needs. Such as the case study mentioned before in chapter 3.2 of the farmers highlands of Peru, their largest bottleneck was found to be high labour intensity, but this was overcome by participatory collaboration and trial design.

Another example previously mentioned is that farmers have to share the pesticide sprayer, but SIFAZ doesn't seem to know about these dynamics illustrates less voice for farmers.

> "We are given one sprayer. With the mothers and even the babies we share. By the time the sprayer is coming back, most of the crops are damaged. Because of sharing the spraying machine." (F4)

This could be linked again to the fact that there is a long and hierarchical chain of communication in SIFAZ. CIMMYT designs the research components, but these are implemented mostly by extension officers who work for the Ministry of Agriculture. This was an issue brought up in the women farmer's focus group, they expressed that the process of reaching extension officers directly was difficult. Especially for the baby farmers, they have to go first to the mother farmers, who contact the camp officer, who then contacts the extension officer. Therefore, when SIFAZ farmers have questions and concerns, they are not that easily and quickly connected with someone that is able to hear and help them. This also relates to the structure of development funding that measures indicators of success which do not cover aspects of human and social capital. If indicators of success included these kinds of human and social aspects, development funding could contribute to giving farmers more agency in the long run (Ton et al., 2015).

Farmer-farmer extension is also not something that should be underestimated as a knowledge source, they constantly observe and look at what their neighbours are doing, which is demonstrated by the fact that even some other farmers that were not part of the mother-baby initiatives were trying out strip cropping on small scales. These neighbours also attend the field days even though they're not part of it.

This relates to the different types of learning that Stone discusses in his 2016 paper. Environmental learning, where one observes and bases decisions on the payoff of information gained through experimenting, is not the only type of learning relevant here. Environmental learning in pest management is tricky, as farmers do not always possess knowledge about specific insects, as shown in chapter 5.2 of this thesis. Farmers showed to have mixed understanding of insects, illustrated by the varied responses regarding pesticide use and beneficial insects. Some said pesticides do not kill beneficial insects because they would just fly away, others said they do not see them at all, or they do not even exist. Next to that, some farmers theorized about observing the impact of weeds on the FAW, some said they helped, others said they made the damage worse. Environmental learning goes beyond just observability, in particular when the effects of the technology change through time. For example, when the trials were impeded by the drought from the 2024 season, showing a different pest damage variability from the years before, which cannot fully be explained by only observing other farmers. Next to that, the farmers might not be able to distinguish between FAW damage and other pest damage, impeding environmental learning. Environmental learning has a high risk of leading to maladaptation (Stone, 2016). This also connects back to the hardware and software components of technologies that Rogers (1983) describes. Only having a good hardware observability component, the 'class without walls', is not enough for accelerating effective adoption. If other farmers only observe through environmental learning what has been done in terms of planting, they will not understand the knowledge base of this technology. If the software component is lacking, as even the mother farmers themselves do not really seem to have information on the underlying principles of using strip cropping or CA techniques, can lead to poor understanding and misinformed adoption.

Social learning is the second type of learning that comes into play here. The internal motivation to try something new, like the neighbor farmers trying the technologies despite not participating in SIFAZ, will not only have been based on the results of the experiments observed, but also social factors. For example, observing the status of the farmer, or the 'social group' of SIFAZ farmers as a whole, as well as what these people have said about SIFAZ, can contribute to a decision of adoption. Emulating local trends or prestigious people makes farmers feel like they have some type of safety net and a point of reference, by basing their adoption on the people perceived as successful. (Stone, 2016). But since the project targets smallholder farmers who are already better off than some of their neigbours, if the project expands, poorer farmers will face even greater risks. Mother farmers have expressed neighbours had frequently shown interested and asked questions about the trials, and they are happy to share and teach. Their main motivation expressed as "because we benefited, we want others to benefit, so we make sure to give the farmers who ask clear information so that they can also benefit". Again, this can be maladaptive, as poorer farmers do not face the similar socio-environmental-economic circumstances that farmers who have reaped high rewards from SIFAZ have.

Farmers will rely more on social or didactic learning when there is less possibility for environmental learning, for example due to incurred costs or inaccuracy of environmental learning (Stone, 2016). Didactic learning is learning derived from external parties that pursue their interests through instruction, demonstration and so on, such as the type of learning SIFAZ provides. The presence of serving own interests is apparent here, as the on-farm trials had an agenda of collecting data that also served SIFAZ and not necessarily the agenda of improving farmers' circumstances. Connecting this back to the Farmer First movement: the goal of agricultural programs should be to place didactic learning in the service of environmental learning and farmers interests and needs (Stone, 2016).

7. Conclusion

This thesis set out to explore how rural smallholder farmers from the SIFAZ project related to agroecological pest management strategies by means of on-farm trials, and understanding the challenges and constraints they face. This knowledge aimed to help contribute to long-term impacts of innovations for ecological pest management, to ensure that these are tailored to farmer's needs and capabilities.
In regards to the first research question, how smallholder maize farmers in communities in eastern Zambia perceive and adapt to the threat of FAW, a complex shaping of their experiences was revealed. They had different opinions on how severe of a problem the FAW was within the various challenges they encounter, and a multitude of pest management methods for FAW was shown. Next to that, they had different understandings of pests and beneficial insects, showing that environmental learning is complex. Farmers perceived some relative advantages of using intercropping, in particular the four-row strip crop as working well against FAW damage.
The second research question aimed to explore how their understanding shapes their engagement with agroecological pest management innovations, via the SIFAZ trials. Initially, I set out to study the perceptions of FAW and the crop diversification trials, but what emerged more importantly, was a big gap between farmer and researchers. A major challenge lies in the tension between the agenda of researchers - like having controlled trials to compare treatments - and what the farmers really need. While some farmers had the experience that the trials were somewhat compatible with their usual farming practices or previous intercropping experience, there were significant barriers present. Initially it was confusing and difficult for participating farmers to understand the new methods and to follow the instructions precisely. Except from that the trials were not sufficiently clearly described to the farmers, many farmers were labour constrained, and it was difficult for them to provide the extra labour needed to perform the trials in the way the researchers wanted. The main challenges from the trials were crop spacing, weeding, and labour demands.
A fundamental problem was that farmers social realties were not considered by the researchers. Innovations that seek to solve farmers' problems, must fit into farmers' realities, not idealized ones, being sensitive to the complexity and dynamics of their constraints like labour, crop theft, or droughts. Providing a "package of technologies" without regards to this will not provide a useful solution to the farmers. Learning and experimentation emerged as a particularly important issue. It seems the farmers were not given sufficient information about the purpose of different activities, which is significantly limiting to farmer learning and adoption. Farmers rely on different types of learning, didactic, environmental and social. It is important to stimulate farmer trialability and

experimentation, but since these techniques were introduced in a rigid way with rules to be followed precisely, there was no space for farmers to experiment more with this themselves. For the sake of the trials, during these five years, they also need to maintain plots that don’t work well. This is discouraging, as they still need to put labour and time into it, while not obtaining good yields. If early participation of farmers in the research design would have taken place, it would have led to the selection of more context sensitive project characteristics which may have otherwise been excluded by researchers working by themselves.

8. Recommendations

The need for a shift in the design, implementation, and communication surrounding research with farmer trials is evident. Based on my findings, I suggest future studies must clearly identify whether the primary goal is to get reliable and controlled scientific data, or to support farmers in improving their practices. If the emphasis is on scientific precision and rigidness, it might be better to perform aspects of the research on a research station. This type of research is valuable, but when executed on-farm, it treats farmers instrumentally. Making them passive participants rather than active co-experimenters who often bear the most of the risks and disadvantages in this scenario. If the main research goal is aimed at improving farmer's circumstances, these types of trials should be designed in a participatory manner from the outset. They must consider different types of farmer learning, where their own experimentation is encouraged, and making sure they financially safeguard them from risks if experiments go wrong. In order to have successful diffusion and adoption, participatory methods need to be studied and facilitated so trial designs would not be too complex, more culturally and context-sensitive, and taking into account locally available resources, labour capacities, and socio-economic situations. Rather than offering them a standard packaged technology, researchers and farmers should sit together to find solutions that are adaptable and work well for them. Researchers should prioritize to learn from farmers, rather than provide a top-down way of didactic learning according to their own research agenda. This process must also include clear communication about the intentions behind certain practices, and include the opportunity for non-restricted feedback mechanisms going both ways. Fostering farmer-to-farmer dissemination should also not be overlooked, as this can help in sharing observations, new practices, and inspiration. Reversing the ToT top-down model is essential to create space for truly mutual learning and stimulating experimentation. Taking this into account in future research, will help moving towards research processes that build effective resilience in the face of challenges like the FAW.

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Popular science summary

The fall armyworm (FAW) is a crop pest that threatens the production of staple crops such as maize across parts of Africa. Maize is widely grown and a significantly important staple crop in Zambia, where this study takes place. However, the FAW invasion is causing a threat to its people's food security. This study targeted rural smallholder maize farmers in two farming communities in Zambia's Eastern Province, who are affected by this pest. The farmers were participating in a network of on-farm trials that investigated crop diversification - growing maize alongside other crops, in this case legumes - as a means to reduce FAW damage, increase food security, nutrition, and income. By using crop diversity to tackle FAW, farmers can reduce the need for chemical pesticides, helping to protect the health of both farmers and the environment.

This study explored farmers' experiences with FAW, to understand how they relate to agroecological pest management strategies by means of the implemented on-farm trials. Farmers reported different opinions on how important the challenge of FAW was with respect to the various challenges they encountered. They use many pest management methods for FAW, including both pesticides and cultural methods. The understanding of pests and beneficial insects was also widely variable. The findings show that farmer learning is complex. Many farmers saw advantages to using crop diversification strategies, in particular the four-row strip crop as working well against FAW damage.

However, what stood out more importantly, was that there was a big gap between farmer and researchers. A major challenge lies in the tension between the research agenda of scientists, and what the farmers really need. Farmers social realties were not investigated by the researchers. Innovations that seek to solve farmers' problems, must fit into farmers' realities, being sensitive to the complexity and dynamics of their systemic constraints like labour, crop theft, or droughts. Farmer learning was limited in the on-farm trials, as farmers were not given sufficient information about the purpose of different activities. Providing a predetermined "package of technologies" without regards to farmer's social realities will not become useful to the farmers. Therefore, it is essential to move towards research processes that shift away from a top-down model, and advocate for bottom-up processes. This is essential to create space for truly mutual learning and facilitating useful farmer experimentation. Future research that takes this into account will help moving towards research processes that give farmers more power in the face of challenges such as the FAW.

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