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Why we should rethink 'adoption' in agricultural innovation: Empirical insights from Malawi

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Abstract

The challenges of land degradation, climate change and food insecurity have led to the introduction of conservation agriculture (CA) aimed at enhancing yield and soil quality. Despite positive biophysical results, low adoption rates have been the focus of studies identifying constraints to wider uptake. While the adoption framework is popular for measuring agricultural innovation, objective adoption measurements remain problematic and do not recognize the contextual and dynamic decision-making process. This study uses a technographic and participatory approach to move beyond the adoption framework and understand: (a) how agricultural decision-making takes place including the knowledge construction, (b) how agriculture is performed in a context of project intervention and (c) how practice adaptation plays out in the context of interacting knowledge. Findings confirm that farmer decision-making is dynamic, multidimensional and contextual. The common innovation diffusion model uses a theory of change, showcasing benefits through training lead farmers as community advocates and demonstration trials. Our study shows that the assumed model of technology transfer with reference to climate-smart agriculture interventions is not as linear and effective as assumed previously. We introduce four lenses that contribute to better understanding complex innovation dynamics: (a) social dynamics and information transfer, (b) contextual costs and benefits, (c) experience and risk aversion, and (d) practice adaptation. Investments should build on existing knowledge and farming systems including a focus on the dynamic decision process to support the 'scaling up, scaling out and scaling deep' agenda for sustainable agricultural innovations.

KEYWORDS

climate-smart agriculture, conservation agriculture, Malawi, no-tillage, scaling, southern Africa

1 | INTRODUCTION

To improve the resilience and adaptation of agriculture to climate change threats and land degradation, the Food and Agricultural Organization of the United Nations (FAO) proposed the climate-smart agriculture framework, of which conservation agriculture (CA) is widely

promoted across southern Africa (Lipper et al., 2014). CA is a set of technologies, based on three key principles: (a) minimum soil disturbance (no-tillage or zero-tillage); (b) soil surface cover with crop residues or cover crops; and (c) crop rotation or diversification with inter-cropping (FAO, 2015). It has been widely promoted as a land management practice to maintain and enhance soil quality and yields

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(Thierfelder et al., 2015). However, CA adoption rates in countries such as Malawi have remained low, with a reported 5–6% of the arable land farmed using CA (Kassam et al., 2019). This has been the subject of various studies measuring adoption, identifying adoption constraints and understanding dis-adoption (Chinseu et al., 2019; Ngwira et al., 2014; Thierfelder et al., 2015; Ward et al., 2018).

Agricultural innovations are often conceptualised as a technical package of practices, distributed to new areas with the help of instruction (Glover et al., 2017), with adoption rates representing a primary way of measuring success and impact of this distribution measured (Glover et al., 2016, 2019). The processes of adoption and diffusion, that is, expanding the use of the agricultural innovation, are often characterised as 'scaling'. However, recent literature has highlighted that scaling occurs across multiple levels and dimensions, which are not always considered (Sartas et al., 2020; Wigboldus et al., 2016). To acknowledge these multiple ways in which scaling can take place, specific scaling types have been defined: upscaling refers to extension of the innovation to higher levels (e.g., national), out-scaling to expansion within the same level (e.g., within the community) and deep scaling to a change in the mindset and culture (Moore et al., 2015; Schut et al., 2020). This 'scaling up, scaling out and scaling deep' discourse, a linear diffusion of innovation model, remains popular among development initiatives despite various critiques (Chambers et al., 1989; Glover, 2011). It is embedded in the idea that farmers mainly make individual yes or no decisions with a linear development of replacing old methods with new ones (Glover et al., 2016).

A broad literature on the diffusion of agricultural innovation recognises the importance of context and enabling conditions on shaping technology transfer and adoption dynamics (Whitfield et al., 2015; Zanello et al., 2016). Moreover, attention is required on the dynamic connection between the farmer and the system context, which co-evolve and adapt in relation to each other (Engler et al., 2019). Drawing on science and technology studies (STS), there is also an emergent critical response to simplistic narratives around the 'rational' adoption of successful technologies, highlighting the socially constructed and contested nature of agronomic knowledge (Sumberg, 2017). A focus on metrics of adoption overlooks the important processes and decision-making through which innovation happens on farms and may miss out on considering the prerequisite conditions (Sumberg, 2005), namely if the technology is needed and suitable to potential users and local contexts. It also fails to recognise the multiple ways in which farmers do not simply adopt, but continually experiment with and adapt technologies to these contexts (Whitfield, 2015). Therefore, both technology implementation constraints, and the ways in which farmers engage with these constraints, also termed tinkering (Higgins et al., 2017), are contextual and heterogeneous.

Objective measuring of CA adoption remains problematic (Andersson & D'Souza, 2014; Giller et al., 2015) due to the definition of practices that constitute CA and the spatial (e.g., area covered), quality (e.g., how many principles of what) and temporal (e.g., how many seasons) thresholds when it 'counts' as adoption. For example, a systematic review has shown that few papers discussing technology adoption adequately define what adoption is (Loevinsohn et al., 2013). Therefore, questions

have been raised in terms of the validity of adoption statements (Andersson & D'Souza, 2014; Brown et al., 2017; Giller et al., 2015).

Recent studies have also called for exploring the adaptation of CA to agro-ecological and socio-economic contexts of the targeted smallholder farmers to increase the CA uptake (Brown et al., 2018b, 2018a; Thierfelder et al., 2015). In order to 'measure' adoption, the question of 'what is CA' is important and often found to be challenging (e.g., land size, time, all practices) ranging from technical definitions to farmers self-defining CA (Hermans et al., 2020). With adoption or non-adoption used as a measure, adoption in itself has become a metric of success for policies or development programmes.

There is a building portfolio of evidence across southern Africa that the science of new agricultural practices does not directly translate into farmers' implementation (Bell et al., 2018; Giller et al., 2009; Ndah et al., 2018; Ngwira et al., 2014; Ward et al., 2018). The agronomically designed top-down 'fixed' package is designed with a focus on biophysical improvements and is often not fully suitable for the local adaptation it will undergo. Methodologies and research are needed that acknowledge the differences, negotiations and conflicts in processes of agricultural decision-making including contextualization (Thompson & Scoones, 1994).

Technography is the social science describing the technology-in-use and can support other approaches, such as participatory approaches or system theories (Glover, 2011; Jansen & Vellema, 2011). It can be used as a tool to understand the contextualized processes through which agricultural practices are decided upon, insights into how and why certain practices are implemented, and how they differ between farmers (Glover, 2011). It also enables the understanding of the temporal aspect in farmer decision-making. The approach uses a social constructivist underpinning, namely that knowledge and realities of farmers are continually shaped by contextual interactions and experiences. This is supported by the analytical framework of 'agriculture as performance', which emphasizes that farmer decision-making is a reaction in a certain moment embedded in a social and ecological context (Richards, 1989, 1993). The technography approach promotes more open questions about how farmers make decisions when the new technologies are introduced and how this leads to agricultural practice change.

In this paper, we use a method based on the technographic and participatory approaches, to rethink and move beyond the concept of 'adoption' or 'non-adoption'. Our aim is to understand farmer decision-making after the introduction of CA in two communities in Malawi and to explore the dynamics and nuance of decision-making processes. The paper seeks to understand: (a) how agricultural decision-making takes place and how the knowledge for process is constructed, (b) how agriculture is performed in a context of development project intervention, including the interaction around this intervention and (c) how CA practice adaptation plays out in the context of interacting knowledge.

1.1 | CA in Malawi

Malawi depends on rain-fed agriculture with maize being the major staple food crop, covering 80% of the cultivated land area and the

major calorific intake (Ngwira et al., 2012). The traditional practice is to prepare the land manually with a hand-hoe. Planting is often done on ridges made annually with approx. 75–90 cm row spacing (Bunderson et al., 2017; Fisher et al., 2018). This traditional practice results from the focus on soil degradation of colonial policy in southern Africa since the 1930s (Andersson & D'Souza, 2014). Residues are burned, removed or buried in furrows.

Malawi, besides Zambia and Zimbabwe, has been on the forefront of CA promotion in southern Africa since the late 1990s (Andersson & D'Souza, 2014). The first CA initiative was established by the NGO Sasakawa Global 2000 in 1998 and supported by the Malawian government (Dougill et al., 2017; Thierfelder et al., 2013). The Sasakawa initiative promoted minimum tillage and mulch cover among small-holder farmers and provided resources packages, similar to national government starter packs, including NPK fertilizer, urea and improved hybrid maize seeds funded by various donors (Dougill et al., 2017). The set of management practices included planting population instructions (1 seed per station in 75 cm ridges and an in-row spacing of 25 cm) and herbicides, which farmers had to buy themselves (Ito et al., 2007; Ngwira et al., 2014). The “SG2000 package” also received extension support to improve “production management” (Ito et al., 2007:420). This support has become a characteristic of CA promotion initiatives leading to the association and accusation that CA requires high inputs, and critique on the sustainability of such systems and its resulting adoption (Andersson & D'Souza, 2014; Dougill et al., 2017).

The Malawi CA introduction process was renewed in 2004 through a collaboration between the International Maize and Wheat Improvement Centre (CIMMYT), the Malawi Government Extension Services, and later the NGO Total LandCare (TLC) (Ngwira et al., 2014; Thierfelder et al., 2013). This effort focused on the establishment of demonstration trials in communities that enable discussions on CA technologies to prevent land degradation and yield decline (Ngwira et al., 2014). The theory of change that drove this agricultural research for development project in the communities is that demonstrating benefits through 'demonstration trial plots' and training lead farmers to become community advocates, will lead to a snowballing of rational adoption decisions, building on local interactions and innovation systems.

Currently, CA has been widely promoted by NGOs, government, international research centres and development organisations to improve maize yields and drought resilience. Initial CA advocacy has taken place without the development of a national strategy or guidelines, resulting in agreement about CA as an approved technology in 2013 and the formulation of National Guidelines for its promotion in

2016 through a National Conservation Agriculture Task Force (NCATF) (Dougill et al., 2017). This agenda is still being promoted now.

2 | MATERIALS AND METHODS

2.1 | Study sites

This study was carried out in two Malawian communities, which are part of CIMMYT's network of on-farm trials in southern Africa: Mwansambo in the central region and Lemu in the southern region. Both communities have six CA on-farm trial replicates, supported by Total LandCare (TLC) and Machinga Agricultural Development District (ADD). The trials have the following three main treatments: (a) Conventional practice with ridge and furrow system (CP) prepared with a hand-hoe, and following Sasakawa planting spacing (75 × 25 cm and one seed per station); (b) Conservation Agriculture with sole maize (CAM). In this treatment, there is no tillage and maize is planted with a dibble stick. Residues are retained as surface mulch; (c) Conservation Agriculture (same as b) with maize and legume inter-crop (CAML): cowpea (*Vigna unguiculata* L.) in Mwansambo and pigeon pea (*Cajanus cajan* L.) in Lemu. All are in annual groundnut (*Arachis hypogaea* L.) rotation with a pigeon pea alley cropping (doubled-up legume system) (Table 1).

2.2 | Methods

A pilot study based on four focus groups and community visits was conducted in October 2018. Subsequently a triangulation of methods was used to examine agricultural decision-making and drivers of change in agricultural practices. Firstly, focus groups were organized using participatory methods including timelines, mapping and ranking exercises. The focus groups were conducted with the trial farmer group (six farmers) and groups of non-trial farmers (8–10 farmers). One focus group per community was conducted with trial farmers, and two for each community with groups of non-trial farmers. In total, six focus group discussion events were organized.

This was followed up with semi-structured interviews to understand individual and household decision-making. Interviews focused on diversity and depth to build understanding of farmer variable decision-making. Timelines of agricultural decisions focusing on changes in practice and drivers of these decisions were constructed during interviews. This timeline approach using oral history enabled discussing changes in

TABLE 1 Community context indicators including both climate and socio-economic

Community	Latitude (°)	Longitude (°)	Soil Texture	Rainfall (mm)	Extension	Year CA start	Lineage majority	Distance market
Mwansambo, Central Malawi	−13.32	34.11	Sandy Clay Loam	1330–1359	Total Land Care (TLC)	2005	Patrilineal	30 km
Lemu, Southern Malawi	−14.79	35.00	Sandy Loam	605–1226	Machinga ADD (Gov)	2007	Matrilineal	30 km

agricultural practice over time and what factors led to these changes (Whitfield & Marshall, 2017). In addition, it approached decision over a longer time to avoid bias of the fieldwork year's particular wet season. The one-on-one interviews were based on the six trial farmers and a subsequent snowball methodology to select 12–14 farmers with different relations to the trial per community. In total, 38 interviews were conducted. In addition, ethnographic observation in the farming communities for a duration of 3–4 months was conducted (Jansen & Vellema, 2011).

Written consent was obtained from all participants before interviews. It was clarified that the interview had no influence on the participation in any programme. Ethical consent for this research was granted by the Environment Faculty Research Ethics Committee at the University of Leeds (AREA 17–147) and Lilongwe University of Agriculture and Natural Resources. Pseudonyms have been applied to anonymize participant identities.

The case-studies presented were selected to showcase the diversity, multidimensionality and complexity in farmer decision-making and practice experimentation and adaptation. The cases were selected from both communities regardless of its agro-ecology and social makeup (patrilineal/matrilineal) to support exploring this diversity, since the theory of change for the diffusion model is applied in both communities. While the cases are diverse and contextual, they represent the (non-linear) ways in which farmer decision-making and practice implementation take place for the wider population. Therefore, case-study analysis still provides relevant representation and validity for a bigger scale (Flyvbjerg, 2006).

3 | RESULTS

The following case-studies are the stories of seven individuals from the CA trial hosting communities. Their relation to the on-farm trials differs from trial farmers to farmers with no direct connection to the trials (see Figure 1).

It is important to note that the definition of promotional 'packages' such as CA and Sasakawa is sometimes defined differently by the farmers, who may just refer to sub-practice (components) from the package. Sasakawa, among the farmers, in this case just refers to the spacing introduced with Sasakawa Global 2000 (75 × 25 cm ridges and one seed per station), thus not the practices of residue retention or minimum soil disturbance. In the case of CA, the practices are named separately when referred to, or as all three practices in the full CA package.

3.1 | Case 1: The 'lead' farmer

One of the farmers who maintains a demonstration trial is Albert. The main income of his household is farming groundnut, maize, pigeon pea, sweet potato and cassava. He runs a CA trial, for which he had the 'courage' to start because he was told he would receive fertilizer, seeds and herbicides.

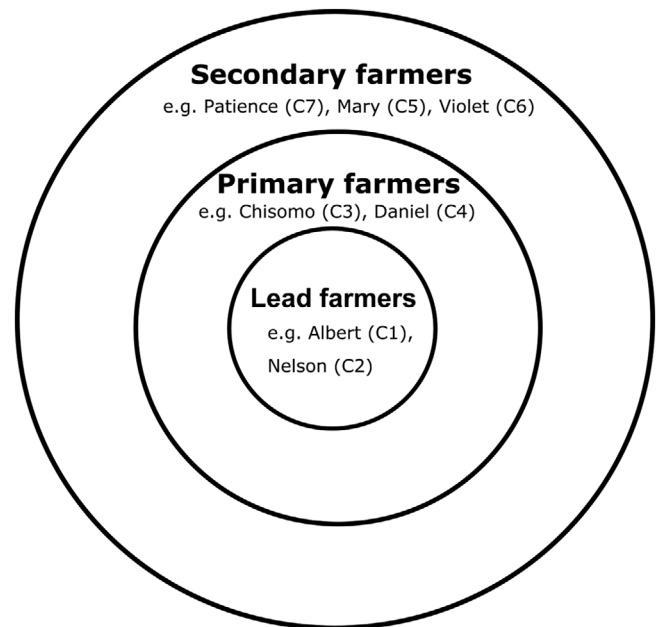


FIGURE 1 This model shows the linear diffusion of innovation model, where demonstration plots and trained lead farmers are the source of information for new agricultural practices. They will be community advocates, which should lead to other community farmers implementing the new agricultural innovation. Primary farmers have a direct and regular connection to the lead farmers. Secondary farmers have no direct connection to a lead farmer but receive information via other community members or trial observation when passing by. The case-studies are selected along these groups, but will show no perfect model fit. C refers to the case-study number

“In the third year of the trial, was when they told us we need to do what we do in the trial also in our own field.”

Following this idea, outside the trial he practices 0.1 ha of CA and on the remaining 0.8 ha of maize, he plants on ridges with burying crop residues (“...for soil fertility”) due to a variety of reasons including land tenure. He rents land every year although the size depends on the money available. He mentions that custom land law prescribes that they do not rent for more than 3 years because otherwise the owners are afraid the renters start to treat it like their own land. Due to this, he does not see the benefits of a practice change to invest in soil fertility and will only practice conventional agriculture on the rented land.

The unpredictable weather is problematic for his choice of agricultural practice. He knows CA is good when it is dry, which is why he promotes it since there have been more dry spells. However, he also stresses that:

“CA is not good when the heavy rains come, but I do not know [when] so I do not know what to do anymore”.

In his view, if there is a lot of rain it is better to do the conventional ridge and furrow system, since the ridges keep the maize up high and

out of waterlogged conditions. That is why he does both practices on his own land. He does not practice CA for groundnut, because he believes groundnut does not do well with residues.

3.2 | Case 2: The 'options open Chief' farmer

Demonstration plots on major roads are run by well-connected and respected farmers, which help the distribution of innovations according to the theory of change. Nelson is one of the trial farmers who has a demonstration trial near a major community road and is also a Chief, and thus a well-respected member of the community.

Starting from 2005, he always did 'Sasakawa', but this year his wife was ill so they could not afford the needed fertilizer, which has to be applied to more planting stations with Sasakawa. Traditionally, farmers are applying the fertilizer by station with a bottle-top, instead of applying the fertilizer per area, which explains the difference in fertilizer requirement. Due to health expenses, he also decided not to do his usual 0.4 ha of CA because they could not get the herbicides. There has been a previous season, in 2014/2015, where he decided not to do 0.4 ha of CA. That season there was too much rain, which meant the soil held too much water and the fertilizer did not work.

For his 1 acre of CA, he imports additional maize residues because the mix of his groundnut and maize residues is not enough in his view. Whenever he is unable to do CA or Sasakawa, he makes ridges with buried residues, like this year. He was given instructions that burying is better because it restores the soil and builds soil fertility, whereas burning does not add anything. He commented that:

“I chose to do ridges because I am used to it and it is easier. I find flat ground with planting and fertilizer too involving.”

If there are ridges and he does not find the money for herbicides or fertilizer, he can always do ridge weeding with a hoe. Although CA has better yields in his opinion, particularly when there is little rain. When he started the trial on his field, he expected to see improvement in yield, soil fertility and drought resistance, and his expectations were rewarded. However, the expectations he had about it being labour and cost effective were not met, due to more labour for planting and fertilizer application, in response to a higher plant population and residue import.

3.3 | Case 3: The 'first step progress' farmer

One of the farmers who interacts directly with lead farmer Nelson is Chisomo. He lives near the demonstration trial of the community chief, with his wife and five children. When the Chief's trial started, he was invited to see the trial and listen to the extension officer. They were introduced to CA and Sasakawa, and he noticed on the trial that the yield improved. After listening to what the extension officer said and what he noticed on the trial for years, he summarized:

“They [extension officers] encourage both CA and Sasakawa, but more [people] do Sasakawa because people think it is easier compared to CA. Sasakawa is perceived easier because you do not need to import residues. You only have to make ridges 75 cm apart and then plant, whereas on CA you have to do the same in the first place - make 75cm planting rows but then also import residues.”

If he has enough fertilizer from the subsidy, he uses Sasakawa for 0.1 ha, which he finds manageable in terms of resources and breaking up the ridges from 90 cm to 75 cm. On the rest of the fields, he continues with making ridges and burying the residues, like most of them in the community do.

Burying residues, which he learned improves soil fertility, is not more work, whereas residues on top like in CA. He explains that:

“Ridges is what farmers believe in. They make ridge and then planting the seeds, then weeding, then banking. So, it becomes hard to adopt a new system.”

At the same time when CA was introduced, they were told that if they feel CA is too difficult, then they can keep ridges. Others may adopt CA because they see the benefits of CA and find it worth the effort. In his own experience, the soil gets hard on the flat land, especially when there are insufficient crop residues, whereas the ridges make the soil soft again, which makes it easier for maize to grow.

3.4 | Case 4: The 'distributing benefits' farmer

Besides direct lead farmer or trial connections, there are also informal routes for innovation diffusion. In 2009, Daniel was invited to the Chief's house where the TLC extension officer told him about CA. He was interested and noted that the government extension officer remained quiet because “...he had given advice against the TLC officer before.” According to him, the quietness of the government officer suggests the TLC officer was right.

It took him 2 years to be convinced about the benefits of CA, but since 2011, he consistently practices 0.2 ha of CA on his own land. He was motivated by the contact with the TLC extension officer but also because he ran out of time at some point to clear the field as usual. This shortage of time gave him no other option but to leave the residues on the field, and, to his surprise, he noticed the yield improved that season. After some confusion about where the 0.2 ha CA is, he explains that this 0.2 ha of CA moves around every season. This way the whole field enjoys improvement in soil fertility. If he sees the residues are not sufficient or the weeds are problematic, he decides to heap up the soil (bank) to control the weeds.

Since he knows the soil needs to be well covered, he imports the residues and also takes some from the neighbours who would burn them otherwise. This collection is enough for 0.2 ha in order to cover the field to the level that ridges are not needed, as observed on the trial.

For all his other fields he just plants the maize on old ridges, without renewing them and banks when weeding is needed. In the past, when he made new ridges, the rain would come and wash them away. So, when TLC introduced the planting on old ridges, many of the farmers in the community liked it, making it now a common practice. To help his work on the land, he hires labour but he would never do that for his 0.2 ha CA because they mess it up or ask for more money.

3.5 | Case 5: The 'age adapter' farmer

Mary is excited to talk about the 3-year system she uses to cultivate because she wants to minimize the labour due to her husband's and her poor health. She thought of this in 1994 when she was late with land preparation due to her teaching job. She notes that the first year is the most work when new ridges are made including the burying of residues. In the next 2 years, she leaves the ridges without splitting them to make new ridges and places the residues between them. Once she completes weeding, she places them on the ridges. For these 2 years of no-tillage, she also does not need to spend money on hiring labour. The old ridges are also good for her land because the strong old ridges will not wash away easily on the slope.

Since she had to pay school fees for children, she could never buy fertilizers, so she liked the idea of burying crop residues that still improve soil fertility. She started burying residues when she moved away from her parents, after learning from neighbours that residues improve soil fertility.

“Adding residues is the only way people can cultivate without fertilizer.”

Despite her preference, due to poor health, to avoid making ridges, she sees it as necessary to make new ridges every 3 years because otherwise her clay soil gets too hard.

When she is lucky to be part of the fertilizer subsidy programme, she can do Sasakawa on a smaller piece of land she rents, which will give her more yield than normal, particularly when there is a drought. She tried doing this since she was invited to a field day at a trial 5 minutes from her house. For her other field, she never considers Sasakawa because it is too big.

“The big field is fertile, but Sasakawa can only be done with hybrid seeds and these seeds need fertilizer.”

She tried hybrids on the big field 4 years ago but without fertilizer, which resulted in very poor yields. Based on her parents farming she continued to intercrop through the fields. For the groundnut fields, she noticed on the demonstration trials that farmers are applying residues, but she believes residues are not good for groundnut so she has not changed the practices. While these practices are described as normal, she does admit that she gets mocked as being lazy for her 3-year system by others. She does not like this since “...people want to be admired to work hard” - but her health does not give her many options.

3.6 | Case 6: The 'female family caregiver' farmer

In a house far from the main road and not easily accessible lives Violet. This divorced farmer has five children but takes care of nine people in total in her household. She farms, burns charcoal and works in other people's fields and on a roadside development. Furthermore, she had to rent out 1.6 ha because of her financial problems.

Due to all her livelihood supporting jobs, she wants as little work as possible on her fields. That is why she burned the residues this year and planted them on old ridges. On the fields where the children helped her, they made new ridges, because her children oppose to not making new ridges despite her own observation that maize does better when planted on old ridges. In 2008, she did Sasakawa and CA on 1 acre, but she felt intimidated by others. People were laughing that the plants were so close to each other and will not do well. They said:

“...it takes you more time to plant 1 seed per station so you will be the last to finish planting.”

She also heard residues will bring fall armyworm. The next year she did it only on 0.1 ha. She still kept the 0.1 ha Sasakawa because the yield was good. The others still disparaged but 0.1 ha was acceptable by them as a test.

Right now, peoples' mindset is changing, due to the trials. She mentions that the conventional practice is the easiest and that the new practices are not useful. There are two things that make the new practice hard: (a) not enough fertilizer and herbicides, (b) putting residues on the field. On the main road, she noticed the trial farmers stopped importing residues but now there are not enough residues on the trial fields. She knows that the practice on the trial started with support so

“...everyone expects that support is needed to start.”

She says that most of them think that the trial farmers do it only because they get support and are the extension officer's farmers. The extension officer is limited in where he can help, which she also reports as the cause of one of the main challenges, namely the lack of knowledge. Information is not shared properly via the lead farmers and

“...there is only one lead farmer per village so they also cannot cover all.”

3.7 | Case 7: The 'disappointing experience' farmer

The CA demonstration trials are not the only trials in these communities. There is a history of other organisations, such as National Smallholder Farmers' Association of Malawi (NASFAM), also using demonstration trials to showcase new agricultural practices. Patience is one of the farmers who was involved with another NASFAM demonstration trial.

She was a member of NASFAM, for which she paid a membership fee but received free groundnut seeds. She only did this for one season because NASFAM did not get back to her about it and she was not reimbursed. She just followed what they told her to do but she did not observe a change. Overall, she liked the trial system but did not expand and burned the residues again, which she continues to do now. Since nobody put effort in the trial or told her the objectives, she did not feel like continuing the practice. With the current CA trials, she mentions that

“Most people think only the trial [lead] farmer was chosen to do that farming. He was chosen by TLC.”

The extension officer never comes to her area so she struggles to contact him and would not know how to start the new practice by herself. In particular, planting with a marked string looks complicated and too involving. She never asked anything herself to the lead farmer, but the extension officer could tell her more in detail because he went to school and was trained.

On her own field, she has good maize so she does not feel compelled to change but she would like to know from the extension officer about how to do certain things.

4 | DISCUSSION

The various stories of individuals in these communities hold within them themes that contribute to a more nuanced understanding of adoption and innovation dynamics, which are often overlooked in linear innovation diffusion discourse. In the following section we highlight and discuss four lenses that can contribute to our understanding of farmer decision-making: *social dynamics and information transfer*, *contextual cost and benefits*, *experience and risk aversion*, and *practice adaptation*.

4.1 | Lens 1: Social dynamics and information transfer

Farm-level knowledge and decision-making are socially constructed have been recognised in an emergent STS literature (Glover et al., 2016; Whitfield, 2015) and critical extension studies (Leeuwis & Van den Ban, 2004). In the case of CA in Malawi, we have seen how social dynamics shape farmers' perceptions and experiences of innovation, including decisions about whether and at what points to engage with or disengage from a process of trialling new practices.

Decision-making does not only include economic or technical dimensions as social acceptability is also important. Family members' help on the field and their opinion make implementing agricultural practice change unlikely because they want to make ridges. Only 0.1 ha seems feasible in terms of social dynamics due to the social approval of it as a 'trial'. Others were intimidated or mocked for being 'lazy'. This wording comes up frequently in farmer discussion, showing

that not making ridges is still associated with 'laziness', whereas 'hard-working' is seen as the virtue for a farmer to be food secure. This is contradicting, since a perceived increase in labour, related to the planting without ridges and residue retention, is also seen as discouraging CA. On the other hand, the release from making ridges is also a motivation in favour of CA. Therefore, it seems labour remains a contested topic with beliefs, consideration of total season labour (Thierfelder et al., 2016) and its timing.

Social acceptability is associated with community group dynamics and connected flow of information. Farmers observed from the trial that support was given to start CA. This makes farmers think they need that same support to make the change work, leading to a belief that it is not worth trying on one's own. The trial farmers are part of the club and the farmers receive extension officer's attention and support. Even farmers who implemented CA on their own feel they are part of the club with access to information on modern technology. A distinct problem is that while the theory of change of demonstration trials and farmer to farmer distribution assumes homophily (i.e., people in the community are equal) (Rogers, 2003), the group dynamics create heterophily, which makes the diffusion of innovation not as effective.

There are beliefs and social dynamics in the community that are also of importance to farmers' decision-making. For example, the general belief that residues are not good for groundnut, despite data showing more harvest under CA (Bunderson et al., 2017). Similarly, the increase of planting population under Sasakawa creates the belief of higher fertilizer need. However, less fertilizer per plant leads to similar fertilizer need per area. The consensus of what is sufficient residue is different among farmers, and based on the CA introduction and trials, residue import to create a thick layer was needed. These instructions have now changed to just leaving leftover residues but the idea of 'sufficient' seems to still differ between farmers. The concept of 'residues being a limiting factor' may therefore be based on the belief on how much is sufficient. In the narrative of residues, the belief of residue import risking disease transfer (e.g., fall armyworm) is widely accepted, although proliferation of fall armyworm through crop residues is uncommon and only applies to stalk borers. This shows that having access to information can support practice change but common beliefs may counteract this.

The closeness to a trusted source of information affects the belief in the validity of the information (Fisher et al., 2018; Holden et al., 2018). Farmers in direct contact with the extension officer trust and implement more of the information, than when it comes to indirect ways such as trial observation or other community farmers. Some state that the lead farmer dissemination approach works since they are closely connected, whereas others note that this does not work. As previously reported in Brown et al. (2020), farmers report problems with information sources and lack of training due to lack of contact with extension officer and lead farmers. Alternatively, studies by Cofré-Bravo et al., (2019) have shown that there is a wide variety in the configuration of knowledge and support networks used by farmers, depending on livelihood, farm and innovation goals. In this light, the focus on lead farmers to instigate innovation diffusion does

not fully accommodate the diversity in knowledge and support networks. The assumed model of technology transfer, which relies on expanding social connections, leading to information transfer that turns into implementation, as illustrated in Figure 1 may not be as linear and effective.

4.2 | Lens 2: Contextual costs and benefits

As recognised in diffusion theory (Rogers, 2003), sustained engagement with a new innovation depends on whether or not there is a relative advantage of the new practice over the current practice. An assessment of relative advantage includes a consideration of the compatibility of innovation with the existing context. While diffusion theory acknowledges that context plays a role, this is often limited to biophysical or technical factors or assuming linear and rational decision-making, thereby not addressing the full multi-dimensionality and dynamic decision-making process. The case of CA in Malawi helps to demonstrate that there are complex set of contextual costs and benefits that shape decision-making, and that these are themselves socially constructed.

Farmers consider the balance between costs and benefits for their context. This is not only economic but also includes social and ecological aspects and the intangible 'cost' of changing to something new. Two economic elements that increase the 'costs' or lower the benefits are rented land and hired labour. On rented land, the benefits of practices perceived as CA are not experienced, and in hiring labour, oversight is needed or more remuneration. Another economic aspect is that practice implementation is dependent on the fertilizer subsidy received that year. In most cases, the major challenge to agricultural improvement is identified as access to the resources. This challenge is associated with the belief that CA systems can only be applied with high input packages. Farmers do not have the 'courage' to try new practices because they do not get the resource or knowledge support, they feel they need.

Other factors also play a role in the contextual balance. Farmer experimentation and adaptation are based on health and labour concerns (e.g., ridge making labour, residue import, string planting) and agro-ecological dimension (e.g., soft soil, land slope). Some farmers know the benefits but the perceived effort costs are too high. Benefits from residue are most evident during droughts, which provide a convincing entry point. However, it was also mentioned that the year after a drought there are very little residues, thereby increasing the challenge of residue retention. Over the farming season, these factors interact and are affected by the context's institutions and structures, creating reinforcing cycles of productivity, health, resource access and labour (Jew et al., 2020). The benefits need to be sufficient and address the farmers' needs and challenges, which are dynamic and focused on short-term benefits rather than longer-term sustainability.

The balance of costs and benefits is contextual and can be dependent on the introduction of other changes in agricultural practices, such as planting on old ridges, Sasakawa planting or residue burying. The common methods of old ridges and banking are also seen as an improvement, which saves work. The observation of the trial farmer importing the residues, the agro-ecological observations and the government message that

Sasakawa planting is already an improvement forms the beliefs of costs and benefits. The burying of residues for soil fertility improvement was easily adopted than the CA package because the cost was low compared to the benefit. Mentioning of 'others may find it worth it' shows that the cost and benefit balance is individualistic, addressing the challenges given by Glover (2011) that decision-making is multidimensional and dynamic.

The contextualization and livelihood dependency of the costs and benefits balance (Farnworth et al., 2016; Mutenje et al., 2019) can especially be elaborated in Violet's case. It is representative of various female farmers interviewed who are divorced, separated or widowed. They have additional jobs, which become the focus of cash income. There is shortage of labour for their fields and there is no money for herbicides or hired labour to replace that work, particularly weeding. A change of practice is observed as too much work and effort (including the learning process). This shows the livelihood context of decision-making and shows that there is a risk in change, which comes with intangible costs that for some are not worth the benefits.

4.3 | Lens 3: Experience and risk aversion

In the context of complex costs and benefits, particularly for resource-constrained farmers, a risk-averse approach to new technologies and investments may predominate (Whitfield, 2015). We also see, in this case, how past experiences of technologies and interventions can contribute to an aversion to risk. This is evident in the cases of disengagement or small-scale and incremental experimentation with CA practices.

Individual experiences play a role and show that current decision-making is not only rational. For example, disappointment with a previous trial project, not understanding its purpose, lack of observable improvement and contact with extension officer all create less willingness to change practice again. There is a lack of feeling involved or ownership of the trial. This was also reported in Brown et al. (2020), who highlighted that lead farmers did not understand that they can expand beyond the trial. The farmer stories present that decision-making can result from information flow interacting with personal (sometimes accidental) experimentation.

Risk-averse behaviour to keep options open also guides farmers' decision-making. One main challenge is the uncertainty of the weather. Risk is spread by using both the conventional practice in case of heavy rains and the perceived CA practices, of which the main focus is residue retention, in case of droughts (Ngwira et al., 2013). The conventional method is seen as leaving options open in case the resources cannot be found because banking and weeding with a hoe can be done. Other strategies are the back-up plan of banking in case the weeds still get through the residue layer.

4.4 | Lens 4: Practice adaptation

In agricultural innovation, we rarely see a linear perfect and whole-scale replacement of old practices by new ones (Glover, 2011). The

adaptation or 're-invention' of practices shows that there is change in the used agricultural practices, which can be beneficial for sustainability of the implementation of new practices (Rogers, 2003). As such, there may not be a single moment of technology adoption or a clear distinction between those that do and those that do not adopt a technology, which emphasizes the dynamic process (Kiptot et al., 2007). Rather, as in the case of CA in Malawi, we might observe a continually changing mosaic picture of resultant practices, across space and time, which reflect the socially constructed knowledge, local costs and benefits, and risk aversion and experimentation of different farmers.

Farmers use CA information and experimentation, and implement this in various manners, as has also been mentioned in CA adaptation literature (Brown et al., 2018b, 2018a). There is hybridization of old and new practices. In particular, Sasakawa planting is seen as a modern agricultural improvement and a step towards the perceived CA package but without removing the ridges. The CA package introduction included the first year with Sasakawa planting with residues retention and the conventional field in the on-farm trials is also Sasakawa planting. There are associated costs with Sasakawa planting such as fertilizer and labour for breaking up the ridges for the first time. However, it is seen as using improved modern techniques, but does not meet the costs or investment that comes with perceived CA practices (e.g., residue retention). Planting on old ridges and banking is also a variation moving forward from the old practices and can be found in the CA package introduction where ridges should not be remade. Therefore, farmers, in their own way, negotiate and work with constraints, a process also called tinkering (Higgins et al., 2017), to use new information on agricultural innovation.

Other dynamic implementations are on temporal and spatial scales. New practices are done on limited land areas, most frequently in 0.1 or 0.2 ha, the usual trial size, for various reasons including social acceptance and labour limitations. Alternative strategies include moving the 0.1 ha around so that the entire land can be improved. On the temporal scales, conscious choices are made to change practices every season due to rainfall or health affecting resources.

While re-invention is often not considered good, it is not necessarily bad once the reasoning behind the choices is understood. Considering the adaptation of practices that is occurring, including an increase in the 'left-over' information from the Sasakawa introduction, crop diversification or residue retention, we notice that farmers are interacting with the introduction of new practices. This response is dynamic and resulting from the interaction of the individual farmer and system context (Engler et al., 2019). The use of information is not always in the exact introduced form but it does allow for the customization to local context (Rogers, 2003). The impact of introduction of new agricultural practices, such as the CA package, is therefore wider than adoption measurements indicate.

The linear based theory of change is connected to the pre-determined adoption measuring framework, since it is based on the view that agriculture innovation diffusion is 'technology transfer'. However, this does not cover the complexity of the agricultural systems and farmers' decision-making. Therefore, both complexity-aware theory of change and evaluation criteria (Douthwaite & Hoffecker, 2017) may be

more suitable. This evaluation acknowledges that outcomes can be technological implementation, but also the innovation process, in terms of effectiveness, and to what extent capacity for development, innovation and adaptation within the system have been built up.

4.5 | Recommendations

Establishing this dynamic process and moving away from adoption measuring framework, thereby provide empirical insights to the work of Glover (2016, 2019), which shows that there is need to shift investment away from perfecting a technology and instead focus on the process and farming system the innovation can adapt to. This requires considering and exploring the relationship and co-evolution of the farmer decision-making and the system context, which will be increasingly important when scaling agricultural innovation (Engler et al., 2019; Sartas et al., 2020; Wigboldus et al., 2016). Furthermore, this should be paired with a shift to focusing on the end goal, namely the extent needs are met through innovations, instead of the extent of adoption. Funding structures and incentives often reinforce the situation of organisations being tied to the promotion of specific technologies and innovations, and competing to demonstrate the relative advantage, often using adoption rates as a metric of success that reinforces their claim to success (Sumberg et al., 2012). However, shifting focus and incentives to the end goal of innovation could encourage a movement away from narrowly conceived technological solution and focus efforts on the quality of innovation processes. For example, building on adaptation that farmers already implement, such as planting on old ridges, any form of residue retention or the Sasakawa planting. This also provides the opportunity to change the approach to focus on supporting farmers' intrinsic motivation to adapt practices and experiment, thereby acknowledging the differences in farming styles and goals. Projects could therefore learn from these case studies to improve farmers' ownership, empowerment, develop 'complexity-aware' non-linear theory of change and evaluation (Douthwaite & Hoffecker, 2017) and become process facilitators (Kessler et al., 2016) in the change towards improving livelihoods and sustainable agriculture.

Innovation platforms, as also suggested in Schut et al. (2016) and Brown et al. (2020), including farmer and extension officers can support further development of existing extension, knowledge and practice systems. They can also provide better connection between introduced agricultural packages and community-based agricultural development. To capture and work with dynamic farming systems, including the non-predictable contextual emerging challenges and opportunities, continuous reflection and feedback is important to match the needs and actions (Kilelu et al., 2014). This requires evolving learning processes, through a dynamic learning agenda (Kilelu et al., 2014), in which extension services play an important role. For the 'scaling up, scaling out and scaling deep' discourse, it will be of importance to take into account these dynamic interactions and the ways in which new innovations can be processed into implementation.

4.6 | Reflection on the approach

The qualitative approach enabled going beyond the adoption measuring framework and associated challenges with CA definitions. It uncovered the diversity in adaptation of practice and how farmers process and interact with agricultural innovation information and interventions. Its focus on depth over large area representativeness has supported the concept of agriculture as performance and the contextualised process of dynamic and multidimensional farmer decision-making, including the temporal aspects (Glover, 2011; Richards, 1989, 1993). The challenges of the adoption measuring framework are embedded in the agricultural systems' problem (Glover et al., 2016), in terms of how these systems are defined, and its dynamics, diversity and complexity acknowledged. This farmer-centred approach, including ethnographic informed interviews, enables a cross-disciplinary look, considering these system challenges for the diffusion of innovation and associated theory of change.

5 | CONCLUSIONS

In this study, a method based on the technographic and participatory approach was used to rethink the concept of 'adoption', understand how agricultural decision-making takes place and how the knowledge is constructed after the introduction of CA in two Malawian communities. The approach has shown that farmer decision-making is dynamic, multidimensional and contextual. There is a large range of interacting factors that play a role in the decision-making at a particular point in time: agro-ecology, health, labour, economics, resource endowment, family size, age, gender, experience, risk aversity, alternative practices available and social dynamics. The trade-offs of these are different for individual farming systems and livelihoods at a certain time. This is dependent on the relative advantage in the individual farmer's perception change to farming practice.

The theory of change underpinning the common agricultural innovation diffusion model is based on demonstrating benefits through 'demonstration trials' and training lead farmers to become community advocates. Our study has shown that social dimensions, including acceptability and group dynamics, play an important role in the farmer decision-making and efficiency of the diffusion model. The level of closeness and trust in the source of information influence the agricultural decisions, which balance between new information, level of trust, common beliefs and experience. The assumed model of technology transfer is, therefore, not as linear and effective as often assumed.

Moving beyond the adoption measuring framework has shown that there is a wide diversity in practice adaptation and re-invention. While the re-invention of introduced practices is not always considered positively, it does provide opportunity to adapt to local context and shows the presence of innovation changes. Considering this wider picture of agricultural practice implementation and change, the influence of agricultural interventions and introductions is larger than can be measured in an adoption framework. To capture these dynamics and complex processes of agricultural systems and farmer decision-

making, both complexity-aware theory of change and evaluation criteria are more suitable. Investments should increase focus on the dynamic process and fit of innovation in farming systems, considering the mutual adaptation between farmer and system context, instead of solely perfecting a technology. For example, building on already occurring adaptations, such as planting on old ridges or any form of residue retention (mainly burying). The focus on dynamic processes to develop agricultural innovations in farming systems also means agencies can move away from being tight to their specific promoted agronomic solution. To build on the existing knowledge and farming systems, innovation platforms, including farmers and extension staff, and dynamic evolving learning processes, including feedback and reflection, are important to support the 'scaling up, scaling out and scaling deep' agenda for agricultural innovations like CA.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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