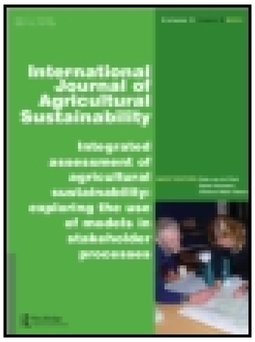

International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: http://www.tandfonline.com/loi/tags20

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To cite this article: Monica Fisher, Stein T. Holden, Christian Thierfelder & Samson P. Katengeza (2018): Awareness and adoption of conservation agriculture in Malawi: what difference can farmer-to-farmer extension make?, International Journal of Agricultural Sustainability, DOI: 10.1080/14735903.2018.1472411

To link to this article: https://doi.org/10.1080/14735903.2018.1472411

Published online: 09 May 2018.

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INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
https://doi.org/10.1080/14735903.2018.1472411

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Awareness and adoption of conservation agriculture in Malawi: what difference can farmer-to-farmer extension make?

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ABSTRACT

Despite the potential of conservation agriculture (CA) for increased crop yields, energy savings, soil erosion control, and water-use efficiency, smallholder farmers in sub-Saharan Africa have been slow to adopt. Farmer-to-farmer extension (F2FE) may have a role to play in overcoming the information access problems and lack of knowledge that may preclude widespread adoption. This study uses data for 180 lead farmers linked to their 455 followers to investigate how F2FE influences awareness and adoption of CA technologies in Malawi. Results from a bivariate probit model for follower farmer awareness and adoption of the three CA principles (minimum soil disturbance, crop residue retention, and crop diversification) reveal four main findings: First, lead farmer motivation increases their effectiveness at diffusing CA practices to their followers. Second, lead farmer familiarity with and adoption of CA both matter to the spread of CA practices, but familiarity appears more important. Third, lead farmers play a more critical role in increasing awareness than adoption of the CA practices. Finally, F2FE is a complement rather than a substitute for other sources of agricultural extension in Malawi's pluralistic extension system and should support but not replace current systems. Research and policy implications are discussed.

KEYWORDS

Africa; conservation agriculture; farmer-to-farmer extension; Malawi; technology adoption

Introduction

Conservation agriculture (CA) has increasingly been promoted by international organizations, donors, and non-governmental organizations as a means to achieve improved and sustained agricultural productivity under a changing climate, increased farm profits, and food security, while preserving and enhancing the resource base. CA is defined by three linked principles: minimum soil disturbance, crop residue retention, and crop diversification through rotation or intercropping. On-farm research in sub-Saharan Africa (SSA) reveals some important advantages of CA systems over conventional tillage-based agriculture. CA systems can be yield enhancing after 2–5 cropping seasons, due to their greater infiltration and soil moisture (Thierfelder et al., 2017; Verhulst et al., 2011). Gradual changes in soil fertility and organic carbon have been reported, especially where some diversification is introduced (Powlson, Stirling, Thierfelder, White, & Jat, 2016), which results in greater drought and heat resistance of crops (Steward et al., 2018). This explains why CA systems are considered to be more 'climate-smart'. Economic benefits have also been reported, which should make CA more attractive to smallholders (Thierfelder et al., 2016).

The suitability of CA for smallholders in SSA has been much debated in recent years, sparked by the paper of Giller, Witter, Corbeels, and Tittonell (2009) and others that followed (Andersson & D'Souza, 2014). More recently it is argued that the 'niche' where CA fits in eastern and southern Africa is large and growing (Baudron, Thierfelder, Nyagumbo, & Gérard, 2015). CA holds great potential in terms of saving energy (including labour and draft power), controlling soil erosion, and water-use efficiency (Baudron et al., 2015). CA appears to be highly relevant for

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Malawi, given high rural population density (for a sub-Saharan country), very small landholdings, water constraints, accelerated soil degradation, low livestock densities, and low demand for crop residues for livestock feed (Andersson & D'Souza, 2014; Ngwira, Johnsen, Aune, Mekuria, & Thierfelder, 2014). On-farm research conducted between 2004 and 2015 in central and southern Malawi revealed a significant increase in maize grain yields over time under CA compared with the traditional ridge and furrow system, especially in situations where moisture was limiting during the season (Thierfelder et al., 2013, 2015, 2016). Longitudinal research in Malawi also showed that uptake of agro-ecological farming practices can enable farm households to achieve sizable improvements in household wealth and food security (Kangmennaang et al., 2017).

Despite the promise of CA, adoption by farmers in SSA remains (s)low (Andersson & D'Souza, 2014; Giller et al., 2009), and some abandonment of basin-based CA systems has been documented in selected areas, for example in Zambia (Arslan, McCarthy, Lipper, Asfaw, & Cattaneo, 2014). Other studies showed a shift from manual-based CA systems to more mechanized systems, especially where farm labour is a major impediment (Grabowski, Haggblade, Kabwe, & Tembo, 2014). A recent estimate for six districts of central and southern Malawi in 2009/10 is that 18.5% of farmers were practicing two or three CA principles on an average 10% of their agricultural landholding. This represents about 2.1% of cultivated area (Ngwira et al., 2014).

Explanations for a so-far low adoption of CA by smallholders in southern Africa include several challenges, some biological (e.g. competition for crop residues, increased weeds in the first years after conversion, limited land area to rotate, some pests and diseases specific to CA) and others economic (e.g. farmers are risk averse, cash constrained, have poor access to markets for inputs and outputs, lack appropriate implements, and have insufficient information and knowledge about CA) (Holden & Lunduka, 2014; Holden & Quiggin, 2017; Thierfelder et al., 2015). Of particular relevance to the present paper is empirical evidence pointing to information gaps as a key impediment to the diffusion of agricultural innovations, including CA practices, and the importance of learning from other farmers for overcoming such failures (Foster and Rosenzweig, 2010; BenYishay & Mobarak, 2014).

Farmer-to-farmer extension (F2FE) may have an important role to play in overcoming the information access problems and lack of knowledge that may preclude widespread adoption of CA. Entrusting in farmers the important task of diffusing new agricultural technologies is consistent with empirical evidence that farmers are more likely to learn about and accept new technologies if their peers have been experimenting with the technology (BenYishay & Mobarak, 2014: Matuschke & Qaim, 2009). F2FE is particularly relevant where public extension is insufficient or ineffective, owing to low budgetary allocation, lack of mobility, outdated information, understaffing, and low staff morale, as in many countries of SSA (Kiptot, Karuhanga, Franzel, & Nzigamasabo, 2016; Wall, 2007). However, convincing evidence on the effectiveness and sustainability of F2FE programmes in SSA is sparse, because most research to date has been based on small-sample datasets or used descriptive rather than econometric analysis (e.g. Kiptot et al., 2016; Wellard, Rafanomezana, Nyirenda, Okotel, & Subbey, 2013).

This paper asks if F2FE can help spread CA practices to Malawi smallholders, potentially leading to greater experimentation and adoption in the long term. F2FE has become an important element of Malawi's public agricultural extension system as a way to extend the reach of agricultural extension services in the face of limited budgets for employing more agricultural extension officers. Malawi's Department of Agricultural Extension Services (DAES) currently works with more than 12,000 lead farmers country-wide who train and promote agricultural technologies, including CA, through their networks of follower farmers ('followers') and through demonstrations.[1] National policy support is essential for effective and sustainable F2FE programmes, but observers note other critical factors, such as having lead farmers that are motivated, knowledgeable about new technologies, and have good communication skills (Davis, Franzel, & Spielman, 2016).

Using a new dataset collected in 2016 from a survey of lead farmers ($n = 180$) and their followers ($n = 455$) in four districts of central and southern Malawi, we examine how much influence lead farmers have on the awareness and uptake of CA among their follower farmers. A bivariate probit model is used to test whether awareness and adoption of CA among follower farmers is influenced by their lead farmers' motivation (Hypothesis 1), awareness of CA (Hypothesis 2), and adoption of CA (Hypothesis 3). Unfortunately, data are not available to examine the association between lead farmer

communication skills and technology diffusion to their followers and that is left for future work. The study focuses on three CA principles (minimum soil disturbance, crop residue retention, and crop diversification through rotation) and one supporting practice (organic manure). Survey data are available for these practices and they are being promoted by the Government of Malawi as key elements of sustainable agriculture intensification and climate-smart agricultural development.

This study contributes to the literature on adoption of sustainable agricultural practices in three main ways. First, we employ a unique dataset on 180 lead farmers linked to their 455 follower farmers, enabling a more direct examination of lead farmer influences on technology diffusion than is otherwise possible. We know of only a few other studies on F2FE that used this type of data. Some of the studies offered comparative estimates across a few countries but were based on small samples in each country studied (e.g. Kiptot et al., 2016; Wellard et al., 2013). Only one study used multiple regression analysis to control for factors beyond F2FE influences (Nakano, Tsusaka, Aida, & Pede, 2015).

A second contribution is comparative estimates of the role of learning from lead farmers vs. other sources of agricultural information. In southern Africa, information on CA has been spread using a variety of approaches (e.g. lead farmers, extension agent visits, field day and demonstration trials, the mother and baby approach, innovation systems, the research cluster approach, the market incentive approach, and electronic media). We examine the relative importance of different information sources for the familiarity with and adoption of CA among follower farmers. Empirical studies have explored the role of extension services (Anderson & Feder, 2004), information and communication technologies (e.g. ICT-based extension; Aker, 2011), and social learning (Bandiera & Rasul, 2006; Matuschke and Qaim, 2009), but rarely have the various sources of agricultural information been studied together (Krishnan & Patnam, 2013).[2]

A third contribution is evidence on the role of lead farmers in diffusing a range of CA technologies and their supporting practices. The influence of lead farmers is likely to differ across technologies for several reasons, such as the complexity of the technology and its stage in the diffusion process. In addition, lead farmer success is often based on how much the technology's performance varies across farms and therefore the perceived applicability of the lead farmers' advice and experience (Liverpool-Tasie & Winter-Nelson, 2012; Matuschke & Qaim, 2009; Munshi, 2004). The literature is rather thin on this topic, and we add another empirical point towards filling this knowledge gap.

Study context

Situation, environmental conditions, and agricultural systems in Malawi

Malawi is a landlocked, agricultural country in southern Africa with a population of 17 million. Agriculture accounts for one-third of the gross domestic product (GDP) and almost 80% of employment (FAO, 2015). The country is divided into three regions (north, central, and south) and most farmers in Malawi are smallholders with average landholdings of 1.2, 1.1, and 0.7 ha in the northern, central, and southern regions, respectively, according to Malawi's most recent (2006/07) national census of agriculture and livestock (NSO, 2010).

Crop production takes place mainly in the mid-altitude (600–1300 m.a.s.l.) and low-altitude (100–600 m.a.s.l.) areas. Rainfall ranges from 700 to 2500 mm per annum (Ngongondo, Xu, Gottschalk, & Alemaw, 2011). Land preparation for cropping is mostly done manually using hand hoe. A carryover from previous colonial laws, crops are predominantly grown on annually ridged fields, with ridges varying in size from 25 to 50 cm in height with row spacing of 75–90 cm. In the north of Malawi, some tillage with animal traction and the mouldboard plough is practiced.

While ridging is effective in removing excess water from the field, it has some disadvantages for farmers, such as increased erosion, high labour requirements especially for women and children, and inflexibility to adjust to other crops that require a different row spacing (e.g. legumes). Soil erosion on ridged fields has been estimated to average 20 tons/ha/year (Yaron et al., 2011), while making the ridges requires 25–35 labour days more than planting on the flat under no-tillage, depending on the soil type and the agro-ecology. An additional 10–15 labour days can be saved if herbicides are used for weeding, although this requires an additional cost for purchasing herbicides (Bunderson et al., 2015; Ngwira, Thierfelder, & Lambert, 2013; Thierfelder et al., 2016). Annual ridging and consecutive operations such as

weed control with hand hoes exposes more land area to evaporation and cuts some roots of maize, which has negative effects in years of seasonal droughts or dry-spells (Ngwira et al., 2013; Thierfelder et al., 2013).

In Malawi, crop residues are traditionally removed, burned, or buried in the furrow with negative consequences for soil fertility and plant health. Residue cover is important for protecting the soil from the heavy impact of rainfalls. They further conserve moisture, suppress weeds and enhance biological activity in the soil which are all supportive of increased aggregation, water infiltration, and available soil moisture (Thierfelder & Wall, 2009).

Maize (*Zea mays* L.) is the main staple food crop in Malawi, accounting for 63% of plots cultivated by smallholder farmers and about 50% of total area under crops (NSO, 2010). Other important crops are groundnuts (*Arachis hypogaea* L.), cassava (*Manihot esculenta* Crantz), tobacco (*Nicotiana tabacum* L.), tea (*Camellia sinensis* (L.) Kuntze), sugar (*Saccharum officinarum* L.), and coffee (*Coffea arabica* L.). Due to limited land area available per farmer, incomplete markets for crops other than maize, and food security concerns, 75% of maize plots are pure stand (NSO, 2010). Maize monocropping has negative implications for soil health and human nutrition, as monocropped maize is more susceptible to pests and diseases, leads to soil fertility decline, and results in low dietary diversity among the rural population. In southern Malawi, maize is intercropped or rotated with pigeonpea (*Cajanus cajan* (L.) Millsp.), cowpea, (*Vigna unguiculata* L. Walp) and groundnuts (*Arachis hypogaea* L.) as the most common crops.

Conservation agriculture (CA) systems are based on three basic principles: minimum soil disturbance, crop residue retention, and crop diversification through rotation or intercropping (Kassam, Friedrich, Shaxson, & Pretty, 2009). CA is not a new way of farming, but it aims at removing the unsustainable parts of current conventional farming systems by replacing tillage with minimum tillage, residue removal with retention, and monocropping with diversification (Thierfelder et al., 2015). CA, as introduced in Malawi since the early 2000s, is predominantly built on planting with hand hoes in planting basins or with a dibble stick. Other supportive agricultural practices, such as herbicide application, manure and compost use, agro-forestry, and early and row planting, have been introduced alongside CA principles to enhance their productivity and profitability (Garrity et al., 2010; Ngwira et al., 2013; Thierfelder et al., 2013).

Background on the public agricultural extension system and F2FE in Malawi

In Malawi, agricultural extension services are largely the responsibility of the Department of Agriculture Extension Services (DAES), one of seven technical departments of the Ministry of Agriculture, Irrigation, and Water Development (MoAIWD). Public agricultural extension services are also provided by specific programmes of MoAIWD, such as the Farm Income Diversification Project. In the last few decades, there has been increased involvement of non-state actors in agricultural extension provision, owing to the introduction in 2000 of a policy that promoted pluralistic and demand-driven extension systems, but DAES remains the main extension service provider in the country, often working in collaboration with non-governmental organizations (NGOs). Non-state actors involved in agricultural extension include private-sector organizations (e.g. companies that supply farm inputs to farmers, such as agro-dealers or seed companies), farmer organizations, and NGOs (Masangano & Mthinda, 2012).

The government extension system in Malawi relies on Agricultural Extension Development Officers (AEDOs) who are employed by the MoAIWD to work with individual farmers and conduct village-wide demonstrations and field days. The AEDOs are in theory responsible for one agricultural extension section (locally called Extension Planning Area or EPA) each, covering about 15–25 villages. However, in practice AEDOs are responsible for multiple EPAs, due to field staff shortages (BenYishay & Mobarak, 2014). In 2011, for example, the ratio of AEDOs to farmers was 1/1,848 (Khaila, Tchuwa, Franzel, & Simpson, 2015). The shortage of transport (e.g. motorcycles and fuel to run it) poses another challenge to government extension services.

Based on these limitations, the DAES began using the F2FE approach in 2003, which was formally institutionalized within DAES' programmes in 2007 (Kundhlande, Franzel, Simpson, & Gausi, 2014). Under the F2FE approach, each AEDO partners with one lead farmer per village who is responsible for training other farmers in some of the technologies and topics for which the AEDO would otherwise be responsible (BenYishay & Mobarak, 2014). The DAES also advocates community awareness raising

meetings and participatory rural appraisals to orient communities in the use of F2FE (Khaila et al., 2015).

There are no firm guidelines for lead farmer selection in Malawi (Khaila et al., 2015). Two recent surveys of lead farmers and extension organizations using F2FE reveal that lead farmers are usually selected by the communities they serve with the main selection criteria being literacy, community residence, being a hard worker, having a reputation of good behaviour, innovativeness, and availability (Khaila et al., 2015; Kundhlande et al., 2014). The selected lead farmers generally receive an initial training from extension organizations, covering technical topics and communication skills (Khaila et al., 2015). The amount of training received is not extensive – typically covering a single day and limited to an initial training only. While most lead farmers interviewed by Khaila et al. (2015) say they have sufficient knowledge and skills for the job, many perceive their performance could improve with more training.

After they receive training, the lead farmers are asked to set up demonstration plots where they demonstrate agricultural activities including the technologies they intend to disseminate to other farmers. Lead farmers register their follower farmers as those farmers who are observed following the lead farmer activities. On average, the lead farmers surveyed by Khaila et al. (2015) had 61 follower farmers (median = 25). Their main activities as lead farmers are training, advising, monitoring their followers, and establishing demonstration plots. The main technologies promoted are CA principles, maize basin planting, row planting (Sasakawa planting method), compost making, and agroforestry technologies.

Lead farmers report two main motivations for becoming and remaining lead farmers: to improve their knowledge of farming and to help others (Khaila et al., 2015). They appear to receive minimal monetary compensation and material support. Observers recommend providing low-cost incentives as a future priority to help recruit and retain lead farmers and maintain a high quality of service (Khaila et al., 2015).

Data and methods

Data

The data used in this study come from a household survey conducted in six Malawi districts in 2016 (Figure 1). The survey focused mainly on four districts: Lilongwe and Kasungu in the central region and Machinga and Zomba in the southern region. In addition, we have a smaller sample from Chiradzulu and Thyolo districts in the southern region. The selection of the four (six) districts followed earlier surveys where data were collected on panel households between 2006 and 2015. The first round of the panel surveys took place in 2006 where an initial sample was drawn using a simple random sampling technique. The sampling procedure began by purposely choosing six districts to capture dynamic land issues in Malawi. In each of the districts, the primary sampling unit (PSU) was the enumeration area (EA) following the second Integrated Household Survey of 2004 (IHS2). Two EAs were randomly sampled in Thyolo, Chiradzulu, and Machinga districts, while three were sampled in Zomba, Kasungu, and Lilongwe districts.

The current survey changed the primary sampling unit from EA to EPA but followed the same villages as in 2006. The reason for the change from EA to EPA was purely administrative – to allow AEDOs at the EPA office to guide the sampling of lead farmers and follower farmers. As mentioned earlier, in Malawi lead farmers are typically chosen by members of the community they serve, while followers are identified by the lead farmers as those farmers who are following their technology dissemination activities. The AEDOs provided a complete list of lead farmers in each of the EPAs. The number of lead farmers was relatively small in our previous survey villages; we therefore added several villages from the sampled EPAs to enlarge the sample of lead farmers.[3] While we included all the lead farmers in each EPA, we randomly chose two to four followers of each lead farmer. We obtained a list of follower farmers for each sampled lead farmer from which the sample of follower farmers was drawn. The final sample includes 181 lead farmers and 455 followers.

A simplified and modified for our purpose version of the fourth Integrated Household Survey (IHS4) instrument was used. A set of additional questions related to CA technologies and extension contacts were among the parts added to the survey instrument. It was programmed in the software Survey Solutions (World Bank) and the data were collected using tablets that also were used to record the GPS locations of respondents and to measure their farm plots. Fifteen enumerators were trained in the use of the tablets for the interviews. In the beginning they managed to interview only one household per day, but as they became more skilled they managed to complete two interviews in a day.

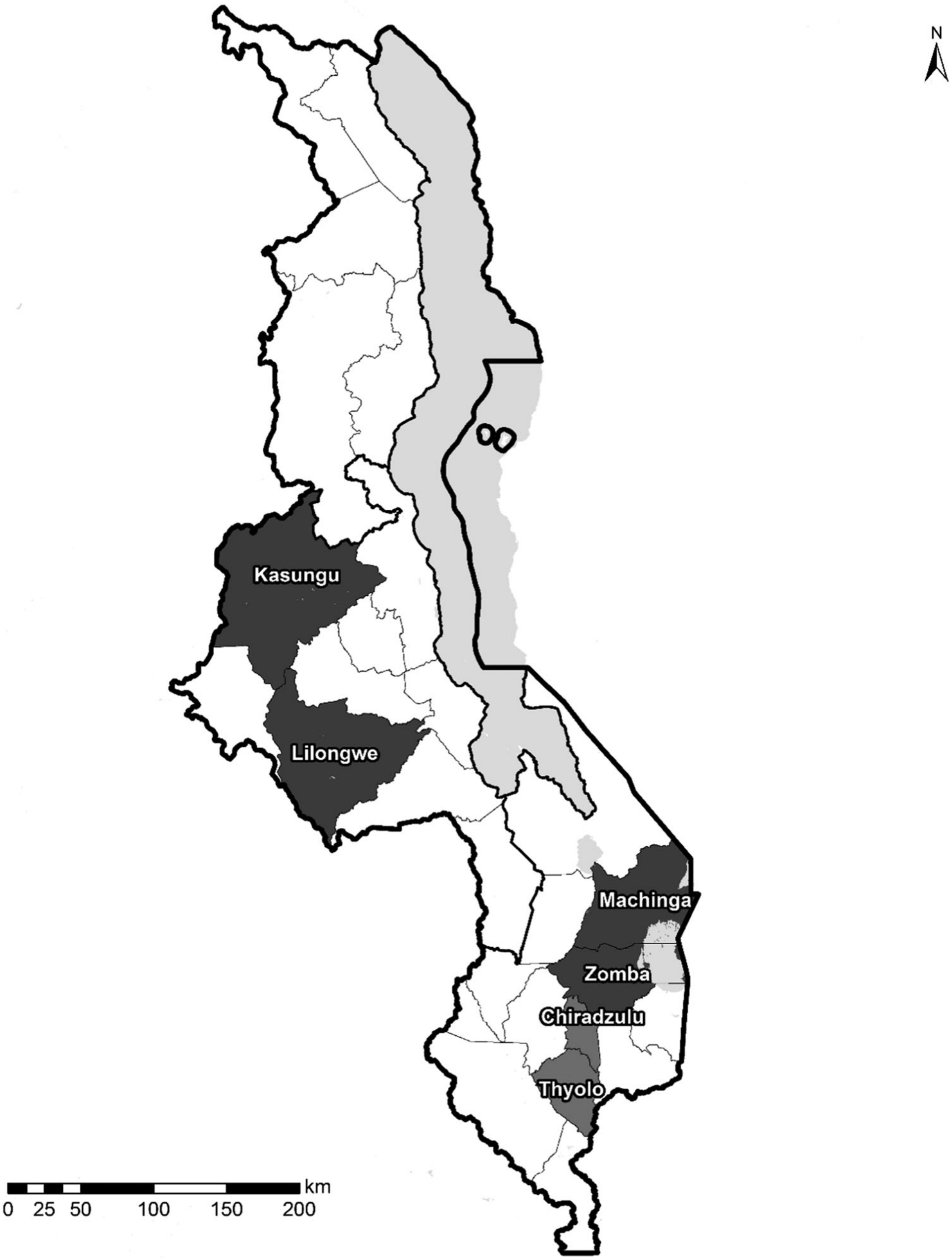

Figure 1. Map of the study area.

The uniqueness of this dataset lies in the sampling of lead farmers with the subsample of followers which allows us to assess the impacts of lead farmer characteristics on their followers' familiarity with and adoption of CA technologies. The lead farmer is directly in contact with his/her followers mainly through demonstration plots. Usually these are farmers from the same EPA section and in most cases from the same village as the lead farmer. This implies that both the lead farmer and follower farmers are quite familiar with each other. The follower farmer is able to follow the activities of their lead farmer and is likely to be influenced by his/her familiarity and adoption of the technologies and may be able to witness their performance on the

lead farmers' own fields as well as on demonstration field plots.

Estimation strategy

We analyze follower farmer adoption of CA practices as a two-stage process (Lindner, Pardey, & Jarrett, 1982). In the first stage, followers gain awareness/familiarity with a practice. This stage terminates once information has been acquired from an adequate number of sources such that technology awareness is achieved. In the second stage, the farmer uptakes the CA practice, which occurs once the farmer is sufficiently convinced that the expected benefits of adoption exceed the expected costs. In a few studies (e.g. Lambrecht, Vanlauwe, Merckx, & Maertens, 2014; Moser & Barrett, 2006), the adoption stage is separated into tryout and continued use (or disadoption), but data are unavailable for such separation here. For each of the four CA practices, the two-stage model is specified as

$$\text{Familiarity:}F = 1[\alpha_0 + \alpha_1\boldsymbol{L} + \alpha_2\boldsymbol{E} + \alpha_3\boldsymbol{X} + \alpha_4\boldsymbol{D} + \varepsilon_F > 0] \\ = 0, \text{otherwise.} \tag{1}$$

$$\text{Adoption:}A = 1[\beta_0 + \beta_1\boldsymbol{L} + \beta_2\boldsymbol{E} + \beta_3\boldsymbol{X} + \beta_4\boldsymbol{D} + \varepsilon_A > 0] \\ = 0, \text{otherwise.} \tag{2}$$

To estimate the two-equation system for each CA practice, we use the bivariate probit model specification, representing decisions that are potentially interdependent (Greene, 2018, sec. 17.9; Hardin, 1997).[4] While there were a few adopters in our sample who were unfamiliar with the CA technologies, adoption was much more likely for farmers who were familiar with CA. Joint maximum likelihood estimation of the bivariate probit model is preferred because it achieves more efficient and consistent parameter estimates. It corrects for selection bias related to the dependence of adoption on familiarity by allowing the error terms in the two models to be correlated. The correlation between the error terms of the familiarity and adoption equations, rho = Corr(ε_F, ε_A), is different from zero if familiarity and adoption are interdependent.

In the familiarity and adoption equations (1) and (2) above, ***L*** is a vector of variables that proxy lead farmer extension quality (i.e. motivation, familiarity, and adoption), ***E*** represents other sources of extension information, ***X*** is a set of household and farm characteristics, and ***D*** denotes district fixed-effects. Inclusion of the three proxies for F2FE quality enables us to test three hypotheses for how information about the CA technologies flows from lead farmers to their followers. Hypothesis 1 is that lead farmers' motivation (as lead farmers) influences the familiarity with and adoption of CA technologies among their followers. Motivation was measured in our survey on a scale from one (unmotivated) to four (very motivated) based on how farmers responded to the question 'How motivated are you as a lead farmer?' We assume lead farmers, like any other providers of extension information, will be better at convincing followers about the advantages of the CA technologies if they are motivated about their role in informing farmers. BenYishay and Mobarak (2014) found that offering peer farmers in Malawi a small performance incentive increased their effort to learn about pit planting and, in turn, their effectiveness at convincing other farmers to adopt. Other qualitative studies suggest that motivation of lead farmers is important to the success of F2FE in disseminating new technologies (Davis et al., 2016).

Hypothesis 2 is that lead farmers' familiarity with CA technologies increases followers' familiarity with and adoption of CA technologies. Familiarity was measured in our survey by asking farmers which CA technologies they are familiar with. Familiarity/awareness with a CA principle or supporting agricultural practice is a necessary condition for a lead farmer to diffuse the technology to other farmers.

The third hypothesis proposes that lead farmers' own experimentation and adoption of CA technologies is positively associated with followers' familiarity with and adoption of CA technologies. That is, we assume that a key avenue for followers to learn about new technologies is by observing lead farmers' experimentations. There is some empirical work in support of this contention. Matuschke and Qaim (2009), for example, found in their study of hybrid seed adoption in India that a farmer's decision to adopt a new technology was strongly influenced by the adoption choices of the farmer's social network members. Bandiera and Rasul (2006) examined how Mozambican farmers' decisions to adopt a new crop (sunflower) are influenced by the adoption choices of their social networks. They found a nonlinear (U-shaped) relationship between probability of adoption

and the number of adopters among family and friends. In other words, social effects were positive when there were few adopters in the network, and negative when there were many.

The empirical model controls for several other sources of CA information (***E***), including agricultural extension officer visits, NGO contacts, farm field days, village extension meetings, other farmer advice contacts, and electronic media. Multiple sources of information are useful for diffusing new technologies. For example, Beaman, BenYishay, Magruder, and Mobarak (2015) found that farmers in Malawi needed to receive information from multiple sources before they were willing to try out pit planting. Krishnan and Patnam (2013) found for Ethiopia that learning about improved seeds and fertilizer from extension agents was initially high, but wore off after some time, whereas the importance of learning from other farmers was sustained over time. A third related study (Genius, Koundouri, Nauges, & Tzouvelekas, 2013) found that irrigation technology adoption in Greece was strongly determined by both extension services and social learning, and the effectiveness of these information channels was enhanced by the presence of the other.

Multiple factors beyond lead farmers and other sources of extension information should influence follower farmer familiarity with and adoption of CA technologies, including the context in which follower farmers live and farm (measured using district fixed-effects ***D***) and individual and household characteristics (***X***). There is variation in rainfall conditions, agro-ecology, livestock ownership, and market access across (and within) the six Malawi districts under study and such variation should associate to differences in CA familiarity and adoption. The empirical model includes five household-level variables commonly featured in empirical studies of agricultural technology adoption: gender and age of the household head, average education of adult household members, household size, and farm size.

Research shows that female farmers have less access to agricultural information and lower rates of technology adoption than male farmers (Fisher & Carr, 2015; Fisher & Kandiwa, 2014; Lambrecht, Vanlauwe, & Maertens, 2016). Age is often used to proxy farming experience, and more experienced farmers would be expected to have greater awareness of agricultural innovations. On the other hand, older farmers are often viewed as more risk averse and therefore less willing to learn about and adopt new technologies (Ghadim & Pannell, 1999). Previous evidence indicates that educated individuals are better able to quickly and effectively process information about new technologies (Foster & Rosenzweig, 2010); thus, we anticipate a positive association between education and CA familiarity and adoption. Household size is used to proxy labour availability and its expected association with CA adoption may vary depending on whether a CA practice is labour demanding, labour saving, or labour neutral. Preparation, transportation and application of organic manure are labour demanding, particularly where there is scarcity of easily available organic matter, as in central and southern Malawi (Holden & Lunduka, 2012). It is often assumed that farmers with larger operations will be more willing to invest in new technologies, and several studies have found a positive association between farm size and CA adoption; but a negative association has also been found (Knowler & Bradshaw, 2007).

Descriptive analyses

The data indicate differences in familiarity with the four CA technologies between followers and lead farmers and similarly for adoption of the practices (Figures 2 and 3). We include herbicides in the figures but not in the empirical analysis, because the very low adoption of herbicides presented estimation issues for the bivariate model. Familiarity and adoption levels are higher for the lead farmers than their followers for all the technologies, but the differences are not large in most cases. For familiarity, the difference between lead and follower farmers is greatest for organic manure, a 10 percentage point difference, and smallest for crop rotation and mulching, about a 5 percentage point difference (Figure 2). For adoption, the difference is largest for organic manure and smallest for mulching and minimum tillage (Figure 3).

Extension contacts were evident with government agricultural extension contacts being the most frequent (Table 1). However, there was substantial variation in the number of contacts for all sources. Average household size of follower farmers was about five members, average adult education equivalent to three years of primary school, and average farm size one hectare.

Results

Table 2 presents the bivariate probit model results. We begin by reporting the marginal effects for the

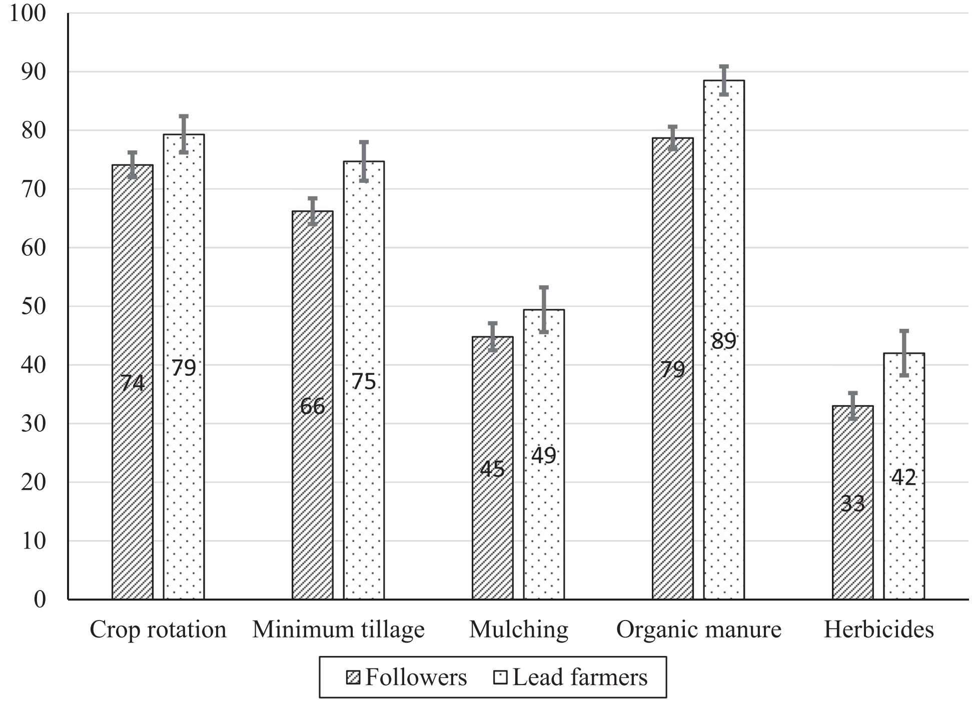

Figure 2. Familiarity with the three CA principles, organic manure, and herbicides among followers and their lead farmers. Source: NMBU Malawi CA survey 2016. The figure gives average rates for followers and the lead farmers of the same followers (lead farmers weighted by the number of followers in the sample).

familiarity equations, focusing first on the variables used to proxy the quality of F2FE (i.e. lead farmer motivation, familiarity, and adoption). Table 2 shows that for three of the four CA practices lead farmers' familiarity is positively associated ($p < 0.05$) with followers' familiarity with these technologies. Lead farmers' adoption of the CA technologies is positively associated with followers' awareness of minimum tillage and mulching. Lead farmer motivation is positively and significantly associated with followers' awareness of mulching and organic manure.

Many of the other extension contact variables are statistically significant in Table 2. Village extension meetings stand out as a source of agricultural information that positively associates with follower farmer familiarity for nearly all the CA practices (the exception is mulching). At the other extreme, other farmer advice contacts are found to have no statistically significant influence on familiarity with CA among the sample of followers. Table 2 also shows some systematic variations across the CA technologies in terms of the role of other extension contacts. Crop rotation familiarity is positively associated with nearly all the other extension contact variables. By contrast, while mulching increases with the number of private agricultural extension contacts, it decreases with the number of government agricultural extension and NGO contacts, field visits, and electronic media messages.

A few of the household characteristic variables are statistically significant in Table 2. Age of the household head is negatively associated with follower familiarity with crop rotation and organic manure. Follower farmer familiarity with minimum tillage is found to be increasing in household size and average education of adult household members. The district dummy variables suggest that location matters to follower farmer familiarity. For example, compared with their counterparts in Kasungu district, follower farmers in Lilongwe district are generally more likely to be familiar with CA practices, whereas follower farmers in Thyolo district are less likely to have awareness of crop rotation and organic manure.

We turn now to the results for CA technology adoption in Table 2. The statistical significance of rho suggests there is correlation between the error terms of the familiarity and adoption equations and supports our decision to use the bivariate probit

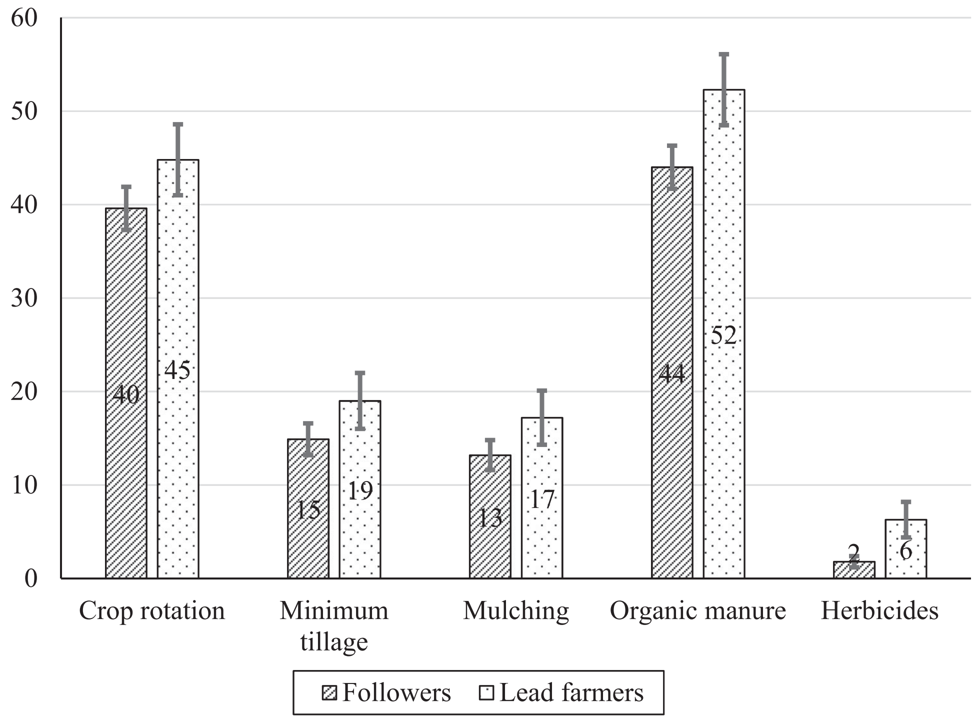

Figure 3. Adoption of the three CA principles, organic manure, and herbicides by followers and their lead farmers. Source: NMBU Malawi CA survey 2016.

Note: The table gives the distribution of the number of CA technologies adopted by followers and their lead farmers.

Table 1. Descriptive statistics for follower farmers' other extension contacts, household characteristics, and district of residence.

Variable	Obs	Mean	Std. Dev.	Min	Max
Government ag extension contacts	455	1.93	2.24	0	11
Private ag extension contacts	455	0.08	0.45	0	6
NGO contacts	455	0.18	0.63	0	7
Farm field day visits	455	0.23	1.14	0	10
Village extension meetings	455	0.07	0.61	0	7
Other farmer advice contacts	455	0.10	0.41	0	5
Electronic media contacts	455	0.29	0.97	0	8
Female head, dummy	451	0.19	0.39	0	1
Age of household head	451	47.90	13.70	12	86
Hh size	455	5.30	1.96	1	12
Average education of adults in hh	455	3.04	2.56	0	20
Owned farm size, ha GPS	444	1.06	1.20	0.03	17.10
District FE: Base: Kasungu	455	0.21			
Lilongwe	455	0.22			
Machinga	455	0.15			
Zomba	455	0.35			
Chiradzulu	455	0.07			
Thyolo	455	0.004			

Source: NMBU Malawi CA survey 2016.

model. The marginal effects for the adoption equations are conditional on farmers being familiar with the given technology, that is they relate to the probability that both the adoption and familiarity variables are equal to one. Findings in the table indicate that follower farmers have a higher probability of adopting crop rotation and organic manure if they have a lead farmer who is familiar with the given CA practice. Lead farmer motivation is positively associated with followers' adoption of minimum tillage and mulching. Whether a lead farmer has adopted CA practices is found to have no statistically significant relationship with follower farmer CA adoption.

Several of the other extension contacts are found to be important for the adoption of CA technologies. Crop rotation adoption is positively associated with government agricultural extension, NGO contacts, farmer field days, and village extension meetings. Adoption of mulching is positively associated with private agricultural extension contacts. And there is a positive association between follower farmer adoption of organic

Table 2. Marginal effects from bivariate probit models for adoption conditional on familiarity with CA technologies.

	Crop rotation	Min. tillage	Mulching	Org. Manure
Familiarity models				
Constant	0.466	−1.058**	−1.034**	0.086
Lead farmer familiar with technology	0.377**	0.607****	0.238*	0.028
Lead farmer has adopted technology	0.092	0.421**	0.392**	0.079
Lead farmer motivation: 1(low)-4(high)	0.048	−0.016	0.229**	0.161*
Government ag extension contacts	0.130****	0.046	−0.092***	0.116****
Private ag extension contacts	0.349**	−0.037	0.741****	−0.011
NGO contacts	0.325**	0.326**	−0.274***	0.033
Farm field day visits	0.218***	−0.030	−0.164**	0.072
Village extension meetings	5.403****	5.543****	0.147	4.966****
Other farmer advice contacts	0.282	−0.065	0.112	0.003
Electronic media contacts	−0.030	0.092	−0.202**	−0.082
Female head, dummy	−0.109	0.097	−0.251	−0.017
Hh head age	−0.008*	−0.005	−0.003	−0.010**
Household size	−0.015	0.112***	−0.013	0.001
Adult education mean years	−0.011	0.078***	−0.006	0.007
Own farm size, ha GPS	0.109	−0.016	0.082	0.083
District FE: Kasungu = base				
Lilongwe	−0.108	0.400*	0.580***	0.536**
Machinga	−0.264	0.051	0.005	0.011
Zomba	−0.404*	0.323*	0.454**	0.304
Chiradzulu	−0.552	1.374****	0.889***	0.369
Thyolo	−8.287****	0.081	−5.096****	−0.631
Adoption models				
Constant	0.254	−3.104****	−2.516****	−1.380***
Lead farmer familiar with technology	0.369**	0.273	0.072	0.455**
Lead farmer has adopted technology	0.151	−0.002	0.356	0.082
Lead farmer motivation: 1(low)-4(high)	−0.030	0.362***	0.273**	0.017
Government ag extension contacts	0.124****	0.015	0.012	0.076***
Private ag extension contacts	0.072	−4.874****	0.478***	0.188*
NGO contacts	0.310***	−0.005	−0.142	0.001
Farm field day visits	0.311***	0.066	0.037	−0.077
Village extension meetings	0.221*	−0.146	−3.576****	0.061
Other farmer advice contacts	0.068	0.187	−0.871**	−0.040
Electronic media contacts	−0.115*	0.026	−0.104	0.045
Female head, dummy	−0.249	0.025	−0.445**	−0.034
Hh head age	−0.007	0.000	0.005	0.002
Household size	−0.034	0.063	−0.026	0.059*
Adult education mean years	−0.024	0.033	0.020	−0.001
Own farm size, ha GPS	0.079	0.029	−0.003	−0.037
District FE: Kasungu = base				
Lilongwe	−0.812****	−0.337	0.386	0.175
Machinga	−0.543**	−0.025	0.049	0.163
Zomba	−0.777****	0.105	0.323	0.306
Chiradzulu	−0.745**	0.774**	0.355	0.623**
Thyolo	−6.675****	1.183	−5.226****	0.253
Athrho constant	0.544****	0.852****	1.179****	0.617****
Rho	0.496****	0.692****	0.827****	0.549****
Log pseudolikelihood	−457.960	−399.981	−380.836	−480.088
Prob > chi2	0.000		0.000	
Number of observations	440	440	440	440

Source: NMBU Malawi CA survey 2016. *Note*: Results from bivariate probit models with robust standard errors. Significance levels: *0.10; **0.05; ***0.01; ****0.001.

manure and both government and private agricultural extension contacts. There are also some negative marginal effects. For example, follower farmer adoption of minimum tillage is found to be a decreasing function of private agricultural extension contacts.

Results in Table 2 indicate that household characteristics are far less important than F2FE quality and other extension contacts for explaining follower farmer adoption of CA practices. Only two household characteristic variables are statistically significant. Follower farmers are less likely to adopt mulching if the household head is female, and more likely to adopt organic manure if the household has many members. Several of the district fixed-effects are

statistically significant. Adoption of crop rotation is much more likely in Kasungu district than in the other districts. Minimum tillage and organic manure are more likely to be practiced by follower farmers in Chiradzulu vs. Kasungu district.

Discussion

What difference can F2FE make for fostering awareness and adoption of CA practices among smallholder farmers in Malawi? Four main sets of findings speak to this question. First, motivated lead farmers are more effective than less motivated lead farmers at increasing followers' familiarity with mulching and organic manure and adoption of minimum tillage and mulching. These results are in support of Hypothesis 1 and agree with other studies that found the motivation of lead farmers important for the diffusion of new agricultural technologies (e.g. BenYishay & Mobarak, 2014; Davis et al., 2016). Minimum tillage is a non-negotiable part of CA and mulching is also an important CA principle, and both technologies are not widely used at the study sites. To foster lead farmer motivation and thereby follower farmer adoption of CA, continuation and standardization of the small performance-based incentives (e.g. boots, bags of seed) that are currently part of F2FE in Malawi is recommended, keeping in mind that stronger incentives may create distortions that may not lead to durable adoption. Extension providers can also make their F2FE programmes more effective and sustainable by learning what drives their lead farmers (e.g. increased knowledge or altruism) and tailoring incentives accordingly (Kiptot et al., 2016).

Second, we find that lead farmer familiarity and adoption both matter to the diffusion of CA practices, but familiarity appears to matter more. Lead farmer familiarity is found to positively associate to their follower farmers' familiarity with the three CA principles and adoption of crop rotation and organic manure, providing evidence for Hypothesis 2. Lead farmer adoption is significant with a positive sign in two of the familiarity models (minimum tillage and mulching), in support of Hypothesis 3, but has no significant association with follower farmer adoption of CA practices. To help lead farmers gain familiarity with the various CA practices, expansion of the lead farmer training programme may be warranted with specific emphasis on training lead farmers in the various CA practices. As mentioned earlier, a survey of lead farmers in Malawi suggests lead farmers do not currently receive sufficient training (Khaila et al., 2015).

Third, our study suggests that lead farmers are playing a more critical role in increasing awareness of CA than promoting adoption of the practices. This finding is consistent with lead farmers providing information, but not changing the profitability of the technologies other than the expected return through the information provided. Initial adoption of minimum tillage may require subsidies for herbicides to overcome the initial weed problem and high costs of removing weeds (Ares, Thierfelder, Reyes, Eash, & Himmelstein, 2015). Unfortunately, we are unable to test this hypothesis given very low levels of herbicide adoption at the study sites.

Further insights on why lead farmers may play a more important role in increasing follower familiarity than adoption come from the household survey data and the work of Rogers (1995). Further inspection of the data reveal that, compared to follower farmers, lead farmers are younger and more educated, have greater labour availability, operate larger farms, and have greater wealth (as measured by the value of livestock holdings and farm equipment). In the terminology of Rogers (1995), lead and follower farmers have heterophilous ties. According to Rogers (1995), homophilous and heterophilous networks have distinct and complementary roles in the diffusion of innovations. Heterophilous networks, such as that between lead and follower farmers, are more important in triggering awareness of a new technology, because new ideas most often enter a system through individuals who have higher status and are more innovative. Homophilous networks are, however, more useful than heterophilous ties in persuading potential adopters of the merits of the innovation.

BenYishay and Mobarak (2014) found evidence in favour of this proposition for the case of adoption of pit planting and Chinese compositing in Malawi. In their study, peer farmers (i.e. chosen to be similar to the average farmer in the study villages) performed better than lead farmers (wealthier, progressive farmers) at encouraging adoption among a random sample of farmers, and the most persuasive peer farmers were those most similar to other farmers in their village in terms of resource access. The implication is that if F2FE is to have a greater role in encouraging follower farmers to adopt innovations it may be necessary to identify lead farmers that are capable and motivated to train other farmers but not too socially distant from the target population of farmers in terms of

personal characteristics and innovativeness. Further research should investigate the importance of the social position of lead farmers for their influence on technology adoption among their followers.

Finally, results make clear that F2FE can complement rather than substitute for other sources of agricultural extension. We find that follower farmers are learning about CA practices from multiple sources, particularly lead farmers, government and private agricultural extension officers, and village extension meetings. That farmers need to receive information about a new technology from multiple sources before they will adopt is consistent with other agricultural technology adoption studies (Beaman et al., 2015; Genius et al., 2013; Krishnan & Patnam, 2013) and in line with Malawi's pluralistic extension system (Masangano & Mthinda, 2012). Our results also show variation across CA practices in how a pluralistic extension system influences technology diffusion. Most notable are the differences between crop rotation and mulching. Crop rotation awareness and adoption increase with receipt of information from nearly all the extension sources studied. For mulching, by contrast, there are roughly equal positive and negative associations between extension sources and awareness and uptake. This might indicate that the various extension sources are coordinated in their efforts to diffuse crop rotation to farmers but are sending mixed messages for the case of mulching. It is also conceivable that some extension personnel lacked technical training on mulching practices or have advised their clients against adoption. Further research is recommended to better understand these results and thereby uncover ways to improve the design, coordination, and targeting of agricultural extension programmes to specific CA practices.

Conclusions

This paper examines awareness and adoption of CA technologies among follower farmers of lead farmers to assess the role F2FE can plan in diffusing CA in Malawi. Data for the study come from a 2016 farm household survey conducted in central and southern Malawi that links 180 lead farmers to their 455 followers. We model follower farmer adoption of CA practices as a two-stage process in which farmers gain awareness/familiarity in a first information-seeking stage and then adopt the technology once they are sufficiently convinced the expected benefits exceed the expected costs.

The data are used to estimate a bivariate probit model of follower farmer familiarity and adoption of the three CA principles and one supporting practice (organic manure). The study has four main findings on the role of F2FE for spreading CA practices to smallholder farmers in Malawi. First, we find that motivated lead farmers are more effective at diffusing CA practices to their followers. Second, lead farmer familiarity with and adoption of CA both matter to the spread of CA practices, but familiarity appears to matter more. Third, lead farmers are found to play a more critical role in increasing awareness than adoption of the CA practices. Finally, F2FE is a complement rather than substitute for other sources of agricultural extension in Malawi's pluralistic extension system.

What practical implications might these results provide for enhancing the effectiveness of F2FE as a means to spread CA practices to smallholder farmers in Malawi? First, small, performance-based incentives may be important for motivating lead farmers and could be tailored to the specific motivations of lead farmers (e.g. knowledge or altruism). Second, increased and targeted training of lead farmers with an approved set of CA guidelines can ensure they are sufficiently familiar with the CA practices. Third, it may be necessary to identify a specific group of lead farmers that is capable and motivated to train other farmers but not too socially distant from the target population of farmers in terms of personal characteristics and innovativeness. Finally, improved and seamless collaboration among the various players in Malawi's pluralistic extension system can enable a more coordinated effort to diffuse CA practices to smallholder farmers.

Notes

1. We use the term 'lead farmer' when referring to such farmer trainers, given its prominence in Malawi, the geographic focus of our study. Several other labels are also commonly used (e.g. opinion leader, model farmer, community knowledge worker, contact farmer, volunteer farmer, master farmer, community volunteer), depending on the specific roles and tasks performed.
2. Exceptions are Beaman et al. (2015), BenYishay and Mobarak (2014), Krishnan and Patnam (2013), and Genius et al. (2013).
3. This added to the survey costs and the survey budget caused a more limited coverage in Chiradzulu and Thyolo districts.
4. We also tested heckprobit models, i.e. sequential probit models, but these did not perform satisfactorily.

Acknowledgements

This is an output from the 'Adoption of Conservation Agriculture Technologies in Malawi' project of the School of Economics and Business, Norwegian University of Life Sciences. The data collection and most researcher time was funded by the CGIAR Independent Science and Partnership Council and the NORAD-funded NORHED 'Climate-Smart Natural Resource Management and Policy (CLISNARP)' project. Researcher time to contribute to this publication was also supported by the MAIZE CGIAR Research program (www.maize.org). We acknowledge the help of Kai Sonder in preparing the map of survey districts. Many thanks are due to the survey enumerators and survey respondents in Malawi.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This is an output from the 'Adoption of Conservation Agriculture Technologies in Malawi' project of the School of Economics and Business, Norwegian University of Life Sciences. The data collection and most researcher time was funded by the CGIAR Independent Science and Partnership Council and the NORAD-funded NORHED 'Climate-Smart Natural Resource Management and Policy (CLISNARP)' project. Researcher time to contribute to this publication was also supported by the MAIZE CGIAR Research program (www.maize.org).

References

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), 631–647.

Anderson, J. R., & Feder, G. (2004). Agricultural extension: Good intentions and hard realities. *The World Bank Research Observer*, *19*(1), 41–60.

Andersson, J. A., & D'Souza, S. (2014). From adoption claims to understanding farmers and contexts: A literature review of conservation agriculture (CA) adoption among smallholder farmers in southern Africa. *Agriculture, Ecosystems & Environment*, *187*, 116–132.

Ares, A., Thierfelder, C., Reyes, M., Eash, N. S., & Himmelstein, J. (2015). Global perspectives on conservation agriculture for small households. In *Conservation agriculture in subsistence farming: Case studies from South Asia and beyond* (pp. 22–54). Wallingford: Cabi Publishing.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., & Cattaneo, A. (2014). Adoption and intensity of adoption of conservation farming practices in Zambia. *Agriculture, Ecosystems & Environment*, *187*, 72–86.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The Economic Journal*, *116*(514), 869–902.

Baudron, F., Thierfelder, C., Nyagumbo, I., & Gérard, B. (2015). Where to target conservation agriculture for African smallholders? How to overcome challenges associated with its implementation? Experience from Eastern and Southern Africa. *Environments*, *2*(3), 338–357.

Beaman, L., BenYishay, A., Magruder, J., & Mobarak, A. M. (2015). Can network theory-based targeting increase technology adoption? Unpublished manuscript.

BenYishay, A., & Mobarak, A. M. (2014). *Social learning and communication* (Vol. NBER Working Paper no. W20139). Cambridge, MA: National Bureau of Economic Research.

Bunderson, W., Jere, Z., Thierfelder, C., Gama, M., Mwale, B., Ng'oma, S., & Mkandawire, O. (2015). Implementing the principles of conservation agriculture in Malawi: Crop yields and factors affecting adoption. In A. H. Kassam, S. Mkomwa, & T. Friedrich (Eds.), *Conservation agriculture for Africa: Building resilient farming systems in a changing climate* (pp. 75–99). Wallingford: Cabi Publishing.

Davis, K., Franzel, S., & Spielman, D. (2016). Extension options for better livelihoods and poverty reduction: A selected review 2012–2015: MSU International Development Working Paper.

Fisher, M., & Carr, E. R. (2015). The influence of gendered roles and responsibilities on the adoption of technologies that mitigate drought risk: The case of drought-tolerant maize seed in eastern Uganda. *Global Environmental Change*, *35*, 82–92.

Fisher, M., & Kandiwa, V. (2014). Can agricultural input subsidies reduce the gender gap in modern maize adoption? Evidence from Malawi. *Food Policy*, *45*, 101–111.

Food and Agriculture Organization of the United Nations. (2015). *Malawi country fact sheet on food and agriculture policy trends*. Retrieved from FAO website: http://www.fao.org/3/a-i4491e.pdf

Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annual Review of Economics*, *2*(1), 395–424.

Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., … Bayala, J. (2010). Evergreen agriculture: A robust approach to sustainable food security in Africa. *Food Security*, *2*(3), 197–214.

Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2013). Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *American Journal of Agricultural Economics*, *96*(1), 328–344.

Ghadim, A. K. A., & Pannell, D. J. (1999). A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics*, *21*(2), 145–154.

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*, *114*(1), 23–34.

Grabowski, P. P., Haggblade, S., Kabwe, S., & Tembo, G. (2014). Minimum tillage adoption among commercial smallholder cotton farmers in Zambia, 2002 to 2011. *Agricultural Systems*, *131*, 34–44.

Greene, W. (2018). *Econometric analysis*. New York: Pearson.

Hardin, J. W. (1997). Bivariate probit models. *Stata Technical Bulletin*, *6*(33), 15–20.

Holden, S., & Lunduka, R. (2012). Do fertilizer subsidies crowd out organic manures? The case of Malawi. *Agricultural Economics*, *43*(3), 303–314.

Holden, S. T., & Lunduka, R. W. (2014). Input subsidies, cash constraints, and timing of input supply. *American Journal of Agricultural Economics*, *96*(1), 290–307.

Holden, S. T., & Quiggin, J. (2017). Climate risk and state-contingent technology adoption: Shocks, drought tolerance and

preferences. *European Review of Agricultural Economics*, *44*(2), 285–308.

Kangmennaang, J., Kerr, R. B., Lupafya, E., Dakishoni, L., Katundu, M., & Luginaah, I. (2017). Impact of a participatory agroecological development project on household wealth and food security in Malawi. *Food Security*, *9*(3), 1–16.

Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The spread of conservation agriculture: Justification, sustainability and uptake. *International Journal of Agricultural Sustainability*, *7*(4), 292–320.

Khaila, S., Tchuwa, F., Franzel, S., & Simpson, B. (2015). The farmer-to-farmer extension approach in Malawi: A survey of lead farmers: ICRAF Working Paper.

Kiptot, E., Karuhanga, M., Franzel, S., & Nzigamasabo, P. B. (2016). Volunteer farmer-trainer motivations in East Africa: Practical implications for enhancing farmer-to-farmer extension. *International Journal of Agricultural Sustainability*, *14*(3), 339–356.

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy*, *32*(1), 25–48.

Krishnan, P., & Patnam, M. (2013). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics*, *96*(1), 308–327.

Kundhlande, G., Franzel, S., Simpson, B., & Gausi, E. (2014). Farmer-to-farmer extension approach in Malawi: A survey of organizations: ICRAF Working Paper.

Lambrecht, I., Vanlauwe, B., & Maertens, M. (2016). Agricultural extension in Eastern Democratic Republic of Congo: Does gender matter? *European Review of Agricultural Economics*, *43*(5), 841–874.

Lambrecht, I., Vanlauwe, B., Merckx, R., & Maertens, M. (2014). Understanding the process of agricultural technology adoption: Mineral fertilizer in eastern DR Congo. *World Development*, *59*, 132–146.

Lindner, R. K., Pardey, P. G., & Jarrett, F. G. (1982). Distance to information source and the time lag to early adoption of trace element fertilisers. *The Australian Journal of Agricultural Economics*, *26*(2), 98–113.

Liverpool-Tasie, L. S. O., & Winter-Nelson, A. (2012). Social learning and farm technology in Ethiopia: Impacts by technology, network type, and poverty status. *Journal of Development Studies*, *48*(10), 1505–1521.

Masangano, C., & Mthinda, C. (2012). Pluralistic extension system in Malawi.

Matuschke, I., & Qaim, M. (2009). The impact of social networks on hybrid seed adoption in India. *Agricultural Economics*, *40*(5), 493–505.

Moser, C. M., & Barrett, C. B. (2006). The complex dynamics of smallholder technology adoption: The case of SRI in Madagascar. *Agricultural Economics*, *35*(3), 373–388.

Munshi, K. (2004). Social learning in a heterogeneous population: Technology diffusion in the Indian Green Revolution. *Journal of Development Economics*, *73*(1), 185–213.

Nakano, Y., Tsusaka, T. W., Aida, T., & Pede, V. O. (2015). The impact of training on technology adoption and productivity of rice farming in Tanzania: Is farmer-to-farmer extension effective?

National Statistical Office. (2010). *National census of agriculture and livestock 2006/07 main report*. Retrieved from National Statistical Office website: http://www.nsomalawi.mw/images/stories/data_on_line/agriculture/NACAL/Nacal%20Report.pdf

Ngongondo, C., Xu, C.-Y., Gottschalk, L., & Alemaw, B. (2011). Evaluation of spatial and temporal characteristics of rainfall in Malawi: A case of data scarce region. *Theoretical and Applied Climatology*, *106*(1–2), 79–93.

Ngwira, A., Johnsen, F. H., Aune, J. B., Mekuria, M., & Thierfelder, C. (2014). Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. *Journal of Soil and Water Conservation*, *69*(2), 107–119.

Ngwira, A. R., Thierfelder, C., & Lambert, D. M. (2013). Conservation agriculture systems for Malawian smallholder farmers: Long-term effects on crop productivity, profitability and soil quality. *Renewable Agriculture and Food Systems*, *28*(4), 350–363.

Powlson, D. S., Stirling, C. M., Thierfelder, C., White, R. P., & Jat, M. L. (2016). Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agroecosystems? *Agriculture, Ecosystems, & Environment*, *220*, 164–174.

Rogers, E. M. (1995). Diffusion of Innovations: modifications of a model for telecommunications. In M. W. Stoetzer, & A. Mahler (Eds.), *Die Diffusion von Innovationen in der Telekommunikation* (pp. 25–38). Berlin: Springer.

Steward, P. R., Dougill, A. J., Thierfelder, C., Pittelkow, C. M., Stringer, L. C., Kudzala, M., & Shackelford, G. E. (2018). The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields. *Agriculture, Ecosystems & Environment*, *251*, 194–202.

Thierfelder, C., Chisui, J. L., Gama, M., Cheesman, S., Jere, Z. D., Bunderson, W. T., … Rusinamhodzi, L. (2013). Maize-based conservation agriculture systems in Malawi: Long-term trends in productivity. *Field Crops Research*, *142*, 47–57.

Thierfelder, C., Chivenge, P., Mupangwa, W., Rosenstock, T. S., Lamanna, C., & Eyre, J. X. (2017). How climate-smart is conservation agriculture (CA)?–Its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. *Food Security*, *9*(3), 537–560.

Thierfelder, C., Matemba-Mutasa, R., Bunderson, W. T., Mutenje, M., Nyagumbo, I., & Mupangwa, W. (2016). Evaluating manual conservation agriculture systems in southern Africa. *Agriculture, Ecosystems & Environment*, *222*, 112–124.

Thierfelder, C., Rusinamhodzi, L., Ngwira, A. R., Mupangwa, W., Nyagumbo, I., Kassie, G. T., & Cairns, J. E. (2015). Conservation agriculture in Southern Africa: Advances in knowledge. *Renewable Agriculture and Food Systems*, *30*(4), 328–348.

Thierfelder, C., & Wall, P. C. (2009). Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil and Tillage Research*, *105*(2), 217–227.

Verhulst, N., Nelissen, V., Jespers, N., Haven, H., Sayre, K. D., Raes, D., … Govaerts, B. (2011). Soil water content, maize yield and its stability as affected by tillage and crop residue management in rainfed semi-arid highlands. *Plant and Soil*, *344*(1–2), 73–85.

Wall, P. C. (2007). Tailoring conservation agriculture to the needs of small farmers in developing countries: an analysis of issues. *Journal of Crop Improvement*, *19*(1–2), 137–155.

Wellard, K., Rafanomezana, J., Nyirenda, M., Okotel, M., & Subbey, V. (2013). A review of community extension approaches to innovation for improved livelihoods in Ghana, Uganda and Malawi. *The Journal of Agricultural Education and Extension*, *19*(1), 21–35.

Yaron, G., Mangani, R., Mlava, J., Kambewa, P., Makungwa, S., Mtethiwa, A., & Kazembe, J. (2011). *Economic valuation of sustainable natural resource use in Malawi*. Lilongwe, Malawi: Government of Malawi Ministry of Finance and Development Planning.