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The adoption potential of Conservation Agriculture technologies in Malawi: A lead farmer promoter-adopter approach and assessment[1]

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Abstract

This paper assesses the adoption potential of conservation agriculture (CA) technologies in Malawi, where CA appears highly appropriate. Estimation of CA adoption rates and their determinants is complicated by the relatively recent introduction of these technologies and limited awareness of CA among the general population of smallholder farmers.

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We propose a lead farmer promoter-adopter approach and use it to assess the adoption potential of CA among smallholder farmers in Malawi. This approach relies on the promoters being potential adopters themselves, having had sufficient exposure and access to the technologies, and their incentives not having been distorted by excessive incentives. These conditions are reasonably satisfied in our application with a sample of 181 lead farmers from central and southern Malawi.

We find adoption rates for the lead farmers of 56% for organic manure and crop rotation, 26% for minimum tillage, 30% for mulching, and 12% for herbicide application. Lead farmers recommend CA to their followers at rates of 66% for organic manure, about 50% for crop rotation and minimum tillage, 28% for mulching, and less than 10% for herbicide application. Assuming the validity of the promoter-adopter approach, these findings together suggest that, in central and southern Malawi, organic manure and crop rotation have the highest adoption potential, mulching and minimum tillage come next, and herbicide application has the lowest potential. With the farmer-to-farmer extension approach gaining popularity in many countries, we expect that our promoter-adopter approach to assessing adoption potential of new technologies will be of broad interest.

Keywords: Africa; conservation agriculture; farmer-to-farmer extension; Malawi; promoter-adopter approach; technology adoption

Introduction

Conservation agriculture (CA) aims to achieve improved and sustained agricultural productivity, increased profits and food security, while preserving and enhancing the resource base, through the application of three linked principles: minimum soil disturbance, permanent soil cover, and crop rotation (FAO, 2013). The suitability of CA for smallholders in sub-Saharan Africa (SSA) has been much debated in recent years, sparked by the paper of Giller et al. (2009). More recently, it is argued that the "niche" where CA fits in Eastern and Southern

Africa is large and growing, given the potential of CA in terms of saving energy (including labor and draft power), controlling soil erosion, and enhancing water-use efficiency (Baudron et al., 2015). CA seems highly relevant for Malawi, given the country is characterized by high rural population density (for SSA), very small landholdings, water constraints, soil degradation, low livestock densities, and low demand for crop residues for livestock feed (Andersson and D'Souza, 2014; Ellis et al., 2003; Ngwira et al., 2013; Wani et al. 2009). Despite the promise of CA, adoption by farmers in Malawi and elsewhere in SSA remains low (Andersson and D'Souza, 2014; Giller et al., 2009), and high abandonment of practices has been documented in some areas (Arslan et al., 2014). A recent estimate is that CA was practiced on 2.1% of the total cultivated land in six districts of central and southern Malawi in the 2009/10 cropping season (Ngwira et al., 2014).

Explanations for limited adoption of new agricultural technologies are many, including limited awareness among farmers, imperfect markets for credit and agricultural inputs, farmer risk aversion, and the technologies do not meet farmer criteria (e.g. Croppenstedt et al., 2003; Feder et al., 1985; Foster and Rosenzweig, 1995; Shiferaw and Holden, 1998; Holden and Quiggin, 2016; Lunduka et al., 2012). Of particular relevance to the present paper is empirical evidence pointing to "information failures" as a key impediment to the technological diffusion process and documenting the importance of learning from other farmers for overcoming such failures (Foster and Rosenzweig, 1995; BenYishay and Mobarak, 2014). From a methodological standpoint, information failures complicate estimation of technology adoption rates and their determinants. Estimates of the average adoption rate for a new technology suffer from non-exposure bias, because farmers who have not been exposed to the new technology cannot adopt it, but they might have adopted had they known about it (Diagne and Demont, 2007).

This study assesses the adoption potential of CA technologies in Malawi by studying the motivation, activity level (e.g. number of demonstration trials), own adoption, and recommendations of a sub-sample of lead farmers who have been exposed to the technologies due to their assigned role in dissemination of CA practices.[2] Farmer-to-farmer extension (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. In 2011, for example, the ratio of agricultural extension officers to farmers was 1/1,848 (Kaunda, 2011 cited in Khaila et al.). 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 and with the use of demonstration trials.

We assess CA adoption potential using new data for a sample of lead farmers promoting CA technologies in four districts of central and southern Malawi. A conceptual framework is developed that identifies potential links between the incentives, training, and extension information received by lead farmers and their motivation, activity level, familiarity, own adoption, and recommendations to follower farmers. The conceptual framework guides the empirical analysis of five research questions: (1) How motivated and active are the lead farmers, and what are the main factors associated with these variables? Motivation is measured through self-report, while activity level is measured by number of demonstration trials and number of followers. (2) How familiar are lead farmers with the different CA technologies, and how is this familiarity related to their exposure to training, motivation, experience, and having held demonstration trials? (3) To what extent have lead farmers themselves adopted the CA technologies on their own farms? (4) What drives lead farmers to recommend adoption of

[2] We use the term "lead farmer" when referring to such farmer trainers, given its prominence in Malawi the geographic focus of our study, but several other labels are also commonly used (e.g. model farmer, community knowledge worker, contact farmer, volunteer farmer), depending on the specific roles and tasks performed.

CA technologies to their followers? (5) What are the pros and the cons of the CA technologies that lead farmers emphasize and that are important for the adoption potential?

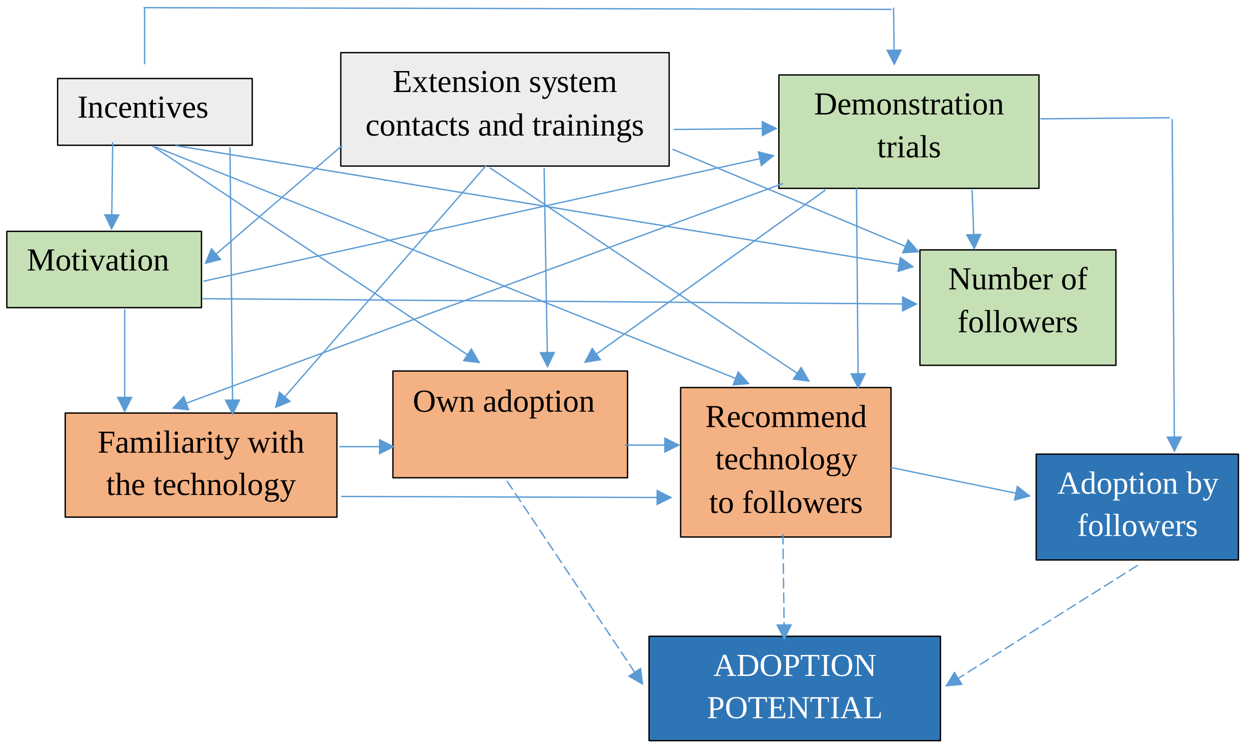
Conceptual framework

We develop a framework to assess the adoption potential of new technologies based on the exposure, perceptions, and behaviors of well-informed promoters (i.e. lead farmers) who are also potential users of the technologies. Technology adoption may be constrained by many factors including limited awareness and information about the technologies, limited availability, low profitability, high initial costs, delayed returns, high risk, high skill or other specific requirements. In particular, farmers who have not been exposed to the new technology cannot adopt it, but they might have adopted had they known about it (Diagne and Demont, 2007). For these reasons it is challenging to judge the potential of new technologies from a general sample of farmers. However, a sample of promoters who may be early adopters or at least well-informed prospective adopters can provide useful insights about the potential of such technologies. This group should be more informed and have better access to the technologies than the general farming population, and their perceptions and behavior therefore reveal valuable insights about the underlying technology potential, so long as these promoters are not too different from the average farmer in their area in other relevant characteristics.

We assess this promoter and potential adopter model through a study of lead farmers and the potential of CA technologies in Malawi. Lead farmers are promoters of CA technologies as well as potential adopters. As promoters they may, however, also be constrained by their motivation or level of information. We assess such variation and control for it. This also gives additional insights about the information channels and efficiency of the lead farmer model to technology promotion. The conceptual framework that guides our empirical analyses is illustrated in Figure 1. In the figure, the gray boxes represent government inputs into F2FE, green boxes are lead farmer inputs into diffusing the technologies, the orange boxes are lead farmer outcomes, and the dark blue boxes are outcomes for followers and farmers in general. The hashed lines indicate how adoption potential may be drawn from a number of indicators, while the posited underlying causal mechanisms are represented by solid lines.

The conceptual framework indicates that government inputs into F2FE (incentives, extension system contacts, and training) influence lead farmers' motivation and activity levels (number of demonstration trials and number of followers). Inputs into F2FE on the part of government and lead farmers (i.e. motivation and activity levels) are posited to impact lead farmers' familiarity with CA practices. All of these factors may directly or indirectly encourage lead

Figure 1. The lead farmer promoter-adopter model for assessing adoption potential of CA technologies



farmers to adopt and recommend CA to their followers. And, it is the lead farmers' adoption and recommendation rates that provide insights on the adoption potential of CA practices in Malawi. We assess adoption potential for a bundle of five CA technology components: crop rotation, minimum tillage, use of herbicides, soil coverage (mulching), and use of organic manure.

Data and descriptive statistics

The analysis is based on a survey of lead farmers in four districts in the Central and Southern regions of Malawi in 2016. The survey also included a random sample of households that have been resurveyed many times and a random sample of followers of lead farmers. This paper focuses primarily on the data collected from the lead farmers to assess the adoption potential of CA technologies. Given that the data are cross-sectional, we have to be careful about drawing causal inferences.

In order to assess the representativeness of the lead farmers as potential adopters, we present the characteristics of lead farmer households and their farms compared to a random sample of households in the same four districts in Central and Southern Regions of Malawi.

Table 1 shows that, on average, lead farmers' households are better educated, more likely to be headed by a young male, have larger farm size, more livestock, and more farm equipment. They also have on average larger household size, a larger adult labor force that is present on-farm, and their family is less engaged in off-farm *ganyu* work. The observed differences between lead farmers and follower farmers may imply that the former are relatively less constrained in their CA technology adoption for reasons beyond limited information and limited availability of the technologies. It is therefore important to control for these observable differences in the technology adoption models.

[Table 1 about here.]

Table 2 provides the shares of lead farmers (n = 181) who held demonstration trials, had familiarity, adopted on their own farm, and recommended follower farmers to adopt, for five specific CA technologies. Herbicide use is the least well known technology and it has the lowest adoption level, as would be expected. However, the adoption level is essentially the same as the extent of demonstration trials, and the low rates for both could be related to limited availability of equipment for herbicide application. Minimum tillage is well known by many lead farmers but the adoption rate is low compared to the extent to which they have had demonstration trials and even recommend this technology. Organic manure is the most well known and most widely adopted of all the CA technologies. It is worth noting that adoption levels for crop rotation and use of organic manure are higher than for having had demonstration trials while the opposite is the case for minimum tillage and mulching. The highest share of lead farmers having had demonstration trials is for minimum tillage and for use of organic manure. The most popular technologies to recommend to other farmers appear to be use of organic manure followed by crop rotation and minimum tillage. Herbicide use is least popular but it is also the technology that the fewest number of lead farmers have experience with through having demonstration trials.

[Table 2 about here.]

Table 3 presents estimates for the number of adopters of the CA technologies among the followers of the lead farmers in our sample. This is based on the lead farmers' own assessment of the number of followers they have and the adoption rates among follower farmers for the CA technologies the lead farmers have recommended. Table 3 demonstrates large variation in the extent of adoption of the different CA technologies among followers of lead farmers. Herbicide use is lagging far behind. Crop rotation is not a new technology and may be close to its adoption potential already.

[Table 3 about here.]

Methods

Simple ordinary least squares (OLS) and linear probability models (LPM) are used in the analyses. An important advantage of the LPM versus probit or logit is that LPM coefficients can be directly interpreted as marginal effects. In many situations, LPM and logit model results are practically indistinguishable, and the LPM is then the clear choice given its interpretability. Furthermore, the LPM model is more applicable for causal analysis than logistic regression (Hellevik, 2007). For these reasons, the LPM has gained popularity in recent years and has been advocated among others by Angrist and Pitschke (2008). The LPM is less efficient than some non-linear alternative models and therefore gives more conservative significance levels. This can be an advantage when the number of significance tests is large as it leads to fewer type II errors (wrongly identifying insignificant variables as significant). However, it can also lead to higher probability of Type I errors (failure to detect significant variables as significant), particularly when the sample size is small.

Following from the conceptual framework in Figure 1, we estimate OLS and LPM models where the dependent variables are motivation, demonstration trials, number of followers, CA familiarity, own adoption of CA, and recommending CA to followers. Our primary interest is to assess the relationships among variables shown by arrows in Figure 1. Initial model runs included additional explanatory variables for individual and household characteristics of the lead farmers (e.g. age, education, household size) as well as district fixed-effects to control for sample selection and local conditions. Very few of these variables were statistically significant at standard test levels ($p < 0.05$). Furthermore, we found that the significant relations for variables in Figure 1 were robust to inclusion of the household characteristics and district fixed effects. For increased clarity, we therefore exclude the latter variables from the results tables that follow, but the full set of results are available upon request.

Results

Motivation and activity level of lead farmers

We begin with models where the dependent variables are the motivation of lead farmers, the number of demonstration trials they have had, and the number of followers they stated to have at the time of the survey (mid 2016). The data show that 66.5% of lead farmers stated that they were very motivated for their role as lead farmers and 23.1% stated that they were quite motivated. Only 8.8% were not so motivated and 1.7% were unmotivated. Table 4 reports results for parsimonious models that relate how the experience as lead farmers (number of years as a lead farmer), number of incentives received by lead farmers, number of trainings received in CA agriculture, number of other types of training received, and the number of contacts with different types of extension advice sources are associated with these three inputs into F2FE on the part of lead farmers.

[Table 4 about here.]

Results suggest that provision of incentives to lead farmers is important for their motivation, the number of demonstration trials they manage, and the number of followers they have. CA training is also important for lead farmer motivation, while receipt of other forms of training is not significantly related to motivation. Lead farmer motivation, in turn, is positively associated with the number of followers lead farmers have, but has no significant association with their efforts with demonstration trials. Factors positively associated with the number of demonstration trials are other forms of training, contacts with government extension workers, having farm field visits, participation in village extension meetings, and participation in agricultural extension courses.

Lead farmers' familiarity with CA technologies

As revealed earlier in Table 2, lead farmers have high familiarity with all technologies, although less so for herbicide use and mulching. This suggests that lead farmers' own adoption and recommendations of these technologies may be a good indicator of their adoption potential. LPM models are estimated for the five CA practices to gain an understanding of the factors that increase lead farmer familiarity. Table 5 shows that lead farmers' familiarity with the specific CA technologies is driven mainly by their specific training for CA technologies and the total number of demonstration trials they have had as lead farmers. These results are consistent with literature suggesting that farmers learn about new technologies from many sources, including their own experimentation and the technical information available from extension services (e.g. trainings) (Foster and Rosenzweig, 1995).

[Table 5 about here.]

CA technology adoption among lead farmers

Table 6 reports results on lead farmer adoption of the five CA technologies. We have included as explanatory variables the familiarity variables which were dependent variables in the previous table, as well as the factors that are posited in Figure 1 to influence familiarity. We anticipate these latter variables have both direct and indirect associations with adoption. Models without the familiarity variables provided low explanatory power even though many of the variables were correlated with the familiarity variables.

[Table 6 about here.]

We see that familiarity is the dominant factor associated with lead farmer adoption of the CA technologies, except in the case of herbicide use where the years of experience variable is most influential. Together with the previous table, results suggest that the primary effect of training and having had many demonstration trials has been to improve the lead farmers' familiarity with the CA technologies and this familiarity, in turn, encourages lead farmers to adopt.

As a complement to the findings in Table 6, we present below lead farmers' stated reasons for adopting and not adopting each of the technologies. This is based on survey questions asking lead farmers to rank the first three reasons for why they did or did not adopt the CA technologies. We present these rankings for adoption (Table 7) and non-adoption (Table 8) of the five CA practices.

[Tables 7 and 8 about here.]

Table 7 shows that improved yield was the most commonly stated and highest ranked reason for adopting all the technologies except herbicide use. Moisture conservation was also important for adoption of minimum tillage, organic manure, and mulching technologies, while reduced pest and disease problems were an important reason for adoption of crop rotation. Table 8 suggests that cash constraints was the most important reason why herbicide use has not been adopted.

Lead farmers' CA technology recommendations

This section assesses the factors associated with lead farmers recommending the CA technologies to other farmers. We estimated a number of different models and results of the most informative model specification is presented in Table 9. Findings indicate that lead farmers' recommendation decisions are strongly driven by their experience with CA (i.e. demo trials), familiarity with CA, and own adoption. These three variables are strongly significant and positive for all the CA technologies with the exception that familiarity with herbicide use has an insignificant relationship with whether the lead farmers recommended herbicide use. The latter finding is not surprising given that herbicide use was the least popular CA technology among the lead farmers with very few adopters, and lead farmers mentioned cash constraints as a main barrier to adoption.

[Table 9 about here.]

Conclusion and discussion

The present study implements a promoter-adopter approach to assessing adoption potential of CA technologies in Malawi using a sample of lead farmers tasked with diffusing CA practices. This approach rests on lead farmers having largely overcome the information constraints that may limit their ability to judge the potential of the technologies. Lead farmer familiarity with organic manure, crop rotation, and minimum tillage is very high in the study area, but familiarity was lower for herbicide application and mulching (about 50% were familiar), and this may somewhat limit the lead farmers' ability to judge adoption potential of these two practices. Whether lead farmers' own adoption and recommendation rates represent a good guide for adoption potential also depends on whether the lead farmers' household and farm characteristics are representative for the target areas for the technologies and whether lead farmers' adoption rates are distorted by excessive incentives such as subsidized inputs. We find that lead farmers' characteristics are reasonably similar to those of other farmers in their areas and the amounts of incentives provided were very limited and have not led to distorted "excessive" adoption rates. We therefore think that our promoter/adopter approach gives a good basis for assessment of the adoption potential of CA technologies promoted through the F2FE approach in Malawi. With the lead farmer F2FE approach gaining popularity in many countries, we expect that our promoter-adopter approach to assessing adoption potential of new technologies will be of interest in Malawi and elsewhere.

Data from a survey of 181 lead farmers reveal "maximum exposure" adoption rates (rates conditional on lead farmers being familiar with the technologies) for 2015/16 of 56% for organic manure and crop rotation, 26% for minimum tillage, 30% for mulching, and 12% for herbicide application. The lead farmer recommendation rates are 66% for organic manure, about 50% for crop rotation and minimum tillage, 28% for mulching, and less than 10% for herbicide application. Assuming the validity of the promoter-adopter approach, these findings together suggest that, in central and southern Malawi, organic manure and crop rotation have the highest adoption potential, mulching and minimum tillage come next, and herbicide application has the lowest adoption potential.

The empirical results provide some explanations for differences in adoption potential. Regression results suggest that familiarity is a main factor influencing lead farmer own adoption and has both indirect and direct associations with farmer recommendations of CA to their followers. Consistent with the regression findings are descriptive statistics showing that lead farmers were most familiar with organic manure and crop rotation and least familiar with mulching and herbicide use. Lead farmers also mentioned the high cost of herbicides as a factor limiting adoption and labor shortages as a constraint to the uptake of mulching. Interestingly, lead farmers are more likely to recommend organic manure and minimum tillage to other farmers than they are to adopt them themselves. For minimum tillage, this may reflect lead farmers' perceptions that minimum tillage has important benefits in terms of yield and moisture conservation, but the skills to adopt this practice are sometimes lacking. We are not sure how to explain this finding for organic manure, however.

Given the importance of familiarity to lead farmer adoption and recommendation of CA to other farmers, it is important to understand how the lead farmers acquire familiarity with CA in Malawi. Our results indicate that lead farmers gain familiarity with CA practices through training in CA and other agricultural topics and by their own experimentation (i.e. demonstration trials), and that lead farmer experimentation is positively influenced by extension contacts and receipt of incentives (e.g. mud boots or bags of seed).

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Table 1. Selected characteristics of lead farmers and a random sample of smallholder households in the same districts

	Random sample households			Lead farmers		
	Mean	St.Err.	N	Mean	St.Err.	N
Hh size	5.189	0.147	243	**5.808**	0.146	177
Average education of adults in hh	2.492	0.137	243	**3.300**	0.194	177
Female headed household	**0.270**	0.029	241	0.136	0.026	177
Age of household head	**52.282**	0.984	241	47.169	0.885	177
Spouse of head present in hh	0.652	0.031	244	**0.854**	0.027	178
Hh head is literate, 1=yes, 2=no	**1.324**	0.030	241	1.107	0.023	177
Hh head is English literate, 1=yes, 2=no	**1.664**	0.030	241	1.384	0.037	177
No of females in hh	2.683	0.098	243	2.763	0.108	177
No of adult females in hh	1.243	0.038	243	1.237	0.042	177
Adult labor availability in hh	26.350	0.707	243	**29.169**	0.909	177
Ganyu total days of all hh members	**37.374**	4.210	243	25.593	3.558	177
Owned farm size, ha GPS measured	1.060	0.058	238	**1.420**	0.117	176
Livestock value MK	117156	24256	244	**211069**	49287	178
Farm equipment value MK	26550	6436	244	**49532**	8377	178
Fertilizer coupons (subsidy)	0.539	0.034	243	0.576	0.039	177
Seed coupons (subsidy)	0.181	0.025	243	0.237	0.033	177

Source: Comparisons for four districts (Kasungu, Lilongwe, Machinga and Zomba). Bolded figures indicate that they are significantly larger than for the other group.

Table 2. The demonstration trial rate, familiarity rate, adoption rate, and recommendation rate of sampled lead farmers, by CA practice

	Crop rotation	Minimum tillage	Herbicide use	Mulching	Organic manure
Had demonstration trials for CA techn.	0.242	0.478	0.066	0.242	0.456
Familiar with CA technologies	0.780	0.731	0.412	0.495	0.857
Adopted CA technologies in 2015-16	0.462	0.198	0.066	0.170	0.500
Adopted CA, conditional on being familiar	0.556	0.256	0.120	0.300	0.564
Recommend CA technologies in 2016	0.495	0.445	0.060	0.280	0.659

Source: NMBU Malawi CA survey 2016. Based on responses from 182 lead farmers.

Table 3. Technologies recommended by lead farmers to follower farmers and lead farmers' indicated adoption rates among follower farmers

	Recommended to number		No of adopters		Lead farmers			
Technologies	Mean	p50	Mean	p50	N	Lead farmer rate recommend technology	Follower farmer adoption rate	Total adopters (followers)
Crop rotation	52.5	11	44.2	9	90	0.495	0.842	3979
Minimum tillage	53.8	13	13.0	4	81	0.445	0.242	1055
Herbicide use	45.9	15	16.7	2	11	0.060	0.364	184
Mulching (residue retention)	33.6	15	22.5	6	51	0.280	0.668	1145
Organic manure	39.8	10	24.5	6.5	120	0.659	0.615	2938

Source: NMBU Malawi CA survey 2016. Based on responses from 182 lead farmers. We caution that lead farmers may have overstated adoption rates for some of the technologies among their followers.

Table 4. Factors associated with the motivation, the number of demonstration trials and number of followers that lead farmers have

	Motivation	No of Demo trials	No of Followers
Number of incentives received	-0.159**	0.396*	0.232**
Number of CA training received	-0.156**	0.170	0.094
Number of other trainings received	-0.027	0.751****	0.094
Years of experience as lead farmer	-0.010	0.033	0.007
Government ag extension contacts	-0.006	0.210***	0.012
Private ag extension contacts	0.038	0.236	-0.242
NGO contacts	-0.039	0.127	-0.037
Farm field day visits	0.011	0.445*	0.126
Village extension meetings	0.032	0.713****	-0.027
Other farmer advice contacts	-0.362	0.590	0.765
Electronic media contacts	0.055	-0.012	-0.075
Motivation		-0.253	-0.335***
Number of demo trials			0.004
Constant	2.042****	0.466	2.366****
Prob > chi2	0.027	0.000	0.003
R-squared	0.140	0.486	0.188
Number of observations	181	181	181

Note: Motivation: 1=Very motivated, 2=Quite motivated, 3=Not so motivated, 4=Unmotivated. Significance levels: * 0.10 ** 0.05 *** 0.01 **** 0.001.

Table 5. Lead farmers' familiarity with CA technologies and how it is associated with their motivation and activity levels in general.

	Crop rotation	Minimum tillage	Herbicide use	Mulching	Organic manure
Motivation level of lead farmer	-0.023	-0.054	0.020	0.024	0.015
Number of incentives received	-0.043	0.008	0.074*	0.018	-0.062**
Number of CA trainings received	0.139****	0.197****	0.192****	0.029	0.073**
Number of other trainings received	-0.016	-0.103****	-0.005	0.070**	-0.026
Years of experience as lead farmer	-0.020***	-0.004	0.005	-0.011	-0.004
Total number of demo trials of lead farmer	0.041****	0.031**	0.035**	0.023	0.032***
Constant	0.631****	0.640****	-0.159	0.181	0.775****
Prob > chi2	0.000	0.000	0.000	0.001	0.001
R-squared	0.246	0.204	0.278	0.121	0.120
Number of observations	181	181	181	181	181

Note: Linear probability models. Significance levels: * 0.10 ** 0.05 *** 0.01 **** 0.001.

Table 6. Factors associated with lead farmers having adopted the CA technologies on their own farms in 2015-16.

	Crop rotation	Minimum tillage	Herbicide use	Mulching	Organic manure
Motivation level of lead farmer	0.124**	-0.069	0.028	-0.012	-0.018
Number of incentives received	-0.012	0.041	-0.009	0.046	0.025
Number of CA trainings received	0.050	-0.001	0.027	-0.050	0.027
Number of other trainings received	0.027	-0.013	-0.008	-0.016	0.001
Years of experience as lead farmer	0.012	-0.008	0.019****	-0.006	-0.005
Total number of demo trials of lead farmer	0.009	-0.010	0.012	0.023**	0.014
Familiarity with crop rotation	0.381****				
Familiarity with minimum tillage		0.207***			
Familiarity with herbicide use			0.030		
Familiarity with mulching				0.253****	
Familiarity with organic manure use					0.402****
Constant	-0.221	0.194	-0.131*	0.053	0.073
Prob > chi2	0.000	0.016	0.000	0.000	0.004
R-squared	0.195	0.093	0.176	0.168	0.111
Number of observations	181	181	181	181	181

Note: Linear probability models. Significance levels: * 0.10 ** 0.05 *** 0.01 **** 0.001.

Table 7. Ranked reasons for adoption of CA technologies by lead farmers

Reasons for adoption	Rank of reason	Crop rotation	Minimum tillage	Herbicide use	Mulching (residue retention)	Organic manure
	1	58	40	1	24	95
Increase yield	2	10	16	1	10	20
	3	0	2	0	0	0
	1	9	26	0	15	20
Conserve moisture	2	12	33	0	18	48
	3	3	0	0	1	6
	1	38	0	2	0	0
Reduce pests & diseases	2	28	2	0	0	0
	3	8	1	1	1	3
	1	1	2	6	0	2
Easy to use	2	7	3	0	1	5
	3	1	4	1	4	6
	1	0	3	1	2	0
Save labor	2	2	2	7	1	0
	3	1	3	0	1	1

Table 8. Ranked reasons for not adopting CA technologies by lead farmers

Reasons for not adopting	Rank of reason	Crop rotation	Minimum tillage	Herbicide use	Mulching (residue retention)	Organic manure
Lack of skills	1	1	9	3	1	0
	2	0	0	2	0	0
	3	0	0	0	0	0
Labor shortage	1	0	3	0	5	2
	2	0	0	0	1	1
	3	0	0	0	0	0
Cash constraint	1	0	1	13	0	0
	2	0	0	1	0	0
	3	0	0	0	0	0
Lack of equipment	1	1	1	1	2	0
	2	0	1	0	1	0
	3	0	0	0	0	1

Table 9. How lead farmers' experience with CA technologies is associated with whether they recommend the technologies to other farmers

	Crop rotation	Minimum tillage	Herbicide use	Mulching	Organic manure
Number of incentives received	0.046	0.060	-0.009	0.000	-0.018
Number of CA trainings received	-0.016	0.009	0.010	-0.037	-0.035
Number of other trainings received	0.024	-0.006	-0.007	0.024	0.041
Years of experience as lead farmer	-0.009	-0.003	0.000	0.010*	0.001
No of demo trials by lead farmer	0.001	-0.004	0.005	0.016	0.003
Familiar with crop rotation	0.226***				
Adopted crop rotation	0.431****				
Demo trials with crop rotation	0.235***				
Familiar with minimum tillage		0.185**			
Adopted minimum tillage		0.315****			
Demo trials with minimum tillage		0.332****			
Familiar with herbicide use			0.043		
Adopted herbicide use			0.571****		
Demo trials with herbicide use			0.131**		
Familiar with mulching				0.166***	
Adopted mulching				0.347****	
Demo trials with mulching				0.344****	
Familiar with organic manure use					0.423****
Adopted use of organic manure					0.201***
Demo trials with use of organic manure					0.179**
Constant	-0.004	0.031	-0.007	-0.054	0.081
Prob > chi2	0.000	0.000	0.000	0.000	0.000
R-squared	0.428	0.346	0.495	0.505	0.309
Number of observations	181	181	181	181	181

Note: Linear probability models. Significance levels: * 0.10 ** 0.05 *** 0.01 **** 0.001.