Vol.14(3), pp. 148-162 July-September 2022
DOI: 10.5897/JAERD2022.1306
Articles Number: 41DD4ED69735
ISSN: 2141-2170

http://www.academicjournals.org/JAERD

Journal of Agricultural Extension and Rural Development

Full Length Research Paper

Use of climate-smart agriculture practices and smallholder farmer market participation in Central Malawi

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Received 21 January, 2022; Accepted 31 May, 2022.

In the past few decades, climate-smart agriculture (CSA) has been promoted to improve food security and raise incomes as a strategy for sustainable agricultural development. The adoption rates among smallholder farmers, particularly in Africa, remain low and have varied in different contexts. This study investigated the market participation spillover effects from the adoption of CSA practices in central Malawi using the control function approach to address any endogeneity in the relationship. The hypothesis that the extent of the use of CSA practices in the past 10 years can lead to production surpluses that enable smallholder farmers to participate in markets and thereby increase in agricultural incomes was tested. Using survey data from 470 households in two districts of rural Malawi, a clear positive association between the number of CSA practices used and the extent of market participation was found. The findings suggest, among others, the need to intensify efforts to promote CSA adoption specifically over a longer period for benefits of the technologies to materialise. The adoption of CSA practices over time enhances crop market participation, an important aspect required for production sustainability as well as for transforming agriculture towards greater market orientation among smallholder farmers.

Key words: Climate-smart agriculture, adoption, market participation, spillover effects, Malawi.

INTRODUCTION

Agricultural productivity in sub-Saharan Africa has lagged compared to other developing regions (World Bank, 2009; NEPAD, 2013). The decimal agricultural performance has been associated with food insecurity, stagnant agricultural incomes, and poverty (FAO, 2020). The severity of these outcomes is more evident among smallholder farmers whose livelihoods depend on rain-fed agriculture (AGRA, 2016). Furthermore, concerns

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about population growth vis-a-vis the increased demand for food and the urgency to provide the same sustainably have become apparent in regional and national policy discourse (FAO et al., 2015; GoM, 2020). Recent trends in climate change-related stresses and shocks coupled with declining soil fertility increases farming households' vulnerability, with some studies showing worsening climate-induced vulnerability to poverty (Shiferaw et al., 2014; Maganga et al., 2021). In recognition of these challenges, multilateral organizations, development partners and national governments have been promoting the use of CSA practices as a strategy for sustainable agricultural development to increase food security and raise incomes. According to FAO (2013), CSA is meant to address the intertwined challenges of food security, climate change adaptation and mitigation. Thus, there is recognition that agriculture itself impacts climate change (evident in emissions from the sector and practices that allow enhanced soil carbon sinks, for example) and that climate change threatens agricultural output (Hazell et al., 2010). The adopters of CSA practices conserve and enhance natural resources by being efficient in the way they use land, water, and other inputs in agricultural value chains. The three objectives of CSA include sustainably increasing agricultural production, building resilient agriculture and food systems that can adapt to climate change and reducing greenhouse gas emissions from agriculture (FAO, 2013). In practice, these objectives are implemented together at various levels, scales and time horizons addressing context-specific priorities to achieve increased incomes, food security and development. Several practices, including those for soil and water conservation, soil fertility management, crop portfolio management, fertilizer use, and agroforestry tree cultivation, are promoted in the CSA approach to farm production.

A substantial body of literature has emerged to analyse the factors influencing the adoption of CSA practices (Mazvimavi and Towmlow, 2009; Teklewold et al., 2013; Andersson and D'Souza, 2014; Ngwira et al., 2014; Simtowe et al., 2016; Theriault et al., 2017; Hagos et al., 2018). Other studies examine the impacts of such adoption on outcomes such as productivity, food security and income, or poverty reduction (Corbeels et al., 2014; Arslan et al., 2016; Manda et al., 2016; Kotu et al., 2017; Hasan, 2018; Tambo and Mockshell, 2018). However, studies linking the extent of adoption of sustainable agricultural practices to market participation among smallholder farmers in Africa are scarce. One exception is a study by Awotide et al. (2016) on the impacts of improved rice adoption on market participation in Nigeria. Adoption of sustainable agricultural practices has potential to improve soils and support increases in crop productivity. With this increased crop production, households can obtain marketable surplus that can then be used to participate in output markets and therefore earn higher agricultural incomes more sustainably (Mccarthy and Brubaker, 2014; Richards et al., 2019).

However, adoption rates of various CSA practices in Africa are low and varied (Teklewold et al., 2013; Arslan et al., 2016). In addition, the low adoption of sustainable agricultural practices inhibits increases in production surplus, essentially limiting the extent of crop market participation, resulting in lower incomes among smallholder farmers. This study investigates the relationship between smallholder market participation and the extent of adoption of CSA practices in rural Malawi. The approach to analysis recognises that smallholder farmers adopt CSA practices through experimentation with multiple practices as observed by others (Wollni et al., 2010; Teklewold et al., 2013) and that some of the practices cannot be used annually in certain circumstances. Additionally, literature suggests that longer periods of exposure are required to facilitate the adoption of some technologies (Holden et al., 2018; Musa et al., 2018) therefore, this study uses a rich dataset that asked farmers about the use of CSA practices in the past 10 years. Unlike previous studies, the multivariate analysis employed addresses any endogeneity issues arising from selection into technology adoption and market participation.

Drivers of agricultural technology adoption and links to market participation

A large body of literature exists that identifies the drivers of agricultural technology adoption, drawing on household decision making models. A household decides to use and adopt CSA practices with the aim of maximising utility from leisure, own consumption of agricultural output, and consumption of market purchased goods subject to production, time, and income constraints (Barnum and Squire, 1979). CSA practices offers several benefits in different contexts that would motivate adoption, including enhancing the resilience of households to climate change-related shocks and promoting the efficient use of resources, which could other things being constant likely increase the profitability of agriculture. For instance, the literature suggests that crop diversification is among the adaptation strategies used by households in the face of increasing climate vulnerability in sub-Saharan Africa (Shiferaw et al., 2014; McCord et al., 2020). Other benefits from CSA adoption related to household food security situation. As demonstrated by Brüssow (2017) in Tanzanian, households that adopted climate smart strategies were on average found to be more food secure than nonadopters. Relatedly, the adoption of conservation agricultural elements has been found to assist with soil moisture retention in Zambia and Zimbabwe (Thierfelder and Wall, 2009) with the potential to increase yields and reduce crop failure in periods of drought across Africa (Corbeels et al., 2014). A study by Kiptot et al. (2014) demonstrates the substantial contribution of agroforestry to food security in Africa through increased crop and fruit production for food and income. Similarly, soil management technologies have been shown to improve smallholder farmer livelihoods in Kenya (Wanyama et al., 2010). Of course, these benefits are contextual depending on the agroecological and biophysical environment as well as other social and economic factors that drive the adoption of CSA.

Numerous studies have investigated drivers of the adoption of technologies that improve agricultural productivity. The decision by a farming household to use a technology and its extent of use is subject to several factors. The existing literature points to the relevance of information in creating awareness about a technology to kick-start the adoption process, making agricultural extension, and training a relevant factor influencing adoption (Giller et al., 2009; Arslan et al., 2014, 2016; Shiferaw et al., 2015; Wossen et al., 2017; Hagos et al., 2018). Such information and interest in trying a technology may be strengthened by membership in farmer groups, as discovered in Nigeria regarding the use of improved rice varieties (Awotide et al., 2016), or in Honduras in relation to the adoption of soil conservation practices among farmers (Wollni et al., 2010). Furthermore, Corbeels et al. (2014) argue that good markets for purchased inputs and sale of produce are important for the adoption of conservation technologies in Africa. This is supported by the finding from Wollni et al. (2010) that participation in organic markets in Honduras encouraged the use of soil conservation practices. Relatedly, for some practices, such as conservation agriculture, there is a trade-off between using crop residues as soil cover versus feeding them to animals, which has both costs and benefits for the farmer (Andersson and D'Souza, 2014; Corbeels et al., 2014).

There are also differences in the perceived short- and long-term benefits of CSA to be considered by a farmer when deciding to use a technology. For instance, Corbeels et al. (2014) demonstrates that increases in income with CSA adoption were less evident, possibly due to the long duration required for soil fertility improvement to yield results from land use change. This is more important in situations where the food security first strategy is key for the survival of smallholder farmers who are both producing and consuming economic agents (World Bank, 1986; Dillon and Barrett, 2017). Such perceptions about the period required to realise gains from CSA technologies may explain the lack of and/or inadequate adoption of *ex ante* risk management strategies to cope with climate change. In relation to this, Coulibaly et al. (2015) found that farmers in Malawi largely adopted *ex post* strategies such as participating in seasonal labor markets and selling forest products rather than sustainable ones such as those promoted under CSA like farm irrigation, change of crop type/variety and crop diversification. Additionally, constraints related to economic factors such as land, labor and capital availability prevent the implementation of some CSA practices (Nhemachena et al., 2014; Pannell et al., 2014; Awotide et al., 2016). These resources may be inadequate among smallholder households, therefore affecting the uptake of technologies.

The productivity improvements arising from adopting individual or a package of CSA practices are expected to support increased farm production. Such production increases could assure households of availability and access to food while allowing for increased marketable surpluses. Market participation is of course subject to market and price constraints, transaction, and infrastructure costs (Mather et al., 2013). However, a household would maximise its utility by deciding to participate in markets if expected utility from market participation is higher than expected utility from consumption. In relation to this, some studies have found, to varying degrees, that market participation reduces poverty and improves nutrition in households (Pingali and Rosegrant, 1995; Carletto et al., 2017; Ogutu and Qaim, 2019). One of the key drivers of market participation is output because without marketable surplus, households would not engage in markets. It therefore follows that the productivity-enhancing technologies that the CSA approach promotes would positively contribute to increased outputs. In addition, the resilience built will support livelihoods, making it easy for households to participate in markets knowing they could be cushioned by the resilient livelihood activities. Other drivers of the extent of market participation on the production side include gender, access to improved seeds, education, landholding, off-farm income and labor, to mention a few (Awotide et al., 2016). These factors indirectly affect the market orientation of households through the marketable surplus pathway. On the market side, factors that smoothen agricultural trade and reduce transactional costs also influence market participation (Pingali et al., 2005). These factors include access to credit, social networks, and market information, as well as distance to the market. Using the data available, we controlled for some of these factors in our analysis.

METHODOLOGY

Study area, sampling, and samples

This study used cross-sectional data collected from the two districts namely Mchinji and Ntchisi, in central Malawi. These districts are associated with high production of food and cash crops, including tobacco, the main export crop. Surplus production of food crops such as maize, groundnuts and soya beans are marketed. The study areas constitute 'the food basket' of the country because of their production efficiency (Asfaw et al., 2017). Thus, even though this study accounts for district fixed effects, the findings cannot be extrapolated to all regions in Malawi because the two study districts are in the same agroecological and livelihood zone. As a country, Malawi has 10 livelihood zones with different agricultural production potential (GoM, 2005). The study sites are therefore already advantageous in terms of production and CSA is more likely to be adopted by smallholder farmers.

The data used in this study were collected as part of a longitudinal study by Agricultural Policy Research in Africa (APRA)[1] investigating pathways to commercialisation and its outcomes (Matita et al., 2018). A sample of 470 households interviewed in September/October 2018 was used in the analysis. The households were drawn and tracked based on an original random sample interviewed in 2007 as part of the evaluation of the Agricultural Input Supply Programme in Malawi (SOAS et al., 2008; Matita et al., 2021). The dataset used in this study constitutes 42% of the original households and 58% branching out households composed of household members that were found to lead independent lives at the time of the survey. The households provided information about their livelihoods, food security situation, experienced shocks, adoption of agricultural technologies including various CSA practices that was solicited using a structured questionnaire. The reference farming season for data collection was 2017/2018 agricultural season.

Model estimation

The following model was estimated to explain the effects of the extent of adoption of CSA practices on the extent of market participation among smallholder farmers:

$$HCI_i = \beta_0 + \beta_1 CSA_i + \beta_2 \boldsymbol{X}_i + \varepsilon_i \qquad (1)$$

where HCI_i is the household crop commercialisation index for household *i*, CSA_i is the number of CSA practices used – an indicator of the extent of adoption, $\boldsymbol{X}_i$ is a vector of control variables and ε_i is the random error term.

The estimation strategy used in this study recognises that the adoption of CSA practices can be endogenous and that the use of ordinary least squares in estimating β_1 may lead to biased estimates arising from the correlation between CSA_i and ε_i. Farmers that adopt CSA practices may have unobserved characteristics that systematically differ from nonadopters. Consequently, these unobserved characteristics can correlate with the market-orientated behaviour of farmers. To address this endogeneity problem, the control function (CF) approach involving two stages is used (Woodridge, 2010).

In the first stage, the determinants of the extent of adoption of CSA practices are estimated to obtain predicted residuals. The following model was estimated:

$$CSA_i = \alpha_0 + \alpha_1 \boldsymbol{EA}_i + \alpha_2 \boldsymbol{H}_i + \alpha_3 \boldsymbol{Z}_i + u_i \qquad (2)$$

where CSA_i is the indicator of the extent of adoption of CSA practices by household *i*, $\boldsymbol{EA}_i$ is the vector of extension service access variables, $\boldsymbol{H}_i$ is a vector of household characteristics, $\boldsymbol{Z}_i$ is a vector of control variables including the number of agricultural shocks experienced by a household in the past two years and u_i is the random error term. In estimating Equation 2, the study did not account for plot-specific characteristics pertaining to soil and slope properties that may necessitate the adoption of some CSA practices as found relevant elsewhere (Arslan et al., 2016; Kotu et al., 2017) due to data limitations.

Given that the indicator of the extent of CSA adoption is a count variable, Poisson regression would be the likely model to be used. However, the Poisson assumes that adoption occurs with the same probability, an assumption that may not be valid in multiple adoption of CSA practices because experience and information gathered about prior technologies becomes useful in the decision (Wollni et al., 2010; Teklewold et al., 2013). Some studies model this relationship as a dichotomous choice of adopting a specific practice or package of practices using probit models (Arslan et al., 2014; Simtowe et al., 2016). Others use multinomial logit models to explain adoption behaviour across several practices. However, in a few studies, ordered probit has been used to capture the fact that farmers tend to adopt a package of practices partially or adopt multiple practices (Wollni et al., 2010; Teklewold et al., 2013). In this study, the ordered probit model is used.

The CF approach requires the inclusion of instrumental variables (IVs) in the first stage that correlate with adoption but are not correlated with the extent of market participation. Previous studies have used access to agricultural extension advice on technologies representing spillover effects of extension services, advice, and knowledge in a community (Arslan et al., 2016; Ragasa and Mazunda, 2018). Here, the average number of good agricultural practices (GAP) for which households in a community received information is used. Intuitively, the adoption of CSA practices may be influenced by the number of technologies for which information is made available. Information and knowledge on different technologies is largely lacking among smallholder farmers in sub-Saharan Africa (Shiferaw et al., 2015). Improving access to extension information could facilitate experimentation and peer learning, especially among the early adopters that try technologies when the associated costs and risks are unknown in their setting. However, there is no reason to suspect that information on GAP might influence how much of the harvested crop should be sold, especially in this context, where smallholder farmers largely produce for subsistence, with market participation decisions made after production. The costs associated with receipt of extension information may therefore be regarded as a fixed transaction cost (Key et al., 2000). In any case, a new set of factors may have to be considered for the decision on how much output to sell such as food requirements versus marketable surplus, availability of markets, and their risks – which at the marketing point have less to do with whether they received information on GAP or not. This IV was found to significantly influence the adoption of CSA but did not correlate with the outcome of interest using pairwise correlation. The variable was further included in both models to test for its exogeneity.

In the second stage, the predicted generalised residuals from the first stage are used as one of the covariates in estimating Equation 1. A significant coefficient of the residuals in Equation 1 implies endogeneity and inclusion of residuals correct for the bias in β_1,

[1]See www.futureagricultures.org/apra for details on APRA and in particular research work in Malawi.

Table 1. List of CSA practices investigated.

Soil fertility improving	Soil and water conservation	Fertilizer trees
Crop residue	Grass strips	Any fertilizer tree *(Tephrosia, Gliricidia, Sesbania, Faidhebia)*
Animal manure	Contour ridges	
Inorganic fertilizer	Bench terraces	
Legume cover crop	Drainage channels	
Compost	Pit planting	
Intercropping	Box ridges	
Crop rotation	Swales	
No tillage	Infiltration pits	

Source: FAO (2013).

while an insignificant coefficient implies that Equation 1 can produce an unbiased estimate of β_1 when residuals from the first stage are excluded in the estimation. Here, the impact of CSA on the extent of market participation models is estimated using fractional logit models because the dependent variable crop commercialisation index is censored taking values between zero and one (Woodridge, 2010). Several variables influencing farmer market participation are controlled for, consistent with the existing literature (Pender and Alemu, 2007; Jaleta et al., 2009; Wale and Baiyegunhi, 2015; Kabiti et al., 2016; Woldeyohanes et al., 2017; Mmbando et al., 2015; Rubhara and Mudhara, 2019), including receipt of subsidized farm inputs[2] and an indicator of household food security – the coping strategy index calculated based on Maxwell et al. (2014). To check the consistency of the results, the double-hurdle estimation which allows for selectivity into market participation, was employed consistent with other studies (Mather et al., 2013; Sibande et al., 2017).

Description of key variables

The dependent variable, the household commercialisation index (HCI), was calculated as the total value of agricultural output that was sold or planned to be sold from the 2017/2018 agricultural season by the household, consistent with others (Carletto et al., 2017; Sibande et al., 2017). The HCI take the values between zero and one, with the latter indicating no market participation and the former indicating complete sale of what is produced. The study used the selling prices stated by farmers to compute the value of all crops cultivated by the household.

The main explanatory variable is the extent of adoption of CSA represented by the count of CSA practices used by the households in the past 10 years. Households were asked if in the past 10 years they have used any soil fertility improvement, soil and water conservation or cultivated agroforestry tree crops as listed in Table 1. The use of the CSA practices in the past can be intermittent over the reference period. Furthermore, the data did not include questions that could be used to verify continued use of the practices in the year of study. To capture usage, a dummy variable equal to one or zero otherwise was created to indicate if a household had used a CSA practice. This approach to defining the variables, however, does not reflect the differences in the intensity of use. For example, some farmers may apply the recommended rate of manure, while others may apply far less than the recommended rate. However, in this study they were all treated as having used the technology. Using the different CSA dummy variables, a total count of practices used by the farmer was calculated and used in the econometric modelling.

It is hypothesised that the greater the extent of use of CSA practices, the more improved soils become and the higher the productivity, leading to more marketable surplus, hence greater engagement of the household with the output market and a higher level of market participation – consistent with the aims of CSA to increase incomes. As previously mentioned, the modelling controls for different household socioeconomic and farming characteristics. However, this study failed to account for the possibility that some unobserved characteristics might influence the extent of market participation and the adoption of CSA practices at the same time – for example, risks and time preferences. This is an area that future investigation might consider. Table A1 provides the description of the variables and expected sign of relationship with extent of CSA practices adoption and market participation.

RESULTS

CSA practices used by sampled farmers

Table 2 presents the proportion of households using various CSA practices. The top two practices reported by over 80% of the households included crop rotation and application of inorganic fertilizer. This may be explained by the government large-scale input subsidy programme that provides inorganic fertilizers and increased rotation of maize cultivation with legume crops in the study districts. The proportion of farmers in the sample who received subsidized farm inputs is only 7% but approximately 61% of the farmers purchased commercial inorganic fertilizers in the 2017/2018 farming season. It seems that over the past 10 years in question the technologies were taken up by farmers irrespective of programme participation, signifying technology diffusion.

[2]For details about the Malawi Farm Input Subsidy Programme see Chirwa and Dorward (2013)

Table 2. Proportion of households using CSA practices (%).

Variable	Mean	Std. dev.	Variable	Mean	Std. dev.
Crop residue	0.59	0.49	Grass strips	0.33	0.47
Animal manure	0.52	0.50	Contour ridges	0.27	0.44
Inorganic fertilizer	0.89	0.31	Bench terraces	0.11	0.31
Legume cover	0.33	0.47	Drainage channel	0.38	0.49
Compost	0.37	0.48	Pit planting	0.06	0.23
Intercropping	0.50	0.50	Box ridges	0.43	0.50
Crop rotation	0.81	0.39	Swales	0.03	0.17
No tillage	0.13	0.34	Infiltration pits	0.04	0.20
Any agroforestry tree	0.33	0.47	-	-	-
Number of observations			470		

All variables are dichotomously equal to 1 for the stated practice and 0 otherwise for the base category.
Source: Author, 2022.

Table 3. Quantiles of HCI and indicators of CSA practices used.

Panel A	Q1		Q2		Q3		Q4		Q5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HCI	0.02	0.06	0.38	0.09	0.66	0.05	0.84	0.05	0.99	0.02
No of CSA used	5.05	2.59	6.07	2.50	6.06	2.74	6.96	2.58	6.40	3.19
N	94		94		94		95		93	
Panel B	**Mean**	**SD**	**Min.**	**Max.**						
Number of CSA practices used	6.11	2.79	0	14						
Proportion of CSA used out of 17 available	0.36	0.16	0	0.82						
Commercialisation index	0.58	0.35	0	1						
N	470									

Panel A presents the mean and standard deviation (SD) by quantiles (Q1 to Q5) of the HCI. Panel B shows descriptive statistics for the different measures of CSA practices used in this paper.
Source: Author, 2022.

The study found that no tillage is the least commonly used technology for improving soil fertility. The most used soil and water conservation practices in the past 10 years are box ridges, drainage channels and grass strips, which were reported by 43, 38 and 33% of the farmers, respectively. Agroforestry trees have been planted by 33% of the sample in the past 10 years.

Table 3 present quantiles of the household crop commercialisation index and indicators of the extent of adoption of CSA practices. The least commercialised farmers in quantiles 1 and 2 sold 3 and 38% of their produce, respectively, while those in quantile 3 sold 66% of their produce (panel A). The quantile differences in the extent of market participation were statistically significant at the 1% level. On average, the extent of market participation defined by the HCI is estimated at 58% of crop produce (panel B). Households in the study used six of the CSA practices for which information was sought on average. The least commercialised households (in quantile 1) adopted only five CSA practices. Using Bonferroni's adjustment for pairwise correlation analysis, we observed significant differences between quantiles 1 and mean values obtained in quantiles 4 and 5 for the number of CSA and proportion of those technologies used.

Descriptive statistics of variables used in estimated models

Table 4 presents descriptive statistics of the variables used in estimated models. The average age of household heads was 41 years, and most of them were male headed with a maximum of eight years of education in the household. Widespread receipt of extension messages was reported by 85% of the households with

Table 4. Descriptive statistics of variables used in the models.

Variable	Mean	Std. dev.	Min.	Max.
Age of household head (years)	41.0	16.21	17	90
Male-headed household (0/1)	0.83	0.38	0	1
Maximum years of schooling in household	8.16	3.36	0	22
Adult equivalents	4.23	2.13	1	15
Asset index	1.33	0.58	0	1.8
Total livestock units (TLU)	0.52	1.43	0	18
Received any agriculture extension (0/1)	0.85	0.36	0	1
Received extension on farm business management (0/1)	0.40	0.49	0	1
Community has a lead farmer (0/1)	0.36	0.48	0	1
Land holding size (ha)	1.60	2.89	0	40
Number of crops cultivated	2.99	1.55	1	11
Plot managed by male head (0/1)	0.70	0.46	0	1
Plot managed by female head (0/1)	0.16	0.36	0	1
Male head makes crop income use decisions (0/1)	0.67	0.47	0	1
Female head makes crop income use decisions (0/1)	0.18	0.39	0	1
Household hired agricultural labor (0/1)	0.31	0.46	0	1
Household has a member of farmer club (0/1)	0.13	0.33	0	1
Household obtained credit (0/1)	0.09	0.29	0	1
Household received subsidized fertilizer (0/1)	0.07	0.26	0	1
Household purchased commercial fertilizer (0/1)	0.60	0.49	0	1
Number of GAP with extension provided	7.23	6.02	0	19
Number of observations	470			

(0/1) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category.
Source: Author, 2022.

the average number of GAP for which extension advice was received at seven. Approximately 36% reported the presence of lead farmers in their community. The households cultivated, on average, 1.60 ha of land, with most plots managed by male heads (70%) relative to female heads (16%). Similarly, male heads tended to make most of the decisions on crop sales income relative to female heads. Hiring of agricultural labor was observed among 31% of the farmers, with 13% having a household member participating in a farmer club and 9% obtaining any credit. Only 7% received subsidized farm inputs in the 2017/2018 farming year with many – estimated at 61% – purchasing commercial fertilizer on the market. The proportion of households with a member in community farmer groups is estimated at 13%.

Determinants of extent of adoption of CSA practices

Table 5 presents the regression results on determinants of the extent of adoption of CSA practices from an ordered probit estimation. Overall, the model was significant judging by the obtained probabilities for the Wald statistic. The IV, the intensity of receipt of GAP information, was statistically significant, implying that the number of CSA practices adopted is likely to be greater with increased intensity of receipt of GAP information. This finding is supported by the strong and positive association between the different variables measuring access to extension services (receipt of extension services, presence of farmer clubs, lead farmers) and adoption of CSA practices. We further found a significant positive relationship between the adoption of CSA and maximum years of education in the household ($p<0.01$). The number of crops cultivated was also associated with a significantly higher number of CSA practices being used.

However, the study failed to find a relationship between the number of CSA practices adopted and variables such as land, household size and hiring of agricultural labor, indicating that these variables do not present constraints to the extent of technology adoption.

Effect of the extent of CSA practices adoption on market participation

Table 6 shows regression estimates of the effect of the

Table 5. Determinants of the extent of adoption of CSA practices.

Dependent variable: number of CSA practices used	Coeff.	Robust SE
Age of household head	0.001	(0.004)
Male-headed household	0.120	(0.146)
Maximum years schooling in household	0.055***	(0.015)
Adult equivalent	-0.014	(0.030)
Asset index	0.026	(0.097)
TLU	0.010	(0.028)
Received any agriculture extension (0/1)	0.306**	(0.145)
Presence of lead farmer (0/1)	0.209**	(0.106)
Land (ha)	0.019	(0.014)
Number of crops cultivated	0.092***	(0.031)
Plot managed by male head (0/1)	-0.068	(0.108)
Household hired agriculture labor (0/1)	0.121	(0.111)
Household has member of farmer club (0/1)	0.341**	(0.161)
Average number of GAP with extension received	0.231*	(0.122)
Number of agricultural shocks	-0.014	(0.031)
Coping strategy index	-0.008	(0.005)
Original household (0/1)	0.192	(0.162)
Pseudo R-squared	0.038	
Wald Chi-squared	96.406	
Log pseudolikelihood	-1096.8982***	
N	470	

Table presents regression results of the determinants of the extent of CSA practices adoption from the ordered probit model. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Author, 2022.

extent of CSA practices adoption on the level of market participation. The inclusion of the CF residuals term from stage one model on the determinants of CSA adoption was statistically insignificant. Therefore, endogeneity in technology adoption was not an issue for the sample. The analysis further checked whether there was any selectivity into market participation that could influence the level of participation. This was conducted using a double-hurdle estimation. The obtained inverse Mills ratio was not significant, implying that there was no selectivity into market participation for the study sample (Table A2). Therefore, the results from the preferred model – the fraction logit estimation without residual term were interpreted. This model was significant overall judging by the obtained Wald statistic (p<0.01).

The study found the expected positive relationship between CSA adoption and HCI. This association was statistically significant at 1%. When an additional CSA practice was used, a household experienced a 1.6% increase in the predicted extent of market participation. With respect to household characteristics, a weak but positive relationship between maximum years of schooling in a household and market participation (p<0.10) was established, with about 1% increase in the extent of crop marketing. However, this study has been unable to demonstrate that large household sizes are associated with production surplus that can be used for marketing as found in some studies (Rios and Shively, 2009; Martey et al., 2012; Radchenko and Corral, 2018). Instead, the relationship between the extent of market participation and household size defined by adult equivalents was significantly negative (p<0.05). An additional household member reduced the extent of market participation by 2%. As expected, the results indicate that original households participate significantly less in crop marketing compared to branching out households. Specifically, original households experienced a 14.4% reduction in predicted HCI relative to the base category.

Further findings showed a positive association between the number of crops cultivated and the extent of crop marketing, indicating that crop diversification supported market participation for households consistent Sibande et al. (2017) finding in context of maize selling. An additional crop cultivated is associated with predicted increase in HCI of 5% (p<0.01). Receipt of input subsidies was found to positively influence the extent of market participation. Households that received subsidized fertilisers

Table 6. Impact of adoption of CSA practices on the extent of market participation.

Dependent variable: HCI	Coeff.	SE	Average marginal effects
Number of CSA practices	0.074***	(0.026)	0.016
Age of household head	0.005	(0.007)	0.001
Male-headed household	0.003	(0.213)	0.001
Maximum years schooling in household	0.041*	(0.023)	0.009
Adult equivalent	-0.090**	(0.039)	-0.020
Asset index	0.040	(0.140)	0.009
TLU	0.056	(0.055)	0.012
Received FBM extension	0.237	(0.145)	0.052
Presence of lead farmer (0/1)	0.203	(0.149)	0.045
Land (ha)	0.013	(0.036)	0.003
Received off-farm income (0/1)	0.150	(0.155)	0.033
Number of crops cultivated	0.225***	(0.052)	0.050
Male head makes decisions on income (0/1)	0.131	(0.158)	0.029
Hired agricultural labor (0/1)	-0.042	(0.176)	-0.009
Obtained credit (0/1)	0.058	(0.255)	0.013
Farm input subsidy beneficiary (0/1)	0.467*	(0.271)	0.103
Bought commercial fertilizer (0/1)	0.077	(0.153)	0.017
Member of farmer club (0/1)	0.153	(0.226)	0.034
Coping strategy index	-0.007	(0.007)	-0.002
Mchinji District (0/1)	0.288**	(0.137)	0.063
Original household (0/1)	-0.646***	(0.237)	-0.144
Constant	-1.243***	(0.423)	-
Pseudo R-squared	0.074		
Wald Chi-squared	104.948		
Log pseudolikelihood	-296.2205***		
N	470		

The table shows the regression results of the impact of the extend of adoption of CSA practices on the level of market participation from the fractional logit model. FBM = Farm business management. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Author, 2022.

experienced a 10% increase in HCI relative to those that were not beneficiaries (p<0.10). The study also found that residence in Mchinji district significantly influenced the extent of crop marketing relative to Ntchisi district, suggesting that location-specific factors are important for market participation. Households in Mchinji district experienced a 6% increase in predicted HCI relative to those in Ntchisi district (P<0.5). Although both districts are in the same agroecological zone, Mchinji district is relatively more developed in terms of infrastructure and economic activity than Ntchisi district. Furthermore, Mchinji borders the Zambia district of Chipata, which facilities agricultural trade (Chirwa and Matita, 2015).

Other factors such credit access, purchase of commercial fertilizers, hiring of labor and membership in farmer clubs were not significantly associated with a greater extent of market participation, a finding contrary to study expectations.

DISCUSSION

This present study set out to assess the relationship between the extent of adoption of CSA practices and market participation among smallholder farmers. This work contributes to existing knowledge by determining drivers of the extent of adoption of CSA practices using a rich dataset with 17 CSA practices used by smallholder farmers in the past 10 years in various categories, namely, agroforestry tree crops cultivation, water and soil conservation, and soil fertility management. The indicator of CSA adoption employed reflects the recognition that farmers may not necessarily use these practices annually, and adoption often occurs through an experimentation process of what works or not. The study used a count of CSA practices to capture the extent of adoption rather than the usual dummy variable approach which only indicates the decision of whether to adopt a particular technology. The study advance knowledge on intermediate outcomes of such adoption with particular focus on the spillover effects on market participation, a step towards increased agricultural commercialisation.

The study found that, on average, households adopted six CSA practices with a maximum of 14 practices out of the 17 for which information was sought (proportion of 36%). Crop rotation and application of inorganic fertilizers were the top practices used in line with trends in other sub-Saharan African countries, largely due to opportunities for both food and marketing of grain legumes (Giller et al., 2009) as well as government input subsidies on legume seeds and fertilizers over the period in Malawi (Nkhoma, 2018). The least commonly used soil fertility management practice was no tillage. Approximately 33% of the sample households cultivated agroforestry tree crops in the past 10 years. Intercropping was also widespread for half of the sample, and approximately one-third used box ridges, drainage, and grass stripes to conserve soil and water.

The results indicated no evidence of an association between the extent of adoption of CSA practices and most socioeconomic factors (such as gender and age of household head, asset index and land), consistent with other studies (Arslan et al., 2014), although at odds with literature suggesting these present constraints on adoption (Andersson and D'Souza, 2014; Kotu et al., 2017; Musa et al., 2018; Tambo and Mockshell, 2018). There are several possible explanations for this result. It could be because adoption is considered over a longer period – the past 10 years in this study– and therefore current land and household size as well as hiring of agricultural labor may not influence technology use in the past. Additionally, some authors like Andersson and D'Souza (2014) have speculated that in the Malawi context, concerns about land degradation and associated recurrent food shortages have not triggered increased intensity of CSA adoption, contrary to expectations.

The only socioeconomic characteristic that was found significant in this assessment was maximum years of schooling in the household, signifying the importance of education in assimilating information about CSA practices and their use. This finding, while consistent with Wollni et al. (2010), departs from the tendency to investigate the role of education of the household head or farm managers only (Wossen et al., 2017; Musa et al., 2018; Tambo and Mockshell, 2018), which misses the combined effect of educating different members of a household on the adoption of farm technologies. The results obtained also confirm findings of other studies about the importance of extension in improving the adoption of CSA (Arslan et al., 2014; Awotide et al., 2016; Knowler and Bradshaw, 2007; Musa et al., 2018; Simtowe et al., 2016; Teklewold et al., 2013; Wossen et al., 2017; Zakaria et al., 2020). Membership in farmer clubs, presence of lead farmer and receipt of any extension services, including GAP, emerged as strong predictors of adoption of CSA practices. These have been demonstrated to offer opportunities for networking and peer learning that assist in overcoming constraints to adoption, corroborating Corbeels et al.'s (2014) idea that dissemination strategy matters for improved adoption of technologies. The farmer-to-farmer extension branded lead farmer approach in Malawi has been found to be effective in promoting various technologies, including recommending the adoption of conservation agriculture to follower farmers based on their own familiarity and experience (Holden et al., 2018), although generally only a few farmers are reached by lead farmers (Ragasa and Niu, 2017).

Surprisingly, smallholder farmers' risk attitude, signified by the number of crops cultivated, was positively associated with the adoption of CSA practices, contrary to findings elsewhere in the Philippines (Mariano et al., 2012), where crop diversification did not matter for the adoption of certified seed technologies. Perhaps as farmers attempt to manage and adapt each crop to climate variation to avoid crop failure, different CSA practices are taken up in mitigation. Similar observations have been made by others (Shiferaw et al., 2014; Kuntashula et al., 2015; Brüssow, 2017; McCord et al., 2020).

With respect to the extent of market participation, households sold on average 58% of what was harvested, and a greater extent of crop marketing was associated with a higher number of CSA practices adoption. This finding suggests that CSA practices may be widely taken up by smallholder farmers that are market-oriented, a finding supporting Corbeels et al. (2014) that market opportunities must be considered when promoting technologies. Previous studies have also emphasised the importance of technology adoption for market participation and income increases. For example, the adoption of a combination of conservation agriculture practices was strongly associated with increases in incomes in several African countries (Tambo and Mockshell, 2018) as well as higher crop revenues (Ng'ombe et al., 2017) and poverty reduction (Abdulai, 2016). Additionally, the adoption of several CSA practices has been found to increase yields with consequent increases in marketed surplus affecting household welfare (Arslan et al., 2016; Awotide et al., 2016; Brüssow, 2017). Together, these results provide important insights into the potential of using a combination of CSA practices over time to spur greater crop marketing.

In conclusion, this study found that the number of CSA practices adopted over a period likely increased crop marketing in central districts in rural Malawi among populations vulnerable to the effects of climate variability, low crop productivity and poor soil fertility. However, adoption was found to be associated with receipt of CSA extension messages. Therefore, the study recommends the use of a variety of extension approaches to support experimentation and take-up of CSA practices in smallholders' environments over time. More importantly, linking the farmers adopting CSA practices to markets for the realised yield would create incentives for continued use of the technologies. Furthermore, longer term exposure to CSA practices is required for the likely benefits to materialise hence this study recommends assessing the implications of CSA adoption over a longer reference period particularly because some practices cannot be used annually and others require time to yield outcomes. In sum, the adoption of CSA practices enhanced crop market participation spillover effects among smallholder farmers – an important aspect required for production sustainability as well as for transforming agriculture towards greater market orientation among smallholder farmers in Malawi and elsewhere in sub-Saharan Africa.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdulai AN (2016). Impact of conservation agriculture technology on household welfare in Zambia. Agricultural Economics. Agricultural Economics 47(6):729-741. https://doi.org/10.1111/agec.12269.

Africa Agriculture Status Report (AGRA). (2016) Africa Agriculture Status Report 2016: Progress towards Agricultural Transformation in Africa. Nairobi: AGRA.

Andersson JA, 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 and Environment 187:116-132. https://doi.org/10.1016/j.agee.2013.08.008.

Arslan A, Belotti F, Lipper L (2016). Smallholder productivity under climatic variability : Adoption and impact of widely promoted agricultural practices in Tanzania. ESA Working pp. 16-03. Rome: FAO.

Arslan A, Mccarthy N, Lipper L, Asfaw S, Cattaneo A (2014). Adoption and intensity of adoption of conservation farming practices in Zambia. Agriculture, Ecosystems and Environment 187:72-86. https://doi.org/10.1016/j.agee.2013.08.017.

Asfaw S, Cattaneo A, Pallante G, Palma A (2017). Impacts of modifying Malawi's farm input subsidy programme targeting. FAO Agriculutral Development Economics Working Paper No. 05. Rome: Food and Agriculture Organization of the United Nations.

Awotide BA, Karimov A A, Diagne A (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. Agricultural and Food Economics 4(1):1-24. https://doi.org/10.1186/s40100-016-0047-8.

Barnum HN, Squire L (1979). An econometric application of the theory of the farm-household. Journal of Development Economics 6:79-102.

Brüssow K (2017). Implications of climate-smart strategy adoption by farm households for food security in Tanzania. Food Security 9(6):1203-1218. https://doi.org/10.1007/s12571-017-0694-y.

Carletto C, Corral P, Guelfi A (2017). Agricultural commercialization and nutrition revisited : Empirical evidence from three African countries. Food Policy 67:106-118. https://doi.org/10.1016/j.foodpol.2016.09.020.

Chirwa EW, Dorward A (2013). Agriculture Input Subsides:the recent Malawi experience (First Edit). Oxford: Oxford University Press.

Chirwa EW, Matita M (2015). Space, Market and Employment in Agriculture Development, Malawi Country Report, Institute for Poverty, Land and Agrarian Studies Research Report No. 45. Cape Town: Institute for Poverty, Land and Agrarian Studies Research.

Corbeels M, Graaff J De, Hycenth T, Penot E, Baudron F, Naudin K, Andrieua N, Chirata G, Schulerc J, Nyagumboe I, Rusinamhodzib L, Traoref K, Mzobag HD, Aldowa IS (2014) Understanding the impact and adoption of conservation agriculture in Africa: A multi-scale analysis. Agriculture, Ecosystems and Environment 187:155-170. https://doi.org/10.1016/j.agee.2013.10.011.

Coulibaly JY, Gbetibouo GA, Kundhlande G, Sileshi GW, Beedy TL (2015). Responding to Crop Failure: Understanding Farmers' Coping Strategies in Southern Malawi. Sustainability 7(2):1620-1636. https://doi.org/10.3390/su7021620.

Dillon B, Barrett CB (2017). Agricultural factor markets in Sub-Saharan Africa: An updated view with formal tests for market failure. Food Policy 67:64-77. https://doi.org/10.1016/j.foodpol.2016.09.015.

Food and Agriculture Organization (FAO) (2013). Climate-Smart Agriculture Sourcebook. Rome: Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization (FAO) (2020). Emergency Agriculture Food Survellience System (EMA-FSS): Evidence based decision support in emergency situation through provisionof data and information, COVID-19 Rapid Response. Rome: Food and Agriculture Organization of the United Nations.

Giller KE, Witter E, Corbeels M, Tittonell P (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. Field Crops Research 114(1):23-34. https://doi.org/10.1016/j.fcr.2009.06.017.

GoM (2005). Malawi Baseline Livelihood Profiles Version 1. Lilongwe: Government of Malawi.

GoM (2020). Malawi's Vision: An Inclusively Wealthy and Self-reliant Nation. Malawi 2063. Lilongwe: Government of Malawi.

Hagos H, Ndemo E, Yosuf J (2018). Factors affecting adoption of upland rice in Tselemti district, northern Ethiopia. Agriculture and Food Security 7(58):1-9. https://doi.org/10.1186/s40066-018-0210-4.

Hasan K (2018). Impact of climate-smart agriculture adoption on the food security of coastal farmers in Bangladesh, Food Security. https://doi.org/10.1007/s12571-018-0824-1

Hazell P, Poulton C, Wiggins S, Dorward A (2010). The Future of Small Farms: Trajectories and Policy Priorities. World Development 38(10):1349-1361. https://doi.org/10.1016/j.worlddev.2009.06.012.

Holden ST, Fisher M, Katengeza SP, Thierfelder C (2018). Land Use Policy Can lead farmers reveal the adoption potential of conservation agriculture? The case of Malawi. Land Use Policy 76:113-123. https://doi.org/10.1016/j.landusepol.2018.04.048.

Jaleta M, Gebremedhin B, Hoekstra D (2009). Smallholder commercialization: Processes, determinants and impact. Discussion Paper No. 18. Addis Ababa: International Livestock Research Institute.

Kabiti HM, Raidimi NE, Pfumayaramba TK, Chauke 1 PK (2016). Determinants of Agricultural Commercialization among Smallholder Farmers in Munyati Resettlement Area, Chikomba District, Zimbabwe. Journal of Human Ecology 53(1):10-19. https://doi.org/10.1080/09709274.2016.11906951.

Key N, Sadoulet E, Janvry A De (2000). Transactions Costs and Agricultural Household Supply Response. American Journal of Agricultural Economics 82(2):245-259.

Kiptot E, Franzel S, Degrande A (2014). Gender, agroforestry and food security in Africa. Current Opinion in Environmental Sustainability 6:104-109. https://doi.org/10.1016/j.cosust.2013.10.019.

Knowler D, Bradshaw B (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy 32(1):25-48. https://doi.org/10.1016/j.foodpol.2006.01.003.

Kotu BH, Alene A, Manyong V, Hoeschle I, Larbi A (2017). Adoption and impacts of sustainable intensification practices in Ghana, International Journal of Agricultural Sustainability 15(5):539-554, https://doi.org/10.1080/14735903.2017.1369619.

Kuntashula E, Chabala LM, Chibwe TK, Kaluba P (2015). The Effects of Household Wealth on Adoption of Agricultural Related Climate Change Adaptation Strategies in Zambia The Effects of Household Wealth on Adoption of Agricultural Related Climate Change Adaptation Strategies in Zambia. Sustainable Agriculture Research 4(4):88-101. https://doi.org/10.5539/sar.v4n4p88.

Maganga AM, Chiwaula L, Kambewa P (2021). Climate induced vulnerability to poverty among smallholder farmers : Evidence from Malawi. World Development Perspectives 21:100273. https://doi.org/10.1016/j.wdp.2020.100273.

Manda J, Alene AD, Gardebroek C, Kassie M, Tembo G (2016). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. Journal of Agricultural Economics 67(1):130-153. https://doi.org/10.1111/1477-9552.12127.

Mariano MJ, Vallano R, Fleming E (2012). Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. Agricultural Systems 110:41-53. https://doi.org/10.1016/j.agsy.2012.03.010.

Martey E, Al-hassan RM, Kuwornu JKM (2012). Commercialization of smallholder agriculture in Ghana: A Tobit regression analysis. African Journal of Agricultural Research 7(14):2131-2141. https://doi.org/10.5897/AJAR11.1743.

Mather D, Boughton D, Jayne TS (2013). Explaining smallholder maize marketing in southern and eastern Africa: The roles of market access, technology and household resource endowments. Food Policy 43:248-266. https://doi.org/10.1016/j.foodpol.2013.09.008.

Matita M, Chinsinga B, Mgalamadzi L, Mazalale J, Chimombo M, Stevier K, Chirwa EW (2018). A Longitudinal Tracker Study of Groundnuts Commercilisation and Livelihood Trajectories in Malawi. APRA Research Note 1. Brighton: Futures Agricultures Consortium. Available at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/14006 (Accessed: 21 May 2018).

Matita M, Chirwa EW, Kaiyatsa S, Mazalale J, Chimombo M (2021). Determinants of Smallholder Farmers' Livelihood Trajectories: Evidence from Rural Malawi. APRA Working Paper 50. Brighton: Futures Agricultures Consortium. Available at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/16479 (Accessed: 26 March 2021).

Maxwell D, Vaitla B, Coates J (2014). How do indicators of household food insecurity measure up? An empirical comparison from Ethiopia. Food Policy 47:107-116. https://doi.org/10.1016/j.foodpol.2014.04.003.

Mazvimavi K, Twomlow S (2009). Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agricultural Systems 101(1-2):20-29. https://doi.org/10.1016/j.agsy.2009.02.002.

Mccarthy N, Brubaker J (2014). Climate-smart agriculture and resource tenure in sub-saharan africa: a conceptual framework. Rome:FAO.

McCord PF, Cox M, Schmitt-harsh M, Evans T (2020). Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. Land Use Policy 42:738-750. https://doi.org/10.1016/j.landusepol.2014.10.012.

Mmbando FE, Wale EZ, Baiyegunhi LJS (2015). Determinants of smallholder farmers' participation in maize and pigeonpea markets in Tanzania. Agricultural Economics Research, Policy and Practice in Southern Africa 54(1):96-119. https://doi.org/10.1080/03031853.2014.974630.

Musa FB, Kamoto JFM, Jumbe CBL, Zulu LC (2018). Adoption and the Role of Fertilizer Trees and Shrubs as a Climate Smart Agriculture Practice: The Case of Salima District in Malawi. Environments 5(11):122. https://doi.org/10.3390/environments5110122.

New Partnership for Africa's Development (NEPAD) (2013). Agriculture in Africa: Transformation and Outlook. Johannesburg: NEPAD (New Partnership for African Development).

Ng'ombe JN, Kalinda TH, Tembo G (2017). Does adoption of conservation farming practices result in increased crop revenue? Evidence from Zambia. Agrekon (Agricultural Economics Research, Policy and Practice in Southern Africa). https://doi.org/10.1080/03031853.2017.1312467.

Ngwira A, Johnsen FH, Aune JB, 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. https://doi.org/10.2489/jswc.69.2.107.

Nhemachena C, Hassan R, Chakwizira J (2014). Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. Journal of Development and Agricultural Economics 6(5):232-241. https://doi.org/10.5897/JDAE12.0441.

Nkhoma PR (2018). The evolution of agricultural input subsidy programs : contextualizing policy debates in Malawi's FISP. World Development Perspectives 9:12-17. https://doi.org/10.1016/j.wdp.2017.12.002.

Ogutu SO, Qaim M (2019). Commercialization of the small farm sector and multidimensional poverty. World Development 114:281-293. https://doi.org/10.1016/j.worlddev.2018.10.012.

Pannell DJ, Llewellyn RS, Corbeels M (2014). Agriculture, Ecosystems and Environment: The farm-level economics of conservation agriculture for resource-poor farmers. Agriculture, Ecosystems and Environment 187:52-64. https://doi.org/10.1016/j.agee.2013.10.014.

Pender J, Alemu D (2007). Determinants of Smallholder Commercialization of Food Crops IFPRI Discussion Paper No. 00745. Washington, DC: IFPRI.

Pingali P, Khwaja Y, Meijer M (2005). Commercializing Small Farms: Reducing Transaction Costs. ESA Working Paper No. 05-08. Rome: FAO.

Pingali PL, Rosegrant MW (1995). Agricultural commercilisation and diversification: processes and policies. Food Policy 20(3):171-185.

Radchenko N, Corral P (2018). Agricultural Commercialisation and Food Security in Rural Economies: Malawian Experience. Journal of Development Studies 54(2):256-270. https://doi.org/10.1080/00220388.2017.1283014.

Ragasa C, Mazunda J (2018). The impact of agricultural extension services in the context of a heavily subsidized input system: The case of Malawi. World Development 105:25-47. https://doi.org/10.1016/j.worlddev.2017.12.004.

Ragasa C, Niu C (2017). The State of Agricultural Extension and Advisory Services Provision in Malawi: Insights from household and community surveys (Technical Report). Lilongwe: IFPRI.

Richards M, Arslan A, Cavatassi R, Rosenstock T (2019). Climate change mitigation potential of agricultural practices supported by IFAD investments An ex ante analysis (IFAD Research Series No. 35). Washington DC: IFAD

Rios AR, Masters, WA, Shively GE (2009). Farm Productivity and Household Market Participation: evidence from LSMS Data, Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.

Rubhara T, Mudhara M (2019). Commercialization and its determinants among smallholder farmers in Zimbabwe. A case of Shamva District, Mashonaland Central Province. African Journal of Science, Technology, Innovation and Development 11(6):711-718. https://doi.org/10.1080/20421338.2019.1571150.

School of Oriental and African Studies (SOAS) (2008). Evaluation of the 2006/7 Agricultural Input Supply Programme, Malawi: Final Report. London: SOAS. Wadonda Consult, Overseas Development Institute and Michigan State University.

Shiferaw B, Kebede T, Kassie M, Fisher M (2015). Market imperfections, access to information and technology adoption in Uganda: challenges of overcoming multiple constraints. Agricultural Economics 46(4):475-488. https://doi.org/10.1111/agec.12175.

Shiferaw B, Tesfaye K, Kassie M, Abate T, Prasanna BM, Menkir A (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and

policy options. Weather and Climate Extremes 3:67-79. https://doi.org/10.1016/j.wace.2014.04.004.
Sibande L, Bailey A, Davidova S (2017). The impact of farm input subsidies on maize marketing in Malawi. Food Policy 69:190-206. https://doi.org/10.1016/j.foodpol.2017.04.001.
Simtowe F, Asfaw S, Abate T (2016). Determinants of agricultural technology adoption under partial population awareness: the case of pigeonpea in Malawi. Agricultural and Food Economics 4(7):1-21. https://doi.org/10.1186/s40100-016-0051-z.
Tambo JA, Mockshell J (2018). Differential Impacts of Conservation Agriculture Technology Options on Household Income in Sub-Saharan Africa. Ecological Economics 151:95-105. https://doi.org/10.1016/j.ecolecon.2018.05.005.
Teklewold H, Kassie M, Shiferaw B (2013). Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia. Agricultural Economcis 64(3):597-623. https://doi.org/10.1111/1477-9552.12011.
Theriault V, Smale M, Haider H (2017). How Does Gender Affect Sustainable Intensification of Cereal Production in the West African Sahel? Evidence from Burkina Faso. World Development 92:177-191. https://doi.org/10.1016/j.worlddev.2016.12.003.
Thierfelder C, Wall PC (2009). Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil and Tillage Research 105(2):217-227. https://doi.org/10.1016/j.still.2009.07.007.
Wanyama JM, Nyambati EM, Mose LO, Mutoko CM, Wanyonyi WM, Wanjekeche E, Rono SC (2010). Assessing impact of soil management technologies on smallholder farmers ' livelihoods in North Western Kenya. African Journal of Agricultural Research 5(21):2899-2908.
Woldeyohanes T, Heckelei T, Surry Y (2017). Effect of off-farm income on smallholder commercialization: panel evidence from rural households in Ethiopia. Agricultural Economcis 48(2):207-218. https://doi.org/10.1111/agec.12327.
Wollni M, Lee DR, Thies JE (2010). Conservation agriculture, organic marketing, and collective action in the Honduran hillsides. Agricultural Economcis 41(3-4):373-384. https://doi.org/10.1111/j.1574-0862.2010.00445.x.
Woodridge JM (2010). Econometric analysis of cross section and panel data. London: MIT Press.
World Bank (1986). Agricultural Housheold Models: Exptensions, Aplications and Policy. (Singh I, Squire L, Strauss J, Eds.). Baltimore and London: The Johns Hopkins University Press.
World Bank (2009). World Development Report 2008: Agriculture for Development. Washington DC: World Bank.
Wossen T, Abdoulaye T, Alene A, Haile MG, Feleke S, Olanrewaju A, Manyong V (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. Journal of Rural Studies 54:223-233. https://doi.org/10.1016/j.jrurstud.2017.06.022.
Zakaria A, Alhassan SI, Kuwornu JKM, Azumah SB, Derkyi MAA (2020). Factors Influencing the Adoption of Climate-Smart Agricultural Technologies Among Rice Farmers in Northern Ghana. Earth Systems and Environment 4(1):257-271. https://doi.org/10.1007/s41748-020-00146-w

Appendices

Table A1. Description of variables.

Variable	Description	Expected relationship with CSA	Expected relationship with HCI
Extent of CSA adoption	Number of CSA practices used	-	+
Market participation	HCI = crop sales value/ harvest value	-	-
Household head characteristics	Age of household head (years), gender of household head	+/-	+/-
Household education level	Maximum years of schooling in a household	+	_
Household size	Adult equivalents	+	+/-
Durable assets	Asset index	+	+
Livestock assets	TLU	+	+
Extension services access	Received any agriculture extension (0/1), Received extension on farm business management (FBM) (0/1), Community has a lead farmer (0/1), Household has a member of farmer club (0/1), Number of GAP with extension provided	+	+
Land holding	Land holding size (ha)	+	+
Crop diversification	Number of crops cultivated (#)	+	+
Gender of decision maker	Male head is the plot manager (0/1), Male head controls crop income (0/1)	+	+
Farming characteristics	Household hired agricultural labor (0/1), Household obtained credit (0/1), Household received subsidized fertilizer (0/1), Household purchased commercial fertilizer (0/1)	+	+
Food security situation	Coping strategy index	+/-	-
Agricultural shocks experience	Number of agricultural shocks experienced	+	-

The symbols + and – refer to a positive and negative relationship, respectively.
Source: Author, 2022.

Table A2. Double hurdle estimates of market participation.

Variable	Market participation		Extent of market participation	
	Coeff	SE	Coeff	SE
Number of CSA practices	0.084**	(0.036)	0.007	(0.005)
Age of household head	0.007	(0.009)	0.001	(0.001)
Male-headed household	0.127	(0.236)	-0.010	(0.043)
Maximum years schooling in household	0.051*	(0.030)	0.003	(0.005)
Adult equivalent	-0.103*	(0.057)	-0.008	(0.008)
Asset index	-0.052	(0.164)	0.009	(0.028)
TLU	0.294	(0.190)	0.003	(0.010)
Received FBM extension	0.243	(0.213)	0.030	(0.029)
Presence of lead farmer (0/1)	0.256	(0.206)	0.032	(0.029)
Land (ha)	-0.032	(0.038)	0.005	(0.005)
Received off-farm income (0/1)	0.196	(0.212)	0.021	(0.031)
Number of crops cultivated	0.565***	(0.098)	-	-
Male head makes decisions on income (0/1)	0.203	(0.203)	0.001	(0.032)
Hired agricultural labor (0/1)	-0.128	(0.238)	0.002	(0.033)
Obtained credit (0/1)	-0.315	(0.348)	0.047	(0.049)
Farm input subsidy beneficiary (0/1)	4.926	(222.340)	0.059	(0.050)
Bought commercial fertilizer (0/1)	-0.226	(0.199)	0.048	(0.030)
Member of farmer club (0/1)	0.333	(0.380)	0.004	(0.043)
Coping strategy index	-0.006	(0.010)	-0.002	(0.002)
Mchinji District (0/1)	-0.178	(0.178)	0.087***	(0.027)
Original household (0/1)	-0.753**	(0.302)	-0.094*	(0.049)
Inverse Mills Ratio	-	-	0.049	(0.072)
Constant	-0.921*	(0.485)	0.522***	(0.094)
Sigma constant	-	-	0.253***	(0.010)
Chi-squared LR	99.016355			
Log likelihood	-159.18425***			
Number of observations	470			

Standard errors in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.
Source: Author, 2022..