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USE OF CLIMATE-SMART AGRICULTURE PRACTICES AND SMALLHOLDER FARMER MARKET PARTICIPATION IN CENTRAL MALAWI

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ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
APRA	Agricultural Policy Research in Africa
CF	control function
CSA	climate-smart agriculture
FAO	Food and Agriculture Organisation of the United Nations
FBM	farm business management
GAP	good agricultural practice
GoM	Government of Malawi
HCI	household commercialisation index
IV	instrumental variable
NEPAD	New Partnership for Africa's Development
SOAS	School of Oriental and African Studies
TLU	total livestock unit
UNDP	United Nations Development Programme

EXECUTIVE SUMMARY

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. We investigated the market participation spill over effects from the adoption of CSA practices in central Malawi. We tested 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 agricultural incomes. Using survey data from 470 households in two districts of rural Malawi, we found a clear positive association between the number of CSA practices used and the extent of market participation. 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.

1 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 magnitude of these negative outcomes is more evident among the rural population in countries like Malawi where the majority depend on rain-fed agricultural livelihoods (AGRA, 2016). For instance, over half of Malawians are multidimensionally poor and gross national income per capita is at least three times lower than the sub-Saharan Africa average (UNDP, 2020). Furthermore, concerns about population growth *vis-a-vis* the increased demand for food and the urgency to provide the same sustainably have become apparent in national policy discourse (GoM, 2020). Recent trends in climate change-related stresses and shocks coupled with declining soil fertility amplify farming households' vulnerability, with some studies showing worsening climate-induced vulnerability to poverty (Shiferaw et al., 2014; Maganga, Chiwaula and Kambewa, 2021). This described situation has serious effects among smallholder farmers whose resilience to climate- and weather-related shocks and adaptation mechanisms are limited (Shiferaw et al., 2014; Makate et al., 2019; Murendo, Kairezi and Mazvimav, 2020).

In recognition of these challenges, multilateral organisations, 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. CSA is promoted in line with global food security objectives as an approach to sustainable farm production. According to FAO (2013), it 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). CSA presents an integrative approach with an array of practices that supports the production of food in a more efficient way and builds greater resilience to climate change and shocks. 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, fertiliser use, and agroforestry tree cultivation, are promoted in the CSA approach to farm production.

Wide literature exists on adoption rates and factors influencing the adoption of CSA practices (Mazvimavi and Towmlow, 2009; Teklewold, Kassie and Shiferaw, 2013; Andersson and D'Souza, 2014; Ngwira et al., 2014; Simtowe, Asfaw and Abate, 2016; Theriault, Smale and Haider, 2017; Hagos, Ndemo and Yosuf, 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, Belotti and Lipper, 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, Karimov and Diagne, (2016) on the impacts of improved rice adoption on market participation in Nigeria. Proponents of CSA assert that the adoption of sustainable agricultural practices can lead to improved soils, which in turn likely supports 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).

There is, however, increasing concern that adoption rates of various CSA practices in Africa are low and varied (Teklewold, Kassie and Shiferaw, 2013; Arslan, Belotti and Lipper, 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 present study investigates the relationship between smallholder market participation and the extent of adoption of CSA practices in rural Malawi. Our unique contribution recognises that smallholder farmers adopt CSA practices through experimentation with multiple practices as observed by others (Wollni, Lee and Thies, 2010; Teklewold, Kassie and Shiferaw, 2013;) and that some of the practices cannot be used annually in certain circumstances. Therefore, we used a rich source of data that asked farmers about the use of CSA practices in the past 10 years. This is in line with the literature suggesting that longer periods of exposure are required to facilitate the adoption of some technologies (Holden et al., 2018; Musa et al., 2018). Our data provide wide information on the use of various CSA practices applicable in different agroecological and biophysical environments present in the study districts of Mchinji and Ntchisi in central Malawi where maize and groundnuts are the main food crops. Unlike previous studies, our multivariate analysis methods address any endogeneity issues arising from selection into technology adoption and market participation.

2 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. 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, Franzel and Degrande (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; Shiferaw et al., 2015; Arslan, Belotti and Lipper, 2016; Wossen et al., 2017; Hagos, Ndemo and Yosuf, 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, Karimov and Diagne, 2016), or in Honduras in relation to the adoption of soil conservation practices among farmers (Wollni, Lee and Thies, 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, Lee and Thies (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 (Singh, Squire and Strauss, 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 labour 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, labour and capital availability prevent the implementation of some CSA practices (Nhemachena, Hassan and Chakwizira, 2014; Pannell, Llewellyn and Corbeels, 2014; Awotide, Karimov and Diagne, 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, Boughton and Jayne, 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, Corral and Guelfi, 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 labour, to mention a few (Awotide, Karimov and Diagne, 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, Khwaja and Meijer, 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.

3 METHODS

3.1 Study area, sampling, and samples

This study used cross-sectional data collected from the two districts Mchinji and Ntchisi in central Malawi. These central districts of Malawi are associated with high production of food and cash crops, including tobacco – the main export crop. Maize and groundnuts are key food crops grown by smallholder farmers in these districts with produced surpluses marketed. The agroecological and biophysiological characteristics of the locations make agricultural production more efficient in these locations (Asfaw et al., 2017). These areas are therefore considered to constitute 'the food basket' of the country. Thus, even though this study considers 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 potentials (GoM, 2005), and our study locations happen to be in the supposedly most production efficient zone (Asfaw et al., 2017). 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 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 follow-up dataset used in this study constitutes 42 per cent of the original households and 58 per cent of branching-out households composed of household members that were found to lead independent lives at the time of the survey. These households were engaged in farming activities in the 2017/18 agricultural season. Using a structured questionnaire, they provided information about their livelihoods, food security situation and experienced shocks, including adoption of agricultural technologies and CSA practices.

3.2 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 by household i, $\boldsymbol{X}_i$ is a vector of control variables and ε_i is the random error term.

Our estimation strategy 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, we use the control function (CF) approach involving two stages (Woodridge, 2010).

In the first stage, we estimated determinants of the extent of adoption of CSA practices 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

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

pertaining to soil and slope properties that may necessitate the adoption of some CSA practices as found relevant elsewhere (Arslan, Belotti and Lipper, 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, Lee and Thies, 2010; Teklewold, Kassie and Shiferaw, 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, Asfaw and Abate, 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, Lee and Thies, 2010; Teklewold, Kassie and Shiferaw, 2013). In this study, we used the ordered probit model.

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, Belotti and Lipper, 2016; Ragasa and Mazunda, 2018). Here, we use the average number of good agricultural practices (GAPs) for which households in a community received information. 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 GAPs 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, Sadoulet and Janvry, 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 GAPs or not. This IV was found to significantly influence the adoption of CSAs 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 $\boldsymbol{\beta}_1$, while an insignificant coefficient implies that equation (1) can produce an unbiased estimate of $\boldsymbol{\beta}_1$ 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, Gebremedhin and Hoekstra, 2009; Wale and Baiyegunhi, 2015; Kabiti et al., 2016; Woldeyohanes, Heckelei, and Surry, 2017; Mmbando, Ogutu and Qaim, 2019; Rubhara and Mudhara, 2019), including receipt of subsidised farm inputs[2] and an indicator of household food security – the coping strategy index calculated based on Maxwell, Vaitla and Coates (2014). To check the consistency of the results, we employed the double-hurdle estimation, which allows for selectivity into market participation, as applied in other studies (Mather, Boughton and Jayne, 2013; Sibande, Bailey and Davidova, 2017).

3.3 Description of key variables

Our 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 2017/18 agricultural season by the household, consistent with others (Carletto, Corral and Guelfi, 2017; Sibande, Bailey and Davidova, 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. We used the selling prices stated by farmers to compute the value of all crops cultivated by the household.

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

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 3.1. The use of the CSA practices in the past can be intermittent over the reference period. Furthermore, our data did not include questions that could be used to verify continued use of the practices in the year of study. To capture usage, we created a dummy variable equal to one or zero, 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 our approach, they are all treated as having used the technology. Using the different CSA dummy variables, we created a total count of practices used by the farmer that was 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, we 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 therefore consider. Table A1 provides the description of the variables and expected sign of relationship with extent of CSA practices adoption and market participation.

Table 3.1: List of CSA practices investigated

Soil fertility improving	Soil and water conservation	Fertiliser trees
1. Crop residue	9. Grass strips	17. Any fertiliser tree (*Tephrosia, Gliricidia, Sesbania, Faidhebia*)
2. Animal manure	10. Contour ridges	
3. Inorganic fertiliser	11. Bench terraces	
4. Legume cover crop	12. Drainage channels	
5. Compost	13. Pit planting	
6. Intercropping	14. Box ridges	
7. Crop rotation	15. Swales	
8. No tillage	16. Infiltration pits	

Source: Authors' own

4 RESULTS

4.1 CSA practices used by sampled farmers

Table 4.1 presents the proportion of households using various CSA practices. The top two practices reported by over 80 per cent of the households included crop rotation and application of inorganic fertiliser. This could be attributed to the government large-scale input subsidy programme that provides inorganic fertilisers and increased rotation of maize cultivation with legume crops. The proportion of farmers in our sample who received subsidised farm inputs was only 7 per cent but approximately 61 per cent of the farmers purchased commercial inorganic fertilisers in the 2017/18 farming season. It seems that over the past 10 years in question the technologies were taken

Table 4.1: 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 fertiliser	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		

Notes: All variables are dichotomously equal to 1 for the stated practice and 0 otherwise for the base category.

Source: Authors' own

Table 4.2: 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
Commercialisation index	0.02	0.06	0.38	0.09	0.66	0.05	0.84	0.05	0.99	0.02
Number of CSA practices 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			

Notes: 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: Authors' own

up by farmers irrespective of programme participation, signifying technology diffusion. We found that no tillage was the least commonly used technology for improving soil fertility. The most used soil and water conservation practices in the past 10 years were box ridges, drainage channels and grass strips, which were reported by 43, 38 and 33 per cent of the farmers, respectively, while swales, infiltration pits and pit planting were used by a few households. Agroforestry trees have been planted by 33 per cent of the sample in the past 10 years.

In Table 4.2, we 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 per cent and 38 per cent of their produce, respectively, while those in quantile 3 sold 66 per cent of their produce (panel A). The quantile differences in the extent of market participation were statistically significant at the 1 per cent level. On average, the extent of market participation defined by the HCI is estimated at 58 per cent of crop produce (panel B). On average, households used six of the CSA practices for which information was sought, representing 33 per cent of practices being used. 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 CSAs and proportion of those technologies used.

4.2 Descriptive statistics of variables used in estimated models

In Table 4.3, we present 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 per cent of the households with the average number of GAPs for which extension advice was received at seven. Approximately 36 per cent reported the presence of lead farmers in their community. The households

Table 4.3: 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 labour (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 subsidised fertiliser (0/1)	0.07	0.26	0	1
Household purchased commercial fertiliser (0/1)	0.60	0.49	0	1
Number of GAPs with extension provided	7.23	6.02	0	19
Number of observations	470			

Notes: (0/1) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category.
Source: Authors' own

cultivated, on average, 1.60ha of land, with most plots managed by male heads (70 per cent) relative to female heads (16 per cent). Similarly, male heads tended to make most of the decisions on crop sales income relative to female heads. Hiring of agricultural labour was observed among 31 per cent of the farmers, with 13 per cent having a household member participating in a farmer club and 9 per cent obtaining any credit. Only 7 per cent received subsidised farm inputs in the 2017/18 farming year with many – estimated at 61 per cent – purchasing commercial fertiliser on the market. The proportion of households with a member in community farmer groups was estimated at 13 per cent.

4.3 Determinants of extent of adoption of CSA practices

Table 4.4 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. Our 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 consistent with the strong and positive association between receipt of agricultural extension services, participation in farmer clubs and presence of a lead farmer in community and likely adoption of higher number 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, we failed to find a relationship between the number of CSA practices adopted and variables such as land, household size and hiring of agricultural labour, indicating that these variables do not present constraints to the extent of technology adoption. This corroborates findings elsewhere in Zambia (Arslan et al., 2014). This could be because here adoption is considered over a longer period – the past 10 years – and therefore current land and household size as well as hiring of agricultural

Table 4.4: 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 labour (0/1)	0.121	(0.111)
Household has member of farmer club (0/1)	0.341**	(0.161)
Average number of GAPS 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	

Notes: 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: Authors' own

labour may not influence the use of some technologies in the past. Additionally, Andersson and D'Souza (2014) explain 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.

4.4 Effect of the extent of CSA practices adoption on market participation

Table 4.5 shows regression estimates of the effect of the extent of CSA practices adoption on the level of market participation. The inclusion of the CF residuals term from stage one models on determinants of CSA adoption was statistically insignificant. Therefore, endogeneity in technology adoption was not an issue for our sample. Our analysis further checked whether there was any selectivity into market participation among the study households 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 (see results in Table A2). Therefore, we interpreted the results from our preferred model – the fraction logit estimation without residual term. This model was significant overall judging by the obtained Wald statistic (p<0.01).

Table 4.5: Impact of adoption of CSA practices on the extent of market participation

Dependent variable: number of CSA practices used	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 labour (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 fertiliser (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		

Notes: 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: Authors' own

We found the expected positive relationship between CSA adoption and the household crop commercialisation index. This association was statistically significant at 1 per cent. When an additional CSA practice was used, a household experienced a 1.6 per cent increase in the predicted extent of market participation. With respect to household characteristics, we found a weak but positive relationship between maximum years of schooling in a household and market participation ($p<0.10$), with about 1 per cent increase in the extent of crop marketing. However, there was a significantly negative relationship between the extent of market participation and adult equivalents. This contradicts the assertion that household size provides family labour that may increase crop production with likely surplus output that can be used for marketing (Rios. Masters and Shively, 2008; Martey, Al-hassan and Kuwornu, 2012; Radchenko and Corral, 2018). It is possible that large household sizes increased the food requirements for households in this context where food insecurity and poverty were persistent. In addition, other studies have shown that own-produced food meant for consumption is sold by households in a typical distress selling fashion (Jones, 2016; Carletto, Corral and Guelfi, 2017), which may explain the negative relationship. In addition, the need to attain food security limited the extent of crop sales – a finding also reported by Chirwa and Matita (2012). As expected, the results indicate that original households used significantly smaller number of CSA practices than branching out households. This could be due to aging and the associated reduction in physical labour to engage in agricultural activities.

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. With diverse crop production, households could easily allocate crops for food and sale purposes, as found in another study with respect to maize marketing (Sibande, Bailey and Davidova, 2017). We 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. 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).

With respect to market factors, we found that contrary to our expectation, credit access, participation government farm inputs subsidy programme, purchase of commercial fertilisers, hiring of labour and membership in farmer clubs were not associated with a greater extent of market participation. Apparently, credit financing for agriculture is largely non-existent, with most farmers using their own savings for input purchases in Malawi and across other sub-Saharan countries (Adjognon, Liverpool-tasie and Reardon, 2017). In our sample, only 9 per cent reported obtaining credit, but we could not ascertain if it was used for agricultural purposes due to data limitations. For households receiving subsidised farm inputs and purchasing commercial fertilisers, it is likely that they largely do so for purposes of producing their own food for consumption, a typical occurrence among subsistence farmers, while in other settings, these same technologies could increase marketed surplus (Mather, Boughton and Jayne, 2013; Carletto, Corral and Guelfi, 2017; Sibande, Bailey and Davidova, 2017). Additionally, farmer organisations present in rural settings seem to be biased towards production and not marketing, and where they invest in market value chains, farmers fail to sustain project activities beyond the lifespan of assisting projects (Chinsinga and Matita, 2021). In any case, farmer organisations in the study districts were found to be lacking in funds, performance of functions, and the associated structures to effectively engage in markets without external support (Chimombo et al., forthcoming).

5 DISCUSSION AND CONCLUSION

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 our recognition that farmers may not necessarily use these practices annually, and adoption often occurs through an experimentation process of what works or not. It was defined as a count of CSA practices used 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. We contribute to knowledge on intermediate outcomes of such adoption with particular focus on the spill over effects on market participation, a step towards increased agricultural commercialisation.

We 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 per cent). Crop rotation and application of inorganic fertilisers 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 fertilisers over the period in Malawi (Nkhoma, 2018). The least commonly used soil fertility management practice was no tillage. Approximately 33 per cent 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). The only socioeconomic characteristic that we 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, Lee and Thies, (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 CSAs (Knowler and Bradshaw, 2007; Teklewold, Kassie and Shiferaw, 2013; Arslan et al., 2014; Shiferaw et al., 2015; Awotide, Karimov and Diagne, 2016; Simtowe, Asfaw and Abate, 2016; Wossen et al., 2017; Musa et al., 2018). Membership in farmer clubs, presence of lead farmer and receipt of any extension services, including GAPs, 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 (2013) conclusion 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, Vallano and Fleming, 2012), where crop diversification did not matter for the adoption of certified seed technologies. We suspect that 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 per cent 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. (2013) that market opportunities must be considered when promoting technologies. Previous studies have also emphasised the importance of the adoption of technologies for market participation and resulting 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, Kalinda and Tembo, 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, Belotti and Lipper, 2016; Awotide, Karimov and Diagne, 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. Interventions to promote CSA adoption using a variety of extension approaches supported the experimentation and take-up of CSA practices that worked in smallholders' environments over time. More importantly, increased adoption of CSA practices with associated yield increases greatly expanded marketable surplus among smallholder farmers, creating incentives for continued use of the technologies. The results demonstrate that with the adoption of CSA practices in the past 10 years, farmers likely benefitted in terms of increased income from crop sales, therefore supporting welfare. It seems that intensifying efforts to promote CSA adoption specifically over the long term allows gains from CSA practices to materialise. In sum, the adoption of CSA practices enhanced crop market participation spill over 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.

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7 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	-	-
m	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 GAPs 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 labour (0/1), Household obtained credit (0/1), Household received subsidized fertiliser (0/1), Household purchased commercial fertiliser (0/1)	+	+
Food security situation	Coping strategy index	+/-	-
Agricultural shocks experience	Number of agricultural shocks experienced	+	-

Notes: the symbols + and – refers to a positive and negative relationship, respectively.
Source: Authors' own

Table A2: Double-hurdle estimates of market participation

	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 labour (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 fertiliser (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: Authors' own

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