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Contents

Tables

Figures

Abstract

In many developing countries the adoption of climate sustainable practices is hindered by resource and risk barriers. This paper assesses the interactions between participation in Malawi's largest public works programme, the Malawi Social Action Fund (MASAF), and three widely promoted climate-smart agriculture (CSA) practices. The underlying hypotheses to be tested are: (a) that participation in the MASAF programme reduce both the budget and the risk constraints to the adoption of sustainable management practices; and (b) the joint treatment effect of MASAF and CSA increases household farms' productivity and welfare. Drawing on three waves of national panel household survey data, we find that participation in MASAF significantly increases the probability that farm households adopt all the CSA practices considered for this study. We empirically demonstrate that the standalone impact of the CSA practices on maize productivity and the value of crops harvested under normal and dry conditions is, in most cases, not significantly different from zero. However, we find a reduction in sensitivity to low precipitation when MASAF participation occurs in the previous agricultural season. Moreover, the joint treatment effect of MASAF participation with prolonged adoption of soil water conservation structures substantially increases households' productivity and welfare. This synergistic benefit is likely driven by the transfer of skills learned during MASAF public works to farmers' own fields. Results suggest that the CSA agenda can be enhanced by explicitly integrating existing social protection interventions with the promotion of CSA practices.

Keywords: climate vulnerability; climate adaptation; social protection; smallholder; climate-smart agriculture; Malawi.

JEL codes: C01; C23; I32.

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1 Introduction

There is an urgent need to identify effective strategies to reduce the vulnerability of farmers' livelihoods and farm systems to the effects of a rapidly changing climate (IPCC, 2013). Nowhere is this more important than in Africa, where the climate is discernibly changing and large segments of the farm population operate under rain-fed conditions, with few resources to cope with, and adapt to these changes (Engelbrecht *et al*., 2015; Hua *et al*., 2016; Souverijns *et al*., 2016).

Integrated, multi-sectoral approaches that combine agricultural interventions with social protection support have shown promising results for reducing the vulnerability of smallholders to climate change (Asfaw *et al.*, 2017; Kuriakose *et al.*, 2013; Tirivayi, Knowles and Davis, 2016). Climate adaptive social approaches remain the exception not the rule. Limited coordination between ministries responsible for social welfare interventions and ministries of agriculture lead to parallel, yet potentially complimentary, activities to address the climate vulnerability of smallholder populations.

Concepts such as *climate-smart agriculture* (CSA)[1] figure prominently in many national agricultural policies in Africa and are used to guide agricultural interventions to enhance agricultural productivity and resilience in the context of climate change (Lipper *et al.*, 2014). The CSA agenda in Africa has focused most intently on promoting the adoption of practices such as conservation agriculture, agricultural diversification, improved seed use, agroforestry, soil conservation, integrated soil management, and others (Amadu *et al*., 2020; Sitko and Jayne, 2018). However, the CSA agenda in Africa has thus far achieved limited success. The upfront costs of adopting many CSA practices, including direct financial costs and opportunity costs to land and labour, are often prohibitive for many African farmers (Amadu, McNamara and Miller, 2020; Arslan *et al.*, 2014). Moreover, many CSA practices entail significant short-term production risks relative to conventional practices, including yield reductions, increased weed pressure and, in some cases, greater sensitivity to certain weather events, such as waterlogging. The uncertainty associated with these practices, in the short-term, acts as a barrier to their adoption particularly in the context of resource constrained smallholder households, where production choices and consumption outcomes are inseparable, and missing markets push farmers to favour practices that reduce short-term consumption risks (Arslan *et al*., 2015; Knowler and Bradshaw, 2007). As a result, adoption rates of many CSA practices are low, and farmers frequently do not sustain adoption long enough to generate noticeable benefits (Arslan *et al.*, 2014; Campbell *et al.*, 2014; Doss, 2006; Murage *et al.*, 2015; Peterson, 2014; Thierfelder *et al.*, 2017).

At the same time, African governments and development partners are piloting and implementing a wide-range of social protection interventions, including conditional and unconditional cash transfers, public works programmes, and food-aid, in order to address issues of entrenched poverty and to help smooth consumption in the face of myriad socio-economic risks and vulnerabilities. As of 2015, the World Bank estimated that approximately 25 percent of people in African countries are covered by some form of social protection (World Bank, 2015). These programmes are typically managed by social welfare ministries, with very limited coordination

[1] The term climate-smart agriculture is comprised of three pillars: increased productivity, resilience, and mitigation. In practice, the term CSA is used to describe a range of practices and technologies associated with other commonly used terms, such as sustainable agriculture and sustainable intensification. In this paper, we use the term CSA with the understanding that other terms may be equally appropriate.

with the agricultural sector, despite the importance of agriculture to the majority of the world's poor. Potential links between social assistance and productive support programmes have been underutilized. However, recent evidence gathered worldwide points out that the synergies between cash transfers and programmes related to production factors (for example, inputs) should be taken into greater consideration to achieve the paramount objective of reducing rural poverty (Carrasco Azzini, 2020).

Conceptually, there are significant potential benefits from integrating the promotion of CSA practices and the provision of social protection assistance. By providing a source of income or in-kind resources to poor farm households, social protection programmes may help to directly and/or indirectly ease the constraints of adopting CSA practices (Devereux, 2016; Tirivayi, Knowles and Davis, 2016). Moreover, by reducing livelihood risks and consumption uncertainty, social protection programmes may enable farmers to move from experimenting with CSA practices to more intensive and sustained levels of adoption (Holden, Barrett and Hagos, 2006).

In this paper a conceptual and empirical framework is developed to investigate the linkages between social protection programmes and CSA practices in the context of smallholder climate vulnerability. In particular, this paper examines the empirical linkages between a range of CSA practices and participation in a public works programme, implemented through the Malawi Social Action Fund (MASAF). These linkages are explored using data from three waves of panel household surveys, merged with spatially explicit historical weather information.

The empirical strategy developed in this paper explores three interrelated questions. First, does participation in MASAF influence the probability of adopting and sustaining the adoption of CSA practices? We focus particularly on the adoption of soil and water conservation (SWC) structures, legume intercropping (LI), and organic fertilizer (OF) application. These practices vary in their relative requirements for land, labour, and capital, and are representative of different typologies of CSA practices promoted in Malawi (Amadu, McNamara and Miller, 2020). Second, does participation in MASAF and/or the adoption of CSA practices jointly or standalone influence the productivity and welfare of smallholder systems? Finally, does participation in MASAF and/or adoption of CSA practices jointly or independently contribute to a marginal improvement in welfare and productivity outcomes under low rainfall conditions? For the last two questions, the impacts are estimated for both short-term and sustained adoption of the CSA practices, in order to disentangle temporal differences in impacts.

This paper makes three important contributions to the current literature. First, it contributes to an emerging strand of research on the relationships between social protection interventions and agricultural investments, and expands this literature by focusing on CSA-related land management practices (Covarrubias, Davis and Winters, 2012; Daidone *et al.*, 2019; Holden, Barrett and Hagos, 2006; Tirivayi, Knowles and Davis, 2016). We show that participation in MASAF is associated with a significant increase in the likelihood that a farmer will adopt the SWC, LI and OF. Second, this is one of the first studies to be attentive to the temporal impacts of CSA practices and policy instruments for supporting sustained adoption. The results show that participation in MASAF is positively associated with the adoption of the three CSA practice analysed. Furthermore, the sustained adoption of SWC over, at least two consecutive agricultural seasons, increases both the maize yield and the total value of the crop harvested when household farmers also received a cash transfer from the MASAF programme. Finally, it contributes to an ongoing debate over the efficacy of MASAF at improving household welfare. Beegle *et al.* (2017) find no impact of MASAF participation on household food security and

inorganic fertilizer use, which are two of the key objectives of the programme. Yet, the World Bank's Independent Evaluation Group (IEG, 2016) finds overall high levels of participant satisfaction with the programme, which is further corroborated by McCarthy *et al*. (2018) who find that MASAF participation improved food consumption expenditure in the wake of widespread flooding in 2014/15.

The findings presented in this paper suggest a positive synergistic relationship between CSA promotion and social protection support, which can be strengthened through intentional integration of the two. Moreover, they highlight the importance of longer evaluation timeframes and attention to climate risks when evaluating the welfare effects of programmes such MASAF.

This paper is organized as follows. Section 1 provides contextual information on MASAF and the selected CSA practices. Section 2 is devoted to the theoretical framework, which links social protection interventions and CSA practices with climate vulnerability. Section 3 presents the identification strategies and the estimation procedures followed for the empirical analysis. Section 4 describes data sources and variables used in the analysis. Empirical results are presented and discussed in Section 5. Finally, Section 6 concludes by assessing the policy implications of the findings.

2 Contextual background: climate-smart agriculture (CSA) and public works programme (PWP) in Malawi

2.1 Public work programme in Malawi

In Malawi, public works programmes (PWP) are the most widespread form of social protection in the country. Overall, Malawi ranks fourth among all low and middle income countries in terms of population coverage by PWPs (World Bank, 2015). Introduced in 1996, the largest of these programmes is the Malawi Social Action Fund (MASAF), which seeks to develop community assets, including all season roads, soil conservation and drainage, reforestation, and irrigation infrastructure, by providing short-term labour-intensive employment for able-bodied individuals. Thus, the programme is anticipated to have both individual and community-level benefits. In this study we focus on the individual benefits but acknowledge that community-level impacts are also likely and should be further explored.

MASAF is implemented nationally in a decentralized manner, through a two-stage geo-targeting process. It is implemented during the post-harvest period in order to capitalize on periods of low farm labour demand and to improve farmers' ability to access inputs (Beegle, Galasso and Goldberg, 2017). Programme beneficiaries are provided a total of 48 days of work with potential earnings of up to USD 44 per year (Beegle, Galasso and Goldberg, 2017). This wage rate is set at the average piecework (*ganyu*) rate in Malawi to encourage self-targeting on needy individuals.

During the production years considered in this paper, MASAF underwent a considerable expansion in coverage. Beginning in 2012, an additional funding window (AF2) was created to help Malawian's cope with adverse impacts of economic reform measures, including exchange rate and food price liberalization (IEG, 2016). As a result of AF2, monetary disbursements more than doubled in 2012 compared to 2010, and beneficiary numbers increased from an average of 244 000 to 590 000 (IEG, 2016). The increase in beneficiary numbers is evident in our survey data, where participation increased from 2.6 percent of the population in 2010 to 14 percent in 2013.[2]

Globally, there is considerable debate over the efficiency and cost effectiveness of PWPs in improving beneficiary welfare. For example, the National Rural Employment Guarantee Act (NREGA) in India was found to lower consumption volatility among beneficiaries (Ravi and Engler, 2015). Moreover, positive spill over effects of the NREGA programme were found for poor non-beneficiary households, due to upward pressure on wage rates created by the programme (Deiniger and Liu, 2013). However, Maxwell (1993) estimates that the labour involved in typical PWPs have a direct cost of 1 000 calories per day, which may not be sufficiently covered at low wage rates. Moreover, Subbarao *et al*. (1997) estimate that a typical PWP spend between 30 to 60 percent of budgets on beneficiary wages, with the remainder absorbed by administrative overhead and materials.

In Malawi, there are divergent findings related to the impact of MASAF on household welfare. Beegle *et al*. (2017) find no impact of MASAF on food security among beneficiaries in the 2013 farming season and no impact on input use or asset accumulation. In addition, no spill-over

[2] The survey did not distinguish MASAF from other public works programme in 2010 so the percentage is likely to be overestimated.

effects were found from the programme, in terms of wage rates or reduced labour supply. The lack of impact holds even under different programme implementation modalities, such as changes in timing of labour activities and increased frequency of payment.

Conversely, the MASAF project evaluation carried out by the World Bank's Independent Evaluation Group (IEG, 2016), finds that 88 percent of MASAF beneficiaries stated that MASAF contributed positively to household welfare, 50 percent of beneficiaries indicated that MASAF helped them meet their immediate food needs, while 740 000 beneficiaries stated that the programme also allowed them to purchase farm inputs (IEG, 2016). While these results are not based on experimental data, they are indicative of positive perceptions by programme beneficiaries, particularly in terms of reducing food insecurity risks. This is corroborated by McCarthy *et al*. (2018), who find a positive effect of MASAF on food consumption expenditure in the context of widespread flooding that affected the country in 2015/16.

These divergent results suggest the need for further analysis. In particular, the reduction in food access constraints and improvements in household welfare reported in IEG (2016) and McCarthy *et al*. (2018) is indicative of a reduction in food insecurity risk. This risk reduction, coupled with liquidity provided through the programme, may facilitate changes in farm-level resource allocation, including investment in the adoption of CSA practices. If MASAF is effective at reducing resource and risk barriers to CSA adoption, the impacts are likely to be highest for CSA practices that are the most resource intensive, and least likely to be adopted autonomously by farmers (Amadu, McNamara and Miller, 2020).

2.2 Climate-smart agriculture practices in Malawi

CSA practices can be usefully grouped into six categories, based on their biophysical attributes and their relative resource requirements in terms of land, labour, and capital (Amadu, McNamara and Miller, 2020). In this study we focus on three practices that are widely promoted in Malawi, and which are representative of three of the six categories of CSA: legume intercropping, organic fertilization, and soil and water conservation structures (SWC). In the subsections below, literature on the adoption constraints and impacts of these three practices are discussed.

Legume intercropping (LI)

Cereal-legume intercropping (LI) is widely promoted in Malawi as a strategy to maximize differential nutrient uptake between crops, enhance soil fertility, enrich soil nutrient supply, and ultimately increase and stabilize yields (Branca *et al.*, 2011). Moreover, diversification of production through LI allows farmers to reduce production and market risk relative to less diverse systems (Rusinamhodzi *et al.*, 2012). Ultimately, LI can help to suppress weed growth and reduce labour demands for weeding by improving soil cover (Gowing and Palmer, 2008). However, the impacts of LI on yield growth, stability, and farm profitability, at least in the short-term, are highly variable (Thierfelder, Matemba-Mutasa and Rusinamhodzi, 2015; Waddington *et al.*, 2007). Overtime this variability reduces as soil quality improves, leading to higher yields relative to conventional practices. The variability and uncertainty associated with the impacts of LI in the early stages of adoption act as a barrier to adoption (Ngwira, Aune and Mkwinda, 2012).

However, LI is considered the least risky and resource intensive of the practices included in this analysis because it makes effective use of land, does not require substantial additional investment in inputs and labour, and contributes to risk reducing diversification. Because of this,

LI is more likely to be adopted autonomously by many farmers, and does not require additional programmatic support, beyond normal extensions advice, to increase uptake (Amadu, McNamara and Miller, 2020).

Soil and water conservation (SWC)

Soil degradation across large parts of Malawi's often rugged topography is an area of considerable concern. It is estimated that 41 percent of Malawi land area is categorized as a "hotspot" of land degradation (Kirui and Mirzabaev, 2014). Building SWC structures is considered one of the most effective and affordable techniques for resource poor smallholders to prevent and reverse soil degradation in Malawi (Nakhumwa and Hassan, 2003).

Common SWC practices promoted in Malawi, and elsewhere in Sub-Saharan Africa, include physical or biological bunds, tied and marker ridging systems, terracing, and contour farming. Agronomic evidence on these practices suggests benefits in terms of productivity, particularly under low moisture conditions. For example, evidence on tied ridge systems and bunds from Burkina Faso shows that by enhancing water holding capacity and permitting more time for water infiltration, smallholder yields are improved (Hulugalle and Rodriguez, 1988; Lal, 1995). Moreover, the adoption of biological bunds, which is common in Malawi, can contribute income diversification when planted with forage or food crops (Chauhan and Gill, 2014).

However, as shown by Posthumus and De Graaff (2005), while SWC structures such as terracing can increase yields, the overall benefits in terms of household production may be negligible due to the land area lost when constructing the terraces (roughly 20 percent). Reductions in available cultivatable land due to investments in soil conservation are an important adoption constraint for small farms, particular in a country such as Malawi where average land sizes are already small and shrinking (Anseeuw *et al.*, 2016). The construction of SWC structure is also highly labour intensive (Amadu, McNamara and Miller, 2020). Given the resource requirements of SWC adoption, we anticipate that adoption barriers of this practice are high, and autonomous adoption, particularly among the poor, is unlikely. We anticipate, therefore, that interventions that reduce risk and liquidity constraints, such as MASAF, will increase the likelihood of adopting SWC structures.

Organic fertilizers (OF)

The term organic fertilizer refers specifically to composted crop residues and animal manure and does not include crop residues retained on the field. Composting in Malawi has been a part of the Government's extension programme since independence (Anseeuw *et al.*, 2016). Four composting methods are commonly practiced and promoted in the country: *changu, chimato,* pit, and box or thatched. Composting is considered a low-cost option for addressing declining soil fertility and improving the resilience of crop production systems to drought stresses.

In Malawi, the application of compost is found to enhance soil carbon, total soil nitrogen and phosphorous, and to improve water retention under low rainfall conditions (Ngwira *et al.*, 2014). However, under high rainfall conditions mulching and other forms of organic soil amendments can lead to crop water logging and yield loss (Ngwira *et al.*, 2014*)*.

Limitations in the quality and quantity of compost produced by smallholder households is also an area of concern (Vanlauwe and Giller, 2006). Mustafa-Msukwa *et al*. (2011) find that of those household that use compost in Malawi, the amount produced covers only an average of 17 percent of their total cultivated area. Moreover, there is concern that in the maize centric

systems of Malawi the quantities of green legume feed stock ingredients available to produce compost is insufficient to achieve the appropriate carbon-nitrogen ratios needed to facilitate nutrient uptake by plants. Finally, the collection of organic materials, the management of composting systems, and the spreading of composted fertilizers are all highly labour intensive, making the practice difficult to adopt in labour constrained situations.

Thus, while organic compost and other organic soil amendments have the potential to increase and stabilize production under low rainfall conditions, production risks from floods are important, and resource constraints within Malawi's smallholder production systems may limit effective adoption. This practice, therefore, occupies an intermediate location on the spectrum of CSA resource requirements and risks, and we anticipate the impact of MASAF participation on adoption to be positive (Amadu, McNamara and Miller, 2020).

3 Theoretical framework

Our analysis draws theoretical insights from the literature on vulnerability, which focuses on understanding how social-ecological systems respond to stresses or perturbations, including weather and climate related shocks (Adger, 2006; Janssen and Ostrom, 2006; Miller *et al.*, 2010b). The epistemic community involved in vulnerability analyses is diverse, leading to numerous interpretations of vulnerability. However, in general vulnerability studies seek to understand the degree to which a system is susceptible to, and is unable to, cope with adverse conditions, such as those created by climate change (Adger, 2006; Turner *et al.*, 2003). Underlying this are the concepts of exposure, sensitivity, and adaptive capacity, which informs most of the work on vulnerability (Adger, 2006; Kasperson *et al*., 2005; Miller *et al*., 2010).

An important contribution of the vulnerability literature is its focus on the interactions between exposure to a particular stress or hazards, such as extreme weather events, the capacity of actors or systems to respond to this exposure, and how this affects the well-being of the system (Adger, 2006; Luers *et al.*, 2003; Miller *et al.*, 2010a; Ribot, 1995). Thus, analyses of vulnerability focus attention on both the effects of stresses on outcome, as well as mechanisms that may alter this impact (Luers *et al.*, 2003).

Vulnerability, therefore, provides a useful conceptual lens for understanding the interactions between social protection interventions, CSA practices, and climate related risks in the context of smallholder systems. We acknowledge, however, that vulnerability is a multi-dimensional outcome, and that our study is focused on a fairly limited set of factors that can affect vulnerability. With this in mind, we operationalize the functional element of vulnerability in the following ways. Weather risk exposure is computed by merging historical weather station and interpolated granular geospatial rainfall data to household spatial coordinates and then calculating a Standardized Precipitation Index (SPI) proposed by McKee *et al*. (1993, 1995). In the rain-fed production systems that characterize smallholder agriculture in Malawi, deviations in rainfall are arguably the most pressing adverse weather risk. In our framework, SPI is used to measure all three dimensions of weather risk exposure: magnitude, character (in this case flood or drought), and rate or probability. Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring. Historic rainfall data is smoothed using a moving width equal to the number of months desired (typically 1, 3, 6 or 12) and is fitted to a gamma distribution through a maximum likelihood estimator. Representing the rainfall distribution with a cumulative probability function allows for the spatial identification of weather shocks of varying severity within a given year by using different standard derivation thresholds from historical means, where positive deviations indicate higher than normal rainfall and negative derivations lower. By summing the number of low and high precipitation episodes over the reference period, it is possible to use the SPI index to create a measure of risk exposure to climate shocks. Mathematically, the risk exposure index is the ratio between the number of low and dry precipitation episodes during the reference period and the number of years considered.

Sensitivity to weather risk is assessed by testing the “treatment effect” of MASAF participation, adoption and sustained adoption of CSA practices, and their combinations, under normal and low precipitation conditions. In this paper, sensitivity is measured along two dimensions. The first dimension is crop-specific and is measured in terms of maize productivity, which is the dominant staple crop in Malawi. The second dimension is farm-specific and is measured by the total value of the harvest at market prices. This variable therefore captures impacts across the full range of crops grown.

Finally, we empirically examine the relationships between participation in MASAF and the adoption and adoption duration of different CSA practices. This provides insights into the extent to which the programme affects the capacity of smallholder to adopt farming practices that are promoted as climate change adaptation strategies.

Literature suggests that social protection interventions, such as MASAF, can affect smallholder sensitivity to weather risks, and their capacity to adopt CSA practices along two dimensions. Directly, social protection interventions can help to stabilize incomes and consumption when weather risks occur through transfers of cash and in-kind resources to households with few alternative resources to manage these risks (Devereux, 2016). Poor smallholder households are particularly vulnerable to production and price volatility risks associated with weather shocks, due to limited access to resources, weak markets, and a lack of formal risk management instruments (Dorward *et al.*, 2006). By helping to smooth consumption and/or income when shocks occur, social protection can mediate household sensitivity to adverse weather events, and reduce the likelihood that a household will turn to negative coping strategies, such as asset liquidation and reduction in the quality and quantity of food consumed (Tirivayi, Knowles and Davis, 2016). Moreover, social protection programmes can directly ease the credit and liquidity constraints faced by poor rural households, thus increasing their capacity to invest in productive farm assets (Covarrubias, Davis and Winters, 2012).

Indirectly, by providing households with cash or in-kind transfers, social protection programmes can help ease the constraints associated with opportunity costs and risks of adopting new farming practices (Devereux, 2016; Tirivayi, Knowles and Davis, 2016). Access to social protection systems may be particularly important for supporting the adoption and sustained adoption of the CSA practices considered in this paper, which require households to allocate scare resources, but which may not produce immediate production benefits (and can even contribute to short-term reductions in yield).

Due to the risks associated with adopting many CSA practices, farmers who do adopt them often do so on a limited basis (Corbeels *et al.*, 2014; McCarthy, Lipper and Branca, 2011; Thierfelder *et al.*, 2017). This includes dedicating small parts of their land to experiment with CSA practices and only adopting the practices for short periods of time (Doss, 2006). Under conditions of low intensity or short duration adoption, the benefits of the practices are quite limited (Corbeels *et al.*, 2014). If access to social protection programmes is able to reduce these risks in ways that enable farmers to adopt CSA practices with higher level of intensity or for longer durations, the combined impact of CSA with social protection on weather risk sensitivity will be marginally higher than their standalone impacts.

Against this conceptual background, this study proposes to test the impact of MASAF and the selected CSA practices on the welfare and the climate vulnerability of the household farmers. It does this by testing three hypothesises: (1) participation in MASAF affects the probability of adopting CSA practices, and helps sustain adoption overtime; (2) the adoption of CSA practices and/or participation in MASAF, jointly or standalone, positively affects household crop productivity and welfare; (3) the adoption of CSAs and/or the participation in MASAF, either standalone or jointly, benefits marginally more the sub-sample of the population experiencing adverse weather conditions.

4 Empirical strategy

Two estimation strategies are used to test the three hypotheses motivating this paper, and we divide this section into two different subsections in order to give a detailed explanation of each.

4.1 Multivariate probit model

The adoption of CSA practices is modelled within a random utility framework, where farmers decide to switch to a specific regime if the expected utility from adoption of a specific CSA is higher than the alternatives. Since interrelationships between observed and unobserved factors shape farmers' decisions, the treatments are derived from a latent variable model. Assuming that the latent variable U_j is the utility difference between the treatment and the alternative, each farm household selects a specific regime j if, and only if, the spread is positive.

Formally, the empirical strategy starts from the following adoption model:

$$Y_j^* = X_j\beta_j + \upsilon_j, j = 1, \dots, N \quad (1)$$

where Y_j^* is a latent variable capturing the farmers demand and/or preference for the practice *j*, X_j is a vector of household sociodemographic, institutional and geographic[3] characteristics affecting the adoption of the CSA practice *j*; and υ_j is a stochastic error term (Kassie *et al.*, 2013). For this study, the vector X also contain a binary variable indicating that the household received cash wages from the MASAF programme during the considered agricultural season.

Given the latent nature of Y_j^*, the procedure is based on a set of observable binary discrete variables Y_j, which denote the choice of adopting or not each specific agricultural practice *j*:

$$Y_J = \begin{cases} 1 \; if \; Y_j^* > 0 \\ 0 \; otherwise \end{cases} \quad (2)$$

The estimation procedure is implemented using the Multivariate Probit Model (MVP). The model is particularly suitable to this study's purpose since it models simultaneously the influence of the set of explanatory variables on a vector of dependent variables, taking into account the matrix of variance-covariance among the disturbance term of each equation by allowing for the free correlation between the error terms of each pair of equations.

In particular, when a pair of practices is independent, the error terms are independent as well $(\rho = 0)$, when they are complements the error terms are positively correlated $(\rho > 0)$, while a negative correlation $(\rho < 0)$ is expected when two practices are linked by a substitution relationship (Belderbos *et al.*, 2004). Accordingly, in the first case *m* univariate probit models estimated separately yield consistent and efficient estimates. However, in the last two cases the univariate models do not capture the relationships among the adoption decisions on different practices, resulting in bias and inefficient estimates. In this case, the MVP estimators increase the efficiency of the results by simultaneously modelling the adoption equations. Doing that, the

[3] Including the risk exposures to low and high precipitation conditions.

model assume that error terms of the adoption model are multivariate standard normal [$\upsilon_j \sim \mathrm{N}(0,1)$] and their variance-covariance matrix is given by:

$$\Sigma = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & .. & \rho_{1m} \\ \rho_{12} & 1 & \rho_{23} & .. & \rho_{2m} \\ \rho_{13} & \rho_{23} & 1 & .. & \rho_{3m} \\ : & : & : & 1 & : \\ \rho_{1m} & \rho_{2m} & \rho_{3m} & .. & 1 \end{bmatrix}$$

The joint multivariate normality assumption determines that the diagonal element indicating the variance of the error terms are all normalized to 1. The off-diagonal elements, ρ_{jm} represent the unobserved correlation between the stochastic component of the mth and jth practice. Testing the statistical significance of each ρ_{jm} provide evidence on the complementarity\substitutability relationship between the adoption decisions.

4.2 Two-ways fixed effect model for a difference in difference

The standalone and the joint treatment effects of participating in MASAF and adopting CSA practices, are estimated using a two-way fixed effect model (2FE) implemented in the spirit of a Difference-in-Differences (DiD) model, but in the context of a complex research design. DiD models are most appropriate in settings where there are two clearly defined time periods, “pre” and “post”, and two groups, “treatment” and “control” (Bertrand, Duflo and Mullainathan, 2004; Callaway and Sant’Anna, 2018; Goodman-Bacon, 2018). However, the research setting for this study is characterized by multiple treatment groups, and as a result there is not a unique baseline for each treatment and no common post-treatment period. Farmers, instead, may adopt the CSA practices and participate in MASAF at different times and for different durations over the three survey waves.

In this context, the underlying rationale for the 2FE approach is to estimate the within variation of groups exposed to the treatment at different times. When there is no heterogeneity in the average treatment effect (ATE) across groups and over time, under the assumption that the “interventions is as good as random, conditional on time and group fixed effects” (Bertrand, Duflo and Mullainathan, 2004), ATE can be consistently estimated using a 2FE.[4] Given the rich set of control variables included in the model and the short temporal dimension of the panel, this assumption is expected to hold for this particular analysis.

[4] It is worth noting that a recent development in the methodological literature (see among others, de Chaisemartin and D’Haultfœuille, 2020; Goodman-Bacon, 2018) points out that when the treatment effect is heterogeneous across groups and times the two-way fixed effect approach is a weighted average of all two possible two-group/two-period estimators in the data. When, under specific conditions, some weights are negative the interpretation of the unique coefficient for the ATT estimated through a two-way FE is misleading. To relax these concerns, according to (de Chaisemartin and D’Haultfœuille, 2020) the weights attached to the regressions estimated with the two-way fixed effect have been calculated and none of them have been found to be negative.

In addition, as one of the aims of this study is to estimate the treatment effects of CSA and MASAF under adverse weather conditions, we interact a third variable, identifying rainfall dry shocks, with the treatment variables. As a result, our empirical strategy consists in estimating the following regression model for each CSA practice considered:

$$Y_{it} = a_t + c_i + \beta_1 CSA_{itj} + \beta_2 MASAF_{it} + \beta_3 Dry\_Shock_{it} + \beta_4 CSA_{itj} * Dry\_Shock_{it} + \beta_5 MASAF_{it} * Dry\_Shock_{it} + \beta_6 CSA_{itj} * MASAF_{it} + \beta_7 CSA_{itj} * MASAF_{it} * Dry\_Shock_{it} + \theta X_{it} + \epsilon_{it} \quad (3)$$

Where, Y_{it} is the outcome variable of interest (either the logarithm transformation of maize yield, or total value of harvest)[5] for household i at time t; a_t and c_i capture the time and the households fixed effect, respectively; CSA_{itj} is the binary treatment representing the adoption of the j practice at the time t from the household i. $MASAF_{it}$ is a binary variable that takes the value 1 if the household i participates to the programme in time t and 0 otherwise; Dry_Shock_{it} is a binary variable that is equal to 1 if the households i resides in an enumeration areas (EA) that experienced a substantial[6] negative deviation from normal rainfall during the considered period and 0 otherwise; and X_{it} identifies the set of control variables that are likely to affect the outcomes such as: household sociodemographic characteristics (female headed household, household size in adult equivalent, average educational level at household level, religion, share of income from off-farm activities); institutional framework (participation into the farmer input subsidy programme, access to credit, access to extension officer's advices); assets endowment (size of the land owned, number of livestock in tropical livestock units (TLU), agricultural wealth index cellphone); access to infrastructure (distance to the nearest paved road, distance from the nearest weekly agricultural market, distance from the nearest Agricultural Development and Marketing Corporation (ADMARC), distance from the nearest auction place); community characteristics (presence of an extension officer within the community, implementation of any irrigation scheme, agricultural collective action) and; agricultural characteristics (use of inorganic fertilizers and adoption of other CSA practices).[7]

For the purpose of this analysis, we are interested in the coefficient β_1 and β_2 , which represent the standalone treatment effect of adopting CSA and MASAF during normal rainfall periods; β_4 and β_5, which capture, respectively, the additional (differential) impact under low rainfall periods and; β_6 and β_7 , which capture the additional (differential) treatment effect of the joint adoption of MASAF and CSA practices during normal and low rainfall periods, respectively. Similarly, to the adoption model, the definitions of MASAF and CSA adoption have been changed when the treatment effect of sustained adoption has been estimated.

[5] The few households reporting a value of 0 for the considered outcome have been retained in the sample. Robustness checks on the sub-sample of household reporting a positive value for the outcome confirms that these extreme values do not alter the results obtained with the full sample and are available upon request

[6] For this study, a substantial negative deviation is identified when the SPI index is smaller than -1.

[7] The vector of CSA practices varies in each model specification includes the other practices that are not considered as treatment in order to control for multiple adoption.

5 Data sources and descriptive statistics

Survey data come from the panel component of the Malawi Integrated Household Surveys (IHS), which have been conducted by the Central Statistics Authorities of Malawi in collaboration with the World Bank in 2010/11 (IHS3), 2012/13 (IHPS) and 2015/16 (IHS4). The surveys are representative at the national, urban/rural and regional levels and include household, agriculture, fishery, and community questionnaires. The panel tracks individual household members, including individuals that form new households. In total, 7 524 observations comprise the full three wave panel sample (2 508 households per wave).[8] To ensure the comparability and the soundness of the empirical analysis, this study focuses on a restricted sample of rural households cultivating maize that report a crop harvest (i.e. the information is not missing). After these adjustments, the analysed sample frame encompasses 3 522 observations (1 174 households per wave).

As the geographic locations of the households are known, the survey data is merged with long-term historical and granular information on rainfall precipitations. Rainfall data for each decade (10 days) interval are extracted from the Africa Rainfall Climatology version 2 (ARC2) of the National Oceanic and Atmospheric Administration's Climate Prediction Centre (NOAA-CPC) over the period 1983–2016. ARC2 data is based on the latest estimation techniques on a daily basis and have a spatial resolution of 0.1 degrees (~ 10km).

Table 1 reports the summary statistics for all the treatment variables analysed on the restricted sample considered. It shows that the weighted percentage of households building SWC structures has increased from 48.2 percent in 2009/2010 to 51.2 percent in 2012/2013, and then slightly decreased to 49.9 percent during the agricultural season 2015/2016. A similar but more pronounced trend characterizes LI, which nearly doubled from 28 percent during the agricultural season 2009/2010 to 52.9 percent in 2012/2013 and then decreased to 44.9 percent during the agricultural season 2015/2016. On the other hand, OF has monotonically increased across the waves from the 17.7 percent during the agricultural season 2009/2010 to 24.3 percent during the season 2012/2013 to 35.9 percent during 2015/2016 season. MASAF coverage increased from 2.6 percent during the first wave,[9] to 14 percent of the second wave and then decreased to 6.2 percent during the third wave.

Finally, Table 1 shows that the average total gross income among Malawian smallholders ranged between USD 490 in 2010 to USD 783 in 2016. The average transfer value of USD 44 available through MASAF is, therefore, equivalent to 9 percent of the total gross income of an average farmer in 2010. This level of transfer represents a non-trivial contribution to the average farmers' overall income basket, and may be sufficient to enable changes in farm-level investment choices.

[8] This entails an attrition rate at household-level of about 4 percent.

[9] It is worth noting that 2.6 percent is referred to households which were included in a PWP for cash in 2010 although for the first wave is not possible to disaggregate the information in order to distinguish how many of them was specifically included in MASAF. This analysis assumes that this small group of households is included into the MASAF. Robustness checks obtained by excluding them from the treatment group has been estimated and widely confirm the general findings and are available upon request.

Table 1. Summary statistics about adoption of CSA practices and PWP participation by survey round

	2010 IHS3		2013 IHPS		2016 IHS4	
	Mean	N	Mean	N	Mean	N
Climate-smart agriculture practices (percent of households)						
Household using soil and/or water conservation structure	0.482	1 174	0.512	1 174	0.499	1 174
Household intercrops legume with any other crop	0.280	1 174	0.529	1 174	0.449	1 174
Household uses organic fertilizers	0.177	1 174	0.243	1 174	0.359	1 174
public work programmes (percent of households)						
Household is included in PWP	0.028	1 174	0.176	1 174	0.083	1 174
Household is included in MASAF for cash	0.026	1 174	0.140	1 174	0.062	1 174
Household is included in PWP for cash (other than MASAF)			0.013	1 174	0.022	1 174
Gross total income (USD 2010)						
Household gross total income	494.24	1 174	760.24	1 174	820.37	1 174

Source: Author's own elaboration.

Table 2 reports the summary statistics of the other variables included in the analysis. For the sake of parsimony, in what follows we provide details only for variables that are not self-explanatory. The total value of the harvest has been obtained by deflating the nominal figures using the consumer price index (CPI)[10] and converting them into USD using the nominal exchange rate during the base year 2010.[11] It includes the value of crops sold at market price and the imputed value of the crop retained for self-consumption.

The agricultural wealth index is constructed by normalizing the results of a principal component analysis, which includes all the agricultural assets owned by the household. It ranges from 0 (poorest) to 1 (wealthiest). This index exhibits a moderate decline over the panel waves suggesting a worrisome depletion in smallholder assets.

Low and high precipitation episodes have been identified at household level using the Standard Precipitation Index (SPI) that is a widely used index to characterize meteorological drought on a range of timescales. According to the range of the timescales selected, the SPI can be used to monitor soil moisture (shorter timescale) or groundwater and reservoir storage availability (longer timescale). For the purpose of this study, the accumulation period selected ranges from November to April and reflects the cumulative distribution of the rainfall during the whole agricultural season to be used as an indicator for reduced stream flow and groundwater recharge. The thresholds to identify a rainfall shock have been set at -1 and 1 allowing the identification of different rainfall episodes ranging from an anomalous dry/wet period to severe droughts/flood (McKee *et al.*, 1993). As shown in Table 2, few households were exposed to high

[10] The consumer price index reflects changes in the cost to the average consumer of acquiring a basket of goods and services.

[11] The historical series on the CPI and the nominal exchange rate are from the World Development Indicator database of the World Bank Group (available at https://databank.worldbank.org/data/source/world-development-indicators).

rainfall events during the production years considered in this study. By contrast, 71.8 percent of the sample population experienced low precipitation episodes in 2015/16. We therefore focus on low rainfall risks in our empirical analysis.

Table 2. Selected variables summary statistics by survey round

	2010 IHS3		2013 IHPS		2016 IHS4	
	Mean	N	Mean	N	Mean	N
Output variables						
Average household maize yield (kg/ha)	1 499.30	1 174	1547.68	1 174	1114.64	1 174
Household gross Income from all crops (USD 2010)	195.03	1 174	340.07	1 174	277.31	1 174
Household characteristics (percent of households)						
Household head is female	0.23	1 174	0.25	1 174	0.29	1 174
Household size in adult equivalent	4.20	1 174	4.48	1 174	4.41	1 174
Average household education of members in working age	5.28	1 174	5.57	1 174	5.44	1 174
Household uses inorganic fertilizers	0.81	1 174	0.78	1 174	0.82	1 174
Share of income from non-farm activities	0.30	1 174	0.25	1 174	0.29	1 174
Institutions (percent of households)						
Household received credit	0.12	1 174	0.20	1 174	0.26	1 174
Household D received extension services' advice	0.42	1 174	0.73	1 174	0.79	1 174
Household received FISP coupon	0.64	1 174	0.54	1 174	0.41	1 174
Wealth and assets						
Total land owned (acres)	1.68	1 174	1.61	1 174	1.70	1 174
Total number of cattle in TLU	0.05	1 174	0.07	1 174	0.07	1 174
Agricultural Wealth Index (normalized)	0.28	1 174	0.25	1 174	0.24	1 174
Household own a cell phone (percent of households)	0.32	1 174	0.36	1 174	0.46	1 174
Infrastructure (km)						
Distance from nearest tarmac road	9.80	1 174	9.88	1 174	9.79	1 174
Distance from nearest weekly market	4.02	1 174	4.30	1 174	4.86	1 174
Distance from nearest ADMARC	7.30	1 174	7.49	1 174	7.51	1 174
Distance from nearest auction	71.88	1 174	73.16	1 174	73.41	1 174
Community (percent households)						
Extension services located within the community	0.42	1 174	0.47	1 174	0.31	1 174
Irrigation scheme within the community	0.12	1 174	0.16	1 174	0.17	1 174
Collective action within the community	0.36	1 174	0.22	1 174	0.35	1 174
Weather risk and shocks (percent households exposed)						
Low precipitations during the agricultural season	0.09	1 174	0.10	1 174	0.71	1 174
Long-term exposure to low precipitation episodes	10.62	1 174	9.92	1 174	9.42	1 174
High precipitations during the ag. season	0.00	1 174	0.00	1 174	0.03	1 174
Long-term exposure to high precipitation episodes	13.14	1 174	12.12	1 174	10.87	1 174
Geographic (percent of households)						
Household is in the northern region	0.11	1 174	0.11	1 174	0.11	1 174
Household is in the central region	0.40	1 174	0.40	1 174	0.40	1 174
Household is in the southern region	0.48	1 174	0.48	1 174	0.48	1 174

Source: Author's own elaboration.

Based on the historical time series of the SPI indexes, the long-term risk exposure to different rainfall shocks has been calculated as the number of either low or dry precipitation episodes from 1983 to the year preceding each specific agricultural season. In other words, the risk exposure index is the ratio between the number of episodes (either dry or wet periods) during the reference period and the number of years considered.

6 Empirical results

We divide the results section into two subsections, which correspond to the two empirical models estimated in this paper. The first provides evidence on the impact of receiving cash through MASAF on the probability of adopting CSA practices. The latter examines the impacts of MASAF and CSA adoption (both stand-alone and joint) on maize yields and total value of the crop productions, under both normal and low rainfall conditions.

6.1 MASAF participation and adoption of CSA practices

Figure 1 presents the results of the MVP model estimating the relationship between participation in MASAF and the adoption of the three CSA practices.

Consistent with expectations, the results show that, other factors constant, participation in MASAF is associated with a positive and significant increase in the probability of adopting SWC, LI and OF during the year in which households participated to the programme.

This supports the evidence highlighted by Amadu *et al.* (2020) who states that external support may be necessary for reducing adoption constraints for CSA practices. In particular, the average marginal effects (AMEs) calculated from the estimated coefficients[12] show that receiving cash through MASAF increases the probability of SWC, LI and OF adoption by about 2.66, 2.47 and 2 percentage points in the year in which the household also receives a cash transfer related to the MASAF programme. It is worth highlighting that, given the limited coverage of the MASAF programme in a sample representative of the whole rural population (smaller than 2.6 percent in 2010, 6.2 percent 2016, and 14 percent in 2013), it is not surprising that the estimated AMEs are quite small. Moreover, adoption of CSA practices is not part of MASAF's programmatic objectives. With more explicit integration with the promotion of CSA practices, it is plausible to expect that the marginal effects of MASAF on adoption would be higher.

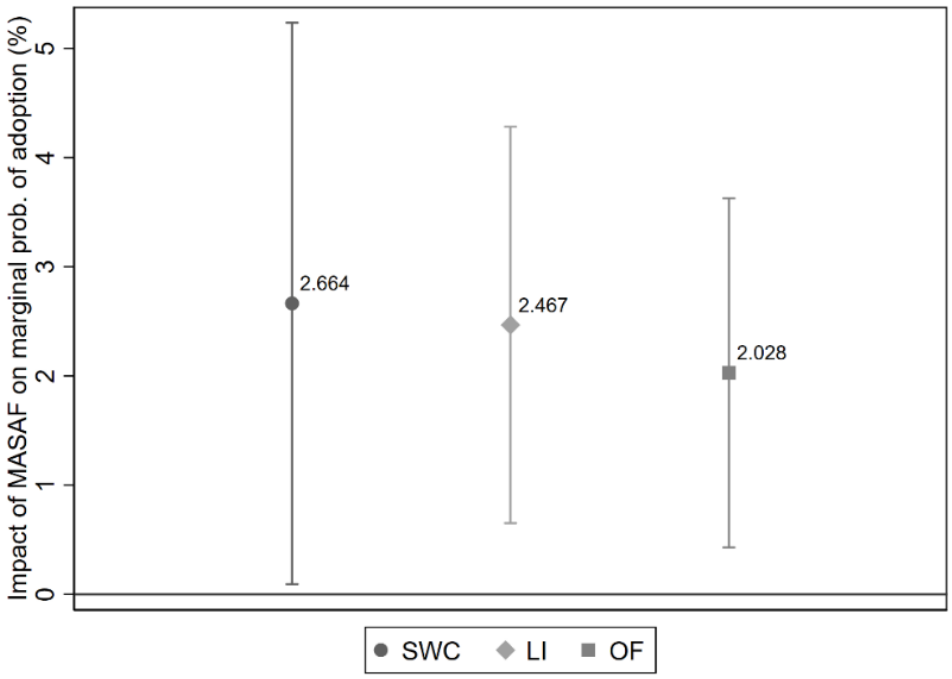
Although we do not find a remarkable heterogeneity across the practices analyzed, it is worth noting that the estimation procedure does not take into account the unobserved factors that could shape the relationship between MASAF and adoption of CSA practices. Controlling for the selection bias and other unobserved variables related to the implementation of the programme, we expect that a greater heterogeneity among practices entailing different constraints for farmers in terms of risks and resources would emerge. As an example, LI pose less risks to the farmers and doesn't require significant upfront investments while the construction of SWC structure, and to a lesser extent OF application, are resource intense practices which increase the risks faced by farmers in the short run. Another source of potential heterogeneity is related to the characteristics of the public works carried out through MASAF. To the extent that farmers receiving MASAF are employed in building erosion control and drainage structures for the community, we expect that, controlling for unobserved characteristics

[12] The cluster robust average marginal effects (AMEs) have been calculated setting, one at a time, the outcome variables of the reference equation to one and using the predicted observation-level log-likelihood following the procedure described by David Roodman (the online discussion is available at https://www.statalist.org/forums/forum/general-stata-discussion/general/1295765-feature-added-to-cmp-computing-margins-of-probabilities-of-certain-outcomes) and recommended by Stephen P. Jenkins when the number of outcomes is greater than two (the online discussion is available at https://www.statalist.org/forums/forum/general-stata-discussion/general/1350594-post-mvprobit-calculate-margin-mvppred-or-margin).

such as the skills acquired through the participation in the programme, the positive empirical association between MASAF and SWC could be relatively higher than other CSA practices since the skills learned through the public work could be applied by some households to their own plots.

Overall, these findings suggest that safety net programmes that target able-bodied farming households, such as the MASAF public work programme, can serve as useful policy instruments to facilitate the adoption of widely promoted CSA practices, and is associated with farmers' sustaining adoption for multiple agricultural seasons. These results are in line with those of Holden *et al*. (2006), who find that food-for-work programmes in Ethiopia help to "crowd-in" land conservation investments by farmers, and do not "crowd-out" these investments by diverting labour. As argued by Hagos and Holden (2006), this positive association is likely the result of a reduction in the risk profile of asset-poor farm households, which helped to reduce their intertemporal discount rates, and made relatively risky and long-term investments in CSA practices feasible.

Figure 1. Estimated average marginal effects by CSA practice



Source: Authors' own elaboration.

The estimated coefficients of the other control variables in the model provide insights into complementary factors that support the adoption of these practices (complete results are available in table A1 in the annex). Among them, it is worth highlighting that all the CSA practices are land and knowledge intensive, while SWC and OF also depend on the endowments of agricultural assets. These findings are consistent with other studies highlighting the same enabling factors to the adoption of sustainable agricultural practices (Corbeels *et al*., 2014; Holden *et al*., 2006; Holden and Lunduka, 2012; Ngwira *et al*., 2012) and provides further evidence for our assertion that the resource requirements for these practices may be prohibitive for many farmers in the absence of some form of external support.

6.2 Treatment effect on productivity and welfare outcomes

In this section, we present results of three 2FE models (one for each CSA practice), which estimate the standalone and the joint treatment effect of adopting CSAs practices and participating in the MASAF programme, under normal and low rainfall conditions (i.e. dry shock). These models are estimated for both contemporaneous adoption of the CSA practices with participation in MASAF, and sustained adoption of the CSA practice. In the latter case, sustained adoption of CSA involves adoption of the practice in two consecutive survey waves, with MASAF participation occurring in the first of these waves for the joint treatment. The treatment effects are summarized graphically in Figures 2 and 3 and will be discussed separately in what follows (the complete results from the two-way fixed effect model are reported in the table A2 and A3 in the annex).

The empirical estimations are derived for the following treatments: standalone under normal conditions (CSA and MASAF); standalone under low rainfall conditions (CSA* Dry Shock and MASAF* Dry Shock); joint impact of the treatment under normal rainfall conditions (CSA*MASAF) and; joint impact under low rainfall conditions (CSA*MASAF*Dry Shock). The coefficients of these interacted terms are interpreted as additional (differential) effects relative to the other terms of the interaction. As an example, the coefficient associated with the triple interaction (MASAF*CSA*Dry Shock) represents the additional (differential) effect of the treatment relative to the CSA (practice?) and MASAF standalone under normal and low rainfall conditions, and the joint impact of CSA (practice?) and MASAF (CSA*MASAF) under normal rainfall conditions. If such a coefficient is positive and significantly different from zero, it means that the effect of MASAF in combination with the CSA practice in areas experiencing low precipitation has an additional positive effect on the outcome, relative to the standalone treatment effects under normal and low rainfall conditions and the joint impact of the treatments under normal rainfall conditions. In what follows, according to the research questions motivating this study, the estimated coefficients will be reported rather than an overall marginal effect of each single treatment.

Treatment effects of contemporaneous participation in MASAF and adoption of CSA

This subsection focuses on the contemporaneous treatment effects of MASAF participation, adoption of CSA practices, and their combinations on maize productivity and total value of crops harvested. To account for weather related heterogeneity, an additional interaction term is added which equals 1 if the household experienced a low precipitation shock during the agricultural season considered and zero if otherwise.

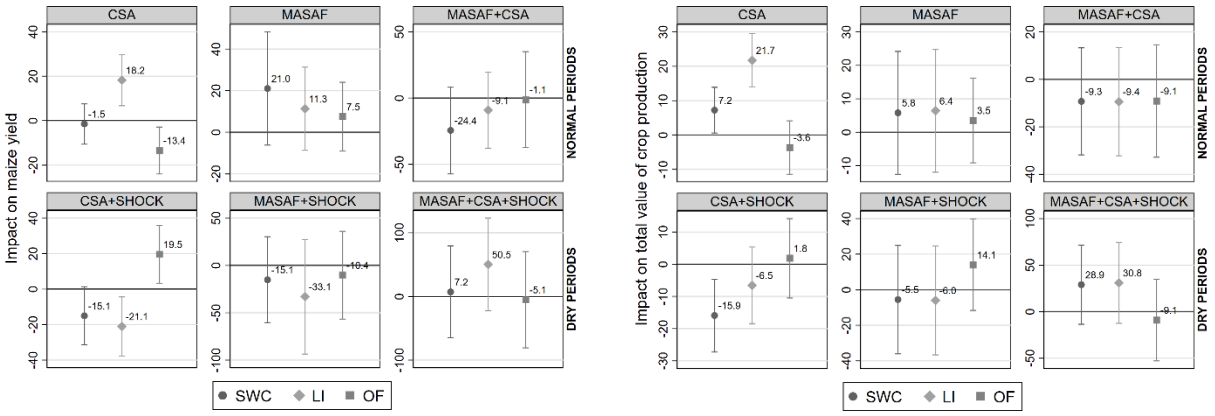
The results summarized in figure 2 show that of the three CSA practices, only LI has a positive effect on maize yields (+18.2 percent) and value of harvest (+21.7 percent) during normal rainfall conditions. These direct and immediate benefits further justify why interventions may not be required to promote the adoption of LI (although interventions to improve LI management is likely required). Under low rainfall conditions, however, the maize yield benefits from LI are nullified (-21.1 percent), although the benefits in terms of value of harvest remain (no significant difference relative to normal conditions). Pigeon peas is the most widely grown intercrop legume in Malawi, and its drought tolerance may help to explain why the value of crops harvested remain stable under dry conditions.

SWC adoption does not exhibit an impact on maize yields under short-term adoption but is positively associated with increase of value of the crop harvested in areas characterized by

normal precipitation (+7.2 percent). This is probably driven by diversification of food and forage crops associated with construction of biological SWC structures. However, these gains are nullified for adopters operating in areas characterized by low precipitation (-15.9 percent). Conversely, OF is negatively associated with maize yield in areas following a normal rainfall pattern (-13.4 percent), but the advantages of adopting the practice for maize productivity are evident under dry conditions (+19.5 percent). These results point to the heterogeneous and uncertain impacts of CSA practices, and highlight the importance of targeting practices based on prevailing and forecasted weather conditions.

The empirical results from this model specification do not signal any effect of MASAF participation, nor any synergies between MASAF and the CSA practices. Thus, in the short-term MASAF does not contribute to measurable changes in productivity or welfare, which is in line with the results reported by (Beegle, Galasso and Goldberg, 2017).

Figure 2. Selected coefficients from two-way fixed effect model (contemporaneous adoption) by outcome variables (y axis)



Source: Authors' own elaboration.

Delayed treatment effects of MASAF participation and sustained CSA adoption

In this subsection, we examine the delayed effects of MASAF participation, and the joint effect of MASAF participation and sustained adoption of CSA practices. Contrary to our expectations, the sustained adoption of the CSA practices does not, in most cases, result in significant productivity and welfare benefits, relative to the farmers who do not adopt the considered practice for multiple consecutive agricultural seasons. The results show that long-term standalone adoption of SWC structures under normal rainfall conditions is associated with a reduction in maize yields (-19.2 percent), although this does not translate into a significant reduction in the value of harvest, perhaps due to diversification of forage and food crops associated SWC adoption.

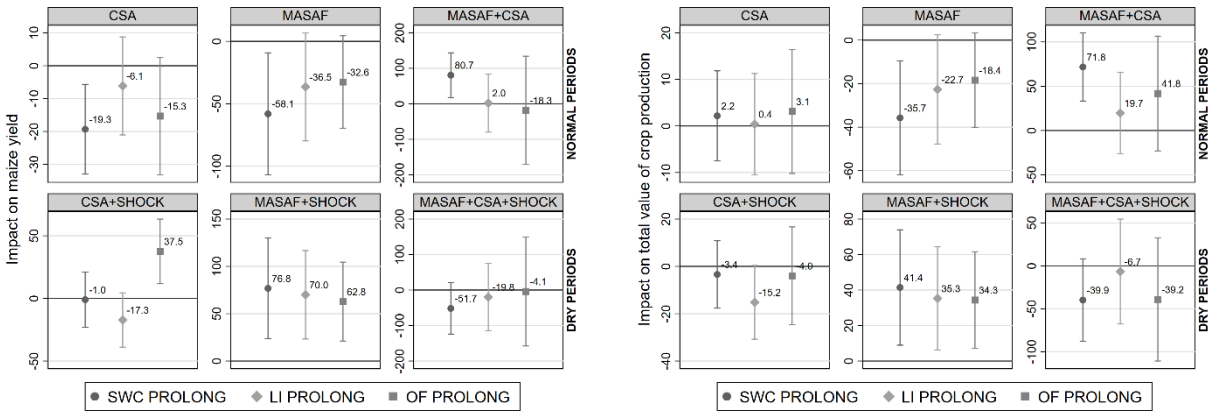
The standalone effect of having received MASAF during the previous survey wave is not significantly different from zero in two out of three specification, and when significant is negative (the SWC equation). However, this negative effect is more than compensated for by the joint adoption of MASAF and SWC, which is positive and significant for both maize yield (+80.7 percent) and total value harvested (+71.8 percent). Together, these results suggest that synergies between having received cash wages through MASAF and building SWC structures on the fields exist. These synergies are likely driven by two factors. First, because MASAF public

works often involves building community-level SWC structures, participants develop skills that they can apply when building SWC structures on their own fields. Second, MASAF participation may allow households to maintain more household labour on their own fields or hire in labour to help build the structures, resulting in better built and better maintained structures. Further research is needed to understand the underlying mechanism for this positive effect.

Under dry conditions, only the sustained application of OF is found to result in measurably higher yields, likely because this practice builds up soil quality slowly over time. In areas affected by low precipitation, the results show that the standalone impact of having received MASAF in the previous survey wave is significantly positive for yield and value of harvest in all the three specification. These findings suggest that MASAF generates reductions in climate vulnerability over the medium-term, perhaps by smoothing consumption and reducing adverse coping strategies, such as the liquidation of productive assets. This is consistent with the positive consumption effects found in McCarthy *et al*. (2018) and the World Bank's Independent Evaluation Group (IEG, 2016). Moreover, under normal rainfall conditions having received MASAF is associated with higher maize productivity and greater value of crop production when the households also adopt SWC structures for multiple consecutive agricultural seasons. However, the joint impact of MASAF and CSA practices under low precipitation conditions provides no measurably different results. This raises obvious concerns about the level of climate-smartness associated with the practices and highlights the need for more concerted efforts to develop appropriate practice and technologies for smallholder farmers facing multiple climate risks.

Overall, these results suggest the effect of receiving MASAF on the productivity and welfare are delayed or realized only under specific circumstances, such as low rainfall conditions or when combined with the sustained adoption of SWCs. This specificity helps to reconcile differences in the literature regarding the impact of MASAF on participants' welfare and productivity. Evaluations of programmes such as MASAF should, therefore, be attentive to temporal and risk-related heterogeneity to provide a complete picture of its impacts.

Figure 3. Selected coefficients from two-way fixed effect model of sustained adoption by outcome variables (y axis)



Source: Authors' own elaboration.

7 Conclusions and implications for policy and research

This paper provides evidence of potentially synergistic benefits from integrating public works programmes and the promotion of CSA practices. The underlying hypothesis tested in this study are that: (a) MASAF reduces the resource and risk constraints faced by household farmers to adopt CSA practices; and (b) the skills acquired through the participation in the public work programme are applied by the farmers on their own fields and increase their productivity and welfare. We show that participation in MASAF public works is in fact associated with increased adoption of all three CSA practices analysed. Moreover, we find evidence that in the case of sustained adoption of SWC structures, participation in MASAF generates substantially better productivity and welfare benefits for farmers than standalone adoption. Nonetheless, while the standalone effect of receiving MASAF is not apparent in the short-term, it has measurable delayed benefits to farm households, particularly under conditions of low precipitation.

These results have important implications for policies and programmes aimed at supporting the CSA agenda in Malawi and elsewhere. First, for CSA that is perceived as riskier or more resource intensive, programmatic interventions that help farmers to reduce these burdens are required to achieve widespread and sustained adoption. This study has shown that cash payment provided through public works contributes to this objective. This was achieved without any explicit connection between MASAF participation and CSA promotion. Modalities that explicitly incentivize adoption, such as conditional cash payments or soft conditions coupled with extensive training, are likely to result in more pronounced outcomes.

Second, bundling training on CSA practices with interventions that reduce adoption barriers is effective at improving the benefits generated by adoption. In the case of MASAF, we show that the positive impacts of adoption and the joint treatment effects of MASAF and sustained adoption, are most pronounced for SWC structures. This practice is an important part of the community-level work carried out under MASAF, and the skills learned through the public works is likely transferred by participants to their own fields.

Third, the benefits of social protection interventions may take time to accrue and may become apparent only when disasters strike. When designing social protection instruments to support increased resilience of smallholders to climate-related risks, longer-term support to allow behaviour changes to occur is essential. Moreover, when evaluating these programmes, it is important to be attentive to their impacts over the medium term.

Taken together, our results highlight how improving coordination between existing programmes, and policies offers substantial opportunities to advance the CSA agenda. In particular, integrating the design and implementation of existing social protection programmes with the promotion of CSA practices may be a cost effective and politically feasible option for incentivizing CSA adoption and improving the effectiveness of adoption. This could entail, for example, providing extension advice on CSA practices to social protection recipients, ensuring that public works activities provide skills that are transferable to the farm level, and ensuring that poor, but able-bodied farming households are consistently covered by social protection systems. Ultimately, the challenges faced by poor farming households in the context of a changing climate are multidimensional and will require multifaceted approaches to address them.

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Annexes

Table A1. Complete estimates of the adoption model

	Soil and water conservation (SWC)	Legume intercropping (LI)	Organic fertilizers (OF)
Household receive cash from MASAF	0.259**	0.316***	0.210**
	(0.103)	(0.108)	(0.094)
Household head is female	-0.012	0.118	0.003
	(0.072)	(0.073)	(0.074)
Household size in adult equivalent	-0.030**	-0.011	-0.030**
	(0.013)	(0.018)	(0.015)
Average household education of members in working age	0.018*	0.027***	0.032***
	(0.009)	(0.010)	(0.010)
Household receive at least one FISP coupon	0.100	0.185***	-0.000
	(0.067)	(0.070)	(0.059)
Share of income from non-farm activities	0.107	-0.158	-0.210**
	(0.113)	(0.112)	(0.092)
Total land owned (log of acres)	0.169***	0.055*	0.121***
	(0.029)	(0.032)	(0.035)
Total number of cattle in TLU	-0.115**	-0.154	0.102
	(0.054)	(0.118)	(0.065)
Agricultural wealth index (normalized)	0.461***	0.026	0.523***
	(0.153)	(0.183)	(0.181)
Long-term exposure to high precipitation episodes	0.010	0.005	0.009
	(0.008)	(0.011)	(0.007)
Long-term exposure to low precipitation episodes	-0.012	-0.003	-0.002
	(0.011)	(0.018)	(0.011)
Region dummy: North	0.018	-0.802**	-0.407**
	(0.174)	(0.318)	(0.207)
Region dummy: Center	-0.151	-1.260***	-0.135
	(0.130)	(0.192)	(0.116)
Year dummy: 2013	0.158**	0.875***	0.183***
	(0.074)	(0.112)	(0.066)
Year dummy 2016	0.178*	0.686***	0.532***
	(0.091)	(0.102)	(0.073)
Constant	-0.543***	-0.502	-1.256***
	(0.198)	(0.313)	(0.205)
Number of observations	3,522		
RESIDUAL CORRELATION COEFFICIENTS BETWEEN CSA PRACTICES AND MASAF			
Soil and water conservation – legume intercropping	0.183***		
	(0.040)		
Soil and water conservation – organic fertilizers	0.121***		
	(0.037)		
Legume intercropping – organic fertilizers	0.095**		
	(0.039)		

Notes: The levels of significance are *** p<.01, ** p<.05, * p<.1. Robust standard-errors clustered at enumeration area level. The dummy for the survey wave 2010 and that for the southern region have been used as pivots.

Source: Author's own elaboration.

Table A2. Complete estimates from the two-way fixed effect "contemporaneous" impact model

	Soil and water conservation (SWC)		Legume intercropping (LI)		Organic fertilizers (OF)	
	Maize yield	Total harvest (USD 2010)	Maize yield	Total harvest (USD 2010)	Maize yield	Total harvest (USD 2010)
MASAF+SWC	-0.244	-0.0928				
MASAF+SWC+Dry shock	0.0719	0.289				
MASAF+LI			-0.0912	-0.0943		
MASAF+LI+Dry shock			0.505	0.308		
MASAF+OF					-0.0111	-0.0914
MASAF+OF+Dry shock					-0.0509	-0.0907
MASAF	0.210	0.0580	0.113	0.0640	0.0751	0.0349
MASAF+Dry shock	-0.151	-0.0554	-0.331	-0.0602	-0.104	0.141
SWC	-0.0151	0.0724*	-0.0820*	0.0193	-0.0811*	0.0204
SWC+Dry shock	-0.151	-0.159**				
LI	0.117**	0.196***	0.182***	0.217***	0.111*	0.194***
LI+Dry shock			-0.211**	-0.0653		
OF	-0.0668	-0.0404	-0.0673	-0.0390	-0.134**	-0.0364
OF+Dry shock					0.195**	0.0184
Dry shock	0.210***	0.203***	0.212***	0.151***	0.0854	0.121**
Household head is female	-0.285***	-0.163***	-0.281***	-0.158***	-0.279***	-0.159***
Household size in adult equivalent	0.00130	0.0734***	0.00492	0.0750***	0.00121	0.0742***
Average household education working age members	0.0123	0.0127*	0.0132	0.0132*	0.0125	0.0131*
Non-muslim household (household head religion)	-0.108	-0.0453	-0.105	-0.0477	-0.109	-0.0485
Household receive credit	0.0454	0.0681*	0.0413	0.0682*	0.0427	0.0689*
Household receive extension services' advice	0.0361	0.0698*	0.0323	0.0709*	0.0325	0.0697*
Household receive at least one FISP coupon	-0.0387	-0.00114	-0.0433	-0.00169	-0.0404	-0.00154
Household uses inorganic fertilizers	0.108	0.173***	0.103	0.167***	0.105	0.166***
Share of income from non-farm activities	-0.438***	-0.674***	-0.447***	-0.677***	-0.430***	-0.671***
Total land owned (log of acres)	-0.0413	0.136***	-0.0402	0.136***	-0.0396	0.135***
Total number of cattle in TLU	0.0434	0.0563	0.0470	0.0556	0.0406	0.0538
Agricultural wealth index (normalized)	0.0755	0.534***	0.0789	0.532***	0.0671	0.532***
Household own a cell phone	0.0440	0.175***	0.0364	0.171***	0.0403	0.172***
Distance from nearest tarmac road (log km)	-0.0325	0.0551	-0.0250	0.0595	-0.0288	0.0579
Distance from nearest weekly markets (log km)	0.0322	0.0278	0.0280	0.0231	0.0278	0.0231
Distance from nearest ADMARC (log km)	0.213***	0.00135	0.220***	0.00623	0.211***	0.00504
Distance from nearest auction (log km)	-0.0618	0.0924	-0.0729	0.0907	-0.0576	0.0962
Extension services within the community	-0.111**	0.0904**	-0.119**	0.0890**	-0.112**	0.0908**

	Soil and water conservation (SWC)		Legume intercropping (LI)		Organic fertilizers (OF)	
	Maize yield	Total harvest (USD 2010)	Maize yield	Total harvest (USD 2010)	Maize yield	Total harvest (USD 2010)
Irrigation scheme within the community	-0.0682	0.0789	-0.0368	0.0912*	-0.0619	0.0838*
Collective action within the community	-0.0257	0.0278	-0.0248	0.0285	-0.0288	0.0265
Year dummy: 2013	-0.0883*	0.499***	-0.102**	0.495***	-0.0808*	0.499***
Year dummy 2016	-0.673***	0.105**	-0.673***	0.104**	-0.673***	0.107**
R^2 within	0.115	0.306	0.115	0.305	0.114	0.305
R^2 between	0.0360	0.466	0.0322	0.461	0.0331	0.461
R^2 overall	0.0780	0.386	0.0758	0.384	0.0766	0.384
Number of observations	3 521	3 521	3 521	3 521	3 521	3 521

Notes: The levels of significance are *** p<.01, ** p<.05, * p<.1. Robust standard-errors clustered at household and enumeration area level. The outcome variables are all expressed in logarithm but the observations for which the non-log transformed outcome is equal to 0 has been retained. The dummy for the survey wave 2010 has been used as pivot.

Source: Author's own elaboration.

Table A3. Complete estimates from the two-way fixed effect "sustained" impact model

	Soil and water conservation (SWC)		Legume intercropping (LI)		Organic fertilizers (OF)	
	Maize yield	Total harvest (USD 2010)	Maize yield	Maize yield	Total harvest (USD 2010)	Maize yield
MASAF+SWC	0.807**	0.718***				
MASAF+SWC+Dry shock	-0.517	-0.399				
MASAF+LI			0.0205	0.197		
MASAF+LI+Dry shock			-0.198	-0.0666		
MASAF+OF					-0.183	0.418
MASAF+OF+Dry shock					-0.0410	-0.392
MASAF	-0.581*	-0.357**	-0.365	-0.227	-0.326	-0.184
MASAF+Dry shock	0.768**	0.414**	0.700**	0.353**	0.628**	0.343**
SWC	-0.193**	0.0218	-0.153**	0.0538	-0.143**	0.0536
SWC+Dry shock	-0.00972	-0.0341				
LI	-0.143*	-0.0453	-0.0615	0.00388	-0.146*	-0.0493
LI+Dry shock			-0.173	-0.152		
OF	0.0108	0.0317	0.0117	0.0292	-0.153	0.0311
OF+Dry shock					0.375**	-0.0398
Dry shock	0.0847	0.114**	0.114	0.133***	0.0476	0.107**
Household head is female	-0.283***	-0.155***	-0.286***	-0.159***	-0.283***	-0.158***
Household size in adult equivalent	0.00425	0.0761***	0.00614	0.0770***	0.00418	0.0762***
Average household education working age members	0.0143	0.0144*	0.0140	0.0141*	0.0146	0.0139*
Non-muslim household (household head religion)	-0.0972	-0.0471	-0.106	-0.0547	-0.0998	-0.0480
Household receive credit	0.0466	0.0669*	0.0502	0.0698*	0.0520	0.0755*

	Soil and water conservation (SWC)		Legume intercropping (LI)		Organic fertilizers (OF)	
	Maize yield	Total harvest (USD 2010)	Maize yield	Maize yield	Total harvest (USD 2010)	Maize yield
Household receive extension services' advice	0.0221	0.0632*	0.0266	0.0696*	0.0216	0.0669*
Household receive at least one FISP coupon	-0.0283	0.00480	-0.0386	-0.00138	-0.0252	0.000461
Household uses inorganic fertilizers	0.107	0.177***	0.105	0.177***	0.103	0.174***
Share of income from non-farm activities	-0.434***	-0.678***	-0.441***	-0.682***	-0.435***	-0.680***
Total land owned (log of acres)	-0.0449*	0.139***	-0.0436*	0.140***	-0.0406	0.140***
Total number of cattle in TLU	0.0342	0.0412	0.0359	0.0410	0.0412	0.0405
Agricultural wealth index (normalized)	0.0582	0.530***	0.0622	0.529***	0.0495	0.527***
Household own a cell phone	0.0491	0.175***	0.0423	0.171***	0.0407	0.173***
Distance from nearest tarmac road (log km)	-0.0214	0.0676	-0.0281	0.0613	-0.0231	0.0619
Distance from nearest weekly markets (log km)	0.0303	0.0266	0.0287	0.0243	0.0280	0.0238
Distance from nearest ADMARC (log km)	0.210***	0.0122	0.210***	0.0116	0.210***	0.00950
Distance from nearest auction (log km)	-0.0561	0.113	-0.0577	0.111	-0.0577	0.114
Extension services within the community	-0.102*	0.0863**	-0.113**	0.0772**	-0.100*	0.0853**
Irrigation scheme within the community	-0.0444	0.0870*	-0.0401	0.0905*	-0.0445	0.0867*
Collective action within the community	-0.0125	0.0294	-0.0124	0.0282	-0.0134	0.0290
Year dummy: 2013	0.0380	0.563***	0.00494	0.539***	0.0353	0.549***
Year dummy 2016	-0.545***	0.149***	-0.565***	0.138**	-0.545***	0.142**
R^2 within	0.120	0.302	0.119	0.300	0.119	0.299
R^2 between	0.0589	0.481	0.0601	0.492	0.0570	0.487
R^2 overall	0.0934	0.395	0.0932	0.399	0.0922	0.397
Number of observations	3521	3521	3521	3521	3521	3521

Notes: The levels of significance are *** p<.01, ** p<.05, * p<.1. Robust standard-errors clustered at household and enumeration area level. The outcome variables are all expressed in logarithm but the observations for which the non-log transformed outcome is equal to 0 has been retained. The dummy for the survey wave 2010 has been used as pivot.

Source: Author's own elaboration.

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