Gender of plot manager, adoption of erosion control strategies and crop productivity in the face of drought: Evidence from Malawi.

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Abstract

The present study investigates whether the adoption of soil erosion control strategies differs between male and female plot managers, and whether drought mediates this gendered adoption of the strategies in question. The paper further examines whether adoption relates to maize productivity. We test these relationships using nationally representative plot level data from Malawi that was collected between 2013 and 2019. Linear probability and probit models were employed to understand the relationship between gender and adoption of the erosion control strategies, and instrumental variables to uncover the relationship between the gendered adoption of the strategies and crop productivity. Our results indicate that men adopt erosion control strategies more than women, which suggests that agriculture policy should aim to improve erosion control strategy adoption among female plot managers. The results also indicate that, with or without drought, adoption of erosion control strategies does not affect crop productivity on both male and female managed plots. We show that plots managed by women are not less productive than those managed by men once we control for plot and farmer characteristics, and that in both types of plots, the adoption of erosion control strategies does not successfully increase maize productivity. Understanding conditions under which the adoption of erosion control strategies increases crop productivity, is a potential subject for future research.

List of acronyms

CRU	Climatic Research Unit
IHPS	Integrated Household Panel Survey
IV	Instrumental variable
LPM	Linear probability model
NSO	National Statistical Office
OLS	Ordinary least squares
SSA	Sub-Saharan Africa

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I. Introduction

1.1 Study context

Soil erosion continues to threaten the sustainability of crop productivity around the globe through accelerating land degradation (Eswaran, 2019). The erosion impedes plant growth by washing away soil nutrients and reducing water retention capacity of soils (Crossley, 2002; Chalise, 2019. The situation is more profound in Sub-Saharan Africa (SSA), where unfavourable weather shocks intersect with poor land management practices (Muzari, 2012; Cordingley, 2015). About 65 percent of the region's land area is degraded. Moreover, despite introduction of various erosion control strategies (Wolka, 2018), SSAs cereal yields have, for over 5 decades, stagnated at less than 1,500 kilograms per hectare (Zingore, 2015). Reasonable assumptions are that either fewer farmers adopt the erosion control strategies, or the strategies are less effective in mitigating erosion-related productivity losses (Muzari, 2012).

Researchers investigate factors that determine the adoption of erosion control strategies in SSA (hDrechsel, 2005; Ndah, 2014). For a farming household, the gender of the household head has been identified as one of the key determinants of adoption (Nigussie, 2017; Mulwa, 2017; Njuki, 2008). Nevertheless, a more critical aspect of farming that is under-researched about is the gender of the plot manager. This classification is crucial, since SSA farming is mostly practised by women (Saito, 1994; Petesch, 2018), despite household headship being predominantly male. Therefore, results on adoption of erosion control strategies that limit to gender of household head are less informative, for ignoring the many women, especially in male headed households, who manage agricultural plots. For instance, in Malawi, the percentage of female plot managers was 25 percent in 2016 and 41 percent in 2019.[1]

Another important aspect of farming that is often ignored is the impact of drought on the gendered adoption of erosion control strategies by the plot managers. This is despite SSA's recent increase in drought occurrences, and evidence that drought accelerates soil erosion (Masroor, 2022). Under drought, farmers could therefore be adopting erosion control strategies to reduce impacts of the drought on soil erosion. However, the adoption requires time, capital, and labour, factors of production. These are unequally distributed by gender within households. Even more so when the erosion control strategies are adopted, it remains unclear how they impact crop productivity on male and female managed plots differently.

Therefore, the first objective of this paper is to investigate whether the adoption of erosion control strategies differs between women and men plot managers, and the mediating role that drought plays on the decision to adopt. The second objective is to investigate whether the gender differences in adoption of

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[1] This is based on the authors' own calculations using data from the Malawi Integrated Household Panel Survey that can be found at https://microdata.worldbank.org/index.php/catalog/3819.

erosion control strategies affects crop productivity. The paper addresses these two objectives using data from Malawi. The country is an interesting case to study for this topic because it is in the south-eastern part of the SSA, where soil degradation from erosion and low crop productivity are common (Zingore, 2015; Li, 2017). Recently, the country has been experiencing droughts that affect a larger proportion of farmers than any other types of shocks do (Chabvungma et. al., 2014). The presence of drought allows testing whether there is a gendered relationship between erosion control strategy adoption and crop productivity when agricultural production faces droughts. Furthermore, Malawi collects plot-level agricultural data, which allows nuanced analyses at the level of plot manager.

This study uses two main data sources. The first is a nationally representative Integrated Household Panel Survey (IHPS) conducted by the Malawi National Statistical Office (NSO) in three waves (2013, 2016 and 2019), which provides plot-level information. The second is the University of East Anglia's Climatic Research Unit (CRU), which provides daily gridded rainfall data that we use to estimate drought occurrences. We merged these two sources' datasets using geographical coordinates collected in the survey. We used linear probability models (LPMs) to analyse gender-based differences in strategy adoption and relied on the exogenous occurrence of drought as an identification strategy. We adopted an instrumental variables approach, in which community average adoption is used as an instrument for plot-level adoption, to analyse gender-based differences in the effect of erosion control on productivity. The results show that in normal times (i.e., in the absence of drought), men adopt erosion control strategies more than women do, but that adoption does not affect maize productivity for male or female plot managers. We further show that male plot managers obtain larger yields than female plot managers do. However, this disappears when we control plot quality and farmer attributes.

Our study first contributes to the literature on adoption of erosion control strategies. Existing studies show that female-headed households adopt erosion control strategies less than male-headed households do (Bedeke et al., 2019 and Asfaw & Neka, 2017 in Ethiopia; Ndiritu et al., 2014 in Kenya). One possible reason for this is that erosion control strategies demand time and labour, and women take on more household roles that constrain their commitment to the farm (Montt and Lou, 2020). In contrast, Tenge (2005) found that female-headed households adopt more soil and water conservation practices in Tanzania, especially because they occupy erosion-prone lands. Tufa et al. (2022) explore gender-based differences in the adoption of agricultural technology in Malawi and show that male and female plot managers tend to adopt different strategies. Like Tufa et al. (2022), we examine gendered adoption at the plot level. We show that women adopt less than men, but only in the absence of drought.

Erosion control strategy adoption could also be influenced by weather events. In the event of climatic stress, like during or after a drought, farmers might change their attitude towards the use of erosion control strategies. For example, Ding et al. (2009) and Mutenje et al. (2019) show that the adoption of soil and water conservation management practices increases with dry weather conditions. Arslan et al. (2014), on the other hand, find that rainfall variability is associated with the likelihood and intensity of adoption of conservation farming practices. This could also be gender-specific, with women and men having different probabilities of changing their attitude towards the use of strategies in the face of drought. In the context of our study, we find that both men's and women's decisions regarding the use of erosion control strategies are not affected by the occurrence of a drought.

Second, the study contributes to the literature on the impact of erosion control strategy adoption on agricultural productivity. Existing evidence on the topic remains inconclusive. For instance, Kuntashula et al. (2014), Adgo et al. (2013) and Mwango et al. (2014) find there is a positive relationship between strategy adoption and crop productivity in Zambia, Ethiopia, and Tanzania, respectively. However, McCarthy et al. (2021) find that minimum tillage, stone bunds, and vetiver grass do not increase yields in Malawi. Furthermore, Adimassu et al. (2017) point out that stone bunds reduce yields because they reduce the effective cultivable area. Also, the effect of conservation strategy adoption on yields depends on the characteristics of the farmer. For instance, Teklewold et al. (2019) find that male-headed households and non-poor households benefit the most from conservation strategy adoption.[2] Our study adds to the erosion control literature by showing that adoption does not affect maize yields for either male or female plot managers, both in normal times and in times of drought, in Malawi.

Finally, we contribute to the literature on gender and agricultural productivity. In earlier research, Quisumbing (1996) observed that productivity was lower in the fields cultivated by women and attributed this to women having less access to inputs and extension services and occupying land of poor quality. In 2012, the Food and Agriculture Organisation (FAO) of the United Nations confirmed this, showing that female farmers might be able to increase their yields by 20 to 30 percent if they had the same access to resources as men do. However, more recently, the World Bank (2014) evaluated results from studies conducted in six SSA countries, including Malawi, and concluded that even with the same resources as men, women would still obtain lower yields due to gendered differences in the use of agricultural inputs. Recently, Tufa et al. (2022) found a gendered productivity gap in favour of men in Malawi, even when men and women had the same resources. In this paper, we show that there exists no difference in maize productivity between male- and female-managed plots once we control for the age and education level of the plot manager and several plot quality characteristics, and our results are invariant to drought.

Our findings have implications for policy. First, to encourage the adoption of erosion control strategies by farmers, interventions should target women plot managers in normal times and focus on both men and

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[2] Furthermore, the strategies' effect on yields is also use-dependent. For example, Baptista et al. (2015) found, in the Cabo Verde drylands, that combining strategies produced greater yields than using a single strategy did.

women plot managers in times of drought. Second, more investment is needed in research that investigates the conditions under which erosion control strategies become effective in improving agricultural productivity, rather than merely expanding the number of strategy options. In addition, agriculture policy should address the challenges women face in owning good-quality arable land to curb the gender-based differences in productivity that are contingent on land quality.

The rest of the paper proceeds as follows. In Section 1.2, we discuss the conceptual framework that guides our methodology and the meaning of the results. In Section 1.3, we describe the data used and provide statistics on our sample. We present the methodology we adopted to establish our findings in Section 2 and discuss our findings in Section 3. Finally, we conclude the paper in Section 4.

1.2 Conceptual framework

This study adapts a conceptual framework originally developed by Bryan and Behrman (2013) and adjusts it to describe how male and female plot managers with different farmer profiles adopt erosion control measures in the presence of a weather shock-drought. Figure 1 illustrates the hypothetical conditions faced by a Malawian smallholder plot manager.

The plot manager (male or female) farms in an environment that is subject to weather shocks like droughts. In the presence of such a shock, plot managers (male or female) decide to either adopt or not adopt soil erosion control strategies. We acknowledge the following points in our framework; firstly, adoption of erosion control measures happens even in the absence of a weather shock depending on the farmer profile (Abegunde, Sibanda, & Obi, 2020; Amadu, McNamara, & Miller, 2020). Secondly, there exist joint decision-making process between male and female plot managers especially in a male headed household.

Gender is an important characteristic that broadly refers in this case to the social, cultural, and psychological traits that are linked to males and females through particular social contexts (Lindsey, 2011). For simplicity, in this study, gender implies the sex of the plot manager. It should be noted that when climate shocks hit, several attributes determine a plot manager’s vulnerability to the shock. These attributes range from individual plot manager-specific characteristics to plot characteristics and institutional factors. Malawian plot managers use erosion control bunds, vetiver grass, terraces, gabions/sandbags, tree belts, water harvest bunds, and drainage ditches to mitigate the effects of a drought shock. These strategies are aimed at improving the resilience of maize plots, especially by enabling plot managers to achieve both stable maize yields and improved productivity.

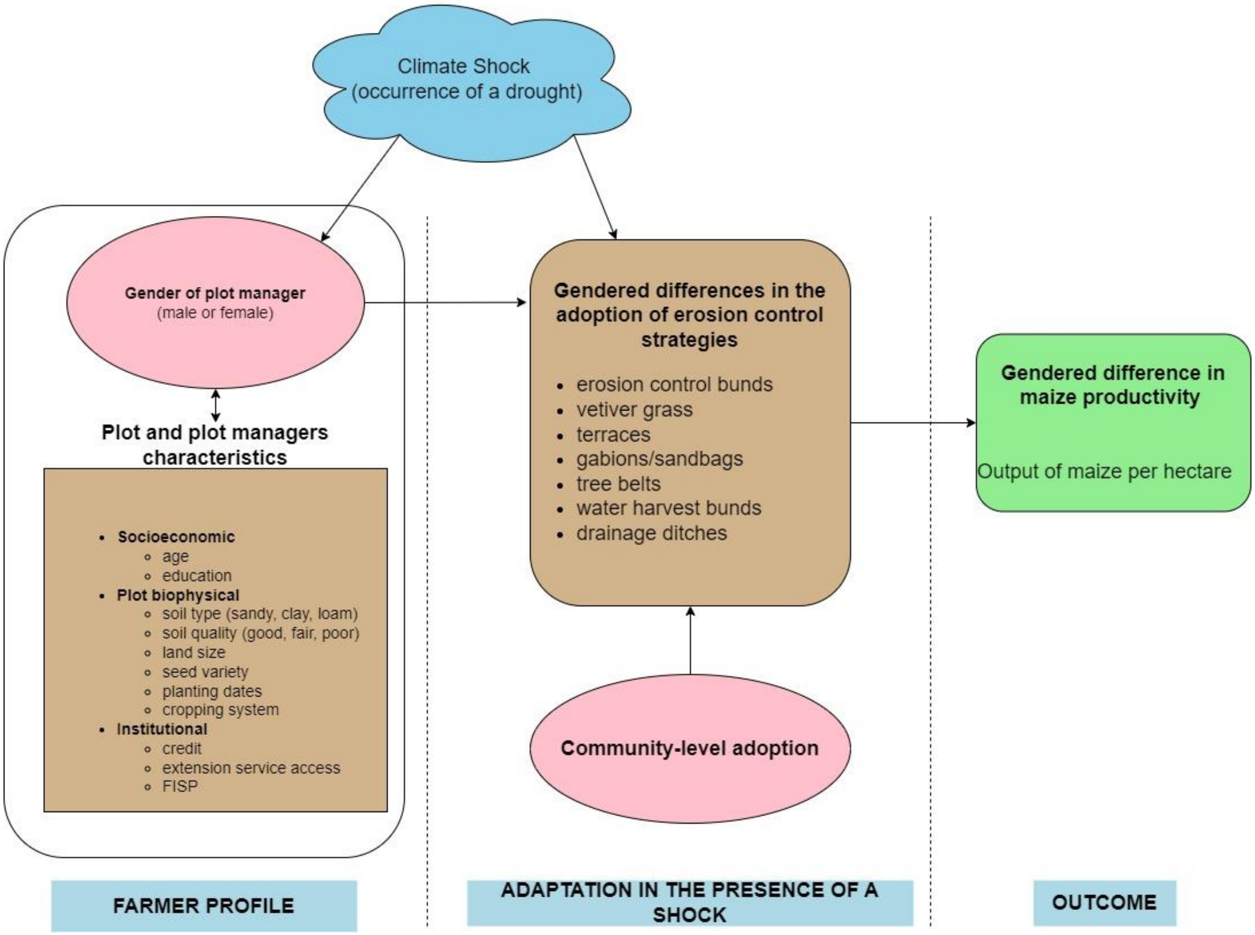
Thus, plot characteristics and individual characteristics affect one's decision to adopt (or not) erosion control strategies. The biophysical characteristics of a farm or the area where a farmer resides influence a farmer's level of exposure to and experience with weather shocks and ultimately affect how they cope with or mitigate the effects of weather shocks (Ngigi & Birner, 2013). Furthermore, institutional arrangements, such as access to extension services, can be instrumental in helping individuals, households, and communities acquire technical knowledge and increase their resilience to climate change (Mueller, Spangler, & Alexander, 2013). For example, extension services like crop extension, animal extension, credit extension and forestry extension could be instrumental in enabling farmers to increase their resilience to weather changes.

Furthermore, farmers and individuals can gain the know-how they need to respond to weather shocks through extension services.

Therefore, we hypothesise that gendered differences in erosion control strategy adoption and adaptation to a drought shock might have an impact on the productivity gains of male and female plot managers. We define "adoption" as the uptake of one or more soil erosion control strategies and "adaptation" as the adoption of strategies that yield maize production gains.

Lastly, we acknowledge that community-level adoption of erosion control measures has an influence on individual farmer-level adoption of said measures. The assumption is that community adoption could reflect common area pre-conditions for adoption that would lead individuals to adopt the measures independent of their farming abilities. This becomes crucial in explaining the productivity gains observed by individual farmers. However, community level-adoption is beyond the scope of this study. We therefore limit to plot level adoption of the erosion control strategies.

Figure 1: Conceptual framework



1.3 Data and variables

1.3.1 Data sources

This study uses data from two sources. The first source is the Malawi Integrated Household Panel Survey (IHPS). This is a nationally representative survey that is conducted by the NSO with technical support from the World Bank. The survey provides agricultural and socio-economic characteristics about rural and urban households in Malawi. The IHPS has a short panel interviewing same people between 2010 and 2013, and a long panel that interviewed a subsample of the short panel across 2013, 2016, and 2019 (NSO, 2020; NSO, 2017a; NSO, 2017b). Our unit of analysis is the farm plot. The IHPS also provides information on individual, household, and community attributes. Individual attributes include the gender and age of the plot manager. The survey also administered agricultural questions that provide information including erosion control strategy adoption, crop production and landholding characteristics. While the IHPS longitudinally traces the same households and individuals, agricultural plots are identified using different codes in each wave. This makes it impossible to merge the plot-level information to form a panel. Consequently, we pooled the data from the three waves to form an overall sample of 7,864 plots. The second data source is the University of East Anglia's CRU,[3] from which we obtained monthly historical rainfall information for the sampled districts. The rainfall data made it possible to construct our drought variable. Together with the plot-level information from the IHPS, the historical rainfall data enabled us to answer our study objectives. The two datasets were linked using geographical coordinates provided in each source.

1.3.2 The outcome variables

This study used two outcome variables, each representing one of the research objectives. The first outcome captures adoption of erosion control strategy. This is a categorical variable for which 1 represents plots on which managers used at least one soil erosion control or water harvesting strategy and 0 represents those on which no strategy was used. The possible strategies were erosion control bunds, vetiver grass, terraces, gabions or sandbags, tree belts, water harvest bunds, and drainage ditches.[4] In our sample, there was minimal adoption of a single strategy. For instance, the most frequently adopted strategy was erosion control bunds, at 20.74 percent, followed by vetiver grass at 7 percent and plateaus at 5 percent. The low percentages informed our decision to create a single dummy outcome variable for the adoption of at least one strategy. We are aware that each mitigation strategies demands specific suitability attributes that may not be all present in one area. For instance, differences in soil type and topography could allow adoption of one strategy but not the other (Kuntashula et al., 2014; Mengistu et al., 2016; Gnansounou et al., 2017; Mwale, 2019). The IHPS provides details on these agronomical characteristics at the plot level. We therefore controlled for them in the analysis.

The second outcome variable, crop productivity, is continuous. The IHPS provides information on crop production and the land area on which crops were produced. We chose maize, the staple crop for Malawi, and calculated productivity as yield in kilograms per hectare of the maize. Yield was generated by dividing total maize production by total landholding. The data from the IHPS also allowed classify yields as having been cultivated in the wet or dry season. We then used the inverse hyperbolic sine transformation of the yields to evade the influence of outliers and be able to interpret the findings in terms of percentage change. We opted for this method over the traditional log method to avoid the problem of log transforming zero yields into negative numbers.

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[3] https://crudata.uea.ac.uk/cru/data/hrg/

[4] Question 25 of the Agriculture Model asks: "What types of erosion control/water harvesting facilities are on this plot? List up to two structures." The possible answers are no erosion control, terraces, erosion control bunds, gabions/sandbags, vetiver grass, tree belts, water harvest bunds, drainage ditches, and other.

1.3.3 The treatment variables

The main treatment variables for this study are the gender of the plot manager and weather shocks. The gender of the plot manager variable is categorical, with 1 capturing the male manager, and 0, the female manager. While some plots were managed by more than one person and could therefore be classified under either gender, we limit our definition to the gender of the *primary* plot manager.

The weather shocks variable is captured in the study by drought during the agricultural season that precedes the harvest. To construct our drought variable, we used rainfall data sourced from the CRU. The dataset includes monthly precipitation estimates from 1901 to 2020 and provides rainfall data for all areas. We extracted information only for points that were used in the IHPS, to make it possible to link the two data sources. We follow Dessy et al. (2020) and Shah and Steinberg (2017), to define drought as a negative rainfall shock. The variable $Drought_{a,t}$ equals 1 for year t, if the standardised rainfall deviation in each area a falls below the 20th percentile,[5] and 0 otherwise. The standardised rainfall deviation is the difference between the precipitation over the entire agricultural season[6] of year t and the historical area-specific mean, divided by the historical standard deviation for area a. Appendix A presents the occurrence of droughts in Malawi between 2010 and 2020.

II. Methodology

2.1 Descriptive statistics

Table 1 represents a summary of the key variables used in our analysis. There is a statistical difference in the number of plots managed by men and by women that are subject to erosion control strategies. Male plot managers adopt strategies more than female plot managers do. In terms of productivity and land size, male-managed plots dominate on both fronts. The same trend is shown when it comes to education level attained. Male plot managers are slightly more educated than their female counterparts. Appendix B provides detailed descriptive statistics for all the plot and plot manager characteristics used in our models. Plots managed by men and women differ in terms of their plot manager's access to extension services, their soil type and the maize varieties that are planted in them. Our set of controls also includes gender of

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[5] The results are stable when we use the 15th percentile as an alternative threshold.

[6] We consider the agricultural season for year t to be the period running from the beginning of November of year t-1 to the end of April of year t.

household head. We see that 36 percent of female-managed plots are managed by females from male-headed households.

Table 1: Plot-level descriptive statistics

	Full sample	Plots managed by Males	Females	Difference
Erosion control	0.444	0.465	0.411	0.054***
Drought	0.159	0.147	0.178	-0.031***
Productivity (kg per ha)	3,632.578	4,402.975	2,473.547	1,929.428*
Production (kg)	551.210	681.226	355.608	325.617**
Land area (ha)	0.306	0.323	0.280	0.043***
Age (years)	43.623	43.238	44.203	-0.964**
Education level (school years)	6.413	7.223	5.194	2.029***
Observations	7,864	4,724	3,140	7,864

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations from IHPS data

2.2 Empirical strategy

This study estimates two empirical models. The first pertains to gendered differences in the adoption of erosion control strategies when adapting to drought, and the second regards gendered differences in the effects of erosion control strategy adoption on maize yields.

For the first model, consider a utility-maximising male or female farm manager who is facing drought. Also, consider that the farmer can choose whether to adopt erosion control strategies, conditional on the expectation that doing so reduces the negative impacts of the drought in the farm. Erosion control strategies should be adopted if the expected utility of adopting them is greater than that of not adopting them (Gravelle & Rees, 2004). However, in the face of drought, the decision to adopt could differ between men and women. This could be because, for instance, male and female managers face different labour and capital constraints. We therefore specified an econometric model for the decision to adopt strategies for plot i located in community c at time t as a function of drought, a male manager categorical variable and the interaction between drought and the male manager categorical variable as follows:

$$Adoption_{ict} = \beta_1 Male_{ict} + \beta_2 Drought_{ct} + \beta_3 (Male_{ict} \times Drought_{ct}) + \delta' X_{ict} + \varepsilon_{ict}. \quad (1)$$

The gendered difference in strategy adoption in the face of drought can be measured by $Male_{ict} \times Drought_{ct}$. Because Equation (1) includes this interaction between drought and the male manager, the covariate $Male_{ict}$ represents male managers who did not face drought, and the covariate $Drought_{ct}$ represents female managers who faced drought. The reference group is female managers who did not face drought. The differences between male and female managers' strategy adoption in the absence of drought is captured by β_1. The mediating role of drought on adoption by female managers is captured by β_2, while the mediating role of drought on adoption by male managers is captured by $\beta_2 + \beta_3$. Finally, the gendered difference in adoption in the face of drought is captured by $\beta_1 + \beta_3$. In Equation (1), X_{ict} indicates the control variables used in the model, while ε_{ict} is the error term.

Our empirical application of Equation (1) started with estimating an LPM while accounting for possible heteroskedasticity using robust standard errors. All standard errors were clustered at the enumeration area level. We then checked the robustness first by employing a probit model and deriving marginal effects from the probit to ensure the probit estimates were comparable to the LPM output. The results from the two models were qualitatively the same in terms of the significance and direction of the relationship. We therefore proceeded with our second level of robustness checks with only the LPM output.

One second-level robustness check involved splitting the sample by drought instead of interacting the drought covariate with the male manager dummy. In this formulation, the assumption was that plot managers who reside in communities that experienced drought could be affected by the control variables in Equation (1) differently. With this approach, Equation (1) can be changed to the following two functions:

$$Adoption_{ict} = \beta_1 Male_{ict} + \delta' X_{ict} + \varepsilon_{ict} \quad if\ drought = 1; \quad (2)$$

$$Adoption_{ict} = \beta_1 Male_{ict} + \delta' X_{ict} + \varepsilon_{ict} \quad if\ drought = 0. \quad (3)$$

We also conducted other secondary robustness checks: we changed from clustering standard errors at the enumeration area level to clustering them at the family level and we controlled for family fixed effects by including the 2013 household identifiers in Equation (1) as controls to capture that different plots could be managed by members that originate from the same 2013 household.

For the second model, pertaining to maize yields, consider plot i in community c. A manager should adopt erosion control strategies for this plot only when the expected maize productivity gains due to adopting them outweigh those due to not adopting them. However, the erosion control strategies' effectiveness at achieving the expected gains could also depend on other factors that are often skewed by gender, such as the quality of the land. We specified an econometric model for maize productivity as a function of the gender of the plot manager categorical variable, erosion control strategy adoption and the interaction between those two variables as follows:

$$Yields_{ict} = \beta_1 Male_{ict} + \beta_2 Adoption_{ict} + \beta_3 (Male_{ict} \times Adoption_{ict}) + \gamma Drought_{ct} + \delta' X_{ict} + \mu_{ict}. \quad (4)$$

$Yields_{ict}$ is the maize output per hectare for plot i located in community c at time t. It is possible to estimate gendered differences in yields' response to the adoption of erosion control strategies due to the inclusion of the interaction term $Male_{ict} \times Adoption_{ict}$. The covariate $Male_{ict}$ represents male managers who did not adopt an erosion control strategy, and the covariate $Adoption_{ict}$ represents female managers who adopted an erosion control strategy. The reference group is female managers who did not adopt an erosion control strategy. The differences in the yields of male- and female-managed plots in the absence of erosion control strategy adoption is captured by β_1. The mediating role of adoption on the maize yields of female plot managers is captured β_2, while the mediating role of adoption on the yields of male plot managers is captured by $\beta_2 + \beta_3$. Finally, the gendered difference in yields due to erosion control strategy adoption is captured by $\beta_1 + \beta_3$. Considering that drought could drive a plot manager's adoption decision, Equation (4) also includes a control variable for drought for the years in question. X_{ict} indicates the control variables, while μ_{ict} is the error term. We also control for previous adoption by including a set of dummies that indicate if any erosion control strategy was adopted in year t-6, t-5, …, t-1.

Our empirical application of Equation (4) began with estimating a baseline ordinary least squares (OLS) model. Thereafter, we applied an instrumental variable (IV) technique to the equation to account for possible endogenous selection in adoption. One possible source of this selection bias is when less productive farmers occupy poor-quality plots that desperately require erosion control to increase yields. Conversely, less productive poor farmers could be less likely to adopt these systems because they cannot afford the initial cost of investment. In such circumstances, the OLS coefficient of adoption would be biased downward.[7] We therefore use community average adoption as an instrument for individual manager adoption.[8] We argue that community adoption could reflect common area pre-conditions that would lead individual plot managers to adopt erosion control strategies independent of their farming abilities. We use robust standard errors clustered at the community level for both the OLS and IVs approaches.

Our robustness checks for our main results included estimating the yield functions while clustering standard errors at the family level and controlling for family fixed effects. We also estimated models that split the sample by drought to understand whether the maize yields' gendered response to erosion control strategy adoption is conditional on climate stress. Finally, we split the sample by gender to allow the control variables to have a different effect on the outcome depending on the gender of the plot manager.

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[7] Including in the model several control variables that indicate the quality of the plot already partially rules out this potential bias.

[8] We use a leave-out mean indicator of community adoption to avoid it being correlated with individual adoption.

III. Estimation results

In this section, we present our estimation results for our two objectives. Because our main interests were 1) testing for the presence of differential erosion control strategy adoption between male and female plot managers in both normal times and times of drought, and 2) testing for the presence of differential changes in maize yields due to adoption of erosion control strategies between male and female managers, we limit our description to the following main covariates of interest: drought and male for Equation (1) and adoption and male for Equation (2), and their interaction terms. We present that show all estimates including those of control variables in Appendix C. Furthermore, standard errors were clustered at the enumeration area level when estimating these results. The results with clustering at the family level are also included in Appendix C.

3.1 Adoption of erosion control strategies by male and female plot managers

Table 2 presents our estimation results for gendered differentials in erosion control strategy adoption in the face of drought. Column 1 shows the results estimated using the LPM and includes the interaction term (Male*Drought (β_3)). Column 2 presents the marginal effects from estimating a probit model with similar specifications as were used for Column 1. The LPM results shows that male managers that did not face drought adopted strategies 6.5 percent more than female managers that did not face drought. The coefficient of adoption by female managers mediated by drought is insignificant, as is the joint significance test for the corresponding coefficient for male managers ($p\colon \beta_2 + \beta_3 = 0$). Furthermore, we find no gendered differences in adoption when it is mediated by drought, as the joint significance test for gendered difference ($p\colon \beta_1 + \beta_3 = 0$) is insignificant. The results shown in Column 2 are qualitatively the same as those shown in Column 1, with the only difference being the size of the coefficients.

Columns 3 and 4 in Table 2 show the results when the sample is split by drought and the LPM model is used. More specifically, Column 3 reveals the results when the sample is limited to plots located in communities that faced drought at time t: we observe that there are no gendered differences in strategy adoption. For Column 4, the sample was limited to plots located in areas that did not face drought. Strategies were adopted 6.4 percent more among male plot managers than female plot managers in these areas. This coefficient is close to that observed in the LPM estimates in Column 1. This is evidence that the using different estimation strategies does not change the outcomes of interest. The results suggest that gendered differences in adoption are limited in drought conditions.[9]

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[9] To ensure that our results are robust to the drought specification, we changed the drought threshold from 20 percent to 15 percent. Doing so did not qualitatively change our results.

Table 2 The role of drought on the gendered adoption of erosion control strategies

Dep: Erosion control	(1) LPM	(2) Probit	(3) LPM (Drought)	(4) LPM (No drought)
Male (β_1)	0.065***	0.171***	0.008	0.064**
	(0.024)	(0.064)	(0.047)	(0.025)
Drought (β_2)	0.029	0.083		
	(0.041)	(0.106)		
Male*Drought (β_3)	-0.054	-0.148		
	(0.042)	(0.108)		
Constant	0.368***	-0.346	0.598***	0.318***
	(0.111)	(0.295)	(0.201)	(0.116)
Manager controls	Yes	Yes	Yes	Yes
Plot quality controls	Yes	Yes	Yes	Yes
Planting month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	7,864	7,856	1,254	6,610
$p: \beta_2 + \beta_3 = 0$	0.520	0.531		
$p: \beta_1 + \beta_3 = 0$	0.804	0.835		

Notes: The probit model was not exactly identified; some observations were dropped, leaving 7,856 in the end. The robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

3.2 Maize yields and adoption of erosion control strategies by male and female plot managers

Table 3 presents our estimation results for gendered differences in maize yields conditional on erosion control strategy adoption. Considering that drought could be determinant in the decision to adopt, we control for community exposure to drought in the reference growing period. As expected, exposure to drought during the last rainy season reduces yields. We also attempted similar estimations with different lags of the drought, and their results (not shown) remained the same.

Column 1 in Table 3 shows the OLS estimates without control variables for manager and plot-quality characteristics. We observe that the yields of the plots managed by males who did not adopt erosion control strategies are 33 percent larger than those of the plots managed by females who did not adopt strategies. The gendered difference in yields is similar among strategy adopters: male managers who adopted strategies obtained larger yields than did female managers who adopted strategies (the probability value of $\beta_1 + \beta_3$ is significant at 1 percent).

The plots managed by females who adopted erosion control strategies (β_2) are not statistically different from those managed by females who did not. The same is true for males: the test for the joint significance value of $\beta_2 + \beta_3$ reveals that the yields of the plots managed by males who adopted erosion control strategies were not significantly larger than those of the plots managed by males who did not. The results in Column 1 thus suggest that erosion control strategies are not effective in increasing yields for either gender. Also, a gender gap exists in terms of productivity.

Column 2 in Table 3 shows whether the results hold true when both manager and plot-quality characteristics are controlled for in the model. We observe in Column 2 that men lose the yield advantage observed in Column 1 both in the case of non-adoption (β_1) and in the case of adoption ($\beta_1 + \beta_3$). This suggests that female plot managers are not necessarily inefficient in managing their plots but rather have inferior plots relative to men.

Columns 3 and 4 in Table 3 present the same types of results as are shown in Columns 1 and 2, respectively, but this time estimated using the IVs approach. In Column 3, we observe that gendered differences limit only non-adopters (the probability value of $\beta_1 + \beta_3$ is not significant). More specifically, the plots managed by males who did not adopt erosion control strategies experience a 40 percent increase in yields relative to the plots managed by females who did not adopt the strategies. However, Column 4 shows that the gendered difference in productivity once again disappears when we control for plot quality and other manager-specific characteristics. The gendered differences in maize yields observed in Column 3 could be due to female plot managers occupying marginal lands that are less productive. Moreover, the adoption of erosion control strategies does not affect maize yields neither for men nor for women. In both Columns 3 and 4 the first-stage statistic for our IVs is above the threshold of 10, which infers that our instrument is relevant.

To summarise, our yield results suggest that the adoption of erosion control strategies in the Malawian context fails to help men or women obtain larger yields. When we split the sample by drought occurrence, we find that this is true in both normal times and times of drought.[10] In addition, we show that there are gendered differences in the productivity of male- and female-managed plots that is not robust to the inclusion of manager and plot-quality attributes.

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[10] These results are not shown in this paper but are available from the authors upon request.

Table 3: The role of erosion control strategy adoption on gendered maize yields

	(1)	(2)	(3)	(4)
Dep: Maize yields (kg/ha)	**OLS (No controls)**	**OLS (Controls)**	**IVs (No controls)**	**IVs (Controls)**
Male (β_1)	0.327***	0.015	0.443**	0.180
	(0.080)	(0.089)	(0.214)	(0.176)
Erosion control (β_2)	0.083	0.097	0.533	0.600
	(0.084)	(0.084)	(1.108)	(0.990)
Male*Erosion control (β_3)	-0.040	-0.090	-0.319	-0.470
	(0.097)	(0.094)	(0.459)	(0.374)
Drought	-0.890***	-0.806***	-0.904***	-0.818***
	(0.222)	(0.189)	(0.231)	(0.193)
Lag EC adoption	Yes	Yes	Yes	Yes
Manager controls	No	Yes	No	Yes
Plot quality controls	No	Yes	No	Yes
Planting month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	8,190	7,864	8,188	7,863
$p: \beta_2 + \beta_3 = 0$	0.600	0.928	0.818	0.884
$p: \beta_1 + \beta_3 = 0$	0.003	0.507	0.650	0.227
First-stage coefficient			0.359***	0.314***
First-stage F-statistic (F-test)			28.98	23.05

Notes: The inclusion of controls with some missing values reduced the sample to 7,864 observations for Column 2 , while inclusion of the instrument further reduced the sample to 7863 in Column and 4. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

3.3 Robustness checks

To understand if our results are robust across different estimation specifications, we conducted robustness checks. Tables C3, C4, C5, C6, and C7 in Appendix C provide the robustness check estimates. The first alteration was changing from clustering standard errors at the enumeration level to clustering them at the family level (see Table C3 for adoption and Table C4 for yields). This was done to correct for the fact that some plots belonged to different managers who originated from the same 2013 household and can then be considered members of the same extended family. Both the adoption and maize yield results remained qualitatively the same, with no differences in coefficient sign or significance level.

The second alteration involved controlling for family fixed effects in recognising that some plots could face similar time-invariant unobserved characteristics attributable to managers originating from the same 2013 household. Most results also remained consistent with the maize yield estimate results in which family fixed effects were not controlled for. The only difference in the adoption model (Table C5) was that the interaction between Male and Drought became negative and significant; however, the joint significance test for $\beta_1 + \beta_3$ showed that there are no gendered differences in adoption that are conditional on drought.

When it comes to yields, controlling for family fixed effects does not change the conclusion of our main findings: the yields of plots managed by males who did not adopt strategies differ from those of plots managed by females who did not adopt strategies only when manager and plot-quality attributes are not controlled for in the estimation model (see Table C6). However, with this specification, the estimates using the IVs approach give the unexpected result that male-managed plots produce smaller yields when they are subject to erosion control strategies ($\beta_2 + \beta_3$ is negative and significant).

Finally, in Table C7 in Appendix C, we present the results on the effects of adopting erosion control strategies on maize yields. The estimations were split by gender; therefore, we have separate results for male and female plot managed plots. The split results, which are consistent across both the OLS and IVs approaches, reveal that erosion control strategy adoption does not affect maize yields. These results are also robust to controlling for manager and plot-quality attributes.

4.0 Conclusions and policy implications

Global demand for food continues to increase while food productivity is declining in most rural economies. SSA is one region that faces this imbalance, with poor land management practices and droughts being among the factors that contribute to the problem. Adopting soil erosion control strategies is therefore considered a potential mitigation strategy, yet research on the adoption of these strategies is sparse. This study provides evidence on two key gender and food productivity norms: whether there is a gender-based difference in male and female plot managers' adoption of erosion control strategies, and whether plot managers' strategy adoption choice affects the crop productivity of the plots they manage. Both questions are answered by testing whether outcomes from the relationships studied in each objective differ when the plots face drought or not. This study uses plot-level information from Malawi and drought data from the University of East Anglia's CRU.

Our results show that male plot managers are more likely to adopt erosion control strategies than female plot managers are in the absence of drought. This is corroborated by evidence from existing studies that use the gender of the household head as the treatment variable and show that male household heads adopt erosion control strategies more than female household heads do. This gender gap could emerge due to women having limited access to production capital, including access to extension services and good-quality land. However, in our results, the gender gap persists when we control for all these attributes that could correlate with female plot managers' low adoption of erosion control strategies. The gender gap could therefore be due to gendered differences in household roles and risk perception that influence men's and women's attitudes towards adopting erosion control strategies (Ngigi et al., 2016). Policies that aim to increase the adoption of erosion control strategies should therefore focus on women, especially in normal times, when there is no drought.

Our results also confirm that drought reduces the crop productivity of both male- and female-managed plots. However, erosion control strategies are not able to counter this trajectory because we see no relationship between erosion control strategy adoption and the maize yields of either male- or female-managed plots. Although our data does not enable us to determine the mechanisms behind the ineffectiveness of the strategies, other studies suggest that it could result from using the lack of necessary skills to effectively use the erosion control strategies (Baptista et al., 2015). The ineffectiveness of the strategies could also mean the strategies only manage to reduce soil erosion but not necessarily increase yields, as found by McCarthy et al. (2021). Our results therefore provide an exploratory foundation for future research that should investigate the conditions under which erosion control strategies successfully reduce soil erosion *and* increase crop yields. Furthermore, the results call for governments to invest effort in extension services to ensure strategies are effectively implemented.

In addition, we show that female plot managers are not less productive than male managers. Rather, they produce less per plot because they are less educated, cultivate smaller pieces of land, manage poor-quality land, use poor-quality maize varieties, and have limited access to extension services. We arrive at this conclusion because once these attributes are controlled for in our models, the gendered difference in maize yields between male- and female-managed plots disappears. Our results contrast with those of the Word Bank (2014), which reported that under similar observed conditions, men still produce more than women do. The difference could emerge since their evidence does not trace gender by plot management. Therefore, our results call for policies that promote equitable access to production capital for male and female plot managers.

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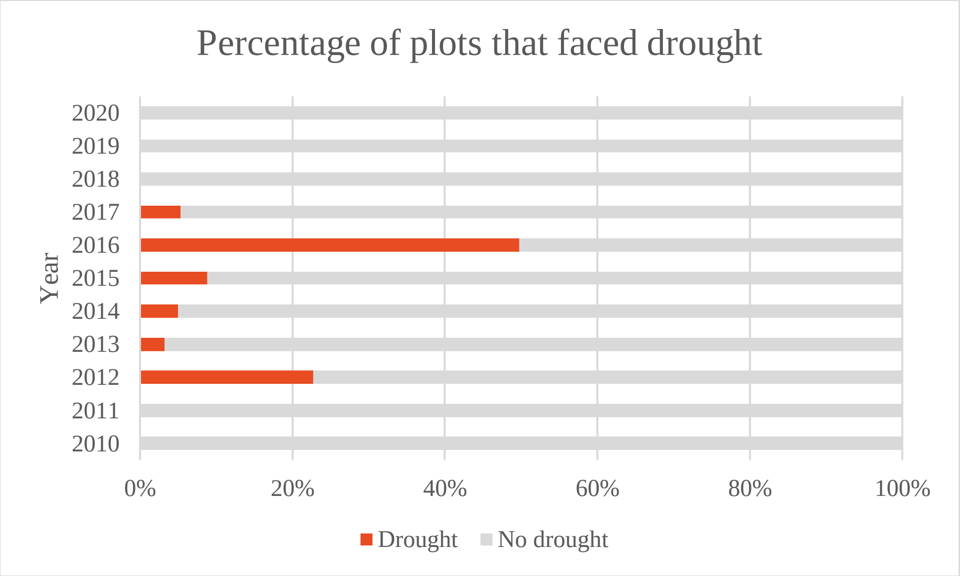
Appendices

Appendix A: Frequency of droughts and floods in Malawi

Figure A1 shows the occurrence of droughts in Malawi from 2010 to 2020. The country was affected by drought from 2012 to 2017. The prevalence of drought was the highest in 2016, affecting about 49 percent of plots, followed by 2012, when 23 percent of plots were affected.

Figure A1: Occurrence of droughts in Malawi, 2010-2020 (Source: Climatic Research Unit, 2022)



Appendix B: Summary of the variables used

Table B1: Description of the variables used in the econometric models

		Plots managed by		
	Full sample	Males	Females	Difference
Erosion control	0.444	0.465	0.411	0.054***
No erosion control	0.556	0.534	0.589	-0.054***
Drought	0.159	0.147	0.178	-0.031***
Productivity (kg per ha)	3,632.578	4,402.975	2,473.547	1,929.428*
Production (kg)	551.210	681.226	355.608	325.617**
Land area (ha)	0.306	0.323	0.280	0.043***
Age	43.623	43.238	44.203	-0.964**
Education level (school years)	6.413	7.223	5.194	2.029***
Crop extension	0.606	0.637	0.561	0.076***
Animal extension	0.217	0.238	0.186	0.052***
Forestry extension	0.189	0.203	0.168	0.035***
Credit extension	0.132	0.14	0.121	0.018*
Monocropping	0.387	0.423	0.334	0.088***
Soil is sandy (mchenga)	0.187	0.178	0.201	-0.023*
Soil is between clay and sandy	0.523	0.541	0.496	0.045***
Soil is clay (katondo)	0.247	0.238	0.260	-0.022*
Soil is of another type	0.043	0.043	0.043	0.000
Soil quality is good	0.533	0.542	0.519	0.022
Soil quality is fair	0.343	0.341	0.347	-0.006
Soil quality is poor	0.124	0.117	0.134	-0.016*
Maize variety is local	0.500	0.449	0.576	-0.127***
Maize variety is OPV	0.011	0.013	0.008	0.005*
Maize variety is hybrid	0.397	0.443	0.327	0.116***
Maize variety is recycled	0.092	0.095	0.089	0.006
Seed quantity (kg)	8.346	8.544	8.048	0.496
FISP beneficiary household	0.331	0.335	0.325	0.010
Male-headed household	0.735	0.982	0.363	0.620***
Household size	5.166	5.310	4.949	0.361***
Cluster adoption (IVs)	0.438	0.433	0.447	-0.014***
Rainy season	0.990	0.989	0.991	-0.002
Matrilineal matrilocal kinship	0.726	0.688	0.783	-0.095***
Planting month: January	0.007	0.006	0.008	-0.003
Planting month: February	0.003	0.003	0.003	0.000
Planting month: March	0.002	0.002	0.002	0.000
Planting month: April	0.001	0.000	0.001	0.000
Planting month: May	0.001	0.001	0.000	0.001*
Planting month: June	0.000	0.000	0.000	0.000
Planting month: July	0.002	0.002	0.003	-0.001
Planting month: August	0.003	0.002	0.004	-0.001
Planting month: September	0.005	0.005	0.004	0.001
Planting month: October	0.032	0.032	0.031	0.001
Planting month: November	0.312	0.286	0.352	-0.066***
Planting month: December	0.580	0.602	0.546	0.056***
Observations (number of plots)	7,864	4,724	3,140	7,864

Notes: The unit of analysis is the plot. Individual-level characteristics pertain to the plot manager, and household-level characteristics pertain to the plot manager's household.

Appendix C: Outputs for model results

Results presented in the main text (in Tables 2 and 3) that display control variables coefficients

Table C1: The role of drought on the gendered adoption of erosion control strategies

Dep: Erosion control	LPM	Probit	LPM (Drought)	LPM (No drought)
Male	0.065***	0.171***	0.008	0.064**
	(0.024)	(0.064)	(0.047)	(0.025)
Drought	0.029	0.083		
	(0.041)	(0.106)		
Male*Drought	-0.054	-0.148		
	(0.042)	(0.108)		
Age	0.001	0.002	-0.001	0.001*
	(0.001)	(0.002)	(0.001)	(0.001)
Education level	0.003	0.009	0.011**	0.002
	(0.002)	(0.006)	(0.005)	(0.003)
Land area (ha)	0.075***	0.139*	0.263***	0.021
	(0.028)	(0.079)	(0.068)	(0.029)
Crop extension	0.035**	0.090*	0.042	0.030
	(0.017)	(0.046)	(0.052)	(0.021)
Animal extension	0.009	0.023	-0.004	0.014
	(0.026)	(0.068)	(0.072)	(0.026)
Forestry extension	0.078***	0.204***	0.073	0.073**
	(0.026)	(0.068)	(0.072)	(0.029)
Credit extension	-0.035	-0.086	-0.036	-0.035
	(0.032)	(0.085)	(0.078)	(0.033)
Monocropping	-0.145***	-0.375***	-0.193***	-0.133***
	(0.021)	(0.056)	(0.049)	(0.020)
Soil is mixed	0.013	0.035	-0.034	0.021
	(0.019)	(0.050)	(0.056)	(0.021)
Soil is katondo	0.040	0.104	-0.082	0.061*
	(0.030)	(0.078)	(0.065)	(0.032)
Soil is of another type	0.002	0.008	-0.096	0.018
	(0.045)	(0.116)	(0.102)	(0.051)
Soil quality is good	-0.083***	-0.224***	-0.043	-0.093***
	(0.023)	(0.060)	(0.048)	(0.025)
Soil quality is fair	-0.054**	-0.148**	-0.088	-0.054**
	(0.026)	(0.068)	(0.062)	(0.027)
Maize variety is OPV	0.161**	0.431**	0.579***	0.148*
	(0.078)	(0.208)	(0.066)	(0.079)
Maize variety is hybrid	0.027*	0.077*	-0.026	0.040**
	(0.016)	(0.041)	(0.050)	(0.018)
Maize variety is recycled	0.035	0.089	0.014	0.035
	(0.026)	(0.068)	(0.062)	(0.028)
Seed quantity (kg)	0.000*	0.006**	0.000***	0.003***
	(0.000)	(0.003)	(0.000)	(0.001)
FISP beneficiary household	0.019	0.051	0.031	0.021
	(0.016)	(0.041)	(0.041)	(0.017)
Male-headed household	-0.001	-0.004	-0.015	0.004
	(0.025)	(0.067)	(0.068)	(0.028)
Household size	-0.004	-0.012	-0.019**	-0.001

	(0.003)	(0.008)	(0.007)	(0.003)
Rainy season	-0.045	-0.145	-0.050	-0.056
	(0.090)	(0.236)	(0.150)	(0.104)
Matrilineal matrilocal kinship	0.013	0.034	-0.089	0.016
	(0.026)	(0.068)	(0.085)	(0.028)
Year 2016	0.000	0.006	0.178	-0.008
	(0.033)	(0.086)	(0.114)	(0.035)
Year 2019	-0.057**	-0.145**		-0.059**
	(0.027)	(0.071)		(0.028)
Constant	0.368***	-0.346	0.598***	0.318***
	(0.111)	(0.295)	(0.201)	(0.116)
Planting month dummies	Yes	Yes	Yes	Yes
Observations	7,864	7,856	1,254	6,610
$p: \beta_2 + \beta_3 = 0$	0.520	0.531		
$p: \beta_1 + \beta_3 = 0$	0.804	0.835		

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C2: The role of erosion control strategy adoption on gendered maize yields

Dep: Maize yields (kg/ha)	(1) OLS (No controls)	(2) OLS (Controls)	(3) IVs (No controls)	(4) IVs (Controls)
Male (β_1)	0.327***	0.015	0.443**	0.180
	(0.080)	(0.089)	(0.214)	(0.176)
Erosion control (β_2)	0.083	0.097	0.533	0.600
	(0.084)	(0.084)	(1.108)	(0.990)
Male*Erosion control (β_3)	-0.040	-0.090	-0.319	-0.470
	(0.097)	(0.094)	(0.459)	(0.374)
Drought	-0.890***	-0.806***	-0.904***	-0.818***
	(0.222)	(0.189)	(0.231)	(0.193)
Age		0.007***		0.007***
		(0.002)		(0.002)
Education level		0.061***		0.060***
		(0.010)		(0.010)
Landholding		-0.900***		-0.897***
		(0.167)		(0.166)
Crop extension		0.246***		0.246***
		(0.080)		(0.079)
Animal extension		-0.013		-0.016
		(0.081)		(0.081)
Forestry extension		0.082		0.080
		(0.096)		(0.099)
Credit extension		-0.084		-0.086
		(0.102)		(0.101)
Monocropping		-0.021		0.001
		(0.070)		(0.099)
Soil is between clay and sandy		0.093		0.105
		(0.083)		(0.088)
Soil is sandy		0.041		0.050
		(0.110)		(0.108)
Soil is of another type		0.168		0.164
		(0.183)		(0.183)
Soil quality is good		0.156*		0.170**

		(0.080)		(0.085)
Soil quality is fair		0.094		0.110
		(0.080)		(0.078)
Maize variety is OPV		0.366**		0.374**
		(0.169)		(0.175)
Maize variety is hybrid		0.256***		0.252***
		(0.077)		(0.076)
Maize variety is recycled		0.214*		0.209*
		(0.116)		(0.115)
Seed quantity (kg)		-0.001		-0.001
		(0.002)		(0.002)
FISP beneficiary household		0.102		0.099
		(0.081)		(0.079)
Male-headed household		0.294***		0.292***
		(0.095)		(0.096)
Household size		-0.002		-0.001
		(0.015)		(0.014)
Rainy season		2.655***		2.690***
		(0.708)		(0.699)
Matrilineal matrilocal		-0.247**		-0.253**
		(0.124)		(0.123)
Erosion control (t-1)	-0.097	-0.078	-0.318	-0.288
	(0.106)	(0.095)	(0.738)	(0.692)
Erosion control (t-2)	0.188	0.227	0.187	0.223
	(0.166)	(0.156)	(0.165)	(0.155)
Erosion control (t-3)	-0.011	-0.131	-0.015	-0.138
	(0.196)	(0.204)	(0.195)	(0.205)
Erosion control (t-4)	-0.067	0.071	-0.070	0.068
	(0.180)	(0.177)	(0.183)	(0.182)
Erosion control (t-5)	0.037	-0.022	0.054	-0.001
	(0.170)	(0.170)	(0.178)	(0.177)
Year 2016	-0.280*	-0.334**	-0.270*	-0.328**
	(0.143)	(0.133)	(0.144)	(0.131)
Year 2019	-0.323***	-0.384***	-0.318***	-0.374***
	(0.092)	(0.083)	(0.093)	(0.085)
Constant	7.334***	3.860***	7.208***	3.673***
	(0.110)	(0.725)	(0.288)	(0.766)
Observations	8,190	7,864	8,188	7,863
$p: \beta_2 + \beta_3 = 0$	0.600	0.928	0.818	0.884
$p: \beta_1 + \beta_3 = 0$	0.003	0.507	0.650	0.227
First-stage F-statistic			28.98	23.05

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Results of robustness checks that cluster standard errors at the family level

Table C3: The role of drought on the gendered adoption of erosion control strategies

Dep: Erosion control	(1) LPM	(2) Probit	(3) LPM (Drought)	(4) LPM (No drought)

Male	0.065** (0.023)	0.171*** (0.062)	0.009 (0.050)	0.064*** (0.024)
Drought	0.029 (0.036)	0.083 (0.092)		
Male*Drought	-0.054 (0.041)	-0.148 (0.105)		
Year 2016	-0.000 (0.025)	0.006 (0.065)	0.174* (0.092)	-0.008 (0.027)
Year 2019	-0.057*** (0.022)	-0.145** (0.058)	0.000 (0.000)	-0.059*** (0.022)
Constant	0.368*** (0.105)	-0.347 (0.279)	0.598*** (0.217)	0.318*** (0.120)
Observations	7,864	7,856	1,254	6,610
$p: \beta_2 + \beta_3 = 0$	0.413	0.426		
$p: \beta_1 + \beta_3 = 0$	0.785	0.821		

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C4: The role of erosion control strategy adoption on gendered maize yields

Dep: Maize yields (kg/ha)	**(1) OLS (No controls)**	**(2) OLS (Controls)**	**(3) IVs (No controls)**	**(4) IVs (Controls)**
Male (β_1)	0.327*** (0.078)	0.015 (0.094)	0.443** (0.188)	0.180 (0.179)
Erosion control (β_2)	0.083 (0.098)	0.097 (0.092)	0.533 (0.601)	0.610 (0.601)
Male*Erosion control (β_3)	-0.040 (0.106)	-0.089 (0.098)	-0.319 (0.413)	-0.470 (0.386)
Drought	-0.890*** (0.109)	-0.806*** (0.104)	-0.904*** (0.111)	-0.818*** (0.105)
Lag EC adoption	Yes	Yes	Yes	Yes
Manager controls	No	Yes	No	Yes
Plot quality controls	No	Yes	No	Yes
Planting month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	8,190	7,864	8,188	7,863
$p: \beta_2 + \beta_3 = 0$	0.631	0.926	0.678	0.808
$p: \beta_1 + \beta_3 = 0$	0.001	0.452	0.612	0.232
First-stage coefficient			0.357***	0.314***
First-stage F-statistic			67.87	53.33

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Results of robustness checks that control for family fixed effects and cluster standard errors by enumeration area

Table C5: The role of drought on the gendered adoption of erosion control strategies

Dep: Erosion control	**(1) LPM**	**(2) Probit**	**(3) LPM (Drought)**	**(4) LPM (No drought)**

Male	0.063** (0.025)	0.216*** (0.078)	-0.057 (0.071)	0.072*** (0.023)
Drought	0.061 (0.051)	0.196 (0.164)		
Male*Drought	-0.076* (0.043)	-0.243* (0.138)		
FISP beneficiary household	-0.010 (0.021)	-0.040 (0.064)	0.127 (0.105)	-0.030 (0.022)
Year 2016	-0.014 (0.036)	-0.035 (0.118)	0.643*** (0.172)	-0.005 (0.038)
Year 2019	-0.041 (0.030)	-0.135 (0.099)	0.000 (0.000)	-0.036 (0.032)
Observations	7,864	6,598	1,254	6,610
$p: \beta_2 + \beta_3 = 0$	0.786	0.776		
$p: \beta_1 + \beta_3 = 0$	0.757	0.837		

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C6: The role of erosion control strategy adoption on gendered maize yields

Dep: Maize yields (kg/ha)	(1) OLS (No controls)	(2) OLS (Controls)	(3) IVs (No controls)	(4) IVs (Controls)
Male (β_1)	0.167** (0.077)	-0.017 (0.104)	0.360* (0.194)	0.128 (0.188)
Erosion control (β_2)	-0.011 (0.117)	-0.023 (0.116)	-1.084 (1.251)	-1.493 (1.257)
Male*Erosion control (β_3)	0.061 (0.107)	0.042 (0.111)	-0.286 (0.523)	-0.249 (0.474)
Drought	-0.369** (0.182)	-0.298* (0.174)	-0.359* (0.168)	-0.257 (0.163)
Lag EC adoption	Yes	Yes	Yes	Yes
Manager controls	No	Yes	No	Yes
Plot quality controls	No	Yes	No	Yes
Planting month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	8,190	7,864	8,189	7,864
$p: \beta_2 + \beta_3 = 0$	0.600	0.820	0.175	0.095
$p: \beta_1 + \beta_3 = 0$	0.035	0.824	0.830	0.701
First-stage coefficient			0.312***	0.261***

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C7: The role of erosion control strategy adoption on gendered maize yields, by gender

Dep: Maize yields (kg/ha)	(1) Male (OLS, no controls)	(2) Male (OLS, controls)	(3) Male (IVs, no controls)	(4) Male (IVs, controls)	(5) Female (OLS, no controls)	(6) Female (OLS, controls)	(7) Female (IVs, no controls)	(8) Female (IVs, controls)

Erosion control	0.018	0.031	-0.037	0.190	0.131	0.067	1.062	0.920
	(0.089)	(0.087)	(0.851)	(0.830)	(0.107)	(0.102)	(1.545)	(1.346)
Drought	-0.825***	-0.686***	-0.825***	-0.686***	-1.014***	-0.948***	-1.067***	-1.001***
	(0.212)	(0.179)	(0.216)	(0.176)	(0.287)	(0.238)	(0.317)	(0.260)
Lag EC adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Manager controls	No	Yes	No	Yes	No	Yes	No	Yes
Plot quality controls	No	Yes	No	Yes	No	Yes	No	Yes
Planting month dummies	No	Yes	No	Yes	No	Yes	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,907	4,724	4,906	4,724	3,283	3,140	3,283	3,140
First-stage coefficient			0.403***	0.370***			0.339***	0.284***
First-stage F-statistic			54.81	48.71			33.88	21.98

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.