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Research Application Summary

Determinants and impact of climate smart agriculture technology adoption on the welfare of smallholder farmers in Malawi

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Abstract

This study identifies factors affecting adoption of multiple climate change adaptation technologies and its impact. An ordered probit model, a full Mahalanobis matching and a variety of propensity score matching methods were used. Age of household head, total area of land that a household owns, being involved in petty trading and formal employment reduce the probability of adopting more than two technologies. Farmers that observed changes in moisture levels for about 20-year period prior to our survey had lower probability of adopting four technologies compared to those that did not observe any changes in moisture for the same time period. Interestingly, the study has shown that household income does not affect the number of technologies adopted. Overall, technology adopters performed better than non-adopters, as they were well off in their yield and sources of revenue. Irrigation and water harvesting technology adopters are better off as compared to adopters of the other technologies which had a mixed bag. This study recommends that relevant stakeholders should strive to provide smallholder farmers with climate smart agriculture related extension messages, if more farmers are to adopt many technologies to make their agricultural production systems resilient to climate change.

Key words: Adoption, marginal effects, ordered probit model, propensity score matching

Résumé

Cette étude identifie les facteurs qui influencent l'adoption de multiples technologies d'adaptation face au changement climatique et son impact. Le modèle de probit ordonné, le test de correspondance complète de Mahalanobis et une variété de méthodes d'appariement de coefficient de propension ont été utilisés. L'âge du chef de ménage, la superficie totale de terres du ménage, la pratique d'un petit commerce et un emploi formel réduisent la probabilité d'adoption de plus de deux technologies. Les agriculteurs qui ont observé des changements dans les niveaux d'humidité pendant une période d'environ 20 ans avant notre enquête avaient une probabilité d'adoption de quatre technologies inférieure à celle de ceux qui n'ont pas observé de changements d'humidité pendant la même période. L'étude a montré que le revenu des ménages n'affecte pas le nombre de technologies adoptées. Dans l'ensemble, les producteurs ayant adoptés de technologies ont de meilleurs performances que ceux n'ayant pas adoptés de technologies, car ils avaient les rendements et les revenus meilleurs. Les producteurs ayant adoptés la technologie d'irrigation et de récolte d'eau sont plus nantis que les producteurs utilisant un mélange de technologies. Cette étude recommande que les acteurs concernés s'efforcent de fournir aux petits agriculteurs des messages de vulgarisation sur l'agriculture intelligente face au climat, si les agriculteurs devraient adopter de plus en plus de technologies afin de rendre leurs systèmes de production agricole résilients aux changements climatiques.

Mots clés: adoption, effets marginaux, modèle probit ordonné, appariement de coefficient de propension

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Background

Malawian smallholder farmers do farm between 0.5 and 2 hectares of land. They dedicate more than half of their expenditure to food items and self-produce almost all the maize they eat. They do devote most of their land to staple crops including horticulture for self-consumption. Their poverty rate reached 52% in 2007. About 47% of the smallholder farmers are estimated to fall below the national poverty line (Douillet, 2012).They do apply many adaptation opportunities suitable for climate variability. These adaptation methods include both on and off farm activities and are sometimes referred to as Climate Smart Agriculture (CSA). Notwithstanding growing policy interest in CSA technology adaptation measures, the level of use of these practices in Malawi is generally quite low, perhaps leading to stagnant or worsening yields and continuing land degradation. One question raised is whether these practices are actually effective adaptation strategies in the specific circumstances of Malawian farmers. A second question is how household and system level adaptive capacity, or lack thereof, affects the selection of farm practices with adaptation benefit.

This study provides literature on climate variability in agriculture by providing a micro perspective on the issue of adaptation, food security, productivity and profitability. This paper discusses determinants and impact of climate smart agriculture technology adoption.

Summarized literature review

Agricultural growth and development is not possible without yield enhancing technological options, because merely expanding the area under cultivation to meet the increasing food needs of growing populations is no longer sufficient (World Bank, 2008). Research and technology adoption are thus crucial to increasing agricultural productivity and reducing poverty, while sustaining the agro-ecosystems that support livelihoods. Climate variability may affect food systems in several ways ranging from direct effects on crop production to changes in markets, food prices and supply chain infrastructure (Fuhrer, 2003).

Adaptation is about decreasing the dangers posed by climate variation to people's lives and livelihoods. It refers to responses by individuals, groups and communities to actual or expected changes in climatic conditions or their effects. Adaptation measures deal with the impacts of climate variation and have the objective of reducing the vulnerability of human and natural systems in general (FAO, 2012). Climate Smart Agriculture (CSA) aims to enhance the capacity of agricultural systems to support food security. It incorporates the need for adaptation and the potential for mitigation into sustainable agriculture development.

CSA concept is evolving and there is no one size fits all blueprint for how it might be pursued (IPCC, 2012). CSA implementation options are country specific depending on capacities, and enabled by access to better information, aligned policies, coordinated institutional arrangements and flexible incentives and financing mechanisms. At farm level, a wide range of adaptation strategies do include modifying planting times and changing to varieties resistant to heat and drought (Phiri and Saka, 2008); development and adoption of new cultivars (Eckhardt *et al*., 2009); changing the farm portfolio of crops and livestock (Howden *et al.*, 2007); improved soil and water management practices including conservation agriculture (McCarthy *et al*., 2011); and shifting to non-farm livelihood sources (Morton, 2007).

Study description

The study focused on technology adoption as a choice over four technologies involving 1) portfolio diversification, 2) soil and water conservation, 3) soil fertility improvement, 4) irrigation/rain water harvesting and our control were farmers in zero or no adaptation category (Table 1).

Table 1. Definitions of CSA technologies under study

CSA Technology	As defined in this study
Portfolio diversification	Using improved crop varieties, intercropping, different crop varieties that survive in adverse climatic conditions
Soil and water conservation	Farmers' use of mulching, planting of cover crops, minimum tillage operations (conservation agriculture), full tillage operation and digging ridges across slopes
Soil fertility improvement	Agroforestry, applying fertilizer and organic manure
Irrigation/rain water harvesting	Involving storage and supplying water to the farm
No / zero adaptation	Farmers not using any adaptation method to counteract the negative impact of climate variability

Adoption of the technologies

Adopters in the study were lead farmers of different CSA technologies, while follower farmers and any other farmer were categorized as non-adopters. From these four CSA technologies, 24 various combinations of CSA strategies that farmers may adopt can be obtained, each with its own determinants and probability of adoption. At individual CSA technology level, 34.9% of the respondents reported to have adopted portfolio diversification, 43.7% practiced soil and water conservation, 24.2% of the sample reported that they practiced soil fertility improvement while 31.4% said they practiced irrigation and water harvesting (Figure 1). Generally, levels of adoption are low in the sample for all CSA strategies. Soil and water conservation is the most adopted CSA strategy with 44% of the farmers reporting to have adopted it. This may be the case because a lot of extension messages on CSA issues hover around soil and water conservation.

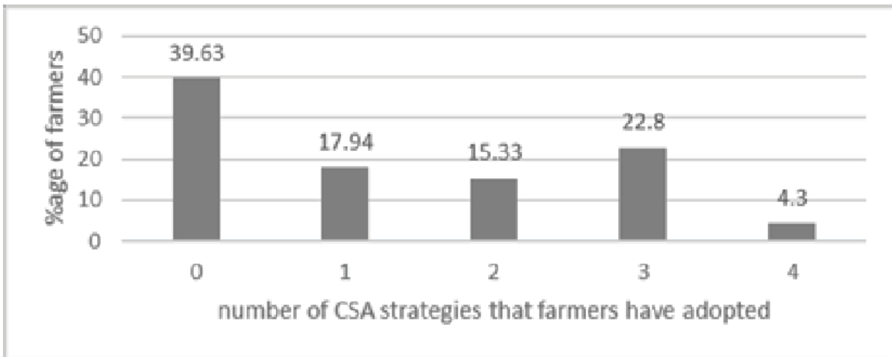

Figure 1. percentage of farmers adopting numbers of CSA practices

Results

Determinants of CSA technologies adoption

The model's Chi Square coefficient (165.17 with 27 degrees of freedom) is statistically significant at 1% level of probability (P<0.0001). All the threshold parameters are significant; implying natural ordering of the response variable (and are significant at 5% level of probability whereas is significant at 1% level of significance). Wollni, Lee and Thies (2010) posit that the coefficient estimates of the ordered probit model are not easily interpretable. Instead, they did recommend to concentrate on the marginal effects after estimating the ordered probit model. To understand how each independent variable changes the probability of adopting the number of CSA technologies given the covariates.

An increase in age of the household head reduces the probability of adoption of more than two CSA practices by 4.5% (Table 2). This is in agreement with what Tecklewold, Kassie and Shiferaw (2013) found in Ethiopia. An increase in age of the household head was speculated to reduce the probability of adopting more than two CSA technologies, because as farmers advance in age, they tend to minimize activities that demand much of their labour and management skills. Further, due to experience with climate-related shocks over years, older farmers acquire indigenous knowledge that allow them to be relatively resilient to shocks than younger farmers such that they find it convenient to rely on their indigenous knowledge than adopt modern practices that may have steep learning curves (Nyong, Adesina and Elasha, 2007).

Holding all factors constant, an acre increase in area of total land owned reduces the probability of adopting more than two CSA practices by 11% (Table 2). Generally, increasing the area that a typical smallholder farmer controls would entail introducing additional costs to the farmer which they may fail to cover given their resource base. The probability of adopting more than two CSA strategies has a 15% increase for every additional acre. This result makes sense when one considers how resource constrained smallholder farmers are to manage a lot of climate-smart technologies on a bigger plot of land.

The status of being a lead farmer was used as a proxy for ample access to CSA extension messages given that most Non-Governmental Organizations (NGOs) in the study area are training and using lead farmers to drive adoption of CSA practices. As expected, the marginal effects show that being a lead farmer, as opposed to being regular/follower farmer, increases the probability of adopting more than two CSA practices by 36% (Table 2). This result implies that ample access to extension services can help get many farmers adopt a mix of CSA technologies that can make their agricultural production system more resilient and sustainable.

For those who reported not being employed during the survey, being a petty trader increases and being formally employed reduces the probability of adopting more than two CSA strategies by 21% and 34%, respectively (Table 2). Although not expected, these results make sense because that farmers who have diversified their income generating activities are generally more able to handle impacts of climate-related agricultural production shocks through purchasing food, using other means, and no need to make their agricultural production more resilient. Most farmers who are involved in off farm income generating activities rarely attend CSA extension activities and this affects their probability of adopting the CSA strategies.

Farmers who observed an increase in floods in a 20year period preceding the survey had 9% higher probability of adopting more than two climate-smart agriculture practices than those who reported not observing any increase in frequency of floods in the said 20year period (Table 2). These were expected results given that, it is only those farmers who appreciate the risk that floods pose to their agricultural enterprise that see the need to adopt CSA practices to make them more resilient to the shocks.

Farmers who reported observing changes in moisture levels in their area during a 20 year period before the survey had a 19% lower probability of adopting four CSA technologies. A positive relationship was expected between observing changes in moisture levels in the farmer's area with adoption of higher numbers of CSA practices, given the importance of moisture in agricultural production. However, the marginal effects show otherwise.

Table 2. Ordered probit results with marginal effects

Ordered Probit Model						
		Marginal Effects				
Variables	Coefficients	Prob(Y=0|X) dy/dx	Prob(Y=1|X) dy/dx	Prob(Y=2|X) dy/dx	Prob(Y=3|X) dy/dx	Prob(Y=4|X) dy/dx
Age of household head	-0.130** (0.0597)	.0489***	-0.005*	0.001	-0.012**	-0.032***
Age of household head square	1.646** (0.800)	-0.620***	0.065*	-0.014	0.153**	0.416***
Log of land area	-0.263* (0.145)	0.099*	-0.010*	0.002	-0.024*	-0.066*
Farmer type (lead farmer=1)	1.142*** (0.139)	-0.422***	0.042***	0.017	0.105***	0.256***
Polygamous married	0.385 (0.349)	-0.134	0.022	-0.017	0.025*	0.104
Smallholder farmer (yes=1)	-0.154 (0.141)	0.057	-0.006	0.002	-0.013	-0.035
Petty trader (yes=1)	-0.658** (0.285)	0.257**	-0.014***	-0.035	-0.075**	-0.132***
Formally employed (yes=1)	-1.409** (0.682)	0.493***	-0.0166***	-0.136	-0.149***	-0.191***
Household dependency ratio	0.0344 (0.0415)	-0.012	0.001	-0.0003	0.003	0.008
Log of land area used	0.429*** (0.143)	-0.161***	0.016**	-0.003	0.039***	0.108***
Observed change in moisture over past 20 years(yes=1)	-0.701* (0.387)	0.220**	- 0.056	0.052	-0.024	-0.19*
Observed increase in floods over past 20 years(yes=1)	0.270* (0.141)	-0.101*	0.011*	-0.003	0.024*	0.068*
Access agricultural extension(yes=1)	0.153 (0.134)	-0.0580852	0.005	-0.0003	0.014	0.037
Received climate change training	0.106 (0.130)	-0.0399444	0.004	-0.0009541	0.009	0.026
α_1	5.546** (2.669)					
α_2	6.142** (2.666)					
α_3	6.670** (2.667)					
α_4	8.032*** (2.675)					
Observations	420					
Wald chi2(27)	165.17					
Prob > chi2	0.0000					
Log pseudolikelihood	-520.22665					
Pseudo R2	0.1406					

Robust standard errors in parentheses

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

Marginal effects (dy/dx) are calculated at the mean for continuous variables and for a discrete change from 0 to 1 for dummy variables.

[1] Farmers who are supported by extension service providers and NGO to provide agricultural extension services to other farmers in their communities (Franzel and Simpson, No Date)

A positive and significant relationship between household income and intensity of adoption of technologies was expected, literature suggests that household income is an important driver of adoption (see Boz and Akbay (2004); Wollni, Lee and Thies (2010) and Katengeza, *et al.* (2012)). It was expected that higher-income households were supposed to have higher probabilities of adopting more than one CSA technology given their potential to purchase inputs that may help sustain many CSA technologies as compared to lower-income households. However, this study shows that household income does not significantly affect adoption of multiple CSA practices.

CSA technology effectiveness on food security

The percentage increase of different output variables after CSA adoption (Table 3), shows that when the base technology (zero adaptation) is compared with any CSA technology adopted there was a marked difference. Confirmed by what other studies already found that CSA technologies do improve productivity (IFPRI, 2009).

Table 3. % household crop, revenue expenditure increase by CSA technology

Production, Revenue and Expenditure	Portfolio Diversification	Soil and water conservation	Soil Fertility Improvement	Irrigation and Water Harvesting
	%	%	%	%
Production (kg)				
Maize harvest	26.1	37.5	8.9	25.6
Millet	12.0	3.2	31.5	-
Revenue (MK)				
Crop revenue	46.6	41.7	60.4	36.1
Non-farm Rev.	14.8	27.0	43.1	38.2
Tot. Rev.	17.7	27.0	40.6	35.9
Expenditure (MK)				
Agriculture Cost	146.6	98.1	184.8	119.3
Capital Exp.	83.2	111.5	183.3	112.4
Other Exp.	53.6	41.9	56.8	798.4
Total Exp.	38.4	41.0	55.5	55.2

Our basis of comparison is on zero technology adopters not shown in this table

There were a lot of households suffering a six month's food shortage. Further analysis to find out the specific severely deficit months of food revealed that most households experience acute food shortages during the months of December, January and February. A total of 35% of the respondents had enough staple food (maize) to last the whole year, the rest usually had food stocks taking them 4-7 months (May to November) or less. About 42% of the lead farmers (adopters) had a higher share of those with food throughout the year followed by the follower famers (non-adopters) who had 26% only (Figure 2).

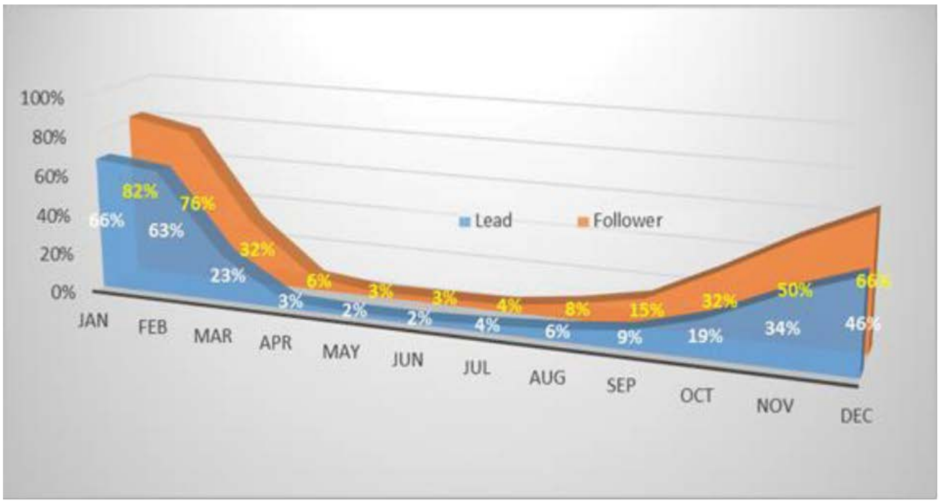

Figure 2. Households experiencing monthly food shortages over the year in % CSA technology impact on per capita income and expenditure

a) Irrigation and water harvesting

There is a 15% increase in per capita income because of farmer's involvement in irrigation and water harvesting using nearest neighbor matching at 1% significant level. The stratification and kernel matching methods, also did increase per capita income by 11 and 18% respectively at a 1% significance level. There is a 47.2% increase in per capita expenditure at 1% significant level. Stratification and kernel matching methods, shows an 18.7 and 29.4% respectively at a 1% significance level.

b) Soil and water conservation

There is a 27% reduction in per capita income because of farmer's involvement in soil and water conservation technologies using nearest neighbor matching at 5% significant level. Stratification and kernel matching methods reduced per capita income by 12 and 7% respectively at a 5% significance level. Similarly there is an 8.3% reduction in per capita expenditure at 5% level. The stratification and kernel matching methods reduces per capita expenditure by 3.1 and 27.4% respectively at a 5% significance level.

c) Soil fertility improvement

The nearest neighbor matching result shows no reduction nor an increase in per capita income at 1% significant level. Stratification and Kernel Matching increases per capita income by 3 and 2% respectively at a 1% significance level. There is a 12.5% reduction in per capita expenditure at 1% significant level. There is 6.9 and 6.2% increase in per capita expenditure at a 1% significance level when using stratification and kernel matching methods respectively.

d) Portfolio diversification

The per capita income shows an 18% reduction at 1% level. There is reduction per capita income by 21 and 22% respectively at a 1% significance level from the stratification and kernel matching methods. The per capita expenditure did increase by 27.5 % at a 1 % significance level. The same is with stratification and kernel matching methods, as there is an increase in per capita expenditure by 6.7 and 20.7 % respectively at a 1 % significance level.

Conclusion

Age of household head, total area of land that a household owns, being involved in petty trading and formal employment reduces the probability of adoption of more than 2 CSA strategies. Farmers who reported having observed changes in moisture levels in their areas for the 20-year period prior to the survey have a lower probability of adopting 4 CSA strategies compared to those who reported not observing any changes in moisture in the same time period.

Being a lead farmer, which proxied ample access to climate smart agriculture extension message and training access, acreage used in agricultural production in the year preceding our survey and observing an increase in incidences of floods in a 20-year period prior to our study increased the probability of adopting more than two CSA strategies. Interestingly, being in polygamous marriage contract was found to increase adoption of three CSA strategies.

Ordered probit model and the resultant calculation of marginal effects indicate that of the socioeconomic and institutional factors that conceptually affects the number of climate smart agriculture strategies that the farmers adopt significantly affects the probability of adopting two CSA strategies. Household income does not significantly affect the adoption of multiple CSA strategies, contrary to my expectation.

Plots of CSA technology users performed better than non-CSA users. For instance, maize production had 26%, 37%, 9% and 26% yield improvement if farmers did adopt portfolio diversification, soil and water conservation, soil fertility improvement and irrigation and water harvesting technologies respectively.

Lack of positive impact from the other technologies might be a result of respondents hiding information on income earned/spent and assets available in anticipation to receive handouts from the research assistants. It may also be because, Nsanje farmers do not take up some CSA technologies as Nsanje soils are thought to be already fertile. The study recommends all relevant stakeholders to strive in providing smallholder farmers with relevant extension messages if more farmers are to adopt many CSA techniques that will make their agricultural production systems resilient to climate change. Never the less increased effort in research on these technologies by providing optimum plot specific productivity rates is necessary for policy formulation.

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