INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS
ICAE
29th | Milan Italy 2015
UNIVERSITÀ DEGLI STUDI DI MILANO AUGUST 8 - 14
AGRICULTURE IN AN INTERCONNECTED WORLD

Adoption of Conservation Agriculture Under Alternative Agricultural Policy and Market Access Indicators: Evidence From Eastern and Southern Africa

Paswel Marenya[a], Menale Kassie[b], Moti Jaleta[c], Dil Rahut[d], Olaf Erenstein[d]

[a] Corresponding author: International Maize and Wheat Improvement Center (CIMMYT), P.O. Box 5689, Addis Ababa, Ethiopia. Email: p.marenya@cgiar.org, Tel. +251-11-64-62-324

[b] International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia

[c] International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya.

[d] International Maize and Wheat Improvement Center (CIMMYT), El Batan, Email:

Abstract: *Minimum tillage combined with mulching (MTM) are two critical components of conservation agriculture (CA) that can have important economic benefits for adopting farmers and positive environmental impacts for the community. Using a unique set of plot level, four-country data that includes household demographic and plot characteristics, this paper uses a binary probit model followed by post-estimation simulations to examine the effect of micro-level factors (plot, farmer characteristics, social capital), meso-level factors (access to markets) and national level policy variables (government input subsidy expenditures and investments in agricultural extension staffing), as predictors of MTM in Ethiopia, Kenya, Malawi and Tanzania. Key policy principles in promoting CA should clearly focus on long term strategies to aggressively invest in agricultural extension but also reduce the costs of farm inputs.*

Key words: adoption, agricultural extension, conservation agriculture, policy, input subsidy

JEL: Q01, Q18, Q12

1. Introduction

The need for sustainable intensification of agriculture has gained considerable urgency in the face of dwindling supplies of land, shrinking agricultural frontiers and ongoing unfavorable climatic changes (The Royal Society, 2009). One of the practices that has been discussed in the literature and policy circles is conservation agriculture (CA) based on the possible agronomic and biophysical benefits that can accrue from practicing the various elements of CA such as minimizing soil disturbance, continuous maintenance of soil cover, and practicing crop diversification (in rotations, intercropping or other crop associations). There is growing interest in CA among agronomists, economists and agricultural development experts because it entails a promising suite of practices which when applied consistently and compositely, can preserve soils and in the long run improve soil properties, conserve moisture, stabilize and even enhance crop yields (Hobbs, Sayre and Gupta 2008; FAO 2012). While the vast majority of successful CA adoption have been in the United States, Canada and Latin America - most notably Brazil and Argentina - (Trigo et al 2010; Ekboir 2010), there is much interest in Africa south of the Saharan in the potential for CA to contribute to sustainable agricultural crop productivity while preserving the underlying natural resource base. Within the smallholder context, there has been some adoption of no-till systems in Ghana, India, Pakistan and Bolivia (Trigo et al 2010; Ekboir 2010).

The productivity and environmental benefits of the minimum and no-till aspects of CA have been documented in various literatures as confirmed in reviews by Erenstein (2010) and Hobbs (2007). Minimum tillage (in some case no tillage, hereinafter no-till) are seedbed preparation methods that involves keeping the number of tillage operations to a minimum by opening up only limited slots for placing the seed. This can be done by using specialized machines (seeders) that open up small farrows in which seed is placed. In situations involving manual land preparation, “jab planters” or dip stick are used to poke holes into the ground into which seeds are placed. In both cases there is minimal soil disturbance since the rest of the field is left untilled. Mulching is the practice of spreading crop residues and other plant materials on the surface of the plot in order to provide as much cover as possible on the soil surface. The mulch serves to protect the soil from erosion, sun, and wind. The biomass on the surface provides nutrition to soil biota whose activity help aerate the soil, mimicking the tillage function. The benefits of mulching were enumerated by Erenstein (2003) to include beneficial impacts on soil conservation, soil ecology, crop yields and the environment.

If implemented properly, the combination of minimum tillage (or no-till) and mulching (MTM) practices can alleviate and even halt soil erosion, lead to water conservation and run-off reduction, ground water replenishment and enhancement of soil biotic communities. In some cases, yield stabilization and increases have been observed as a result (Carsky et al. 1998; Erenstein, 1999; 2003). An FAO (2007) study on CA found that in the United States, no-till systems could potentially reduce water runoff by 31 percent, increase water infiltration by at least 9 percent and reduce soil erosion by as much as 90 percent. The resultant environmental benefits such as reduced sediment loads in rivers and pollutants in water bodies can be significant.

Beyond the biophysical and agronomic evidence, the development and diffusion of conservation agriculture for smallholder farmers requires answers to several important complex questions regarding farm level adoption and how diffusion can be achieved at scale. There are still large gaps in understanding the exact social, economic and policy conditions which can stimulate widespread adoption and up scaling of CA to become part of the wider farming system. Conservation agriculture and related practices are likely to contend with similar impediments to adoption that other agricultural technologies have faced. These impediments to adoption include seasonal labor scarcities for weeding, given that absent herbicides, weed management can become more labor demanding in minimum tillage systems (Nyamangara et. al 2014). Other constraints relate to the opportunity cost of crop residues for feed rather than mulch (Panell et al. 2014, Jaleta et. al. 2013, 2015), cases of short-term yield depression in the initial years of implementing zero tillage and mulching (Panell et al. 2014), short term planning horizons among famers due to high discount rates arising from - unwillingness to accept yield penalties for a few years to improve the soil conditions and better yields in later years - (Panell et al. 2014). This is because delays in benefits occur even after farmers invest in "learning, local adaptation and fine-tuning and institutional change" (Erenstein 2003). In addition, the absence of risk management and pooling mechanisms and weak input and output markets that neither deliver inputs at affordable prices nor offer lucrative prices for outputs can be factors in preventing adoption of MTM.

The objective of this paper is to examine the role and contribution of micro level household but also policy variables in conditioning adoption two important aspects of CA, minimum tillage combined with mulching (hereinafter, MTM). We use a unique set of plot level four-country data that includes household demographic and plot characteristics, perceptions on various risks, market access, credit availability and extension access among others. In addition to the household and plot level covariates, the data used in this study also include two important country level policy variables:

i. *extension personnel to farmer ratio*
ii. *percentage of agricultural budgets spent on farm input subsidies*.

We use a binary choice model to empirically identify significant factors that can explain adoption of MTM at plot level among households in Ethiopia, Kenya, Malawi and Tanzania. Using this type of data and model, the contribution of this paper to the literature on the adoption of MTM (as two critical aspects of CA[1]) is as follows.

First, the use of a multi-country dataset offers the opportunity to analyze, in one setting the co-determinants of adoption of MTM across diverse environments represented by several countries (Ethiopia, Kenya, Malawi and Tanzania in this case). Our reviews show that much of the evidence is still based on localized cross sectional surveys (Erenstein 2010, Hobbs 2007, Trigo et al. 2010) and sometimes extrapolations from cross sectional surveys (Erenstein 2010). To the best of our knowledge such multi-country analysis of adoption of MTM (or CA broadly) has yet to be done in the east and southern Africa region and among smallholder farmer contexts. Yet this kind of multi-location, multi-region and multi-country approach is needed to document more evidence from across different environments to help improve the external validity of existing findings but also to help develop recommendation domains for CA[2] from the emergent body of agronomic, economic or adoption evidence.

Second, this paper helps answer an important outstanding question in the literature regarding whether MTM; based on its resource conserving and cost (labor) reduction advantages can circumvent the challenges faced by other agricultural innovations with regard to adoption.

[1] See FAO, (2001) for a detailed discussion of the three components of CA (minimum tillage, mulching and crop associations) as well as the key economic considerations of CA

[2] In this paper we will use the term conservation agriculture (CA) when talking more broadly and minimum tillage with mulching (MTM) when referring to the specific analysis in this paper. Consequently we will tend to use both acronyms interchangeably.

We do this by analyzing the predictors of adoption using models that are similar in approach and hypothesis with those used in adoption studies generally. Third, we fill a notable gap in the literature concerning the need to analyze the adoption of components of CA beyond the micro-level. Some researchers such as Knowler and Bradshaw (2007) have reported that whereas most of the CA costs are incurred at the farm level, most of the (environmental) benefits transcend the farm boundary. If nothing else, this is a factor that brings CA adoption into the orbit of policies meant to achieve sustainable agricultural production. Yet, there is little information on how the broader agricultural policy environment can determine whether farmers adopt CA (or not) and by extension whether they will realize the reported benefits (or not). Our contribution in this regard is to demonstrate how national level policy actions on government input subsidy expenditures and investments in agricultural extension staffing, are relevant predictors of CA adoption in maize growing areas of the four study countries. We draw policy lessons therefrom.

The rest of this paper is organized as follows. Section 2 is an overview of the literature on the economics of CA with special focus on minimum tillage and mulching using crop residues. Section 3 outlines the background of CA in the four study countries, describes the data collection methods and the analytical approach. Section 4 presents and the results from a binary probit estimation using the pooled and individual country samples, followed by post-estimation simulation and section 5 concludes this paper by summarizing the key findings and stating the policy implications.

2. Literature Overview on the Farm Level Economics and Diffusion of Conservation Agriculture (CA)

2.1. Farm Level Economics of Minimum Tillage and Mulching Using Crop Residues in Smallholder Systems

The weight of evidence suggests that on average, the application of elements of CA compared to conventional practices has positive economic impacts. Panell et al. (2014) provide a wide ranging review of the farm level economics of conservation agriculture with a focus on smallholder systems. The main thrust of Panell et al. (2014) review is that the volume of literature in the economics of CA in smallholder systems is still small. Moreover, few of the extant studies report the economics of the full package CA.

From extant literature, one of the main advantages of CA is that reduced tillage lowers the costs involved in land preparation (Fowler and Rockstrom, 2001), such as reduced tractor and fuel costs as has been observed in places such as the indo-gangetic wheat and rice systems. In non-mechanized smallholder settings, these labor savings are not inevitable especially if herbicides are not available to manage increased weed pressure (Rockstrom et al., 2009; Erenstein et al., 2012). For example, Nyamangara et al. (2014) report on the reduced tillage practice in Zimbabwe involving planting basins dug out by hand hoes. They found that labor demand on this reduced tillage system was more than twice that of conventional systems involving oxen ploughing. This was due to increases in weed populations and now the fields required more frequent hand weeding. The evidence is mixed on the yield increases due to reduced or minimum tillage and yields could even decline in initial years. It is possible that yields under minimum tillage could exceed those of conventional practices but only after several years of consistent implementation (Giller et al. 2009 cited in Panell et al., 2014). Erenstein (2010), estimated that some 620,000 farmers in India had adopted zero-tillage wheat cultivation practices in some form across approximately 1.8 million hectares, earning annual benefits on the order of US$180–340 per household from both reductions in production costs and gains in yield. Having considered various sources of recent evidence on the performance of minimum tillage as a critical part of CA, Panell et al. (2014) conclude that minimum tillage is likely to succeed among farmers with [low discount rates], those who have little uncertainties about the cost-benefit calculus of adopting this practice and among farmers who have larger farms with concomitantly more resource endowments.

The evidence on mulching is also mixed, being complicated by the critical tradeoffs between mulch, feed and other uses (Jaleta 2013, 2015). Using data from a study conducted in Morocco, Magnan, Larson and Taylor (2012) calculated the opportunity costs of crop residue in zero-tillage systems and found that the shadow value (its value in livestock feeding as opposed to soil mulch) was 25 percent of the total value of the crop produced during normal rainfall and 75 percent during drought (when crop residues become most valuable as animal feed). Their findings suggest that the value of crop residues in alternative uses are very significant in this context, and should be considered carefully when promoting CA among smallholders because it can be a deterrent to use of crop residues for mulch. Similarly, Valbuena et al. (2012) compare CA practices in South Asia and Africa south of the Sahara to demonstrate how the opportunity costs of residues are a key determinant in CA profitability and adoption. Their study gives evidence to show that crop residue use in zero-tillage cultivation is most feasible in what they describe as "high-potential areas" where, despite high population and livestock densities, biomass production levels are sufficient to meet the demands of both livestock and mulching. Low- and medium-potential areas, biomass production levels are lower and the pressure for residue use in feeding livestock is higher, making mulching for zero-tillage systems much more difficult. In high rainfall areas, mulching can lead to yield reductions (Rusinamhodzi et al. (2011).

A review of the economics of crop associations (especially rotations or intercrops using legumes) in the context of CA was done by Panell et al. (2014) whose broad conclusion is that the profitability of legumes crop associations (compared to mono-cropping) though generally positive is context dependent[3]. The application of the full suite of CA technologies is a rare phenomenon among smallholder farmers (Giller et al. 2009, Kaumbutho and Kienzle, 2007). When the full suite is combined, FAO (2001) and Knowler and Bradshaw (2007) showed that the majority of studies report that CA practices have better financial returns than conventional practices. The crux of the matter then is how to get farmers to eventually the complete set of CA components for maximum benefit.

2.2. Possible Determinants of Adoption and Diffusion of CA Among Smallholder Farmers

The micro-level (individual, household), community, institutional and policy factors that enable the diffusion of CA remain largely unanswered for most of smallholder situations. For example, how can CA be promoted under conditions characterized by credit, labor and extension services bottlenecks? Are there policy and institutional factors that may help provide the incentives to smallholder for CA adoption? The implementation of CA as an alternative production system can represent significant outlays for resource poor farmers who, *ex ante*, are not using any significant amounts of external inputs. For these farmers, the financial resources needed for complementary external inputs such as herbicides (or fertilizers) and the increased labor demand for weed management can still represent *relatively* high resource expenditures if they are starting from base production practices involving little more than family labor. Many of

[3] See Panell et al. (2014, p.56) for a review of the economics of legume-cereal rotations

such farmers can find it difficult to put the critical learning and experimentation costs required to adopt CA. Another fact is that CA implementation may actually be associated with high inputs levels especially if the envisaged yield gains were to come about (Rusinamhodzi et al., 2011). Therefore, farmers may fail to adopt even a labor saving practice such as CA if they start from very low levels of resources. Under these circumstances, if opportunities for the supply of financial products (credit) or the ability to earn cash income are limited, technologies that require up front commitment of finances, labor or both may not be readily adopted (Jack 2013).

Therefore, at the micro-level, the need to meet minimum subsistence food needs and lack of financial resources (savings or cash income) can prevent the adoption of even profitable agricultural innovations (Antle and Dagana 2001). Therefore if the opportunity costs of labor are not fully (if at all) accounted for, prospects for CA adoption may remain limited.

Risk perceptions, information availability, safety first behavior and ambiguity aversion can also play an important role in agricultural technology adoption and can be similarly relevant for CA adoption among low income subsistence oriented farmers. If farmers perceive CA as a riskier undertaking than conventional practice, that perception could be based on an objective understanding or mis-perception of the real situation. Assuming farmers can access the labor and other inputs for CA (through family or hired labor, self-financing or credit) they can still fail to adopt CA if they erroneously consider CA practices to be riskier or less profitable than they actually are. This could happen because they lack the knowledge and skills to implement them properly. They may then abstain from adopting CA because previous attempts were disappointing or fail to experiment with these altogether because of inaccurate information about their profitability. Farmer education through high quality extension can help remedy this situation.

3. Background, Data and Methods

3.1. Country Background on Conservation Agriculture

An overview of the history of CA in the four countries suggest that its promotion has been attributable to development projects (Milder, Mejanen and Scherr, 2011). The emergence of CA as a tool in sustainable agriculture in east and southern Africa (ESA) can be traced in the literature to the 1990’s with a notable milestone being the 1996 World Food Summit where the Soil Fertility Initiative was launched followed by the Better Land Husbandry approach; and for

Africa, a 1998 conservation tillage workshop in Zimbabwe and the formation in 2000 of the African Conservation tillage network (Benites *et al*, 1998, Bishop-Sambrook et al. 2004). The core support for the promotion of CA in Africa south of the Sahara has invariably been based on projects supported by donor funding. For example in 2003 in Zambia, FAO piloted draught animal power (DAP) ripping and input packs as part of an FAO's emergency agricultural intervention plan in the country. The Monsanto seed company in collaboration with Sasakawa-Global (SG2000) also has promoted no-till practices that rely on herbicides and the retention of crop residues in countries such as Burkina Faso, Ghana, Guinea, Mali, Malawi, Nigeria, Senegal, Ethiopia, Kenya, Mozambique, Uganda and Tanzania (Bishop-Sambrook et al. 2004). In Ethiopia, one of the early efforts to introduce minimum tillage was done by the Sasakawa-Global (SG2000) in South Achefer district (Matsumoto, Plucknett and Mohammed, 2004). Using on-farm demonstrations of minimum tillage, improved maize varieties and herbicides, the program was implemented for some years involving field demonstrations. There is evidence that in these areas where SG2000 worked, minimum tillage practices are still being used by smallholder farmers.

In Kenya, conservation agriculture has been formally promoted since 1998 under the Kenya Conservation Tillage Initiative (KCTI) and by 2005; KCTI had projects in five districts in the country with plans at that time to scale up the pilot programs through farmer field schools. From these efforts, CA is now emerging in several parts of Kenya among a diverse group of farmers in such areas as the semi-arid as well as the high potential areas in the eastern areas and in the smallholder sub-humid western regions of the Kenya. Perhaps as an indication of the growing prominence of CA in Kenya, the 3rd World Congress on Conservation Agriculture was held in Kenya. During this Congress, the government (represented by the vice president of the Republic of Kenya at that time), expressed its commitment to CA in its strategy to revitalize agriculture (ACT, 2008 p. 9).

There is some evidence that experimental trials on CA in Malawi can be traced back to the 1980's at Bunda College (Mloza-Banda, 2002). In recent years, the authorities have shown keen interest to promote processes and policies to redress land degradation evidenced by the creation of a National Conservation Agriculture Task force (NCATF). This task force has the mandate of overseeing the proper application of sustainable use of natural resources and land management practices and the advocacy of CA initiatives throughout Malawi. The NCATF participates in CA-based land management policy processes bringing together researchers, developers and policy-makers to share information and advance conservation agriculture.

One of the earliest concerted efforts at promoting CA in Tanzania is reported in Marietha et al. (2011) in which they report that in 2004, a joint program between the German Ministry of Agriculture and FAO, supported CA practices in Northern Tanzania. The project used farmer field schools as entry points for extension and farmer education on CA. The project also encouraged the private sector to participate in the fabrication; retailing and developing custom hire services for CA equipment such as jab planters, ripper sub-soilers and DAPs. These projects were pioneered in the North Eastern regions of Arusha and Kagera later expanding to Manyara region (also North East) and Kilimanjaro (in the North West). Overall, this brief review suggests that there have been notable interest in CA in the study countries. Efforts to better understand the merits of CA and the preconditions for its diffusion in these countries are therefore warranted.

3.2. Data and Data Sources

This paper is mainly based on household- and plot-level data collected through surveys conducted in 2010/11 in Kenya, Malawi, Ethiopia, and Tanzania. In Ethiopia, the survey was carried on selected maize-legume based farming systems in different regions of the country (SNNP, Benshangul and Oromia regions). A multi-stage sampling was employed to select households to be included in the survey. In the first stage nine districts were selected purposively based on the importance of maize and the associated agro ecology (Bako Tibe, Gubuesyo, Shalla, Dudga, Adami Tullu, Mesrak Badawacho, Meskan, Hawassa Zuriya and Pawe). In the second stage, 69 Peasant Associations (PAs) were randomly picked from a list of PAs in each district. At the final stage, a total 2187 households were randomly selected from the various PAs; with the number of households selected from each PA proportional to the number of the households in the PA as per the local latest official census figures.

In Kenya, five districts were selected (two districts from western Kenya region (Bungoma and Siaya) and three districts from eastern Kenya region (Embu, Meru South and Imenti South). In total 613 households were enumerated in the Kenya survey with the two regions being assigned an equal number of sample households (approx. 300 each). The households in a region were distributed across the respective districts according to the total number of farm households per district (proportionate sampling). Multi-stage sampling was employed to select lower level sampling clusters: divisions, locations, sub-locations, and villages. In total, 30 divisions were selected – 17 from western Kenya and 13 from Eastern Kenya. Efforts were made to ensure representation of the sample depending on the population of the study areas. Proportionate random sampling was designed to select divisions from each district, sub-locations from each division, villages from each sub-location, and households from each village.

In Malawi as with the rest of the countries, purposive sampling was used in the first stage to select regions of the country where smallholder maize farming is important. Stratified sampling was used to select six districts; five in the Central region (Lilongwe, Kasungu, Mchinji, Salima and Ntcheu) and one (Balaka) in the South. Eventually, 64 Extension Planning Areas (EPA's), 89 Sections and 235 villages were selected using multi-stage random sampling combined with probability to proportional size. Similarly, using the same process, 1870 households from the 235 villages were selected for this study.

In Tanzania the survey targeted two maize-legume based farming systems in the eastern and northern zones of Tanzania (Kilosa and Mvomero in the eastern zone and Mbulu and Karatu districts in the northern zone). These districts were purposively selected followed by multi-stage random sampling to arrive at a total sample of 60 villages and using probability to proportional size, a final tally in the data involved 681 households. From the four countries, the total data set comprised of 5,356 farm households and 11,188 maize plots from 700 villages in 43 districts.

3.3. Estimating the Adoption Equation

When presented with the decision to implement MTM or not, farmers are essentially making a binary choice. There are several elements in this choice process including the environment in which farmers operate and the observed household and farm characteristics of the farmer (e.g. gender, educational attainment, age, plot characteristics) and unobserved attributes (risk attitudes, motivation, etc.) that condition the final choice. We use a set of farm household and environment indicators in a binary probit model to estimate the factors that affect plot level adoption of conservation agriculture in the study sites. Below, we describe the groups of variables and the hypotheses informing their use in the adoption model.

3.3.1. Variables Included in the Adoption Model

The following groups of variables are use in the adoption model based on the reasoning advanced in sections 2.1 and 2.2. The variables range from self-reported assessments of plot level characteristics, household demographics such head of the household, their education levels and main income activities. Finally we explain the two policy variables included in the adoption model and used in the simulation framework.

Plot characteristics: Plot characteristics are important in influencing technology adoption decisions. Studies such as those by Kaizzi et al. (2002) and Yanggen, et al. (1998) found that there was a tendency for farmers to apply organic soil fertility management practices on plots with poor soil fertility and fertilizer on plots with high fertility. The basic point is that the plot characteristics can determine the adoption patterns of soil investments. We include self-reported plot characteristics in the adoption model to control for these effects in MTM adoption as well.

Physical capital and livestock ownership: Physical capital endowment should generally be a positive predictor of adoption of diverse types of practices especially to the extent that these variables proxy for greater farm sophistication and access to equipment. Likewise, livestock endowment has frequently showed a significant positive impact on adoption of fertilizer and manure. In terms of MTN, a negative impact on adoption can be expected from greater livestock ownership resulting from the competition for crop residues between mulch and feed. Defoer *et al.*, (2000) and Ryan and Spencer, (2001) also showed that farmers with mixed livestock-crop systems are able to enhance soil fertility more sustainably than those growing crops or keeping livestock only. Farm size can be expected to be positively associated with greater technology adoption to the extent that this proxies for higher resource endowments not captured by livestock or value of farm equipment.

Household demographics and human capital: Demographic variables such as sex of the decision maker or household head, their education or experience and age can be predictors of technology adoption. For example, in many rural societies there are marked differences between men and women farmers. These differences occur because women in Africa south of the Sahara and similar areas of the world have a disproportionately lower share and control of many agricultural resources (land, fertilizer, labor, information and finance) than men, incommensurate with their levels of contribution to agricultural labor (e.g. Peterman et al. 2011, Slavchevska, 2015). Due to these variations women farmers may be inclined to use some technologies that save on their most scarce resources (e.g. use manure instead of fertilizer which is more expensive). For example male headed households, are mostly dual adult (husband and wife) households and are likely to have more adult members and so may implement labor demanding practices. Family size should generally indicate greater availability of family labor. Family labor is one of the most important sources of farm power where households lack cash to hire equipment or use labor markets to bring in extra labor. The impact of education derives from the fact that more educated farmers are more likely to use knowledge intensive practices, due to greater access to extension or ability to acquire, process and use information as well as experiment with new practices. Ability to earn extra income from other employment than agriculture could indicate that a household has access to cash for input purchases and hiring labor to implement various agricultural practices such as MTM.

Access to markets and rural services: Proximity to markets reduces the costs of acquiring inputs and selling output so that this increases the profitability of technology adoption. There is likely to be higher likelihood to use modern inputs for farmers closer to agricultural markets consistent with expectation that transaction costs (mainly because of lower transportation and information gathering costs) tend to be lower for farmers in close proximity to major markets. Access to credit can help famers to access the finance needed at critical time of farm operations for purchases of inputs and for consumption smoothing thereby strengthening the ability of those who can access credit to adopt resource intensive practices (in terms of cash and hired labor).

3.4. Policy Variables

The importance of liquidity and information constraints raises the question about which policies can be used to relieve these constraints. Two main policy levers for facilitating widespread adoption and upscaling of conservation agriculture are greater investments in agricultural extension to increase the availability of information and policies designed to relieve financial and credit constraints to adoption (e.g. subsidies programs and credit schemes). This is a subject that still needs to be analyzed in the case of CA (as is true for other agricultural innovations broadly). With regard to input subsidy programs, fertilizer subsidies have made something of a return in several African countries after a period of their absence in the wake of the structural adjustment programs of the 1980s and 1990s. At their peak in the 1960s and 1970s the main reasoning was that the lessons from the Asian green revolution showed that subsidies were crucial in supporting the widespread adoption of improved seeds and fertilizers. Consequently, public expenditures on subsidies have been considerable in countries that have chosen to implement them. For example, Malawi spent about 72% of its agricultural budget in 2008/09 on agricultural input subsidies (Dorward and Chirwa 2010). The consensus in much of the literature on the issue is that carefully designed subsidies can enable liquidity constrained farmers to overcome short-term financing constraints. Keeping other things constant; by lowering the overall costs of inputs, beneficiary farmers may find it easier to use fertilizer and other complementary practices such as CA. The key design principles of a sustainable subsidy policy which can help in achieving these objectives will depend on careful targeting and should be implemented using existing input market channels as much as possible (Smale, Byerlee and Jayne 2011).

In terms of information availability and farmer capacity enhancement, agricultural extension is a critical public service. The importance of information is such that even if farmers had access to resources, if they lack the information on how best to implement recommended practices, they may fail to do so, because they lack the technical knowhow to adopt them optimally and profitably (Jack 2013). In the policy sphere, there is a new impetus to revamping extension services in many parts of ESA after some years of neglect subsequent to the 1980s contraction of public expenditures (Rivera and Alex 2004, Pye-Smith, 2012). At the peak of investments in extension in the pre-structural adjustment years, the developing country average of extension-agent-to-farmer-ratio was 1 in 300 and that declined to 1 in 1500-3000 by 2012 (Pye-Smith, 2012). The fact remains that investing in and improving extension is critical in order to overcome challenges such as few extension personnel serving many farmers spread over large areas, low technical skills and lack of private extension services (Coen and Eisner, 1987 cited in Zapeda, 2001). This fact was observed by Milder, Mejanen and Scherr (2011) who stated that

> "…the single most effective way to scale up CA for smallholder farmers is to vastly increase extension support and technical backstopping. Since the successful adoption of CA requires a departure from conventional farming methods—supported by a new knowledge base—there is really no substitute for a dense

network of trainers and extensionists at the field level. This is particularly true for the many parts of Africa where existing levels of capacity are very low…”

3.5. Policy Simulations

In order to capture the relative importance of these two policy issues, we implement a series of policy simulations based on a fitted regression (binary probit) model results to compare the predicted probabilities of adoption under different extension and subsidy expenditure scenarios. Specifically, we simulate the following three types of scenarios regarding extension personnel farmer ratio and proportion of agricultural budgets spent on subsidies:

(a) *Base Model:*

$\mathrm{E}[Pr(CA_i|\mathrm{p}_i)]$, in the base scenario, is the expected probability of MTM adoption in country *i* when the policy variable (extension farmer ratio or proportion of expenditures on subsidies) is set at respective country *i's* observed value, where *i*=Ethiopia, Kenya, Malawi and Tanzania.

(b) *Changing the Policy Variables From the Base Levels*

$E[Pr(CA_i|p_j)]$, is the expected probability of CA adoption in country *i* when the policy variable takes on an alternative value p_j *(where* $i \neq j$ *) and j*= Ethiopia, Kenya, Malawi and Tanzania. In this case *j* would be policy value based on the country which best typifies the policy in question. For expenditures on input subsides; Malawi had the highest expenditure on subsidies (see Table 1), so in this simulation scenario, the other three countries' expenditure on input subsidies was changed to Malawi's level. For extension to farmer ratios, Ethiopia had the highest extension to farmer ratio (EFR) (Table 1), so the other three countries' EFRs were changed to Ethiopia's level.

(c) *Combining Different Levels of the Two Policies*

Finally, in a third category of comparisons we combine different levels of subsidy expenditures and EFRs to reflect the fact that policies can be combined or sometimes policy tradeoffs have to be made. For example what would happen if Malawi reduced the subsidy expenditures but raised the number of extension personnel instead, for instance to Ethiopia's level? Alternatively what would happen if Ethiopia's EFR was reduced and the resources spent on input subsidies instead? Different policy permutations are always possible in the real policy world. The implied interaction effects of simulating what the predicted probabilities would be if a particular policy value was combined with a different policy level e.g. high numbers of extension staff but low input subsidies or low fertilizer-maize price ratios with low input subsidies is meant to reflect this. Therefore:

$E[Pr(CA_i|p_{j,}p_{j,})]$, is the expected probability of CA adoption in country i when the policy variable takes on a combination of EFR and subsidy expenditure levels. In this case i and j would be a set of two policies specifically based on combinations of 1 or 2 country extension to farmer ratio and subsidy expenditure values. The choice of the country value combinations (tradeoffs) was based on which value pair best typifies the policy combination of interest. More details are presented in the simulation results section.

<<Table 1>>

Table 1 shows the EFR and subsidy expenditure as a percent of agricultural budgets (SER) in each of the four countries. We chose data for the year 2010 because the household data were also collected during 2010. In cases where the data for EFR and SER for 2010 were not available, we chose the data for the year nearest to 2010. In terms of extension–personnel-to-farmer-ratio (EFR) - measured as the number of frontline staff per 10,000 farmers- Ethiopia had the highest EFR at 16, followed by Kenya (10), Malawi (6) and Tanzania (4). Malawi spent the most (58.9%) on input subsidies as a percent of government's agricultural budgets (SER) between 2009 and 2011 compared to Ethiopia (10%), Kenya (19%) and Tanzania (46%).

4. Results and Discussions

4.1. Household Variables Descriptive Statistics

We summarize the descriptive statistics in Table 2. These data show that MTM was variously used in the study sites of Ethiopia (30%), Kenya (4%), Malawi (35%) and Tanzania (11%) respectively with a pooled sample average of 22%. Although these are plot level counts, the rates of adoption at the household level are consistent with plot level counts at 31, 4, 41 and 15 percent for Ethiopia, Kenya, Malawi and Tanzania respectively. The percentages of those observed to have implemented MTM is consistent with what has been published in recent literature. For example, Kassie et al. (2014) showed a 30 percent adoption of minimum tillage in Ethiopia. In Kenya, maize-legume rotations and no or minimum tillage adoption were reported to be 4 and 4.5 percent respectively by Ndiritu et al., (2014). Ngwira et al. (2014) reported the results of a survey of six districts in the central and south regions of Malawi and find adoption rates of CA ranging between 1.5 to 38.9 percent. In Tanzania, Kahimba et al. (2014) report that in Arusha region, 23.7 percent were reported to be adopting minimum tillage practices (such as zero tillage, ripping, and minimum tillage) and the in Dodoma region 29.1 percent in Dodoma had adopted planting pits (*chololo*).

The demographics of the farming population as per this sample show that on an average, the farmer in Kenya was older (50 years) compared to the Tanzania (45 years), Ethiopia (43 years) and Malawi (42 years). The Kenyan farmer had on average 7.5 years of formal schooling compared to 3.0, 5.7 and 5.4 in Ethiopia, Malawi and Tanzania, respectively. Only a minority had any non-farm sources of income; 23% of the Kenyan households had non-farm source of income, followed by Malawi (13%), Tanzania (6%) and Ethiopia (5%). The average household size appears to be within a narrower range in all the three countries ranging from 5 members in Malawi to 7 members in Ethiopia. As expected, households in Ethiopia had the highest livestock numbers (6.24 TLUs or tropical livestock units) and Malawi had the lowest at 0.72 TLUs. The farm size cultivated during the major agricultural season was least in Kenya at 1.32 ha and highest Tanzania (4.7 ha) followed by Malawi (3.4 ha) and Ethiopia (2.6 ha). The value of non-livestock assets was highest in Ethiopia ($ 883) and least in Tanzania ($152). The data on credit constraint shows that typically, about 50% of households reported needing credit and not finding it. In Ethiopia, Kenya and Malawi credit constrained households were 56%, 45% and 49%. In

Tanzania relatively few (26%) of the households reported needing credit and not finding it. Overall, 25 percent of the farmers belonged to various types of farmers' groups. Similar proportion was observed in Tanzania. Malawi had the highest proportion (39 percent) of farmers belonging to any farmer groups and in Kenya and Ethiopia the proportion was approximately 20%.

<<Fig. 1>>

Table 2

4.2 Results From Adoption Model:

Table 3 presents the results from the adoption model. We discuss each group of variables in turn.

Household demographics: In this category, the sex of the household head was significant only in the Kenya and the pooled sample. More years of education was significantly and negatively associated with adoption of MTM in Kenyan sample. Although the estimate was insignificant, the sign of the education variable was positive in the other cases. Those who had salaried employment were significantly less likely to have adopted MTM (coefficient negative for all samples and significant for Ethiopia sample). Similarly, those who had non-farm self-employment were less likely to have MTM on their plots (Kenya sample) but more likely in the Tanzania sample). The negative correlation between accesses to non-farm income may suggest higher opportunity costs for these households thereby limiting the extent to which they will commit labor to implementing labor demanding activities on their own farms. However the result is not universal as the positive coefficient for Tanzania sample suggests complementarity and perhaps better integration of farm and off-farm activities than in the other countries.

Access to infrastructure, markets and agricultural extension: Those who reported that they were credit constrained were significantly less likely to have been the adopters of MTM (except in Malawi where the coefficient was insignificant but negative similar to the rest of the estimations)[4]. This confirms the centrality of credit and availability of finance in MTM adoption. The longer it took to walk to the nearest market, the less likely was MTM likely to have been adopted in any of the household's plots in Malawi and Tanzania, suggesting that even when practices require non-tradable inputs, the effect of market access is still strong, suggesting that markets change the terms of trade and opportunity costs of labor and other inputs needed for MTM implementation. Finally those famers who reported that they were confident in the skills and advice given by their extension staff were more likely to have plots with MTM (in the pooled, Ethiopia and Kenya samples), indicating that beyond access to extension the quality of extension services as perceived by farmers is important.

Plot characteristics: In cases where the respondent regarded their plot as being medium fertility or good fertility, the more likely they were to be practicing MTM. We cannot confirm if this results from an endogenous process where those who are good plot managers are also likely to be experimenting with new methods such as MTM. In Malawi on the other hand, those who viewed their plot as "good" fertility were less likely to be adopting MTM. Additionally and except in Malawi, medium sloped plots were more likely to have MTM on them. Steep sloped plots were significantly less likely to have MTM in the Malawi and Tanzania results and in Ethiopia (though not significant). The sign for steep slope was positive but insignificant for Kenya. In a FAO (2001) study, it was reported that soil erosion and other soil degradation indicators were positively associated with adoption of minimum tillage (Stonehouse, 1991) and as reported by Uri (1997) there was evidence that plots with low levels of fertility were the ones where minimum tillage was likely to be adopted on. The cited literature and our results suggest that the relationship between MTM adoption and plot quality is not uni-directional, and that in some cases, farmers may be more likely to adopt MTM as a land improvement practice on plots that they deem to be good for crop production or that they may refrain from investing in the maintenance of poor plots with low returns (perhaps reflecting the fact that these plots are not suitable for production). Alternatively, considering that MTM is one way to rehabilitate plots regarded by the farmers as of poor quality, they may experiment on the lower quality plot first before fully adopting them on their other main plots. Therefore, the direction of the relationship

[4] To test if this is because of the high fertilizer subsidies in Malawi we ran the models without the subsidy and variable. The results (not reported) were qualitatively the same.

between perceived quality or fertility of the plot and MTN adoption is clearly context specific and difficult to predict *apriori*.

Physical capital and livestock assets: As expected, the more livestock was available in the household, the less likely was MTM to have been adopted in any of the household's plots. Although the sign is negative in all cases, as expected, the result is only significant in Ethiopia (a livestock abundant system). The more non-livestock assets the household possessed, the more likely they were to have adopted MTM . This result was consistently significant across all country samples. This confirms the centrality of assets as an overriding determinant of MTM adoption if aspects such as seeding on an untilled or minimally tilled seedbed can be implemented. It also suggests the importance of endowments generally which is partly captured in the non-livestock asset variable.

Social capital: The more traders the household head reported knowing the less likely they were to have adopted CA in Ethiopia and Tanzania. This appears indicative of the fact that those already having a strong market orientation (having interactions with and knowing many traders) and already intensifying their production by using higher amounts of fertilizers and more successful farms may find the opportunity costs of experimentation needed for CA to be too high and therefore fail to commit to the experimentation and adaptive process needed for MTM adoption. The higher the number of relatives the household head thought they could rely on in times of need, the more likely they were to have adopted CA. Except in Kenya where the effect was negative. Those who belonged to a farm association were more likely to have adopted CA. The effect was however significantly negative in Malawi. Although the results are not similar in all cases, the positive association and ability to find support from non-relatives, suggests the influence of social connectivity as a predictor of agricultural technology adoption either through information or resource flows and other mutual support systems.

Table 3

Risk perceptions: In the Kenyan sample, there were self-reported risk perceptions on drought, pests and diseases, unfavorable prices for inputs and output and personal health. Those who perceived the risk of future drought as a major concern were more likely to have MTM on any of their plots. Also the probability of having adopted MTM was higher if the farmer felt that personal health would be a major issue in future. These two results are intuitive because, first MTM is one aspect of mitigating the effects of droughts and the resulting soil moisture stresses and farmers who understand the benefits of MTM in this regard (or who have been in contact with project extension personnel who inculcated in them this type of benefit) may be willing to implement MTM. Secondly if famers are worried about current and future illnesses, economic setbacks and other personal difficulties (which may affect availability of family labor), the labor saving benefits of MTM may be attractive, providing an impetus for them to try it out.

Effect of country dummies and policy variables. The country dummies show that controlling for differences across the four countries in household characteristics, access to infrastructure, markets and rural services, plot characteristics, physical capital and livestock assets and social capital, the observed adoption rates in Kenya and Tanzania are statistically lower; and the adoption rates in Malawi are statistically higher than those in Ethiopia. The coefficients of the EFR and SER variables are highly statistically significant, showing that in instances of high concentration of extension workers or where strong input subsidy programs exist, the adoption of CA has the potential to spread among farmers at scale. This result confirms our hypothesis that, as will be true with all other agricultural innovations, adoption of CA is likely to succeed in environments with good agricultural extension and information networks and also in areas where complementary inputs to CA (e.g. fertilizers) are affordable for many farmers. This would allow many farmers to acquire the necessary information needed to evaluate, try and adopt CA but also relieve the liquidity constraints that may hamper complementary input acquisition and allow them to lock in family labor on-farm to implement these practices.

4.4. Policy Simulations

4.4.1 Extension Simulations

Increasing individual country's extension to farmer ratios (EFR) to Ethiopia level: The first simulation of the impact of extension to farmer ratio (EFR) on the predicted probability of CA are reported in Fig. 2. In Kenya, the probability of adoption increases from 3.9 (base level) to 6.5 percent by increasing the EFR from 10 to 16 (the Ethiopian level). Similarly, in Malawi and Tanzania the probability of adoption increased from about 3.4 percent to about 5 percent and from 10 to 21.4 percent in Tanzania respectively.

<<Fig. 2>>

Reducing extension (EFR) but increasing subsidies (SER) instead: In Fig. 2, we report simulation results of what would happen if extension were reduced (by setting the other three countries' EFR at Tanzanian level) and at the same time increasing SER (hereinafter simply referred to as subsidy) to Malawi's rate of 58.9 percent. The results suggest the powerful impact of subsidy expenditures on probability of adoption. Despite reducing EFR in Ethiopia by 75 per cent, the probability of adoption increases by approx. 4 percentage points (from 26 to 30 percent). The result for Malawi provides a "counterfactual" in this case. Since the SER stayed the same; only that the EFR was reduced to Tanzanian level, the probability of adoption reduced in Malawi's case from about 34 to31 per cent. For the other three countries' simulations, the increased SER appear to more than compensate for the reductions in EFR, so that probability of adoption increases despite reductions in EFR (Fig. 2).

<<Figure 3>>

Simultaneously increasing extension (EFR) and reducing subsidies (SER): This is the mirror image of simulations in Fig. 3 and reflect the effect on the other three countries MTM adoption if the EFR and SER policies were similar to Ethiopia's. In effect, the results show the effect of simultaneously increasing EFR to compensate for reductions in SER as a policy alternative. For the Malawi and Tanzanian cases, the probability of adoption declines by between 2 percent (Tanzania) and 14 percent (Malawi). This is intuitive because in this setting, even though Tanzania had a 78% reduction in subsidy, Malawi's subsidy was reduced by 82%. The EFR in Tanzania was increased by 300 per cent and Malawi's was increased by 260 percent. This may explain the (relatively) small 2 point drop for Tanzania compared to Malawi's 14 percentage point drop because Tanzania had a bigger increase in EFR and a smaller drop in subsidy. In effect, there was a larger compensatory effect in Tanzania compared to Malawi. When the Malawi and Tanzania results are looked at from the point of view that the magnitudes of these changes are within similar orders of magnitude, the effects of these changes appear dependent on the starting point, so that the absolute changes are less important compared to the relative changes. The relative changes in turn depend on the base level from which the simulations are made. Therefore, in the subsidy-heavy Malawian base scenario, a 1 percentage point decrease in subsidy had larger effects than a similar change in Tanzania or Kenya (see Fig. 4).[5]

<<Figure 4>>

Increasing extension (EFR) with no credit availability: In these simulations (Fig. 5), the compensatory effect of high extension with a lack of credit is demonstrated. This was achieved by setting the EFR at the highest (Ethiopian) level, and making the credit constraint variable to be 100 percent binding. The results show that in all cases (except Ethiopia) predicted adoption increased from base levels by approx. 2 percent in Kenya, 13 percent in Malawi and 9 percent in Tanzania. The decrease in probability of adoption in Ethiopia provides a useful benchmark for demonstrating the effect of credit constraint on probability of adoption: the probability of adoption fell from 26 to 18 percent by making all households credit constrained. In the other three countries the lack of credit was somewhat compensated for by increase in EFR while in the Ethiopia simulation the EFR remained unchanged as credit availability was eliminated. Without suggesting that credit access is unimportant, these results are indicative of the fact that increases in the reach of extension systems and information can make up for lack of credit, pointing to the

---

[5] See Appendix Table A1 and A2 for the point "elasticities" of adoption with respect to EFR and SER respectively. The elasticity results seem to confirm the fact that the responsiveness of adoption to SER is higher than that of EFR.

fact that information availability can go a long way in enabling adoption even under severe credit limitations (independent of other factors).

<<Figure 5>>

4.4.2. Subsidy Simulations

Changing individual country's input subsidies (SER): In Fig. 6, the results show that setting SER at the Malawian level increases probability of adoption by more than 100 percent in Ethiopia and Kenya and by about 80 percent in Tanzania. These strong and significant impacts of SER and the earlier reported results for EFR (section 4.4.1) are indicative of the potential that still exists for information delivery and bringing down the cost of agricultural inputs.

<<Figure 6>>

Reducing subsidies (SER) and increasing credit availability: In Fig. 7, we compare the compensatory effects between subsidies (SER) and credit. Lowering SER (to Ethiopian level) and increasing credit (by treating every household as if they all had credit) leads to lower probability of adoption in all cases. The assumed universal access to credit does not adequately compensate for reduced subsidy, except in Ethiopia where SER remained unchanged while credit constraint was removed and therefore the probability of adoption increased albeit by slightly by 3% points from 26 to 29 percent.

Increasing subsidies (SER) with no credit availability: In the simulations that assumed no credit was available but with a compensating increase in subsidy at the highest (Malawian) level (also Fig. 7), the probability of adoption increased in all cases except in Malawi where credit availability was eliminated but SER was unchanged, leading to a reduction in probability of adoption from 34 to 31 percent. The high levels of SER more than made up for the lack of credit.

<<Fig. 7>>

5. Conclusions and Policy Implications

In this paper we set out to determine the impact of extension-personnel-to-farmer-ratio, government expenditures on input subsidies in empirically predicting adoption of minimum tillage combined with mulching (MTM), controlling for household demographic, plot and market characteristics. From both the base probit and subsequent simulation results, we find that the likelihood of MTM adoption was greatly enhanced by increasing input subsidies and (or) by increasing the extension-staff-to-farmer-ratio. Generally the results showed that both subsidy and extension had powerful effects on the probability of adoption. When the extension-personnel-to-farmer-ratios were compared to public expenditures on subsidies, the effect of the subsidy variable appears to have had the stronger effect on MTM adoption in simulations involving reductions in subsidy and increasing extension. Similarly, when subsidy (SER) was reduced and extension (EFR) increased, probability of adoption fell nevertheless. The impact of credit availability compared to subsidy expenditures showed that when subsidy was reduced, a universal availability of credit did not prevent the probability of MTM adoption from falling and when the simulation involved no credit but with high levels of subsidy expenditures, the probability of adoption still increased, an intuitive result because subsidy can alleviate credit constraints. The strong effect of extension was clear in simulations where the extension variable was compared to credit availability. By increasing extension, the probability of adoption increased even in the complete absence of credit. The relative balance of investing in extension and other public goods compared to subsidies have been made by Lohr and Salomonsson (2000) and Genius, Pantzios and Tzouvelekas (2006). Information availability is an effective strategy for positively influencing adoption because more and high quality information enables farmers to learn, experiment, evaluate and allocate resources to new practices more effectively.

The implications of these results are threefold. First, the power of input subsidies in predicting MTM adoption implies that lowering costs of complementary inputs is central in encouraging CA adoption. Considering that subsidies are essentially ways to reduce prices of inputs and given sustainability concerns, diverse options for structurally lowering input-output price ratios should be put on the policy table. Second, investing in agricultural extension systems and increasing the number of extension personnel (increasing the extension personnel to farmer ratio in our case) and expanding the reach of publicly funded extension systems among other complimentary providers, is a crucial element in the success of CA as was confirmed by the large, positive and significant impacts of high EFRs on probability of CA adoption in the simulations. Third, although CA consists of a set of practices that are resource conserving with demonstrable cost advantages (and sustainable intensification dividends), CA faces similar challenges as other agricultural innovations. Policy attention for upscaling CA should remain focused on solid information delivery through strong agricultural extension, better access to markets and providing inclusive finance. The key policy principles in promoting CA should clearly focus on long term strategies to aggressively invest in agricultural extension but also reduce the costs of inputs.

While this study provides important evidence into the relative importance of two critical policy variables for agricultural development, we recognize that this paper, based on a snapshot view from cross-sectional data analysis, is limited in scope. Similar policy simulation studies may benefit more from panel data sets and models involving dynamic behavior. Further simulations cast within Monte Carlo frameworks may yield more robust results under a wide range of conditions. This lack of sensitivity analysis and panel data should be corrected in similar studies in the future. Finally, this study does not capture the political economy and power relations that inherently underlie any public policy, reducing the ability to offer more insights into why we observe the policy differences in the four countries.

References

ACT, 2008. Linking Production, Livelihoods and Conservation; Proceedings of the Third World Congress on Conservation Agriculture, 3 - 7 October, 2005, Nairobi. African Conservation Tillage Network, Nairobi.

Benites, J., Chuma, E., Fowler, R., Kienzle, J., Mapolang, K., Manu, J., Nyagumbo, I., Steiner, K.,van Veenhuizen, R., (eds) 1998. Conservation tillage for sustainable agriculture. Proceedings from an International Workshop, Harare, 22–27 June, Part 1 (Workshop Report).

Bishop-Sambrook, C., Kienzle, C.J., Mariki, W., Owenya, M., Ribeiro, F., 2004. Conservation Agriculture as a Labour Saving Practice for Vulnerable Households. A Joint Study by IFAD and FAO, FAO Rome.

Carsky, R.J., Tarawali, S.A., Becker, M., Chikoye, D., Tian G., Sanginga, N., 1998. Mucuna – herbaceous cover legume with potential for multiple uses. Resource and Crop Management Research Monograph 25. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Coen, R.M., Eisner, R., 1987. Investment, in J. Eatwell, M. Milgate and P. Newman, eds., The new Palgrave Dictionary of Economics, *vol 2*. Stockson Press, NY.

Defoer, T., Budelman, A., Toulmin, C., Carter, S.E., 2000. Building common knowledge. Participatory learning and action research Part (1). In: Defoer, T., Budelman, A., (Eds.). Managing Soil Fertility in the Tropics: A Resource Guide for Participatory Learning and Action Research, Royal Tropical Institute, Amsterdam, the Netherlands/International Institute for Environment and Development, London, UK, p. 208.

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D.A., Flohrs, A., Riese, J., Lamb, C., Zerfu, E., 2010. In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Improvement. International Food Policy Research Institute (IFPRI) Discussion Paper No. 01041, IFPRI, Washington DC.

Dorward, A., Chirwa, E., 2010. Evaluation of the 2008/9 Agricultural Input Subsidy Malawi: Notes on Regression Analysis of Maize Production. School of Oriental African Studies (SOAS), London.

Ekboir, J., 2010. Learning Organizations That Support Innovation: Mexico's Produce Foundations. http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/8478371-1330712114326/Module1-IAP2.pdf.

Erenstein, O., 1999. The economics of soil conservation in developing countries: The case of crop residue mulching. Wageningen, the Netherlands: Wageningen University.

Erenstein, O., 2003. Smallholder conservation farming in the tropics and subtropics: a guide to the development and dissemination of mulching with crop residues and cover crops. Agriculture, Ecosystems & Environment. 100(1), 17–37.

Erenstein, O., Sayre, K., Wall, P., Hellin, J., Dixon, J., 2012. Conservation agriculture in maize- and wheat-based systems in the (Sub) tropics: lessons from adaptation initiatives in South Asia, Mexico, and Southern Africa. Journal of Sustainable Agriculture. 36, 180-206.

Erenstein, O., Thorpe, W., 2010. Crop-livestock interactions along agro ecological gradients: A meso-level analysis in the Indo-Gangetic Plains, India. Environment, Development and Sustainability.12, 669–689.

FAO, 2007. Conservation agriculture website. http:// www.fao.org/ag/ca/ (accessed April 16, 2007).

FAO, 2001. The Economics of conservation agriculture. Rome: Land Use and Water Development Division, FAO.

FAO, 2012. Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security. Rome, FAO.

Fowler, R., Rockstrom, J., 2001. Conservation tillage for sustainable agriculture: an agrarian revolution gathers momentum in Africa. Soil and Tillage Research 61(1–2), 93–107.

Genius, M., Pantzios, Ch., Tzouvelekas, V., 2006. Information acquisition and adoption of organic farming practices. Journal of Agricultural and Resource Economics. 31(1), 93-113.

Giller, K.E., Witter, E., Corbeels, M., Tittonell, P., 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. Field Crops Research. 114, 23-34.

GoK (Government of Kenya), 2012. National Agricultural Sector Extension Policy (NASEP). Agricultural Sector Coordination Unit (ASCU), Government of Kenya, Nairobi, Kenya.

Hobbs, P., 2007. Conservation agriculture: what is it and why is it important for future sustainable food production? Journal of Agricultural Science. 127-138.

Hobbs, P., Sayre, K. D., Gupta, R. K., 2008. The role of conservation agriculture in sustainable agriculture. Philosophical transactions of the royal society. 363,543-555.

Jack, B. K., 2013. Constraints on the adoption of agricultural technologies in developing countries: Literature Review. Agricultural Technology Adoption Initiative, J-PAL (Massachusetts Institute of Technology) and CEGA (University of California, Berkeley).

Jaleta, M., Kassie, M., Shiferaw, B., 2013. Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. Agricultural Systems. 121, 96–105.

Jaleta, M, Kassie, M., Erenstein O., 2015. Determinants of maize stover utilization as feed, fuel and soil amendment in mixed crop-livestock systems, Ethiopia. Agricultural Systems. 134, 17–23.

Jayne, T.S., Rashid, S., 2013. Input subsidy programs in sub-Saharan Africa: A synthesis of recent evidence. Agricultural Economics. 44*(*6*),* 547–562.

Lohr, L., Salomonsson, L., 2000. Conversion subsidies for organic production: results from Sweden and lessons for the United States. Agricultural Economics. 22, 133-146.

Kahimba, F.C., Mutabazi, K.D., Tumbo, S.D., Masuki, K.F., Mbungu, W.B. 2014. Adoption and scaling-up of conservation agriculture in Tanzania: Case of Arusha and Dodoma Regions. Natural Resources. 5, 161-176.

Kaizzi, C.K., Ssali, H., Nansamba, A., Vlek, P., 2002. The potential, and benefit of velvet bean (mucuna pruriens) and inorganic N fertilizers in improving maize production under soils of different fertility. Policy workshop, 17-19, April 2002 Africana Hotel, Kampala Uganda. Mimeo, Center for Development Research (ZEF) University of Bonn, Germany.

Kassie, M., Teklewold, M., Jaleta, M., Marenya, P., Erenstein, O., Mekuria, M., 2014. Conservation agriculture and improved maize varieties adoption impact on crop income and input use: empirical evidence from Malawi. CIMMYT, Nairobi, Mimeo.

Kaumbutho, P., Kienzle, J., 2007. Conservation agriculture as practiced in Kenya: Two case studies. African Conservation Tillage Network, Centre de Coope´ ration Internationale de Recherche Agronomique pour le De´veloppement, Food and Agriculture Organization of the United Nations, Nairobi, Kenya.

Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy. 32(1), 25-48.

Magnan, N., Larson, D.M., Taylor, J.E., 2012. Stuck on Stubble? The Non-Market Value of Agricultural Byproducts for Diversified Farmers in Morocco. American Journal of Agricultural Economics. 94, 1055-1069.

Marietha, Z.O., Wilfred, L. M., Josef, K., Theodor, F., Amir, K., 2011. Conservation agriculture (CA) in Tanzania: the case of the Mwangaza B CA farmer field school (FFS), Rhotia Village, Karatu District, Arusha. International Journal of Agricultural Sustainability 9(1), 145-152.

Matsumoto, T., Plucknett, D. L., Mohamed, K., 2004. Evaluation of the Sasakawa Global 2000 Program in Ethiopia, *1992-2002*. Sasakawa Africa Association.

Milder, JC, Majanen, T., Scherr, SJ. 2011. Performance and potential of conservation agriculture for climate change adaptation and mitigation in Sub-Saharan Africa. Ecoagriculture Discussion Paper no. 6. Washington, DC: Ecoagriculture Partners.

Mloza-Banda, H.R., 2002. Development and application of conservation agriculture in Malawi's smallholder subsistence and commercial farming systems, in: H.R. Mloza-Banda, W.F. Kumwenda, M. Manda, and M. Bwalya, eds., Proceedings of Workshop on Conservation Farming for Sustainable Agriculture. Lilongwe, Malawi, 20-24 October 2002.

Ndiritu, W. S., Kassie, M., Shiferaw, B., 2014. Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. Food Policy. 49,117-127.

Nyamangara, J., Nyengerai, K., Masvaya. E.N., Tirivavi, R., Mashingaidze, N., Mupangwa, W., Dimes, J., Hove, L., Twomlow, S., 2014. Effect of conservation agriculture on maize yield in the semi-arid areas of Zimbabwe. Experimental Agriculture, doi: 10.1017/ S0014479713000562

Ngwira, A., Johnsen, F.H., Aune, J.B., Mekuria, M., Thierfelder, C., 2014. Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. Journal of Soil and Water Conservation. 69(2), 107-119.

Pablo, S., Precious, G., Kelvin, S., Alexander, L., 2008. *HIV/AIDS,* Climate change and disaster management: Challenges for institutions in Malawi. Policy Research Working Paper

4634. The World Bank Development Research Group, Sustainable Rural and Urban Development Team. World Bank, Washington D.C.

Pannell, D.J., Llewellyn, R.S, Corbeels, M., 2014. The farm-level economics of conservation agriculture for resource-poor farmers. Agriculture, Ecosystems and Environment. 187(1), 2-56

Peterman, A., Behrman, J., Quisumbing, A. R., Nkonya, E., 2010. Understanding complexities surrounding gender differences in agricultural productivity in Uganda and Nigeria. Journal of Development Studies, Forthcoming.

Pye-Smith, C., 2012. Agricultural xtension, a Time for Change: Linking Knowledge to Policy and Action for Food and Livelihoods. Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA). Wageningen, the Netherlands.

Rivera, W.M., Alex, G., 2004. The Continuing role of the public sector in pluralistic extension systems. Proceeding of the association for international agricultural and extension education. AIAEE 20th Annual Conference, Dublin:

Rockstrom, J., Kaumbutho, P., Mwalley, J., Nzabi, A.W., Temesgen, M., Mawenya, L., Barron, J., Mutua, J., Damgaard-Larsen, S., 2009. Conservation farming strategies in East and Southern Africa: yields and rain water productivity from on-farm action research. Soil and Tillage Research. 103, 23–32.

Rusinamhodzi, L., Corbeels, M., van Wijk, M.T., Rufino, M.C., Nyamangara, J., Giller, K.E., 2011. A meta-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. Agronomy for Sustainable Development 31, 657–673.

Ryan, J.G., Spencer, D.C., 2001. Future challenges and opportunities for agricultural R&D in the semi-arid tropics. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 83 pp.

Slavchevska, V., 2015.Gender differences in agricultural productivity: the case of Tanzania. Agricultural Economics. 46(3), 335–355.

Smale, M., Byerlee, D., Jayne, T., 2011. Maize Revolutions in Sub-Saharan Africa. World Bank Development Group, Policy Research Working Paper, No. 5659. World Bank, Washington D.C.

Stonehouse, D. P, 1991. The economics of tillage for large-scale mechanized farms. Soil and Tillage Research.20, 333-351.

The Royal Society. 2009. Reaping the benefits. Science and the sustainable intensification of global agriculture. Royal Society Policy Document 11/09.

Trigo, R.M., Vaquero, J.M., Stothers, R.B., 2010. Witnessing the impact of the 1783-1784 Laki eruption in the Southern Hemisphere. Climatic Change.99, 535-546.

Trigo, E., Cap, E., Malach, V., Villarreal, F., 2009. The case of zero-tillage technology in Argentina, in D.J. Spielman and R. Pandya-Lorch, eds., Proven Successes in Agricultural Development. A Technical Compendium to Millions Fed. International Food Policy Research Institute, Washington D.C.

Uri, N.D., 1997, Conservation tillage and input use. Environmental Geology. 29(3/4), 188–201.

Valbuena, D., Erenstein, O., Homann-Kee Tui, S., Abdoulaye, T., Claessens, L., Duncan, A.J., Gérard, B., Rufino, M.C., Teufel, N., van Rooyen, A., van Wijk, M.T., 2012. Conservation Agriculture in mixed crop–livestock systems: scoping crop residue trade-offs in Sub-Saharan Africa and South Asia. Field Crops Res.132, 175–184.

Yanggen, D., Kelly, V., Reardon, T., Naseem, A., 1998. Incentives for fertilizer us in sub-Saharan Africa: A review of empirical evidence on fertilizer response and profitability. Michigan State University International Development Working Paper, 70.

Zepeda, L., 2001. Agricultural investment, production capacity and productivity, in L. Zepeda, ed., Agricultural Investment and Productivity in Developing Countries. FAO, Rome, 2001.

Tables

Table 1. Policy Simulation Variables

	Ethiopia	Kenya	Malawi	Tanzania	Average
Extension personnel per 10,000 farmers (EFR)					
	16.0	10.0	6.2	4.0	9.0
Period	2010	2012	2008	2010	2008-2012
Source[a]	Davis et al. (2010)	GoK (2012)	Pablo et al. (2008)	Davis et al. (2010)	
Input subsidy expenditure as a percent of public agriculture spending (%) (SER)					
	10.4	19.0	58.9	46.0	33.6
Period	2009-2011	2009-2011	2009-2011	2009-2011	2009-2012
Source	Jayne and Rashid (2013)	Jayne and Rashid (2013)	Jayne and Rashid (2013)	Jayne and Rashid (2013)	

[a]Source: Authors' computations unless otherwise indicated

Table 2. Variable Definitions and Summary Statistics

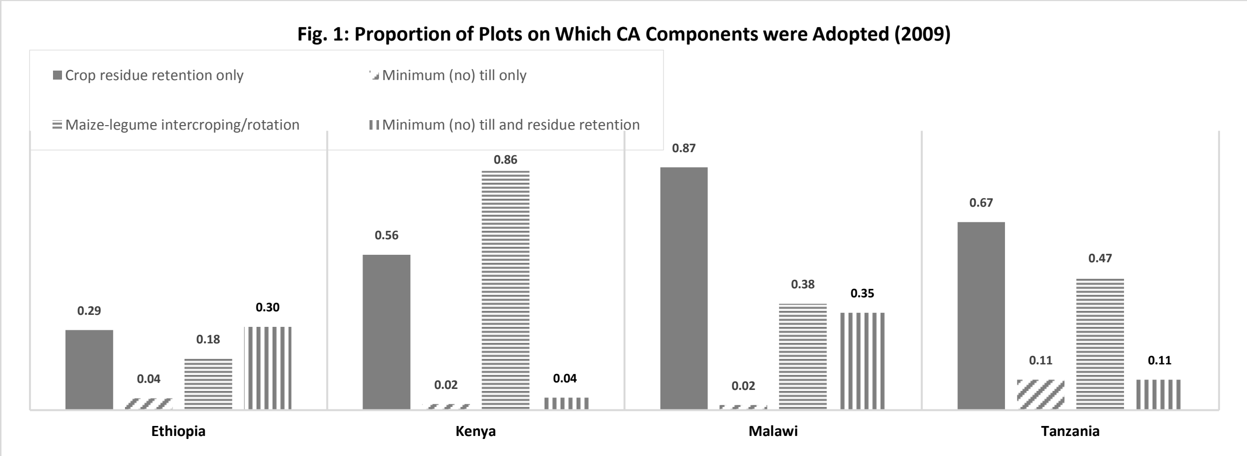
	Pooled (N=11,188)		Ethiopia (N=3,861)		Kenya (N=2851)		Malawi (N=2937)		Tanzania (N=1539)	
Variable Description	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Conservation agriculture practices on plot	0.22	0.41	0.30	0.46	0.05	0.21	0.35	0.48	0.11	0.31
Sex of household head is male (male =1)	0.87	0.33	0.94	0.24	0.82	0.39	0.83	0.37	0.88	0.32
Age of the household head (years)	45.0	14.2	42.5	12.7	50.7	14.3	42.4	14.4	45.9	13.8
Education of the household head (years of schooling completed)	5.21	3.96	3.03	3.33	7.54	3.82	5.73	3.74	5.40	3.16
Main source of income is:										
Crop and livestock farming	0.93	0.26	0.99	0.11	0.77	0.42	1	NA	0.94	0.23
Salaried employment	0.03	0.16	0.01	0.08	0.08	0.27	NA	NA	0.04	0.19
Non-farm self-employment	0.03	0.17	0.00	0.05	0.10	0.30	NA	NA	0.02	0.13
Casual labor	0.02	0.13	0.00	0.05	0.06	0.23	NA	NA	0.002	0.04
Number of family members	5.98	2.56	6.81	2.60	5.85	2.70	5.21	2.17	5.65	2.29
Livestock owned (in Tropical Livestock units (TLU))	4.75	61.19	6.24	5.74	2.40	2.47	0.72	1.74	3.49	7.15
Total farm size cultivated (ha)	2.75	3.12	2.58	1.85	1.32	3.14	3.38	2.60	4.66	4.78
Total non-livestock assets owned by the household in ($)	647	1163	883	1371	740	1134	506	1033	152	507
Household is credit constrained (yes=1)	0.47	0.50	0.56	0.50	0.45	0.50	0.49	0.50	0.26	0.44
Respondent confident in skill and advice of extension provider (yes=1)	0.28	0.45	0.29	0.45	0.26	0.44	0.25	0.43	0.39	0.49
Perceived plot soil fertility is:										0.52
Poor	0.11	0.31	0.07	0.25	0.14	0.35	0.14	0.34	0.08	0.28
Medium	0.50	0.50	0.465	0.499	0.54	0.50	0.39	0.49	0.72	0.45
Good	0.39	0.49	0.468	0.499	0.32	0.47	0.48	0.50	0.20	0.40
Perceived plot slope is:										
Gentle/flat	0.57	0.50	0.67	0.47	0.47	0.50	0.62	0.49	0.39	0.49
Medium	0.37	0.48	0.30	0.46	0.49	0.50	0.27	0.44	0.51	0.50
Steep	0.06	0.24	0.03	0.17	0.04	0.20	0.11	0.31	0.10	0.29
Number of grain traders from outside village known to respondent	4.26	6.20	4.21	5.35	3.52	3.59	6.14	6.04	2.19	10.10
Number of non-relatives from outside the village respondent can rely on for help	4.27	8.30	4.93	10.84	5.98	8.80	2.66	4.00	2.54	4.23
Household head belongs to a farmers' association (cooperatives etc.) 1= yes, 0 otherwise	0.25	0.44	0.20	0.40	0.19	0.40	0.39	0.49	0.25	0.43
Walking minutes to the nearest market	64.79	61.42	47.987	34.67	80.649	54.72	32.69	26.47	138.83	94.36
Drought perceived as a major future risk (yes=1)	NA	NA	NA	NA	0.15	0.36	NA	NA	NA	NA
Pests and diseases perceived as a major future risk (yes=1)	NA	NA	NA	NA	0.15	0.36	NA	NA	NA	NA
High input and low crop prices perceived as a major future risk (yes=1)	NA	NA	NA	NA	0.19	0.39	NA	NA	NA	NA
Personal health or economic situation perceived as a major future risk (yes=1)	NA	NA	NA	NA	0.17	0.38	NA	NA	NA	NA

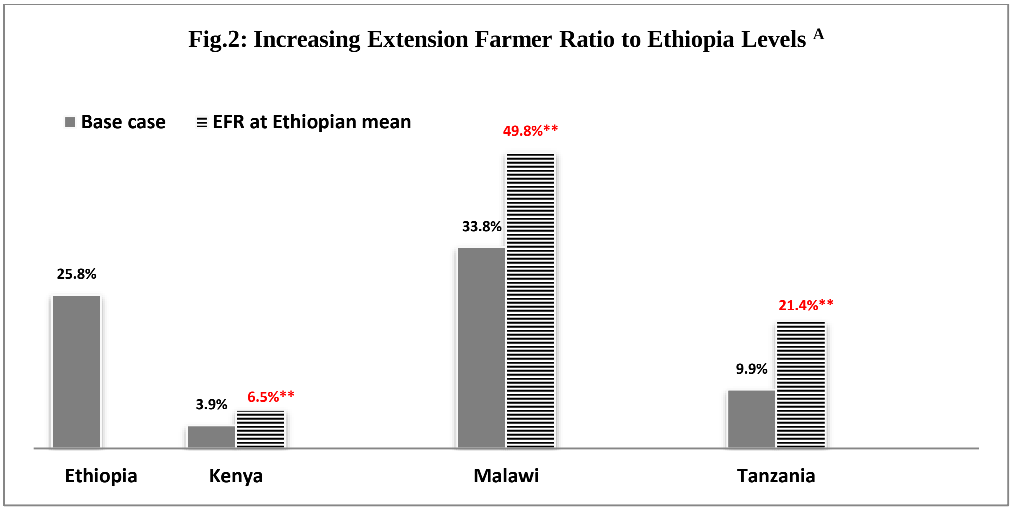
Table 3: Probit Estimate of Factors that Affect Plot Level Adoption of Minimum Tillage in Ethiopia, Kenya, Malawi and Tanzania

VARIABLES	Pooled with country dummies	Pooled with country EFR and SER variables	Ethiopia	Kenya	Malawi	Tanzania
Sex of household head is male (male =1)	0.082*	0.082*	-0.021	0.417***	0.067	0.102
	(0.047)	(0.047)	(0.103)	(0.151)	(0.069)	(0.152)
Age of the household head (years)	-0.001	-0.001	-0.000	-0.000	-0.001	0.004
	(0.001)	(0.001)	(0.002)	(0.004)	(0.002)	(0.004)
Education of the household head (years completed)	0.002	0.002	0.002	-0.031**	0.007	0.020
	(0.004)	(0.004)	(0.007)	(0.014)	(0.007)	(0.017)
Main source of income is:						
Salaried employment (c.f. Farming)	-0.158	-0.158	-0.913**	-0.092		-0.181
	(0.128)	(0.128)	(0.394)	(0.196)		(0.257)
Non-farm self-employment (c.f. Farming)	0.028	0.028	0.015	-0.456**	Not estimated[A]	-0.533*
	(0.126)	(0.126)	(0.516)	(0.206)		(0.289)
Casual labor (c.f. Farming)	0.247*	0.247*	0.55	0.247		Not estimated[A]
	(0.149)	(0.149)	(0.405)	(0.183)		
Number of family members	-0.010*	-0.010*	-0.017*	-0.006	0.000	0.000
	(0.006)	(0.006)	(0.010)	(0.021)	(0.012)	(0.022)
Livestock owned (in tropical Livestock Equivalent (TLU))	-0.000	-0.000	-0.010**	-0.052	-0.000	0.005
	(0.000)	(0.000)	(0.005)	(0.032)	(0.000)	(0.007)
Total farm size in long rain season (ha)	0.008*	0.008*	0.112***	-0.107*	0.003	-0.065***
	(0.005)	(0.005)	(0.014)	(0.059)	(0.008)	(0.020)
Total non-livestock assets owned by the household in USD$	0.000023*	0.000023*	-0.000035*	-0.000162**	0.000089***	0.000023*
	(0.000012)	(0.000012)	(0.000018)	(0.000066)	(0.000025)	(0.000012)
Number of grain traders from outside village known to respondent	-0.004**	-0.004**	-0.007*	0.008	-0.000	-0.059***
	(0.002)	(0.002)	(0.004)	(0.008)	(0.003)	(0.015)
Number of non-relatives outside village respondent can rely on for help	0.005***	0.005***	0.007***	-0.011*	0.005	0.019***
	(0.001)	(0.001)	(0.001)	(0.006)	(0.003)	(0.007)
Household head belongs to a farmers' association (cooperatives etc.) 1= yes, 0 otherwise	0.107***	0.107***	0.613***	0.129	-0.242***	0.166
	(0.033)	(0.033)	(0.055)	(0.123)	(0.052)	(0.113)
Household is credit constrained (yes=1)	-0.218***	-0.218***	-0.267***	-0.219**	-0.062	-0.759***
	(0.029)	(0.029)	(0.046)	(0.096)	(0.049)	(0.144)
Respondent confident in skill and advice of extension provider (yes=1)	0.064**	0.064**	0.097*	0.382***	0.044	0.145
	(0.035)	(0.031)	(0.050)	(0.100)	(0.056)	(0.108)
Medium soil fertility (c.f. poor soil fertility)	0.082	0.082	0.207**	0.437**	0.042	0.548***
	(0.051)	(0.051)	(0.099)	(0.179)	(0.076)	(0.204)
Good soil fertility (c.f. poor soil fertility)	-0.038	-0.038	0.304***	0.553***	-0.337***	0.524**
	(0.051)	(0.051)	(0.100)	(0.187)	(0.075)	(0.218)
Medium sloped plot (c.f. gentle/flat)	0.180***	0.180***	0.343***	0.231**	0.029	0.234**
	(0.032)	(0.032)	(0.050)	(0.100)	(0.056)	(0.103)
Steep sloped plot (c.f. gentle/flat)	-0.199***	-0.199***	-0.089	0.228	-0.136*	-0.854***
Walking minutes to the nearest	-0.001***	-0.001***	0.000	0.000	-0.002**	-0.003***

market						
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Kenya dummy	-1.168***					
	(0.057)					
Malawi dummy	0.359***					
	(0.076)					
Tanzania dummy	-0.669***					
	(0.061)					
Number of extension personnel per 10000 farmers		0.151***				
		(0.007)				
Percent of agricultural budget spent on subsidy		0.055***				
		(0.004)				
Drought perceived as a major future risk (yes=1)				0.266**		
				(0.104)		
Pests and diseases perceived as a major future risk (yes=1)				0.019		
				(0.104)		
High input and low crop prices perceived as a major future risk (yes=1)				-0.018		
				(0.115)		
Personal health or economic situation perceived as a major future risk (yes=1)				0.773***		
				(0.103)		
Constant	-0.080	-3.941***	-0.352*	-1.231***	-0.090	-0.891**
	(0.099)	(0.353)	(0.182)	(0.384)	(0.167)	(0.401)

Figures





[A]In this figure (Fig. 2), and in Fig. 3 - Fig. 7, *, ***, *** denote the difference in probability of MTM adoption between the simulated outcome and the base level was significant at 10, 5 and 1% levels respectively.

Fig. 3: Reducing EFR to Tanzania Level (lowest) and Increasing SER to Malawi Level (Highest)

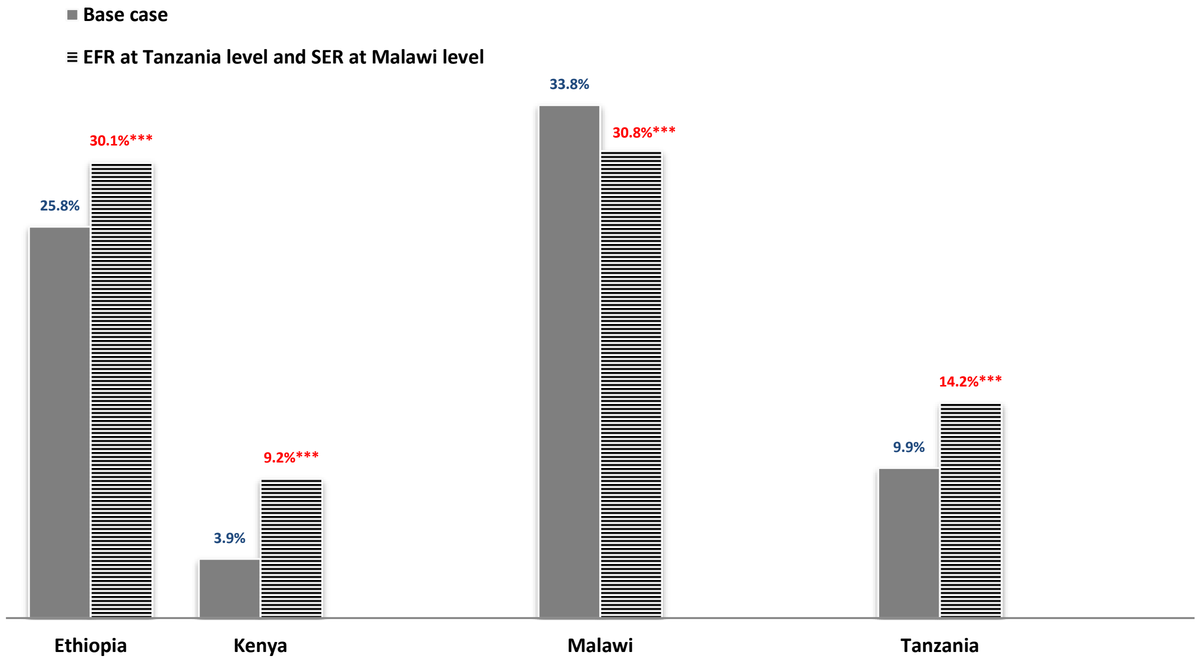


Fig. 4: Effect of Ethiopia's EFR and SER Policies on CA Adoption Kenya, Malawi and Tanzania

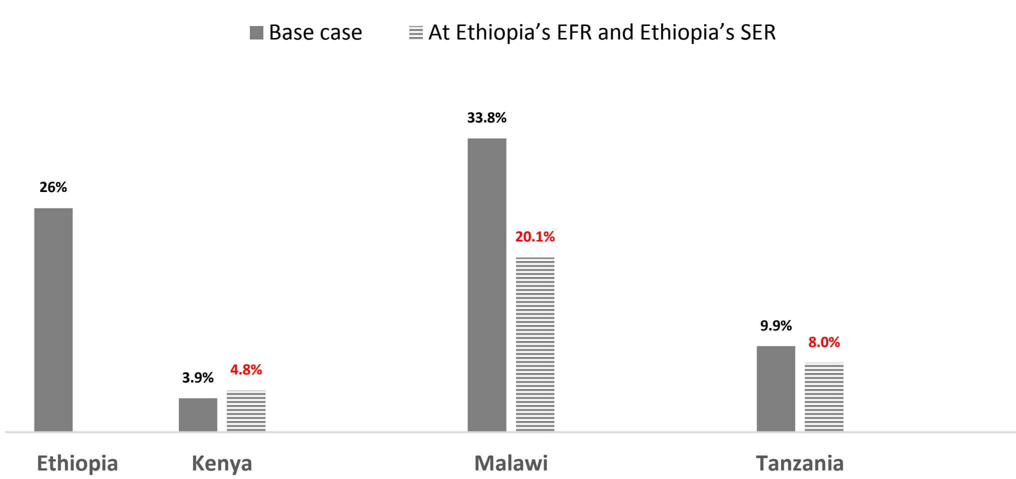


Fig. 5: Efect of High Levels of EFR but no Credit Access on CA Adoption

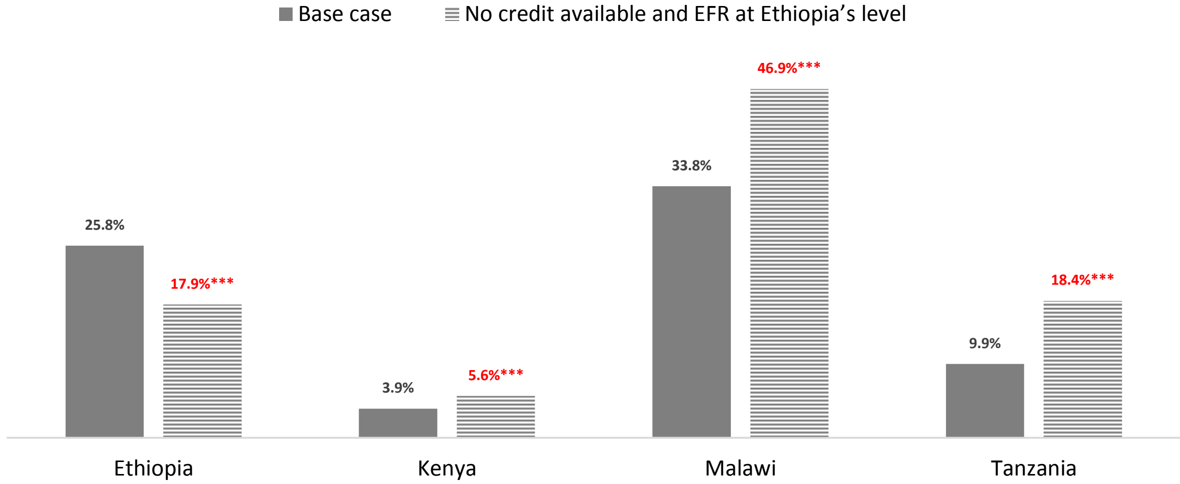


Fig. 6: Increasing SER for for all Countries to Malawi's Level

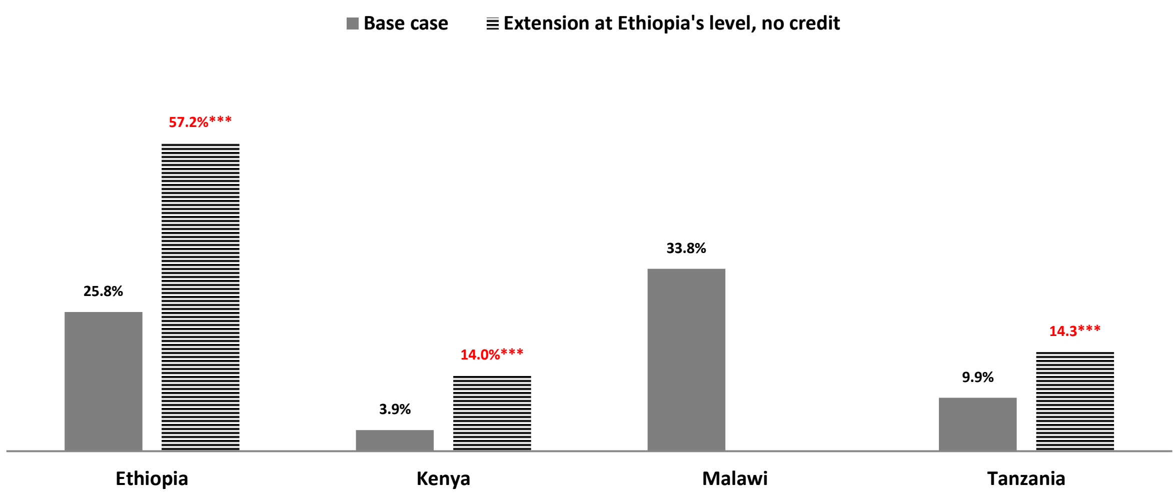


Fig. 7: SER and Credit Availability radeoffs

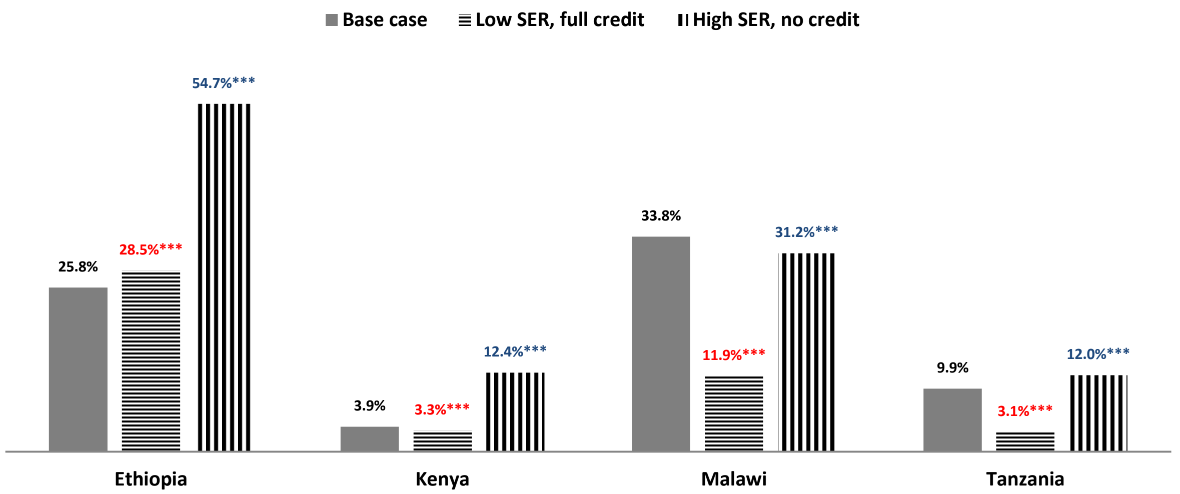


Table A1: Extension Simulations

	Predicted probability of CA Adoption by sample				
	Whole sample	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base case (**A**)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of changing Extension-Staff-to-Farmer-Ratio (EFR): for each country set EFR at Ethiopian level*					
EFR at Ethiopian mean (**B**)	0.214*** (0.019)	NA	0.065*** (0.013)	0.498*** (0.067)	0.214*** (0.057)
Chi-square tests **A=B**	5.47***	NA	4.47**	5.91**	4.10**
Elasticities of adoption wrt EFR **A to B**	0.795	NA	1.111	0.284	0.387
Panel II: *Effect of low EFR and high subsidy (SER): For each country set EFR Tanzania's level and SER at Malawi's level*					
At Tanzania's EFR *and* Malawi's SER (**C**)	0.213*** (0.023)	0.301*** (0.037)	0.092*** (0.029)	0.308*** (0.014)	0.142*** (0.019)
Chi-square tests **A=C**	3.85*	1.31	3.60*	6.50*	5.62*
Panel III: *Effect of high EFR with low SER (keeping both EFR and SER at Ethiopia's level)*					
At Ethiopia's EFR *and* Ethiopia's SER (**D**)	0.129*** (0.015)	NA	0.048*** (0.006)	0.201*** (0.047)	0.080*** (0.015)
Chi-square tests **A=D**	7.22**	1.31	3.61*	7.89*	2.35
Panel IV: *Effect of high extension with complete absence of credit: for each country set credit constraint at 1 and EFR at Ethiopia's level*					
No credit available and EFR at Ethiopia's level (**E**)	0.192*** (0.019)	0.179*** (0.022)	0.056*** (0.011)	0.469*** (0.067)	0.184*** (0.051)
Chi-square tests **A=E**	1.75	12.16***	2.33	4.04*	2.73*

Table A2: Subsidy Simulations

	Predicted probability of CA Adoption by sample				
SER level	**Whole sample**	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base Level (A)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of changing input subsidy as a percent of public expenditure on agriculture (SER): for each country set SER at Malawi's level*					
At Malawian mean (**C**)	0.319*** (0.67)	0.572*** (0.126)	0.140*** (0.057)	NA	0.143** (0.019)
Chi-square tests					
A=B	5.12**	6.38**	3.11*	NA	5.62**
Elasticities of adoption wrt SER					
A to B	1.194	0.261	1.233	NA	1.585
Panel II: *Effect of low subsidy with full credit availability: for each country set SER at Ethiopia's level and credit constraint at 0*					
At Ethiopia's SER *and* no credit constraint (**C**)	0.109*** (0.024)	0.285*** (0.010)	0.033*** (0.006)	0.119*** (0.062)	0.031*** (0.017)
Chi-square tests					
A=C	6.15**	19.3***	2.54	11.83***	17.93***
Panel III: *Effect of high subsidy with no credit available: for each country set credit constraint at 1 and SER =at Malawi's level*					
At Malawi's SER *and* no credit available (**D**)	0.292*** (0.064)	0.547*** (0.126)	0.124*** (0.052)	0.312*** (0.010)	0.120*** (0.017)
Chi-square tests					
A=D	3.80*	5.34*	2.61	20.96***	1.63