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Abstract

Population growth, increasing wealth and changing diets require agriculture in Sub-Saharan Africa to intensify to meet future food demand and ensure food security in the region. Intensification must be sustainable, as agriculture is also an important source of environmental degradation. Conservation agriculture can increase yields in the long run and reduce the negative environmental impacts of intensive farming. In changing the mix of resources used and how they are managed, the adoption of conservation agriculture can have a direct impact on farm labour. This paper studies the effects of conservation agriculture on labour input requirements as it is implemented in five Sub-Saharan African countries. It focuses on the amount of work required and the source of the work employed (household or hired, by gender, by children and by production stage) as well as yields. We apply multinomial endogenous switching regression models on a panel of household and farm data from Ethiopia, Kenya, Malawi, Mozambique and Tanzania. Conservation agriculture increases farms' labour input requirements. Higher demand is driven by more work during the harvesting and threshing stages. Increases in labour requirements are usually met by household labour, not paid work. The workload change is also higher for women than for men, and, in certain cases, met by children. As adopted in these countries, maize yields are not higher under CA. In the short-term, CA needs more labour and does not necessarily increase household's income or food security. In the long-term, higher yields may be possible, but higher labour requirements may become a trade-off against households' opportunity to engage in other off-farm activities.

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1. Introduction

Worldwide, more than 800 million people work in agriculture and around two-thirds of the world's poor are related to the sector. Agriculture is a source of employment, income, food security and economic growth for more than 200 million people who work in agriculture in Sub-Saharan Africa (ILO, 2017). Agriculture is also a source of environmental degradation. More than 20 per cent of global greenhouse gas emissions stem from the agricultural sector (IPCC, 2014). The conversion of natural ecosystems to agricultural land, the improper use of fertilizers, herbicides and pesticides as well as the burning of agricultural residues contribute to GHG emissions, the pollution of other ecosystems, erosion, eutrophication and biodiversity loss. Conventional agricultural practice also reduces carbon matter in the soil, degrading soil quality and threatening future productivity (Tilman et al., 2002).

The projected increase in food demand, due to population growth, increased wealth and dietary changes (Alexandratos & Bruinsma, 2012), requires the intensification of agricultural production, but this cannot be sustainably achieved with conventional agricultural practices (Pingali, 2012; Swaminathan & Kesavan, 2017). Conservation agriculture (CA) has been proposed as an environmentally sustainable method to intensify agriculture production systems (United Nations Food and Agriculture Organization [FAO], 2011, 2015). CA involves minimum tillage, crop diversification and maintaining a soil cover with crop residues or other crops. Implemented together, these practices help maintain soil quality, reduce water consumption and increase the carbon capture capacity of the soil (Johansen et al., 2012).

Minimum or no-tillage limits the harmful effects of conventional tillage. Conventional tillage reduces soil quality because it reduces the soil's organic matter, it lowers its water holding capacity, increases its susceptibility to erosion, reduces the soil's ability to release nutrients in synchrony with crop demand, and lowers the density of microorganisms and fauna which improve the soil's physical properties. Regular tillage may also cause the creation of a hardpan at the bottom of the cultivated layer and increases evaporation from the soil surface, exposing seedlings to water stress (Johansen et al., 2012).

When combined with minimum tillage, maintaining a permanent organic soil cover from crop residues produces a layer of mulch that protects the soil from physical impacts of the sun, rain and wind, and that stabilizes soil moisture and temperature. The top layer also feeds soil biota and provides a "biological tillage" that replaces the functions of conventional tillage (FAO, 2001). The mulch becomes a living habitat for a number of organisms and performs a buffer function that enhances the soil's water and nutrient retention.

The third pillar of CA is crop diversification through crop rotation or intercropping. Crop rotation interrupts the infection chain between subsequent crops and makes full use of the physical and chemical interactions between different plant species (FAO, 2001). Intercropping reverses the negative effects of monoculture and allows plant roots to grow at different soil depths and absorb nutrients from different soil layers. When combined with minimum tillage and residue retention, crop diversification could work as an integrated pest management practice and improve the soil's nutrient content.

In addition to the environmental and agronomic benefits, crop yields are generally higher under CA, at least in the long run (Friedrich et al., 2017; Johansen et al., 2012; Knowler & Bradshaw, 2007; Lalani et al., 2017; Pannell et al., 2014). Studies from farmers' field experiments and farm surveys show higher yields under CA across diverse agro-ecologies for a variety of crops in Sub-Saharan Africa, including Ethiopia (Araya et al., 2011; Zerihunet al., 2014), Malawi (Ngwiraet al., 2012; Nyagumbo et al., 2016), Western Africa (Bayala et al., 2012) and Zambia, (Abdulai, 2016). Using farm survey data, Lalani et al. (2017) find that benefits could also extend to the poorest group of farmers for a variety of crop mixes and risk levels.

However, increased yields are not always guaranteed under CA. Yield benefits often depend on a variety of factors and the combined implementation of different practices (Nyamangara et al., 2014; Thierfelderet al., 2015; Zheng et al., 2014). Yield increases are often realized when CA is practiced for several years (Rusinamhodzi et al., 2011) because it takes time for soil quality to improve and farmers to gain experience implementing CA. Moreover, successful CA adoption in developing countries is usually accompanied by the addition and correct management of external inputs such as fertilizers, pesticides, herbicides and improved seed varieties (Giller et al., 2009), as well as the investment in special machinery and skills (Johansen et al., 2012).

CA is currently practiced in over 125 million hectares, around 9 per cent of worldwide arable land. Initially adopted rapidly in certain countries in Latin America, CA has also expanded across farms in Australia, Canada and the United States. CA is also practiced in the Arctic Circle, the tropics and the Southern extremes, at sea level and at 3,000 meters of altitude, in extremely rainy and extremely dry areas (Friedrich et al., 2017). Several organizations promote its adoption in Sub-Saharan Africa, owing to its applicability and observed benefits across different climates, soil types, crops and farm characteristics.[1]

CA alters how agriculture is carried out, potentially changing the amount of labour required across different production stages (e.g. land preparation, weed control, harvesting and threshing). In minimizing tillage, the amount of labour required in the early stages of the growing season (e.g. land preparation) may be lower (Baker & Saxton, 2007; FAO, 2001), but may increase labour requirements in the following stages (e.g. weed control if the same herbicides are used) (Erenstein, 2002; Pannell et al., 2014). In producing higher yields, CA may also increase the labour required in the harvesting and threshing stages (Farnworth et al., 2016).

If some of these activities which increase in importance under CA are predominantly carried out by women, then CA can alter the gender balances in agricultural work. If CA requires more work and this work is spread out relatively evenly across each stage, then household labour can meet the increased demand for work, potentially affecting households' possibilities to earn income from non-farm activities. If the increased labour demand is concentrated in a few days, it may require the hiring of external workers or engaging children in farm activities. Importantly, as noted above, the benefits of CA are contingent on a learning period and the implementation and adequate management of complementary practices like improved seed varieties, chemical inputs and specialized machinery. Their use will necessarily affect how and when CA increases or reduces the demand for labour.

Little attention has been given to how CA impacts the requirement and distribution of labour in Sub-Saharan Africa. Teklewold et al. (2013) is one exception. They explore CA's labour outcomes in Ethiopia by considering the three components of CA and the adoption of improved seed varieties. The

[1] CA is promoted as a sustainable alternative to conventional agriculture by development and non-governmental organizations and some private firms in the agricultural input sector. The United Nations Food and Agriculture Organization (FAO) has promoted CA since the 1990s (see, for example, FAO, 2001, 2011, 2015). The World Bank promotes it in the context of climate-smart agriculture. Organizations like CABI (e.g. Baker & Saxton, 2007) and CIMMYT (e.g. Thierfelder & Siamachira, 2016) promote it, as do large agricultural input firms like Monsanto and John Deer (Ekboir, 2013).

study evaluates the impacts of conservation tillage (which refers to either reduced tillage or zero tillage combined with residue retention), improved maize variety and crop diversification on household income, agrochemical use and demand for labour. They find that minimum tillage adopted in isolation actually increased labour demand when compared to conventional agriculture, but the impact on labour demand became statistically insignificant when minimum tillage is combined with crop diversification. Indeed, the specific availability of machinery, chemical inputs and skills in Sub-Saharan Africa may result in CA having different effects on labour requirements than those observed in other regions or in experimental studies.

International and non-governmental organizations have used potential labour savings, higher yields and higher profits as a way enhance the attractiveness of CA and promote its adoption (Knowler & Bradshaw, 2007).[2] These effects, however, may not apply to Sub-Saharan Africa. The labour-saving assumption is largely based on the claim that minimizing tillage lowers the demand for work during land preparation but has not been tested against the other different practices associated with CA, their effect across different production stages or their effect in the specific Sub-Saharan African context. Moreover, the labour-saving effects on profits only takes place when a large part of labour is sourced from hired labour, as opposed to household labour. Finally, any effects on profits may not accrue if yields are not higher under CA.

This paper addresses the question of how CA affects the need for work and the distribution of this work in Eastern and South Africa. It analyses longitudinal farm data from Ethiopia, Kenya, Malawi, Mozambique and Tanzania, exploring how the impacts on work differ by the source of the work carried out (by gender, household work or paid work, by children). It takes into account the different ways farmers adopt CA, by looking at each CA practice individually and in combinations. Unlike the few papers studying CA's impact on work requirements in Sub-Saharan Africa, this paper takes into account the way CA affects labour requirements across the different production stages in the season (land preparation, weeding, harvesting, and threshing).

Our results suggest that, as applied in these countries, and contrary to findings that focus only on one aspect of CA and one production stage, CA increases labour requirements, which are met with farm labour (not by hired labour), with implications for the gender distribution of work and for child labour. CA, as currently implemented in these countries, does not seem to reduce farmers' possibility to earn off-farm income.

The following section provides more detail on the data and empirical strategy adopted.

[2] See, for example, Li et al., 2014; and Li and Li, 2012, both used as training material by the United Nations Food and Agriculture Organization.

2. Data

This paper uses longitudinal data for Ethiopia, Kenya, Malawi, Mozambique and Tanzania from the International Maize and Wheat Improvement Center (CIMMYT)'s *Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa* (SIMLESA) program. SIMLESA selected villages/communities to represent maize-based farming systems in Eastern and Southern Africa and randomly surveyed households in 2010 and 2013 using a standardized household questionnaire (small variations were added in the questionnaire to customize to local conditions like currency or crop names) (Muricho et al., 2017 provide detailed information about the survey).

Several farming practices are surveyed in SIMLESA, including whether each of the household's plots adopts intercropping, minimum tillage or leaving crop residue on the field. These practices have been previously used to assess CA adoption and its impacts (e.g. Abdulai, 2016; Kassie et al., 2015; Kassie et al., 2015a; Manda et al., 2016; Teklewold et al., 2013). For each plot, we identify whether it adopts each CA practice in isolation or in combination with other practices, including the adoption of all three practices as a full package.

In addition to questions on farming practices, the survey provides information on the number of person days worked on each plot. Labour information is provided by gender and, in 2013, by children or adults and by household members or hired workers. Yields per plot, in kilograms by hectare, distinguish between maize and legume. As legumes are a heterogeneous category, in this paper we only use the information of plots planting maize to explore CA's impact on labour outcomes and yields. We convert labour use and yields to person work days per hectare and kilograms per hectare, respectively.

We use plot level characteristics available in the survey, such as soil fertility, soil depth, soil slope, plot ownership, plot distance to residence, and the use of improved seed varieties and chemical inputs (fertilizers, pesticides, herbicides and manure) to account for heterogeneity in CA impacts. In addition, we draw on household-level information on demographic characteristics, resource constraints, social network, access to markets, and the amount of livestock owned. The survey also provides information on the household's income from off-farm activities. Measured in local currency, we convert them to 2010 US Dollars.

Following other research that measures the impact of CA using panel data, we analyze plot level information, controlling for household characteristics over time (e.g. Khonje, Manda, Mkandawire, Tufa & Alene, 2018; Kassie et al., 2017). In particular, we conduct a balanced panel of maize farming households and unbalanced pool of maize plots over the two survey rounds. To take advantage of the variability in the dataset, and given that some CA practices are adopted with a relatively low frequency, we pool the individual country samples into one, full, panel sample.

The majority (82 per cent, 2,984 households) of the 3,617 households surveyed in 2010 were resurveyed in 2013.[3] Attrition is explained by household migration, separation or the unavailability of the household's head due to hospitalization, death, travel or him/her not being located within their villages (Muricho et al., 2017). A large source of attrition is due to the survey dropping a district in Mozambique

[3] A third wave of the survey was carried out in 2015, but the complete dataset including income, household and farm characteristics and labour requirements was not yet available when this paper was written in March, 2018.

(125 households) due to civil strife in 2013. There is little concern for attrition bias: we compare summary statistics of the samples with and without attrition in 2010 and 2013 and observe that they are relatively balanced, especially in terms of CA adoption choices (see Supplementary Materials, Tables S1 and S2).

3. Empirical strategy

We estimate models to predict the effect of households' CA adoption on the number of days worked in a plot per hectare of land. We estimate different models to explore the effect on overall days worked per hectare of land owned by the household, the days per hectare worked by men and women, by children, by household members, and by hired labourers. We also estimate models on overall days worked per hectare by production stage (land preparation, weeding, harvesting, threshing), on the household's income earned from off-farm sources, and maize yields in kilograms per hectare of land. We account for time-invariant endogeneity using the Mundlak device (Mundlak, 1978); we estimate effects that control for selection bias using multinomial endogenous switching regression models (MESR); and use the counterfactual framework to calculate the average treatment effects on the treated to estimate the impact of CA adoption on each of our dependent variables. We account for country-level differences by including country-fixed effects in all models. We describe the Mundlak device, MESR and the counterfactual framework in detail below.

3.1 Mundlak device

The Mundlak (1978) device controls for the time-invariant heterogeneity across households. As implemented by other studies on CA using SIMLESA, the Mundlak device is preferable to panel fixed-effects in cases of little variation within units over time and in cases where time-invariant observables affect both adoption decisions and outcomes, as is the case of households in SIMLESA in 2010 and 2013. Using panel fixed-effects would reduce the explanatory power of the models. The Mundlak device consists of estimating random-effects regression models and adding the mean of observable time-variant regressors. The underlying assumption is that the mean of observable time-variant variables is correlated with, and can be used as proxy for, unobserved time-invariant components (Mundlak, 1978; Semykina & Wooldridge, 2010).

3.2 Multiple endogenous switching regression

Sub-Saharan African farmers' decision to adopt CA is not random. Gender, age and education of the household head, as well as household size affect whether households adopt CA. Adoption decisions have also been shown to be influenced by household resource constraints, number of livestock, self-assessed food security, and social network such as kinship, number of trusted traders and membership in informal and formal rural institutions. Farm characteristics such as plot size, plot distance from residence, land ownership, soil fertility, and soil slope and soil depth also play important roles in determining adoption (Kassie et al., 2015; Knowler & Bradshaw, 2007).

These factors that determine CA adoption are also likely related to the amount and type of work required in the farm (Bryan et al., 2013; Di Falco & Bulte, 2013; Kassie et al., 2015; Knowler & Bradshaw, 2007; Manda et al., 2016; Teklewold et al., 2013). Estimating the relationship between CA adoption and labour outcomes by including CA practices as a set of dummy variables in a regression will yield biased estimators as a result of this selection effect.

As is common in other studies measuring CA adoption's impact on plot level outcomes, we use MESR to correct for selection bias and to treat CA practices adopted separately and in combinations.[4] The MESR model is a two-stage procedure that calculates selection correction terms in a first stage and includes them in a second stage to estimate unbiased regression coefficients. MESR also enables us to identify the complementary effects between specific CA practices, since the simultaneous adoption of two practices could result in different outcomes when compared to the addition of the effects of each practice adopted in isolation, as MESR accounts for changes to the slope effects (rather than just the intercept effect) through the estimation of different models for each CA practice (Di Falco & Veronesi, 2013; Kassie et al., 2017; Kassie et al., 2015; Teklewold et al., 2013).

The first MESR stage estimates the selection term using a multinomial logit model. It estimates a household *i*'s likelihood of adopting CA practice *j* in their plot *k* (with *j* =0, 1, 2… 7 for each CA practice and their combinations).

$$\boldsymbol{Probability}\left(J = j \middle| X_{itj}, H_i, W_{iktj}\right) =$$

$$P_{iktj} = \frac{exp\left(\alpha_j + X_{itj}\beta_j + W_{iktj}\delta_j + H_i + \epsilon_{iktj}\right)}{\sum_{m=1}^{J} exp(\alpha_m + X_{itm}\beta_m + W_{imkt}\delta_m + H_i + \epsilon_{iktm})} \tag{1}$$

In our models, *j* = 0 (no adoption) is the reference category. X_{itj} includes observables at the household level that affect adoption decisions and a time dummy. W_{iktj} includes observables at the plot level that affect adoption decisions. H_i includes unobservable household time-invariant effects. ϵ_{itj} is the stochastic shock with expected mean zero. Following the Mundlak device, we include the household level mean $\overline{X}_i$ as a proxy for H_i.

The second stage model estimates the impact of each CA practice (individually and in combination) on labour, off-farm income and yield impacts. We estimate eight outcome equations, one for non-adopters and one each for households that adopt each CA practice and their combinations.

$$\begin{cases} CA\ 0: Y_{ikt0} = \theta_0 + Z_{it0}\omega_0 + V_{ikt0}\varphi_0 + H_{i0} + \mu_{ikt0} \\ CA\ 1: Y_{ikt1} = \theta_1 + Z_{it1}\omega_1 + V_{ikt1}\varphi_1 + H_{i1} + \mu_{ikt1} \\ \cdots \\ CA\ 7: Y_{ikt7} = \theta_7 + Z_{it7}\omega_7 + V_{ikt7}\varphi_7 + H_{i7} + \mu_{ikt7} \end{cases} \tag{2}$$

Y_{iktj} is the labour, off-farm income or yield outcome for household *i's* plot *k* at time *t* that adopts CA option *j*. θ_j is an intercept term for CA practice *j*. Z_{itj} is a set of covariates at the household level that affects each outcome and a time dummy variable for the survey year. V_{iktj} contains a set of plot level covariates that affects the labour outcome (e.g. plot characteristics and chemical inputs). The household level means for Z_{ij}, $\overline{Z}_{ij}$ are used as a proxy for H_{ij}. Following standard practice for two-stage regressions, all exogenous variables in the second stage (V_{iktj} and Z_{itj} in equation (2)) are included in the first stage

[4] A Chow test shows that coefficients are not the same across different CA practices and their combinations, supporting our identification strategy. See Table S3 in the Supplementary Materials for the test results.

(as part of X_{itj} and W_{iktj} in equation (1)).

We follow Bourguignon, Fournier and Gurgand (2007) to estimate the selection correction term, γ_{iktj}, from equations (1) and (2):

$$\boldsymbol{\gamma_{iktj}} = \sum_{m \neq j}^{J} \boldsymbol{\rho_j} \left[\frac{\boldsymbol{P_{iktm}} \ln(\boldsymbol{P_{iktm}})}{1 - \boldsymbol{P_{iktm}}} + \ln(\boldsymbol{P_{iktj}}) \right] \tag{3}$$

ρ_j is the correlation coefficients between the error terms of the first and second stage equations (ϵ_{iktj} and μ_{iktj}). This is an updated Dubin and McFadden estimate for γ_{iktj} which provides a good selection-bias correction for the outcome equation even when the independence of irrelevant alternatives assumption is violated. In our model, a farmer's decision to select CA practice j depends on the selection probability of j itself and the selection probability of the other alternatives ($m \neq j$).

We re-estimate the second stage MESR model with the vector of selection terms γ_{iktj} from equation (3):

$$\begin{cases} \boldsymbol{CA\ 0}: \boldsymbol{Y_{ikt0}} = \boldsymbol{\theta_0} + \boldsymbol{Z_{it0}} \boldsymbol{\omega_0} + \boldsymbol{V_{ikt0}} \boldsymbol{\varphi_0} + \widehat{\boldsymbol{\gamma_{ikt0}}} \boldsymbol{\tau_0} + \boldsymbol{time} * \widehat{\boldsymbol{\gamma_{ikt0}}} \boldsymbol{\pi_0} + \boldsymbol{H_{i0}} + \boldsymbol{\varepsilon_{ikt0}} \\ \boldsymbol{CA\ 1}: \boldsymbol{Y_{ikt1}} = \boldsymbol{\theta_1} + \boldsymbol{Z_{it1}} \boldsymbol{\omega_1} + \boldsymbol{V_{ikt1}} \boldsymbol{\varphi_1} + \widehat{\boldsymbol{\gamma_{ikt1}}} \boldsymbol{\tau_1} + \boldsymbol{time} * \widehat{\boldsymbol{\gamma_{ikt1}}} \boldsymbol{\pi_1} + \boldsymbol{H_{i1}} + \boldsymbol{\varepsilon_{ikt1}} \\ \cdots \\ \boldsymbol{CA\ 7}: \boldsymbol{Y_{ikt7}} = \boldsymbol{\theta_7} + \boldsymbol{Z_{it7}} \boldsymbol{\omega_7} + \boldsymbol{V_{ikt7}} \boldsymbol{\varphi_7} + \widehat{\boldsymbol{\gamma_{ikt0}}} \boldsymbol{\tau_7} + \boldsymbol{time} * \widehat{\boldsymbol{\gamma_{ikt7}}} \boldsymbol{\pi_7} + \boldsymbol{H_{i7}} + \boldsymbol{\varepsilon_{ikt7}} \end{cases} \tag{4}$$

We also interact the predicted γ_{iktj} with the time dummy variable to capture changes in the selection effect over time. Standard errors are bootstrapped to account for the heteroscedasticity that results from estimating the second-stage estimated from generated regressors.

We use the exclusion restrictions from Khonje et al. (2018) as selection instruments in the first stage so that the selection procedure does not come solely from the non-linearity of the multinomial logit estimation. These exclusion restrictions are included in X_{itj} and W_{iktj} but excluded in V_{iktj} and Z_{itj} because exclusion restrictions are expected to affect outcome variables only through the channel of CA adoption. Our exclusion restrictions include access to improved agricultural technology information, number of government extension contacts, number of NGO extension contacts, and household walking distances to main (output) market and seed (input) market. A falsification test (as used in Di Falco et al., 2011) shows that the exclusion restrictions significantly affect the adoption decisions but not directly affect the outcomes (see Table S4 in the Supplementary Materials for the falsification test results).

3.3 Counterfactual and expected observed adoption effects

In addition to selection and time-invariant heterogeneity, household and plot time-variant heterogeneity can also bias the estimates (Di Falco et al., 2011; Kassie et al., 2015; Teklewold et al., 2013). We use the counterfactual framework to overcome this bias and calculate the average treatment effect on the treated (ATT) by comparing CA-adopted plots' expected labour outcomes to those as if the plots would not have been implemented with CA (counterfactual outcomes). This framework is common in the impact evaluation literature, including measurements of the impacts of agricultural technologies (Kassie et al., 2017). The ATT captures the impact of CA on labour, off-farm income and yield outcomes controlling for household and plot time-variant heterogeneity.

The expected (actual) outcome for adopted plots is estimated as:

$$\begin{cases} E[Y_{ikt1} | \, j=1] = \theta_1 + Z_{it1}\omega_1 + V_{ikt1}\varphi_1 + \widehat{\gamma_{ikt1}}\tau_1 + time * \widehat{\gamma_{ikt1}}\pi_1 + H_{i1} \\ E[Y_{ikt2} | \, j=2] = \theta_2 + Z_{it2}\omega_2 + V_{ikt2}\varphi_2 + \widehat{\gamma_{ikt2}}\tau_2 + time * \widehat{\gamma_{ikt2}}\pi_2 + H_{i2} \\ \dots \\ E[Y_{ikt7} | \, j=7] = \theta_7 + Z_{it7}\omega_7 + V_{ikt7}\varphi_7 + \widehat{\gamma_{ikt7}}\tau_7 + time * \widehat{\gamma_{ikt7}}\pi_7 + H_{i7} \end{cases} \quad (5)$$

The expected outcome for adopted plots had they not been adopted (counterfactual outcome) is estimated as:

$$\begin{cases} E[Y_{ikt0} | \, j=1] = \theta_0 + Z_{it1}\omega_0 + V_{ikt1}\varphi_0 + \widehat{\gamma_{ikt1}}\tau_0 + time * \widehat{\gamma_{ikt1}}\pi_0 + H_{i1} \\ E[Y_{ikt0} | \, j=2] = \theta_0 + Z_{it2}\omega_0 + V_{ikt2}\varphi_0 + \widehat{\gamma_{ikt2}}\tau_0 + time * \widehat{\gamma_{ikt2}}\pi_0 + H_{i2} \\ \dots \\ E[Y_{ikt0} | \, j=7] = \theta_0 + Z_{it7}\omega_0 + V_{ikt7}\varphi_0 + \widehat{\gamma_{ikt7}}\tau_0 + time * \widehat{\gamma_{ikt7}}\pi_0 + H_{i7} \end{cases} \quad (6)$$

The difference between the actual and counterfactual expected outcomes in equation (7) (the difference between equations (5) and (6), for each *j*) is the average treatment effect on the treated (ATT). It is the estimated impact of the adoption of a particular CA practice, controlling for unobserved endogeneity. As these estimates draw on the MESR, they also control for selection bias.

$$\begin{cases} ATT_{j=1} = E[Y_{ikt1} | \, j=1] - E[Y_{ikt0} | \, j=1] \\ ATT_{j=2} = E[Y_{ikt2} | \, j=2] - E[Y_{ikt0} | \, j=2] \\ \dots \\ ATT_{j=7} = E[Y_{ikt7} | \, j=7] - E[Y_{ikt0} | \, j=7] \end{cases} \quad (7)$$

4. Results

4.1 Descriptive results

Table 1 shows the percentage of maize plots implemented with CA practices in 2010 and 2013. These are the plots belonging to households that participated in both the 2010 and 2013 surveys. In 2013, residue retention and intercropping (individually or in combination) were the most common CA practices adopted, with 19.9 per cent of plots adopting residue retention, 18.0 adopting intercropping and 15.9 adopting both. The adoption of minimum tillage was comparatively low (2.2 per cent independently, 1.3 per cent in combination with intercropping and 2.0 per cent in combination with residue retention). Adoption of the full CA package remained low, at only 1.6 per cent of total plots surveyed. Overall, between 2010 and 2013, the share of plots that did not adopt any CA practice increased from 27.1 to 39.1 per cent.[5]

Table 1: CA practice adoption at the plot level in 2010 and 2013, percentages

CA practice	2010	2013
No adoption	27.1	39.0
Intercropping	11.5	18.0
Residue retention	30.2	19.9
Minimum tillage	0.3	2.2
Intercropping + residue retention	25.8	15.9
Intercropping + minimum tillage	0.6	1.3
Residue retention + minimum tillage	2.4	2.0
Full package	2.1	1.6
N	*5,358*	*5,305*

Note: Only maize plots belonging to households that participated in both the 2010 and 2013 surveys are included in the calculations.
Source: Own calculation based on SIMLESA.

Table 2 provides summary statistics for variables at the household level in the 2013 sample, by CA adoption (results for the 2010 sample with no attrition are available in Table S5 in the Supplementary Materials). The majority of households (86 per cent) were headed by men, the average household head was 48 years old and had more than 5 years of education. Households that adopted CA tended to be headed by older members with more education than households that did not adopt CA. Household size, defined by the total number of children and adults within each household, averaged at around 6 members.

[5] Of the 3,002 households in both the 2010 and 2013 surveys, 2,404 households adopted at least one CA practice in one of their plots in 2010. Of those that adopted at least one CA practice in 2010, 1,838 households continued to practice at least one CA practice in 2013 (76 per cent) while 566 households dis-adopted all CA practices (24 per cent). We run logit and probit regressions using 2013 data for the 2,404 households to see the characteristics that predict CA dis-adoption. Land tenure and access to information are significantly and negatively correlated with dis-adoption while soil depth and plot size are significantly and positively correlated with dis-adoption. Results are reported in the Supplementary Materials Table S7. Other research on dis-adoption of agricultural technology point to important factors which are not covered in the SIMLESA dataset, such as discontinuation of NGOs support or the previous year's rainfall (Neill & Lee, 2001; Pedzisa, Rugube, Winter-Nelson, Baylis, & Mazvimavi, 2015).

Table 2: Household characteristics descriptive statistics, 2013

	No adoption	Adoption at least 1 CA	Intercrop	Residue retention	Min. tillage	Intercrop+ residue retention	Intercrop + min. tillage	Residue+ min. tillage	Full package	All sample
HH head male (%)	90	84	86	85	92	80	89	84	83	86
HH head age (years)	46	49	51	47	46	50	51	50	50	48
HH head education (years)	5.21	5.72	6.43	4.82	5.31	6.18	6.28	5.58	4.69	5.52
HH size (number)	6.48	6.18	6.38	6.18	5.72	6.15	5.62	5.63	5.93	6.30
Asset (US$)	10113	16560	16371	17709	25929	14688	29663	6221	12052	14044
Food secured (%)	80	84	85	82	79	85	85	84	81	82
Credit constraint (%)	78	79	79	82	64	80	69	61	71	78
Livestock (TLU)	8.24	5.52	5.51	5.65	5.26	5.50	4.51	4.96	6.13	6.58
Land owned (ha)	6.25	6.30	5.88	8.65	3.14	3.72	13.49	9.31	2.02	6.28
Salaried income (US$)	151	196	247	108	90	302	127	73	26	179
Farm wage income (US$)	23	59	76	38	43	52	91	56	194	45
Nonfarm wage income (US$)	31	48	49	30	26	79	42	35	19	42
Nonfarm business income (US$)	173	285	294	211	248	371	291	324	216	241
Information access (%)	86	71	73	71	69	71	65	55	49	76
Kinship (number)	15.46	13.26	13.32	12.52	15.02	13.20	20.69	10.43	17.28	14.12
Trusted traders (number)	6.65	6.94	7.29	6.36	7.03	7.15	7.94	6.80	7.25	6.83
Rely on govt support (%)	71	59	62	61	64	55	52	50	40	64
Confident on govt staff (%)	79	75	81	72	78	74	68	67	61	76
Member of an institution (%)	84	95	95	94	89	98	100	95	98	91
Contacts govt extension (number)	67.83	31.91	34.35	32.16	93.78	23.12	10.42	28.23	24.86	46.00
Contacts NGOs extension (number)	1.25	4.60	4.08	5.42	1.42	5.00	1.25	7.06	0.87	3.29
Distance to market (minutes)	104.64	109.23	98.29	116.86	108.83	110.97	103.23	116.00	115.41	107.43
Distance to seed dealer (minutes)	73.55	94.51	77.39	106.35	93.90	95.88	95.14	110.66	104.67	86.34
N	*2,070*	*3,235*	*952*	*1,056*	*118*	*854*	*71*	*106*	*87*	*5,305*

Note: Adoption identifies the plots that adopted at least one CA practice (intercropping, residue retention, minimum tillage or a combination of the three). Full package identifies the plots that were implemented with the three practices simultaneously. Currency values are in 2010 US$. Results for 2010 available in the Supplementary Materials Table S6.
Source: Own calculation based on SIMLESA.

Household resource constraints include assets, self-assessed food security and credit constraints. Assets were, on average, higher among adopting households than non-adopting households. More than 80 per cent of the households considered themselves as food secure. Consistent with findings on resource constraints in developing countries, a large majority of households surveyed (78 per cent) reported not having their credit needs met in 2013. Livestock owned is measured in tropical livestock units (TLU) and was higher, on average, for non-adopters than for CA adopters. Land owned averaged 6 hectares per household, reflecting the small scale structure of farms in the five surveyed countries.

Off-farm income includes income from different sources other than household farming, including salaried wage, casual farm wage, casual non-farm wage, and self-owned nonfarm business income. Summary statistics show that off-farm income was lower in 2013 among non-adopting households than adopted households.

Other characteristics included in Table 2 have been shown to be related to CA adoption and/or the productivity of the farm. More than three quarters of the households surveyed (76 per cent) had access to information on agricultural technology through extension services in 2013. Social network includes the number of relatives living in and outside of the village, number of trusted grain traders, reliance on government support when crop fails, and confidence on government extension staff. A majority of households surveyed were members of some rural institution. Though the majority of both CA adopters and non-adopters were members of a rural institution, membership was slightly higher among adopters. The number of contacts with government extension staff was higher among non-adopters.

Table 3 provides summary statistics for variables at the plot level, by CA practice adopted in the 2013 sample (statistics for the 2010 are reported in Table S6 in the Supplementary Materials). Total labour required by each plot for the crop year is measured by total labour days per hectare, by gender and type of labour (farm labour versus hired labour) and by production stage. At a descriptive level, total labour required by the plot varies depending on the CA practice adopted but are systematically higher in adopted farms than non-adopted farms. CA practices are generally related to higher labour requirements during all production stages, but particularly higher during the weeding and harvesting stages. Contrary to the labour-saving benefit mentioned in the reviewed literature, on average, minimum tillage implemented in isolation and in combination with residue retention increases labour demand during land preparation. This might be due to the small proportion of households that adopt minimum tillage as shown in Table 1, or other unobserved heterogeneity that we will address further in the regression results. Female labour inputs are higher on average under all CA practices. Higher labour requirements seem to be met by farm rather than hired labour. Average child labour is also higher under CA adoption than non-adoption. Maize yields were generally lower in plots that adopted CA compared to plots that did not adopt any CA practice, except for plots that adopted residue retention.

Table 3 summarizes plot-level characteristics that could affect both CA adoption and the plots' productivity. These include farm agronomic characteristics such as soil fertility, soil slope and soil depth. Chemical inputs also play an important role. Pesticide and herbicide use was low among farmers in the sample as a whole. Herbicide use was highest among plots that adopted the combined residue retention and minimum tillage and the full package, averaging 21.3 and 22.3 per ha, respectively. Average fertilizer use varied across CA practices, with the highest use observed among non-adopting plots (111.5 kg per ha) and lowest under residue retention and minimum tillage adoption (74.2 kg per ha).

Table 3: Plot characteristics descriptive statistics, 2013

	No adoption	Adoption at least 1 CA	Intercrop	Residue retention	Min. tillage	Intercrop+ residue retention	Intercrop + min. tillage	Residue+ min. tillage	Full package	All sample
Total labour (person days/ha)	111.41	192.97	111.12	336.06	222.25	122.52	119.08	131.56	131.19	161.14
Male labour (person days/ha)	60.03	60.52	47.17	79.93	50.78	55.00	50.54	52.94	55.11	60.33
Female labour (person days/ha)	41.47	82.81	51.33	128.93	164.04	56.40	61.47	59.68	59.57	66.68
Child labour (person days/ha)	9.92	49.63	12.62	127.21	7.43	11.12	7.08	18.94	16.51	34.14
Farm labour (person days/ha)	42.26	48.08	38.98	54.26	48.79	47.19	46.38	54.53	63.51	46.68
Hired labour (person days/ha)	11.58	15.73	10.31	13.14	86.21	15.41	17.15	18.32	25.68	14.73
Land preparation (person days/ha)	31.55	39.74	29.01	44.22	148.36	33.75	30.16	33.77	28.55	36.54
Weeding (person days/ha)	39.22	73.02	30.20	154.72	36.75	35.25	39.87	38.16	35.27	59.83
Harvesting (person days/ha)	20.23	54.69	27.75	108.05	21.24	28.91	28.88	34.27	43.48	41.24
Threshing (person days/ha)	20.41	25.52	24.15	29.07	15.91	24.62	20.17	25.36	23.89	23.53
Maize yield (kg/ha)	2342	1920	1479	2912	2058	1334	939	1724	1241	2085
Plot shock (%)	49	68	69	60	65	74	75	77	82	61
Soil fertility (1-3:good-poor)	1.70	1.78	1.82	1.74	1.64	1.83	1.77	1.58	1.91	1.75
Soil slope (1-3: gentle-poor)	1.40	1.47	1.47	1.41	1.50	1.49	1.50	1.72	1.51	1.44
Soil depth (1-3: Shallow-deep)	2.37	2.20	2.30	2.08	2.27	2.22	2.41	2.13	2.21	2.27
Herbicide (kg/ha)	5.59	5.11	7.69	2.06	1.86	2.99	1.19	21.30	22.25	5.29
Pesticide (litre/ha)	0.96	1.90	2.89	0.31	0.35	2.84	0.90	1.28	5.11	1.53
Fertilizer (kg/ha)	111.45	85.30	83.10	88.39	108.98	79.73	74.15	86.80	100.98	95.50
Manure (kg/ha)	376.27	688.22	714.53	468.53	200.74	1011.13	936.43	381.86	762.47	566.50
Plot size (ha)	4.04	4.01	11.98	0.75	0.69	0.58	0.66	0.80	0.93	4.03
Plot distance (minutes)	15.14	18.92	12.13	23.10	23.79	19.37	17.15	30.57	18.68	17.44
Plot ownership (%)	87	91	90	92	92	91	90	86	84	89
Improved variety adopted (%)	93	82	91	78	83	77	86	78	87	86
N	*2,070*	*3,235*	*952*	*1,056*	*118*	*854*	*71*	*106*	*87*	*5,305*

Note: Adoption identifies the plots that adopted at least one CA practice (intercropping, residue retention, minimum tillage or a combination of the three). Full package identifies the plots that were implemented with the three practices simultaneously. Currency values are in 2010 US$. Results for 2010 available in the Supplementary Materials Table S6.
Source: Own calculation based on SIMLESA.

Some 86 per cent of the plots in the sampled households planted improved seed varieties on their plots in 2013; non-adopters were more likely to use improved seed varieties more frequently than CA adopters.

The higher labour requirements and lower yields observed under CA could be a result of selection. Adopters could tend to plant more labour-intensive crops, have different kinds of plots in terms of soil characteristics, or have access to fewer resources, requiring more labour and/or producing lower yields per hectare. The MESR models account for these selection effects, the results of which are described in further detail below.

4.2 MESR results

As noted above and highlighted by the literature, CA adoption decisions differ by household and farm characteristics as well as resource constraints and plot characteristics. Such factors that influence CA adoption are also likely to affect labour, off-farm income and yield outcomes. We use MESR to correct for this selection bias and test for the causality of CA adoption on labour inputs, off-farm incomes and maize yields. To facilitate the interpretation, we present the results as average treatment effects on the treated in Figures 1 to 5 (full regression results for the two-stage MESR models with total labour inputs as the outcome variable are reported in Supplementary Materials Tables S8 and S9). In the figures, bars depict the size of the treatment effect; the longer the bar, the larger the estimated effect of CA adoption on a particular outcome. If colored solidly, the estimate is statistically significant; if colored in dashes, the estimate is not statistically significant (full ATT results for all outcomes are presented in Tables S10 to S25 in the Supplementary Materials).

As shown in Figure 1, for the majority of CA practices and net of household and plot characteristics and chemical inputs, CA adoption brings a statistically significant increase in the days worked per hectare per year. Full CA adoption leads to 55 more days worked per hectare per year. There is no statistically significant change in labour requirements resulting from minimum tillage (note, however, that the share of plots that implemented minimum tillage alone is less than 3 per cent, see Table 1).[6] Net of selection and other covariates, the increase in labour demand is heavily met by women rather than men. The redistribution of labour according to tasks may explain how the change in women's labour input under CA is actually higher than men's under most CA practices. This is consistent with studies noting the gendered impact of CA (Giller et al., 2009; Teklewold et al., 2013).

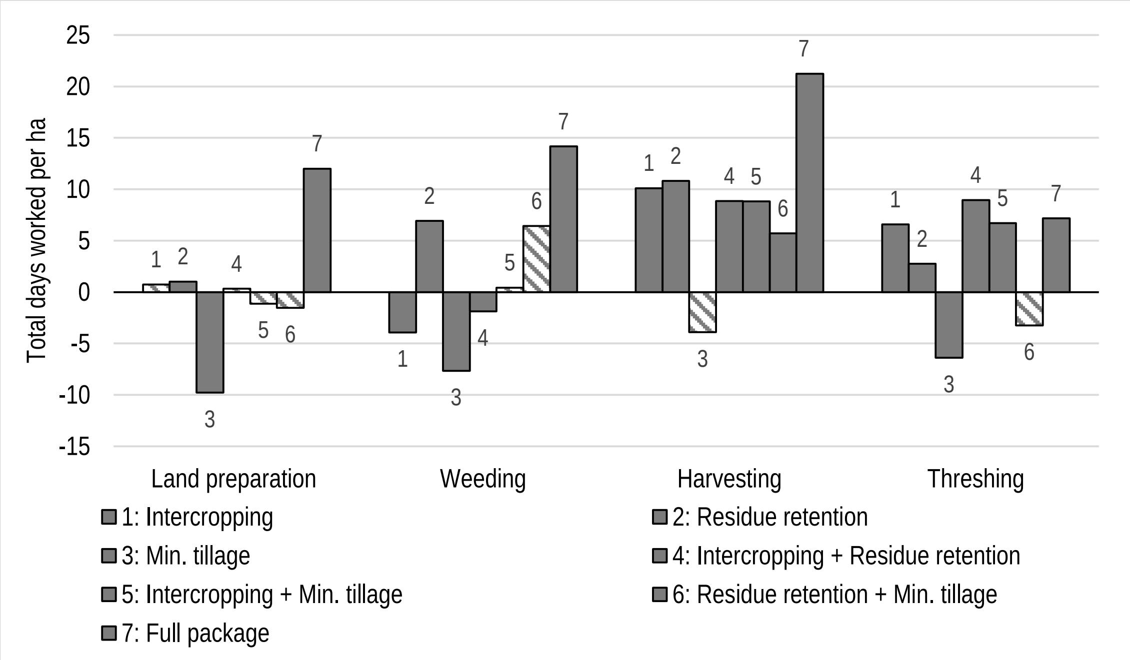
[6] These results are based on the full sample, which combines the five countries surveyed in SIMLESA, with controls at the country-level. We analyse the pooled plot level data to analyse CA practices independently of each other. We tested for between-country differences in these coefficients. Given the relatively low rates of adoption of some CA practices and country-specific sample sizes (see Table S26 in the Supplementary Materials), there was not sufficient variation or statistical power to estimate the effects or detect statistical significance at the individual country level.

Figure 1: Average treatment effects of CA adoption on labour requirements

Note: Total, female and male labour result is calculated using longitudinal data. Full-coloured bars indicate statistically significant results ($p < 0.05$); dashed bars indicate non-significant results.
Source: Own calculation based on SIMLESA.

The adoption of different CA practices generally increases labour requirements. In changing how agriculture is carried out, this overall increased demand for labour may hide different levels of demand across the season. As shown in Figure 2, and after accounting for plot and household characteristics as well as the use of chemical inputs, CA redistributes labour across different production stages. Minimum tillage adopted in isolation saves working time during land preparation, weed control, and threshing, while only intercropping adopted in isolation and in combination with residue retention save time during the weed control stage. For the rest of CA practices and for the rest of the activities in the farm, CA increases, or at best does not change, the labour demand. Labour demand increases are highest during the harvesting stage for plots adopting all three CA practices, the full package. Labour demand increases are consistently higher during harvesting and threshing, where most CA practices (except minimum tillage) increase the demand for work.

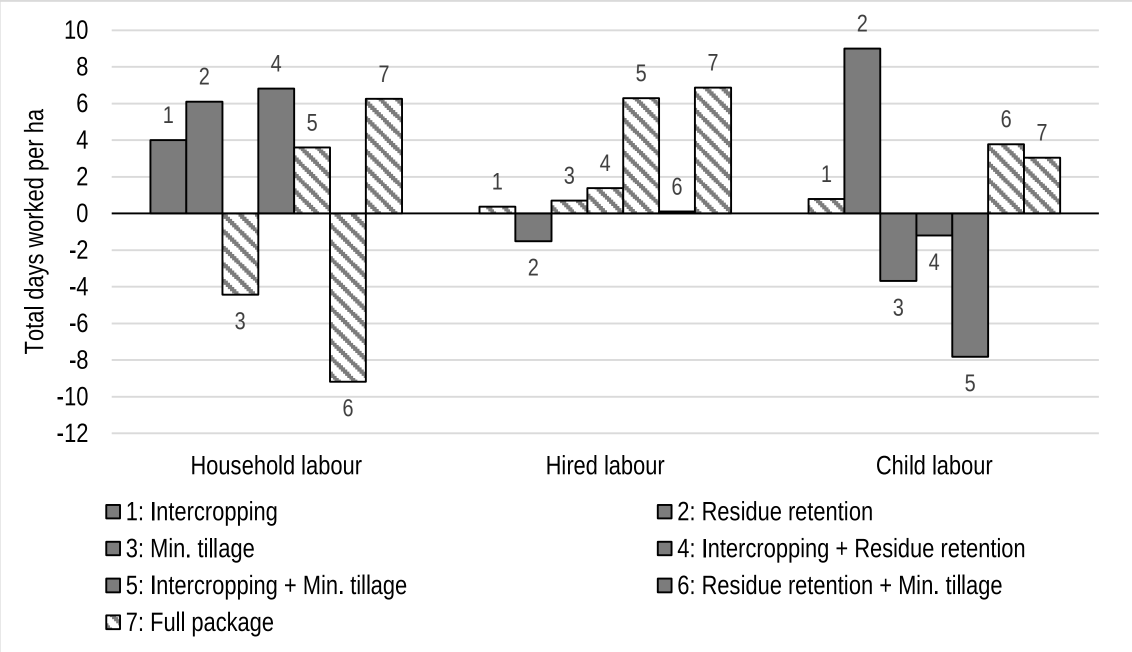
Figure 2: Average treatment effects of CA adoption on labour requirements by production stage



Note: Full-coloured bars indicate statistically significant results ($p < 0.05$); dashed bars indicate non-significant results.
Source: Own calculation based on SIMLESA.

The source of the labour used in each plot can only be analysed cross-sectionally for 2013 because the relevant questions were only included in the 2013 survey. Figure 3 distinguishes the type of labour required under CA in comparison to non-CA adopters. The extra amount of farm labour required under CA tends to be met with household labour. Total hired labour does not change statistically significantly under most CA practices while total household labour increases statistically significantly under intercropping and residue retention. These results suggest that the increased labour demand under CA is evenly spaced across each production stage and is not concentrated on particularly heavy periods. For larger plots than those observed in SIMLESA, it may be the case that the increased labour cannot be met by household members alone. The fact that increased labour is mostly met by household farm labour reduces household members' availability for off-farm activities, domestic work or child care. As shown in Figure 3, child labour increases significantly under residue retention and actually decreases under other practices.

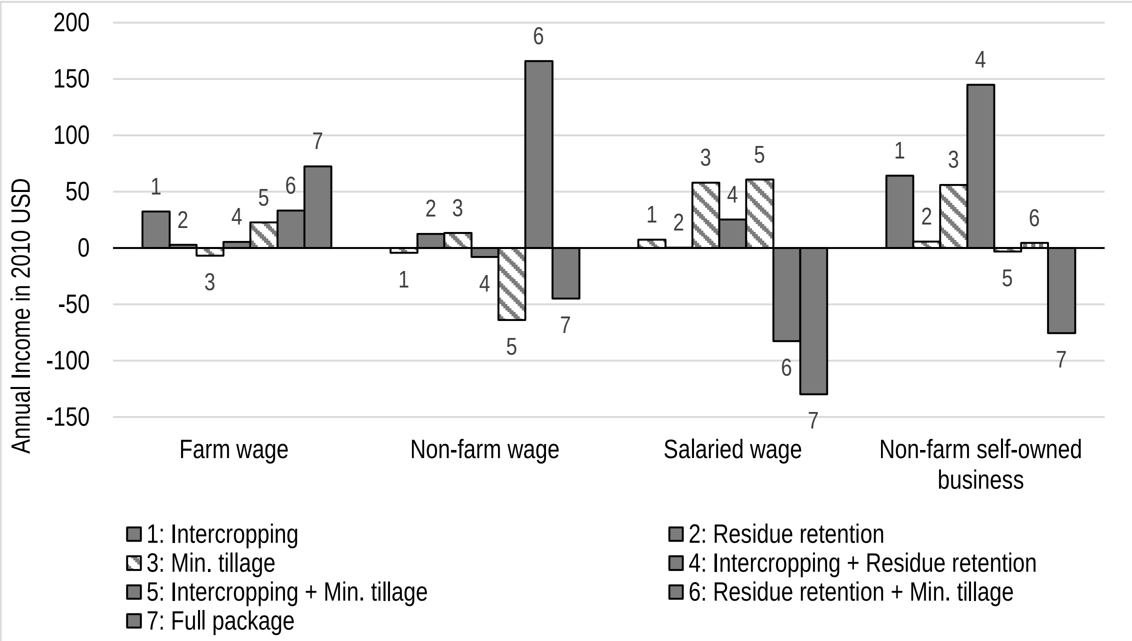
Figure 3: Average treatment effects of CA adoption on household, hired and child labour



Note: Full-coloured bars indicate statistically significant results ($p < 0.05$); dashed bars indicate non-significant results. Child, farm and hired labour results are calculated based on 2013 data due to the unavailability of these variables in the 2010 dataset.
Source: Own calculation based on SIMLESA.

Figure 4 shows that CA adoption is, despite its higher labour requirements, compatible with off-farm income. CA adopters earned more farm wages than non-CA adopters. These are wages earned from working on other farms. This is possible if the higher labour requirements under CA do not conflict with the labour-intensive periods of other farms. CA adopters also earn more from non-farm self-owned business, signalling that the labour demand increases under CA are compatible with entrepreneurship activities. CA adoption is not consistently related to other off-farm income sources.

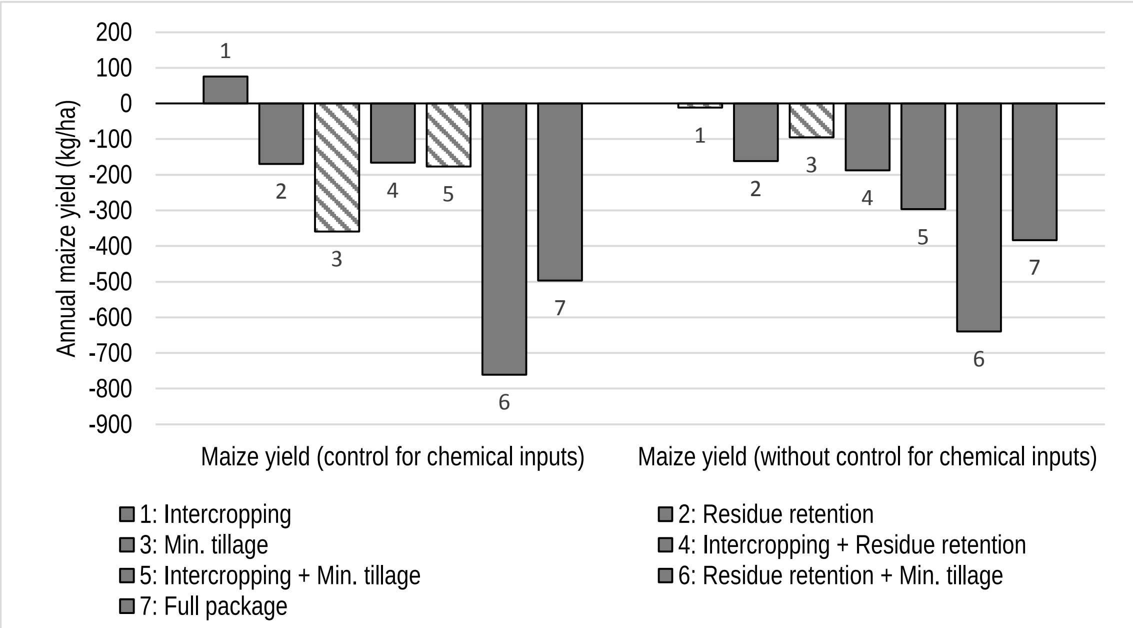
Figure 4: Average treatment effects of CA adoption on off-farm income



Note: Full-coloured bars indicate statistically significant results ($p < 0.05$); dashed bars indicate non-significant results.
Source: Own calculation based on SIMLESA.

Figure 5 explores CA's adoption effects on maize yields, measured in kilograms per hectare. These effects control for the use of improved seed varieties and chemical inputs. They show that, for the majority of CA practices, maize yields are lower. They are only higher under intercropping, when adopted in isolation. This suggests, and is consistent with the evidence noted earlier, that increased yields under CA are not guaranteed. CA requires a waiting period for the soil to recover its quality, time for farmers to get used to the new production methods, and requires proper management of chemical inputs and machinery to increase yields. Optimal management of chemical inputs under CA is different than under conventional agriculture. Still, lower yields remain after dropping controls for chemical inputs, suggesting that the optimal mix of fertilizers, herbicides and pesticides for CA are not currently in place as farmers are implementing CA, and that the optimal mix under CA is different than under conventional practices.

Figure 5: Average treatment effects of CA adoption on maize yields



Note: Full-coloured bars indicate statistically significant results ($p < 0.05$); dashed bars indicate non-significant results.
Source: Own calculation based on SIMLESA.

Overall, the results presented here suggest that CA increases the demand for labour. This increased demand is met primarily by household labour, with a stronger female contribution than men's. It does not result in more wage work in the rural economy. In some limited cases, it is met by child labour. The increase in labour required does not seem to limit farmer's ability to seek off-farm income. As currently implemented, CA does not lead to higher yields, which could explain why CA adopters tend to earn more from off-farm sources than CA non-adopters. Lower yields could be explained by CA's waiting period or by the improper use of necessary complementary inputs. These results contribute to explaining why, between 2010 and 2013, CA adoption declined in the sample.

Higher returns to labour under CA can increase food security and generate more cash for adopting households. This is not, however, observed as CA is adopted in Eastern and Southern Africa. CA has the potential to be especially beneficial for smallholders, but this potential is not currently being achieved. Though CA remains compatible with non-farm income earning activities, its higher labour requirements may be a reason for dis-adoption, and its higher initial yields a reason not to invest in the necessary waiting period CA requires.

5. Discussion

Conservation agriculture has been proposed as a means to achieve environmentally sustainable intensification in agriculture, particularly in the context of projected growth in food demand and plateauing productivity in the sector. By minimizing tillage, diversifying crops and maintaining a soil cover, CA can lead to higher yields and a lower environmental impact. By changing the mix and management of resources, CA redistributes labour, leading to higher profits to CA farms if labour costs decrease.

Experimental and case studies do show lower labour demand under CA, particularly since minimizing tillage reduces the need for labour during land preparation. The lower labour intensity and higher yields are observed when CA is adopted with the appropriate machinery and nutrient and pest management practices which help contain any labour increases in weeding, harvesting and threshing.

These effects do not hold as CA is currently being implemented in Eastern and Southern Africa. Yield increases are not guaranteed with CA, as CA is a mix of practices best implemented in combination. Moreover, it requires a waiting period for soil quality to recover, and a specific mix of chemical inputs, machinery and skills to produce higher yields and actually reduce labour.

As implemented in Ethiopia, Kenya, Malawi, Mozambique and Tanzania all three principles of CA are seldom applied together. In 2013, fewer than 2 per cent of the surveyed plots implemented CA as a full package. If at all, farmers tended to adopt residue retention (soil cover) and/or intercropping. Minimum tillage was rarely taken up. Importantly, the share of plots that did not adopt any CA practice increased between 2010 and 2013. This is not surprising as smallholders are less able to invest in new equipment, are more risk averse than large farmers, generally have weak links to new information systems outside those of the community, and usually manage more complex crop-livestock systems (Wall, 2007). Dis-adoption could also be the result of the fact that CA benefits take time to materialize (Jat et al., 2014).

After accounting for the selection process in CA adoption, we find that CA actually increases the demand for labour. This is consistent with findings from Teklewold et al. (2013) that take a broad look at CA and its effect on labour in Ethiopia. The increase in labour demand we observe is largely met by an increase of household labour, with little impact on hired labour. The increase in labour demand is met, to a larger extent by women and, in some cases, by children. In most cases, CA adoption did not lead to higher yields for farmers and the higher labour demand did not necessarily restrict their ability to seek off-farm income.

Several factors can explain the difference between these findings for Eastern and Southern Africa and the presumed labour-saving potential of CA found in experimental studies and the literature for other regions. First, the labour-saving potential of CA is usually attributed to, and sometimes restricted to, the implementation of minimum tillage. In the countries we study, very few farms implemented minimum tillage. Changing from tillage-based systems to minimum tillage involves long-term investments to restore soil quality as well as investment in direct-seeding equipment which can be difficult for smallholder and family farms in the region. However, farms that implemented minimum tillage in combination with other CA practices did not show lower labour demand either. This leads to a second potential explanation: as CA involves a change in the use of various inputs, it may be the case that CA adoption is not being accompanied by these complementary practices in an optimal way (notably chemical inputs, skills and machinery), leading to lower yields and higher labour demand. A third possible explanation relates to the time it takes for CA benefits to accrue. It could be the case that farmers have yet to get accustomed to the new practices and have yet to capitalize on the labour-saving potential of CA, particularly given that CA adoption requires a transition period for soil quality to recover. CA requires intensive knowledge to understand its specific practices, as well as to understand and implement complementary inputs in an optimal manner (Wall, 2007). These explanations are consistent with the fact that we observe lower yields under most CA practices, leading to the hypothesis that CA is not currently being adopted in ways that will ultimately benefit farmers. This, in turn, explains why CA practices are being dis-adopted in the region.

Given the urgency of adopting intensive and sustainable forms of agriculture around the world, and the fact that sustainable forms of agriculture like CA change the organization of work in rural economies, more research is required to understand the specific ways in which CA can achieve such outcomes. This includes addressing the difference in skills and technology requirements between conventional agriculture and CA. Conservation agriculture is skills-intensive and requires specific technology. Research can inform policy in effective investment in human capital development and other outreach services. More research is also required to understand the characteristics and institutional mechanisms that need to be in place for these benefits to accrue or for CA benefits to be maximized. This includes research that explores effective and fair access to markets (e.g. addressing information asymmetries and power imbalances between farmers and downstream actors, or by exploring forms of organization that promote vertical integration as is the case of cooperatives). This research can then inform development programs that promote the adoption and implementation of CA. As CA involves a transition period, these development programs could be accompanied by income support measures and should be accompanied by access to machinery, skills development and the safe and proper management of chemical inputs.

The aggregate impacts of CA adoption should be explored as well. If CA requires more labour and eventually produces higher yields, it can enhance food and income security among smallholder and family farms. As households dedicate more of their time to the farm, however, they have fewer opportunities to pursue off-farm income, placing them at higher risk for income volatility in situations of drought or price fluctuations. Importantly, in increasing farm labour intensity, these practices can increase child labour as well and, in certain cases, increase labour for women, reducing progress in other key dimensions of sustainable development. The promotion and implementation of CA should, then, be complemented with policies and programs that advance decent work in rural economies (e.g. the ratification and enforcement of core international labour standards like the Worst Forms of Child Labour Convention, 1999 (No. 182) or the Convention concerning Discrimination in Respect of Employment and Occupation, 1960 (No. 111)).

Our analyses are not free from caveats. In pooling the five country samples together, we assume that CA adoption has the same slope effects across these countries. Second, the survey does not identify the specific plots, so they cannot be followed over time. Following plots over time could further explain why households dis-adopt CA, providing insight to better promote CA adoption in these countries. Following plots could also allow for better studying the long-term impacts of CA adoption, particularly given that its successful implementation requires an adaptation period for both the soil and the farmers. Third, we focus on maize in our analyses, to allow for better comparability across plots as legumes is a large and heterogeneous category. Including legumes could allow for a better identification of the types of synergies between crops and CA practices in these countries. Lastly, our analysis look at the partial equilibrium of farm production. Analyses that take into account the general equilibrium of the rural economies, for example, through wages or grain prices, would complement our findings and better explore the aggregate effects of widespread CA adoption.

Implemented as it has been in these five Sub-Saharan African countries, CA does not necessarily promote food or income security. CA, as a sustainable alternative to conventional agricultural practices, requires the advancement of the complementary measures to ensure its success. These include capacity-building to farmers, access to chemical inputs, machinery and improved seed varieties, and income support during the transition period. Importantly, the promotion of CA in Sub-Saharan Africa as a way to increase profits through higher yields and lower labour requirements may create false expectations.

References

Abdulai, A. N. 2016. “Impact of conservation agriculture technology on household welfare in Zambia”, in Agricultural Economics, Vol. 47, No.6, pp.729–741. https://doi.org/10.1111/agec.12269

Alexandratos, N.; Bruinsma, J. 2012. World agriculture towards 2030/2050, ESA Working Paper No. 12–03 (Rome, FAO).

Araya, T.; Cornelis, W. M.; Nyssen, J.; Govaerts, B.; Bauer, H.; Gebreegziabher, T.; Oicha, T.; Raes, D.; Sayre, K. D.; Haile, M.; Deckers, J. 2011. “Effects of conservation agriculture on runoff, soil loss and crop yield under rainfed conditions in Tigray, Northern Ethiopia”, in Soil Use and Management, Vol. 27, No. 3, pp. 404–414. https://doi.org/10.1111/j.1475-2743.2011.00347.x

Baker, C. J.; Saxton, K. E. 2007. No-tillage seeding in conservation agriculture (Wallingford, Cabi).

Baudron, F.; M. Mwanza, H.; Triomphe, B.; Bwalya, M. 2007. Conservation Agriculture in Zambia: A case study of Southern Province, Conservation Agriculture in Africa Series (Nairobi, African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, FAO).

Bayala, J.; Sileshi, G. W.; Coe, R.; Kalinganire, A.; Tchoundjeu, Z.; Sinclair, F.; Garrity, D. 2012. “Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis”, in Journal of Arid Environments, Vol. 78, pp. 13–25. https://doi.org/10.1016/j.jaridenv.2011.10.011

Bourguignon, F.; Fournier, M.; Gurgand, M. 2007. “Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons”, in Journal of Economic Surveys, Vol. 21, No. 1, pp. 174–205. https://doi.org/10.1111/j.1467-6419.2007.00503.x

Bryan, E.; Ringler, C.; Okoba, B.; Roncoli, C.; Silvestri, S.; Herrero, M. 2013. “Adapting agriculture to climate change in Kenya: Household strategies and determinants”, in Journal of Environmental Management, Vol. 114, pp. 26–35. https://doi.org/10.1016/j.jenvman.2012.10.036

Di Falco, S.; Bulte, E. 2013. “The impact of kinship networks on the adoption of risk-mitigating strategies in Ethiopia”, in World Development, Vol. 43, pp. 100–110. https://doi.org/10.1016/j.worlddev.2012.10.011

Di Falco, S.; Veronesi, M.; Yesuf, M. 2011. “Does adaptation to climate change provide food security? A micro-perspective from Ethiopia”, in American Journal of Agricultural Economics, Vol. 93, No. 3, pp. 829–846. https://doi.org/10.1093/ajae/aar006

Ekboir, J. 2013. Developing no-till packages for small-scale farmers (Mexico: CIMMYT)

FAO. 2001. The economics of conservation agriculture (Rome: FAO). Retrieved from http://www.fao.org/docrep/004/y2781e/y2781e04.htm#P13_4325

FAO. 2011. Save and grow: A policymaker’s guide to the sustainable intensification of smallholder crop production (Rome, FAO). Retrieved from http://www.fao.org/3/a-i2215e/index.html

FAO. 2015. What is Conservation Agriculture? (Rome: FAO). Retrieved from http://www.fao.org/ag/ca/1a.html

Farnworth, C. R.; Baudron, F.; Andersson, J. A.; Misiko, M.; Badstue, L.; Stirling, C. M. 2016." Gender and conservation agriculture in East and Southern Africa: towards a research agenda", in International Journal of Agricultural Sustainability, Vol. 14, No. 2, pp. 142–165. https://doi.org/10.1080/14735903.2015.1065602

Friedrich, T.; Derpsch, R.; Kassam, A. 2017. “Overview of the global spread of conservation agriculture”, in K. Etingoff (ed.): Sustainable Development of Organic Agriculture: Historical Perspectives (Waretown, CRC Press), pp. 53–68.

Giller, K. E.; Witter, E.; Corbeels, M.; Tittonell, P. 2009. “Conservation agriculture and smallholder farming in Africa: The heretics’ view”, in Field Crops Research, Vol. 114, No. 1, pp. 23–34. https://doi.org/10.1016/j.fcr.2009.06.017$

ILO. 2017. World Employment and Social Outlook Trends 2017 (Geneva).

IPCC. 2014. Climate change 2014: Impacts adaptation and vulnerability (New York, Cambridge University Press).

Johansen, C.; Haque, M. E.; Bell, R. W.; Thierfelder, C.; Esdaile, R. J. 2012. “Conservation agriculture for small holder rainfed farming: Opportunities and constraints of new mechanized seeding systems”, in Field Crops Research, Vol. 132, pp. 18–32. https://doi.org/10.1016/j.fcr.2011.11.026

Kassie, M.; Marenya, P.; Tessema, Y.; Jaleta, M.; Zeng, D.; Erenstein, O.; Rahut, D. 2017. “Measuring farm and market level economic impacts of improved maize production technologies in Ethiopia: Evidence from panel data”, in Journal of Agricultural Economics, Vol. 69, No.1, pp. 76-95. https://doi.org/10.1111/1477-9552.12221

Kassie, M.; Teklewold, H.; Jaleta, M.; Marenya, P.; Erenstein, O. 2015. “Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa”, in Land Use Policy, Vol. 42, pp.400–411. https://doi.org/10.1016/j.landusepol.2014.08.016

Kassie, M.; Teklewold, H.; Marenya, P.; Jaleta, M.; Erenstein, O. 2015. “Production Risks and Food Security under Alternative Technology Choices in Malawi: Application of a Multinomial Endogenous Switching Regression”, in Journal of Agricultural Economics, Vol. 66, No. 3, pp. 640–659. https://doi.org/10.1111/1477-9552.12099

Khonje, M. G.; Manda, J.; Mkandawire, P.; Tufa, A. H.; Alene, A. D. 2018. “Adoption and welfare impacts of multiple agricultural technologies: evidence from eastern Zambia”, in Agricultural Economics, Vol. 49, No. 5, pp. 599-609. https://doi.org/10.1111/agec.12445

Knowler, D.; Bradshaw, B. 2007. “Farmers’ adoption of conservation agriculture: A review and synthesis of recent research”, in Food Policy, Vol. 32, No. 1, pp. 25–48. https://doi.org/10.1016/j.foodpol.2006.01.003

Lalani, B.; Dorward, P.; Holloway, G. 2017. “Farm-level economic analysis - Is Conservation Agriculture helping the poor?”, in Ecological Economics, Vol. 141, pp.144–153. https://doi.org/10.1016/j.ecolecon.2017.05.033

Li, H.; Li, M. 2012. Conservation agriculture (Beijing, Popular Science Press). Retrieved from http://www.fao.org/ag/ca/Training_Materials/Conservation_Agriculture_English.pdf

Li, H.; Xie, M.; He, J.; Jiang, H. 2014. Exchanging experience with conservation agriculture: Towards climate resilience. (Beijing and Washington DC, Popular Science Press and the World Bank). Retrieved from http://www.fao.org/ag/ca/Training_Materials/CA_Cartoon_Book_China.pdf

Manda, J.; Alene, A. D.; Gardebroek, C.; Kassie, M.; Tembo, G. 2016. "Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia", in Journal of Agricultural Economics, Vol. 67, No. 1, pp. 130–153. https://doi.org/10.1111/1477-9552.12127

Mundlak, Y. 1978. "On the pooling of time series and cross section data", in Econometrica, Vol. 46, No. 1, pp.69–85.

Muricho, G.; Kassie, M.; Marenya, P.; Yirga, C.; Tostao, E.; Mishili, F.; Obare, G.; Mangisoni, J. 2017. Cross country report for Adoption Pathways 2013 surveys (Mexico, CIMMYT).

Neill, S. P.; Lee, D. R. 2001. "Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in Northern Honduras", in Economic Development and Cultural Change, Vol. 49, No. 4, pp. 793–820. https://doi.org/10.1086/452525

Ngwira, A. R.; Aune, J. B.; Mkwinda, S. 2012. "On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi", in Field Crops Research, Vol. 132, pp.149–157. https://doi.org/10.1016/j.fcr.2011.12.014

Nyagumbo, I.; Mkuhlani, S.; Pisa, C.; Kamalongo, D.; Dias, D.; Mekuria, M. 2016. "Maize yield effects of conservation agriculture based maize–legume cropping systems in contrasting agro-ecologies of Malawi and Mozambique", in Nutrient Cycling in Agroecosystems, Vol. 105, No. 3, pp. 275–290. https://doi.org/10.1007/s10705-015-9733-2

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", in Experimental Agriculture, Vol. 50, No. 2, pp. 159–177. https://doi.org/10.1017/S0014479713000562

Pannell, D. J.; Llewellyn, R. S.; Corbeels, M. 2014. "The farm-level economics of conservation agriculture for resource-poor farmers", in Agriculture, Ecosystems & Environment, Vol. 187, pp. 52–64. https://doi.org/10.1016/j.agee.2013.10.014

Pedzisa, T.; Rugube, L.; Winter-Nelson, A.; Baylis, K.; Mazvimavi, K. 2015. "Abandonment of Conservation Agriculture by Smallholder Farmers in Zimbabwe", in Journal of Sustainable Development, Vol. 8, No. 1, pp. 69-82. https://doi.org/10.5539/jsd.v8n1p69

Pingali, P. 2012. "Green revolution: Impacts, limits, and the path ahead", in Proceedings of the National Academy of Sciences of the United States of America, Vol. 109, No. 31, pp. 12302–12308.

Rusinamhodzi, L.; Corbeels, M.; Wijk, M. T. van; 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", in Agronomy for Sustainable Development, Vol. 31, No. 4. https://doi.org/10.1007/s13593-011-0040-2

Swaminathan, M. S.; Kesavan, P. C. 2017. “The transition from Green to Evergreen Revolution”, in K. Etingoff (ed.): Sustainable Development of Organic Agriculture: Historical Perspectives (Waretown, CRC Press), pp. 69–77.

Teklewold, H.; Kassie, M.; Shiferaw, B.; Köhlin, G. 2013. “Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor”, in Ecological Economics, Vol. 93, pp. 85–93. https://doi.org/10.1016/j.ecolecon.2013.05.002

Thierfelder, C.; Matemba-Mutasa, R.; Rusinamhodzi, L. 2015. “Yield response of maize (Zea mays L.) to conservation agriculture cropping system in Southern Africa“, in Soil and Tillage Research, Vol. 146, Part B, pp. 230–242. https://doi.org/10.1016/j.still.2014.10.015

Thierfelder, C.; Siamachira, J. 2016. Building a sustainable future: A history of conservation agriculture in southern Africa (México, CIMMYT)

Tilman, D.; Cassman, K. G.; Matson, P. A.; Naylor, R.; Polasky, S. 2002. “Agricultural sustainability and intensive production practices”, in Nature, Vol. 418, No. 6898, pp. 671–677. https://doi.org/10.1038/nature01014

Wall, P. C. 2007. “Tailoring Conservation Agriculture to the needs of small farmers in developing countries”, in Journal of Crop Improvement, Vol. 19, No.1–2, pp. 137–155. https://doi.org/10.1300/J411v19n01_07

Zerihun, A.; Tadesse, B.; Shiferaw, T.; Kifle, D. 2014. “Conservation Agriculture: Maize-legume intensification for yield, profitability and soil fertility improvement in maize belt areas of western Ethiopia”, in International Journal of Plant & Soil Science, Vol. 3, No. 8, pp. 969–985.

Zheng, C.; Jiang, Y.; Chen, C.; Sun, Y.; Feng, J.; Deng, A.; Song, Z.; Zhang, W. 2014. “The impacts of conservation agriculture on crop yield in China depend on specific practices, crops and cropping regions”, in The Crop Journal, Vol. 2, No. 5, pp. 289–296. https://doi.org/10.1016/j.cj.2014.06.006

Appendix

Table A: Attrition across countries surveyed in SIMLESA between 2010 and 2013

	Household 2010	Household 2013	Household Panel	Plot 2010	Plot 2013	Plot Panel
Ethiopia	898	875	875	4,383	4,545	8,928
Kenya	613	535	535	2,851	4,254	7,103
Malawi	895	746	728	2,833	3,393	5,330
Mozambique	510	295	295	1,618	1,270	2,877
Tanzania	701	551	551	1,591	3,205	4,622
Total	3,617	3,002	2,984	13,276	16,667	28,860

Note: The number of observations include all plots (maize and non-maize plots) and households surveyed in SIMLESA.
Source: Own calculation based on SIMLESA.

Table B: Attrition bias - CA adoption distribution (frequency %) in 2010

CA practice	Ethiopia		Kenya		Malawi		Mozambique		Tanzania	
	Full	Panel	Full	Panel	Full	Panel	Full	Panel	Full	Panel
No adoption	70.2	70.0	15.8	13.4	9.4	9.5	5.4	5.1	4.8	4.8
Intercropping	5.4	5.3	23.1	21.9	3.0	3.1	4.1	2.7	26.7	25.0
Residue retention	23.3	23.7	10.5	10.5	64.0	63.5	33.5	31.5	26.8	28.7
Minimum tillage	0.0	0.0	0.1	0.2	0.2	0.2	1.1	1.3	0.3	0.3
Intercropping + residue retention	1.1	1.1	48.7	52.3	22.1	22.2	36.6	35.8	28.9	29.8
Intercropping + minimum tillage	0.0	0.0	0.8	0.9	0.0	0.0	0.6	1.0	2.3	2.1
Residue retention + minimum tillage	0.0	0.0	0.3	0.4	0.9	1.0	11.4	13.6	3.9	3.5
Full package	0.0	0.0	0.6	0.6	0.5	0.6	7.3	9.0	6.4	5.9

Note: The sample includes only plots that grow maize. Full sample includes maize plots of all households in 2010, panel sample includes maize plots of households that were interviewed in both 2010 and 2013. Distribution rates are for 2010.
Source: Own calculation based on SIMLESA.

Table C: Chow test on coefficients across CA practices

CA practice	Total labour model
Intercropping vs other CA adoption	F(50, 6647) = 2.89***
Residue retention vs other CA adoption	F(50, 6647) = 6.21***
Minimum tillage vs other CA adoption	F(50, 6647) = 2.34***
Intercropping + residue retention vs other CA adoption	F(50, 6647) = 3.05***
Intercropping + minimum tillage vs other CA adoption	F(50, 6647) = 2.09***
Residue retention + minimum tillage vs other CA adoption	F(50, 6647) = 2.18***
Full package vs other CA adoption	F(50, 6647) = 2.19***

Note: Each CA practice is tested against the adoption of at least one CA practices (excluding the tested CA practice itself). Asterisks indicate statistical significance of the test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table D1: Exclusion restrictions are jointly significant in the adoption mlogit regression

χ^2 (35) = 176.73***

The five exclusion restrictions (access to information of improved agricultural technology, distances to main market and closest seed dealer, number of government extension contacts and number of NGO extension contacts) jointly affect CA adoption at the $p < 0.01$ significance level.

Table D2: Exclusion restrictions are not jointly significant in the outcome regression for total labour

CA practice	Joint significance test	p-value
Non adoption	F(5, 3221) = 0.75	0.58
Intercropping	F(5, 1416) = 1.15	0.33
Residue retention	F(5, 2422) = 1.43	0.21
Minimum tillage	F(5, 78) = 0.37	0.87
Intercropping + residue retention	F(5, 2023) = 1.67	0.14
Intercropping + minimum tillage	F(5, 63) = 0.65	0.66
Residue retention + minimum tillage	F(5, 177) = 1.76	0.12
Full package	F(5, 153) = 2.06	0.07

Source: Own calculation based on SIMLESA.

Table E: Plot level summary statistics, 2010

	No adoption	Adoption at least 1 CA	Intercrop	Residue retention	Min. tillage	Intercrop + residue retention	Intercrop + min. tillage	Residue + min. tillage	Full package	All sample
Total labour (person days/ha)	91.81	130.96	105.98	131.09	93.61	136.62	86.93	168.13	171.80	120.34
Male labour (person days/ha)	60.48	62.70	50.68	65.08	63.13	62.87	44.87	87.38	69.69	62.10
Female labour (person days/ha)	31.32	68.26	55.30	66.01	30.48	73.76	42.07	80.75	102.12	58.25
Land preparation (person days/ha)	24.46	32.87	21.08	38.06	26.81	30.78	13.69	44.73	41.36	30.59
Weeding (person days/ha)	28.20	35.28	23.90	39.13	31.68	32.18	16.30	63.02	54.81	33.36
Harvesting (person days/ha)	19.90	33.06	32.04	26.97	19.52	39.09	26.54	41.80	45.72	29.49
Threshing (person days/ha)	19.25	29.76	28.96	26.92	15.60	34.57	30.41	18.59	29.91	26.91
Maize yield (kg/ha)	2642	1725	1968	1843	958	1519	2202	1447	1505	1974
Plot shock (%)	52	64	74	54	86	68	94	69	82	61
Soil fertility (1-3:good-poor)	1.70	1.77	1.76	1.73	1.14	1.88	1.53	1.34	1.53	1.75
Soil slope (1-3: gentle-poor)	1.39	1.51	1.57	1.44	2.29	1.55	1.74	1.38	1.54	1.47
Soil depth (1-3: Shallow-deep)	2.25	2.15	2.09	2.22	1.86	2.08	2.24	2.29	2.25	2.18
Herbicide (kg/ha)	1.04	0.10	0.20	0.05	0.71	0.07	0.73	0.09	0.25	0.35
Pesticide (liter/ha)	1.10	3.08	3.44	1.79	17.65	4.68	0.75	2.02	0.23	2.55
Fertilizer (kg/ha)	121.49	98.82	101.41	106.17	79.43	101.83	78.56	37.37	20.08	104.96
Manure (kg/ha)	692.36	1447.46	5424.69	440.35	107.30	996.70	1159.52	321.87	1300.94	1242.69
Plot size (ha)	0.51	0.50	0.43	0.56	0.36	0.45	0.51	0.65	0.55	0.50
Plot distance (minutes)	12.89	17.49	9.43	20.16	20.29	15.65	13.21	37.06	24.54	16.24
Plot ownership (%)	84	91	90	91	100	92	79	93	95	89
Improved variety adopted (%)	91	88	93	90	93	83	97	83	87	89
N	*1,453*	*3905*	*614*	*1,620*	*14*	*1,383*	*34*	*126*	*114*	*5,358*

Note: Adoption identifies the plots that implemented with at least one CA practice (intercropping, residue retention, minimum tillage or a combination of the three). Full package identifies the plots that implemented the three practices simultaneously.
Source: Own calculation based on SIMLESA.

Table F: Plot level summary statistics, 2010

	No adoption	Adoption at least 1 CA	Intercrop	Residue retention	Min. tillage	Intercrop + residue retention	Intercrop + min. tillage	Residue + min. tillage	Full package	All sample
Total labour (person days/ha)	91.81	130.96	105.98	131.09	93.61	136.62	86.93	168.13	171.80	120.34
Male labour (person days/ha)	60.48	62.70	50.68	65.08	63.13	62.87	44.87	87.38	69.69	62.10
Female labour (person days/ha)	31.32	68.26	55.30	66.01	30.48	73.76	42.07	80.75	102.12	58.25
Land preparation (person days/ha)	24.46	32.87	21.08	38.06	26.81	30.78	13.69	44.73	41.36	30.59
Weeding (person days/ha)	28.20	35.28	23.90	39.13	31.68	32.18	16.30	63.02	54.81	33.36
Harvesting (person days/ha)	19.90	33.06	32.04	26.97	19.52	39.09	26.54	41.80	45.72	29.49
Threshing (person days/ha)	19.25	29.76	28.96	26.92	15.60	34.57	30.41	18.59	29.91	26.91
Maize yield (kg/ha)	2642	1725	1968	1843	958	1519	2202	1447	1505	1974
Plot shock (%)	52	64	74	54	86	68	94	69	82	61
Soil fertility (1-3:good-poor)	1.70	1.77	1.76	1.73	1.14	1.88	1.53	1.34	1.53	1.75
Soil slope (1-3: gentle-poor)	1.39	1.51	1.57	1.44	2.29	1.55	1.74	1.38	1.54	1.47
Soil depth (1-3: Shallow-deep)	2.25	2.15	2.09	2.22	1.86	2.08	2.24	2.29	2.25	2.18
Herbicide (kg/ha)	1.04	0.10	0.20	0.05	0.71	0.07	0.73	0.09	0.25	0.35
Pesticide (liter/ha)	1.10	3.08	3.44	1.79	17.65	4.68	0.75	2.02	0.23	2.55
Fertilizer (kg/ha)	121.49	98.82	101.41	106.17	79.43	101.83	78.56	37.37	20.08	104.96
Manure (kg/ha)	692.36	1447.46	5424.69	440.35	107.30	996.70	1159.52	321.87	1300.94	1242.69
Plot size (ha)	0.51	0.50	0.43	0.56	0.36	0.45	0.51	0.65	0.55	0.50
Plot distance (minutes)	12.89	17.49	9.43	20.16	20.29	15.65	13.21	37.06	24.54	16.24
Plot ownership (%)	84	91	90	91	100	92	79	93	95	89
Improved variety adopted (%)	91	88	93	90	93	83	97	83	87	89
N	*1,453*	*3905*	*614*	*1,620*	*14*	*1,383*	*34*	*126*	*114*	*5,358*

Note: Adoption identifies the plots that implemented with at least one CA practice (intercropping, residue retention, minimum tillage or a combination of the three). Full package identifies the plots that implemented the three practices simultaneously.
Source: Own calculation based on SIMLESA.

Table G: Logit and probit regression estimates for the determination of CA dis-adoption

	Logit	Probit
Gender head	0.014	0.030
Age head	0.003	0.002
Education head	0.015	0.009
HH size	-0.010	-0.004
Livestock	-0.007	-0.004
Log asset	0.008	0.006
Credit constraint	-0.118	-0.078
Plot size	0.020***	0.011***
Plot distance from residence	-0.004	-0.002
Land ownership	-0.792**	-0.462**
Soil fertility	-0.119	-0.079
Soil slope	-0.151	-0.057
Soil depth	0.365***	0.208***
Fertilizer	-0.000	-0.000
Pesticide	-0.000	-0.000
Herbicide	-0.001	-0.000
Improved variety	-0.325*	-0.157
Information	-0.523***	-0.315***
Kinship	0.004	0.002
Govt support	-0.111	-0.053
Govt confidence	-0.075	-0.047
Constant	-1.172**	-0.750**
Observations	*2,327*	*2,327*
Country FE	*Yes*	*Yes*

Note: Asterisks indicate statistical significance of the standard errors
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: Own calculation based on SIMLESA.

Table H: Multinomial logit regression results - Determination of CA adoption

	CA1	CA2	CA3	CA4	CA5	CA6	CA7
Gender head	-0.089	-0.016	-0.003	-0.091	0.529	-1.104**	-1.346**
Age head	-0.005	-0.015*	-0.016	-0.015*	-0.028	0.003	0.008
Education head	0.003	-0.001	-0.024	0.013	-0.029	0.027	-0.027
HH size	0.002	-0.030	-0.174**	-0.003	0.199**	-0.074	0.012
Food security	0.305**	0.423***	-0.276	0.283**	0.152	0.253	0.521*
Member	-0.505***	-0.338***	-1.253***	-0.252*	-0.814*	-1.554***	-1.168***
Kinship	-0.002	0.011***	-0.008	0.004	0.001	-0.042***	0.004
Trusted trader	-0.005	-0.018**	0.076***	-0.006	0.049*	-0.007	0.010
Govt support	-0.219*	-0.281***	0.275	-0.277**	-0.219	-0.049	-0.372
Govt confidence	0.567***	0.258**	0.284	0.087	0.118	0.416	0.458*
Improved variety	0.858***	0.180	-0.239	0.330**	0.894	0.206	1.254***
Land own	0.001	-0.004	0.000	-0.002	-0.004	-0.002	0.039*
Livestock	-0.003	-0.004	-0.036**	-0.002	-0.023	-0.004	-0.014
Credit constraint	0.369***	0.303***	0.228	0.131	0.532*	0.614**	0.316
Log asset	-0.125***	-0.009	0.082	-0.057	0.045	0.194***	0.202**
Govt ext contact	-0.001	-0.001	0.003***	-0.000	-0.002	0.002***	0.002***
NGO ext contact	0.004*	0.009***	-0.001	0.006**	-0.100*	0.006	-0.003
Information	0.235**	0.381***	0.945***	0.404***	0.687***	0.584***	0.155
Dist to market	-0.000	-0.001*	-0.005**	-0.001*	-0.002	-0.005***	-0.007***
Dist to seed dealer	-0.001	-0.001**	0.004***	-0.002***	0.000	0.000	0.001
Mean gender	0.083	-0.137	0.473	-0.337	-0.417	1.135*	1.298**
Mean age	0.006	0.014	-0.007	0.011	0.010	-0.010	-0.018
Mean education	-0.009	-0.013	0.012	-0.029**	-0.042	-0.055	-0.092
Mean size	0.048	0.038	0.077	0.073**	-0.217*	0.057	0.092
Mean food security	-0.502***	-0.490***	0.123	-0.562***	0.211	0.435	-0.687*
Mean member	0.448**	0.215	0.412	0.238	0.925	1.018**	1.203***
Mean kinship	-0.003	0.000	0.007	-0.002	0.008	0.005	-0.006
Mean trader	0.016	0.002	-0.083***	-0.004	-0.069	-0.005	-0.030
Mean govt support	0.129	0.132	-0.150	0.228	0.016	1.029***	0.633*
Mean govt confidence	-0.051	-0.012	0.130	0.299*	0.696	-0.319	0.070
Mean improved seed	-0.481**	-0.553**	0.324	-0.987***	0.076	-0.152	-0.752*
Mean land own	-0.001	0.006	-0.002	0.000	0.017***	0.005	-0.114*
Mean livestock	0.005	-0.003	0.020	-0.009	0.013	-0.019	0.002
Mean credit constrnt	0.040	-0.200	-0.410	0.318*	-0.530	-0.281	0.117
Mean log asset	0.080*	0.052	0.180	0.043	0.027	-0.108	-0.178*
Plot size	0.002	-0.003	-0.213	-0.002	-0.050	-0.003	0.002
Plot dist to residence	-0.008***	0.002**	0.001	0.001	-0.006	0.004**	0.000
Plot ownership	0.524***	0.191*	0.738**	0.514***	0.157	-0.017	0.052
Soil fertility	-0.075	0.019	-0.234	0.094*	-0.228	-0.557***	-0.059
Soil slope	0.010	-0.044	0.306*	0.025	0.054	0.197	0.117
Soil depth	-0.096*	-0.077*	-0.122	-0.090*	0.239	0.097	0.214*
Herbicide	-0.001	-0.001	-0.002**	-0.003*	-0.003***	0.002***	0.001
Pesticide	0.001	0.001	0.002	0.001	-0.008**	0.003	0.002
Fertilizer	-0.000	-0.001**	0.002***	-0.000	0.000	0.001	0.001
Manure	0.000	-0.000**	-0.000	0.000	-0.000	-0.000	-0.000
Natural shock	0.247***	-0.105	0.247	0.039	0.693**	0.477***	0.716***
Time dummy	-0.225**	-1.346***	2.403***	-1.324***	0.195	-0.230	-0.702**
Ethiopia	-3.537***	-2.949***	-4.193***	-5.559***	-7.658***	-7.249***	-7.745***
Kenya	-0.727***	-1.839***	-2.809***	-0.537***	-1.801***	-3.420***	-2.421***
Malawi	-2.544***	-0.459***	-3.758***	-1.746***	-7.279***	-3.566***	-3.991***
Mozambique	-2.234***	1.036***	-1.189**	0.563***	-1.398***	0.408	0.295
Constant	0.465	2.103***	-4.083***	2.167***	-2.582***	-0.497	-0.969
N	*9,835*	*9,835*	*9,835*	*9,835*	*9,835*	*9,835*	*9,835*

Note: Asterisks indicate statistical significance of the robust standard errors *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table I: Multinomial Endogenous Switching Regression-Second stage results for total labour intensity

	CA0	CA1	CA2	CA3	CA4	CA5	CA6	CA7
Plot size	-1.26	-13.12	-69.99***	-231.48	-64.99***	-38.21	62.38**	-23.24
Plot distance	-0.22**	0.97**	0.42**	6.69	0.03	1.98	0.24	-0.45
Ownership	8.09	-69.48***	8.45	-705.29	-8.33	-201.36	-112.49	-168.68
Soil fertility	-7.03**	19.48***	-0.57	-175.08	-8.80	26.49	-32.91	-28.77
Soil slope	9.49**	-5.54	-5.91	-461.95	-3.25	-11.04	32.65	10.77
Soil depth	4.46*	16.77***	11.50	69.83	-15.65***	58.50	50.73	34.34
Herbicide	0.03	0.22***	0.08	30.40	0.14	-9.42	0.22	0.08
Pesticide	0.05	-0.12	-0.08	113.99	0.02	-16.59	-0.60	-1.94
Fertilizer	0.13***	0.21***	0.22***	-2.22	0.20***	0.44	-0.13	0.11
Manure	0.01***	0.00	0.00	0.30	0.00	0.01	0.00	-0.00
Shock	10.28**	-31.22**	17.62	1,165.61	1.21	-48.29	-33.71	13.33
Gender	-38.71***	-11.07	52.48	1,492.53	-2.94	81.25	-87.92	-155.75
Age	0.37	-1.00	-1.86	93.94	-1.35	6.61	-2.28	1.89
Education	0.78**	-0.98	1.56	44.95	-0.66	-20.41	-8.39	-5.51
HH size	-0.57	1.67	-1.03	-156.21	3.22	10.52	36.84**	7.97
Food security	-5.60	-16.01	3.54	2,183.15	-29.18*	-156.54	-51.78	141.71
Member	-2.94	53.26**	-38.44	3,630.67	41.99**	112.50	91.13	51.90
Kinship	-0.06	1.88***	0.16	63.94	0.88**	3.59	-1.74	2.02
Trader	-0.67	-1.72*	-0.48	-22.85	-2.35***	4.87	6.33	7.98
Govt support	-4.49	-21.90**	-25.21	693.05	16.44	-48.57	49.67	43.89
Govt confide	2.27	-64.93**	-7.88	-1,756.54*	11.22	-137.25	39.96	51.39
Improv var	9.85	-86.39**	-23.85	-2,618.86	-24.94	-162.39	57.45	55.75
Land own	0.35	-0.08	-0.08	222.62	1.05	-3.27	0.51	-21.13
Livestock	-0.43	-1.40**	-0.63	159.64	0.92	-6.66	-5.57	-4.36
Credit cnstrt	0.44	-12.09	-11.52	-3,273.92	23.67	62.92	33.25	66.79
Log asset	-6.32**	19.04***	10.38	-634.33	3.22	47.38	62.47**	7.16
M_gender	47.97***	-34.83	-53.07	-894.52	29.08	-118.55	208.71	181.43
M_age	-0.04	1.27	1.43	-44.45	1.95*	-4.73	2.83	-3.46
M_education	-0.40	2.09	-2.15	-18.69	-0.89	7.53	1.36	-6.51
M_hhsize	2.19	-7.77*	5.53	-158.17	-4.05	-22.85	-40.90*	-21.95
M_food sec	10.08	60.22***	-48.50	-2,161.27	5.42	200.78	100.48	-132.22
M_member	9.92	-34.35	105.31	-2,651.51	-45.65	-141.43	12.50	38.12
M_kinship	-0.52**	-0.11	0.46	-21.63	0.35	1.53	1.46	-1.73
M_trader	0.74	-0.92	-2.33	-122.98	1.63*	-12.82	-3.59	-9.89
M_govt suprt	-2.87	7.49	46.19	-1,746.60	-16.99	-10.11	-24.44	-97.76
M_govt confi	2.51	19.96	-51.33	1,265.88	-13.52	33.34	-121.12	18.38
M_imprvar	1.92	17.97	23.53	1,877.57	59.35*	60.90	7.96	132.23
M_land	-0.63	-0.11	-0.31	-282.97	0.56	-27.68	-0.63	8.23
M_livestock	0.45	-0.33	0.01	-79.63	-0.61	2.01	-2.73	1.17
M_crdtconstr	10.97	-5.04	20.89	2,705.55	-18.00	-236.67	-83.43	-210.04
M_lnasset	1.53	-12.26**	-4.09	95.67	-1.05	-25.28	73.14**	14.68
Time	3.12	-115.76	-119.65	-549,985.87	269.89***	-281.97	274.92	197.10
Ethiopia	-51.27	184.47	-95.75	7,501.07	121.29	668.63	612.10	-144.58
Kenya	15.20	-70.54**	-20.47	8,372.50	-105.03**	99.53	-61.48	-397.63
Malawi	-59.11	260.58**	39.33	4,163.35	97.59	omitted	342.97	263.89
Mozambique	109.62**	443.38***	226.76***	456.41	75.25*	539.29	173.32	233.07

Υ_0 hat	-17.81	339.01*	-226.42*	1,659,614.92	-371.29**	2,133.89	249.82	34.52
Υ_1 hat	103.22	242.83***	-334.00	-50,414.46	-96.81	1,416.98	-836.65	-689.16
Υ_2 hat	-157.05**	190.77	-65.63	183,378.05***	-98.09	987.52	-17.78	118.86
Υ_3 hat	-285.77	2,318.36*	-201.55	-89,162.76**	-378.14	7,059.82	109.42	4,398.29
Υ_4 hat	45.34	56.50	-34.55	96,362.24	-204.00***	-168.09	-894.24	1,187.07
Υ_5 hat	172.46	634.77**	446.16	2,633,409.78**	524.43*	131.18	1,861.50	1,349.48
Υ_6 hat	-341.90	342.31**	-81.46	927,110.72	-402.97**	-57.87	-162.02	-805.09
Υ_7 hat	826.92***	0.11	14.50	-476,130.80	-205.53	381.82	-212.72	21.86
Time* Υ_0 hat	2.42	-97.12	-302.12	-1645289.60	538.80***	1,210.47	786.03	77.42
Time* Υ_1 hat	12.67	52.03	234.99	44,899.78	262.28***	162.39	747.89	806.86
Time* Υ_2 hat	-24.09	238.59	-16.12	177,911.73***	529.21***	-774.55	654.64	1,270.71
Time* Υ_3 hat	87.13	1,252.27	-187.28	87,389.80***	832.05	6,305.13	-185.53	3,407.90
Time* Υ_4 hat	-76.60	-14.60	-127.55	-72,418.44	107.81***	367.07	352.47	167.01
Time* Υ_5 hat	-226.97	-254.80	1,095.94**	-2621499.47*	1,118.56***	-4.80	1,676.90	2,066.80
Time* Υ_6 hat	431.71*	111.09	-523.55	-932,385.07	241.53*	-138.70	255.38	328.27
Time* Υ_7 hat	-748.13**	-8.10	-20.17	474,721.16*	370.69**	1,089.84	287.35	243.37
Constant	71.68	638.26***	-26.77	561,697.81	170.80	59.12	-109.12	-460.83
N	*3,247*	*1,436*	*2,444*	*113*	*2,056*	*97*	*211*	*188*
R-squared	0.16	0.20	0.05	0.55	0.20	0.82	0.50	0.59

Note: Asterisks indicate statistical significance of the bootstrapped standard errors *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table J: Impact of CA adoption on total labour (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	109.49	96.02	13.48 (1.37)***
Residue retention	151.13	129.65	21.49 (1.51)***
Minimum tillage	230.29	126.86	103.44 (97.27)
Intercropping + residue retention	131.42	115.20	16.22 (1.72)***
Intercropping + minimum tillage	109.87	95.11	14.76 (9.11)
Residue retention + minimum tillage	150.70	143.32	7.38 (9.27)
Full package	156.96	102.42	54.54 (9.92)***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table K: Impact of CA adoption on male labour (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	48.82	44.62	4.20 (0.65)***
Residue retention	71.92	61.88	10.04 (0.68)***
Minimum tillage	54.39	65.90	-11.51 (4.46)
Intercropping + residue retention	59.86	50.85	9.01 (0.80) ***
Intercropping + minimum tillage	48.70	44.03	4.67 (4.16)
Residue retention + minimum tillage	71.15	68.45	2.70 (5.72)
Full package	63.50	47.34	16.17 (3.64) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table L: Impact of CA adoption on female labour (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	52.97	43.76	9.20 (0.77) ***
Residue retention	71.95	62.86	9.09 (0.77) ***
Minimum tillage	169.54	50.94	118.59 (97.14)
Intercropping + residue retention	67.63	59.64	7.99 (1.00) ***
Intercropping + minimum tillage	57.48	41.86	15.62 (6.44) **
Residue retention + minimum tillage	70.94	67.96	2.97 (4.58)
Full package	85.94	47.79	38.15 (7.37) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table M: Impact of CA adoption on land preparation (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	26.11	25.37	0.74 (0.39) *
Residue retention	40.50	39.47	1.03 (0.40) **
Minimum tillage	23.63	33.42	-9.79 (2.35) ***
Intercropping + residue retention	31.99	31.67	0.32 (0.49)
Intercropping + minimum tillage	23.73	24.96	-1.12 (2.87)
Residue retention + minimum tillage	39.97	41.51	-1.54 (3.06)
Full package	36.93	24.94	11.99 (3.49) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table N: Impact of CA adoption on weeding (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	27.72	31.65	-3.93 (0.38) ***
Residue retention	45.81	38.90	6.91 (0.49) ***
Minimum tillage	36.90	44.55	-7.65 (3.14) **
Intercropping + residue retention	33.13	35.02	-1.89 (0.52) ***
Intercropping + minimum tillage	32.23	31.79	0.44 (3.04)
Residue retention + minimum tillage	49.84	43.40	6.44 (4.22)
Full package	47.56	33.40	14.16 (3.81) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table O: Impact of CA adoption on harvesting (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	29.65	19.56	10.10 (0.40) ***
Residue retention	38.83	28.03	10.80 (0.95) ***
Minimum tillage	21.66	25.57	-3.91 (2.05) *
Intercropping + residue retention	35.29	26.45	8.84 (0.55) ***
Intercropping + minimum tillage	29.17	20.36	8.81 (2.69) ***
Residue retention + minimum tillage	38.58	32.86	5.72 (2.25) **
Full package	45.21	23.97	21.24 (2.98) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table P: Impact of CA adoption on threshing (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	26.01	19.44	6.57 (0.59) ***
Residue retention	26.00	23.24	2.76 (0.28) ***
Minimum tillage	16.92	23.29	-6.37 (1.76) ***
Intercropping + residue retention	31.01	22.05	8.96 (0.60) ***
Intercropping + minimum tillage	24.75	18.04	6.71 (2.23) ***
Residue retention + minimum tillage	22.31	25.55	-3.24 (2.00)
Full package	27.26	20.10	7.16 (3.12) **

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table Q: Impact of CA adoption on household labour (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	37.71	33.70	4.01 (0.98) ***
Residue retention	55.88	49.78	6.10 (1.03) ***
Minimum tillage	42.61	47.04	-4.44 (4.02)
Intercropping + residue retention	47.09	40.27	6.82 (1.89) ***
Intercropping + minimum tillage	43.71	40.11	3.60 (4.59)
Residue retention + minimum tillage	57.02	66.20	-9.18 (5.63)
Full package	63.84	57.59	6.25 (5.69)

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table R: Impact of CA adoption on hired labour (person days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	10.28	9.91	0.37 (0.32)
Residue retention	14.03	15.55	-1.52 (0.57) ***
Minimum tillage	12.68	11.98	0.70 (2.57)
Intercropping + residue retention	14.91	13.53	1.38 (0.81) *
Intercropping + minimum tillage	18.32	12.02	6.29 (3.58) *
Residue retention + minimum tillage	16.86	16.76	0.10 (3.73)
Full package	25.29	18.42	6.86 (6.48)

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table S: Impact of CA adoption on child labour (persons days/ha)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	12.95	12.16	0.79 (0.44) *
Residue retention	19.59	10.60	8.99 (0.69) ***
Minimum tillage	7.20	10.89	-3.69 (1.43) **
Intercropping + residue retention	10.69	11.89	-1.20 (0.41) ***
Intercropping + minimum tillage	6.66	14.49	-7.82 (1.60) ***
Residue retention + minimum tillage	19.33	15.56	3.77 (3.30)
Full package	17.23	14.19	3.04 (3.28)

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table T: Impact of CA adoption on farm wage income (2010 USD)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	74.59	42.30	32.29 (4.36) ***
Residue retention	28.82	26.09	2.74 (0.85) ***
Minimum tillage	30.63	37.56	-6.93 (8.91)
Intercropping + residue retention	41.62	36.13	5.49 (1.02) ***
Intercropping + minimum tillage	77.36	54.71	22.65 (25.05)
Residue retention + minimum tillage	58.38	25.21	33.17 (8.65) ***
Full package	100.39	27.90	72.49 (17.53) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table U: Impact of CA adoption on non-farm wage income (2010 USD)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	74.49	78.86	-4.37 (3.49)
Residue retention	45.59	33.05	12.54 (2.14) ***
Minimum tillage	66.05	52.70	13.35 (35.35)
Intercropping + residue retention	81.80	89.80	-8.00 (3.27) **
Intercropping + minimum tillage	41.76	105.81	-64.06 (18.86) ***
Residue retention + minimum tillage	126.58	-39.31	165.89 (26.72) ***
Full package	46.61	91.42	-44.82 (20.85) **

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table V: Impact of CA adoption on salaried income (2010 USD)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	215.05	207.57	7.48 (7.49)
Residue retention	87.92	87.78	0.13 (3.76)
Minimum tillage	125.62	67.72	57.90 (44.22)
Intercropping + residue retention	225.17	199.83	25.34 (7.03) ***
Intercropping + minimum tillage	268.24	207.57	60.67 (82.59)
Residue retention + minimum tillage	82.22	164.79	-82.57 (28.15) ***
Full package	37.11	166.82	-129.70 (22.50) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table W: Impact of CA adoption on non-farm self-owned business income (2010 USD)

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	263.03	198.93	64.11 (6.43) ***
Residue retention	187.11	181.58	5.53 (3.25) *
Minimum tillage	276.47	220.46	56.01 (85.88)
Intercropping + residue retention	337.88	192.97	144.91 (6.50) ***
Intercropping + minimum tillage	276.18	279.21	-3.03 (65.47)
Residue retention + minimum tillage	231.18	226.79	4.39 (35.56)
Full package	125.67	125.67	-75.56 (27.45) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table X: Impact of CA adoption on maize yield (kg/ha) controlling for chemical inputs

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	1721.89	1646.57	75.32 (21.10) ***
Residue retention	1898.90	2068.15	-169.25 (19.52) ***
Minimum tillage	2145.32	2504.95	-359.63 (327.6238)
Intercropping + residue retention	1456.36	1622.35	-165.99 (26.63) ***
Intercropping + minimum tillage	1346.80	1523.52	-176.72 (142.83)
Residue retention + minimum tillage	1613.00	2374.05	-761.05 (141.32) ***
Full package	1372.60	1868.91	-496.31 (110.66) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table Y: Impact of CA adoption on maize yield (kg/ha) not controlling for chemical inputs

CA practice	Actual (A)	Counterfactual (B)	ATT (C=A-B)
Intercropping	1721.89	1733.66	-11.77 (20.22)
Residue retention	1898.90	2060.73	-161.83 (20.49) ***
Minimum tillage	2145.32	2240.79	-95.47 (333.307)
Intercropping + residue retention	1456.36	1643.91	-187.55 (24.37) ***
Intercropping + minimum tillage	1346.80	1643.36	-296.56 (139.08) **
Residue retention + minimum tillage	1613.00	2252.79	-639.80 (138.05) ***
Full package	1372.60	1755.87	-383.27 (116.01) ***

Note: Asterisks indicate statistical significance of the t-test *** p<0.01, ** p<0.05, * p<0.1.
Source: Own calculation based on SIMLESA.

Table Z: Distribution of CA adoption among maize plots (pooled 2010 and 2013 samples)

CA practice	Ethiopia	Kenya	Malawi	Mozambique	Tanzania
No adoption	2,276	433	587	78	149
Intercropping	270	727	167	35	367
Residue retention	496	241	1,065	501	373
Minimum tillage	38	19	9	10	56
Intercropping + residue retention	41	1,020	384	386	397
Intercropping + minimum tillage	1	47	1	6	50
Residue retention + minimum tillage	4	22	28	94	84
Full package	2	40	11	65	83
Total observations (10,663)	3,128	2,549	2,252	1,175	1,559

Note: The sample includes only plots that grow maize.
Source: Own calculation based on SIMLESA.