The intensity of adoption of conservation agriculture by smallholder farmers in Zimbabwe

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Abstract

This article assesses the intensity of technology adoption of conservation agriculture (CA) techniques by smallholder farmers in Zimbabwe. It seeks to understand the drivers of CA adoption intensity in terms of the number of practices implemented using count data analysis. On average, the farmers in our sample adopt five out of eight possible CA practices while only 7.4% use all eight practices in any one year. Practices such as digging planting basins (81.9%), applying manure (73.2%) and timely post-planting weeding (70.1%) are relatively popular, while adoption of crop rotation (22.8%) is comparatively rare. Productivity is positively correlated to the number of techniques used. Farmers adopting all the CA practices are the most productive, with an estimated maize yield of 2.50 tons/ha, compared with a yield of less than 1 tons/ha for those using three techniques or fewer. Results from a Poisson regression indicate that education, agro-ecology, non-governmental input support and extension support have a significant impact on adoption intensity. Subsidised inputs increase the number of components used, although access to those inputs was uneven across regions of Zimbabwe. Further, the number of CA components used in the previous season positively impacts current season adoption intensity, implying that promotions of CA technologies do have a persistent effect, even after those promotions end.

Keywords: adoption intensity, conservation agriculture, count regression, smallholder farmer

JEL codes: Q16, Q15, Q55

1. Introduction

Conservation agriculture (CA) has its roots in the principles of providing permanent soil cover, minimising soil disturbance and rotating crops, and is now considered an important contributor to sustainable agriculture (FAO, 2008; Hobbs *et al.*, 2008). CA is seen as a way to address major causes of food insecurity while protecting natural resources and the environment. Conservation agriculture must be adapted to local conditions, such as soil type, climate and socio-economic settings (Erenstein *et al.*, 2008), but it can be used in all parts of Africa. Because of local adaptations, CA may look different from place to place but must conform to the principles stated above. Conservation agriculture has the potential to reduce water stress in crops, which is critically important in southern Africa as the region braces for the hotter and drier weather predicted by climate change models (Lobell *et al.,* 2008). The benefits of CA have been validated empirically through various studies around the world such as those of Cavalieri *et al.* (2009), Affholder *et al.* (2010), Marongwe *et al.* (2011) and Mazvimavi (2011). As a result, many institutions have invested in efforts to transfer this technology to smallholder farmers, particularly those of sub-Saharan Africa (SSA). Despite this enthusiasm for CA, empirical evidence on CA adoption remains fragmentary (Knowler & Bradshaw, 2007); available studies suggest that adoption of CA practices in Africa remains spotty and adoption rates are generally low (Rockstrom *et al*., 2009; Giller *et al*., 2009; Arslan *et al*., 2014; Andersson & D'Souza, 2014). This lack of adoption has prompted some international experts to openly question the potential of widespread future adoption of CA in Africa (Giller *et al*., 2009).

Application of complete CA packages is rarely observed outside South America (Ekboir, 2003; Derpsch, 2008; Bollinger *et al.,* 2006) and is difficult to achieve right from the onset of CA promotion. Farmers who are willing to follow the path to more sustainable agriculture usually embark on a long journey consisting of consecutive phases, each characterised by the use of specific practices that increasingly incorporate the three principles of CA (Triomphe *et al.,* 2007). Adapting CA to the local environment usually results in partial adoption, creating a gap between CA in theory (as promoters of CA would like it to be implemented) and CA in practice (as farmers are eventually able, or willing, to implement it). Some farmers attribute their deviations from the recommended practices to labour shortages. Partial adoption driven by labour shortages may generate lower returns from the CA practices used and ultimately discourage use of any CA components. Uptake of CA as a package in Africa has been disappointing (Friedrich *et al.,* 2012; Giller *et al.,* 2009) because of the substantial challenges associated with targeting, adapting and adopting the technology, particularly for smallholder farmers (Erenstein *et al.,* 2012).

The nature of CA practices implemented by a farmer depends on environmental, socio-economic, institutional and political constraints (Giller *et al.*, 2011). Some of the determinants clearly relate to the characteristics, preferences and experiences of individual farmers and farms such as the capital available for investing in equipment and inputs, the choice of cover crops, the soil conditions prevailing at the time CA is introduced, the care with which a farmer applies inputs or controls weeds, or the ability to learn new practices and take risks (Erenstein, 2003; Siziba, 2008). Others, however, relate more to the local or regional environment of the farm: ease of access to equipment, inputs and relevant knowledge, links to markets and the existence of policies favouring (or discouraging) the adoption of CA practices (Chiputwa *et al.,* 2011).

In Zimbabwe, promotion of CA is part of an agricultural relief programme aimed at improving the livelihood and food security status of smallholder farmers (Gukurume *et al.*, 2010). Promotion of CA has been suggested as a key strategy to alleviating the negative impact of drought and rainfall variability. Despite promotional efforts by donor agencies in Zimbabwe, adoption rates of CA by smallholder farmers have been disappointing (Marongwe *et al.*, 2011; Andersson & Giller, 2012). In practice, smallholder farmers have modified the CA package and adopted some components of the technology such as digging planting basins while leaving out others, such as mulching and crop rotation (Giller *et al*., 2009; Mazvimavi & Twomlow 2009; Pedzisa *et al*., 2010). These observations are consistent with Gowing and Palmer (2008) who assert that adoption of CA by smallholder farmers is likely to be partial, as opposed to comprehensive.

This study has two main objectives: first, to determine the influence of agro-ecology, household labour supply and institutional support on the level of adoption intensity of CA; and second, to assess the role of learning by doing and the impact of past adoption behaviours on current adoption intensity. Specifically, we ask the following research questions about the number of CA practices adopted, guided by observations from the literature:

1. Do dry agro-ecological conditions discourage adoption of CA components, especially mulching?
2. Does access to labour as measured by household size affect the use of CA components such as weeding and digging basins?
3. Do farmers who receive input assistance and training as lead farmers by NGOs use more CA components?
4. What is the effect of farming and CA experience on the number of components applied?
5. What is the impact of the number of CA components used in the previous season on the number of components to be used in the current season (i.e., is there learning in adoption)?

Table 1 shows the eight components of CA as defined by the Zimbabwe Conservation Agriculture Taskforce (ZCAT, 2009), in its guidelines to NGOs promoting the technology as a standardised package. One factor inhibiting CA adoption is that the technology presents a set of practices rather than a discrete input. Thus adoption of CA is knowledge-intensive and complex (Wall, 2007). Moreover, the components of CA are complementary in that under certain conditions the benefits increase dramatically if more components are used (Gama & Thierfelder, 2011). This complementarity explains why CA is usually promoted as a package; the challenge is to ensure that farmers take up enough elements of the package to generate significant benefits.

Table 1: Eight standard practices which make up the CA technology package in Zimbabwe

Technique	**Description**	**Importance**
Winter Weeding	Removal of all weeds soon after harvesting; there should be little disturbance of the soil	Ensures plot is weed-free at basin preparation and prevent dispersal of weed seeds
Digging planting basins	Holes dug into which a crop is planted	Enhances the capture of water from the first rains and enable targeted application of soil nutrients
Application of crop residues	Mulch is applied on the soil surface to provide at least 30% soil cover	Cushions soil against traffic , suppress weeds through shading and improves soil fertility
Application of manure	A handful of manure or compost is applied into the planting basin	Boosts soil fertility through organic nutrients
Basal fertilizer	One level beer bottle cap is applied per planting basin before the onset of rains	Enhances soil fertility through inorganic nutrients

Technique	Description	Importance
Top dressing fertilizer	One level beer bottle cap of Nitrogen fertilizer is applied per planting basin	Precision application ensures that the nutrients are available where they are needed
Timely weeding	Weed when weeds are still small, which prevents them from setting seed	In combination with mulch, leads to effective weed control
Crop rotation	Key principle of CA. Cereal/ legume rotations ensure there is optimum plant nutrient use by synergy between different crop types.	Improves soil fertility, controlling weeds, pests and diseases, and producing different types of outputs, which reduce the risk of total crop failure in cases of drought and disease outbreaks.

In contrast to most applied literature on CA which defines adoption as a binary outcome, this analysis treats the adoption process as potentially partial and incremental. For the purposes of this study, each component of CA is assessed as a discrete technique. Intensity of adoption is modelled as the number of practices adopted out of a maximum of eight. Given the dependent variable is a count of practices; we use both a Poisson and a negative binomial model to account for the non-continuous nature of the dependent variable. Our approach is different from the usual method, which measures the intensity of adoption as the proportion of total cultivated land under CA practices.

Our data come from a longitudinal dataset from Zimbabwe collected by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT). By monitoring farmers who had adopted some CA practices at one point in time, ICRISAT constructed a five-year panel database, which captures production and socio-economic information of farmers in 15 districts of Zimbabwe (Ndlovu *et al.,* 2013).

This article is structured as follows: the next section briefly reviews adoption literature examining methods used in past studies. The third section presents the research methodology, analytical methods and data. A discussion of empirical results is then followed by a conclusion section giving some policy implications of the findings.

2. Literature Review

Many past studies note that CA adoption is frequently incomplete. According to Mazvimavi (2011), more than 80% of the farmers practise maize mono-cropping on fields that are reported to be under CA in Zimbabwe. Crop rotation is constrained by lack of legume seed on the market and lack of knowledge on growing legumes in the permanent grid of planting basins (Mazvimavi *et al*., 2008). Empirical studies from Zimbabwe that have analysed the adoption of specific CA components have revealed that most farmers were not applying basal fertilizers, crop rotation or applying crop residues due to socio economic constraints (Nyathi, 2011). Inorganic fertilizers are frequently not available on the market, and when they are available, the cost is prohibitive, forcing farmers to use organic manure as a substitute (Winter-Nelson *et al.*, 2013). The communal land tenure system under mixed farming systems prohibits residue retention as such residues are claimed by other community members for grazing (Pedzisa *et al*., 2010).

Chiputwa *et al.* (2011) suggest that different households tend to select and adopt different components of the CA package owing to the heterogeneity of farmers' socio-economic profiles, perceptions and livelihood objectives. Chiputwa *et al.* find that labour intensity diminishes adoption of some CA practices supporting earlier findings that scarcity of labour is one of the main reasons why some farmers would not adopt CA (Haggblade &Tembo, 2003; Baudron *et al*., 2007). Risk aversion may contribute to piecemeal adoption because smallholder farmers in Zimbabwe have little ability to absorb risk and are inclined to adopt the less risky components of the CA technology package first. However, by adopting only parts of the technical package smallholders diminish the benefits of the technology (FAO, 2001; Ito *et al*., 2007).

Many existing studies model technology adoption using a dichotomous variable (adopt or not), where determinants of this choice are assessed econometrically (Fernandez-Cornejo *et al*., 2001). However, the adoption decision of a farmer is not necessarily dichotomous, but can also entail a choice about the level of effort or intensity of adoption (Saint-Macary *et al*., 2010). Measures of adoption intensity have been investigated by Mazvimavi and Twomlow (2009) in the case of CA. Adoption of CA is more appropriately modelled as a multiple technology selection because it is promoted as a package and understanding adoption intensity has become important especially in an environment where farmers have to make complex agronomic choices (Sharma *et al*., 2010).

It is crucial to distinguish between those farmers who adopt one practice and those who use multiple CA practices. When there are a number of technologies that might be adopted and the researcher wishes to examine the intensity of technology adoption, count regression analysis is useful. Adoption of multiple technologies can be analysed using multinomial logit (MNL) and multivariate probit. However, these methods provide computational difficulties when the number of technologies becomes greater than two in the case of MNL or more than four in the case of multivariate probit. Lohr and Park (2002), Rahelizatoro and Gillespie (2004) and Sharma *et al*. (2010) have used the total number of technologies as a measure of adoption intensity. However, count regression models are not commonly used in this literature because most studies focus on the adoption of each specific technology. While count data analysis provides little information as to the type of producer who would adopt a specific technology, the analysis can provide information to target adoption incentives to the less intensive adopters.

The underlying assumption of count regression analysis is that all events have the same probability of occurrence (Wollni *et al*., 2010). Using such analysis to measure adoption intensity requires several assumptions:

1. Use of any one technique of the eight would not preclude the use of any other seven techniques. However, implementation of one technique may not be independent of the implementation of another technique because many of them may be complementary.
2. The use of a greater number of CA techniques is assumed to be preferred by farmers because of high productivity. A limitation of this assumption is that some of the techniques may be considered to be of greater importance than others (Mazvimavi & Twomlow, 2009). In their analysis of adoption intensity of CA among smallholder farmers in Zimbabwe, Mazvimavi and Twomlow (2009) weighted the different techniques and used a Tobit regression.
3. There are no binding physical limits to the number of CA techniques that can be used by a farmer.

To analyse farmers' adoption of a portfolio of practices is a break from past research, which simply looked at individual farming practices in a stand-alone formulation. This study is similar to that of Mazvimavi and Twomlow (2009) in that it uses data from the same ICRISAT study and it also assesses adoption intensity in terms of the number of components used by a practising farmer. However, the current study differs in a number of ways such as the use of a panel data set instead of a cross-section. The panel nature of the data allows us to explore questions associated with past experience and to ask how the number of practices used changes over time. Second, the main assumption underlying the current methodology is that all components of the CA package are equally important, whereas Mazvimavi and Twomlow (2009) allocated subjective scores to the different components. Further, the current study applies count regression models to assess adoption intensity instead of a Tobit model. This article contributes to the adoption literature by examining factors influencing farmers' decision to adopt a greater number of CA components.

3. Materials and Method

The survey households, selected through multi-stage sampling, were representative of the smallholder farming community covering four natural farming regions. Zimbabwe is divided into five agro-ecological regions also known as Natural Regions (NR). Natural Regions are based mainly on quantity of rainfall, whereby rainfall diminishes from NR I to NR V (Vincent & Thomas, 1960). Natural regions III, IV, V are classified as semi-arid areas in Zimbabwe (Moyo *et al.*, 2012). The semi-arid areas have relatively high temperature with mean annual rainfall of less than 800mm. The first stage of sampling involved selection of districts where there was active promotion of CA since 2004 to cover each of four natural farming regions. NR I has been excluded from the sample because there are no smallholder farmers in the region. The second stage involved purposeful selection of two wards in each district where there was an NGO promoting CA. Two villages were randomly selected from each ward. The last stage involved random selection of households from a list of farmers provided by the NGOs. The targeted sample consists of farmers who have been trained and received technical and inputs assistance from NGOs. These farmers were specifically involved in manual CA, commonly known as planting basin CA among practitioners in Zimbabwe. The information collected included detailed agronomic data such as farm operations, inputs and outputs, crops grown, yields and CA practices implemented at the plot level. The household socio-economic characteristics and the training and technical assistance received were also captured. All questionnaires were pre-coded in the field and data was entered into SPSS in preparation for data analysis.

4. Analytical Framework

In this study, the number of CA practices adopted by a farmer is a function of a set of independent variables (X_{it}):

$$\text{In}\,(Y_{it}) = \alpha_0 + \beta' X_{it}\,, \qquad (1)$$

Where Y_{it} is the observed number of CA practices for the *i*th farmer in time *t*. Y_{it} is assumed to be independent and may be over- or under-dispersed. The vector of parameters, β, is dependent on a set of explanatory variables (X_{it}) which are hypothesised to affect the number of CA technologies used by a farmer at any time *t*.

Assuming a Poisson distribution

$$E[Y_{it}]=\exp(^{\beta X_{it}})\ (i=1\ ,\ldots,\ n)\ (t=2008\ldots..,\ 2011) \qquad (2)$$

where $E[Y_{it}]$ is the expected value of the dependent variable for the *i*th observation, exp is the exponential function, β is a 1 by k vector of parameters, X_{it} is a k by 1 vector with the values of the k independent variables for the *i*th observation in time *t*, and n is the number of observations. Equation (2) can be used to predict the expected level of adoption given the values taken by the vector of independent variables X_{it}. Two broad types of explanatory variables are often included in technology adoption studies – qualitative, modelled through dichotomous (dummy) variables, and quantitative, integer or non-integer valued. The impact of these two types of variables on the dependent variable is calculated differently. Notice that equation (2) can also be expressed as:

$$E[Y_{it}] = \exp(^{\beta 1X1_{it}})\ \exp(^{\beta 2X2_{it}})\ \exp(^{\beta kXk_{it}})\ \exp(^{\beta jXj_{it}})\ Cj(i=1\ ,\ldots,\ n) \qquad (3)$$

where j can take any one value from 1 to k and identifies a specific explanatory variable and C is a constant representing the product of the remaining exponential terms in (2). For dichotomous explanatory variables, if X_{jit}, = 0,

$E[Y_{it}]=C_j$, and when X_{jit}, = 1, $E[Y_{it}] =\exp/(^{\beta jXjit})C_j$.

Therefore:

$$100 \times (\exp/(^{\beta jXjit})\ -1), \qquad (4)$$

calculates the percentage change on E[Y] when X_{jt} goes from zero to one, for all observations (*i*) in time t. In general, for independent variables that take several integer values, the percentage change in the expected level of adoption when X_j goes from X_{j1t} to X_{j2t} can be calculated as:

$$100 \times (\exp/(^{\beta jXj2t}) - \exp/(^{\beta jXj2t})/ \exp/(^{\beta jXj2t}) \quad (5)$$

For quantitative explanatory variables the elasticity estimate at Xj_{it} is given by:

$$\partial\epsilon[Y_{it}]/\partial\epsilon[X_{it}](\beta jKj_{it/}E[Y_{it}])= \beta jXj_{it} \quad (6)$$

Count data regression analysis was employed in the estimation of the farmers' decision on how many CA practices to adopt. If overdispersion does exist, the conditional mean estimated with a Poisson model is still consistent, though the standard errors of β are biased downwards.

5. Data

Data used to determine the factors that predict the number of CA practices a farmer adopts were part of a five year panel dataset (2007–2011) collected to monitor adoption patterns of CA by smallholder farmers in Zimbabwe. Only data from four rounds (2008–2011) were used in the analysis (Table 2) because the sample of farmers increased after 2007 to include spontaneous adopters. The list of eight technologies employed by smallholder farmers in Zimbabwe and the proportion of sample farmers using each technique are presented in Table 3. The use of practices such as digging basins and timely weeding is relatively high. As might be expected, digging basins is the most popular CA technique because it determines whether a farmer applies CA or will resort to conventional tillage. Planting basins are used as a basis for determining CA adoption in Zimbabwe. Less prevalent practices include crop rotation (22.5%) and crop residue mulching (32.5%). The precise reason for adoption is an empirical question, but it seems reasonable to assume that farmers will choose options that generate additional private benefit in the short run ahead of those that do not. There was an increase in the uptake of CA components up to 2009; this observation is supported by findings in Mazvimavi *et al*. (2008). However, there was a gradual decline after 2009 representing the post-crisis period that has been characterised by a positive growth in the economy. This economic growth resulted in dwindling of donor support, despite the fact that most smallholder farmers relied on subsidised inputs (seed and fertiliser) for their CA plots. Few farmers invested in fertiliser despite the impressive yield gains associated with CA.

Table 2: Sample size of smallholder farmers in the different agro-ecological regions of Zimbabwe

Natural Region	Sample size per each round of survey			
	2007/08	2008/09	2009/10	2010/11
II	60	59	63	54
III	80	91	86	85
IV	111	101	114	124
V	87	80	86	88
Total	338	331	349	351

Table 3: Uptake of conservation agricultural techniques among Zimbabwe smallholder farmers

CA practice employed	Proportion of farmers applying a specific technique (%)				
	2007/08	2008/09	2009/10	2010/11	Pooled 2008-11
Winter Weeding	68.7	62.4	48.1	38.3	54.3
Mulch Application	31.7	38.3	32.8	26.5	32.5
Digging Basin	94.1	80.5	80.1	72.5	81.9
Spot application of manure	80.9	78.8	62.8	62.8	73.2
Application of basal fertilizer	69.7	39.3	46.2	42.1	49.3
Micro – dosing of nitrogen fertilizer	78.3	59.7	62.8	73.2	68.5
Timely Weeding	87.9	82.4	56.4	53.7	70.1
Crop Rotation	24.7	21.61	20.9	22.9.	22.5.

Source: Author Data Analysis, 2014

Across the four years of the panel, smallholder farmers commonly used between four and seven CA components with a mean of five and median of six components (Table 4). On average, only 7.4% of farmers used all eight techniques in any given year, whereas 16.6% did not apply any of the components in any given year, as the farmers reverted to the plough. The proportion of farmers using the full package declined after 2009 just as donor support declined. Indications of a high-intensity of adoption are that more than half of the farmers used more than five components in any given year. Few of the farmers (23%) used fewer than three techniques, which is indicative of low levels of adoption intensity.

Table 4: Proportion of farmers using number of CA techniques in a given year

Year	Sample Size (n)	Proportion of farmers using CA techniques (%)								
		Number of techniques used								
		0	1	2	3	4	5	6	7	8
2008	327	0.9	0.6	1.5	7.9	12.7	15.9	21.6	17.5	13.8
2009	331	7.1	0.3	0.6	2.9	11.2	19.9	26.1	19.9	8.1
2010	349	12.9	0.3	0.6	1.7	17.6	19.1	20.1	17.6	7.7
2011	335	19.4	1.2	4.5	7.2	19.2	29.5	27.4	8.9	2.6
Pooled (2008-11)	1358	16.6	0.6	1.8	4.9	12.0	17.6	21.6	17.5	7.4

Source: Author Data Analysis, 2014

Table 5 shows how the uptake of specific CA components changed across the agro-ecologies. There were no specific trends and patterns in techniques such as basin digging, timely weeding and crop rotation. However, there was a decline in the use of winter weeding and application of mulch, manure and chemical fertiliser in the drier regions. Fertiliser might not be readily available in the dry regions of Zimbabwe and low biomass production could explain the limited use of crop residue for mulching.

Table 5: Uptake of conservation agricultural techniques across agro-ecologies

CA practice employed	Proportion of farmers applying a specific technique (%)			
	NR II	NR III	NR IV	NR V
Winter Weeding	75.22	61.05	65.25	56.68
Mulch Application	41.58	38.63	31.73	26.52
Digging Basin	99.08	95.04	92.30	93.50
Spot application of manure	92.20	81.51	90.19	73.64
Application of basal fertilizer	76.60	62.37	48.01	47.65
Micro – dosing of nitrogen fertilizer	97.24	76.89	80.01	65.70
Timely Weeding	90.36	77.56	81.17	76.17
Crop Rotation	29.02	25.08	19.89	21.29

Maize yield increases with higher intensity of use of CA technology. Farmers using all eight techniques reported yields almost six times the yield of those using only one technique (Table 6). Farmers using fewer than three techniques had maize yields of less than 1 000 kg/ha, whereas using at least four techniques would shift the yield of maize to well above 1 200 kg/ha. Mean maize yield for farmers who used three techniques were surprisingly large; however, these results were driven by only eight households with particularly high yields, which can be seen by the large standard deviation. While this pattern could be driven by some other factors correlated to both adoption intensity and yield, the trend suggests that intensity of CA adoption could play an important role in its productivity effects.

Table 6: Number of CA techniques and maize productivity

Number of techniques	Observations (n)	Maize yield over 4 years (kg/ha)	
			Standard deviation
1	10	366.67	404.15
2	17	582.12	1065.30
3	54	1579.57	5527.70
4	136	1300.36	1448.51
5	241	1458.47	2613.78
6	258	1688.12	1628.41
7	214	1864.47	2059.67
8	90	2522.18	3802.63

Source: Author Data Analysis, 2014

Table 7: Definition of variables, expected signs and summary statistics

Variable	Definition	Expected sign
Numtech	Number of CA techniques applied by the household	Dependent variable
NGO support	Received inputs from NGOA (1=yes; 0 otherwise)	+
Total livestock holdings	Total livestock by household in tropical livestock units (TLU)	+
CA area	Area under CA for the season (m2)	+
Household size	Number of individuals in the household	+
Male head	Head of household is male (1=yes; 0 otherwise)	+
NR III	Household in Natural region III (1=yes; 0 otherwise)	-
NR IV	Household in Natural region IV (1=yes; 0 otherwise)	_
NR V	Household in Natural region V (1=yes; 0 otherwise)	_
2009	2009 round of survey (1=yes; 0 otherwise)	+-
2010	2010 round of survey (1=yes; 0 otherwise)	+-
2011	2011 round of survey (1=yes; 0 otherwise)	+-
CA experience	Years of using CA since first training (Years)	+
Farming experience	Years since household started farming (Years)	+
Education	Years of schooling of household head (Years)	+
Age	Age of household head	_

Variable	Definition	Expected sign
Lead farmer	Selected to assist other farmers with CA (1=yes; 0 otherwise)	+
Extension visits	Frequency of extension contacts within a season	+
Lnumtech	Number of CA techniques used by the household in the previous season.	+

Table 8 shows the pair-wise correlation coefficients, which depict whether pairs of techniques are complementary, are substitutes, or do not affect each other in their adoption patterns. For the sample of smallholder farmers using CA, correlation among the techniques is not high, specifically, the coefficients are less than 0.5 (i.e., $\rho < 0.5$).[1] Defining correlation coefficients less than 0.25 as low, Table 8 suggests that manure application is only weakly correlated with basal fertiliser use ($\rho = 0.110$), crop rotation ($\rho = 0.127$) and mulching ($\rho = 0.153$). Also, mulching is weakly correlated with digging basins ($\rho = 0.221$) and manure application ($\rho = 0.217$), while top-dressing application and winter weeding are weakly correlated ($\rho = 0.203$). Digging basins, which are used by most of the smallholder farmers (91.5%), are moderately correlated with the other CA practices.

Table 8: Pair wise correlation of CA techniques

	Winter Weeding	Mulch	Digging basin	Manure	Basal fertilizer	Top dressing	Timely weeding	Crop Rotation
Winter								
Weeding	1.000							
Mulch								
Application	0.417	1.000						
Digging Basin	0.296	0.221	1.000					
Manure	0.251	0.218	0.426	1.000				
Basal								
Fertilizer	0.149	0.153	0.259	0.110	1.000			
Top								
Dressing	0.203	0.256	0.433	0.260	0.460	1.000		
Timely Weeding	0.392	0.310	0.440	0.287	0.220	0.366	1.000	
Crop rotation	0.091	0.175	0.138	0.127	0.128	0.163	0.079	1.000

Source: Author Data Analysis, 2014

Table 9 provides the summary statistics for the variables used in the empirical model. The average smallholder farmer in the sample is 52 years old, and who has at least seven years of schooling, approximately 27 years of farming experience and had used CA for more than five years. Approximately 41% of the farmer respondents were male with a household size of six. On overage the number of oxen owned by a household was 0.7 and average number of CA practices used was 5. Almost 74% of the sample farmers had received some form of input support from NGOs and 23% of the sample farmers had been selected as lead farmers meaning those farmers who would technically assist others with the implementation of CA. On average, the total area under CA was 0.32 ha per household relative to a farm size of 1.6 ha. The proportion of farmers located in NR III was 23%, 30% in NR IV and 29% in NR V, and the remainder in NR II. The significance of NR II is that it cannot be classified as semi-arid; it is a high potential area unlike the other three regions. Table 7 provides definitions and the expected signs for the variables used in the empirical model.

Table 9: Summary statistics of variables used in the count regression model

Variable	Mean	Min	Max	Standard Deviation
Numtech	5.34	0	8	1.97
NR III	0.237	0	1	0.425
NRIV	0.309	0	1	0.462
NRV	0.295	0	1	0.456
Malehead	0.413	0	1	0.492
Age	52.06	18	92	14.36
Education level	6.73	0	14	3.81
Household size	6.298	1	23	3.010
Farmexp	27.72	3	76	14.50
CAexp	5.84	2	12	1.861
Total of Livestock	0.716	0	16	1.445
NGO	0.740	0	1	0.439
Leadff	0.235	0	1	0.424
CA area	3222.92	0	56000	3976.66
2009	0.200	0	1	0.400
2010	0.194	0	1	0.395
2011	0.196	0	1	0.395
Lnumtech	4.91	0	8	2.64

6. Results and Discussion

Regression results are presented for the Poisson model in Table 10 and for the negative binomial model in Table 11. The coefficients represent rate ratios and the impact of each explanatory variable of intensity of adoption is captured through the marginal effects. The alpha coefficient for the negative binomial was found to be significant, indicating overdispersion and therefore the negative binomial is preferred over the Poisson model. At the 1 % level of significance, the negative binomial is the suitable model for describing smallholder farmers' intensity of adoption of CA. Nonetheless, results from the two estimations are similar and both sets of results are presented.

Table 10: Poisson model results

Variable	Specification 1			Specification 2		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
NGO support	0.180***	0.034	0.912	0.134***	0.034	0.691
Total Livestock value	0.009	0.004	0.009	0.004	0.009	0.024
CA area	0.00002**	3.21e-06	0.0001	0.00002***	3.22e-06	0.0001
Household size	-0.010**	0.005	-0.049	-0.010*	0.005	-0.054
Male head	0.015	0.029	0.090	-0.017	0.029	-0.088
NR III	-.186***	0.041	-0.998	-0.132***	0.041	-0.682
NR IV	-.172***	0.040	-0.990	-0.125***	0.041	-0.652
NR V	-0.249***	0.042	-1.401	-0.208***	0.043	-1.051
2009	-0.139***	0.035	-0.688			
2010	-0.198***	0.038	-0.999			
2011	-0.186***	0.039	-0.948			
CA experience	0.004	0.010	0.021	-0.006	0.010	-0.029
Farming experience	0.004	0.002	0.019	0.003	0.002	0.016
Education	0.009*	0.005	0.038	0.006	0.005	0.034
Age	-0.001	0.002	-0.004	-0.001	0.002	-0.005
Lead farmer	0.089***	0.031	0.491	0.070**	0.034	0.382
Extension visits	-0.002	0.004	-0.013	-0.003	0.004	-0.0001

Variable	Specification 1			Specification 2		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
Lnumtech				0.042***	0.007	0.222
Constant	1.734***	0.118		1.559***	0.123	
Pseudo R-squared	0.0407			0.041		
Wald Chi-squared	194.39			185.87		

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

Table 11: Negative Binomial model results

Variable	Specification 1			Specification 2		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
NGO support	0.180***	0.034	0.912	0.134***	0.343	0.691
Total Livestock value	0.009	0.004	0.049	0.004	0.009	0.024
CA area	0.00002***	3.21e-06	0.0001	0.00002***	3.22e-06	0.0001
Household size	-0.013**	0.005	-0.070	-0.012*	0.005	-0.054
Male head	0.017	0.029	0.090	-0.018	0.028	-0.088
NR III	-.187***	0.041	-0.958	-0.132***	0.041	-0.682
NR IV	-.183***	0.040	-0.943	-0.125***	0.041	-0.652
NR V	-0.270***	0.042	-1.338	-0.208***	0.044	-1.051
2009	-0.139***	0.035	-0.687			
2010	-0.198***	0.038	-0.999			
2011	-0.186***	0.039	-0.948			
CA experience	0.001	0.010	0.007	0.007	0.010	0.029
Farming experience	0.003	0.002	0.016	0.003	0.002	0.016
Education	0.007*	0.005	0.038	0.004	0.005	0.034
Age	-0.001	0.002	-0.004	-0.001	0.002	-0.005
Lead farmer	0.086***	0.033	0.496	0.070**	0.031	0.382
Extension visits	-0.002	0.004	-0.013	-0.003	0.004	-0.014

Variable	Specification 1			Specification 2		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
Lnumtech				0.042***	0.008	0.222
Constant	1.734***	0.118		1.559***	0.123	
Lnalpha	-22.570			-22.606		
Alpha	1.57e-10			1.52e-10		
Pseudo R-squared	0.0407			0.0408		
Wald Chi-squared	194.39			185.83		

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

Adoption of CA practices appears to be driven primarily by agronomic and climatic factors, with high adoption intensity in NR II compared with the other drier regions. Being in the semi-arid areas of NR III, IV and V is associated with low adoption intensity, as farmers face more crop production constraints relative to those in NR II, which is a high-potential area. In the semi-arid regions, the use of crop residues as mulch is constrained by low biomass production and competition for use of crop residues with livestock. Table 5 shows how the practice of mulching declines and falls out in the drier areas of NR IV and V. Likewise, Table 5 shows a reduction in probability of using chemical fertilisers in drier areas, which would also contribute to the reduced intensity of CA adoption in NR III, IV and V.

The CA practices under study involve considerable drudgery associated with manual digging of basins and they tend to increase labour requirements at least in the first years (Affholder *et al.*, 2010; Mashingaidze, 2013). Results indicate that household size as a measure of family labour has a negative impact on adoption intensity, contrary to expectation. This observation is supported by Mazvimavi and Twomlow (2009) who also observed that household labour availability did not influence adoption of planting basins and might not be a major consideration for the practice. This counterintuitive result may reflect the crudeness of the measurement of labour availability through family size. We also used man day equivalents rather than total household size to measure access to labour, but this failed to reverse the sign of the estimated coefficient. There is some evidence that the area under CA has a positive and significant impact on the number of techniques adopted. The larger the area under CA, the more components are adopted. Holding labour constant, this results further argues that labour available per hectare does not constrain CA adoption.

Receiving NGO input support is positively related to the number of technologies adopted as hypothesised. NGO inputs include basal fertiliser and nitrogen fertiliser, which are components of the CA package. When NGO support is removed from an area, smallholder farmers may be unable to implement CA owing to lack of access to required critical inputs. Underdeveloped private markets for fertiliser in semi-arid areas may make it especially difficult for farmers in NR II, IV and V to maintain CA practices in the absence of NGO support.

Lead farmers are trained so that they can teach and monitor other farmers in their locality. Lead farmers tend to apply more CA components than their counterparts, presumably because they are more knowledgeable and better informed about CA. It is also possible that individuals chosen to be lead farmers are more likely to respond to training owing to factors that are not observed in these data.

Time has a negative and significant coefficient indicating that farmers adopted fewer techniques in subsequent years following the base year of 2008. A risk-averse farmer would use more techniques as he/she gains confidence in the technology; however, in this study, farmers evaluate the performance of the technology each season and subsequently reduce the intensity of use. The sequence of adoption or abandonment varies across farmers, depending on the ecological and market constraints.

We do find that the number of CA practices used during the previous season is positively related to the number of practices used in the current season. A positive coefficient on Lnumtech (lag of number of techniques applied) suggests that those who use more practices this year will adopt more than farmers who used fewer techniques last year. A marginal effect of 0.22 on Lnumtech means that a household that had one more technique last year will have 0.222 more techniques in the current season. This implies that temporary interventions that generate adoption in one year have some persistence into the future.

7. Conclusions

This article contributes to the literature by using a count data estimation procedure to examine the impact of various factors on the number of CA components adopted by smallholder farmers. A suitable econometric method to examine the data has been employed.

Several key determinants of the intensity of CA technologies were identified. Being in the drier agro-ecological regions makes it difficult for farmers to use more CA components, especially mulch and fertiliser, while farmers in high-potential areas of NR II employ a larger number of CA technologies. It becomes difficult to use more components of CA as one moves to the drier regions because of the adverse agro-ecological conditions and production constraints are more limiting.

Smaller households with limited family labour find it easier to use more components of CA relative to their counterparts from larger families. This finding is contrary to the expectation that labour constraints make it difficult to use more components such as weeding and digging basins. The smaller families could have resolved the issues of labour constraints by pooling village labour to form CA labour clubs.

Farmers who received some form of NGO input support adopted more components than those who did not receive any inputs. There appears to be a need to assist individuals or vulnerable households with inputs so that they increase their production through the introduction and adoption of CA. In addition, fertiliser should be made available at local input markets so that farmers can adopt micro-fertilisation to improve yield. The finding that the lagged number of practices applied positively affects adoption intensity suggests that there could be a lingering effect of NGO promotion on future use of CA practices.

The complementarity of the components of CA might either support or discourage adoption. If poor performance with only partial adoption discourages farmers, then use of CA is unlikely to take hold. If partial adoption leads to sufficiently good results that farmers are inclined to adopt more CA techniques over time, the benefits of adoption and the rate of adoption can be expected to magnify over time. It is important to identify the constraints to more intensive adoption so that these barriers are overcome and farmers can use more techniques to realise greater yield impact. An additional technique from the year before only leads to less than one additional technique today, implying that there is a slowdown in the decrease in adoption.

Research should be directed towards adapting the CA package in light of the constraints to the adoption of current components. The most adopted components are digging basins and application of soil amendments such as manure, basal fertiliser and top dressing. For those farmers who are most likely to adopt the technology incrementally, mulching and crop rotation would be adopted last. To facilitate adoption of the whole package, it is useful to identify and alleviate the barriers to adoption for the less-utilised techniques, which might be achieved by ensuring access to fertiliser and legume seed. The emphasis should be on ensuring that the whole package is eventually adopted to maximise environmental and productivity gains.

Note

1 Sharma *et al*. (2010) interpret a correlation coefficient greater than 0.5 (i.e., $\rho > 0.5$) as high.

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