CONSERVATION AGRICULTURE IN AFRICA: EVIDENCE FROM MOZAMBIQUE AND ZAMBIA

FINAL TECHNICAL REPORT

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INTRODUCTION

CA has been promoted as a technology for tackling southern Africa's smallholder farmers' economic and agricultural challenges such as decreasing food production, climate change and variability, and soil nutrient depletion for more than a decade. Despite the investment, empirical evidence suggests variable and often partial adoption rates. Benefits to farmers, including a reduction in the economic and environmental impacts remain highly debated and seem to be context-specific (Baudron, et al, 2012; Arslan et al, 2013; Andersson and D'Souza, 2013). Furthermore, in Zambia, for example, wide discrepancies exist in CA adoption numbers and area reported in both peer-reviewed literature and unpublished project reports (Whitfield et al 2015 and Twomlow et al., 2008). Knowledge of the geographical spread and the number of CA adopters is useful planning tool for policy and evaluating economic and poverty impact at the regional level. The lack of a clear definition of the criteria for CA adoption often leads to confusion on the current extent of CA technology use in the region.

The broad definition of CA and what constitutes adoption have thus been put forth as possible explanations of the discrepancies in adoption statistics in Southern Africa (Twomlow et al., 2008; Andersson and D'Souza, 2013). The term CA refers to the simultaneous use of reduced soil disturbance, provision of permanent soil cover and use of rotations, with variations arising mainly from the degree of comprehensiveness or specificity in application of these three principles. Lack of clarity on what constitutes CA adoption has resulted in some practitioners, researchers and promoters including partial adoption in their statistics, while others measure adoption as a simple dichotomous variable (adopter versus non-adopter), without considering the dynamic nature of the adoption process and intensity of technology adoption. Even where farmers implement all three CA principles, they hardly practice all of them in all cropping cycles, and/or on all their plots. Thus, partial adoption represents a huge challenge in the accurate calculation of adoption rates in southern Africa and continentally. There is therefore a need to present more accurate data on where CA has been adopted and the rates at which components of it are being adopted in specific locations, as useful monitoring tools for CA research and development agencies. Adoption studies also provide the primary evidence and metrics used for return-on-investment (ROI) and impact analysis (Renkow and Byerlee, 2010). Equally important in recording adoption are the settings in which farmers are exposed to and make decision about whether or not, and how to adopt CA technology; that is, how to access, employ and draw benefits from it. These factors are dynamic, they are differentially susceptible to external shocks and to the influence of policy, programmes, projects and farmer circumstances. This review is therefore primarily concerned with how the interaction of technology and prevailing conditions and circumstances influences the process and/or speed of adoption.

This study was designed to respond to the following objectives:

1. Establish and verify the extent of Conservation Agriculture (CA) adoption in Mozambique and Zambia based on regionally accepted key minimums for CA. The study addresses these information gaps through a standardized definition across countries (and at a minimum within each country as informed by country CA task forces).
2. Develop, based on the suggested refinements in CA definition and adoption, a spatially explicit CA adoption atlas showing adoption rates of the various CA elements at an appropriate geographic scale in each country. While the final scale of analysis will be determined by data availability, we propose a district level resolution for the CA adoption numbers or at most by the major agro ecological zones.
3. Overcome the problem of microstudies and regional surveys by employing meta-analysis to develop more accurate estimates of adoption for Mozambique and Zambia; the two countries have been at the forefront of smallholder CA promotion efforts since the mid-1990s. They also represent a range of agro-ecological characteristics, different demographic, socio-economic, and institutional contexts.

METHODOLOGY

Adoption of agricultural innovation is a process that involves a number of stages; awareness, interest, evaluation, trial and adoption (Feder & Umali, 1993; Doss, 2006). CA adoption is defined as the appropriation of knowledge and creation of expertise by smallholders, built through a process of innovation and a learning for three to five years. The practice of CA does not necessarily make a farmer an "adopter". Understanding the different kinds of possible CA 'adoptions' is important in defining and contextualising indicators that relate to the adoption process. A study looking at CA adoption as a binary (adopt or not) choice would offer immensely different results from one that considers CA as a technology package, analysing which components are adopted in what combination by which types of farmers and communities. Defining adoption for complex technology packages such as CA that farmers disentangle into smaller parts and only adopt components they perceive to fit their farming systems requires a two tier process. First, one has to measure whether or not the technology has been adopted at all and secondly the extent to which the various combinations have been adopted. It is also important to bear in mind that resource constrained farmers may use the comprehensive package in a particular niche on the farm to gain one particular benefit that maybe highly desired, rather than fully integrating it into the farming system. To circumvent this problem, adoption was in addition measured in terms of the percentage area where CA technology is applied, the number of adopted components and cropping cycles for all key field crops.

A mixed-method approach complemented with sequential triangulation was employed. The first activity was the expert workshop to develop an inclusive and specific definition of CA adoption. Prior to the workshop, a semi-structure questionnaire was emailed to the Project Managers and Researchers in the CA Development and Research organisations in the two countries. A list of these organisations was obtained from the FAO CA working group through the Ministries of Agriculture. In Mozambique, about 30 Development and six Research organisations and five private cotton companies were involved in the promotion of CA technologies. In Zambia, about 18 Development, five Research and Extension agencies and five private companies (Two cotton, two maize seed and one agricultural equipment companies) were listed as being involved in CA promotion in the 10 provinces. In both countries, only 40% of the CA promoters responded to the semi-structure questionnaire. The respondents were mainly asked to detail how they define and practice CA, CA technologies they were promoting, what they thought should be done to achieve wide scale adoption and who their key partners in the technology development and transfer were. The summarized results were used to guide the discussion in the CA expert workshop.

A meta-analysis was carried out to consolidate the adoption rates by agro-ecological zone and household typologies. Meta-analysis involved three steps as recommended by Hunter *et al*. (1990): retrieving relevant studies, coding the findings reported by individual studies, and accumulating findings. The meta-analysis concentrated on the application of CA technology on important staple, legume and cash crops, including maize, sorghum, cassava, groundnuts, cowpeas, soybean, pigeon peas, cotton and sunflower. Original studies for inclusion in this meta-analysis published after 1990 were identified through keyword searches in relevant literature databanks. Studies were searched in the ISI Web of Knowledge, Google Scholar, and AgEcon Search. To minimize publication bias, several publication outlets were considered, such as journals, conference proceedings, and doctoral dissertations (Lipsey et al. 2000), as well as grey literature, such as conference papers, working papers, meeting and technical reports published by research institutes, government organizations, and non-governmental organisations. Assessment of eligibility of studies to be included in the meta-analysis were done by three institutions—two CGIAR Centres (ICRISAT and CIMMYT) and one independent reviewer to insure independence and objectivity of the analysis. A protocol for the meta-analysis was developed and validated by the review team.

A two-stage screening approach was used to assess the appropriateness of the studies retrieved by our search strategy so as to select those studies that were not only relevant but also whose methodologies for data generation were suitable. First, restricting the search to the two countries, three staple crops (maize cassava, sorghum), legume crops (groundnuts, soybean, pigeon pea, cowpeas, and sesame) and three cash crops (cotton, sunflower and tobacco), we reviewed titles, abstracts, and keywords of publications and documents available in English, or Portuguese in the past 27 years (1990–2017). The time frame of the review was based on the history of CA promotion in the two countries. We applied a four exclusion criteria as follows:

a. The study is not written in English or Portuguese
b. It is not based on primary data;
c. It does not concern smallholder farmers;
d. It is not about or relevant to CA adoption and impact.

Papers that passed the first stage screening were subjected to a second, more detailed screening for conceptual clarity, methodological and contextual detail. This step screened out articles where it was not possible to determine the functional definition of adoption. We looked for clarity on three dimensions of sustained use that affect the productivity and other outcomes

- **How long** farmers have been exposed to the technology?
- Which **components or combination** of CA technology are farmers using?
- On what **area** or proportion of their fields are farmers using the CA technology components?

For methodological quality of studies, we assessed whether the study involved actual data, a randomized probability sampling technique, data were analyzed using suitable econometric or statistical techniques and results were accurately interpreted. Papers were also excluded for lack of clarity of productivity (yield/ha) and description of how it was assessed. We also assessed the description of the conditions and or circumstance under which the CA technology components were appraised and description of the relationship between them and the studied outcomes. Guided by these screening criteria, an overall rating of suitability of articles was assigned on a scale of 1–5, where: 1 = poor; 2 = fair; 3 = satisfactory; 4 = good; and 5 = excellent. Only articles with ratings of 3 (satisfactory) or higher were selected for the full text review.

In our meta-analysis, we assess the role of different measurement approaches on the observed CA technology adoption and productivity relationship, instead of the commonly used random effect model. The rational for selecting this approach was that social science studies estimates are derived from surveys (cross sectional, pooled, or panel data), that have less claim to causality compared to experimental studies of biosciences (Lipsey and Wilson, 2001). Aggregating results within a study would distort the differentiated effects based on measures and intensity of CA adoption. We examined whether the likelihood of reporting a positive or a statistically significant coefficient varies by the research design (sample population, panel versus cross-sectional design, sample size and year of data collection) or the measurement approach as recommended by Boulianne, (2015). The analytic focus was on the proportion of positive coefficients and statistically significant coefficients since the analytical techniques and reporting practices vary greatly among these studies. Though studies used in the meta-analysis often treat p-values below 0.10 as statistically significant, 0.05 was adopted as the cut off threshold (Smets & Van Ham, 2013). In our analysis we code CA technology adoption into minimum tillage only, minimum tillage and crop rotation/association or mulching, and CA full adoption when a combination of all the 3 principles were used simultaneously. Intensity of adoption was measured by proportion of cultivated land under the various CA components and number of years the CA technology had been applied on the plot. The productivity variable measured as crop yield per unit area was transformed to a natural log.

In Mozambique, to complement and verify the results extracted from the meta- analysis carried out by CIMMYT and ICRISAT, two waves of panel data (2010 &2015) and the National Agricultural Household Survey (TIA) partial panel (2008-2012) were analysed. Whereas in Zambia, two waves of panel data (2011 & 2015), as well as longitudinal data from the Rural Agricultural Livelihood Survey (RALS) were analysed. Data will be verified and validated through spatially explicit presentation of the adopters, dis-adopters and non-adopters through space and time. Data was also verified through attending stakeholder forums such as the Conservation Agriculture Working Group of Mozambique (CAWGM), field observation and Focus Group Discussions (FGDs) with farmers randomly selected from project communities. Lastly, the adoption data gathered as proposed above was presented in spatially explicit formats. Essentially, it is intended to develop an atlas of CA adoption in the two study countries, to constitute easily accessible, handy and informative source material for various types of stakeholders in the CGIAR, policy and development communities. This study also generated answers to broad questions relevant to CA research and adoption, as well as contribute to answering a number of questions relevant for CA. The study proposes solutions to various limitations identified regarding CA data, including:

- Whether or not there is a need to develop a regional definition of CA or what the reporting criteria and definitional requirements in adoption studies should be;
- The need for balance between on-farm physical observations and survey recall data;
- The need to develop high-frequency panel datasets;
- Suggestions regarding the conduct of large-scale studies (e.g. LSMS-ISA collaboration).

RESULTS AND DISCUSSION

Contextual definition of CA in Mozambique and Zambia

CA is defined as a system comprising no or minimum mechanical soil disturbance, maintaining at least 30 % of the permanent soil covered using crop residues and green cover crops, and growing crops in rotation sequences or associations (Kassam et al., 2009). Ideal situations with the maximum benefits for the soil and crops is achieved in four distinct phases over several years.

- initial phase (0–5 years), -
- transition phase (5–10 years)
- consolidation phase (10–20 years)
- maintenance phase (20 years of continuous no-till)

Tillage performed in phases 2 to 4 means a return to the initial phase, i.e. to start with CA afresh, since continuous practice is pre-requisite (Derpsch *et al,* 2015). In Mozambique, 78 participants from 28 organizations promoting CA confirmed that they have embraced the FAO definition of CA, though not reflected in practice. About 40% of the organizations did not emphases on minimum tillage but crop diversification, residue retention and good agronomic practices such as planting in lines and timely weeding. Mainly the research organizations and their partners put emphasis on practicing the three CA principles simultaneously. It was also noted that 25% of the organizations promoted CA without fertilizer and herbicides use particularly in northern Mozambique in the cassava- legume farming systems. In agreement with the Mozambican Conservation Agriculture Working Group (CAWG) operational definition of conservation agriculture[1], the experts concurred that among the variants CA practiced, no or minimum mechanical soil disturbance should be a core principle. The CA experts also corroborated that the diverse farming and cropping systems and the context-specificity of the

[1] A farming practice that conserves, improves and makes more efficient use of natural resources through integrated management of the available resources combined with external inputs with a special emphasis on minimum tillage; in-situ crop harvest residue retention or use of mulch or cover crops, and crop rotations and mixtures." (FAO, 2002)

performance and constraints of CA technologies in Mozambique make a context specific definition of CA an absolute necessity. It was commonly agreed (by 80% of the experts) that CA performance depends on soil and climatic conditions, and it should be promoted as one of the sustainable agricultural intensification practices. About sixty percent of the experts said that it is futile to promote CA technologies in the costal sand soil of northern Mozambique, and very humid agro-ecological zones. While it is not possible to develop a single form of CA for the diverse farming systems and agro-ecological zones in Mozambique, the following two CA definitions were unanimous adopted:

a. CA full adoption practiced for a minimum of three years with minimum tillage;
    - Manually with;
        - direct seeding with dibble stick or hand hoe (common in Manica, sofala and Tete provinces)
        - basins (common in northern Mozambique - Cabo Delgado, Nampula, Niassa and Zambezia Provinces)
    - Mechanised – animal traction and tractor ripping –common in Manica & Gaza provinces.

    Crop residues/ thatching grass laid at the start of the season and green manure cover crops (increasingly popular with 60% of the organisations). Maintenance of permanent soil cover was deemed impossible due to the presence of vicious termites and the common institutional laws of free grazing during the winter season.
    Crop Associations/rotation – main staple crop with legume/cash crop, inter cropping with pigeon pea, cowpea and relay cropping with sesame and cow peas.

b. Partial adoption for a minimum of three years in two forms;
    i. Minimum tillage with either crop association/rotation or soil cover.
    ii. Minimum tillage only.

Similarly, CA experts in Zambia expressed complete knowledge of the FAO CA definition though in practice they have adapted it to their organizations' missions and agro-ecological contexts. All the CA experts confirmed that they promoted the three principles of CA. Variations across provinces, organization and stakeholders were on the type of minimum tillage emphasised and other associated practices such fertiliser and herbicides use and agroforestry. About fifteen percent of the 18 development organizations promoting CA focus mainly on organic-low input CA with agroforestry. The experts pointed out that it is mainly development organisations focusing on environmental sustainability who promote organic low input CA. These organisations mainly use market incentives and premium commodity prices as scaling out strategy and for those who are not commercial oriented they target vulnerable households for food and nutritional security. Similar to Mozambique the CA experts concurred that CA performance depends on farming system, soil and climatic conditions. The experts reiterated that the Kalahari sand soils and dominant livestock farming system of western province were not suitable for CA technology scaling out. They also noted that CA technologies had failed to take off in fishing communities of northern and southern province. This suggests that knowledge of the dominant smallholder livelihood strategies is important when designing and targeting technologies. The CA experts defined CA similar to their Mozambican counterparts, but included the geographical scale in their definition. A farmer was considered a CA full adopter if s/he practiced all the three principles for a minimum of three cropping seasons consecutively on at least 0.4 of hectare.

Measuring CA adoption in Mozambique and Zambia

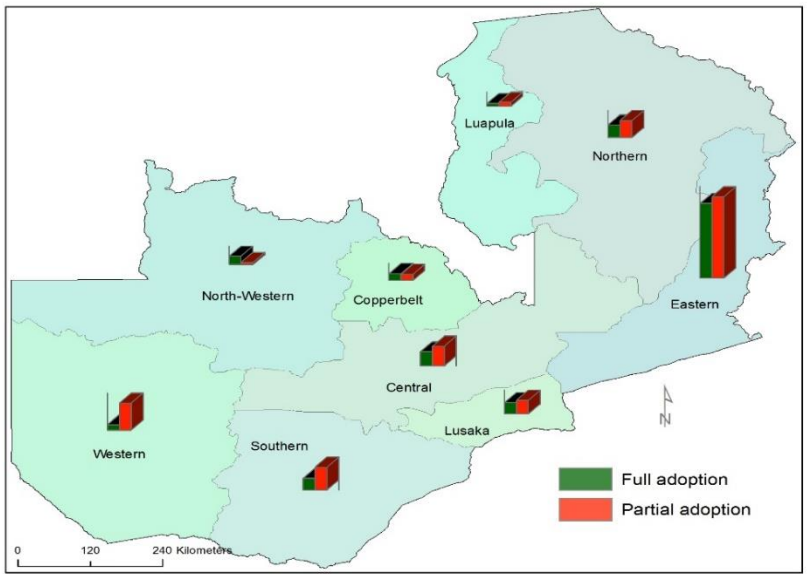

Fig.1: CA adoption in Zambia based on 2014/15 national crop forecasting survey.

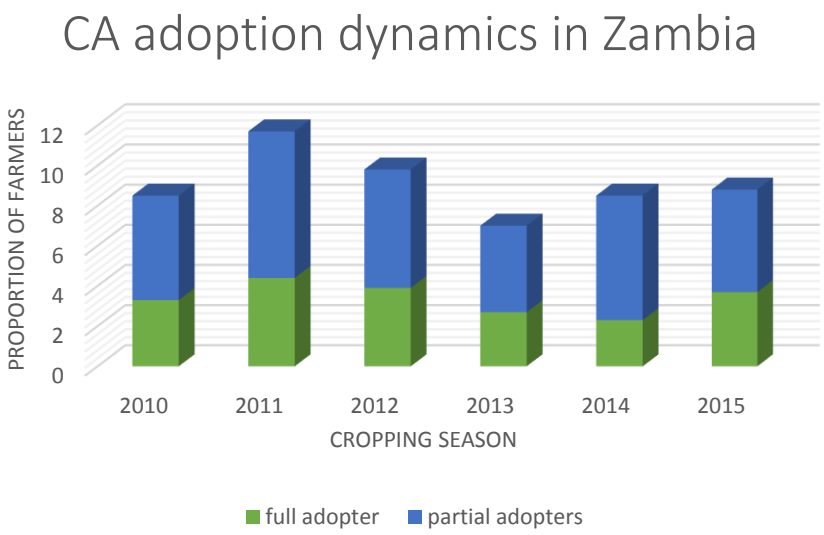

Fig: 2 CA adoption dynamics in Zambia (pooled crop forecasting data)

The national data from the two countries show spatial and temporal CA adoption variations (Fig 1&2; Table 1). Higher CA adoption rates are observed in provinces and cropping number with the highest number of CA promoters in Zambia. While in Mozambique, it is in the provinces were CA have been promoted for a longer period.

Table 1:CA adoption dynamics in Mozambique 2008 -2012 (TIA data)

Province Name	Population of farming households Interviewed	PARTIAL C.A (2008)	Adopted FULL C.A (2012)	PARTIAL C.A (2012)
Niassa	497	17	6	2
Cabo Delgado	578	72	7	11
Nampula	896	81	152	39
Zambezia	910	48	120	23
Tete	673	79	15	41
Manica	584	39	11	5
Sofala	563	55	29	15
Inhambane	838	70	14	5
Gaza	665	105	25	1
Maputo provincia	472	63	7	1
National level	**6744**	**629**	**386**	**143**

Experts from the two countries concurred that the implicit definition of a CA adopter as a farmer who practices any one of the three components of CA on some part of his/her land in a given season is widely used to quantify CA adoption. They attributed the large variation in adoption estimates and inconsistencies to the current short to medium term CA development agenda that is characterized by conservative scaling out strategies without an impact or adaptive research focused on accountability of results to donors. For example, in Mozambique, about 45% the participants highlighted that 60% of the funders provided monitoring and impact assessment tools that focused on outputs not outcomes. Thus these agencies are unable to adequately measure impacts of their projects. Insufficient investment in impact monitoring and evaluation during project designing also contributed to the CA adoption estimates discrepancies. About seventy-five percent of the development organization relied on the figures they obtain from lead farmers, resident extension officers or coordinators without validation.

Meta-analysis Results

The screening resulted in 20 articles being retained (six from Mozambique and 14 from Zambia), with 22 out of the 26 that were excluded failing to provide a functional definition of adoption. A higher proportion of the papers (78%) were excluded because they did not explicitly specify whether, for example, adoption meant a one-time use or multiple use over several cropping seasons. Forty-five percent of the studies are based on pooled cross sectional surveys derived from random samples of general farmer population, and 25% are from panel surveys. These studies reported 142 out the total 196 coefficients used to predict CA adoption and intensity of Adoption. All the studies from Mozambique used cross sectional data to predict CA adoption and the intensity of adoption. It was interesting to note that very few studies (25%) used in the meta analysis measured CA adoption as a binary variable.

Metadata-analysis findings revealed a positive correlation between CA alternatives and the key determinants of adoption. It was observed that random samples of general farmers and maize plots

are more likely to produce positive and statistically significant coefficients compared to other sampling strategies (Table 2). While pooled cross sectional data and panel surveys are less likely produce positive and statistically significant coefficient, the multivariate logistic regression model reveals that the two research designs produce consistent estimates after controlling for sampling strategy and sample size. All things equal, the meta-analysis reveals that panel data, pool cross sectional data from general population sample and large sample size are most consistent predictors of differences in findings about CA adoption variants and impact. Proportion of area allocated to the different CA technology components is the measurement approach that provided the most consistent and significant estimates (Table 3).

Table 2: Aggregating results by study characteristics

	Percentage of positive coefficients	Percentage of significant coefficient
Sample type		
Random sample of general farmer population	71 (0.001)	58 (0.002)
Random sample of cotton farmers	52 (0.09)	39 (0.04)
Random sample of maize farmers	59 (0.003)	41 (0.01)
Random sample of maize plots	66 (0.000)	55 (0.001)
Research design		
Panel design	69	36
Pooled cross section surveys	61	29
Cross section surveys	86	63
Anova Results	F 34.8 (0.001)	F = 20.6 (0.000)
Sample size		
< 1000	78	69
1000 - 5000	73	60
5001 -10 0000	69	65
>10000	54	34
Anova results	F = 3.9 (0.03)	F = 2.87 (0.04)

Table 3: Aggregate Results by measurement approach

Measurement of adoption	Percent of positive coefficients	Percent of coefficients that significant @ 0.05 level
CA adoption as dummy variable (1= adopter 0 = otherwise)	48	26
CA adoption as proportion of cultivated area	67	49
t test	3.1 (0.02)	4.3 (0.001)

The analysis is based on a series of t-test of group means, which in this case refers to the percentage of significant or positive effects. Each study characteristic is a dichotomous variable (e.g. random sample of general farmer population versus all other sample types). Equal variance is not assumed, given the very different sample sizes for each study characteristic. p-values are based on two-tail tests.

Table 4: Multiple adoption estimation results for Mozambique and Zambia

Estimation results for the probability of multiple technology adoption – Trivariate probit model

		Mozambique			Zambia		
Variable	**Variable Description**	**Minimum Tillage**	**Crop diversification**	**Mulching**	**Minimum Tillage**	**Crop diversification**	**Mulching**
Production & Climate variability							
Pmean	Mean maize yield	0.08* (0.01)	0.03***(0.02)	0.04*** (0.001)	0.15* (0.002)	0.06***(0.03)	0.19* (0.06)
Onset CoV	Onset of rain coefficient of variation	0.11 (0.08)	0.26*** (0.09)	0.01** (0.003)	0.21*** (0.001)	0.17*** (0.02)	0.03*** (0.003)
Dry spell	Average number of dry spells per season	0.23 (0.04)	0.05***) (0.02)	0.07 (0.03)	0.10* (0.08)	0.16*** (0.09)	0.13**(0.06)
PCI	Precipitation concentration index	0.09 (0.07)	0.14*** (0.05)	0.15 (0.06)	0.27 **(0.14)	0.05** (0.01)	0.15** (0.04)
Plot level characteristics							
Soil quality	Soil quality(1=very poor fertility; 4 very fertile)	-0.42 (0.12)	-0.31** (0.02)	-0.18 (0.12)	0.61 (0.25)	0.22 (0.13)	-0.98 (0.28)
Soil depth	Soil depth (1= very shallow 4 very deep)	0.29(0.14)	0.22(0.10)	0.27 (0.05)	0.76 (0.19)	0.09 (0.05)	-0.55 (0.16)
Manure	1= Manure applied	0.16 (0.09)	0.39 (0.11)	0.**15** (0.08)	0.48 (0.12)	0.17 (0.04)	-0.31 (0.15)
Urea	Quantity of urea applied (kgs)	-0.05 (0.03)	0.06 (0.001)	0.01 (0.002)	0.04*** (0.00)	0.09** (0.07)	0.02** (0.01)
Basal	Quantity of basal fertiliser applied (kgs)	-0.01 (0.003)	0.07 (0.02)	0.03 (0.01)	0.03*** (0.02)	0.06** (0.02)	0.11** (0.05)
Institutional & market access							
Extension	Extension quality index (weighted)	0.28 *** (0.1)	0.05** (0.04)	1.09 **8(0.423)	0.39*** (0.08)	0.22*** (0.13)	0.26*** (0.05)
CA promoters	Number of CA promoters in community	-0.07** (0.05)	0.03** (0.006)	-0.09** (0.04)	-0.27** (0.11)	-0.15** (0.02)	-0.19** (0.06)
$legumePrice_{t-1}$	Pre-season legume price	0.41 (0.03)	-0.22*** (0.04)	-0.17 (0.08)	0.25*** (0.09)	0.11*** (0.06)	0.31*** (0.13)
$Maize\ price_{t-1}$	Pre-season maize price	0.12 (0.04)	-0.08 (0.03)	0.31 (0.09)	0.22* (0.07)	0.28** (0.10)	0. 3* (0.001)
Tobacco cont	1= tobacco contract farming	-0.65 (0.16)	-0.19 (0.08)	0.03 (0.02)	0.31** (0.12)	0.08** (0.001)	0.18** (0.03)

The trivariate adoption model estimates (Table 4) highlight the essential role played by climate variability, market access and extension quality in shaping farmers' decision to adopt CA technology components. The results indicate that the **higher the expected productivity** (mean maize yield), the **greater the likelihood of technology adoption**. Smallholder farmers in the two countries would be persuaded to apply the three CA principles if they expected their yield to increase significantly at the end of season. The analysis also reveals that the adoption of the three CA principles is strongly and positively correlated with climate variability. The strongly positive significant results observed for the climate variability variables for Zambia (Onset of rainfall season coefficient of variation, average number of dry spells per season and PCI) across all the individual adoption models suggest that exposure to climate shocks is the main driver of CA adoption in the smallholder farming system. For instance, the PCI estimates show that with increased seasonality of the rainfall season and areas experiencing highly seasonal rainfall, farmers are more likely to adopt CA technologies. These results further reveal that increased variability of the onset of rain increase the probability of CA technology adoption. This implies smallholder farmers' response to climate variability and adaptation is greatly influenced by technology options available and knowledge on changes in climatic variability.

Additionally, extension quality is found to positively impact the probability of applying each of the CA principles. According to Derpsch et al., (2015) successful CA scaling out requires continued technical support over a period of at least 10 years until the system is solidly established. Regrettably, most development and research organizations rarely last more than five years, leaving farmer who have not yet consolidated their CA systems to the public extension system. These public extension systems are underfunded, lack motivation and the necessary up-to-date knowledge of CA technology. This partly explains the low adoption of the full suite of CA practices by smallholder farmers in developing countries. Conversely, increased number of CA promoters in a community reduced the propensity to adopt all the individual CA technology components in the two countries. These estimates underscore the importance of collaboration among the actors involved in the adaption and transfer of CA technologies.

Pre-season maize and legume price dynamics also influenced farmers' propensity to adopt CA components in Zambia. The econometric results also indicate the positive impacts of tobacco contract farming in the adoption of CA components. These results corroborate with Grabowski et al, (2014) who observed farmers participating in cotton enterprises that are offered complementary inputs on credit increase minimum tillage adoption.

Conclusion and Recommendations

The study concludes that in light of the diverse of farming systems and agro-ecological setting there is a need to develop a regional functional definition of CA and reporting criteria that provides clarity on three dimensions of adoption, methodological and contextual detail. The importance of adoption studies in supplying data for return-on-investment (ROI) and impact analysis underscores the need to develop high-frequency panel datasets and use of pooled cross sectional data from large random samples of general farmer population. To circumvent the large variations of adoption CA estimates in the same country or region over the same period, suitable spatial and temporal measurement approaches are an absolute necessity as well as a balance between on-farm physical observations and survey recall data.

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