Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Assessing the impacts of conservation agriculture on farmer livelihoods in three selected communities in central Mozambique

Peter Nkala

Doctoral Thesis

Supervisors

Dr. Michael Hauser, Centre for Development Research (CDR), BOKU

Dr. Nelson Mango, International Centre for Tropical Agriculture (CIAT)

Assoc. Prof. Dr. Ika Darnhofer, Institute of Agricultural and Forest Economics, Department of Economics and Social Sciences, BOKU

Vienna (Austria) May 2012

“For there was never yet philosopher that could endure the toothache patiently”, Leonato in William Shakespeare, Much Ado about Nothing Act 5, scene 1, 31–38

Dedicated to my Father **MLISWA NLOMPO MASAYINA NKALA** who passed on aged 85, on 07th April 2011 at a crucial point during my Doctoral Studies

M.H.D.S.R.I.P

Declaration

I declare that this dissertation is an original work and no material in this document has previously been submitted at this or any other University. References from other authors have been duly acknowledged.

Acknowledgements

Completion of this thesis was made possible by many people both in Austria and southern Africa whose contributions provided pillars of support during crucial moments when the end seemed so near and yet so far. I am very grateful to Dr. Rob Delve and Dr. Michael Hauser for facilitating my scholarship through the International Centre for Tropical Agriculture (CIAT) and the University of Natural Resources and Life Sciences (BOKU), Center for Development Research (CDR). I also express my gratitude to the Supervisory Team that comprised Assoc. Prof. Dr. Ika Darnhofer, and Dr. Michael Hauser, Dr. Rob Delve, Dr. Jemima Njuki and Dr. Nelson Mango. Their guidance shaped the course of my studies and the ultimate results of my Doctoral studies. Special mention goes to Dr. Nelson Mango for the key role he played after Dr. Delve and Dr. Njuki left CIAT: he really saved the desperate situation that I was in, I am so much indebted to him and may he forever be blessed. My appreciation for valuable comments and contributions from Dr. Marc Corbeels, Dr. Gentian Veldvisch and Dr. Jeroen Huising is also recorded. My gratitude also goes to Dr. Precious Zikhali for a wonderful contribution and working relationship at some point during the writing of my papers.

I would also like to thank the CARITAS Team, the Farmers and the Extension workers for their cooperation in the field. I would like to make special mention of Ms Katharina Engel and the OEAD Team at the Austrian Agency for International Mobility and Cooperation in Education, Science and Research (OEAD) for their contribution to my work. Lisa Aigelsperger, Florian Peloschenk, Martina Pagliarini and Anna Diop and others at the Center for Development Research (CDR), will always be remembered for good hospitality and support throughout my stay in Austria. Thank you so much all for helping me settle down. A special thank you goes to Ms Isabella Nhamhingura from CIAT for helping with logistics in Zimbabwe and Mozambique sometimes under very difficult circumstances.

I am grateful to Mr. Alfandega Estevao Manjoro, Dean of the Faculty of Commerce and Management, at the Catholic University of Mozambique for facilitating my stay in Mozambique, *Muito obrigado!* My gratitude also goes to all the smallholder farmers in the different research areas who allowed me to spend hours, days, weeks and years studying their farming activities. This thesis could not have been possible without their utmost cooperation and goodwill; I will forever be indebted to their cooperation and understanding.

Fellow Doctoral candidates, Dr. Mastewal Yami Degefa, Dr. Kalyan Gauli, Kirkman Roe, Bella Nyamukure, Dr. Benedito Cunguara and Dr. Sebastiao Famba also assisted in various ways. A lot of wisdom was gained from salient informal and formal exchanges the CDR Baracke 5 and elsewhere. It never really felt like a war zone with everyone around! *Dr*. Benedito Cunguara thank you for organizing my registration while I was back home in Zimbabwe! On the same token I would also like to thank Nqobizitha Nkomo, a musician friend and countryman based Vienna for helping with my final registration at BOKU in November 2011.

My gratitude extend to Nqobizitha Nkomo and his fellow band members Dumisani Sibanda and Vusa all of Insingizi musical group for inviting me to your performances; it felt good to listen to familiar sounds far away from home, it really never felt like I was in “Babylon”. I was really humbled to know you gentlemen!!

Back at the National University of Science and Technology, I am greatly indebted to the Vice Chancellor, Prof. Lindela Rowland Ndlovu, the Pro-Vice Chancellor Prof. Sam Sibanda, the Registrar, who is also my former Biology and Physics Teacher at Mzingwane High School and Mentor, Mr. F. Z. Mhlanga and the Dean of the Faculty of Commerce Mr. Milton Webb Ndlovu: for granting me the 6 months study leave during the last leg of my Doctoral studies despite my busy schedule as the Director of the newly established Institute of Development Studies at NUST (IDS-NUST). To Mr. Mkhokheli Sithole all the members of IDS-NUST staff, I will always remember you for the critical role you played during final stages of my studies, I thank you all!

Finally and most importantly, I am highly indebted to my family, my loving wife Sichelesile, our daughter Sibonelo Mellisa and son, Thandolwenkosi Zibusiso for bracing up with all the inconvenience of an absentee husband and father for the duration of my studies both in Zimbabwe and Austria that stretched almost 10 years. It was your support and encouragement that made it possible to complete all these studies and I am sure this is the last time this will happen. I share this Doctoral Thesis with you and may you ALL forever remain blessed!!!

Personal Note

The journey culminating in this PhD thesis has been long and arduous, smooth sailing sometimes full of thorns impeding the pace and resulting in dented and reduced aspirations, procrastination, tiredness, temptations to throw in the towel and take the easier route of doing nothing! However, as the saying goes persistence is a virtue and results are demonstrated by the deep sense of achievement which remains to be seen by many of my progeny and country-people.

This doctoral study was inspired and driven by sheer adventure and zeal to succeed. Relocating from Zimbabwe to Mozambique in August 2006 seemed to some as not so wise a move since pastures were 'browner" rather than 'greener' compared to *eGoli*, Botswana or anywhere else in the world for that matter. My instincts however showed me opportunities rather than despair. On returning from a United Nations Conference on Trade and Development (UNCTAD) conference in Tanzania in September 2007, I accidentally bumped into an advertisement on the University notice board which had to change the course of events for a lifetime for me. The rest is history, as the next thing was preparations and eventual departure for Vienna, Austria in March 2008 in pursuit of this doctoral study and this was on return from yet another UNCTAD workshop in Cairo, Egypt.

As a young economics graduate from the University of Zimbabwe (UZ), I worked in various institution and fields of development research among them, the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), the Zimbabwe Community Health Intervention Research (ZiCHIRe) and Intermediate Technology Development Group (ITDG) where my interest in scientific investigation among rural communities and smallholder farmers was nurtured. Joining the academic profession at the National University of Science and Technology (NUST) availed even more opportunities for research and travel and career development. Coming to *Universität für Bodenkultur Wien* (BOKU) to work with the farmers as a Doctoral Candidate was just an icing on the cake to a journey that began 12 years ago.

This Doctoral Thesis has taught me that with dedication, willingness, passion and desire for achievement, everything possible in life and that life itself is a journey full of many roads, highways, corners and all. How each one of us undertakes various expeditions in life is different and this has been my route that the Almighty chose for me and I complied. Developing countries models are a minefield with several "*Pandora and Black Boxes* "that Sir Arthur Lewis and others left for other generations to explore. As Antonio in the *Merchant of Venice (I, I, 77-79* said*" I hold the world but as the world, Gratian, A stage where every man must play a part, and mine a sad one."* This is my part among social scientists in developing countries'. Opportunities for further research and innovation are so abundant just requiring young scientists to take that first step – and walk the talk!!!! In my language we say "*Ukufunda kakupheli*" and indeed we learn until we depart from this world, so I may not be done yet until I breathe my last in this world, but only if "Post Docs" are certified!!!

Abstract

Agriculture is the major source of livelihood for more than 80% of the people in Mozambique. Many years of cropping using slash-and-burn practices has resulted in negative environmental impacts which result in low crop productivity, food insecurity, hunger and malnutrition. During the last 20 years there have been a number of initiatives by rural development and research organizations working in partnership with the government to introduce environmentally friendly, more efficient and sustainable technologies, so as to restore soil fertility, improve moisture conservation and ensure increased crop productivity. Among these technologies, conservation agriculture has been promoted since 2007 by the International Centre for Tropical Agriculture (CIAT), the International Maize and Wheat Improvement Centre (CIMMYT) in collaboration with the Ministry of Agriculture (MINAG) in central Mozambique. Conservation Agriculture builds on three principles: minimal soil disturbance, permanent soil cover and crop rotation.

This study assesses the alleged livelihoods benefits of conservation agriculture for smallholder farmers. These benefits include improving productivity, household income, food security and subsequently alleviating poverty. First, the benefits of conservation agriculture in southern Africa as reported in the literature were reviewed. Then empirical data was collected in the communities of Nhanguo, Pumbuto and Ruaca in central provinces of Manica and Sofala in Mozambique. The data was used to assess the differences between 75 households who had adopted (some) conservation agriculture techniques and 90 households who had not adopted any conservation agriculture techniques. Furthermore, how smallholder farmers are redesigning conservation agriculture was examined. Finally, the energy and labor efficiency of conservation agriculture was assessed.

The results show that vulnerable livelihoods, lack of access to agricultural assets, lack of institutions supporting smallholder farmers are among the factors explaining the slow adoption of conservation agriculture in central Mozambique. Under these conditions conservation agriculture has only a weak impact on livelihood outcomes, mostly through a slight improvement in crop productivity. Farmers are actively engaged in redesigning all the three principles of permanent soil cover, minimum tillage and crop rotation, thus indicating that promoting conservation agriculture as a package may not be suitable for all categories of smallholder farmers. Finally, comparing energy use within conservation agriculture and conventional agriculture shows some efficiency gains. The study concludes that conservation agriculture is a complex technology whose short- and long-term benefits are not fully apparent. If smallholder farmers are to adopt the technology, a participatory approach to adapting the technology to their need might be more promising than the current transfer-of-technology approach.

Key words: Conservation Agriculture, Livelihoods, Smallholder, Mozambique

Kurzfassung

Die Landwirtschaft stellt die vornehmliche Lebensgrundlage für mehr als 80% der Bevölkerung in Sub-Sahara Afrika dar. Die ständige landwirtschaftliche Nutzung unter Verwendung rudimentärer Methoden hat sich negativ auf die Umwelt ausgewirkt, was wiederum zu niedriger Produktivität, Ernährungsunsicherheit, Hunger und Mangelernährung in vielen Ländern in der Region beigetragen hat. In den vergangenen 15-20 Jahren wurden durch Entwicklungs- und Forschungsorganisationen in Zusammenarbeit mit Regierungen mehrere Initiativen umgesetzt, um umweltfreundliche, effiziente und nachhaltige landwirtschaftliche Nutzungsmethoden einzuführen. Diese Methoden sollten die Bodenfruchtbarkeit wieder aufbauen, die Wasserspeicherung verbessern und gleichzeitig die landwirtschaftliche Produktivität erhöhen. *Conservation agriculture* (konservierende Landwirtschaft) ist eine solche Methode, welche das International Centre for Tropical Agriculture (CIAT) und das International Maize and Wheat Improvement Centre (CIMMYT) in Zusammenarbeit mit dem Ministerium für Landwirtschaft (MINAG) seit Beginn der Landwirtschaftssaison 2007 im zentralen Mosambik gefördert hat.

Diese Forschungsarbeit gründet auf den angeblichen Nutzen konservierender Landwirtschaft, wie etwa dem Vermögen, Produktivität, Haushaltseinkommen und Ernährungssicherheit zu verbessern; konservierende Landwirtschaft soll demnach mehr zur Armutsminderung von Kleinbauern und Kleinbäuerinnen beitragen als andere Anbaumethoden. Das übergeordnete Ziel dieser Arbeit ist folglich die Wechselwirkungen zwischen konservierender Landwirtschaft und dem Lebensunterhalt der Kleinbäuerinnen und Kleinbauern zu untersuchen. Diese Untersuchung wird anhand der Gemeinden Nhanguo, Pumbuto und Ruaca in den zentralen Provinzen Manica und Sofala in Mosambik durchgeführt. Um das übergeordnete Ziel dieser Arbeit zu erreichen, wurde eine Untersuchung der Literatur zu konservierender Landwirtschaft im südlichen Afrika einschliesslich Mosambik durchgeführt; weiterhin wurde untersucht, welche Rolle konservierende Landwirtschaft zur Verbesserung von Produktivität, Haushaltseinkommen und Ernährungssicherheit (Aspekte der Lebensgrundlagen) spielen kann; schließlich wurde überprüft, auf welche Weise Kleinbäuerinnen und Kleinbauern konservierende Landwirtschaft in ihre Anbaumethoden integrieren und wie energie- und arbeitseffizient konservierende Landwirtschaft ist. Für die empirische Erhebung wurde eine Stichprobe von 75 AnwenderInnen konservierender Landwirtschaft und 90 nicht-AnwenderInnen konservierender Landwirtschaft gewählt und befragt.

Die Ergebnisse zeigen dass die Einführung konservierender Landwirtschaft im Falle vieler Kleinbauern und Kleinbäuerinnen in der Region durch Anfälligkeit sowie durch mangelnden Zugang zu landwirtschaftlichen Anlagegütern und zu unterstützenden Institutionen verlangsamt wird. Zwischen den genannten Aspekten der Lebensgrundlagen und der Einführung von konservierender Landwirtschaft konnte mit Ausnahme der Produktivitätssteigerung nur ein schwacher Zusammenhang festgestellt werden. Die Kleinbäuerinnen und Kleinbauern passen alle drei Prinzipien der konservierenden Landwirtschaft (ständige Bedeckung des Bodens, minimale Bodenbearbeitung und Fruchtfolge) in der Anwendung an; dies zeigt, dass die konservierende Landwirtschaft nicht als Paket eingeführt werden kann. Die Fallstudie schließlich bestätigt die Annahme der überlegenen Energieeffizienz konservierender Landwirtschaft. Die Studie kommt zum Schluss dass konservierende Landwirtschaft eine komplexe Methode ist, und ein partizipativer Ansatz zur Anpassung dieser Methode an die Bedürfnisse der Landwirte eher erfolgsversprechend ist, als die bisher verfolgte Empfehlung die Methode als gesamtes Paket zu übernehmen.

Schlagworte: Konservierende Landwirtschaft, Livelihoods, Kleinbäuerinnnen und Kleinbauern, Mosambik

Abbreviations and Acronyms

ATT	Average Treatment Effect on the Treated
BOKU	University of Natural Resources and Life Sciences
CA	Conservation Agriculture
CDR	Center for Development Research
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIRAD	Center for International Cooperation in Agronomic Research Development
CTIC	Conservation Technology Information Center
CIMMYT	International Maize and Wheat Improvement Center
DFID	Department for International Development (UK)
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field Schools
FRELIMO	Frente de Libertacao de Mozambique
GDP	Gross Domestic Product
GTZ	*Deutsche Gesellschaft für Technische Zusammenarbeit*
HIV &AIDS	Human Immune Virus & Acquired Immune-Deficiency Syndrome
ICB	International Convention on Biodiversity
ICRISAT	International Crop Research Institute for the Semi-arid Tropics
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IIAM	Instituto de Investigação Agrária de Mozambique
INE	Instituto Nacional de Estastica
ITDG	Intermediate Technology Development Group
NGOs	Non-Governmental Organizations
NUST	National University of Science and Technology
OEAD	Agency for International Mobility and Cooperation in Education, Science and Research (Austria)
PARPA	Poverty Reduction Strategy Papers
PCA	Precision Conservation Agriculture
PDA	Provincial Directorate of Agriculture
PSM	Propensity Score Matching
PTD	Participatory Technology Development
RENAMO	Resistencia Nacional de Mozambique
SADC	Southern African Development Community
SLF	Sustainable Livelihoods Framework
SPHFSP	Southern Province Household Food Security Programme
SSA	Sub-Saharan Africa
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on climate change
UNICEF	United Nations Children Education Fund
UNIDO	United Nations Industrial Development Organization
UNPAAERD	United Nations Program of Action for African Economics Recovery Development Research
WB	World Bank
ZiCHIRe	Zimbabwe Community Intervention Research

Structure of Thesis

This thesis comprises of two parts: Part A and Part B.

Part A gives an overview of the thesis and comprises six chapters. Chapter 1 provides some background information to agriculture in Mozambique, and introduces the concepts of conservation agriculture and livelihoods as well as the research objectives. Chapter 2 presents an overview of approaches to understand technology adoption, and provides a justification for the research approach selected for this study. Chapter 3 presents the methods used in this study. Chapter 4 presents an overview of the results. These are then discussed in Chapter 5. The conclusion, recommendations and opportunities for further research are covered in Chapter 6.

Part B consists of four research articles: two papers that have been published in peer-reviewed international journals, and two submitted manuscripts:

1. Nkala, P., N. Mango and P. Zikhali (2011a). Conservation agriculture and livelihoods of smallholder farmers in Central Mozambique. *Journal of Sustainable Agriculture* 35(7): 757–779. (Thompson-ISI Journal impact factor in 2010:0.439)
2. Nkala, P., N. Mango, M. Corbeels, G.J. Veldwisch and J. Huising (2011b). The conundrum of conservation agriculture and livelihoods in Southern Africa. *African Journal of Agricultural Research* 6(24): 5520–5528. (Thompson-ISI Journal impact factor in 2010: 0.090)
3. Nkala, P. and N. Mango (2012). Interlocking and distancing of actor projects: The case of conservation agriculture in central Mozambique. Manuscript submitted to the *Journal of Southern African Studies* on 28 Feb. 2012 (Thompson-ISI Journal impact factor in 2010:0.549)
4. Nkala, P., G. Moitzi and N. Mango (2012). Energy and labour efficiency in smallholder conservation agriculture and conventional farming in central Mozambique. Manuscripts submitted to *Renewable Agriculture and Food Systems* on 25 March 2012 (Thompson-ISI Journal impact factor in 2010:0.621)

These four papers are referred to in curly brackets throughout this thesis.

Table of Contents

PART A: Conservation Agriculture and Livelihoods

1. Introduction

This chapter looks at the background of Conservation Agriculture (CA) and livelihoods with a particular focus on key concepts, characteristics, challenges and causes of low productivity of agriculture in Mozambique. The link between CA and desired livelihoods outcomes including household income, increased wellbeing, reduced vulnerability, improved food security and sustainable use of natural resources are discussed in relation to the sustainable livelihoods framework (SLF).

1.1. Background to agriculture in central Mozambique

Mozambique comprises 10 agro-ecological zones of different climatic, agro-ecological, productivity, socio-economic and demographic characteristics (FAO, 1996; Maria and Yost, 2006; Arndt and Tarp, 2009). The soils in the central and northern regions are of low ineffective exchange capacity, moderate inorganic matter and strong acidity content (Maria and Yost, 2006). The central and northern regions have more favorable climatic conditions, and higher soil fertility, thereby making them of comparatively better productivity than the southern regions of the country. According to Arndt and Tarp (2009) and Hanlon (2010), the smallholder sector in Mozambique is generally characterized by low productivity that is largely attributed to lack of access to improved technologies and endemic poverty.

About 80% of the 22 million people in Mozambique derive their livelihoods from agriculture; a sector that contributes 20% to the gross domestic product (Kormawa and Devlin, 2011). According to the World Bank (2006) there are approximately 3.2 million smallholder families in Mozambique. Eighty-four percent of smallholder families are subsistence farmers and the rest are contract farmers (Hanlon, 2010). Contract farming is a concept that has been recently introduced by private companies in different parts of the country (Hanlon et al., 2010) and also in the two communities of Nhanguo and Ruaca included in this study. Most farmers grow maize which is the staple crop, contract farmers have been introduced to cash-crops like tobacco and cotton.

Crop production is mainly for household subsistence and food security; producing surplus for the market is an exception. Table 1 gives major characteristics of smallholder subsistence and cash-crop production systems (Cypher and Dietz, 2006).

Table 1: Smallholder production versus cash-crop farming in Mozambique

Agricultural concept	Smallholder production	Cash-crop production
Production objective	Family survival and domestic food security	Profit maximization
Labor force	Mainly family members and no direct wage payments	Hired wage labor from outside the family
Productivity of labor	Low, maximize output without regard to number of workers	Productivity higher than the wage rate
Marketing	Mainly for own consumption with small fraction of cash crops for sale	Production for the market
Risk	Extremely risk averse and want to stick to traditional practices	Risk loving and guided by the profit motive
Technology	Extremely labor intensive, uneven adoption of new methods	Capital intensive and highly adaptive to new technologies

Source: Adapted from Cypher and Dietz (2006:331).

This labor-intensive smallholder crop production system depends heavily on labor provided by family members. The employment of laborers from outside the family is done under exceptional circumstances, like for weeding purposes at the peak of the agricultural season.

In Mozambique, the slash-and-burn system of agriculture is still common and often results in numerous negative environmental (deforestation, soil erosion, increased rain-water run-off, reduced infiltration, etc.) impacts. According to Pimentel (2009), these negative environmental impacts of slash-and-burn agriculture may require up to 20-year fallow rotations to reverse. Figure 1 below shows some of the negative environmental impacts of conventional and slash-and-burn tillage systems (Hobbs, 2007).

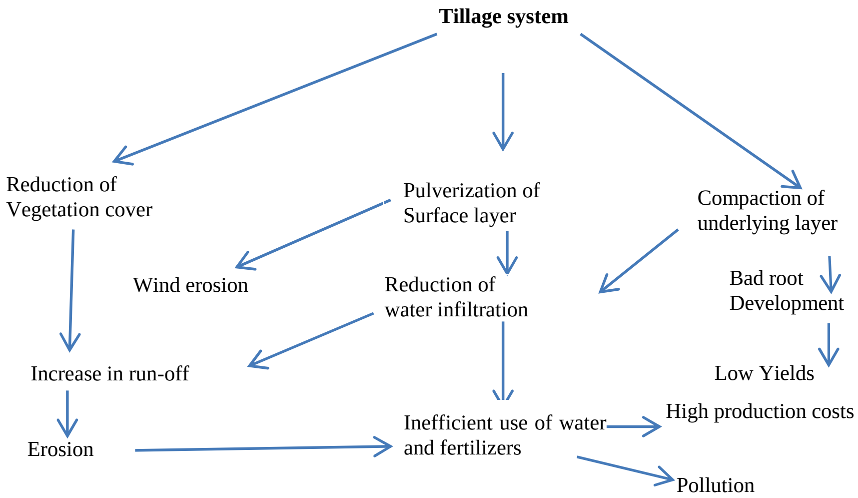

Figure 1: The effects of inappropriate tillage practices
Source: Adapted from Hobbs (2007:129)

The return of refugees at the end of the Mozambican civil conflict in 1992 and the natural increase in population led to an increase in demand for agricultural land and a 3.3% increase in the cultivated area countrywide. Subsequently the increase in demand for agricultural land resulted in the scarcity of land for cropping close to existing homesteads and forced farmers to seek more agricultural land in *Mandingwindi*, 10 – 15 km away where virgin forests that could be cleared for farming still existed.

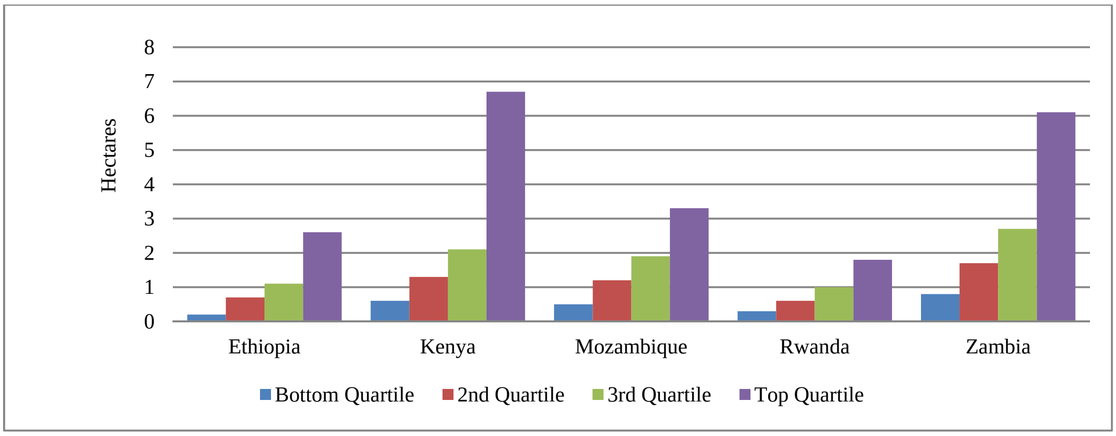

Figure 2: Farm size quartile distribution among smallholder farmers in selected countries
Source: Adapted from Cypher and Dietz (2006: 65).

However, the increasing population and limited family land entitlements are a threat to the sustainability of slash-and-burn practices still common in *Mandingwindi*. The distribution of land ownership among different quartiles of smallholder farmers in central Mozambique is shown in Figure 2. The figure shows a heavily skewed pattern of land ownership with the lowest quartile owning between 0.2 - 0.7 hectares compared to about 3 hectares on average for the top quartile (Cypher and Dietz, 2006). Although 0.2 - 0.7 hectares may seem inadequate for household food production, farmers face challenges in efficiently and timely cultivation of these plots because of lack of requisite equipment. Most smallholder farmers rely on hand-hoes as their basic tools for most of their farming activities, and such tools are less efficient for modern crop production.

1.2. Causes of low agricultural productivity in central Mozambique

Numerous interventions through scientific research, humanitarian and development projects targeting transformation of rural agriculture in Mozambique have been concerned with low productivity in the smallholder sector (Maria and Yost, 2006). Some of the outstanding factors accounting for low productivity are less-fertile soils (Maria and Yost, 2006), use of low yielding traditional varieties, use of untreated seed (Carilho, 1997), unsophisticated tools, limited use and lack of access to fertilizers and chemicals (herbicides and pesticides) (Cypher and Dietz, 2006; Hanlon and Tarp, 2009). Poor handling also results in high post-harvest losses. In recent years, climate change manifested through frequent droughts and floods is also contributing to low productivity challenges[1]. These natural disasters have exacerbated food shortages and vulnerability among farmers already facing immense food insecurity and poverty challenges.

Table 2: HIV & AIDS prevalence rates by region in Mozambique

Region	Province	Provincial Rate (%)	Regional Rate (%)
North	Nampula	5.20	13.20
	Niassa	6.80	
	Cabo Delgado	6.40	
Central	Manica	21.10	18.05
	Tete	19.80	
	Zambezia	12.70	
	Sofala	18.70	
South	Maputo City	13.00	13.08
	Maputo Province	13.70	
	Gaza	16.00	
	Inhambane	9.60	

Source: Adapted from United Nations Economic Commission for Africa (undated) (http://www.uneca.org accessed on 01/04/12)

The high incidences of HIV and AIDS have had negative knock-on effects on labour requirements in the smallholder sector in many sub-Saharan African countries including Mozambique (Hanlon, 2010). In 2005, the national HIV & AIDS prevalence was estimated at 14%, with a mortality rate of 74,000 deaths per year. The central regions of Manica, Tete, Sofala and Zambezia are the worst affected at 21 % prevalence which is far higher than the 14 % national average (see Table 2). Arndt (2003) estimated that at least 25% of Mozambican children would be orphaned as a result of HIV & AIDS by 2010 and this would worsen vulnerability and low productivity in the smallholder agricultural sector.

Furthermore, lack of public sector rural extension services in most districts is another factor responsible for low crop productivity in Mozambique's agriculture (Gemo and Rivera, 2001). According to Owens et al. (2003) public sector extension services tend to increase agricultural productivity by 8%. Rural agricultural extension services have been missing in Mozambique and were only introduced after 1987 with technical and financial support from the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ)[2], the United Nations Children and Education Fund (UNICEF) and the

[1] The observable cycle of natural hazards starting with cyclone Eline in 2000, followed later by Gloria and severe droughts in 1992 and 2005 greatly affected productivity in different parts of the country.
[2]Since January 2011, GTZ changed its name to *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) after bringing *Deutschen Entwicklungsdienst*(DED), Inwent, and GTZ under one roof.

International Fund for Agricultural Development (IFAD) (Davis, 2008). The technical and financial support towards introduction of extension services were channeled to farmers through the farmer field schools (FFS) concept, first in Manica and Tete and later in Zambezia province (Carrilho, 1997). The primary objectives of these efforts in extension services were (a) increasing farm productivity, (b) improving food security, (c) promoting value addition, (d) reducing post-harvest losses and (e) creating market linkages (Rivera and Qamar, 2003). More than two decades later most of these targets have yet to be realized.

The poor agricultural infrastructure connecting farmers to suppliers of inputs and product markets is also responsible for low agricultural productivity in Mozambique. The roads connecting farmers to major markets in Beira and Maputo are not well maintained and most are in alarming states of disrepair (Hanlon, 2010). The 1200 km road linking Beira and Maputo has several stretches of dirt-roads that are difficult to use during the rainy season (Hanlon, 2010). The poor state of the roads has forced most of the population (even for those with modest incomes) to resort to air travel for transport between cities. However, this is not a viable option for smallholder farmers as it is both costly and unsustainable for transporting small quantities of surplus produce.

Finally, access to credit is a major challenge in the purchase inputs, equipment and other farming requirements in Mozambique. According to Kormawa and Devlin (2011), generally only 8% of smallholder farmers in developing countries can access credit (Kormawa and Devlin, 2011). To summarize, widespread mono-cropping, stream-bank cultivation, lack of equipment, limited skills and knowledge all contribute to problems associated with low productivity and sustainability in the smallholder sector in Mozambique (Cypher and Dietz, 2006).

1.3. The concept of conservation agriculture

Conservation agriculture is defined as a technology that rests on three principles (Hobbs, 2007):

(a) minimal soil disturbance,
(b) permanent soil cover, and
(c) crop rotation.

This technology is also referred to as conservation tillage, no-tillage, zero-tillage and direct seeding/planting (Hobbs et al., 2006)[3]. However it should be noted that, although the two concepts of conservation agriculture (CA) and conservation tillage (CT) are often used interchangeably, conservation tillage may include some of the principles of CA but has more soil disturbance resulting in the failure to maintain a permanent or semi-permanent soil cover (Hobbs, 2007). Most importantly, CA should not be viewed as meaning just less soil tillage but be understood as a holistic system with interactions among households, crops and livestock (Hobbs, 2007).

Each principle of CA is linked to a specific purpose. The two principles of permanent soil cover and minimal soil disturbance ensure soil and water conservation and control of soil erosion (Friedrich, 2009). Increased soil biological activity, biodiversity and enhanced soil carbon sequestrations are facilitated by crop residues and cover crops are also embedded in the permanent soil cover principle (Derpsch, 2005). The principle of minimum soil disturbance targets minimum soil aggregation (Hobbs, 2007). Crop rotation is associated with the promotion of healthy and lively soils, thereby reducing pesticide and herbicide requirements, environmental pollution as well as complements natural biodiversity (Derpsch, 2005; Hobbs et al., 2007).

[3] These authors however note that although different forms of agriculture share the same features as CA they should not be confused to be the same as CA, which is more than just a particular method of cultivation.

According to Hobbs (2007), mulch resulting from leftover residues is a key component of CA that helps promote more stable soil aggregates as a result of increased microbial activity and better soil surface protection. For a system to be classified as CA, it should meet the lower limit of 30% crop residue requirement (Hobbs, 2007). The permanent soil cover principle is realized through cover crops or using dead mulching material (grass, leaves or left-over crop residues) (Mazvimavi and Twomlow, 2009). Creepers like pumpkins and melons are usually grown to serve as cover crops in many mixed cropping farming systems in southern Africa. Hobbs (2007) argues that CA reduces the problem of weeds by 50-60 % by inhibiting weed germination through mulch or cover crops.

1.4. Sustainable livelihoods

According to Costanza and Patten (1995:193-194) in biology sustainability means: "avoiding extinction and living to survive and reproduce", while in economics sustainability means: "avoiding major disruptions and collapses, hedging against instabilities and discontinuities". These statements show that sustainability is concerned with inter-temporality and longevity and the desire for bequests future generations with both renewable and non-renewable resources.

Chambers and Conway (1991:6) refer to livelihoods as "capabilities, assets and activities required as means of living" and sustainable livelihoods as "those that can cope and recover from stress and shock, maintain and enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation and which contributes to the net benefit to other livelihoods".

Livelihood capabilities, stores and resources, claims and access to these three are key ingredients to earning a living (see figure 3). According to Carney (1999), through its underlying conceptual framework; the sustainable livelihoods approach allows researchers to follow a people-centered view of the rural development paradigm. In this case, the sustainability of smallholder farmers' livelihoods builds on assets owned and on livelihood strategies engaged in. The interventions within the conservation agriculture project aim at acting as a catalyst towards realizing these livelihood outcomes.

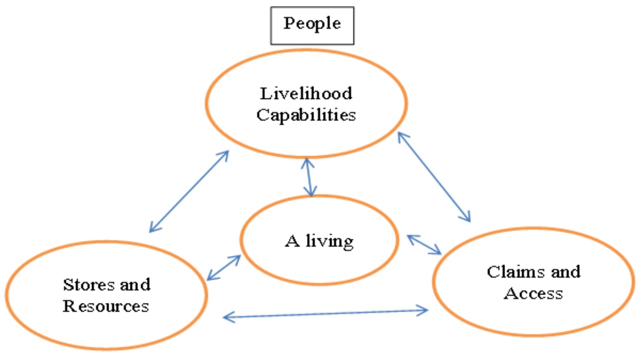

Figure 3: Components and flows in a livelihood perspective
Source: Adapted from Chambers and Conway (1991:7)

CA is part of a system of sustainable agriculture which is an agriculture that "over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically, viable; and enhances the quality of life for farmers and society as a whole" (Weil, 1990:127). These outcomes targeted by CA are achieved through efficient use of environmental and natural resources by guarding the exploitation of non-renewable resources.

The relationship between *stores and resources, claims and access* and *livelihood capabilities* are different components to life (Figure 3). The stores and resources are tangible (e.g. land, farming equipment, etc.) while livelihood capabilities, claims and access are all intangible assets (social claims, rights, networks) contributing to a living (Chambers and Conway, 1991). Smallholder farmers that are classified as poor, often face challenges accessing both tangible and intangible assets.

The Department for International Development (DFID) developed the widely accepted sustainable livelihoods framework (SLF) (see Figure 4). The framework shows the vulnerability context, livelihood assets, transforming structures and processes, livelihood strategies and outcomes in the form of these five interconnected pillars.

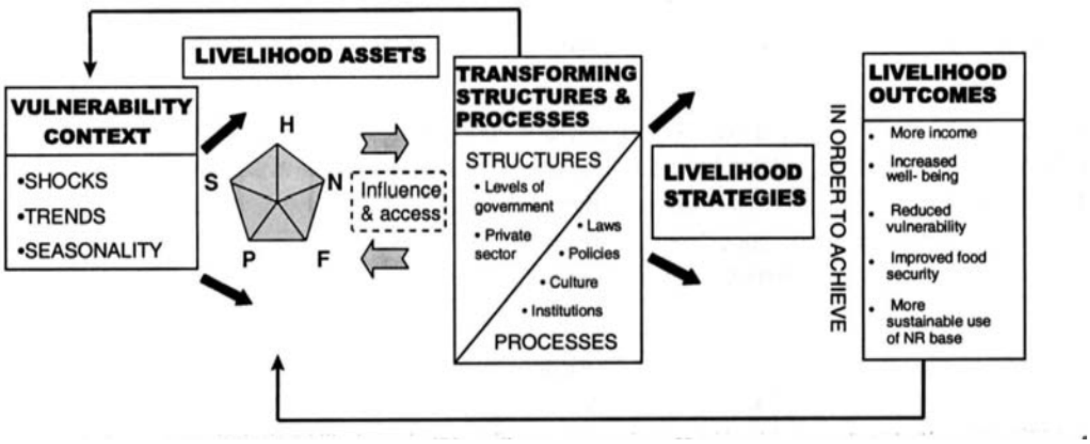

Figure 4 : The sustainable livelihoods framework
Source: Adapted from DFID (1999:11)

According to Carney (1999), this sustainable livelihoods framework concerns itself with a people-centered view of the development agenda; based on the assumption that people draw from assets owned (natural, financial, human, physical and social) to pursue a range of livelihood outcomes (health, income, reduced vulnerability, food security and a more sustainable use of natural resources). The framework emphasizes four types of sustainability, namely economic, institutional, social and environmental sustainability (Carney, 1999).

The five different forms of assets or capital sometimes presented as the great wheel of circulating capital (Chapman et al., 2003), or as a pentagon (Figure 4). The five forms of capital are explained in Box 1.1. Capital is generally the stock of assets or productive resources generated through human action which have a tendency to depreciate, be consumed and utilized in the production process and can be auctioned off (Nguthi, 2007). Ellis (2000) looks at assets as different forms of capital utilized both directly and indirectly to generate household survival options, sustenance or well-being. Scoones (2005) views assets metaphorically as an economic capital base that provides a launch pad of various livelihood strategy options.

Ownership of assets empowers people and facilitates exploration of various livelihood options, strategies and outcomes. In this study, farmers employ assets endowments, to pursue desired livelihood outcomes using conservation agriculture as a vehicle through which those outcomes can be realized. On one hand, depletion of asset may lead people into vulnerability, while the accumulation of capital assets, helps people overcome risk and vulnerability (Niehof and Price, 2001). Thus the main objective of most development interventions including projects addressing the four objectives of this study is assisting people accumulate capital assets.

Box 1.1: The five capital assets of the sustainable livelihood framework
Source: Adapted from Rakodi (2002:11)

Natural capital – the natural resource stocks from which resource flows useful to livelihoods are derived including land, water, and other environmental resources especially common pool resources.

Financial capital – the financial resources available to people (ordinary savings, credit, remittances and pensions) which provide them with different livelihood options.

Physical capital – the basic infrastructure (transport, shelter, water, energy, communication) and the production equipment and means which enable people to pursue their livelihoods.

Social assets and political capital – the social resources (networks, membership of groups, relationships of trust and reciprocity, access to wider institutions of society) on which people draw in pursuit of livelihoods.

Human Capital – the labour resources available to households which have both qualitative and quantitative dimensions. The former refers to the number of household members, and time available to engage in income-earning activities. Qualitative aspects refer to the levels of educational skills and the health status of household members.

The Sustainable Livelihood Framework guides identification and evaluation of the project impacts of CA on livelihoods and shows clearly how the various components are related. The process of formulating questions for the questionnaire was informed by various components of the Sustainable Livelihood Framework. The three pillars of the framework namely the vulnerability context, transformation structures/processes and livelihood outcomes provide a background of developing a profile of how these three concepts apply in the context of smallholder farmers in Mozambique. Shocks, trends and seasonality risks are represented by droughts, floods, wild fires and other natural disasters that have affected smallholder agriculture in recent years.

Organizations and government institutions carrying out interventions like the supply of inputs, training, transport, and marketing of agricultural produce are the transforming structures and processes impacting farmers' livelihoods in various ways (DFID, 1999). The Department of Agriculture and Extension plays a pivotal role in the provision of rural extension services in Mozambique. Policy makers in various government departments decide on where interventions proposed by NGOs are implemented; to ensure equitable distribution of community development projects and avoiding duplication of development efforts. For this reason alone, both domestic and international NGOs and private companies collaborate with government structures and defined government policy frameworks to ensure the smooth and orderly implementation of development projects.

The desired livelihood outcomes or variables that the above mentioned structures and processes seek to influence through conservation agriculture include increasing household incomes, food security, general well-being, reduced vulnerability and sustainable use of natural resources. Almost all these variables are below optimum or desirable levels in most rural smallholder farming communities, hence the need to influence them positively. The sustainable livelihoods framework has been used in a variety of situations in development work and policy, as shown in Box 1.2.

According to Ashley and Carney (1999) this Sustainable Livelihood Framework is an outcome of a continuous process of research and development efforts in the analysis of poverty, hence its adoption in poverty alleviation projects. Farrington et al. (1999) see the Sustainable Livelihood Framework as a major systems thinking milestone that has assisted in looking at poverty from a holistic perspective in the development discourse since the 1990s. Many discussions in southern Africa including Malawi, South Africa, Zambia and Zimbabwe focusing on development and policy agenda at local, regional and national levels have benefited from the Sustainable Livelihood Framework (DFID, 2000). According to Carney (1999), all the DFID research projects worldwide make use of the Sustainable Livelihood Framework. The Programme for Modernisation of Agriculture (PMA) in Uganda relied on the Framework. This application of the Sustainable Livelihood Framework has motivated its use in this study investigating the impacts of CA projects.

Box 1.2: Using the sustainable livelihoods framework to highlight policy issues

Source: Adapted from Ashley and Carney (1999:18)

(a) In case studies in southern Africa, Pakistan, Nepal and India, the SLF approach clearly demonstrated the need for policy and institutional change.
(b) In Zimbabwe, the SLF approach helped illustrate the impact of policy at local level. They facilitated dialogue about how the promotion of modern maize varieties caused a fall-off in planting of millet and sorghum, increasing poor people's vulnerability to drought.
(c) In Mexico and Central America, the SLF approach helped identify the inter-relatedness of two DFID foci at local and policy level: developing capital assets for the poor and enhancing the enabling environment.
(d) In India, the SLF design process helped feed an improved micro-level understanding of poverty into the policy process, leading to the re-orientation of an existing government watersheds initiative. It also highlighted the need to engage with political issues if inequality was to be addressed.

1.5. Conservation agriculture and Sustainable Livelihoods in Mozambique

Agriculture plays a major role in the livelihoods of more than 80% of the people in Mozambique. However, some unsustainable agricultural practices have had a negative impact on the farmers, the environment and supporting institutions. The CA interventions in the provinces of Manica, Sofala and Tete as well as Zambezia, Nampula and Cabo Delgado sought to address those negative effects through an agenda that would lead to the improvement of farmers' livelihoods. Most livelihoods in central and northern provinces are predominantly rural and depend on smallholder subsistence agriculture.

Private sector seed and fertilizer companies and agencies (local and international) like PROMEC, PACDIB, APROS (Austria) and GTZ-PRODER (German) have been working with smallholder farmers for many years, focusing on various area of rural development in Mozambique. The Provincial Directorate of Agriculture (PDA), a government department under the Ministry of Agriculture (MINAG), coordinates all the efforts by the non-governmental organizations working in the area of CA and other interventions including agricultural extension services (Rivera, 1988). It is argued (Rivera and Qamar, 2003) that positive results can be achieved if CA is a community driven development process initiated and owned by farmers through their associations in identifying and implementing best options perceived for an area. Including local, regional and international partners through workshops and training is equally important just as working through a network of partners (SADC, 2010).

1.6. Background and objectives of the study

The study was made as part of the project *"Increasing total farm productivity in vulnerable production systems in Mozambique through improved germplasm, water and nutrient use efficiencies"*. The project was implemented by the International Centre for Tropical Agriculture (CIAT), International Maize and Wheat Improvement Center (CYMMT), Instituto de Investigação Agrária de Moçambique (IIAM) in collaboration with the University of Natural Resources and Life Sciences' (BOKU) Center for Development Research (CDR) from 2007-2011. Before the start of the project CIAT and CIMMYT conducted a base line survey in 2005-2006 to understand key issues relating to smallholder agriculture. The results from the baseline survey were used to select the 13 districts in Mozambique as project sites.

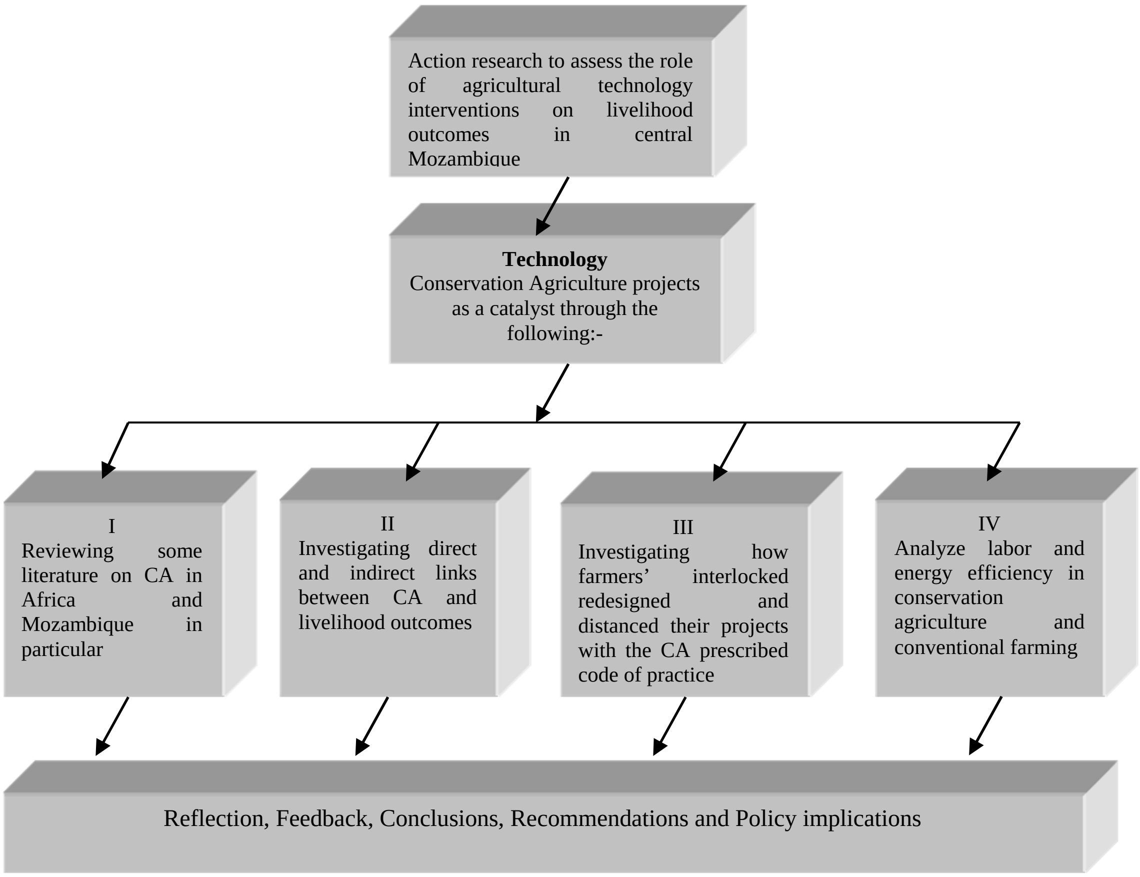

Figure 5: The objectives of the research

This study was guided by four research objectives developed from the broader goals of the programme (see figure 5):

1. To review the literature on Conservation Agriculture technology in Southern Africa in general and Mozambique in particular.
2. To investigate the livelihood contributions of conservation agriculture to smallholder farmers in Mozambique.
3. To analyze the actual practices of CA by smallholder farmers in Mozambique relative to the three recommended theoretical principles of CA.
4. To assess energy and labour efficiency between conservation agriculture and livelihoods.

Objective 4 is driven by the assertion by some researchers that CA tends to exhibit efficiencies in the use of labour and energy compared to other farming technologies (Derpsch, 2005). This assessement will seek to prove or disapprove this assertion by comparing energy and labour inputs with energy outputs between conservation agriculture and conventional farming plots of similar sizes. Conventional farming in this particular component of the study is defined as a farming technology based on unrestricted use or non-use of three principles of CA which could include but is not restricted to preparation of a clean seedbed for planting in total violation of the minimal soil disturbance principle.

2. Adoption of improved agricultural technologies

This chapter reviews theoretical concepts on the adoption of innovative agricultural technologies by farmers. Section 2.1 discusses the theoretical framework on adoption and adaptation of CA in developing countries. Section 2.2 reviews approaches used in the study of adoption of CA.

2.1. Impediments to adoption of CA

Adoption of new agricultural technologies has attracted considerable attention by anthropologists, sociologists and economists, because the majority of livelihoods in developing countries depend on agriculture (Feder et al., 1985). The successful implementation of CA in South American countries like Brazil (Dumanski, 2006) and Argentina (Friedrich, 2009) has been the major driver of CA interventions in developing countries. By 2009, farmers practiced CA on more than 106 million hectares (Friedrich et al., 2009) up from 95 million hectares in 2005 (Derpsch, 2005). The performance of CA in Europe, Asia and Africa has been below expectations especially during the 1970s through the 1990s (Cramb et al., 1999; Cramb, 2000). According to Dumanski et al. (2006), 47% of the 95 million hectares of land under CA in 2005 was largely in South America while rest was shared by North America (39%), Australia and Europe (9%) and Asia and Africa (3.9%).

The introduction of innovative technologies in LDCs has met with partial success (Feder et al., 1985). According to Giller et al. (2009) conservation agriculture in southern Africa is characterized by “distorted adoption” or “partial adoption”. Empirical evidence shows that the achievement of immediate and universal adoption has been rare (Hobbs, 2007, Friedrich et al., 2009). The adoption of CA has met with challenges in developing countries (Cramb and Culasero, 2004) including Mozambique (FAO, 2007). In the case of CA among smallholder farmers in central and northern regions of Mozambique, drought and floods and insufficient crop residues and grass needed for permanent soil cover are problematic (Mupangwa et al., 2005). Bolliger (2007) argues that farmers in the region only temporarily adopt CA as long as a project is running, but soon abandon the practice once the project is terminated.

Implementing agricultural technologies in farming systems of diverse climatic, socio-economic and ecological is challenging (Dumaski et al., 2006). First, Hobbs (2000) argues that overcoming the mindset of farmers in relation to changing the traditional ways of farming especially in systems where tillage is considered essential and serves various purposes can be very challenging. Second, the time delays in the realization of the full benefits of CA due to problems sometimes encountered during the earlier years can be discouraging to farmers expecting immediate benefits from the new technologies (Hobbs et al., 2007; Hobbs, 2007). Donor fatigue is also manifested where donors financing projects like CA do not understand why full benefits of CA may be delayed, thereby requiring sustained funding during the first 3-5 years (Derpsch, 2005). Haggblade and Tembo (2003) blamed lack of resources as the main challenge to adoption facing smallholder farmers in Zambia. As a result, most farmers in Mozambique continued with their traditional practices in other parts of the field even after they were introduced to conservation agriculture, which was implemented only on some (sections of) fields {Nkala and Mango, 2012}.

Some of the constraints responsible for lack of adoption include: lack of credit, limited access to information, risk aversion of farmers, inadequate farm sizes and inadequate incentives for farmers (Feder et al., 1985). In addition, insufficient human capital, absence of mechanization to relieve labor shortages thus preventing timeliness of operations; unreliable supply of inputs such as seed, fertilizer, chemicals and water; and inappropriate transportation infrastructure (Cramb, 2000; Derpsch, 2005; Friedrich et al., 2009). Halderman and Paxson (1991) argue that limited access to credit and lack of opportunities in off-farm income generating activities influences the risk averse disposition of smallholder farmers’ perceptions regarding new technologies. Morduch (1990) and Biswanger and Rosenzweig (1990), using data from India, showed that poorer farmers were more risk averse and preferred less risky and less costly agricultural technologies. The poorer smallholder farmers had difficulties in accessing pesticides and herbicides critical for weed control during the initial 1-3 years of adopting CA (Mazvimavi and Twomlow, 2009).

Low access to credit and high costs constraints of acquiring information tend to immobilize smallholder farmers from smoothening consumption ex-post (Feder et al., 1985). The introduction of targeted credit facilities, information technology, and orderly supply of necessary and complementary inputs, infrastructure investments and better marketing networks have been recommended to encourage farmers' positive attitudes towards new technologies (Feder et al., 1985). Although the primary objective of these efforts is increasing technology adoption, changes in crop production and composition and increasing off-farm incomes can be used as secondary targets in these endeavors (Feder et al., 1985).

Despite the poor adoption rates so far, some researchers argue that CA has the potential to improve productivity and thus enhance food security (Derpsch, 2005; Friedrich et al., 2009) and poverty alleviation in vulnerable production systems in Africa (Mercado et al., 2000; Hobbs 2007). Hobbs (2007) argues that accelerated adoption can be achieved through instituting participatory approaches in the earlier years, involving all stakeholders and carefully monitoring the situation to ward off negative outcomes. The FAO (2007) supported by Friedrich et al. (2009) asserts that benefits of adopting conservation agriculture include reduced environmental degradation, improved air and water quality, improved biodiversity and energy efficiency. Smallholder farmers could achieve the provision of healthy living environments through reduction in the use of fossil fuels, pesticides and other pollutants (FAO, 2007).

According to the World Bank (2001), meeting development targets in developing countries hinges on accurately targeting and realizing goals influencing technology adoption in predominantly rural smallholder farming systems. Farming systems comprises individuals with broadly similar resource bases, enterprise patterns, livelihoods and constraints requiring similar development intervention strategies (FAO, 2007; World Bank, 2001). The natural resource base, pattern of dominance in farming systems and livelihoods strategies in relation to markets and intensity of production activities are the criteria used in the classification of farming systems (FAO, 1996, 2007). The rain-fed cropping systems, artisanal fishing and farming systems and urban based horticultural and livestock production system are the dominant farming systems that support the majority of livelihoods in Mozambique (Hanlon, 2010). The CIAT/CIMMYT conservation agriculture interventions introduced in 2007 targeted the predominantly rain-fed rural cropping system in central and northern parts of the country.

2.2. Review of approaches used to understand the adoption of CA

This study uses action research and meta-analysis to understand the project impacts of conservation agriculture in three communities in Mozambique. These approaches have been used to investigate phenomenon like the effects of organic agriculture on biodiversity and abundance (Tornatzky and Klein, 1982; Loomis and White, 1995), the cost-benefit analysis of investment in international agricultural research centers of the CIAGR (Bengtsson et al., 2005; Tonitto et al., 2005) and the characteristics and factors influencing innovation and adoption of agricultural technologies (Raitzer and Kelly, 2006). Action research and meta-analysis are known to produce results and that have informed government policies (Neuman, 2006).

Nowak (1992) argues that anthropologists and sociologists – unlike economists – adopt qualitative approaches in highlighting the role of farmers' subjective assessments of innovative agricultural technologies and how they influence the adoption decisions and behavior of farmers (O'Mara, 1980; Nowak, 1992; Lin and Molin, 1993). These commodity attribute perceptions have long been of interest to social scientists investigating agricultural technology adoption decisions (Adesina and Baidu-Forso, 1995).

Economists have dismissed the importance of perceptions and omitted them in earlier models mainly because of lack of access to observations to directly and quantitatively test these qualitative hypotheses (O'Mara, 1980). However, the role of subjective preferences and product characteristics in explaining consumer demand is acknowledged by economists studying consumer demand (Lin and Milon, 1993). Extension services, education and media exposure have been included in some agricultural technology adoption models in economics (Strauss et al., 1991). A strong case was raised for inclusion of farmers' subjective perceptions in addition to the commonly used socio-economic and institutional factors in a Tobit model of technology adoption in Burkina Faso (Adesina and Baidu-Forso, 1995).

3. Methods

In this chapter, the various approaches in the selection of research sites, the questionnaire, data collection, data analysis and presentation are discussed. Sections 3.1 - 3.6, look at the role and justification of action research, meta-analysis, and propensity score matching and qualitative approaches as methodologies used in this study. The methods are linked with each of the four objectives of the study.

3.1. Action Research

This study adopts action research as the main investigative approach. As Peters (1997) states, action research is concerned with a variety of methodological traditions involving a diversity of approaches, techniques, research designs applied in various fields of study. "Action" and "research" are dual focuses in "*Action Research*" methodology whereby *action* concerns bringing about change in some community organization or programme while *research* is associated with the search for knowledge to increase understanding of the phenomenon by the researcher (Dick, 2004).

This study adopts multidimensional action research to leverage on the advantages of both quantitative and qualitative approaches. Action research was chosen as the research technique because it could facilitate learning from experiences and various modes of inquiry and thereby contribute to theory that can be used by others (Röling et al., 2004). Personal or professional curiosity to learn and contribute to existing theory is one approach through which action research can be employed (Peters, 1997). The process of action research moves in a spiral formation with numerous periods of feedbacks and feed-forward as the researcher reviews and reflects mileage gained in the research process (Dick, 1993) thus the emphasis of reflection and feedback in the summary of objectives (figure 5).

This approach has also been selected because it facilitates the elicitation of data required to answer each of the four objectives of this study. For example the econometric estimation on the role of CA in livelihoods improvement {Nkala et al., 2011a} required quantitative data, which were collected using a questionnaire. The strengths of combining quantitative and qualitative approaches in this study, was the ability of the technique to relate to the context of the research, study the dynamic processes, determining how farmers interpreted various approaches to CA practices, and collecting data under more naturalistic settings. The flexibility of action research approach allowed for changes during research implementation process, to respond to local situations, conditions and stakeholder needs.

Peters (1997) identifies six possible intended objectives or outcomes that theoretically drive the adoption of an action research methodology. These six are a) improving current performance and approaches, b) improving researchers' own practices, c) improving one's own rational thinking or societal perspectives, d) developing both theoretical and practical understanding, e) achievement of personal and professional development, and f) finding one's position in the system where action research is taking place (Peters, 1997). This study sought to pursue the theoretical and practical understanding of key issues relating to conservation agriculture and livelihoods as well as achieve personal and professional development (Dormon, 2006; Probst et al., 2003) as the two intended outcomes of this action research process.

As a result, this study leverages on the strengths of quantitative {Nkala et al., 2011a; Nkala et al., 2011b; Nkala et al., 2012} and qualitative {Nkala and Mango, 2012} research techniques by using either of the two approaches in the pursuit of the four different objectives (Neuman, 2006). A total of 165 household interviews were conducted with 75 CA and 90 non-CA smallholder farmers using questionnaires. The quantitative data was entered and analysed using the statistical package for the social Sciences (SPSS) (Punch, 2005; Neuman, 2006).

The qualitative data elicitation process made use of group discussions, field notes and observations (Creswell, 2009). Qualitative data were transcribed, coded and analyzed using Nudist, a qualitative data analysis software, that achieves the same objectives as Anthropac, Maxqda or Atlas.ti. Using both quantitative and qualitative approaches helped in triangulation of data and enhancing the validity of findings.

3.2. Literature review

The literature review focused on articles discussing conservation agriculture and livelihoods in southern Africa and Mozambique {Nkala et al., 2011b}. Meta-analysis as a research technique was developed by Gene Glass and associates in the 1950s (Davis and Crombie, 2001). It allows to integrate results of independent researchers at primary, secondary and meta-levels (Davies and Crombie, 2001). Shapiro (1994) looks at meta-analysis as beginning with scientific studies, usually performed by academics or government agencies using secondary literature sources to get data that are run through computer models. Meta-analysis combines findings from independent studies to deduce conclusions about the scientific phenomenon.

This study used primary meta-analysis whereby the review and analysis of articles was done by the researcher as opposed to secondary meta-analysis where one person does the search for articles and another person works on the analysis of those articles. At the next level after secondary meta-analysis, the process is called meta-evaluation specifically seeking delineating, obtaining, and applying descriptive and judgmental information (Raitzer and Kelly, 2007).

There was systematic review of literature pertinent and relevant to this particular area of study particularly adoption trends of conservation agriculture in the world, in Africa and in Mozambique as recommended by Weed (2005). As Davies and Crombie (2001) suggest meta-analysis approaches that strive for a complete coverage of relevant studies, using various data sources, of different durations and diverse settings to give a balanced view were explored. The search was deliberately limited to journal articles, as the ultimate objective was to write a review paper that would contribute to the general understanding of CA in the region.

Literature was retrieved using key words (conservation agriculture, principles of CA, livelihoods, sustainable livelihoods) from various data bases (science direct, scopus). The literature was organized around themes such as origins of CA, principles of CA, benefits of CA, challenges of CA, farmers' perceptions of CA, adoption and adaptation of the technology, etc. The validity of this approach hinges on the quality of the systematic review of articles addressing each theme or sub-theme. The 44 articles provided sufficient data required for understanding core issues on conservation agriculture and livelihoods in southern Africa {Nkala et al., 2011b}.

Like other research approaches meta-analysis has a number of weaknesses that the researcher has had to guard against. For example, in meta-analysis the researcher's biases have a tendency to tilt research results in a particular direction (Stufflebeam, 2001). The more reviewers of selected documents and the more critical these reviewers are, the better will the review article be (Stufflebeam, 2001). The narrative reviews and prior beliefs of the researcher towards certain publications may cause an unbalanced review and distorted picture of the phenomena hence the rigor and objectivity in reporting of research results is necessary (Stufflebeam, 2001). Meta-analysis has been known to favoring studies reporting successes while ignoring critical ones that report failures thereby giving an unbalanced view of the research report (Davis and Crombie, 2001). In Nkala et al. {2011b}, critiques and contributions were received from the five contributing authors and before publication the paper went through several drafts, each being critically appraised and improved.

3.3. Site selection for the collection of empirical data

First, several familiarization visits were made to each of the CA sites in the 13 districts in central and northern Mozambique which were part of the CIAT/CIMMYT conservation agriculture project. Some of these sites were characterized by long distances from each other and lack of good roads which made access difficult, especially during the rainy season. Three of the 13 sites had already been abandoned due to lack of CA activities and absence of a government extension staff working in those areas. Since it was not the objective of this study to compare the impact of the CA project between sites, it was not necessary to cover many sites. It was thus decided that an optimal strategy would be to focus on a few sites, and conducting a detailed analysis of CA in those sites.

Finally, three sites were selected (Nhanguo, Pumnbuto and Ruaca), as the farmers and extension workers in these communities were highly motivated and showed significant progress in implementing CA principles in their farming practices. Although falling in different administrative districts, the selected sites were close to each other. This means that there were no stark differences in terms of soils, cropping patterns, socio-economic and cultural characteristics. This made it possible to combine the data from the three sites.

After the selection of the research sites a research team comprising six people was constituted. This included the field supervisor, one extension worker from each of the selected sites, one staff from CARITAS (in Ruaca) and the researcher. The extension workers and the member of staff of CARITAS provided a very important link to the farming community. The links were maintained throughout the study period and served as conduits for information between the researcher, the farmers and other stakeholders. Several meetings with the extension workers were held where the study was explained and work-plans discussed together with other working arrangements relating to training on data collection, actual data collection schedules and compensation of research assistants.

3.4. Quantitative analysis of adoption effect

This analysis assumed that farmers undertake livelihood strategies after taking stock of their asset endowment. I make a second key assumption that, given their asset endowments, farmers will use CA as a vehicle for achieving desired livelihood outcomes. I further posit that if CA has a positive impact livelihoods, an increase in crop productivity, household incomes and food security should be observed. These hypotheses are based on the assumption that CA is the only variable that has been introduced on farmers participating in the project, in other term contact with the project is the only difference between CA farmers and non-CA farmers. For the purpose of this analysis, CA farmers were defined as those that were involved in the project, and non-CA farmers were all farmers not involved in the project.

To assess the impact of CA on farmer livelihood, a simple random sample of 165 farmers (75 CA and 90 non-CA farmers) was selected. The sampling frame comprised a list of CA and non-CA farmers in the three communities, which was obtained from the local extension workers. Extension workers keep registers with names of all households in each community as well as registers of farmers involved in various farming projects being implemented in their locality. Random numbers were used to select the sample elements from both the CA and non-CA sub-groups. The distribution of the 165 respondents by community, district and province is shown in the table 2.

Table 2: Distribution of respondents by community, district and province

Province	District	Community	Number of Respondents		Total No. of farmers
			CA	**Non-CA**	
Manica	Gondola	Pumbuto	22	25	**47**
	Messica	Ruaca	31	24	**55**
Sofala	Gorongosa	Nhanguo	22	41	**63**
Total			**75**	**90**	**165**

A questionnaire was developed to collect data from the 75 CA and 90 non-CA farmers. The questionnaire covered the 12 explanatory variables which were to be used in the econometric model: age, gender, marital status, household size, educational level, wealth holding, farm size, area cultivated, access to markets, growing maize as a staple crop, access to extension services and location. The three dependent variables used in the econometric model were: crop productivity, household income and food security. The result of the interviews were subject to binary coding, whereby 1 represented improvement in the variable of interest and 0 represented other changes other than the improvement.

The quantitative analysis of the relationship between conservation agriculture and livelihood outcomes was done using a probit econometric analysis {Nkala et al., 2011a}. The propensity score (PSM) model relies on the conditional independence assumption that any correlation between unobserved factors and farmers decision to participate do not influence the investigated effects on productivity, household income and food security (Rosenbaum and Rubin, 1983, 1984; Rosenbaum, 2002). Such a possibility is likely as farmers tend to share knowledge and skills about their farming activities and plot management. The propensity score matching (PSM) semi-parametric framework was used to estimate the model which was specified as follows:

$$\text{ATT} = E[y_{d=1} \mid d = 1, p(\mathbf{X})] - E[y_{d=0} \mid d = 0, p(\mathbf{X})]$$

ATT is an acronym for Average Treatment effect on the Treated. In this case the treated are the CA farmers who were coded 1 and the non-CA farmers coded 0. *P(*X) is the observed propensity score or the conditional probability of being a CA farmer given condition X. X is a vector of covariates that are likely to influence the farmer to practice CA.

A series of tests showed that Propensity Score Matching was an acceptable approach using the data collected. Hence we make a strong assumption that any observed changes between the two groups (75 CA farmers and 90 non-CA farmers) is due to the treatment effect. This is based on another assumption that both groups of farmers are exposed to similar situations, except for the practice of CA. In other terms: whatever other influences there may be, will affect both groups equally and thus can be considered neutral.

A challenge with this model lies in the fact that there is a possibility that the two groups may exhibit systematic differences, which would make them less comparable. This could be the case, if e.g. inclusion into the project was not random but based on some non-random criteria. Indeed, the propensity score matching approach assumes the existence of systematic differences between the CA and non-CA farmers, yet the method controls only for bias among observed covariates. In reality there could be other unobserved variables (e.g. managerial skills, specialized but not documented agricultural training of some farmers and access to extension services) and hidden selection biases that drive the livelihood outcomes. Failure to account for these hidden biases may alter conclusions about the effects of CA. The “Rosenbaum bounds” are therefore used in this study to check whether the results are sensitive to these unobserved covariates and the degree of sensitivity (Rosenbaum, 2002).

In addition, the timing of this study could also jeopardize the outcome of the analysis, as impacts of projects tend to be realized many years after the end of the project. Since this study was done a year after the introduction of the project, this may have been too early to reasonably expect results. The study is thus unlikely to be able to capture the later impacts of the project.

3.5. Qualitative data on farmers' experiments with CA

Action research involve participation by the researcher and the farmers in order to facilitate learning from experiences with the smallholder farmers. The theoretical knowledge gained through meta-analysis was put to test through triangulation with the farmers' practices during this period in the research process. The study employed action research that involved observing, recording and participating in some of the farmer's activities. This allowed to develop a better understanding of various processes and activities of farmers. I observed each of the major processes including land preparation, planting, weeding, harvesting, transportation and storage of grain on the CA and non-CA practices. This part of the research involved a number of repeat visits and discussions with farmers in an attempt to establish their understanding of the technology, what they were doing and why they were doing it that way?

Nkala et al. {2011} examine how farmers attempt to realize optimum benefits from the CA technology, as well as how they adapt CA to integrate it with their other farming practices. This investigation focuses on how farmers interlock, redesign and distance each of the three principles of CA, i.e. permanent soil cover, minimum tillage and crop rotation. Interlocking entails the willingness and ability of farmers to implement the prescribed CA technology by interweaving it with their existing projects. Redesigning is synonymous with adaptating and changing the prescribed CA technology (Mango, 2002; Long and van der Ploeg, 1989). Distancing is used to describe how farmers completely decompose or break up the prescribed CA technology under certain situations or conditions for some very good reasons (Mango, 2002).

Similar qualitative anthropological studies assessing technology adoption were conducted in Burkina Faso and Guinea by Adesina and Baidu-Forson (1995). They used a sample of 57 farmers from Burkina Faso and 110 farmers from Guinea. There results and conclusions were comparable to an earlier study by Adesina and Zinnah (1993a) in Sierra Leone.

In this study data collected from the sample of 75 CA farmers was used to investigate how CA was being implemented by farmers. These 75 CA farmers were the same as those interviewed to collect quantitative data for the econometric analysis {Nkala et al., 2011a}. Of the 75 CA farmers, 31 were from Ruaca; 22 from Pumbuto and 22 from Nhanguo. The rapport that was established during the earlier data elicitation phase helped access to the farmers.

Data collection proceeded through observations, questioning farmers and documenting how each farmer was implementing CA. The focus was on how farmers deviated or adapted the three principles permanent soil cover, minimum tillage and crop rotation. Participant observation in action research helped in understanding salient activities regarded by farmers as non-critical.

3.6. The analysis of labor and energy efficiency

In Nkala et al. {2012} two farming systems; conservation agriculture (CA) and conventional farming (CF), are compared in terms of their energy input and energy output. The objective is finding out which of the two is more efficient in terms of energy and labour inputs. Energy efficiency in this case is measured as a ratio of energy output (EO) to energy input (EI). A more efficient system being one that results in relatively higher ratios of EO/EI meaning that low energy inputs (seed, fertilisers, manure, etc) result in high energy than output (crop yields).

This part of the study is based on the data collected on two plots on which conservation farming and conventional farming was practiced. The plots were 72m x 30m or 2160m^2 in area. Both plots were owned by the same farmer who is one of the many farmers practicing both CA and CF. Basins or shallow pits in which seeds are placed during planting are dug using hoes at intervals of 40 cm along the rows in the field and a distance of 75cm between rows is maintained under both CA and CF as recommended in Oldrieve (2009).

In this study CF refers to farming a technology based on flexible and unrestricted use of CA principles. The analysis builds on the assumption that if CA utilizes energy and labor more efficiently, it would have a positive impact on livelihoods, as energy saved can be used in other activities.

The recording of data started at the beginning of the season and continued throughout the season to cover land preparation, planting, weeding, harvesting and post-harvest activities. Data collection in this case focused on quantities of all inputs and outputs including seed, manure, organic fertilizers, hours of human labor (working either alone or guiding the oxen), and the number of hours the oxen were used for draught power.

Energy equivalents associated with each of the inputs and outputs were used to calculate the amount of energy inputs and outputs. Energy equivalence is a physics concept that the mass of an object is a measure of its energy content, and in agriculture as crops grow and matter is transformed during various stages energy transfer takes place from inputs to outputs. Key sources of these energy equivalent measures for each of the inputs that were used in to calculated the total energy input and output included Pimentel (1979), Stout (1990), Yaldiz (1993), Shreta (1998), Singh (2002), Ozkan (2004), and Panzeri et al. (2011). Historical data on outputs for the previous years was obtained from the farmers records and used for calculating energy efficiency ratios from 2006 to 2010.

4. Results

4.1. The (lack of) adoption of conservation agriculture in Southern Africa

The available literature on Conservation Agriculture in Southern Africa, with a special focus on Mozambique, was reviewed. Several initiatives have been taken in the last 20 years to improve livelihoods through conservation agriculture (Twomlow et al., 2008) by both local and international organizations working with the Ministry of Agriculture (MINAG). However, the publications show that these initiatives have failed to convince farmers to fully integrate conservation agriculture as a core technology in their farming activities. There are disappointingly low adoption rates of conservation agriculture, showing either partial adoption – also called ‘distorted adoption’ – or complete dis-adoption or distancing at the end of intervention projects {Nkala et al., 2011a; Nkala and Mango, 2012}.

The literature shows that farmers have various motives for participating in conservation agriculture projects. When these motives are not fulfilled, the individual farmer decides to pull out of the project. Five primary reasons for failure to continue with conservation agriculture were identified: lack of interest by those farmers who join projects to access cheap inputs, inability to cope with intensive management requirements of CA, lack of resources by poor farmers compared to well-resourced research institutions, lack of access to credit, and failure of CA to achieve high yields in the first 1-3 years {Nkala et al., 2011b}.

In addition, there is a major problem of weeds associated with CA, especially in the first 1-2 years. This problem particularly affects those farmers who cannot afford to buy herbicides (Riches et al., 1997) {Nkala et al., 2011b; Nkala and Mango, 2012}. Most farmers who fail to control the weeds become disillusioned with CA leading to project drop outs. Twomlow et al. (2008) argue that one of the reasons CA has not been well received by farmers is because the technology has not been sequenced in a manner that reflects the social, economic and biophysical constraints affecting smallholder farmers. These constraints include limited resource endowments including tools and equipment, the high illiteracy rates, vulnerability as a result of chronic poverty, and failure to adapt to new technology due to entrenched paradigms inclined to old practices.

However, some studies have reported positive impacts regarding the adoption and adaptation of CA by farmers. In Lesotho (Pretty, 1998, 2000), Zambia (Haggblade and Tembo, 2003), Zimbabwe (Mashingaidze et al., 2006) CA has been well received by some farmers and has led to significant changes in agricultural performance by earlier adopters. The increase in productivity of up to 3.5t/ha – mainly after the third year – is a widely reported positive impact (Fowler and Rockstrom, 2001; Twomlow et al., 2008).

4.2. The impact of CA on livelihood outcomes

A quantitative analysis was made to assess the impact of CA on livelihoods, using productivity, income and food security as indicators. The analysis was based on propensity score matching, an econometric analysis. The results show CA as positively correlated with crop productivity, i.e. higher crop yields {Nkala et al., 2011b}. The results also indicate an indirect impact on household income and food security and subsequently a weak effect on poverty alleviation. Furthermore, these results show that changes in productivity tend to occur immediately, while changes in household incomes and food security might occur over the long-term.

Using both the kernel and nearest neighbor matching methods, there was however no doubts from the econometric model results that CA impacted positively on crop productivity {Nkala et al., 2011a}. The results remained significant even after controlling for the possible self-selection bias with regards to the farmers’ decisions to participate in CA. The positive correlation between CA and productivity is also corroborated in various statements by farmers such as "*since we started practicing this system of agriculture, our harvests have increased substantially*" {Nkala et al., 2011a:62}. Household income was said to have increased from the sale of surplus produce under CA. This income is used to purchase various household assets like bicycles, pay school fees, build better homesteads, purchase livestock and pay for hired labour. This accumulation of assets implies enhanced livelihoods for those farmers that were able to produce surplus. The enhanced livelihoods are synonymous with higher household incomes and improved household food security although these were weakly supported by the results of the econometric model.

Despite these positive outcomes, respondents also complained about challenges faced with CA, particularly weeds. Respondents said that while CA helps improves yields, the weeds were perceived to grow faster in CA thereby negatively affecting the realisation of the full potential positive outcomes of CA. Since most of the farmers cannot afford herbicides or hired labour for weeding, promotion of CA without due regard on how the problem of weeds could be solved may be futile.

Thus, for various reasons including cultivation of smaller areas, adverse climatic conditions particularly droughts and floods the increase in productivity did not seem to automatically translate into better livelihoods for most of the farmers. In other words the socio-economic status of the farmers only showed marginal changes for the better as the majority of farmers could still be classified as poor.

4.3. Redesigning by farmers, and distancing from CA

The farmers are unclear about what CA as a technology entails and how it should be implemented. Indeed, most farmers fail to correctly define what CA is {Nkala and Mango, 2012}. Farmers argued that CA practices can be problematic. For example, some CA farmers argued that in situations of low precipitation, the grass used for mulching reduces infiltration thereby forcing the farmers to temporarily remove the grass as a way of improving infiltration {Nkala and Mango, 2012}. Regarding the principle of minimum tillage farmers argued that they are sometimes forced to violate this principle because weeds tend to grow faster, thus competing with crops, if the land is not ploughed. Finally, farmers also violate the principle of crop rotation because maize is an important staple crop in the study areas, and there is not enough land to implement adequate rotations {Nkala et al., 2012}. The results further show that CA has not become a field-wide practice as farmers are still grappling with extending the permanent soil cover principle to larger sections of their fields perhaps still waiting to learn and apply the other two principles.

Farmers have various reasons for redesigning and sometimes distancing themselves from the technological package of CA {Nkala and Mango, 2012}. Factors leading to redesigning or adaptation of CA include challenges of getting adequate mulching materials for permanent soil cover, wild fires, livestock that are allowed to roam freely after harvest, and purposeful burning of some crop residues like sorghum stalks that do not rot easily. Given these challenges, the recommendation to leave 30% of the crop residue as leftovers (Hobbs, 2007) is hardly met by any of the CA farmers.

These results cast doubt on successful implementation of conservation agriculture among smallholder farmers especially using the classic extension strategy which has been described as 'transfer-of-technology'. Scientists and other intervening organizations could take advantage of the high willingness to learn exhibited by farmers to find common solutions that would lead to a successful adoption of CA. Financial and other resources could be used to identify which CA principles are acceptable to farmers as is, and which CA recommendation might have to be adapted to take into consideration local constraints. Also, a gradual promotion of CA principles could also be envisaged, starting with the most understood principle of permanent soil cover, followed by minimum tillage and crop rotation which are less well understood.

Finally, support systems for poor CA farmers during the initial stages may be necessary. This would ensure that the technology is not only promoted to farmers who are better off, and thus have e.g. the resources to purchase herbicides.

4.4. Energy and labour efficiency

Some authors assert that CA is an energy and labor efficient technology (Derpsch, 2005; Friedrich et al., 2009). The energy output: energy input ratio analysis is used to determine energy efficiency between the two systems comparing CA to conventional farming (CF). As indicated in section 3.6, energy equivalents which can be defined as the amount of energy embodied in any material and in this case seed, fertilizer, manure and labour inputs are added to get the total energy input for CA and CF. Similarly the total energy in joules in the maize yields is calculated as the product of the total yields in kilograms and the energy equivalent in joules per kilogram. The energy ratios, of each system, are calculated by dividing the total energy output (EO) by the total energy input (EI). The system with higher energy analysis ratios is more efficient than one with low ratios.

The results of this analysis show that energy inputs are indeed lower in CA compared to CF {Nkala et al. 2012}. However, despite the low energy inputs, CA results in higher energy output compared to CF. In other words the total energy inputs calculated from seed, manure, fertilizer, labour, etc. would result in higher output per unit under CA than CF. CA is associated with higher levels of productivity per hectare compared to CF whereby the total energy contribution of inputs is higher although resulting in less yields whose total energy equivalent is also low. Higher yields associated with high output: input ratios are also in favour of CA from the results in Nkala et al. {2012}.

It can be deduced from this result that precision conservation agriculture (PCA) where inputs are applied directly into the basins as opposed to anywhere along the row, could result in even higher energy savings. Basins are pits that are dug in the field in which farmers place the inputs directly during planting, fertilizer application, watering and weeding. This version of CA is known as the ‘Zai system’ in West Africa and is known to optimally utilize agricultural inputs due to them being directly applied to these pits or basins (Mazvimavi and Twomlow, 2009).

5. Discussion

The literature review identifies major challenges to the adoption of CA {Nkala et al., 2011b}. These include vulnerable livelihoods, lack of access to important agricultural assets and equipment and lack of supportive institutions or transformation structures for smallholder farmers. Indeed, until Giller et al. (2009) started challenging established views about CA, many researchers had unquestioningly supported the idea that CA would work in southern Africa (e.g. Twomlow and Bruneau, 2000; Derpsch, 2005; Hobbs et al., 2007; Friedrich et al., 2009). However the literature review shows that these recommendations ignore stark realities associated with the socio-economic conditions of farmers, the effects of climate change that has led to a number of droughts and floods in Mozambique in recent years, and entrenched poverty levels.

As a result, the current conditions in rural Mozambique are not favourable to the spread of CA. The high incidences of poverty imply that farmers are likely to abandon CA practices once the project has ended, because they are not be able to afford the inputs required by CA. Authors such as Giller et al. (2009) and Kassie and Zikhali (2009) cast doubt about the sustainability of CA, especially in the smallholder sector.

Even where CA has been adopted, the observed better yields do not seem to improved livelihoods, or contributed to higher food security {Nkala et al., 2011a}. Indeed, only a few early adopters seem to have realized significant benefits from CA. Perhaps this lack of clear benefits from CA to the majority of farmers explains the high number of ‘distancers’, partial adopters, and dis-adopters. CA interventions ignore a number of realities that cripple or contribute to livelihoods transformation implying more ‘noise’ than acknowledged in scientists’ claims of CA success stories (Twomlow et al., 2008).

The short run benefits of practicing CA may gradually increase, and anecdotal evidence shows over the long run successful CA farmers have accumulated some household and farming assets. In Nkala et al. {2011a} the wealth variable (value of livestock was used as a proxy) shows that wealthier households with higher asset endowments are more likely to practice CA. This result was also found by Giller et al. (2009). Some CA farmers have replaced their traditional mud houses with modern brick and cement houses, others have purchased livestock, bicycles, and furniture and household utensils from the proceeds of selling surplus. However, the connection between conservation agriculture and household income and food security is weak {Nkala et al., 2011a}.

The positive influence of CA can be seen in higher crop productivity and higher yields. Statements from some CA farmers support the idea that the increased productivity allows to reduce ‘nomadity’ linked with slash-and-burn agriculture[4]. However observations show that farmers how have (partially) adopted CA are a minority (less than 40% of the population). In other words, most farmers are still practicing slash-and-burn agriculture. Conservation agriculture may thus not be for all categories of farmers particularly for those with few resources. These poorer farmers may need financial and institutional support to be able to adopt CA. Unless such support is provided, they are likely to be left out, thereby confining all the benefits of CA to the already well-resourced farmers.

Results show that all respondents who are ‘CA adopters’ redesign or adapt virtually all the three principles of conservation agriculture, from permanent soil cover, minimum tillage and crop rotation{Nkala and Mango, 2012}. Doing so questions the notion of promoting the

[4] Due to the practice of slash-and-burn agriculture, historically known as shifting cultivation, until ten years ago, most smallholder farmers in Mozambique were still practicing shifting cultivation and as a result did not have permanent homes. After about 5-10 years when the soil became poor as a result of poor land management and cropping system, the family would abandon the land and move to another area in search for more virgin and fertile land. However with the new technologies like CA more and more smallholder farmers are ceasing the practice and desisting from being nomads.

implementation of CA as a uniform package suitable to all smallholder farmers. The widespread redesigning of the specified CA practices could be indicating that new strategies are necessary to promote this technology.

In Nkala and Mango {2012} we note that CA adoption may follow web-like connections explained by interlocking and distancing of actor projects. Misunderstandings among farmers regarding what CA entails, and also what lies behind the three CA principles, was widespread. Most farmers have not really grasped the idea that CA is a technology based on the three basic principles of permanent soil cover, minimum tillage and crop rotation. Even after reminding them about the basic principles of CA, many farmers expressed ignorance when asked to explain what they understood by each of the principles of CA. Confusion regarding crop rotation; mono-cropping and intercropping was apparent. However most farmers did understand what permanent soil cover principle entails, even though they did not apply it to all their fields due to the scarcity of material for mulching. They thus reserved mulching material for fields of special soil fertility and for the production of staple crops.

Linked to the limited understanding of CA principles, attributing higher yields to CA needs to be interpreted with caution, after all the principles are redesigned and adapted. Furthermore, since evidence shows that none of the farmers fully converted to CA, exploring these ‘experimenters’ as a special category of farmers could yield some insights into what they expect from CA. These farmers could be holding the key to unlocking the missing ingredients of CA, or to identifying how the principles would need to be adapted to be context-sensitive. Such a renewed CA could increase the adoption rate. Indeed, despite the various challenges farmers exhibit high levels of satisfaction and show positive perceptions of CA. However, it is unclear whether these positive attitudes are directly related to the characteristics of CA, or whether they are related to not wanting to disappoint researchers by rejecting the CA project.

The support of energy efficiency in conservation agriculture implies better livelihoods for early adopters {Nkala et al., 2012}. CA can be up to three times more efficient than conventional agriculture. However, this efficiency can only be translated to positive outcomes if energy saved can be optimally utilized in other agricultural activities or in off-farm livelihood strategies. Indeed, farmers in rural areas, once they realize better payments from agriculture, tend to target non-agriculture based livelihoods. This means that they may abandon agriculture after realizing higher incomes through CA. However, isolating specific impacts of conservation agriculture in situations where less than 100% of farmers are full implementers of the technology does present serious challenges.

To summarize, the following key messages can be derived:

1. Although farmers tend to have a positive attitude towards CA, the technology seems to be too resource-demanding for a typical smallholder farmer to implement.
2. There is no universal acceptance of any of the three principles of CA, thereby casting doubt whether CA, in its current package, is a technology for the future.
3. Results show that in the short term CA can improve crop productivity. But since farmers only practice CA at very small scale this may not be significant to address the broader food security requirement at community, district, or national level.

CA is still presenting farmers with significant challenges raising the question whether interventions to promote CA among smallholder farmers in central and northern Mozambique is worthwhile. The CIAT/CIMMYT project closed in 2011. It would be interesting to follow up on those farmers who were involved in the project to establish whether they are still practicing CA or whether they have reverted back to their traditional slash-and-burn system. Perhaps CA needs to be more flexible and allow room for innovations by farmers rather than focus only on a standardized package of permanent soil cover, minimum tillage and crop rotation.

6. Conclusion and recommendations

6.1. Conclusion

Given the diverse conditions of the farmers and the fact that it takes at least three years before the full benefits of CA can be realized, conservation agriculture does not seem to be a sufficient condition for improving livelihoods in rural Mozambique {Nkala et al., 2011b}. The positive impacts of CA on productivity found in Nkala et al. {2011a} did not translate into higher incomes or into better food security for the households. This result does not support the link between CA and livelihoods in relation to household incomes and food security as would be critical for the success of a technology such as CA.

The results show that the impact of conservation agriculture project in transforming livelihoods of smallholder farmers in the three communities in Mozambique remains minimal, judging from isolated success cases among practicing farmers. This implies that the current promotion of CA lacks certain components critical to the targeted farmers. For CA to be able to achieve the goals of improving livelihoods hinges on discovering these missing factors. This could include acceptance by the promoters of CA that this technology is rather complex, requires more time to assimilate and should not be simultaneously targeted to all categories of farmers even within the same community. Our results show CA performed differently for the different categories of farmers. Those in the lower quartile realized insignificant benefits compared to farmers in the top quartile. Interventions should therefore introduce a qualifying criterion for farmers to participate in CA rather than use an approach that seeks to include all farmers. However, such a targeting of CA interventions may fail the poor {Nkala et al., 2011b}. The current approach continues to maintain the status quo, i.e. favours those farmers who are already well endowed with resources by local standards.

The positive results related to increase in productivity {Nkala et al., 2011a} and savings in energy {Nkala et al., 2012} could be an analytical artifact, given the small scale in which CA has been implemented. This casts doubt on whether CA can surpass the performance of conventional farming in terms of producing enough food and improving food security. In Nkala and Mango {2012} we note that farmers including those classified as 'CA farmers' engage in dual farming practices. These points to a bleak future of CA and its capability in helping smallholder farmers achieve higher incomes, more food, and other better livelihoods. Most farmers still view CA as an academic experiment by scientists rather than a technology they can rely on to feed their families and communities.

6.2. Recommendations

Evidence from the literature demonstrates that there are many challenges facing smallholder farming in agriculture, and these challenges reduce the adoption rate of new technologies such as CA {Nkala et al., 2011b}. Overcoming the challenges facing the smallholder sector including use of basic tools and equipment, training farmers to enhance their skills and knowledge, working with farmers to appreciate their views and identifying the potential role of innovative technologies in improving productivity could all help increase adoption rates of CA in Mozambique. There is evidence that CA does contribute to higher yields {Nkala et al., 2011a; Nkala et al., 2012} but judging from the small scale to which CA is practiced in Mozambique, and by the fact that all studied farmers adapted the CA principles, it is unclear to what extend CA can contribute to improving livelihoods in rural Mozambique.

Nkala and Mango {2012} show that farmers are redesigning virtually all CA principles. This suggests that it would be productive to implement participatory research with farmers to understand the reasons for redesigning, and how these could be incorporated into CA before recommending it to other farmers. The need for farmers to redesign recommendations clearly points to a lack of coherence between the farmers' needs and scientists' view of which technologies 'should work'. While farmers appreciated the potential of CA, they tended to be skeptical as the package is too complex and too academic for real agricultural practice, as well as not adapted to their context and level of available resources. Thus, more attention needs to be given towards how innovative technologies are promoted and encouraged, e.g. giving more room to participatory development and redesign. These might be more effective strategies compared to the current blanket approach, which seems to be confusing for both extension agents and farmers.

So far research has concentrated on how technologies like CA could be used as vehicles towards better livelihoods. However, this has not been very efficient as the impact has been very limited. This implies that it is necessary to revisit the original strategies so as to identify more effective agricultural practices, especially those appropriate to the context in which farmers have to work. Thus, rather than promoting a package such as CA within a transfer-of-technology strategy, a participatory approach in which farmers, extension agents and researchers together develop innovative farming practices may be more promising.

References

Adesina, A.A., Baidu-Forson, J., 1995. Farmer's perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso, West Africa. *Agricultural Economics* 13: 1-9.

Arndt, C. 2003. HIV/AIDS, human capital, and economic growth prospects for Mozambique. Unpublished manuscript.

Arndt, C., Tarp, F., 2009. *Taxation in low income economy: the case of Mozambique*. Routeledge.

Ashley, C., Carney, D., 1999. Sustainable livelihoods: lessons from early experience. Department for International Development (DFID). London.

Bengtsson, J., Ahnstrom, J., Weibull, A., 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology* 42: 261-269.

Biswanger, H., Sillers, D., 1990. *Are small farmers too poor to be efficient*. World Bank.

Bolliger, A., 2007. Is zero-till an appropriate agricultural alternative for disadvantaged smallholders of South Africa? A study of surrogate systems and strategies, smallholder sensitivities and glycoproteins. PhD Thesis. University of Copenhagen.

Brown, T., Jones, L., 2001. *Action research and postmodernism, congruence and critique*. Open University Press, Philadelphia.

Cahn, M., 2002. *Sustainable livelihoods approach: concept and practice.* Paper presented at the 3rd Biennial Conference of the International Development Studies Network (5th - 7th December 2002) Australia and New Zealand, Massey University.

Carney, D., 1999. Sustainable livelihoods approaches. Progress and possibilities for change. Department of International Development (DFID), London.

Carrilho, J., 1997. Porque foram istalados os Servicos de Extensao Rural e quas os seus principais desafios? In A Extensao Rural em Mozambique (1987 – 1997). Direccao Nacional de Extensao Rural, Maputo.

Carter, M., 1991. Risk, reciprocity and conditional self-finance in the Sahel: Measurement and implications for the trajectory of agricultural development in West Africa. Department of Agricultural Economics, University of Wisconsin.

Chambers, R. and G. Conway., 1992. Sustainable rural livelihoods: Practical concepts for the 21stcentury. IDS Discussion Paper 296. IDS, Brighton.

Chapman, R., Slaymaker, T., Young, J., 2003. Livelihoods approaches to information communication in support of rural poverty elimination and food security. ODI, DFID, FAO.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso S, Hannon B, Limburg K, Naeem S, O'Neil RV, Parvelo J, Raskin RG, Sutton P, and Van den Belt M 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Costanza, R., Patten, B.C., 1995. Defining and predicting sustainability. *Ecological Economics* 15: 193-196.

Cramb, R.A. (Ed.), 2000. Soil Conservation Technologies for Smallholder Farming Systems in Philippine Uplands: A socioeconomic Evaluation. ACIAR Monograph No. 78, Canberra: Australian Center for International Agricultural Research.

Cramb, R.A., Culasero Z., 2004. Land care and Livelihoods: The promotion and adoption of conservation farming systems in the Philippine uplands. University of Queensland, Brisbane and University of the Philippines at Los Banos.

Cramb, R.A., Garcia, J.N.M., Gerrits, R.V., Saguiguit, G.C., 1999. Smallholder adoption of soil conservation technologies: evidence from upland projects in the Philippines. *Land Degradation and Development* 10: 405-423.

Creswekk, J.W., 2009. *Research design: qualitative, quantitative, and mixed method approaches*. SAGE publications, Los Angeles.

Cunguara, B., 2011. Assessing strategies to reduce poverty in rural Mozambique. Doctoral thesis submitted to Institute of Agricultural and Forestry Economics, Department of Economics and Social Sciences, Universität für Bodenkultur, Wien.

Cunguara, B., Moder, K., 2011. Is agricultural extension helping the poor? Evidence from rural Mozambique. *Journal of African Economies* 20: 562-595

Cunguara, B., Darnhofer, I., 2011. Assessing the impact of improved agricultural technologies on household incomes in rural Mozambique. *Food Policy* 36: 378-390.

Cypher, J.M., and Dietz, J.L., 2006. *The process of economic development*. 2nd Edition. Routledge, New York.

Davis, K.E., 2008. Extension in Sub-Saharan Africa: Overview and assessment of past and current models and future prospects. *Journal of International Agricultural and Extension Education* 15: 15-28.

Derpsch, R., 2005. The extent of conservation agriculture adoption worldwide – Implications and impacts. In: Third World Congress on Conservation Agriculture: Linking livelihoods and Conservation, October 3-7, 2005, Nairobi.

DFID, 1999. The Sustainable Livelihoods Framework. Department for International Development. London.

DFID, 2000. Sustainable livelihoods sheets. Department for International Development. London.

Dick, B., 2004. Action Research Literature: Themes and Trends. *Action research* 2: 425-444

Dormon, E.N., 2006. From a technology focus to innovation development. The management of cocoa pests and diseases in Ghana. PhD Thesis, Wagenigen University, Wagenigen.

Dumanski, J., Peiretti R, Benites J.R., McGarry, D., and Pieri, C., 2006. The paradigm of Conservation Agriculture. World Association of Soil and Water Conservation

ECA, undated. Mozambique: The Challenge of HIV & AIDS treatment and care. Commission on HIV&AIDS and Governance in Africa. Economic Commission for Africa, Addis Ababa.

Ellis, F., 2000. *Rural livelihoods and diversity in developing countries*. Oxford University Press, Oxford.

Farrington, J., Carney, D., Ashley, C., Turton, C., 1999. Sustainable livelihoods in practice: Early applications of concepts in rural areas. Natural Resources Perspectives Series, No. 42. Overseas Development Institute (ODI).

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change* 33: 255-298.

FAO, 2001. The economics of soil productivity in Africa. Soils Bulletin. Food and Agriculture Organization, Rome.

FAO, 2004. Conservation of natural resources for sustainable agriculture: training modules. FAO land and water Digital Media Series CD-RM 27. http://www.fao.org/ag/ca/. Food and Agriculture Organization, Rome.

FAO, 2007. Workshop on Conservation Agriculture in Southern Africa. Harrison's Conference Centre. Johannesburg. South Africa. Food and Agriculture Organization, Rome.

Fowler, R., Rockstrom, J., 2001. Conservation tillage for sustainable agriculture. An agrarian revolution gathers momentum in Africa. *Soil Tillage Research* 61: 93-107.

Friedrich, T., Kassam, A.H., Taher, F., 2009. Adoption of conservation agriculture and the role of policy institutional support. Plant Production Division, Food and Agriculture Organization of the United Nations, Rome.

Gemo, D., and Rivera, W. M., 2001. Mozambique's move towards a pluralistic national system of rural extension. Agricultural Research and Extension Network, Paper No. 110, Maputo.

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

Haggblade, S., Tembo, G., 2003. Early evidence on conservation farming in Zambia. A paper prepared for the International Workshop on 'Reconciling Rural Poverty and Resource Conservation: Identifying Relationship and Remedies'. Cornell University Ithaca. New York. May 2-3, 2003.

Halderman, H., Paxson, C.H., 1992. Do poor insure? A synthesis of the literature on risk and consumption in developing countries. Agriculture and rural development department, World Bank.

Hanlon, J., 2010. Mozambique: The war ended 17 years ago, but we are still poor. *Conflict Security and Development* 10: 77-102.

Hanlon, J., Barrientos, A. and Hulme, D., 2010. *Just give money to the poor*. Kumarian Press, Sterling, VA, USA

Heckman, J., 1996. Randomization as an instrumental variable estimator. *Review of Economics and Statistics* 56: 336-341.

Hobbs, P., Gupta R., Meisner, C., 2006. *Conservation agriculture and its applications in South Asia*. Cornell University.

Hobbs, P.R., 2007. Conservation agriculture: What is it and why is it important for future sustainable food production? *Agricultural Science* 145: 127-137.

Hobbs, P.R., Sayre, K., Gupta, R., 2007. The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society of London* 363: 543-555.

INE, 2010. Anuario Estastica. Instituto Nacional de Estastica, Maputo.

Kassie, M., Zikhali, P., 2009. The contribution to sustainable agriculture and land management to sustainable development. Sustainable Development, Innovation Briefs. 7: 05/2009. United Nations.

Kormawa, P.M., Devlin, J., 2011. Promoting effective and innovative financing. In: Yumkella, K.K., Kormawa, P.M., Roepstorff, T.M., Hawkins, A.M. Agribusiness for Africa's prosperity. UNIDO, Vienna.

Lin, C.T.J., Milon, J.W., 1993. Attribute and safety perceptions in double hurdle model of shellfish consumption. *American journal of Agricultural Economics* 75: 724-729.

Loomis, J.B., and White, D., 1995. Economic benefits of rare and endangered species: A summary and meta-analysis. *Ecological Economics* 18: 197-206.

Mashingaidze, A. B., Govere, I., Rohrbach, D., Hove, L., Twomlow, S., 2006. Conservation agriculture in Southern Africa. Harrison's Conference, Johannesburg.

Maria, M.R., and Yost, R., 2006. A survey of soil fertility status of four agro ecological zones of Mozambique. *Soil Science* 171:902-914.

Mazvimavi, K., Twomlow, S., 2009. Socioeconomic and institutional factors influencing adoption of conservation agriculture by vulnerable households in Zimbabwe. *Agricultural Systems* 101: 20-29.

Mercado, A.R., Patindol, M., and Garrity, D.P., 2000. The land care experience in the Philippines: Technical and institutional innovations for conservation farming, *Development in Practice* 11: 495-508.

Morduch, J., 1990. *Risk, productivity and saving: Theory and evidence from Indian households*. Harvard University Press.

Mupangwa, W., Love, D., and Twomlow, S., 2005. Soil-water conservation and other rainwater harvesting strategies in the semi-arid Mzingwane Catchments, Limpopo basin, Zimbabwe. Sixth Water Net -WAR-FSA-GWP Symposium, November 2005, Mbabane, Swaziland.

Neuman, W.L., 2006. *Social research methods: Qualitative and quantitative approaches*. Pearson, New York.

Nguthi, F.N., 2007. Adoption of agricultural innovations by smallholder farmers in the context of HIV and AIDS: The case of tissue culture banana in Kenya. PhD Thesis, Wagenigen University, Wagenigen.

Niehof, A., Price, L., 2001. Rural livelihood systems: A conceptual framework. UPWARD Working Paper No. 5. Wagenigen University, Wagenigen.

Nkala P., Mango, N., and Zikhali, P., 2011a. Conservation agriculture and livelihoods in Central Mozambique. *Journal of Sustainable Agriculture* 35: 757-779.

Nkala, P., Mango, N., Corbeels, M., Veldwisch, G., and Huising, J., 2011b. The conundrum of conservation agriculture and livelihoods in Southern Africa. *African Journal of Agricultural Research* 6: 5750-5770.

Nkala, P. and Mango, N., 2012. Interlocking and distancing of actor projects: The case of conservation agriculture in Central Mozambique. Submitted to *Journal of Southern African Studies*.

Nkala, P., Moitzi, G. and Mango, N., 2012. Energy and labor efficiency analysis in smallholder conservation agriculture and conventional farming in central Mozambique. Manuscript submitted to *Energy, Renewable Agriculture and Food Systems*.

Nowak, P., 1992. Why farmers adopt production technology. *Journal of Rural Sociology* 62: 318-321.

Oldrieve, B., 2009. *Trainer's Manual. Farming in God's Way*. Harare.

O'Mara, G., 1980. The micro-economics of technique adoption by small-holding Mexican farmers. World Bank Development Research Centre, Washington D.C.

Owens, T., Hoddinott, J., and Kinsey, B., 2003. The impact of agricultural extension on farm production in resettlement areas of Zimbabwe. *Economic Development and Cultural Change* 51: 337-357.

Ozkan, B., Kurklu, A., Akcaoz, H., 2004. An input-output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. *Biomass and Bioenergy,* 26: 89-95.

Panzeri, D., Cesari, V., Toschi, I., Pilu, R., 2011. Seed calorific value in different maize genotypes. *Eenergy sources, Part A: Recovery, utilisation and environmental effects,* 33: 1700-1705.

Peters, J. M., 1997. Reflections on Action Research. *New Directions for Adult and Continuing Education* 73: 63-72.

Pimentel, D., Pimentel, M., 1979. *Food, energy and society*. Edward Arnold publishers. London.

Prasad, A., 2011. Nature's matrix: linking agriculture, conservation and food sovereignty. *Landscape Ecology* 26: 451-453.

Pretty, J., 1998. *The Living Land: agriculture, food systems and community regeneration in rural Europe*. Earthscan Publications, London.

Pretty, J., 2000. Can sustainable agriculture feed Africa? New evidence on progress, processes and impacts. Centre for Environment and Society. University of Essex. Colchester.

Probst, K., Hagmann, J., Fernandez, M., Ashby, A. J. 2003. Understanding participatory research in the context of natural resource management: Paradigms, approaches and typologies. AgREN Network paper 130. Overseas Development Institute, London

Punch, K. F., 2005. *Introduction to social research: quantitative and qualitative approaches*. SAGE publications, London.

Raitzer, D.A. and Kelly, T.G., 2007. Benefit-cost meta-analysis of investment in the International Agricultural Research Centers of CGIAR. *Agricultural Systems* 96: 108-123.

Rakodi, C., 2002. *A livelihoods approach: Conceptual issues and definitions*. Earthscan publications, London.

Republic of Mozambique, 2000. Strategic Plan of Higher Education in Mozambique. 2000 – 2010. Maputo

Riches, C.R., Twomlow, S.J., Dhliwayo, H., 1997. Low input weed management and Conservation Tillage in Semi-Arid Zimbabwe. *Experimental Agriculture* 33: 173-187.

Rivera, W.M., 1988. Developing agricultural extension systems nationwide: A structural approach. *Journal of Extension Studies* 4: 29-50.

Rivera, W.M., Qamar, K.M., 2003.Agricultural extension, rural development and food security challenge. Food and Agriculture Organization of the United Nations – Extension and Communications Service Research, Extension and Training Division, Sustainable Development Division. Rome.

Röling, N.G., Hounkonnou, D., Offei, S.K., Tossou, R., Huis, A.V., 2004. Linking science and farmers' innovative capacity: Diagnostic studies from Ghana and Benin. *NJAS-Wageningen Journal of Life Sciences* 52: 211-236.

Rosenbaum, P.R. 2002. *Observational Studies*. Springer. New York.

Rosenbaum, P.R., Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70: 42-55.

Rosenbaum, P.R., and Rubin, D.B., 1984. Reducing bias in observational studies using sub classification on the propensity score. *American Statistical Association* 79: 516-524.

SADC, 2010. State of vulnerability to food insecurity and poverty in the Southern Africa Development Community (SADC), April 2010 – March 2011. SADC Regional Vulnerability Assessment and Analysis Programme. Gaborone.

Scoones, I. 2005. Sustainable rural livelihoods. A framework for analysis. IDS Working Paper 72, Institute of Development Studies, Sussex.

Shapiro, S., 1994. Point/counter point: Meta-analysis of observational studies. *American Journal of Epidemiology* 140: 771-778.

Shrestha, D.S., 1998. Energy use efficiency indicator for agriculture. Http://www.usaskca/agriculture/caedac/PDF/mcrae.

Singh, H., Mishra, D., Nahar, N.M., 2002. Energy use pattern in production agriculture of a typical village in arid zone, India – part I. *Energy, Conversion and Management* 43: 2275-2286.

Singh, J.M., 2002. On farm energy use pattern in different cropping systems in Haryana, India. International Institute of Management, University of Flensburg, Germany.

Solesbury, W., 2003. Sustainable livelihoods: A case study of the evolution of DFID Policy. Overseas Development Institute, London.

Staaz, J., 2011. Enhancing agricultural productivity. In: Yumkella, K.K., Kormawa, P.M., Roepstorff, T.M. and Hawkins, A.M. *Agribusiness for Africa's prosperity*. UNIDO. Vienna.

Stout, B.A., 1990. *Handbook of energy for world agriculture*. Elsevier, Essex.

Strauss, J., Babosa, M., Teixeira, S., Thomas. D., Gomes, R., 1991. Role of education in adoption of technology: A study of upland rice and soya bean farmers in central-west Brazil. *Agricultural Economics* 5: 341-359.

Stufflebeam, D.L., 2001. The meta-evaluation imperative. *American Journal of Evaluation* 22:183-209.

Tonitto, C., David, M.B. and Drinkwater, L.E., 2005. Replacing bare fallows with cover crops in fertilizer cropping systems: A meta-analysis of crop yield and N-dynamics. *Agriculture Ecosystems & Environment* 112: 58-72.

Tornatzky, L.G. and Klein, K., 1982. Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. IEEE *Transactions on Engineering Management*, 29: 28-43.

Treseder, K.K., 2004. A meta-analysis of mychorrizal responses to nitrogen, phosphorous, and atmospheric CO_2 in field studies. Department of Ecology and Evolutionary Biology and Department of Earth System Science, University of California.

Tripp, D.H., 1990. Socially critical action research. *Theory into Practice* 29:158-166.

Twomlow, S., Bruneau, P., 2000. The influence of tillage on semi-arid soil water regimes in Zimbabwe. *Georderma* 95: 33-55.

Twomlow, S.J., Hove, L., Mupangwa, W., Masikati, P., 2008. Precision conservation agriculture for vulnerable farmers in low-potential zones. Paper presented at the CPWF meeting, September 2008, Ghana.

UNIDO, 2011. *Agribusiness for Africa's prosperity*. United Nations Industrial Development Orgnisation, Vienna.

Van Kooten, G.C., Eagle, A.J., Manley, J. and Smolak, T., 2004. How costly are carbon effects? A meta-analysis of carbon forest sinks. *Environmental Science and Policy* 7: 239-251.

Weed, M., 2005. "Meta Interpretation": A method for interpretative synthesis of qualitative research. *Forum: Qualitative Social Research*. 6: 1-17

Weil, R.R., 1990. Defining and using the concept of sustainable agriculture. *Journal of Agronomy Education* 19:126-130.

World Bank, 2006. Mozambique agricultural development strategy, stimulating smallholder agricultural growth. Agriculture, Environment and Social Development Unit. Country Department 2. African Region. Report No. 32416-MZ.

Yaldiz, O., Ozturk, H.H., Zeren, Y., Bascetincelik, A., 1993. Energy use in field crops of Turkey. International Congress of Agricultural Machinery and Energy, Kusadasi, Turkey.

PART B: Published papers and submitted manuscripts

1. Nkala, P., Mango, N., Zikhali, P. (2011a). Conservation Agriculture and Livelihoods of smallholder farmers in central Mozambique. *Journal of Sustainable Agriculture* 35(7): 757–779.

2. Nkala, P., Mango, N., Corbeels, M., Veldwisch, G., Huising, J. (2011b). The Conundrum of Conservation Agriculture and Livelihoods in Southern Africa. *African Journal of Agricultural Research* 6(24): 5520–5528.

3. Nkala, P., Mango, N. (submitted). Interlocking and distancing of actor projects: The case of Conservation Agriculture in Central Mozambique. Manuscript submitted to *Journal of Southern African Studies* on 28 Feb. 2012.

4. Nkala, P., Moitzi, G., Mango, N. (submitted). Energy and labor efficiency analysis in smallholder conservation agriculture and conventional farming in central Mozambique. Manuscript submitted to *Energy, Renewable Agriculture and Food Systems* on 25 March 2012.

Conservation agriculture and Livelihoods of smallholder farmers in central Mozambique

Nkala, P., Mango, N., Zikhali, P.

Abstract. This paper demonstrates how conservation agriculture impacts smallholder farmers' livelihoods in Mozambique through increased crop productivity and yields; using primary data on smallholder farmers practicing conservation agriculture and others not using this technology from Nhanguo, Pumbuto and Ruaca in Manica and Sofala provinces. Data analysis employs semi-parametric propensity score matching methods. Direct correlations between conservation agriculture, higher productivity and yields; and indirect correlations with changes in household incomes and food security are suggested. Conclusively, systematic targeting of conservation agriculture to different farmer categories, can improve livelihoods, household incomes and food security. We recommend integration of conservation agriculture into the rural development policy framework in Mozambique.

Keywords: Conservation Agriculture; Livelihoods; Mozambique; Productivity; Propensity Score Matching; Smallholder farmers

Journal of Sustainable Agriculture, 35:757–779, 2011

ISSN: 1044-0046 print/1540-7578 online
DOI: 10.1080/10440046.2011.606492

Conservation Agriculture and Livelihoods of Smallholder Farmers in Central Mozambique

PETER NKALA,[1] NELSON MANGO,[2] and PRECIOUS ZIKHALI[3]
[1]*Center for Development Research (CDR), BOKU, University of Natural Resources and Applied Life Sciences, Vienna, Austria*
[2]*International Centre for Tropical Agriculture (CIAT), Harare, Zimbabwe*
[3]*International Water Management Institute (IWMI), Southern Africa Regional Office, Pretoria, South Africa*

This article demonstrates how conservation agriculture impacts smallholder farmers' livelihoods in Mozambique through increased crop productivity and yields, using primary data on smallholder farmers practicing conservation agriculture and others not using this technology from Nhanguo, Pumbuto, and Ruaca in Manica and Sofala provinces. Data analysis employs semiparametric propensity score matching methods. Direct correlations between conservation agriculture, higher productivity and yields; and indirect correlations with changes in household incomes and food security are suggested. Conclusively, systematic targeting of conservation agriculture to different farmer categories, can improve livelihoods, household incomes and food security. We recommend integration of conservation agriculture into the rural development policy framework in Mozambique.

KEYWORDS conservation agriculture, livelihoods, Mozambique, productivity, propensity score matching, smallholder farmers

We gratefully acknowledge research funding from the International Centre for Tropical Agriculture (CIAT) and the University of Natural Resources and Applied Life Sciences (BOKU). We also thank all reviewers for their comments and suggestions on earlier drafts of this article.
Address correspondence to Peter Nkala, Center for Development Research (CDR), BOKU, University of Natural Resources and Applied Life Sciences, Vienna, Austria. E-mail: peter.nkala@boku.ac.at or pmasayina@yahoo.co.uk

1. INTRODUCTION

In many regions of Sub-Saharan Africa (SSA) continuous cropping and use of inappropriate farming practices has had massive negative environmental impacts characterized by declining soil fertility and erosion, degradation of vast expanses of arable land further causing low yields, food insecurity and perennial starvation (Guto et al. 2011). These problems are particularly intense in poor developing countries like Mozambique where more than 80% of the population of smallholder farmers still rely on simple traditional technologies and tools; mainly hand-held hoes, minimal use of animal traction and no tractors. Land scarcity, increasing population pressure, poorly targeted agricultural policies and agricultural management strategies exacerbate the problem. Apart from the negative impacts on agricultural productivity, food security, and environmental damage, negative tertiary effects of the smallholder farmers and their families' "resource mining" activities include hunger and imminent threat of malnutrition related illnesses.

During the past three decades many rural development and research organizations[1] in partnership with government ministries have introduced technologies attempting restoration of soil fertility, moisture conservation and increased productivity such as conservation agriculture (CA). Many authors are convinced that such technologies can mitigate the effects of soil degradation, moderate soil surface conditions, improve crop yields, and increase benefits and reduce production costs in the smallholder sector (Derpsch 2005; Chikonye et al. 2006; Govaerts et al. 2009; Guto et al. 2011).

Since 2007, the International Centre for Tropical Agriculture (CIAT), International Maize and Wheat Improvement Centre (CIMMYT), and development agencies from both government and non-governmental organizations have been involved in the promotion of conservation agriculture (CA) in central and northern Mozambique. Demonstrating that agricultural development interventions and research can improve livelihoods of smallholder farmers has been the main objective of these interventions. Experiences with conservation agriculture from the global south countries like Brazil and Argentina have shown that the adoption of productivity enhancing technologies often accelerate livelihood changes in economic and socioinstitutional conditions of actors involved as would be expected (Bailey 1988; Bene 2003; Bene and Obirih-Opareh 2009). The secondary outcomes of sustainable agricultural practices is precipitation of increases in food security, household income and general welfare, which are good and desirable livelihood outcomes especially for the poor groups of smallholder farmers.

Empirical evidence suggests that conservation agriculture generally produces higher net returns compared to conventional tillage in the long run although it may be associated with low short run returns (Sorrenson 1997; Stonehouse 1997; Pretty 2006; Lienhard et al. 2006; Giller et al. 2009). Higher returns are attributed to reduced costs of machinery, fuel and labor combined with better soil and water management strategies. Stonehouse (1997) used a simulation exercise to demonstrate that offsite benefits of conservation tillage accounted for a majority of the net social benefits in southern Ontario, Canada. By 2009, about 6% world's total cropland was being sustainably exploited as a result of efforts to correct the negative impact of conventional agriculture (World Bank 1991; Bolliger 2007; Twomlow et al. 2008; Giller et al. 2009; Lal 2009).

Despite strong assumptions that CA technology increases crop productivity and yield stability, Giller et al. (2009) argue that promotion of CA as a panacea to agricultural problems in the tropics has gone without rigorous debate. For the first time, challenging the authenticity of the claims by organizations like the Food and Agricultural Organization of the United Nations ([FAO] 2008) and other high proponents of CA; on the grounds that different country settings do matter in the successful adoption of CA. Giller et al. (2009) question the rationale of implementing CA as a package among smallholder farmers given different local conditions in SSA compared to the global North and South American countries. Thus, challenges faced with attempted wholesale adoption of CA has resulted in decomposition of CA into those aspects that can be easily implemented and those that need to be decomposed to suit specific conditions of farmers.

According to FAO (2001), CA rests on three pillars: minimum soil disturbance, crop rotation and permanent soil cover.[2] Direct drilling or chiseling the soil only where seeds are placed using in-row chisels, direct seeders, or disk openers ensures minimum soil disturbance. Weed and pest control are done using synthetic herbicides, like glyphosate[3] and pesticides with cultivation only permitted in emergency situations. Permanent cover crops or nonremoval of residues protects the soil from erosion and weeds. Varied crop rotation helps in weed control and boosting soil fertility. Broadly defined, CA is part of sustainable agriculture combining best practices with discontinuation of production systems associated with negative environmental externalities created by conventional agriculture (D'Souza et al. 1993; Kassie et al. 2009).

The main advantage of CA is the technology's ability to address a broad set of farming constraints particularly common among smallholder farmers in vulnerable communities (Lee 2005; Lienhard et al. 2006). The constraints in question include lack of sufficient equipment for land preparation, sowing, weeding and harvesting. High labor requirements still remain a major constraint especially during the wet season when incessant rains give farmers limited chances to weed their fields. Large scale herbicide application is also not feasible given the financial leverage of most farmers, hence, manual weeding is always paramount. All the above factors are common and relevant in Mozambique and affect particularly the smallholder sector.

Despite benefits of CA, adoption of this technology has been slow in Mozambique because farmers lack relevant skills, knowledge, and equipment, yet there are inadequate extension services[4] and poverty among others. CA has also not been widely promoted in Mozambique as only a few nongovernmental organizations are actively involved for fixed time periods and to some extent the technology seems arguably inappropriate for the majority of smallholder farmers given huge resource constraints they face. Farmers' participation in any agricultural technology such as CA depends on multiple farmer and farm specific factors that influence farmers' decision to adopt the technology and what farmers perceive would be the impacts of the technologies on their livelihoods; which all said and done is the ultimate objective driving farmers to engage in productive activities. The livelihood outcomes include positive changes in productivity, household income, wealth endowments, food security, and reduced household exposure to risk and vulnerability. For conservation agriculture to be seen as effective in promoting livelihoods, it should positively impact on these above livelihood outcomes, which sometimes CA may be unable to do in the short run.

As the perceptions paradigm suggests, farmers behavior is shaped by the perception that CA impacts positively in improving livelihoods (Uaiene et al. 2009). These behaviors are driven by farmer specific factors such as age, gender, household size, level of education, and marital status, all of which are indirectly linked to perceptions about livelihood outcomes and intervening technologies. We, therefore, assume the necessity to examine farmers' perceptions on the different technological impacts on livelihoods for the promotion, adoption and sustained use of technologies such as CA.

However, the role of conservation agriculture (CA) in improving livelihoods of smallholder farmers facing low productivity in agriculture and extreme food insecurity is debatable, and most researchers agree that CA impacts positively on livelihoods while others think this is not the case. In this article, we investigate how CA impacts changes in livelihood outcomes through changes in productivity, yields, household income, and food security. The study uses the smallholder CA farmers' households[5] Nhanguo, Pumbuto, and Ruaca communities of Manica and Sofala provinces in Mozambique, as the units of analysis. Very few studies on agricultural systems in Africa go beyond analyzing the determinants of adoption to discussing the impact of CA on farmers' livelihoods and this article seeks to fill that gap. The article extends the debate from adoption to the grounded impact of the technology on people's livelihoods. We employ semiparametric econometric methods that (1) examine the covariates that influence the farmers' decision to practice CA, and (2) assess the impact of CA on livelihood outcomes after controlling for the possibility that CA and non-CA farmers could be systematically different.

The rest of the article is arranged as follows: Section 2 discusses the underlying analytical framework followed by the description of the study setting in section 3. Section 4 presents the data used in the empirical analysis and the outline of empirical model and estimation strategy is done in section 5. The results, conclusions and recommendations are dealt with in sections 6 and 7, respectively.

2. THE APPROACH

The systems dynamics (SD) and sustainable livelihoods framework (SLF) explain how livelihoods benefit from available resources through engaging in certain activities in an environment governed by some existing rules and institutions. People undertake livelihood strategies using assets owned to transform their lives. Assets owned are key in implementing livelihood strategies such as crop farming and livestock rearing which are necessary for realization of desired livelihood outcomes (LaFlamme and Davies 2007). We posit an indirect but positive relationship between the types of assets owned and envisaged livelihood outcomes.

In this article, we adopt the Chambers and Conway (1992) definition of a livelihood as comprising "capabilities, assets and activities required to make a living . . . and to cope with and recover from shocks and stresses" (Krantz 2001, 6). These authors provide a working framework for many international humanitarian and rural development organizations in understanding the importance of resources and transformation structures in realizing welfare goals (Start and Johnson 2004). The framework explains how complex issues of rural development could be approached and successfully addressed (Chambers and Conway 1992).

The sustainable livelihoods framework illustrated in Figure 1, adapted from Chambers and Conway (1992) is a framework showing the relationship among the context of the farmers' assets (represented by different forms of capital), transformation structures, livelihood strategies, and livelihood outcomes. Specifically, the framework illustrates how, by availing households opportunities for livelihood strategies through promotion of agricultural technology, development interventions impact livelihood outcomes. The framework shows the indirect relationship between livelihood outcomes and households' assets and the role of transformation structures and livelihood strategies. The assets comprise natural (land and its resources), financial (savings and credit supplies), physical (infrastructure such as roads), social (social networks), and human forms of capital (skills and education levels). Assets form building blocks of sustainable livelihoods, impacting household capacity to withstand challenges of shocks encountered in improving livelihoods.

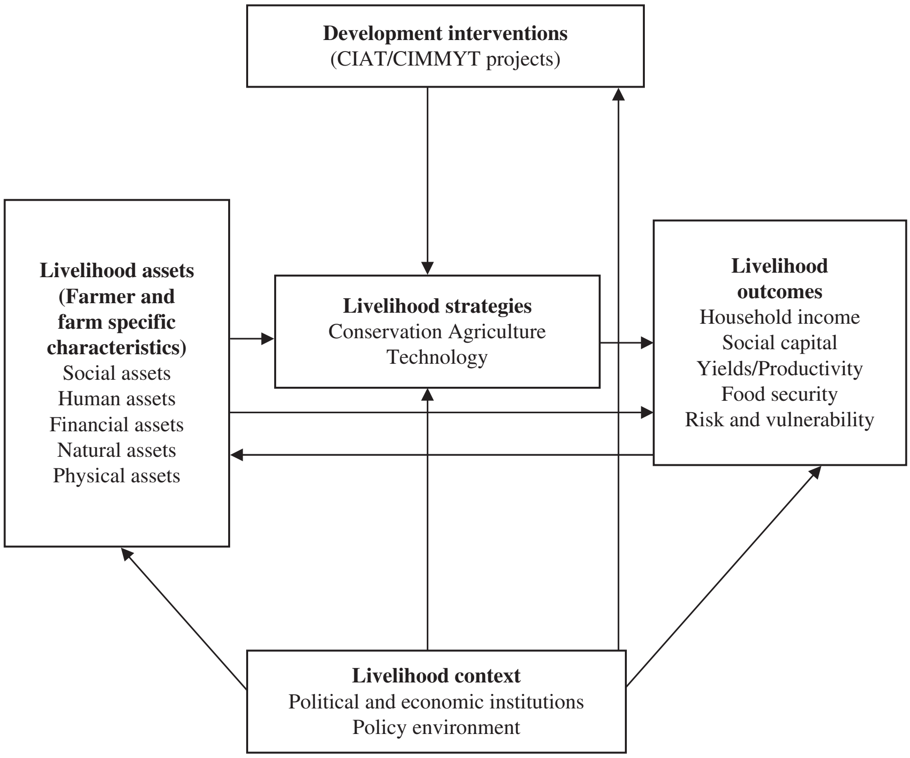

FIGURE 1 Link between conservation agriculture and livelihood outcomes. *Source:* Authors' own adaptation of the Sustainable Livelihoods Framework.

Given asset endowments, households make decisions regarding adoption of technology perceived by farmers to generate positive social and economic outcomes. The livelihood context includes important broad political and economic structures and the existing policy environment. Arguably, these policies and economic structures influence livelihood assets holdings, strategies undertaken, activities of development agencies and ultimately resultant livelihood outcomes.

As illustrated in Figure 1, the system is characterized by forward and backward linkages in response to changes in farm and farmer specific variables captured through livelihood assets and observed livelihood outcomes. A specific "package" of farm and farmer specific factors or livelihood assets is associated with each outcome although each factor may be linked to various other outcomes. Conservation agriculture is an intervening mechanism through which farmers, given their socioeconomic characteristics and farm characteristics, transform livelihoods. That is, farmers adopt CA to enhance land productivity in order to ultimately improve livelihoods. Therefore, socioeconomic and farm specific characteristics and expected positive benefits from CA influence the farmers' decisions about technology adoption/adaptation. The actual and perceived impact of CA on livelihoods varies with the geographical location of the farm, biophysical and institutional constraints and socioeconomic factors that favor specific practices. Farmers are heterogeneous and face dynamic political and economic environments that determine adaptation trajectories taking care of ensuing constraints and opportunities for CA.

3. DESCRIPTION OF THE STUDY SITES

The three study sites discussed in this paper are located in the vulnerable agricultural production regions in Manica and Sofala provinces of Mozambique where livelihood options of farmers are limited to agriculture, vegetable vending, charcoal production and basketry or weaving in a few cases. The vulnerability is characterized by remoteness in location; less fertile soils, obsolete, and inadequate infrastructure (schools, clinics, roads, etc.) and low literacy levels. There are extreme poverty levels in most cases far higher than the national average. Rainfall averages between 600 and 800mm per year in altitudes of 0–200 m and 600–800 m in Manica province, and 200–600 m to 600–1000 m in Sofala province. Soils in Pumbuto, Ruaca, and Gorongosa vary from sandy to sandy-loam and Gorongosa has a mixture of both fertile red-clay and shallow sandy soils.

Furthermore, established livelihoods were seriously disrupted during the 14 years of civil conflict that ended in 1992, with the signing of the peace agreement in Rome, between the main belligerent parties, FRELIMO (Frente de Libertacao de Mozambique) and RENAMO (Resistancia Nacional de Mozambique). During the conflict, many farmers in these study areas fled to neighboring towns of Chimoio, Casa Banana, and Beira. Even farmers who remained in the communities and bore the brunt of the civil war failed to practice agriculture but fled homesteads and sought refuge in the mountains surviving on hunting wildlife and gathering wild plants. The location of the three study sites in relation to the 11 provinces of Mozambique are illustrated in Figure 2 below.

Nhanguo is in Gorongosa district of Sofala; Pumbuto and Ruaca are in Gondola district of Manica province. CIMMYT and CIAT embarked on CA projects in 24 communities in more than 10 districts in Mozambique using the participatory technology development (PTD) approach.[6] Long-term trials were envisaged for each district and for Sussundenga Zonal Research station. Each experimental plot was 3000 m^2 (50×60 m). Farmers' groups numbered 20–30 people; some better off farmers opted for individual experiments on family plots.

Although livelihood strategies are limited, agriculture remains the main source of livelihood in all the three communities. Other livelihood strategies

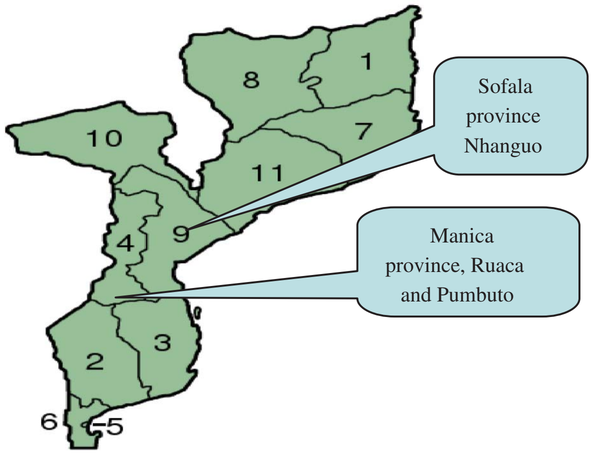

FIGURE 2 The specific project sites in Manica and Sofala provinces in Mozambique. (Color figure available online.)

include, producing and selling charcoal, microenterprises, handicrafts, and local beer *(nippa* or *cabanga)*. Local markets[7] for agricultural produce are not well developed so farmers incur high transport costs to markets in Gorongosa, Gondola, Manica and Chimoio centers. About 30–40% of farmers in all communities have pigs and goats raised for own consumption and to supplement household incomes. Very few farmers in Ruaca own cattle mostly obtained through the CARITAS livestock development project introduced 10 years ago; so the area has traditionally been a non-livestock area.

4. DATA AND DESCRIPTIVE STATISTICS

Direct observations, group discussions and semistructured questionnaires were the main data collection approaches employed in 12 months to October 2009. Individual household interviews were conducted on 165 smallholder farmers' households across the three sites. Forty-eight percent were farmers who had been trained on CA principles by intervening organizations and government extension workers and this distribution is shown in Table 1. Participation in the CA projects was voluntary, although evidence also showed that in some instances experiences of the extension officer, and involvement in farmer field school (FFS) influenced farmer participation.

The CA farmers were purposively sampled (hence, our use of the propensity scores matching technique) from those involved in the conservation agriculture project which started in 2007 and non-CA farmers were

TABLE 1 Number of Respondents by Community, District, and Province

			Number of farmers		
Province	District	Community	CA	Non-CA	Total
Manica	Gondola	Nhanguo	22	25	47
	Messica	Pumbuto	26	29	55
Sofala	Gorongosa	Ruaca	31	32	63
Total			79	86	165

Source: Field study, 2008–2009.

randomly selected from the remaining farmers' households in each community. It was not possible to randomly select CA participants as these had already been identified through purposive sampling. All CA farmers had gone through two cycles of CA on their own, hence, had a relatively good understanding of its impact. Most of the CA farmers in Pumbuto had participated in the FAO FFS project that ended in 2007 and were co-opted into the CIAT/CIMMYT conservation agriculture project.

The questionnaire based data collected covered background characteristics like age, gender, marital status, level of education, and socioeconomic variables like land, livestock ownership, knowledge of CA, perceived changes in household food security, income, access to credit and extension services. Data on field and cash crops, distance to markets and farmers' perceptions about CA's impact on livelihoods since introduction of the technology were also collected.

Notwithstanding different views and controversies on perceptions versus reality, we argue that perceptions of food security risk does influence the household effort expended in agriculture and, hence, the subsequent value attached to own food production (Seeth et al. 1998). Maddison (2007) used perceptions of farmers from 11 different countries to determine the ability of farmers in Africa to detect climate change and how they adapted; the results showed that farmers' perceptions do matter and in most cases available records from weather stations were shorter than memories of farmers. Statistical tests also showed convergence or clustering of farmers who claimed to have observed certain characteristics of climate change, with neighboring farmers also telling a consistent story. This study is, therefore, grounded on the strong assumption that practicing CA is a two stage process whereby first smallholder farmers perceive the technology to improve productivity, yields, and subsequently guaranteeing better livelihood outcomes and then making a firm decision to adopt or not to adopt CA. Despite lack of evidence of actual outcomes, but with support use of surveys and perceptions as in the above studies, this article is still relevant and contributes meaningfully to a broad discussion of CA on smallholder agriculture.

Table 2 gives a summary of statistics and description of variables used in the empirical model that we discuss in the following section. We report

TABLE 2 Descriptive Statistics (Means) of Variables Used in the Analysis

Variable	Description	CA farmer	Non-CA farmer	*t* test (*p*-values)	Both
Dependent variables					
Productivity	1 = improvement in productivity is reported 0 = otherwise	0.72	0.19	0.00	0.44
Income	1 = improvement in household incomes is reported 0 = otherwise	0.67	0.55	0.10	0.61
Food security	1 = improvement in food security is reported 0 = otherwise	0.75	0.74	0.97	0.75
Independent variables					
CA farmer	1 = farmer practices CA 0 = otherwise				0.48
Age	Age of household head	43.23	41.81	0.53	42.49
Gender	1 = female household head 0 = male	0.34	0.41	0.39	0.38
Marital status	1 = single household head 0 = otherwise	0.84	0.74	0.15	0.79
Household size	Total household members	6.94	6.63	0.63	6.78
Education	Highest level of education in the household. 1 = 0–8 years of schooling; 2 = more than 8 years	1.71	1.78	0.47	1.75
Wealth	Monetary value of total livestock holdings in USD	440.92	304.78	0.30	369.96
Farm size	Total farm size, in hectares	4.27	3.43	0.21	3.83
Cultivated area	Area of farm size cultivated annually, in hectares	3.41	3.20	0.59	3.30
Markets	Distance to the nearest primary market, in km	7.23	3.61	0.02	5.36
Maize	1 = household grows maize as the major cash crop 0 = otherwise	0.90	0.74	0.01	0.82
Extension	Distance to the nearest extension office, km	16.37	13.58	0.19	14.92
Pumbuto	Dummy for Pumbuto community	0.39	0.37	0.79	0.38
Ruaca	Dummy for Ruaca community	0.33	0.34	0.91	0.33
Nhanguo	Dummy for Nhanguo community	0.28	0.29	0.86	0.29

this for the CA and non-CA groups separately and for the pooled sample. We perform *t* tests to investigate whether differences in means of these variables are significantly different between the two groups and finally we report the *p* values from these tests.

The statistics indicate that CA farmers were 48% of the sample size of 165 CA and non-CA farmers. Around 44%, 61%, and 75% of the pooled farmers report improvements in productivity, household income and food security, respectively. Reported livelihood changes are statistically different between CA and non-CA farmers with regards to perceived improvements in productivity whereby 72% of CA farmers report improvements in productivity compared to 19% of non-CA farmers.

Overall, the *t* tests reveal very insignificant differences in the characteristics between the two groups. Significant differences exist with regards to productivity and wealth endowments including to a lesser extent differences with regards to access to markets.[8] In addition CA farmers are significantly more likely to grow maize as a cash crop compared to non-CA farmers. This is probably because cowpeas, pigeon peas and maize were selected as demonstration trial crops as all farmers in the three districts were issued with maize seed for the trials. Being a staple crop, maize was also over-represented in both the CA and non-CA farmers groups.

Thirty-eight percent of the farmers are female with an average age of 42 years. The gender over-representation of men links with strong traditional and cultural practices that distinguish gender roles in agriculture mostly biased toward men. Observations revealed the existence of female and child-headed households in all communities.

An average household in the sample consists of seven members with an average annual wealth holding for both groups of farmers of U.S. $369.96. This wealth holding further confirms high poverty levels among smallholder farmers in the three districts. The average farm size is 3.83 hectares and the average cultivated area is 3.30 hectares.

On average, farmers walk about 15 km to the nearest agricultural extension office. These offices are located at the district rather than rural service centers for Pumbuto and Ruaca. In Nhanguo, the local extension worker lives at the rural service center. Access to farmers by the extension workers is problematic because of associated transport problems of living away from work stations.

5. THE EMPIRICAL MODEL AND ESTIMATION STRATEGY

Broadly this empirical analysis explores how changes precipitated by CA subsequently impact changes in farmers' livelihoods. Primary livelihood outcomes of interest are reported changes in crop productivity, household income and food security. Each of these outcomes is binary, recorded as one for improvement in the indicator and zero otherwise.

Our estimation strategy uses a semi-parametric framework, specifically the propensity score matching (PSM) method. This strategy considers the possibility that CA and non-CA farmers might exhibit systematic differences in characteristics that might make them less comparable and that selection into CA or non-CA group has largely been non-random, based instead on certain unobservable criteria. This would complicate attempts to isolate the impact of CA on livelihood outcomes of interest, mainly, because the study uses survey instead of experimental data. Randomization associated with experimental data enables isolation of CA effects by ensuring that the treatment and control groups are selected randomly from a potential population of all farmers. By breaking the correlation between treatment and the confounding unobserved environment, randomization ensures that the CA experimental group is no different from the control group. In this case, a statistically significant difference in the livelihoods of the two groups can be confidently attributed to CA to some extent. However, the fact that we use survey data suggests nonrandom selection into the CA group which poses a risk that those differences between CA and non-CA farmers could be mistaken for effects of CA.

Accordingly, we use the PSM method to deal with these challenges. PSM is a semiparametric method that gives an average treatment effect on the treated (ATT), which is considered a better indicator of whether to continue promoting programs that target specific groups of interest like poor farmers than population-wide average treatment effects given by probit models (Rosenbaum and Rubin 1983; Heckman 1996; Rosenbaum 2002). CA is the treatment variable, while reported improvements in crop productivity, household income, and food security are the outcomes of interest and non-CA farmers are the control group.

PSM is based on the assumption that it is not possible for each farmer to be both in the CA as well as non-CA group. This then necessitates the creation of a counterfactual of what can be observed by matching CA (treatment) and non-CA (control) groups. PSM therefore matches CA to non-CA farmers with similar values of $\mathbf{X}$ giving us the following equation to estimate:

$$\mathrm{ATT} = E[y_{d=1}|d = 1, p(\mathbf{X})] - E[y_{d=0}|d = 0, p(\mathbf{X})]. \tag{1}$$

ATT stands for the average treatment effect on the treated (CA farmers), $y_{d=1}|d = 1$ is the reported changes in livelihood outcomes actually observed in the CA farmer subsample, while $y_{d=0}|d = 0$ is the change observed in the non-CA group. $p(\mathbf{X})$ is the propensity score, which is defined as conditional probability of being in the CA group conditional on $\mathbf{X}$. Matching on the propensity score circumvents the challenge of matching on covariates, which poses a dimensionality problem particularly when matching on many covariates.

The PSM is, thus, a two-stage process, first performing a probit or logit regression by calculating the household's propensity to be in the CA group, that is, $p(\mathbf{X})$ is calculated in this stage. The vector $\mathbf{X}$ contains a set of covariates deemed to influence the decision to practice CA. The second stage uses propensity scores obtained in the first stage to match CA and non-CA farmers. A number of matching methods can be used in this stage, each using a different function to conduct the matching although the result of each is an ATT value that indicates the impact of CA on the selected livelihoods indicators. We use the kernel matching method, which matches a treated unit to all control units weighted in proportion to the closeness between the treated and the control unit, that is, control units receive weights based on the distance between their propensity score and the propensity score of the treated unit to which they are being matched. To check the robustness of the results from kernel matching we also use another matching algorithm in the calculation of the ATT: the nearest neighbor matching method. It involves choosing a unit form the control or comparison group as a matching partner for a treated individual that is closest in terms of the propensity score.[9]

The PSM relies on the conditional independence assumption (CIA), which assumes that the effects of CA are not influenced by any correlation between unobserved factors and a farmer's decision to participate in CA. This means that PSM controls only for bias among the observed covariates. In reality, however, there could be unobserved variables (e.g., managerial skills) or a hidden selection bias that could also be significantly driving these differences. Hidden bias can occur when two farmers with the same observed covariates have different chances of practicing CA due to an unobserved covariate. If this unobserved covariate is related to the livelihood outcomes affected by CA, then failure to account for this hidden bias can alter conclusions drawn about the effects of CA. To check whether our results are sensitive to the effect of unobserved variables we use "Rosenbaum bounds" to investigate how strong the effect of unobservable covariates has to be in order to reverse inferences drawn about the effects of CA (Rosenbaum 2002).

Assume that for household i, $\omega_i \in [0, 1]$ is the unobserved variable that could potentially affect livelihood outcomes. Rosenbaum (2002) shows that when two matched farmers, i and j, with similar observed characteristics may have different probabilities of participating in CA then the bounds on the odds ratio that either of them will participate is:

$$\frac{1}{\Gamma} \leq \frac{p_i(\mathbf{X})(1 - p_j(\mathbf{X}))}{p_j(\mathbf{X})(1 - p_i(\mathbf{X}))} \leq \Gamma, \tag{2}$$

where $p_i(\mathbf{X})$ and $p_j(\mathbf{X})$ are the probabilities of participating in CA by households i and j, respectively, and $i \# j$. The odds ratio for selection into the CA group is given by $\Gamma = \exp[\gamma(\omega_i - \omega_j)]$ for matched households i and j. The effect of the unobserved factor on the participation decision is measured byγ. If $\gamma = 1$ and, thus, $\Gamma = 1$, then both households have the same probability of participating in CA and there is no hidden bias. As Γ increases, the influence of the unobserved factor; if it exists, goes up. Sensitivity analysis evaluates how much the effect of CA is changed by changing the values of Γ, that is, examining the bounds on $1/\Gamma$ and Γ. The limitation of the Rosenbaum bounds method is that it does not indicate whether an unobserved bias exists, but identifies how large the hidden bias would need to be to nullify the estimated treatment effect. The assessment of the matching quality and sensitivity analysis is based on kernel matching; our principal matching method.

6. RESULTS AND DISCUSSION

This section presents and discusses the empirical results from semi-parametric PSM analyses on crop productivity, household income, and food security. We also explore the reliability of the PSM results by assessing the quality of the matching process and performing a sensitivity analysis based on the Rosenbaum bounds, concentrating on the livelihood outcomes for which a significant impact of CA is found.

6.1. What Factors Determine Farmers' Practices of Conservation Agriculture?

Table 3 presents the results from the first stage probit estimation of practicing CA and factors affecting the likelihood of choosing CA. These results give an indication of the socioeconomic determinants of farmers' decisions to practice conservation agriculture.

TABLE 3 Probit Estimates for Adoption of Conservation Agriculture

Variable	Coefficient	Std. error
Log of age	−0.015	0.357
Gender	−0.138	0.249
Marital status	0.248	0.293
Log of household size	−0.023	0.246
Education	0.132	0.201
Log of wealth	0.196***	0.073
Log of cultivated area	−0.269	0.28
Log of markets	0.442***	0.165
Maize	0.649**	0.298
Log of extension	0.260	0.191
Constant	−1.803	1.556
Log likelihood	−104.404	
Likelihood ratio test: $\chi^2(12)$	15.150	
Correct predictions (%)	70	
Observations	162	

Notes: ***,**,* significant at 1%, 5%, and 10%, respectively. The estimation controls for village or community dummies.

The involvement in CA tended to be for the more wealthy farmers, which could be attributed to the fact that a) in Pumbuto farmers co-opted into CA were already members of the FFS and b) common practice that wealthier households are more likely to join interventions. The probability linking wealthier households to CA corroborates well with the effectiveness and willingness to invest in appropriate technology, which is usually a feat for the rich. The wealth variable is proxied by the value of total livestock holdings as an indicator of total assets holdings as other asset holdings by these groups of farmers were insignificant in explaining the household wealth status. This suggests that wealthier households, with higher asset endowments are more likely to practice conservation agriculture than their poorly resourced counterparts as stated in Giller et al. (2009). In Pumbuto, land scarcity was a negative factor as one respondent reiterated "because I do not have enough land for farming, and tools to even work on all the land that I own I cannot practice CA on all my land."

We infer from the results a positive relationship between markets and practices of conservation agriculture as markets create non-farm opportunities that compete with time allocated for agricultural activities. Alternatively, this result could be capturing the fact that the further away from the market a household is, the less the opportunities to pursue alternative competing market driven activities. This leaves households with limited options and, hence, the increased likelihood of practicing conservation agriculture. However, we are also aware that, for Pumbuto, initial involvement in FFS played an important role in participating in CA.

6.2. Treatment Effects From the Propensity Score Matching Methods

The PSM method enables us to investigate how CA has impacted reported changes in livelihood outcomes. The method uses estimated propensity scores from the first stage results presented in Table 3 to generate samples of matched CA and non-CA groups using the kernel and nearest neighbor matching methods.

We impose the common support condition in the estimation by matching in the region of common support. Figure 3 shows the distribution of propensity scores and the region of common support. The bottom half of the figure shows the propensity scores distribution for the nontreated, while the upper-half refers to the treated individuals. The densities of the scores are on the y axis. The figure indicates that the common support condition is satisfied as there is overlap in the distribution of the propensity scores of both treated and nontreated groups.

PSM results are presented in Table 4. Only observations within common support are used, that is, observations for which matches were found (76 CA farmers as indicated in Table 4). As already stated above, ATT is the average treatment effect on the treated. The standard errors for the ATT are calculated

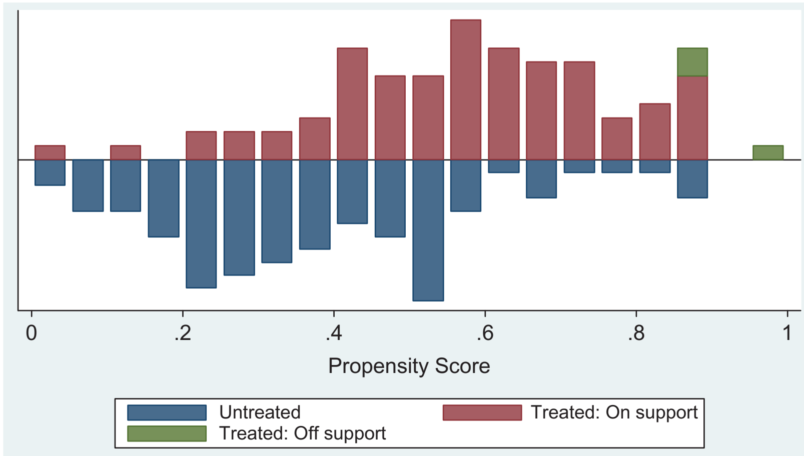

FIGURE 3 Propensity score distribution and the common support condition. (Color figure available online.)

TABLE 4 Average Treatment Effects from Propensity Score Matching

	Productivity		Income		Food security	
	Kernel	Nearest neighbor	Kernel	Nearest neighbor	Kernel	Nearest neighbor
CA farmers	0.71	0.71	0.67	0.67	0.74	0.74
Non-CA farmers	0.18	0.18	0.66	0.71	0.74	0.72
Difference, ATT	0.53***	0.53***	0.01	−0.039	−0.003	0.01
(Std. Error)	(0.10)	(0.12)	(0.10)	(0.12)	(0.10)	(0.12)
Total number of observations						
CA farmers	79	79	79	79	79	79
Non-CA farmers	86	86	86	86	86	86
Number of observations within common support						
CA farmers	76	76	76	76	76	76
Non-CA farmers	86	86	86	86	86	86

Notes: ***, **,* significant at 1%, 5%, and 10%, respectively.

using bootstrapping with 200 replications. The results are used to calculate the impact of CA on reported improvements in crop productivity, household income, and household food security.

The results indicate a positive impact of CA on productivity and this is supported with statements from most farmers in group discussions in Ruaca that

> conservation agriculture is helpful because we see a lot of changes, since we started our harvest has improved and we do not have to move from place to place and have stopped cutting and burning trees as we used to do before.

They indicate that, controlling for socioeconomic characteristics, a randomly chosen farmer among the CA group is shown to be 0.53 probability points more likely to report an improvement in crop productivity than a non-CA farmer.

This result is consistent for both the kernel and nearest neighbor matching methods. However, the results do not reveal a significant direct effect of CA on household incomes and food security hinting at the possibility of an indirect link between CA, household income, and food security. On the contrary, this implies that there is a direct link between CA and productivity. Furthermore, this postulates that changes in productivity are immediate benefits of CA while changes in household incomes and food security might occur in the long term. Our discussions with farmers also implored that early planting could also explain the increase in productivity.

Although it can be argued that the impacts of CA can only be felt by farmers in the medium to long term, our results highlight the positive impacts of CA on livelihoods through increased productivity. As one farmer in Ruaca put it,

> since we started practicing this type of agriculture, *linha-linha*,[10] and our harvest has increased substantially although we experience problems with weeds. We do not have money to pay for weeding but we can pay using grain and if a person is hired to do the weeding for 3 days we give him a bucket of maize. I managed to build this extra house, bought this animal drawn cart and three bicycles that my children use to go to a secondary school in Messica. We now have enough food for the whole year and we use some of the grain to pay for labor for weeding, we used to experience problems with food especially just before the first rains.

In a broader sense, the results underscore the role of CA in improving livelihoods of smallholder farmers through increased crop yields. These benefits remain significant even after controlling for possible self-selection bias with regards to the decision to participate in CA. These results further justify the need to promote CA as a productivity-enhancing technology in areas experiencing low yields in Mozambique.

6.3. Assessing the Quality of the Matching Process

Since the PSM method conditions only on the propensity score we, therefore, assess the quality of the matching process by performing balancing tests that examine the standardized bias for all covariates used in the matching process. This checks whether the matching procedure is able to balance the distribution of the covariates in both the CA and non-CA groups. In the case of a successful matching process, the differences should not exist after matching.

TABLE 5 Balancing Tests for All Matching Covariates

	Mean		Standardized bias		*t* test
Variable	CA	Non-CA	% bias	% reduction in bias	*p* values
Log of age	3.74	3.76	−3.4	72.8	0.84
Gender	0.34	0.35	−2.5	81.2	0.88
Marital status	0.83	0.83	0.6	97.3	0.97
Log of household size	1.98	2.03	−9.6	33.5	0.55
Education	1.72	1.72	0.0	99.6	0.99
Log of wealth	4.63	4.92	−15.4	69.6	0.29
Log of farm area cultivated	1.38	1.46	−16.7	−41.7	0.32
Log of markets	1.63	1.62	1.7	97.5	0.92
Maize	0.89	0.90	−1.0	97.6	0.94
Log of extension	2.54	2.64	−11.3	58.8	0.51
Pumbuto	0.40	0.34	11.0	−163.5	0.50
Ruaca	0.33	0.43	−21.9	−1181.9	0.19

The standardized bias is defined as the difference between the sample means in the CA and the matched non-CA sub-samples as a percentage of the square root of the average of the sample variances in both groups.

Intuitively, the standardized bias considers the size of the difference in means of a conditioning variable between the CA and non-CA groups, scaled by the square root of the average of the variances in the original samples. In addition two-sample *t* tests are used to investigate the significance of the post-matching differences in the covariate means for the two groups. We do this only for reported improvements in productivity for which the CA effect was found to be significant. Table 5 presents the results of this analysis and the results suggests that the propensity score is balanced for each covariate between CA and non-CA groups. The reduction in the standardized bias is substantially reduced after matching and the test of the null hypothesis of *no* significant differences after matching cannot be rejected at 10% for all the variables.

6.4. Sensitivity Analysis

For the sensitivity analysis we adopt Becker and Galiendo's (2007) procedure for bounding treatment effects estimated for binary outcomes. The approach uses the Mantel and Haenszel (MH) test statistic which computes the ATT while setting the level of hidden bias to a certain value,Γ. In this case, the MH statistic tests the null hypothesis of no CA effect and calculates a hypothetical significance level which represents the bound on the significance level of the treatment effect in the case of endogenous self-selection into CA. The lower bound suggests the case when the CA effect

TABLE 6 Sensitivity Analysis Using the Mantel-Haenszel Bounds

Gamma values	Qmh+	Qmh−	pmh+	pmh−
1	6.55	6.55	<0.000	<0.000
2	4.46	8.89	<0.000	0
3	3.30	10.37	0.001	0
4	2.49	11.51	0.006	0
5	1.88	12.43	0.030	0
6	1.38	13.23	0.083	0
7	0.97	13.93	0.167	0
8	0.60	14.56	0.273	0

is underestimated while the upper bound is the case when the CA effect is overestimated.

The results of this analysis are presented in Table 6. Gamma is the odds of differential assignment due to unobserved factors; *Qmh+* is the MH statistic that assumes an overestimation of the CA effect; *Qmh−* is the MH statistic that assumes an underestimation of the CA effect; *pmh+* is the significance level that assumes an overestimation of the CA effect; and *pmh−* is the significance level that assumes underestimation of the CA effect.[11]

Table 6 suggests that in a study free of hidden bias ($\Gamma = 1$) the MH statistic is 6.55 implying a strong impact of CA on productivity. However, in the case where households most likely to practice CA are also more likely to experience productivity improvements then the estimated CA effects overestimate the true effects. An examination of *pmh+* indicates that the critical Γvalue at which we would have to question our conclusion of positive impact of CA lies between 6 and 7. Specifically the cut-off point for Γ at which the hidden bias could reverse our finding that CA leads to a 0.53 increase in the likelihood of perceiving an improvement in crop productivity is 6.

Thus, if an unobserved covariate that almost perfectly predicted reported improvements in crop productivity differed between matched pairs of CA and non-CA farmers by a factor of 6 or more, it would be sufficient to undermine the conclusions regarding the effect of CA on perceived improvements in productivity. This implies that the postulated unobservable effects would have to be considerably large (they specifically have to increase the odds of benefiting from CA by at least 100%) to cast doubt on the computed CA effects. Thus, the PSM results can be regarded reliable and insensitive to hidden bias.

It is important to note that Rosenbaum bounds are worst-case scenarios implying that a critical value of 6 does not mean that unobserved heterogeneity exists. Rather it means the confidence interval for productivity effect would include zero if the odds ratio of treatment assignment differs between CA and non-CA households by 6 due to an unobserved variable.

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

The objective of this article was to investigate how practicing conservation agriculture (CA) impacts changes in livelihood outcomes, particularly focusing on changes in crop productivity, household income and food security. Notwithstanding controversies and disagreements about CA, we find evidence in support of CA's ability to improve smallholder farmers' livelihoods. In particular, we find evidence of productivity-enhancing benefits of CA: Practicing CA is found to be significantly associated with reported improvements in crop yields. This suggests that it is possible to realize small positive short run benefits form CA, which may increase gradually in the long run. This is further supported by anecdotal evidence that shows that successful CA farmers have made significant livelihoods improvements explained by accumulation of household and farming assets and social capital further strengthening the case for conservation agriculture in the enhancement of livelihoods of smallholder farmers.

From this result we conclude that conservation agriculture can improve livelihoods of farmers in Mozambique but it is necessary to be conscious about the different ecologies and categories of farmers in different areas. Conservation agriculture is not for all categories of farmers particularly the very poor farmers; although these are the most deserving of all other groups. The significance of wealth in the likelihood of practicing conservation agriculture suggests that policies that reduce poverty or increase asset holdings of households could positively impact efforts to promote the widespread adoption of CA in Mozambique. Support systems during the initial stages are necessary for poor and more deserving farmers to benefit from CA otherwise the technology would just benefit only the already rich farmers.

Finally, for conservation agriculture to effectively improve livelihoods of farmers in vulnerable production regions of Mozambique, we recommend policies that correctly target conservation agriculture to appropriate categories of well-resourced farmers and empowerment for the poorer groups of farmers. Policies for the reduction of environmental constraints are also necessary for the minimization of negative impacts on the soil and other environmental impacts. Furthermore, such policies should integrate conservation agriculture into the overall development policy framework of Mozambican agriculture.

NOTES

1. These include the Food and Agriculture Organization of the United Nations (FAO), International Centre for Tropical Agriculture (CIAT), and the International Maize and Wheat Improvement Centre (CIMMYT) that have been particularly active in central and northern regions of Mozambique since 2005 and 2007, respectively.

2. This article does not seek to give a detailed description of what CA is; that has been dealt with in other literature (FAO 2001, 2008; Twomlow et al. 2008).

3. Glyphosate is a commonly applied herbicide in CA acclaimed to be non-selective, effective (nothing survives) in killing weeds of all types including grasses, perennials, and shrubs. It gets absorbed into leaves and soft stalk tissue and is then transported to various enzyme systems where it inhibits metabolism leading to death of the plant in days or weeks.

4. Extension services in Mozambique are characterized by under funding and inadequate manpower. In 2004, there were 708 extension workers and these had reduced to 600 in 2009 and only 30% of the rural districts in Mozambique had access to public extension services (Gemo 2006; Uaiene et al. 2009).

5. This is defined as the farmer, his household, and his fields where all decision making on crop production is done and implemented.

6. The PTD approach acknowledges the important role played by the farmer in technology dissemination, hence, places participation by farmers at all levels through workshops that encourage sharing of ideas, building on what is already known by the farmers, as opposed to top-down approaches that seek to enforce ideas of scientists and other technology innovators on the farmers.

7. It is only in Nhanguo where there is a well-constructed market structure whereby farmers rent stalls from which they sell produce, but, in Ruaca and Pumbuto, farmers sell produce from underneath trees or by the roadside at the local business centres.

8. This refers to the local unorganized markets characteristics of Pumbuto and Ruaca.

9. More details on this method can be found in Becker and Ichino (2002). The estimation here uses the STATA 10's psmatch2 routine developed by Leuven and Barbara (2003).

10. *Linha* is a Portuguese word for line, so villages say *linha-linha* to mean that they drop the seeds in a line as opposed to random placement of seed in the soil that they used to do before introduction of CA.

11. Table 6 reports both the lower and upper bounds although for positive and significant effects reporting the lower bounds might not be necessary.

REFERENCES

Bailey, C. 1988. The social consequences of tropical shrimp mariculture development. *Ocean and Shoreline Management* 11:31–44.

Becker, S. O., and M. Calliendo. 2007. Sensitivity analysis for average treatment effect. *Stata Journal* 7:71–83.

Becker, S. O., and A. Ichino. 2002. Estimation of average treatment effects based on propensity scores. *Stata* 2:358–377.

Bene, C. 2003. When fishery rhymes with poverty, a first step beyond the old paradigm on poverty in small-scale fisheries. *World Development* 36(1):945–971.

Bene, C., and N. Obirih-Opareh. 2009. Social and economic impacts of agricultural productivity intensification: The case of brush park fisheries in Lake Volta. *Agricultural Systems* 102:1–10.

Bolliger, A. 2007. *Is zero-till an appropriate agricultural alternative for disadvantaged smallholders of South Africa? A study of surrogate systems and strategies, smallholder sensitivities and soil glycoproteins*. PhD Thesis. University of Copenhagen. Copenhagen, Denmark.

Chambers, R., and G. Conway. 1992. *Sustainable rural livelihoods: Practical concepts for the 21st century*. IDS Discussion Paper 296. Brighton: IDS.

Chikoye, D., J. Ellis-Jones, G. Tarawali, P. Kormawa, O. Nielsen, S. Ibana, and T. R. Avav. 2006. Farmers' perceptions of the spear grass (*Imperata cylindrica*) problem and its control in the lowland sub-humid savannah of Nigeria. *Food Agriculture and the Environment* 4: 118–126.

Derpsch, R. 2005. The extent of conservation agriculture adoption worldwide—Implications and impacts. In *Proceedings on CD. III World Congress on Conservation Agriculture: Linking Livelihoods and Conservation*. Nairobi, Kenya. October 3–7.

D'Souza, G., D. Cyphers, and T. Phipps. 1993. Factors affecting adoption of agricultural practices. *Agricultural Resource Economics Review* 22:159–165.

Food and Agriculture Organization of the United Nations. 2008. Investing in sustainable agriculture intensification, the role of conservation agriculture. A Framework for Action. http://www.fao.org/ag/ca/doc/proposed_framework.pdf

Food and Agriculture Organization of the United Nations. 2001. The economics of soil productivity in Africa. Soils Bulletin. Rome.

Gemo, H. 2006. Recursos humanos na exatensao agraria publica em Mozambique (1987–2006). *Estudos sobre Investigacao e Extensao Agrar*ia Volume 1, IIAM, DNEA, MINAG–Maputo.

Giller, K. E., E. Witter, M. Corbeels, and P. Tittonell. 2009. Conservation Agriculture and smallholder farming in Africa: The heretics' view. *Field Crop Research* 114:23–34.

Govaerts, B., N. Verhulst, A. Castellanos-Navarrete, K. D. Sayre, J. Dixon, and L. Dendooven. 2009. Conservation agriculture and soil carbon sequestration: Between myth and farmer reality. Critical Review. *Plant Science* 28:97–122.

Guto, S. N., P. Pypers, B. Vanlauwe, N. de Ridder, and K. E. Giller. 2011. Socio-ecological niches for minimum tillage and crop-residue retention in continuous maize cropping systems in smallholder farms of central Kenya, soil tillage conservation. *Agronomy Journal* 103(3):644–654.

Heckman, J. 1996. Randomization as an instrumental variable estimator. *Review of Economics and Statistics* 56:336–41.

Kassie, M., P. Zikhali, K. Manjur, and S. Edwards. 2009. Adoption of sustainable agricultural practices evidence from a semi-arid region of Ethiopia. *Natural Resources Forum* 33:189–198.

Krantz, L. 2001. The sustainable livelihood approach to poverty reduction: An introduction swedish international development cooperation agency division for policy and socio-economic analysis. (Unpublished manuscript.)

LaFlamme, M., and J. Davies. 2007. Developing a Shared model for sustainable aboriginal livelihoods in natural-cultural resource management, CRC–Desert knowledge. http://www.desertknowledgecrc.com.au/research/inlandpublications.html (accessed 29 August 2011).

Lal, R. 2009. The plough and agricultural sustainability. *Sustainable Agriculture* 33:66–84

Lee, D. R. 2005. Agricultural sustainability and technology adoption: Issues and policies for developing countries. *American Journal of Agricultural Economics* 87(5):1325–1334.

Leuven, E., and B. Barbara. 2003. *Statistical software components S432001*, Boston College Department of Economics, revised May 2, 2009.

Lienhard, P., H. Tran Quoc, C. Khamxaykhay, T. Sosomphou, F. Tivet, G. Lestrelin, K. Panyasiri,et al.2006. Improving smallholder livelihood, Watershed and soil management through consevation agriculture in Laos (Unpublished manuscript).

Maddison, D. 2007. *The perceptions of and adaptation to climate change in Africa,* Policy Research Working Paper 4308, Development Research Group, Sustainable Rural and Urban Development Team. The World Bank.

Pretty, J. 2000. *Can sustainable agriculture feed Africa? New evidence on progress, processes and impacts*. Centre for Environment and Society. University of Essex. Colchester. UK.

Pretty, J. 1999. Can sustainable agriculture feed Africa? New evidence on progress, process and impacts. Environment, Development and Sustainability 1:253–274.

Rosenbaum, P. R. 2002. *Observational studies*. New York: Springer.

Rosenbaum, P. R., and D. B. Rubin. 1983. The central role of the propensity score in observational studies for causal effects. *Bometrika* 70:42–55.

Seeth, H., S. Chachnov, A. Surinov, and J. Von Braun. 1998. Russian poverty: Muddling through economic transition with garden plots. *World Development* 26(9):1611–1623.

Sorrenson, W. J. 1997. Financial and economic implications of no-tillage and crop rotations compared to conventional cropping systems. TCI Occasional Paper Series No. 9, Rome, Food and Agriculture Organization of the United Nations.

Start, D., and C. Johnson. 2004. Livelihood options? The political economy of access opportunity and diversification. Overseas Development Institute (ODI). Working paper 233.

Stonehouse, P.D. 1997. Socio-economics of alternative tillage systems. *Soil and Tillage Research* 43:109–130.

Twomlow, S. J., L. Hove, W. Mupangwa, and P. Masikati. 2008. Precision conservation agriculture for vulnerable farmers in low-potential zones. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Zimbabwe.

Uaiene, R. N., C. Arndt, and W. A. Masters. 2009. Determinants of agricultural technology adoption in mozambique. Discussion paper no. 67E. National Directorate of Studies and Policy Analysis, Ministry of Planning and Development, Republic of Mozambique.

World Bank. 1991. *World Development Report 1991*. Washington, DC: Oxford University Press.

The conundrum of conservation agriculture and Livelihoods in Southern Africa

Nkala, P., Mango, N., Corbeels, M., Veldwisch, G., Huising, J.

African Journal of Agricultural Research

Abstract. Low crop productivity, food insecurity, hunger and malnutrition; inadequate farming knowledge and skills, implements and inputs are characteristic of smallholder agriculture in Southern Africa. Many researchers argue that conservation agriculture can guarantee higher crop productivity, food security, improved livelihoods and environmental protection, better than the unsustainable traditional systems of slash and burn agriculture. This paper is a meta-analysis of over 40 articles that review conservation agriculture's role in influencing desired livelihood outcomes in Southern Africa. We conclude that the effectiveness of conservation agriculture towards better livelihood outcomes in Southern Africa remains debatable, especially when supportive government policies are lacking.

Key words: Adoption, Adaptation, Conservation Agriculture, Smallholder farmers, Livelihoods, Southern Africa.

African Journal of Agricultural Research Vol. 6(24), pp. 5520-5528, 26 October, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.030
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

The conundrum of conservation agriculture and livelihoods in Southern Africa

Peter Nkala[1]*, Nelson Mango[2], Marc Corbeels[3], Gert Jan Veldwisch[4] and Jeoroen Huising[5]

[1]Centre for Development Research (CDR), BOKU, University of Natural Resources and Applied Life Sciences, Vienna, Gregor Mendel Strasse 33, A-1180 Vienna, Austria.
[2]Centre for International Tropical Agriculture (CIAT), 12.5 km peg, Mazoe Road, Harare, Zimbabwe.
[3]UR Annual Cropping Systems Center for International Cooperation in Agronomic Research for Development, (CIRAD), Avenue Agropolis, 34398 Montpellier Cedex 5, France.
[4]Irrigation and Water Engineering Group, Wageningen University, Droevendaalsesteeg 3a, 6708 PB Wageningen, Netherlands.
[5]Soil Scientist and Coordinator of the Below-Ground Bio-Diversity (BGBD) Project, TSBF-CIAT, ICRAF Campus, UN Avenue, Gigiri, P. O. Box 30677-00100, Nairobi, Kenya.

Accepted 25 August, 2011

Low crop productivity, food insecurity, hunger and malnutrition; inadequate farming knowledge and skills, implements and inputs are characteristic of smallholder agriculture in Southern Africa. Many researchers argue that conservation agriculture can guarantee higher crop productivity, food security, improved livelihoods and environmental protection, better than the unsustainable traditional systems of slash and burn practices. In this paper, we present the results of a meta-analysis of over 40 academic publications to review conservation agriculture's role in influencing desired livelihood outcomes in Southern Africa. We conclude that the effectiveness of conservation agriculture towards better livelihood outcomes in Southern Africa remains debatable, especially when supportive government policies are lacking.

Key words: Adoption, adaptation, conservation agriculture, smallholder farmers, livelihoods, Southern Africa.

INTRODUCTION

Low crop productivity, food insecurity, hunger and malnutrition characterize poor rural smallholder agriculture based communities in Southern Africa. These communities experience problems of inadequate farming knowledge and skills, and insufficient implements and inputs such as seeds, fertilizers, herbicides and pesticides. In general, soil fertility management is poor and climatic conditions are unpredictable and in most cases very extreme. Consequently these factors force smallholder farmers to engage in resource mining activities to earn a living. Conservation agriculture (CA) and agro-ecology (AE) emerged as response strategies to increase food supply with a sustainable environmental protection (Fowler et al., 2001; Hobbs, 2007; Derpsch, 2005). Although the promotion of CA in Southern Africa started many years ago this slowed down with advent of western oriented agronomic technologies and practices (Fowler et al., 2001; Pretty, 2000). Conservation agriculture and other agricultural practices based on indigenous knowledge and practices are of late gaining support of many agronomists and researchers (Kassie et al., 2009).

The Food and Agricultural Organization of the United Nations (FAO), government ministries, non-governmental organization and national and international research institutes have been making conceited efforts to promote CA in Southern Africa since the mid 1980s (FAO, 2001). These efforts hinged on the successful implementation of CA technology in South American countries under similar climatic conditions as those of Southern Africa as well as many others in other parts of the world (Gowing et al., 2008; Giller et al., 2009). The promotion of CA in Southern Africa has largely ignored unique socio-economic conditions of farmers in the region; a factor

*Corresponding author. E-mail: peter.nkala@boku.ac.at. Tel: + 43 1 476542969.

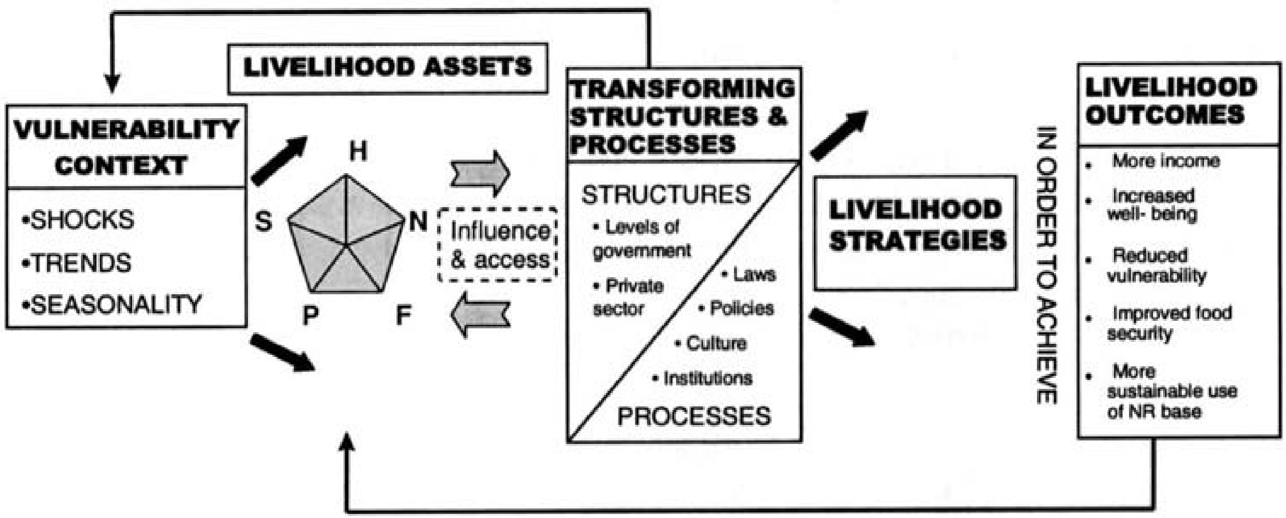

Figure 1. The sustainable livelihoods framework. Source: Adapted from Miranda Cahn (2003), sustainable livelihoods: concept and practice, Massey University.

that requires a different approach to what happened in Brazil and Argentina (Altieri, 1999). Scientists have been cautioned against promoting CA as a panacea to agricultural challenges associated with poor performance in Sub-Saharan Africa (SSA) and that a critical analysis of CA's potential in the region has been missed (Giller et al., 2009). Mazvimavi et al. (2009) further argue that lack of published studies on adoption of CA leads to wrong conclusions on how farmers in Southern Africa received technologies.

Rationale

There are various studies that concentrate on adoption, productivity, energy savings and other benefits of CA yet there are only a few that attempt to explore the link between CA and livelihoods. This paper sets out to do the latter. The paper discusses CA and possible challenges in using CA as a vehicle towards better livelihoods for smallholder farmers in Southern Africa. Livelihood outcomes such as changes in household incomes, vulnerability, food security and welfare of smallholder farmers as outlined in the sustainable livelihoods framework (Cahn, 2003) are discussed in this paper.

METHODS

The paper is a meta-analytical review of 5 books, 16 journal articles, 7 bulletins, 5 conference papers, 4 unpublished research reports, 2 discussion and 3 working papers, 2 PhD theses and some grey literature. The authors' own experiences with CA from various countries in the region have also been used in this paper. The major focus of reviewed articles is broad concepts of CA and livelihoods in Southern Africa. Table 1 is a summary of various data sources used in the paper.

The framework

The sustainable livelihoods framework (SLF) in Figure 1 shows the relationship between resource endowments, livelihood assets, transforming structures/processes and livelihood outcomes (Cahn, 2003). For a detailed discussion on the SLF, see Chambers and Conway (1992). In this paper we analyze enabling factors required for positive livelihood transformations through CA given evidence from developing countries as demonstrated in studies by Lautze (1997) and Scoones (1998) in their application of the SLF.

Despite the widespread adoption and discussion of the SLF establishment a clear link between agricultural technology and desired livelihood outcomes particularly in the context of Southern Africa has been missed. Many studies concentrate on critical analysis of either SLF or technology adoption. In the other sections we discuss and propose the missing link between CA and livelihoods of smallholder farmers in Southern Africa, but first we define key concepts of livelihoods, CA and adoption that are core in our discussion.

What are livelihoods?

According to Chambers and Conway (1992), livelihoods comprise people, their capabilities, means of earning a living, including food, income and assets. Sustainable livelihoods are those that can cope and recover from stresses and shocks, maintain and enhance local and global assets, on which livelihoods depend, imparting bequests and opportunities for future generations (Carney, 2002). Shocks are sudden changes or disturbances in the economy which transform into trends or cycles when the events are prolonged or analyzed over time. Integrating expectations of future generations in today's decision making processes is necessary for the achievement of sustainable livelihoods. Niehof (2004) singles out failure to identify sources of livelihoods as one of the weaknesses of this definition of sustainable livelihoods.

Although agriculture is the core livelihood strategy in Southern Africa, agricultural practices by farmers are unsustainable. Carney (2002) and Toner (2002) argue that CA could be a panacea to sustainable livelihoods for smallholder farmers amid poverty, vulnerability, political and economic instability and civil conflicts.

However, Gowing et al. (2008) and Giller et al. (2009) disagree

Table 1. Summary of data sources consulted.

Data Source	Number reviewed
Books	5
Journal articles	16
Discussion / Working papers	5
Conference papers	5
Bulletins	7
PhD Theses	2
Other (reports, grey literature)	4
Total	44

Source: Authors compilation.

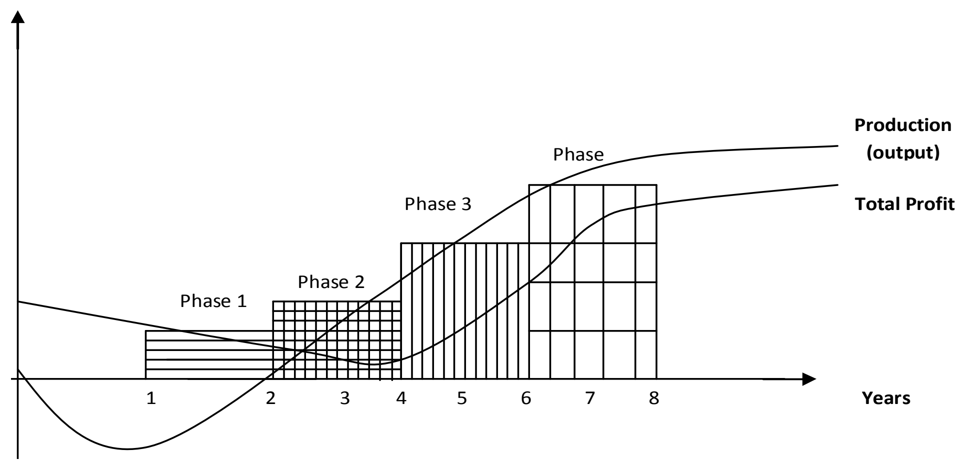

Figure 2. Phases in conversion from traditional to conservation agriculture. Source: Adapted from http://www.fao.org/ag/ca.

and caution against such beliefs.

What is conservation agriculture?

Conservation agriculture is based on three agronomic principles; (1) minimal soil disturbance, (2) permanent soil cover and (3) crop rotations (FAO, 2001). The first and second principles improve soil fertility, organic matter content and rain water infiltration especially in the 0 to 20 cm top layer considered the active yet most vulnerable zone for crop production while crop rotation reduces the necessity of pesticides and herbicides in the long run (Derpsch, 2005). According to Hobbs (2006), Hobbs et al. (2006) and FAO (2001) conservation agriculture is a technology that conserves, improves and efficiently utilizes resources through integrated management of available resources combined with external inputs. The technology is variously known as conservation tillage, no-tillage, and zero-tillage; direct seeding/planting and crop residue mulching (Baker et al., 1996; Ereinstein, 1999; Fowler et al., 2001).

Another variation of CA that has been promoted by the International Crop Research Institute for the Semi Arid Tropics (ICRISAT), the Food and Agricultural organization of the United Nations (FAO) and some local non-governmental organizations (NGOs) in Zimbabwe and Malawi is known as precision conservation agriculture (PCA) (Twomlow et al., 2008). PCA rests on four principles of; (a) minimum tillage; (b) precise application of small doses of nitrogen fertilizer; (c) combining high soil fertility with improved seed and (d) use of crop residues for permanent soil cover (Twomlow et al., 2008). Although conservation agriculture can be referred to by various names depending on scientists, where CA is promoted and the type of farmers targeted by the technology; CA hardly exists as a package proposed by the FAO, especially not in Southern Africa.

What constitutes adoption of CA?

Technology adoption by farmers means sustained technology intervention practices long after projects have been terminated. However what constitutes adoption of CA in Southern Africa is not clear as different meanings have been espoused by different authors resulting in questions on whether to consider adoption as a ‘discrete state with binary variables or a continuous measure?’ (Giller et al., 2009; Doss, 2006). Pannell et al. (2006) argue that adoption is not an all-or-nothing decision characterized by a grey area between small-scale trialing and eventual adoption. For example, Doss (2006) states that a farmer growing at least one improved variety was considered an adopter in the 22 projects in East Africa that were implemented by the International Maize and Wheat Improvement Center (CIMMYT).

The phases in the conversion from traditional to conservation agriculture are as shown in Kaumbutho et al. (2007). Figure 2 shows adoption as a continuous but non linear process occurring in phases of varying time frames, steps and sometimes ending in partial rather than full adoption.

There are various phases of the behavior of output and profits during the adoption of CA, where the two decline initially before becoming positive. Phase 1 is mainly a learning phase during which farmers learn about the techniques of zero tillage as they adjust from traditional agricultural systems to CA. This first phase is characterised by decreases in labour, time and animal traction and accompanied by increases in the demand for agrochemicals (FAO, 2004). Improvements in soil fertility and further increases in crop yields are experienced during phase 2. Minimal profits realised at this stage are used to purchase appropriate implements and inputs. The cropping pattern gets more diversified leading to stable yields and further soil fertility improvement in phase 3. Total yield stability is achieved with peaks in both productivity and profits leading to higher food security, income and enhanced livelihoods in phase 4.

According to FAO (2001, 2004) four requirements must be satisfied for the adoption of CA by farmers; (1) benefits must be immediate and visible, (2) benefits must be substantial, (3) costs of technology dissemination must be affordable and finally, (4) support with extension services for considerable periods of time is necessary. Full benefits of CA on livelihoods can only be realized when all the three principles are well established (FAO, 2001).

Promoters of conservation agriculture in Southern Africa

The Consultative Group on International Agricultural Research (CGIAR) through affiliate organizations such as the Center for International Tropical Agriculture (CIAT), International Maize and Wheat Improvement Center (CIMMYT) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) have shown keen interest on CA in Southern Africa. In addition, FAO working together with ministries of agriculture's extension services and national agricultural research institutions (NARIs) are actively involved in CA projects in the region. Local NGOs like the African Conservation Tillage Network (ACT), Intermediate Technology Development Group (ITDG) and the Organization for Rural Agricultural Progress (ORAP) are major players in CA technology promotion in the region. As a result CA has been introduced in Lesotho, Namibia, Malawi, Mozambique, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe (FAO, 2007). Empirical evidence on CA and livelihoods promotion efforts in Angola, Botswana, and Namibia by various organizations is scarce probably because ranching, mining and other livelihood strategies take precedence over crop farming in some of these countries. Usually funding for CA projects is provided by international research organizations and channeled through local NGOs, government departments and national agricultural research institutions.

In Malawi, Tanzania, Zambia and Zimbabwe CIMMYT facilitates adoption of CA in maize based systems while CIAT attempts to develop sustainable marketing systems that help improve the competitiveness of smallholder farmers. Heltberg et al. (2002) argue that integrating farmers into the market economy requires stimulation of economic growth and development as most poor farmers remain outside the cash economy due high transaction costs and associated risks.

ADOPTION AND ADAPTATION OF CA IN SOUTHERN AFRICA

Conservation agriculture in Southern Africa is characterized by partial adoption, sometimes referred to as 'distorted adoption' or 'farmer uptake' (Giller et al., 2009). From the dichotomous understanding of the CA concept, we note that there is marginal or zero-adoption but adaptation to ensure CA complies with local conditions. Farmers are risk averse, and careful about experimenting with unknown technologies hence traditional practices usually continue on other parts of the fields.

Observations in Mozambique show that smallholder farmers could adopt CA on any of their fields except where they would have planted sorghum because the 'stubbornness' of sorghum residues forces farmers to burn them as they prepare the land for the next planting season. In Zambia, Haggblade et al. (2003) lament lack of resources limiting smallholder farmers' in practicing ideal CA on all their land. The technology is implemented on small plots as an insurance against drought and famine since many believed that CA guarantees some level of yields even during years of drought. About 125 farmers, interviewed in central and southern Zambia revealed that 25% of cotton and 50% of their maize plots were under CA and overall CA accounted for 10 to 20% of cultivated land.

Alongside (partial) adoption also dis-adoption of CA occurs, hence it is not surprising that there are many claims of adoption of CA during tenure of NGO and NARI programs which disappear when the projects terminate, raising critical questions about the sustainability of CA (Giller et al., 2009; Bolliger, 2007). When forerunners of CA like World Vision International (WVI), Development Aid from People to People (DAPP), the Southern Province Household Food Security Programme (SPHFSP) and the Monze Dioceses in Zambia terminated projects in 2003, no evidence of CA remained on the ground.

There are many explanations for these CA adoption practices in Southern Africa. Some farmers join CA projects to access cheap inputs and other forms of support but revert to their traditional farming practices when such assistance stops. Inability to cope with intensive technology management requirements of CA as evidenced in Zambia also lead to dis-adoption of CA (Haggblade et al., 2003; Mashingaidze et al., 2006). Furthermore, ordinary smallholder farmers cannot emulate well resourced research institutions and NGOs despite skills and knowledge acquired from extension workers and scientists. In most cases only a few farmers who are not representative of the majority of local farmers participate in CA programmes introduced by NGOs. In addition, CA is not a technology for the poorly resourced farmers typically found in most countries in Southern Africa. The majority of farmers has no access to capital for purchase of agricultural implements and cannot afford ever rising costs for agrochemicals, seeds and other inputs (Lal, 2009). Finally, we note that smallholder farmers in Southern Africa have reservations about the CA because the reductions in yields in the first few years worsen the already desperate situation of food security.

We acknowledge that modern farmers are active participants, experimenters and re-designers of technologies fitting it into their specific conditions.

Changing soil fertility, climatic conditions and socioeconomic factors throughout the trialing period coupled with the individual famer's economic, social and environmental goals influence adoption and adaptation patterns of the technology. We note that in some regions of Southern Africa CA is an attempt to dismantle traditional systems of rotational fallow, slash and burn agriculture still strong in the minds of the farmers. For this reason smallholder farmers never completely discard traditional agricultural systems and practices despite aggressive attempts to introduce new and innovative technologies. Solving adoption problems requires respecting the farmers' experiences and knowledge of their local conditions.

The livelihood impacts of conservation agriculture in Southern Africa

The commonly discussed positive impacts of CA include increases in productivity through higher crop yields implying food security and consequently better economic and social wellbeing. Pretty (1998, 2000) noted these livelihood benefits among farmers who participated in the Machobane farming system in Butha Buthe and Tebellong communities in Lesotho. In Zambia, Haggblade et al. (2003) reported that CA livelihood outcomes among initial CA adopters include productivity level increases of 30 to 70%, diversification of production, increased social capital through farmers groups, less dependency on food aid and drought resilience. Fowler et al. (2001) reported increases of yields of up to 3.5 t ha^{-1} for most major crops and increased food security in the region. Similar results have been reported about CA in Zimbabwe by Twomlow (2006, 2008), Nyagumbo (1999), Fowler et al. (2001) and Mashingaidze et al. (2006). There is also evidence of limited benefits of CA from our discussions with CA farmers in Gondola, Gorongosa and Manica districts in Mozambique. We however take caution that attributing all livelihood benefits to CA in the absence of robust quantitative approaches capable of isolating effects of other exogenous factors could be oversimplification of an otherwise very complex process.

Farmers usually express negative outcomes of CA including problems of labour distribution among various activities during the agricultural season, especially with weeds. According to Riches et al. (1997) weeding accounts for 60% of labor required for maize production and requires proper planning and effective management. Observations and discussions with farmers in Gondola, Gorongosa and Manica districts of Mozambique also revealed that there were weed control problems during the 2008/2009 season because of floods and incessant rains. These problems affected women more than men because in most traditional farming systems in the region, women and children are responsible for weeding. The problem becomes worse among smallholder farmers who lack capital to purchase herbicides and pesticides.

DISCUSSION

Here, we present our discussion on how CA is interlinked with livelihoods with special focus on the technology's potential in Southern Africa taking cognizance of the various components of the sustainable livelihoods framework as discussed in Chambers and Conway (1992). We explore the link between CA and various livelihood outcomes including, vulnerability, capital assets, livelihood strategies and institutional arrangements on the understanding that economic and agricultural systems depend on natural, social, human, physical and financial capital endowments amid intermittent shocks and (seasonal) trends (Coleman, 1990; Putnam, 1993; Costanza et al., 1997; Pretty, 1998; Pretty et al., 2000).

Conservation agriculture and vulnerability in Southern Africa

Extreme weather patterns, poor soils and lack of institutional support are some of the factors responsible for vulnerability of smallholder farmers in Southern Africa. Cultivation of marginal lands of declining soil fertility and low productivity levels also worsen vulnerability (Norton, 1995). Barrios et al. (2008) argue that agricultural production in SSA has been affected by climate change in the last half of the 20th century. Jones et al. (2008) further argue that impacts of climate change are likely to reduce crop yields by 20 to 30% by 2050 in already marginal cropping regions thereby necessitating a shift from dependence on cropping to livestock as a livelihood option for most poor rural households. On this front Mozambique suffers from severe droughts in some seasons although the country receives substantial amounts of rainfall during summer (Barrios et al., 2008). Since 2000, flooding has worsened farm productivity thereby increasing the vulnerability of smallholder farmers to both extreme rainfall patterns. Floods and wild fires damage various infrastructures such as roads and bridges further compounding transportation problems of agricultural inputs, equipment and personnel to remote areas. Poor extension services provision, poorly organized farmers' organizations, poor means of transport, and insufficient housing for extension workers in the districts also aggravate the vulnerability problem. Furthermore, farmers operate in inefficient product and credit markets characterized by highly distorted prices of both inputs and produce (Kassie et al., 2009). Finally, poverty, political and economic instability exacerbate the problem thereby dampening the impact of CA promotion programmes on livelihoods.

Conservation agriculture and ownership of assets in Southern Africa

Limited access to assets and coping strategies forces farmers in Southern Africa to practice unsustainable livelihoods practices (Cahn, 2003). Conservation agriculture requires well resourced smallholder farmers regarding implements; basic finance and other livelihood assets but most farmers lack such basic resources (Heltberg et al., 2002). Lal (2009) argues that lack of proper seeding equipment like jab planters, disc planters, magoye rippers, zero-drills or cattle for draught power are the principal constraints to adoption of CA in SSA. In most cases organizations carrying out interventions provide such equipment during demo trials as happened in Pumbuto, Nhanguo and Ruaca in Mozambique during the 2008/2009 cropping season. Left alone smallholder farmers would use hand hoes, machetes and slashes which basic implements are owned by most farmers.

Although about 94% of rural households' livelihoods in Mozambique are engaged in agriculture, land belongs to the state and farmers have no title to the land thus prohibiting use of land as collateral. We observe that land is not so limiting factor in Mozambique and farmers practice fallow systems to manage soil fertility problems giving the traditional practice of slash and burn system a comparative advantage over CA.

CA and transformation structures and livelihoods in Southern Africa

Livelihoods are impacted on by transformation structures and processes which comprise both public and private institutions. The importance of these structures and processes characterized by NGOs, local traditional and central government, cannot be ignored in discussing their role in facilitating livelihood outcomes through CA in Southern Africa. These provide employment; agricultural inputs and equipment and also play a major role in influencing the direction of technology transfer. For example introducing CA in rural communities entails lobbying first at policy level to convince politicians and government officials.

Rural communities in Southern Africa comprise a diversity of cultures, economies and traditional political systems which influence farmers' perceptions with regards to new agricultural technologies and livelihood patterns. Culture and traditions do influence the distribution of resources and technologies dissemination in various ways. In most cases communal people are not aware of the rules and regulations governing the use of resources such as land and pastures.

In most cases the traditional and secular livelihoods transforming institutions are weak, ineffective and lack capital, financial and human resources for the effective management of common property resources. So are the management structures governing the role of farmers and their involvement, place and rights to resources, patterns of land use and tenure, dispute settlement, leadership and legal systems. Capacities associated with socio-economic well-being, quality of technology and accessibility, research and extension and government and non-governmental institutional support including policy frameworks expected from administering institutions is largely sub-standard. These institutional problems militate against realization of positive impacts and livelihood outcomes in the smallholder agricultural sectors in the region.

Livelihood strategies and conservation agriculture in Southern Africa

The potential impact of CA on livelihoods is linked to livelihood strategies which mainly comprise agriculture, remittances, microenterprise and trade among others. Livelihood strategies are various activities or adopted household behavior patterns undertaken to earn a living. These are important part of the assets-activities-outcome cycle in livelihoods analysis. The role of agriculture as a key livelihood strategy generating employment at micro-level and significant contributor to national income cannot be doubted (Doss, 2006). Subsistence agriculture supports approximately 90% of the households in Southern Africa (Heltberg et al., 2002). The high input requirements of CA preclude most smallholder farmers engaged in agriculture from realizing full benefits of this technology.

Adopting off-farm livelihood strategies through remittances and pensions is a norm in countries like Lesotho, Malawi, South Africa, Swaziland, and Zimbabwe. Young people migrate to cities in search of greener pastures and formal employment largely because of low and unstable incomes from agriculture. Other livelihood strategies such as brewing traditional beer for sale particularly in Malawi, Mozambique and Zimbabwe, to supplement household income are also common. The success of CA could be realized through the reversal of these off-farm livelihood strategies by exploiting their weaknesses and failures to provide formidable exit from agriculture. However, how CA could facilitate this transition to non-agriculture based livelihood strategies remains debatable and requires more investigation. This will be the subject of future research that seeks to identify livelihood transitions of smallholder farmers that can be attributed to CA in three communities in Gondola, Gorongosa and Manica districts of Mozambique.

Constraints against implementation of CA in Southern Africa

Here, we outline and discuss constraints likely to be encountered during implementation of CA in Southern Africa noting that there is already a deep-rooted belief that all agriculture is conventional. Conservation agriculture has been successful in communities with fertile soils but its performance on poor degraded soils in

Southern Africa remains unclear. Giller et al. (2009) argue that 'the plough has become a symbol of agriculture such that many people involved including, farmers, extension agents, researchers, university professors and politicians find it difficult to believe that agriculture can be possible without tillage'. Moreover, There is skepticism linked to the risk averse disposition of the farmers leading to the reluctance in adopting revolutionary technologies attempting to change the paradigm of farmers. It is difficult to realize a paradigm shift especially on long established practices. The success of CA also depends on its ability to transform mindsets of the smallholder farmers and perceptions on how CA can lead to desired livelihood outcomes.

The top-down approach in technology transfer is another constraint leading to questions whether CA addresses the needs of farmers, scientists or policymakers (Giller et al., 2009)? Non-farmer driven interventions and approaches to technology dissemination tend to fail due to lack of ownership by farmers. The demise of externally driven interventions has been well documented and the introduction of CA in Southern Africa could face a similar fate.

Other constraints directly relate to the principles of CA, particularly the permanent soil cover with crop residues for moisture retention, increased soil biological activity and better protection of the soil (Hobbs, 2007). Many farmers in Southern Africa collect crop residues and use them as stock feed especially in mixed farming systems where livestock are a major source of household income (ICRISAT, 2006). Crop residues are also removed by livestock that roam freely in the fields after harvesting in countries like Zimbabwe, Mozambique, Botswana and South Africa. So, for crop residues to effectively provide permanent soil cover or mulching farmers are forced to fence their fields. Twomlow (2008) argues that 'in systems where farmers are used to grazing cattle on other people's fields in winter, suddenly stopping it (for purposes of CA) would be socially unacceptable'. Furthermore, in Ruaca and Pumbuto communities in Mozambique, crop residues are decomposed by ants such that by the time the cropping season begins there will be no residues left in the field. Giller et al. (2009) argue that if mulching using crop residues improves infiltration, reduces surface erosion and water run-off and suppresses weeds then the benefits of mulching are diminished as a result of these processes. Social harmony and justice seen as part of the social benefits of CA may be an anathema whose solution requires the involvement of all farmers.

The shortage or late arrival of inputs, inexperienced personnel and inadequate access to government extension services is a common problem in Southern Africa (Pretty, 2000). In some remote communities in many countries in Southern Africa government agricultural extension services are unknown and due to resource limitations NGOs cannot reach out to all farmers. In some instances where extension services are provided, extension workers look at their involvement in the CA projects as extra work for which they should be remunerated separately. Since CA is a knowledge intensive technology, it would be difficult to successfully promote this technology without the help of well-trained and experienced extension workers.

Finally, financial support for the smallholder sector is limited in most countries with most smallholder farmers lacking access to credit for purchasing farm implements and inputs (Ereinstein, 1999). Financial institutions classify smallholder farmers as high risk borrowers with no immovable property to use as collateral, since they do not even have formal ownership of the land. Access to finance is therefore a serious constraint to the implementation of CA by the targeted group of smallholder farmers in the region.

Factors akin to livelihood improvements through CA in Southern Africa

While there is general consensus about the theoretical potential social, economic and environmental benefits of CA as a sustainable agricultural practice, there are fears about sustainability of these outcomes in practice, especially on smallholder farmers (Giller et al., 2009; Kassie et al., 2009). Heltberg et al. (2002) and Kassie et al. (2009) argue that speedy infrastructure development and increased market opportunities as evidenced in the Dominican Republic, Kenya and Ethiopia, can lead to rapid adoption of CA and hence food security and better livelihoods among smallholder farmers. Jane (1994) believes that subsistence farming has considerable potential if adequate outlets and incentives are present; which in the case of Southern Africa are missing. Strengthening of government policies supportive of CA especially the provision of infrastructure like roads, dams and irrigations schemes is necessary. According to Dumanski et al. (2006) CA is best achieved when it is community driven, and farmers and their associations can identify best options for their local conditions. This way the mistake of taking 'one size fits all approach' linked to the success of CA in other parts of the world could be avoided. Smallholder farmers should no longer be regarded as passive adopters of technologies but active participants in the development of technologies that would work towards improvement of their own livelihoods.

Twomlow et al. (2008) concluded CA will work in Southern Africa if sequenced in a manner that reflects the social, economic and biophysical constraints of the smallholder farmers. In other words CA should be adapted to suit limited resources, and low levels of education, vulnerability and chronic poverty. Technocrats working with farmers should particularize technology interventions to the physical and socioeconomic fundamentals of communities involved building on what farmers and their associations ‘develop and own’. Such a farmer centered participatory technology development (PTD) approach helps the promoters of CA understand the actual priorities and the various pressing constraints of smallholder farmers, while it may also help farmers understand and appreciate the different principles of CA.

Access to credit is an important factor in up-scaling CA in smallholder agriculture in Southern Africa since the absence of financial capital will prolong the transitions to better livelihoods. Deliberate policies that would enable farmers to use land as collateral in financial institutions however need to be developed through initiatives and discussions between government and financial institutions. This is because destructive elements of conventional tillage were subsidized in Africa through deliberate credit schemes and policies targeting special individuals or farmers groups (Fowler et al., 2001). Such support should not be politicized to enhance social justice and reduce moral hazard among farmers of different political inclinations as some party affiliates may view government assisted loans as ‘gratis’ and carrying no obligations for repayments on the part of farmers.

Conclusions

From the discussions, we conclude that with numerous non-agricultural activities that have an equally damaging effect on the environment, CA may not be a sufficient condition for increased productivity and environmental conservation. The potential success of CA hinges on desirable but non-existent conditions casting doubt on realization of the envisaged livelihood benefits of CA given diverse conditions of farmers across the region. Reducing the length of the different phases in the adoption of CA could accelerate the realization of these livelihood outcomes. Agricultural policies that put sustainable agriculture at the centre, with appropriate donor and government support, incentives, and institutional reform, are necessary for the transformation of farmers’ livelihoods through CA.

Given the issues discussed, the implementation of CA should acknowledge and address the existing economic and ecological constraints facing farmers. Smallholder farmers should be given an opportunity to adapt CA to their local conditions, experimenting with several components to assess what aspects of CA work for them, where, how and when. Farmers should also be made to realize that switching to CA results in declining yields in the short-run calling for patience and necessary policy support through social safety nets during the transition period. Finally, we note that without required infrastructure, resources and skills for technology transfer, CA’s potential contribution to livelihoods in Southern Africa remains a conundrum and subject of further research.

ACKOWLEDGEMENTS

The authors would like to express their gratitude for funding from BOKU and CIAT and also to the International Centre for Maize and Wheat Improvement Institute for giving us access to their conservation agriculture projects in Mozambique. We are also grateful for comments received on earlier drafts of this paper from various researchers including Jemima Njuki, Precious Zikhali, Ika Darnhofer and members of the Centre for Development Research at BOKU. The views expressed in this paper are entirely those of the authors

REFERENCES

Altieri MA (1999). Enhancing the productivity of Latin American traditional peasant farming systems through an agro-ecological approach, Paper for Conference on Sustainable Agriculture: New Paradigms and Old Practices?, Italy, Bellagio Conference Center, 26-30 April 1999.

Baker CJ, Saxton KE, Ritchie WR (1996). Comparison of some tillage methods on soil physical properties and yield of maize and style in degraded ferruginous tropical soil. Soil Till., 18: 63-72.

Barrios S, Ouattara B, Strobl E (2008). The impact of climatic change on agricultural production, Is it different for Africa? Food Policy 33: 287-298.

Bolliger A (2007). Is Zero-Till an appropriate agricultural alternative for disadvantaged smallholders of South Africa? A study of surrogate systems and strategies, smallholder sensitivities and soil glycoproteins. PhD Thesis. University of Copenhagen.

Cahn M (2003). Sustainable Livelihood Approach: Concepts and Practice, Massey University.

Carney D (2002). Sustainable Livelihoods approaches: Progress and Possibilities for change. Department for International Development. London.

Chambers R, Conway G (1992). Sustainable Rural Livelihoods: Practical Concepts for the 21st Century. IDS. Discussion Paper 296: 7 - 8.

Coleman J (1990). Foundations of Social Theory, Mass., Harvard University Press.

Costanza R, d’Arge R, de Groot R, Farber S, Grasso S, Hannon B, Limburg K, Naeem S, O’Neil RV, Parvelo J, Raskin RG, Sutton P, van den Belt M (1997). The value of the world’s ecosystem services and natural capital. Nature, 387: 253-260.

Derpsch R (2005). The extent of Conservation agriculture adoption worldwide – Implications and impacts, in: Third World Congress on Conservation Agriculture: Linking livelihoods and Conservation”. Nairobi. October 3-7, 2005.

Doss C (2006). Analyzing Technology Adoption using micro-studies: Limitations, challenges and opportunities for improvement. Agric. Econ., 34: 207-219.

Dumanski J, Peiretti R, Benites JR, McGarry D, Pieri C (2006). The paradigm of Conservation Agriculture. World Association of Soil and Water Conservation. Paper No. pp. 1-70.

Ereinstein OCA (1999). The economics of Soil Conservation in developing countries: The case of crop residue mulching. PhD Thesis. Wageningen University. Netherlands.

Food and Agriculture Organization (FAO) 2001. The economics of soil productivity in Africa. Soils Bulletin. Rome.

Food and Agriculture Organization (FAO) 2004. Conservation of natural resources for sustainable agriculture: training modules. FAO land and water Digital Media Series CD-RM 27. http://www.fao.org/ag/ca/.

Food and Agriculture Organization (FAO) 2007. Workshop on Conservation Agriculture in Southern Africa. Harrison’s Conference Centre. Corner 12th Avenue and Wessels Street. Rivonia. Johannesburg. South Africa.

Fowler R, Rockstrom J (2001). Conservation Tillage for Sustainable

Agriculture, An agrarian revolution gathers momentum in Africa. Soil Till. Res., 61: 93-107.
Giller KEE, Witter E, Corbeels M, Tittonell P (2009). Conservation Agriculture and Smallholder Farming in Africa: The Heretics' view. Field Crops Res., 114(2009): 23-34.
Gowing JW, Palmer M, (2008). Sustainable agricultural development in Sub-Saharan Africa: The case for paradigm shift in land husbandry. Soil Use Manage., 24: 92-99.
Haggblade S, Tembo G (2003). Early evidence on Conservation Farming in Zambia. A paper prepared for the International Workshop on 'Reconciling Rural Poverty and Resource Conservation: Identifying Relationship and Remedies'. Cornell University Ithaca. New York. May 2-3, 2003.
Heltberg R, Tarp F (2002). Agricultural Response and Poverty in Mozambique. Food Policy 27: 103-124.
Hobbs PR (2006). Conservation Agriculture: What is it and why is it important for future sustainable food production. Agric. Econ., 145: 127-137.
Hobbs P, Gupta R, Meisner C (2006). Conservation Agriculture and Its Applications in South Asia. Cornell University.
International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) (2006). Is Conservation agriculture an option for vulnerable households?. Briefing Note by Twomlow, S. and L. Hove. Bulawayo. Zimbabwe.
Jones PG, Thornton PK (2008). Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change, Environmental Science and Policy, article in press.
Kassie M, Zikhali P (2009). The Contribution to Sustainable Agriculture and Land Management to Sustainable Development. Sustainable Development, Innovation Briefs. 7: 05/2009. United Nations.
Kaumbutho P, Kienzle J, eds. (2007). Conservation agriculture as practised in Kenya: two case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food Agric. Organ. United Nations.
Lal R (2009). The plough and agricultural sustainability. Sustainable Agric., 33: 66-84.
Lautze S (1997). Saving Lives and Livelihoods: The Fundamentals of a Livelihoods Strategy. Medford. MA. Turfs University.
Mazvimavi K, Twomlow S (2009). Socioeconomic and institutional factors influencing adoption of conservation agriculture by vulnerable households in Zimbabwe. Agric. Syst., 101: 20-29.
Mashingaidze AB, Govere I, Rohrbach D, Hove L, Twomlow S, Mazvimavi K (2006). Review of NGO Efforts to promote Conservation Agriculture in Zimbabwe, 2005/2006 season (unpublished). International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Zimbabwe.
Norton A (1995). Soil and Water Conservation for Smallholder farmers in Zimbabwe: Past, present and future. In Twomlow S., J. Ellis-Jones, H. Loos. (Editors). Workshop proceedings of Technical Workshop on Soil and Water Conservation for Smallholder farmers in Semi-Arid Zimbabwe. Silsoe Research Institute Report OD/95/16. Masvingo. April 3-7: 5-21.
Niehof A (2004). The significance of diversification for rural livelihood systems. Food Policy, 29: 321-338.
Nyagumbo I (1999). Conservation Tillage for sustainable crop production systems: experiences from on-station and on-farm research in Zimbabwe (1997-1998). In Kaumbutho P.G and T. E. Simalenga. (Editors). Conservation Tillage with Animal Traction. ATNESA. Harare. Zimbabwe.107-114.
Pretty JN (1998). The Living Land: Agriculture, Food Systems and Community Regeneration in Rural Europe. London. Earthscan Publications Ltd.
Pretty J (2000). Can sustainable Agriculture feed Africa? New evidence on progress, processes and impacts. Centre for Environment and Society. University of Essex. Colchester. United Kingdom.
Pretty J, Ward H (2000). Social capital and the environment. World Development.
Putnam RD, Leonardi R, Nanetti RY (1993). Making Democracy Work: Civic Traditions in Modern Italy. Princeton University Press. New Jersey.
Riches CR, Twomlow SJ, Dhliwayo H (1997). Low input weed management and Conservation Tillage in Semi-Arid Zimbabwe. Expt. Agric., 33: 173-187.
Scoones I (1998). Sustainable Rural Livelihoods, A framework for Analysis. IDS Working Paper Number 72. Brighton.
Toner A (2002). Sustainable Livelihoods Approaches - Can they Transform Development? Bradford Centre for International development. Research Paper Number 2. University of Bradford.
Twomlow S J, Hove L, Mupangwa W, Masikati P (2008). Precision conservation agriculture for vulnerable farmers in low-potential zones. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Bulawayo. Zimbabwe.

Interlocking and Distancing of Actor Projects: The case of Conservation Agriculture in Central Mozambique

Peter Nkala and Nelson Mango

Journal of Southern African Studies
(Submitted on 28/02/12)

Abstract

This paper analyses how smallholder farmers in Nhanguo, Pumbuto and Ruaca in Manica and Sofala provinces of Mozambique interlock, and distance projects with conservation agriculture principles of permanent soil cover, minimum tillage and crop rotation. The last 30 years has seen extensive research on conservation agriculture worldwide with minimal focus on adoption, adaptation and total rejection basic principles of conservation agriculture especially by farmers in developing countries. This paper uses qualitative data from individual households, key informant interviews, focus group discussions and researchers' observations on 75 conservation agriculture farmers visited between 2009 – 2011 agricultural seasons. Purposive sampling based on participation in International Centre for Tropical Agriculture and International Maize and Wheat Improvement Centre projects was employed to choose respondents. Simple Nudist, Anthropac and Excel based qualitative data analysis approaches are used to analyse the degree of divergence from basic principles. The results show interlocking, redesigning and distancing of varying degrees of closeness to conservation agriculture principles as espoused in the Food and Agriculture Organisation of the United Nations technological codes. Only a few farmers have successfully managed to fully interlock components of their practices with conservation agriculture as prescribed in the technological code. Some results show that versions of conservation agriculture being implemented are far divorced from technological code descriptions. Different perceptions of theoretical views of permanent soil cover, minimum tillage and crop rotation, lack of crop residues, appropriate equipment, seed inputs and simple nostalgia are some of the mentioned factors that explain the observed variations. Desired livelihood outcomes like higher incomes, food security, reduced vulnerability and poverty alleviation through conservation agriculture in Mozambique can be achieved by paying attention to detail on how individual components of conservation agriculture are matched with conditions of smallholder farmers.

Key Words: Conservation Agriculture, Interlocking, Redesigning, Distancing, Smallholder farmers, Mozambique

1. Introduction

Conservation agriculture (CA) is a technology that originated in the United States of America in the 1950s and has been recommended as a panacea for increasing productivity, food security and alleviating poverty in developing countries(Friedrich et al., 2009, Friedrich and Taher, 2009, Hobbs, 2007). Although recent research portrays CA as topical and novel, Knowler and Bradshaw argue that principles of CA have been characteristic of farmers' practices in Africa for a very long time (Knowler and Bradshaw, 2007). Nyagumbo (2004) and Chiputwa et al.(2011) contend that farmers in different parts of southern Africa have been using wheel track planting, rip on row, rip and disc and direct seeding into crop residues since the 1950s. Mazvimavi and Twomlow (2009) and Friedrich et al.(2009) argue that CA is a modification of the pit system of agriculture once common in Southern Africa or a variation of the *Zai* system from West Africa. The *Zai* system works by combination of water harvesting in wide shallow pits and precise application of available manure and leaves in the most economical and optimal way possible (Mazvimavi and Twomlow (2009). Small to medium basins are dug out during land preparation to strategically accommodate scarce seed, fertilizers, manure or compost inputs under rain-fed conditions.

As of 2009, estimates showed that CA was practiced on 106 million hectares worldwide with an annual increase of 5.3 million hectares since 1990 (Kassam et al., 2009). CA accounts for only 22.6% of cropped area in the USA compared to 60% in Latin America and less than 2% in Europe. Dating back to the 1970s (Ibid), Brazil, Argentina and Paraguay lead in CA adoption (interlocking) and experience in developing countries. CA in Africa has met with some resistance (distancing) due to questionable relevance of some CA principles in smallholder farming systems in arid and semi-arid regions on the continent (Giller et al., 2009). Generally, CA farmers worldwide practice some form of cultivation with dominance of intensive cereal systems and significant regional differences persisting showing a 'sea' of agricultural matrix dominated by a prevalence of smaller islands of natural landscapes with own definitive characteristics particularly in the tropics.

1.1. Expansion of conservation agriculture in East and Southern Africa

In the last 10 – 15 years non-governmental organizations (NGOs) like the Food and Agriculture Organization of the United Nations (FAO), African Conservation Tillage Network (ACTN), International Centre for Tropical Agriculture (CIAT), International Maize and Wheat Improvement Centre (CIMMYT) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and government agriculture departments have been promoting CA in eastern and southern Africa countries{Nkala et al., 2011}. During this period CA spread to Burkina Faso, Eritrea, Ghana, Kenya, Madagascar, Morocco, Mozambique, Uganda, South Africa, Sudan, Swaziland, Tanzania, Tunisia, Zambia and Zimbabwe (Kaumbutho and Kienzle, 2007, Haggblade and Tembo, 2003, Brett, 2004, Shetto and Owenya, 2007, Baudron et al., 2007, FAO, 2007). FAO has led most of the CA intervention initiatives since 2001 with the procurement of about 1000 Matracas, 200 AT planters, 50 Tractor planters, 100 sprayers and 300 Zamwipes for CA projects in East Africa (Kaumbutho and Kienzle, 2007).

Since 2007 there has been a growing interest in CA in Mozambique driven by perceptions of enhanced resource and water use efficiency, higher productivity and reduced land degradation through integrated management of soil, water and soil biological activity (FAO, 2001, Giller et al., 2009, Kaumbutho and Mwenya, 1999, Mupangwa et al., 2005, Love et al., 2004, Love et al., 2006). Mozambique in general has been a focal point for development related projects in the region since the end of the civil war in 1992 with a number of projects targeting the smallholder farmers in various parts of the country particularly the central and northern regions. Most scholars posit that CA has a huge potential in guaranteeing food security and being a panacea to problems of smallholder farming systems in the tropics (Fowler and

Rockstrom, 2005, Derpsch, 2005, Hobbs et al., 2007, Hobbs, 2007). Except for a few heretics, most non-governmental organizations, government agriculture departments of research and extension and religious organizations promoting CA share this view (Hobbs et al., 2007, Giller et al., 2009). However, understanding and addressing these surprising claims and counter claims is paramount if CA principles could underpin the maintenance of agricultural crop productivity and thereby address global food security (Kirkegaard et al., 2011).

This paper thus sets out to answer the following questions with regards to CA in Mozambique without being judgmental on what constitutes good or bad practices of CA: What do the smallholder farmers perceive as CA? Given their understanding how have they internalised and implemented CA in their societal segments? How have farmers interlocked their project and that of CA? Why are farmers redesigning the CA technological code? What are the reasons for distancing from CA for farmers that are no longer implementing CA? What are the gender dimensions of CA for farmers that have decided to interlock their projects with CA?

2.0.Interlocking, redesigning and distancing of conservation Agriculture

This paper discusses the contemporaneous variable application of CA principles and possibly explanations for these variations among smallholder farmers in the central Mozambican selected communities. While principles of CA can be broadly applicable, innovation and adaptation in the application of principles in different agro-ecological settings is inevitably pragmatic given diverse biophysical and socioeconomic conditions of farmers(Kirkegaard et al., 2011). The implementation process of CA by farmers in Mozambique generally takes three different forms:-

(1) Interlocking or adoption which entails the willingness and ability of farmers to implement the prescribed technological code of CA.

(2) Redesigning or partial implementation of the prescribed CA code (Mango, 2002, Long and Van der Ploeg, 1989)synonymous with adaptation and,

(3) Distancing which is whereby for some very good reasons some components of the prescribed technological code of CA is completely decomposed by farmers(Mango, 2002).

This literature attributes these variations to biophysical, socio-economic, institutional and technological factors affecting farmers and their households (Kaumbutho and Kienzle, 2008). In this paper CA practices generally comprise a series of locally redesigned and simultaneously applied components by farmers (Ereinstein, 2003). For example, a study in Kenya’s Laikipia, Meru and Siaya districts showed that farmers implement CA as various versions of the principles of permanent soil cover, minimum tillage and crop rotation which practices were very different from general theoretical definitions of CA as would be applied in well-resourced national agricultural research stations(Schafer, 2008). Crop rotation and intercropping have been commonly practiced by farmers in Zimbabwe but minimum tillage and mulching are relatively new attributes that are synonymous with the recent introductions of CA (Chiputwa et al., 2011).

These variations suggest the existence of as many different forms of CA as the number of purported CA farmers, reinforcing Myrdal ideas of the irrelevance of Western theories and interventions in understanding and tackling problems of developing countries (Parayil, 2000). Customizing and simultaneous application of complete packages of CA requires years of experimentation thus complete and simultaneous CA packages have not been realized even during the 10 – 15 years since the introduction of CA in developing countries in Africa. The deeper understanding of CA principles required for sustainable agricultural production and intensification is not yet apparent hence farmers redesign CA components according to their own local conditions.

2.1. Smallholder farmers' considerations before adopting conservation agriculture

Smallholder farmers' target goal for technology adoption is based on the conviction that the technology will facilitate the realisation of desired livelihood outcomes like poverty alleviation, food security and reduced vulnerability mainly through increased productivity. Despite their low levels of education modern farmers are very discerning and know that technologies should be scrutinized closely before they are adopted. They will seek to embrace or interlock components that work and discard or redesign others before abandoning practices that have seen them through many good and bad farming seasons(Sall et al., 2000,Brett, 2004, Mayzvimazi and Twomlow, 2009, Gowing and Palmer, 2008). Intelligently farmers also consider the opportunity cost of the exit strategy supposing technology failure rather than success prevails(Gowing and Palmer, 2008). There is no doubt that due to adverse climate conditions including droughts and floods renders farming a risky activity in semi-arid regions thereby inculcating risk averse disposition behaviour in farmers. In addition this behaviour is influenced by the complex nature of the technology, farmers' resource endowments, skills and knowledge. Complex and resource intensive technologies tend to scare smallholder and hence will show a high degree of distancing especially where extension services are non-existent. Technologies that are simple and compatible with existing practices and that exhibit low opportunity costs in case disinvestment becomes necessary are associated with higher positive degree of interlocking and redesigning. However within any group of farmers there will be early adopters (front runners) who are more risks loving, late adopters (laggards) and non-adopters who show varying degrees of risk aversity being more comfortable with a 'wait and see' approach before joining the bandwagon.

Table 2 summaries 8 considerations necessary for interlocking CA with current farming activities according to Friedrich and Kassam (2009). These include farmers organisations, scientific and advisory agents, doing a baseline research, knowledge systems, seed money, mobilisation of input suppliers , lobbying policy makers and including farmers as key stakeholders in the decision making process.

Table 3: The necessary conditions for interlocking CA with current practices

	Necessary Condition	Reason or Justification
1	Inclusion of farmers	Makes use of the farmers' skills and knowledge and increases self-reliance as well substitution of external inputs for human capital.
2	Farmers organizations	Utilizes collective capacities in solving common challenges in agriculture, provide networks and nucleus of agricultural knowledge, more trusted by farmers.
3	Scientists and advisory agents	These are architects and technocrats who provide knowledge and link between technology and the farmers
4	Baseline research	Various researches concentrate on specific topics and missing the bigger picture; baseline research at least attempts to give an overview of the issues surrounding the context of CA.
5	Knowledge systems	Scientists, farmers and extension workers, for the purposes of training, demonstration and exchange of knowledge and experiences with CA
6	Seed money	To finance initials stages, study tours, field days, meetings and other activities.
7	Mobilization of input suppliers	They are part of the stakeholders, can see opportunities for business so the need to link farmers with both ends of the market
8	Lobbying policy makers	They are able to influence legal processes and policies that may lead to the promotion of the technology

Source: Friedrich and Kassam (2009)

Lack of artistry by most scientists in bringing all these factors together in a manner that does not '*academy'* or '*scientific ate*'[13] the process is usually the greatest challenge. Farmers tend to identify with processes that as close to reality as possible rather than abstractions from reality. Thus they distance themselves from knowledge intensive technologies.

3.0. Methodology

This paper is based on data collected from March 2010 and June 2011. The overall approach is largely qualitative and explorative in nature and does not seek to test any hypothesis as this was done in our other work analysing the impact of CA on smallholder farmers' livelihoods {Nkala et al., 2011a} that was part of this project. On average about 30 farmers were classified as CA farmers although for some reasons including non-availability and poor quality data from respondents, only 75 farmers were included in this study. Although most of the research took more than 18 months, data collection for this particular study in each of the research sites was done over a period of six weeks during which the lead researcher held individual and group discussions with farmers, observed and documented important activities and practices pertaining to specific principles of CA, reasons why and what objectives farmers sought to achieve with each approach. Three local research assistants were hired as interpreters and this was even more vital in Nhanguo where local dialects of *Sena* and *Chigorongosa* were totally alien to the first author and in some cases the elderly respondents could not speak Portuguese.

Qualitative data collection techniques included observations, key informant interviews, focused group discussions and individual case studies. The 75 smallholder farmer-respondents were organised on the basis of availability, willingness to participate and involvement in the CIAT/CIMMYT conservation agriculture project. Respondents included men (64%) and women (36%) aged between 19 - 94 years. Table 2 summarises respondents per province/district, community of origin and gender distribution.

Table 4: Location of Research sites, gender and number of respondents

Province	District	Community	Number of respondents		Total	Languages
			Male	Female		
Manica	Messica	Ruaca	18	13	**31**	Shona/Manyika/Ndau
Manica	Gondola	Pumbuto	14	8	**22**	Matewe, Manyika
Gorongosa	Gorongosa	Nhanguo	16	6	**22**	Sena

3.1 The Research Setting

This study was conducted in Nhanguo, Pumbuto and Ruaca communities and this section discusses background characteristic of these communities. There are 57, 60, and 55 households in Nhanguo, Pumbuto and Ruaca, respectively. Nhanguo is in Gorongosa[14] district of Sofala province while Pumbuto and Ruaca are found in Gondola and Messica districts of Manica province (See figure 1). Most families in these communities settled around 1993 – 1997 as returning refugees following the end of the 16 years of civil conflict between the *Frente de libertacao de Mozambique* (FRELIMO) and *Resistencia Nacional de Mozambique* (RENAMO) which has forced people to flee and seek refuge in urban centres or neighbouring countries like Zimbabwe. In all the three communities competition between traditional and political administrative structures exists although the chief is largely accepted as the overall in charge. However in Nhanguo the conflicting interests of traditional and political

[13]Making technology too academic and too scientific for the simple smallholder farmers in rural settings and hence less appealing to them as target groups.
[14]Gorongosa is well known for strong traditional and cultural practices in Sofala province and is home of the famous traditional healer known as "Samatenje" who is believed to capable of performing miracles for those that consult him.

administrative structures was observed. Although Portuguese is the official language of Mozambique, local dialects like Manyika, Matewe, Ndau, Sena and Shona are spoken. Figure1 below shows the location of the central provinces of Manica and Sofala in relation to the other 8 provinces of Mozambique.

Figure 1: The provincial map of Mozambique. Source: Google images (accessed 28/02/12)

Just as in other rural areas communities in Mozambique, rain-fed agriculture is the major source of livelihoods but other livelihood strategies like making and selling charcoal, vending of fish from local rivers, fruits and vegetables from family orchards and gardens and basketry are common . The major field crops grown include maize, sorghum, groundnuts, rice, potatoes, sweet potatoes, cassava, and pumpkins while fruits like mangoes, pine apples, oranges, lemons are grown in small orchards close to the homestead and help supplement vitamins in household diets and household incomes. Agricultural productivity, skills and knowledge of farming is higher in Ruaca compared to Nhanguo and Pumbuto. This could be explained by more fertile soils and better access to water resources and more interventions by NGOs. Pumbuto faces more acute domestic water access problems than the other two due to the non-availability of perennial streams and lack of investment in boreholes and other water sources. Chief Pumbuto actually lamented charcoal production as the major cause of water problems, drought and environmental degradation. Nhanguo and Ruaca are graced with perennial streams that flow from the mountains and a few farmers have used the water to irrigate some portions of their fields, mainly home gardens where cash crops mainly vegetables are grown.

Domesticated livestock include chickens, pigs, goats, ducks and pigeons which are occasionally sold to supplement household diet and income when sold. As of 2010 pigs cost between 600-1000, goats cost about 300 – 800, chickens between 70 – 80 meticais[15]. Cattle were however found only in Ruaca having been introduced through NGO interventions seeking to promote draught power and there were no such interventions mentioned for the

[15] The meticais is the official currency for Mozambique and one dollar exchanged for between 33 and 36 meticais at the time the fieldwork was done.

other areas. Historically, Pumbuto was a tsetse fly infested area and most livestock could not survive tsetse flies transmitted diseases, hence farmers could not keep cattle in particular but of late one commercial farmer has introduced cattle and horses in Pumbuto probably because he can afford costs of livestock medicines.

3.2 The theoretical perspective

Theoretically the paper is guided by the concepts of interlocking, redesigning and distancing of actor projects. In this paper we try to explain and link the interlocking and distancing of projects with the interplay of varying farming and household objectives and the ways in which farmers identify existing constraints and opportunities for agricultural and rural development. The objectives of farmers and their modes of problem identification and resolution, as well as their eagerness to incorporate and redesign new technologies or distance from them, must of course be understood in relation to the diverse settings and choices they may face. The latter include many different dimensions – socio-cultural, political, economic, institutional and agro-ecological (Van der Ploeg, 1990).

As used in this paper, 'interlocking' conveys the image of the interlinking of farmers' projects with those of other actors, especially those interest groups and organisations relevant to the field of agricultural development, i.e. traders, technologists, extension workers, credit institutions, and other farmers. In the process, their projects generally become progressively shaped by the predominant ideology of modernised farming, and their farming practices increasingly affected by the domains of technology and commodity markets and their operative prices. In a more general sense, interlocking is a process of forging particular links between institutions and particular group of farmers(Van der Ploeg, 1994). In this particular case, CIAT, CIMMYT and government extension that have been linking with farmers on CA.

'Distancing', on the other hand, reflects the processes whereby farmers de-link themselves from introduced agricultural innovations and the configuration of institutions that have an interest in the adoption of such innovations. As we show in this paper, distancing can take many forms, ranging from how farmers redesign existing technologies to how they distance themselves completely from them by rejecting or taking no interest in them. The implications are that farmers look for their own solutions to the particular problems they encounter. 'Redesigning' refers to the process by which a new idea or innovation is mixed with local insights and practices. Van der Ploeg (1994:9) understands these technological processes as constituting '*the deconstruction of technical designs whereby particular elements are reconstituted and combined with elements already existing to provide the most methods for 'conversion' and differ sometimes considerably, from the original technical designs*'. Redesigning is one of the manifestations of farmer responses to dominant (state and donor funded) technological regimes. It is these processes of complying with and redesigning and distancing from agricultural technologies that constitute social heterogeneity.

4 Results and discussion

This section assesses how farmers' have internalised, redesigned and distanced from the CA technological code as prescribed in the three principles of permanent soil cover, minimum tillage and crop rotation in the different study sites. We also analyses how CA has impacted on the livelihoods of farmers who have interlocked their projects with it. Gender dimensions in interlocking of actor projects with CA are considered. We do this to highlight different roles played by men and women in interlocking, redesigning and distancing of CA practices. Generally our findings also show that for various good reasons smallholder farmers in our sample practice a mixture of CA and non-CA practices in their implementation of what they perceive as CA i.e. redesigning and distancing from the CA technological package.

4.1 What do farmers understand by Conservation Agriculture?

From the onset this paper sought to demonstrate what farmers understand by the concept CA in order to ensure that whatever they did to adapt or change the technology was done with a specific purpose rather than out of ignorance, hence they were thus asked to explain their conceptualisation of CA. Less than 15% of the farmers correctly explained CA as based on three principles; permanent soil cover, crop rotation and minimum tillage. To most farmers CA was any one or combination of the following:-

(i) an agricultural technology seeking to improve soil fertility and conservation by eliminating burning of crop residues, growing legumes like beans, pigeon peas, groundnuts and application of compost,

(ii) a farming system that integrates growing crops and medicinal plants using compost to improve soil fertility and,

(iii) A holistically integrated cropping and livestock farming system that targets improved nutrition and livelihoods food security, better sanitation and household hygiene.

One respondent in Ruaca explained CA as '*preparing the land during winter, applying liquid manure in the field and then ploughing before planting or directly into basins after germination; putting the stover to improve moisture retention; planting different crops like maize, bambara nuts, and pigeon peas in different rows in the same field to improve yields"*. The use of liquid manure[16] and compost were widely discussed as important in soil fertility improvement in the practice of CA in Ruaca having been introduced by CARITAS and later adopted and becoming a common practice among livestock owners. There are clear misconceptions as expressed in the various definitions and perceptions of farmers' practices of CA. However the farmers' understanding are richer than the three basic principles of CA. Permanent soil cover and minimum tillage were not so much emphasized while crop rotation was mis-interpreted as intercropping or planting different crops in different rows in a single field. This means that from the start different farmers are doing different things although all of them understand this to be CA leading us to the next session where we discuss how each of the principles were pursued given the different individual perceptions and misperceptions.

4.2 Interlocking and Distancing

4.2.1 Various motivations for interlocking projects with CA

Most farmers said they chose to engage in CA because they believed that the technology would lead to improvement of soil fertility, higher productivity and higher yields. These two were assumed precursors for food security and better livelihoods with most of them now able to feed their families throughout the year without experiencing any food shortages as before. Although none of the farmers expressly stated this point, there was evidence of being enticed by the free seed, fertiliser and equipment supplied to participants in the CARITAS, CIAT, CIMMYT, FAO and government collaborated projects. Maize and pigeon pea seed were given to project members free of charge to help standardize experimental crops and other factors. Evidence of extension workers influence on participants was also observed as it was those farmers close to the extension worker who seemed to have a high propensity of being involved in this and previous projects as such farmers get information well ahead of others

CA was also associated with savings in time and labour as more than 80% of the farmers relied on hand-held hoes for land preparation; only 20% of owned cattle. Land preparation begins with removing outgrown shrubs and small bushes with machetes around September –

[16]Liquid manure in this case is fresh cow dung that is collected and mixed with water and stirred in a specially constructed brick and cement tank, plastered on the inside. The mixture is then left for at least 14 days to mature before application in the field.

October before onset of early rains expected in late November. Cattle owners who have significant quantities of manure would then apply it together with compost to fields cleaned out of shrubs and small bushes. Some farmers prepare liquid manure from fresh cow dung mixed with water in special concrete tanks and left for between 10-14 days to "mature'' after which the mixture is economically applied directly into planting basins targeting root development. Non-livestock owners use compost prepared from leaves and grass collected through a very labour intensive process.

4.2.2 Planting practices among CA farmers

Planting or seeding is done a few days before onset of first rains expected during the last week of October or first week of November to avoid double seeding following poor germination which can be costly. Since the introduction of CA in 2007 most farmers now prefer seeding in rows having desisted from broadcasting seed anywhere anyhow as was the practice before – seeding in rows was known as "*linha-linha"*[17], and surprisingly some farmers understood this as the fourth principle of CA. Farmers said they left a space of 20 cm between seeds and 50 cm between rows in order to minimise 'overcrowding' of crops affecting growth and subsequently productivity and yields. Any spacing larger than 20 cm or 50 cm was seen as less than optimal utilisation of land. In reality however these spacing specifications varied between and among farmers and across types of crops grown so whenever they were mentioned maize or maize intercropped with pigeon peas and sorghum was assumed. Practically spaces were either smaller or bigger than theoretically espoused and in some instances the said rows could not be seen in the fields as farmers distanced from the "*linha-linha*" concept which they said was time wasting. In essence we discovered that farmers were simply recalling spacing specifications recommended by intervening organizations and not common practice. However those respondents using basins were much closer to the specifications than others who planted as land was ploughed using oxen.

The influence of weeds on how farmers implement CA was outstanding. Most farmers said the amount of weeds in the field prior to planting determined approaches to field preparation and seeding thus:-

- Seeding preceded weeding when weeds are few, small and posed zero or minimum threat to germination and growth,
- Seeding follows weeding when weeds are overgrown to prevent rapid growth and *chocking* of the major crops.

Farmers concurred that uncontrolled weeds reduced yields by competing for water and plant nutrients with main crops especially during times of drought(Twomlow and Bruneau, 2000). This continued reference to weeds highlighted the extent of the weed problems associated with CA compared to conventional tillage. Significant amount of human labour energy is expended in weed control under CA. During the 2009/2010 season incessant rains and subsequent flooding was said to have escalated the weed problem as farmers could not cope with weed removal. Although herbicides were said to be a necessary and sufficient condition for total weed control, affordability was a major challenge facing most farmers with no known and likely cheaper indigenous knowledge weed control mechanisms to possibly employ.

4.3 The benefits of interlocking of actor projects with CA

Improving food security and well-being of those living on the fringes of desperation is the ultimate objective of introducing technologies like CA in smallholder farming communities. The impacts of such programmes manifest through increased productivity, higher household incomes and wealth endowment otherwise the experiment would have resulted in a

[17]*Linha* is Portuguese for line and this concept derives from this word meaning planting in lines or more correctly rows as opposed to the traditional practice under slash and burn seeds were just broadcast everywhere.

monumental failure. The results in this study show that some CA farmers managed to give their homesteads a facelift since introduction of CA in 2007. The traditional architecture of mud huts were replaced with more durable brick and asbestos structures. A few farmers dug water wells and constructed "blair" toilets. There is no doubt that access to water, sanitation and hygiene has greatly improved especially in Ruaca and Nhanguo although Pumbuto still lags behind.

Although less than 20% of CA farmers managed to produce surplus to sell, purchases of household assets such as bicycles, scotch carts and purchases of cattle, goats, chickens, turkeys and guinea fowls from 2007 – 2010 were observed. Other acquisitions usually considered as status symbol assets in these communities include solar panels, radios, television sets and cellular phones. These increases in asset endowments was financed by income from surplus agricultural produce and cash crops such as vegetables, cotton and tobacco increase in income to sale of agricultural produce largely attributed to changing from the traditional slash and burn agriculture to CA. To quote from an interview with one farmer in Ruaca thus '*this way of farming helped me a lot, it increased my output (yields), I now have enough grain to eat and some to sell. I made a lot of money from selling maize in Messica and bought cattle, a plough, animal drawn cart, cement and roofing sheets for my new house. I bought one cow at first which has since given birth to 3 calves increasing the number of livestock to four. I recently won two beasts, 2 goats, a plough, a bicycle, a radio, sprayer and some maize and beans seeds at a local agricultural show*'. Apart from increased yields, food security, household incomes there were clear observations of food poverty reduction among farmers who embraced CA upon introduction in 2007 which enticed other farmers to join the programme[18].

Observations show a tendency of improvements being confined to a few farmers who historically have always been successful pioneer farmers. Although these changes were attributed to CA as the only variable introduced to their farming system in the last four years, although questions can be raised on the influence of other intervening projects and variables. The traditional slash and burn agriculture was also being blamed for all the past failures including reduced yields, soils degradation, compromised food security forgetting the possibility of other factors like adverse climatic conditions like floods and droughts. As one farmer said '*we used to burn the residues to have a clean field before proceeding with planting which would then be very easy, we did not know that this damages and disturbs soil fertility*'. Nonetheless these positive outcomes corroborate empirical evidence supporting conservation agriculture technology which only a few authors like Giller et al.(2009) have dared to question.

4.4 **Distancing and redesigning conservation agriculture**

Farmers distancing practices took many forms, ranging from how farmers redesign existing technologies to how they distance themselves completely from them by rejecting or taking no interest in them. In this section we look at the three principles of CA and how farmers have unpacked and distanced from them.

4.4.1 The Principle of Permanent Soil Cover

Among other things this research sought to understand farmers' perceptions on mulching as one of the three key principles of conservation agriculture and how they applied it to their fields. In Ruaca leaves, grass and crop residues were mostly used as materials for mulching. Very few farmers in Nhanguo and Pumbuto introduced mulch like grass and leaves from

[18] Although farmers could not explicitly say so, there is a strong possibility that some embraced the CA programme in order to access cheap inputs like seed, fertilizers and use of agricultural equipment provided by interventionists.

external sources. Since some farmers owned cattle in Ruaca these were kept off the fields by CA farmers in order to protect crop residues that would serve as permanent soil cover. This tended to be time consuming and too demanding since most fields had no perimeter fences thus giving a good justification for distancing from this CA technology package.

The scarcity of grass and leaves only allows well-resourced farmers who can afford paying labour for cutting and transport grass to CA fields to ensure permanent soil cover. The cost for a bundle that weighed about 10 kgs during the 2009/2010 agricultural season cost 10 meticais per bundle or 100 meticais per animal drawn cart. A respondent in Ruaca said, *'During the 2009/2010 season I spent 1500 meticais on grass which cost 100 meticais per cart and transported it in my own cart. I also had to buy manure at 50 meticais per cart since my soils are generally poor"*. Poor farmers could not afford to pay for this making it impossible for them to observe this principle of CA thereby having a good reason for distancing mulching in their practice of CA. Observations also showed that most farmers were really struggling to get mulching materials which was very demotivating to some farmers. Pumpkins and melons were then planted as cover crops for mulching. Thus the technology code for residue retention was redesigned and its place taken by pumpkins and melons that acted as cover crops. Furthermore, these challenges forced mulching to be done on small scale only on small plots about 0.5 - 2.5 hectares close to the homestead thus making CA less that field-wide practice for most farmers, too complex a technology to practice on entire fields. Discussions however showed that some farmers were still obsessed with spreading the almost impossible practice to larger fields away from the homestead.

On why permanent soil cover was important those farmers who decided to interlock projects with CA either fully or in a redesigned way stated that permanent soil cover helped in moisture preservation, improving soil fertility and in suppressing weed growth. Later the decomposed mulch was said to serve as an ingredient for fertility improvement. Reducing evaporation and top soil temperatures, improving water infiltration, aggregate soil stability, protecting the soil from the vagaries of weather such as the sun, rain and wind activity were not mentioned by most farmers as other benefits or purposes for mulching.

4.4.2 Challenges associated with interlocking the permanent soil cover principle

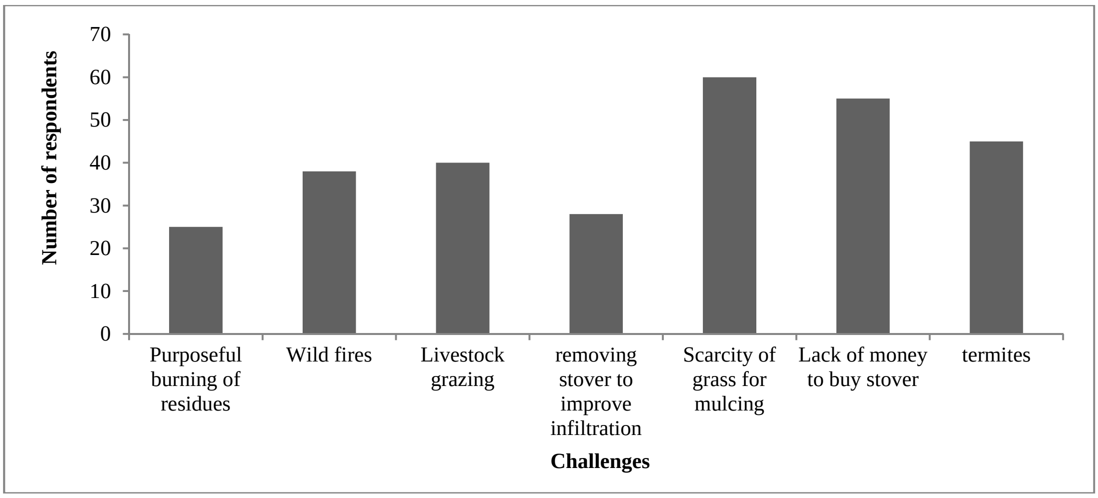

Figure 2: The challenges associated with interlocking permanent soil cover

Farmers were explicitly asked about challenges they faced towards implementing the permanent soil cover principle and figure 2 gives a summary of their responses. In figure 2, the vertical axis is a summary of the challenges while the horizontal axis comprises the number of cases each challenge was mentioned by farmers. Seven main challenges mentioned and that are briefly discussed below include termites, finance, scarcity of grass, livestock, wild fires and the need to burn some stubborn residues.

Termites were a problem in all the three areas although more prevalent in Nhanguo, less in Pumbuto and least in Ruaca. Termites destroyed grass and leaves for mulching, newly germinated crops forcing farmers to re-seed and crop residues from the previous year. Where newly germinated crops were destroyed farmers were forced to re-plant and this has some serious economic implications for poor farmers who could not afford to buy some more seeds. Without funds for buying pesticides, there was no immediate solution in light for this problem among the farmers electing to be part of the CA programmes.

Some farmers said they were forced to voluntarily (purposeful) burn crop residues to chase away rodents, mice and other small creatures living in burrows under crop residues which were a menace in digging and destroying seedlings as they looked for left over seed pods to eat. Second reason for voluntary burning of crop residues was associated with sorghum residues that were said to be resistant and taking too long to rot thereby forcing farmers to burn them. Farmers also said they voluntarily burnt residues to destroy weed seeds in the field usually under crop residues to suppress weed growth. Weeds were understood to be responsible for poor infiltration and low crop yields[19].

Wild fires were common in all the three sites mainly causes by non-CA farmers who still practiced traditional slash and burn agriculture. As fires know no boundaries and there were no fire guards, fires usually spread to neighbouring farms burning and destroying crop residues and mulching grass. As one farmer put it '*wild fires are however a problem which sometimes destroy the purchased grass before it is collected from the seller as happened to me last year and there was nothing I could do because I had already paid for the grass'*. In sum the problem of fire hazards in Mozambique is much broader than the eye can see and requires strong control policies at local and national level.

Competing uses of crop residues as stock feed and permanent soil cover greatly affects farmers in Ruaca due to higher number of livestock owners than in other areas. This problem did not arise in Nhanguo and Pumbuto. Cattle are allowed to roam freely after harvesting and there are no laws prohibiting free movement of livestock after harvest as fields become part of communal pastures. The major concern with this is that farmers who completely distanced themselves from CA and own livestock disagree with preservation of crop residues for permanent soil cover instead of using it as stock-feed as compared to less than 45% who are CA owners. With plans to intensify livestock production competing uses for use of residues as permanent crop cover and livestock feed is likely to rise and there could be good justification for non-CA non-livestock farmers to sell their stover rather than leave it to be eaten freely by neighbours' livestock. These challenges demonstrate an imminent potentially explosive situation that could land a heavy blow on communal peace and harmony. The question that remains is whether CA would be ideal where rearing livestock has been integrated into the farming system and where no fences or laws exist to prevent cattle from grazing everywhere or should farmers just distance themselves from this principle of permanent soil cover?

Although CA requires permanent soil cover, some farmers said when there is insufficient rainfall, grass and stover used as mulch reduces infiltration hence the farmer will temporarily remove mulch to improve infiltration, another reason for distancing. Cutting and transporting of grass to CA fields was said to be '*cumbersome and too demanding requiring hiring of grass cutters and paying them for their labour in order to serve on labour for other*

[19] Biomass can be increased by factor four and water use efficiency by factor 5 for well weeded maize compared to no weed control.

activities'. Verbal contracts are entered into despite the risks of fires and other possible factors that could jeopardize the full execution of the contract by both parties. Furthermore, scrounging for grass all over especially where the expansion of CA is envisaged to expand creating possibly negative environmental impacts and according to farmers, grass is becoming only available along stream-banks so in future it may be impossible to buy the grass. The 30% soil cover threshold as recommended by Mazvimavi and Twomlow (2009) and the US Conservation Technology Information Centre (CTIC, 1999) may be too ambitious a target for most farmers. The 30% crop residue cover threshold is therefore far from being realistic for most farmers hence soil erosion may continue unabated.

Finally lack of financial support associated with lending to smallholder farmers is another problem that makes permanent soil cover principle less attractive to farmers. Some farmers are still stuck with the mentality for a clean aesthetic seedbed associated with conventional farming and cannot fully understand why planting should be done where there are crop residues. As a result most farmers are torn between dividing their fields into CA and non-CA fields where they continue with the old practice, just in case CA does not work!! All the above challenges are justifiable reasons for distancing by smallholder farmers.

4.5 The principle of minimum tillage

Our observations showed that farmers practice rotational tillage (Derpsch, 2005), whereby the farmer occasionally tills their land thereby jeopardizing realization of full benefits of no-till technology(Friedrich and Kassam, 2009). About 50% of farmers stated that burning crop residues is more effective in creating clean seed beds before planting, killing the weeds and rodents since they use hand hoes for tillage. Minimum soil disturbance was understood as a principle that would improve soil fertility and moisture conservation and lamented lack of jab planters, *matracas* and other suitable equipment. Indications are that farmers cannot afford this equipment in the foreseeable future hence many did not adhere to this principle hence the unclear answers on how it was interlocked into their activities. Some expressly said that not ploughing encourages rapid weed growth especially when there is too much rainfall as experienced in 2009 shortly after experimenting with this principle and would not want to re-live that experience. Some farmers ploughing first, turned residues over, introduced grass for mulching and make planting basins using hand hoes, which is rather cumbersome and too labour intensive. Finally minimum tillage was understood to apply to certain crops and not others as one farmer in Nhanguo stated that '*groundnuts do not grow very well when the land has not been ploughed*' implying that there could be "*no agriculture without the plough*". There was also concern of lack of understanding of the importance of the principle as interlocking technology is a learning process that result slowly results in new discoveries, over a long time.

4.5.1 Challenges associated with interlocking the minimum tillage principle

Although minimum tillage is ideal for smallholder farmers without implements, our findings show that some farmers try harder to create clean fields before planting for various reasons. Farmers expressed great concern about weeds militating against full observation of minimum soil disturbance indicating that crop growth rate is stifled especially where there is insufficient labour for weeding. The weed problem caused the reduction of plots sizes where as a labour optimisation strategy in situations of labour shortage. Timely weeding starting in winter when weeds are small and manageable using hand hoes and machetes as recommended by Twomlow and Mazvimavi (2009) was not always feasible depending on rainfall and other climatic conditions. Table three give a summary of the cases and reasons for distancing from minimum tillage principle as explained by respondents.

Table 5: Cases and reasons for distancing from minimum tillage principle

Reasons for distancing	**Number and gender of respondents**		
	Male	**Female**	**Total**
Weeds grow fast when land has not been ploughed affecting crop growth and yields.	35	31	**66**
Labour constraints especially for weeding that is so demanding forces us to sometimes plough the field before planting.	28	26	**54**
Crops do not grow well when the field has not been cleared first because of shrubs.	33	18	**51**
To destroy the weeds while they are still small.	40	23	**63**

4.6 The principle of crop rotation

In all the three communities, the principle of crop rotation was not fully understood with some farmers confusing it with intercropping. We observed no attempts by farmers to interlock crop rotation with current practices but evidence of deliberate intentions intercrop repeatedly from season to season. The only mention of crop rotation was where maize was intercropped with groundnuts, pigeon peas and beans at first and maize with bambara nuts in the following year implying that there will be maize intercropped with something on the same field especially where soils were rich enough to guarantee maize yields. Farmers viewed maize as a staple crop and would not risk experimenting by not planting maize just for the sake of interlocking crop rotation into their farming activities. Doing so would be suicidal and risking household food security if the said crop rotation failed to deliver good yields.

Farmers hedge against crop failure and maximise on land use through intercropping under a very strong conviction that intercropping reduces crop failure, improves soil fertility, yields and guarantees food security during lean seasons. As one farmer put it '*mixing different crops helps improve soil fertility, for example, when we plant pigeon peas, beans and pumpkins this year and maize yields tend to be higher the following year'*. This assumes that during periods of drought, the drought resistant crops amongst all crops grown tend to guarantee "some" harvest no matter how marginal. Intercropping partly solves the problem of land scarcity especially in Nhanguo and Pumbuto. However, this was only true to some extent in Ruaca where intercropping was done for other reasons other than shortage of land since farmers in Ruaca still have some margin of virgin land in *Madingwindi* about 8 - 15 kilometres away where they were still extending their fields. Finally, results suggest that farmers have redesigned intercropping to be synonymous with crop making a statement that crop rotation does not apply in their situation hence cannot be interlocked with their current farming practices as prescribed in CA technological code resulting in total decomposition of CA (complete distancing).

4.6.1 Challenges associated with interlocking the principle of crop rotation

As stated above, intercropping or mixed cropping has replaced crop rotation as a hedging strategy against drought and also where a shortage of seed inputs exist paralysing the otherwise good intentions to rotate maize and other crops. Observations show that respondents relied on seed from local varieties selected from the previous year's harvest with purchases of seed from neighbours very common. Sometimes free seed supplies from non-governmental organizations and government motivated by political and other reasons give farmers limited choices on what to plant. They would then plant whatever seed they are supplied with regardless of what crop was planted the previous year on a particular plot. In summary five challenges regarding crop rotation mentioned by farmer include; 1)

Intercropping minimizes diseases and pests for the second crop 2) Soil cover is quick thus conserving moisture and nutrients 3) Saves labour 4) Maximum utilization of land 5)Weeds are totally smothered 6) Cereals benefits from nitrogen fixation by legumes.

5 Conclusion

The prima facie conclusion from the results is that all specified technological codes of conservation agriculture principles as implemented by smallholder farmers are tempered with further showing the rural and agricultural development does not follow a linear process but is web-like thing entailing interlocking and distancing of actor projects. This is what heterogeneity in agriculture is all about. As noted in the earlier part of this paper farmers' version of minimum or no tillage is whereby land tillage is done in some years and none in others. Crop rotation is to a large extent confused with intercropping characterised by excessive mono-cropping of maize as a staple crop. Permanent soil cover while understood better than crop rotation and minimum tillage also takes on a very elaborate local Mozambican version whereby it is only applied to smaller carefully selected plots and not in others. In short there is distancing of all the three principles of the CA technological codes in preparation for interlocking to suit various challenges faced by individual farmers even within the same locality. This leads us to the conclusion that farmers in Mozambique like others in developing countries where CA has just been introduced are still grappling with various components of how the technology should be implemented. In essence this is what entails development i.e. a difficult process. It is an arena of struggle where various actors strive to create space for manoeuvre with their projects.

A '*sui generis*' orthodox approach as espoused in agricultural technology development theories has since become obsolete necessitating new approaches that recognise situating technology development in the concepts of interlocking and distancing of actor projects. None of the farmers in these areas has really achieved or are moving towards achieving a complete adoption of CA as a package (redesigning) and some farmers have abandoned CA practices completely, even before the end of the projects (total distancing). Observations and discussions with farmers show that an attempt toward permanent soil cover is the most popular and well understood of all the three principles of CA and is least redesigned. The principles of minimum tillage and crop rotation and their role in improving agricultural performance, soil fertility and moisture preservation are least understood by farmers and are heavily redesigned.

Although farmers express high willingness and hope about the impact of CA on their livelihoods, promoting the technology as a package may not work. New strategies and paradigms are necessary to bring perceptions, views and ideas of scientists and farmers together. Huge economic and financial resources may be wasted in pursuing issues of crop rotation and minimum tillage in an agricultural system still characterized mostly by slash and burn practices. Intervention approaches glossing over differential characteristics of smallholder farmers and communities stand to be retrogressive and costly in the long term. More efficient utilisation of financial and economic resources could be achieved if the most understood principle of permanent soil cover's contribution to desired livelihood outcomes is promoted ahead of crop rotation and minimum tillage that are least understood. Giving equal weight to all CA principles is wrong and should at best be avoided for realisation of better livelihood outcomes. Overall, positive farmers' perceptions about CA's role in improving soil fertility, increasing yields and household incomes and guaranteeing better livelihoods posit a good potential for the future of CA in Mozambique.

Acknowledgements: The authors would like to thank the International Centre for Tropical Agriculture (CIAT) and the University of Natural Resources and Life Sciences (BOKU) and the Centre for Development Research (CDR) for funding this study. We are grateful for valuable comments and suggestions from a number of people during the developments of various drafts of this paper.

References

Baudron, F., Mwanza, H. M., Triomphe, B., Bwalya, M., 2007. Conservation agriculture in Zambia: a Case study of Southern Province, African Conservation Tillage Network, and Centre de Cooperation Internacionale de Recherche Agronomique pour le Developpement, Food and Agricultural Organization of the United Nations, Brussels.

Brett, C., 2004. 'Farm level adoption decisions of soil water management technologies in semi-arid Eastern Kenya'. Paper presented at the 48th Annual Conference of the Australian Agricultural and Resource Economics Society, 11 – 13th February, Melbourne.

Chiputwa, B, A., Langyintuo, S., Wall, P., 2011. Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the Shamva District of Zimbabwe: A Tobit model, Paper presented at the meeting of the Southern Agricultural Economics Association (SAEA), Texas.

Conservation Technology Information Centre (CTIC), 1999. What is conservation Tillage? CTIC, Core for Program, Lafayette, IN, USA.

Derpsch, R., 2005. The extent of Conservation agriculture adoption worldwide – Implications and impacts', Third World Congress on Conservation Agriculture: Linking livelihoods and Conservation", October 3-7, Nairobi.

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

Food and Agriculture Organization (FAO)., 2001. The economics of soil productivity in Africa. Soils Bulletin, Rome.

Friedrich, F., Kassam, A.H., 2009. Adoption of Conservation Agriculture Technologies: Constraints and Opportunities. Invited paper, IV World Congress on Conservation Agriculture, 4 – 7 February, New Delhi.

Friedrich, T., Kassam, A.H., Taher, F., 2009.Adoption of Conservation Agriculture and the Role of Policy Institutional Support.Plant Production Division, Food and Agriculture Organization of the United Nations, Rome.

Giller, K.E.E., Witter, E., Corbeels, M., Tittonell, P., 2009. Conservation Agriculture and Smallholder Farming in Africa: The Heretics' view. *Field Crops Research*, 114 (1) : 23-34

Gowing, J. W., Palmer, M., 2008. Sustainable agricultural development in Sub-Saharan Africa: The case for paradigm shift in land husbandry, *Soil Use Management*, 24 (1) : 92-99.

Haggblade, S., Tembo, G., 2003.Early evidence on Conservation Farming in Zambia. A paper prepared for the International Workshop on 'Reconciling Rural Poverty and Resource Conservation: Identifying Relationship and Remedies, Cornell University, May 2 – 3, Ithaca, New York.

Hobbs, P.R., Sayre, K., Gupta, R., 2007. The role of conservation agriculture in sustainable agriculture. *Phil. Trans. R. Soc.* B 363, () : 543 – 555.

Hobbs, P.R., 2007. Conservation Agriculture: What is it and why is it important for future sustainable food production. *Agricultural Science*, 145(2): 127-137.

Kassam, A. H, Friedrich, T., Shaxson, F., Pretty, J., 2009. The spread of Conservation agriculture: justification, sustainability and uptake, *International Journal of Agricultural Sustainability*, 7 (): 292 – 320.

Kassam, A. H., 2009. Adoption of Conservation Agriculture Technologies: Constraints and Opportunities. Invited paper, IV World Congress on Conservation Agriculture, 4 – 7 February, New Delhi, India.

Kaumbutho, P., Kienzle, J., 2007. Conservation Agriculture as practiced in Kenya: Two case Studies, Nairobi African Conservation Tillage Network, Centre de Cooperation Internationale de Recherché Agronomique pour le development, Food and Agriculture Organization of the United Nations, Brussels.

Kaumbutho, P., Mwenya, E., 1999. Preserving the environment through conservation tillage with animal traction. In: Kaumbutho, P. G., Simalenga, T. A., (Eds). Proceedings of the Workshop of Animal Traction Network for Eastern and Southern Africa ATNESA, 20 – 24 September, Mpumalanga, South Africa.

Kirkegard, J., Conyers, M., Hunt, J., Kirkby, C., Watt, M., Rebetzke, G., 2011.Sense and nonsense in conservation agriculture: principles, pragmatism and productivity in Australian mixed farming systems, (*unpublished manuscript*).

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

Long, N., Van der Ploeg, J., 1989. Demythologizing planned intervention: An actor perspective. *Sociologia Ruralis*, 29(3/4): 226–249.

Love, D., Jonker, L., Rockstrom, J., Van der Zaag, P., Twomlow, S., 2007.The challenge of integrated water resource management for improved rural livelihoods in Limpopo basin – an introduction to Water-Net's first network research programme', Fifth Water-Net-WARFSA Symposium, Windhoek, Namibia.

Love, D., Twomlow, S., Mupangwa, W., Van der Zaag, P., Gumbo, B., 2007.Implementing the millennium development food security goals – Challenges of the Southern African context, *Physics and Chemistry of the Earth*, 31(): 731-737.

Mango, N., 2002.Husbanding the Land. Agricultural Development and Socio-technical Change in Luoland, Kenya.(Published PhD Thesis, Wageningen University.

Mazvimavi, K., Twomlow, S., 2009. Socioeconomic and institutional factors influencing adoption of conservation agriculture by vulnerable households in Zimbabwe. *Agricultural Systems*, 101(1-2): 20-29.

Mupangwa, W., Love, D., Twomlow, S., 2005.Soil-water conservation and other rainwater harvesting strategies in the semi-arid Mzingwane Catchments, Limpopo basin, Zimbabwe. Sixth Water Net - WAR-FSA-GWP Symposium, November 2005, Mbabane, Swaziland.

Nkala, P., Mango, N., Corbeels, M., Veldwisch, G., Huising, J., 2011b. The Conundrum of Conservation Agriculture and Livelihoods in Southern Africa, African Journal of Agricultural Research, 6(24): 5750 – 5770.

Nkala, P., Mango, N., Zikhali, P., 2011a. Conservation Agriculture and Livelihoods in Central Mozambique, *Journal of Sustainable Agriculture*, 35 (7):757 – 779.

Nyagumbo, I., 2004. A Review of Experiences and Developments towards Conservation Agriculture and Related Systems in Zimbabwe. Department of Soil Science & Agricultural Engineering, University of Zimbabwe, Harare.

Parayil, G., Development Studies, a progressive research tradition, Science studies, perspective. *Sociologia Ruralis*, 29(3/4): 226–249.

Sall, S., Norman, D., Featherstone, A.M., 2000. Quantitative assessment of improved rice variety adoption: the farmers' perspective. *Agricultural Systems*, 66(2): 129 – 144.

Schafer, N., 2008. Reasons for adoption and spread of conservation agriculture among small-scale farmers. Unpublished, Master's Thesis, University of Bern, Bern.

Shetto, R., Owenya, M., 2007. Conservation agriculture as practiced in Tanzania: three case studies. Nairobi. African Conservation Tillage Network, Centre de Cooperation Internacionale de Recherche Agronomique pour le Developpement, Food and Agricultural Organization of the United Nations, Brussels.

Twomlow, S., Bruneau, P., 2000.The influence of tillage on semi-arid soil water regimes in Zimbabwe, Georderma, 95: 33 – 55.

Van der Ploeg, J. D., 1994. Styles of farming: An introductory note on concepts and methodology. In J.D. van der Ploeg & A. Long. (eds) Born from within: Practice and perspectives of endogenous rural development. Assen: van Gorcum: 7-30.

Van der Ploeg, J. D., 1990. Labour, markets and agricultural production. Westview Special Studies in Agriculture, Science and Policy, Westview Press, Boulder/San Francisco/Oxford (1990) xi 313 pp.(herdrukt in 1992 by Westview Press; studenteneditie uitgegeven in 1995 door vakgroep RS, Wageningen University.

Energy and labor efficiency in smallholder conservation agriculture and conventional farming in central Mozambique

P. Nkala, G. Moitzi and N. Mango

Renewable Agriculture and Food Systems
(submitted on 25 March 2012)

Abstract

This case study analyses labor and energy efficiency in smallholder conservation agriculture and conventional farming systems in Ruaca community in central Mozambique. The paper uses data collected during the 2010/2011 agricultural season through observations and personal interviews with a farmer on two plots measuring 72 m x 30 m or 2160 m^2. Indirect energy input data on seed, human labor, draft power; manure and synthetic fertilizers and total calorific energy value of maize yield are analyzed. Total energy values have been calculated from energy equivalents estimates of various inputs and output derived from various sources. Results indicate an inverse relationship depicted by high energy inputs and low energy output in conventional farming compared to lower energy inputs against higher energy outputs in conservation agriculture. We conclude that adapting conservation agriculture to local conditions and practices of smallholder farmers in central Mozambique could result in better livelihood outcomes and options of channeling energy saved to other productive activities.

Key Words: Energy analysis, labor analysis, conservation agriculture, conventional farming, Mozambique.

1. Introduction

Agriculture is both a producer and consumer of energy (Singh et al., 2002, Canacki et al., 2005) and the main source of livelihoods for more than 80% of the 22 million people in Mozambique, 70% of whom live in rural areas (World Bank, 2006). Although such a high percentage of the population is engaged in agriculture, the sector contributes a meager 20% to gross domestic product {Nkala et al., 2011a}. The increase in population from 16 million in 1997 to 22 million in 2011 (INE, 2010) and the low productivity nature of smallholder agriculture precipitates an increase in food and agricultural energy inputs demand in land preparation, planting, weeding, harvesting, transport and storage. Low input and low productivity is characteristic of smallholder agriculture in Mozambique due to lack of access to inputs, higher input costs, rudimentary tools and equipment, lack of skills and knowledge and excessive post-harvest losses {Nkala et al., 2011b}. The extensive nature of slash and burn agriculture as productivity enhancing strategy is rendered obsolete in situations of simmering land scarcity and *de jure* population increases (Pimentel et al., 1998a). Agricultural extensification rather than intensification[20] is still common practice in Ruaca where farmers basically have two fields; a smaller one close to the homestead and a larger one in *Madingwindi*about 5–10 km from the homestead. Long distances, lack of equipment, transport challenges and the desire to farm large areas renders smallholder agriculture in Ruaca labor intensive and strenuous for most farmers. Long distances to secondary fields forces many farmers to construct makeshift camps to avoid daily commuting between the fields.

1.1. Conservation agriculture (CA) and conventional farming (CF)

Energy efficient cropping systems and technologies like conservation agriculture (CA) help mitigate food security and vulnerability problems caused by low agricultural productivity in developing countries like Mozambique. Food security means the availability and access to adequate nutritional value of food and many authors argue that the low-input-high-yield characteristics qualifies CA as a panacea to food insecurity and poverty in developing countries (FAO, 2001, 2004, 2007, Fowler and Rockstrom, 2001, Derpsch, 2005, Hobbs, 2007, Hobbs et al., 2007, Mazvimavi and Twomlow, 2009, Friedrich et al., 2009).Other schools of thought argue that the high labor and resource input requirements in the early years renders questionable the feasibility and suitability of CA in developing countries (Giller et al., 2009, {Nkala et al., 2011b}).The concept of CA as defined in the literature is discussed in the following paragraph.

In this paper, CA refers to a system of sustainable agriculture based on principles of *permanent soil cover, minimum soil disturbance and crop rotation* adopted at the First CA World Congress in 2001 in Madrid (Kassam et al., 2009). CA requires at least 30% of crop residues in the field during planting and minimum tillage is permitted only where seeding takes place (Khaledian, 2010). Grass leaves or cover crops are sometimes introduced as mulch to supplement insufficient crop residues. The principle of crop rotation entails alternating growing cereals and legumes on different plots in different seasons as a soil fertility enhancement strategy.

Conservation agriculture was introduced to smallholder farmers in 13 districts in Ruaca central Mozambique during the 2007/2008 agricultural season by the International Center for Tropical Agriculture (CIAT) in collaboration with the International Center for Maize and Wheat Improvement (CIMMYT) and the Ministry of Agriculture’s (MINAG) department of

[20] Agricultural intensification is producing more food from the same area while ensuring minimal negative environmental impacts and is part of sustainable agricultural practices as opposed to extensification which seeks to produce more food via increased cropping areas without due regard to environmental protection (Godfray et al., 2010).

research and extension (DNER). Vulnerability characteristics like low rainfall, poor soil fertility, high poverty levels and low crop productivity qualified the 13 districts for inclusion in the CIAT/CIMMYT projects. In sum, the existing unfavorable climatic and socio-economic conditions of the farmers and a high willingness to adopt and adapt CA to their local conditions and practices catalyzed the selection of project sentinel sites. The interventions sought to mitigate food security and poverty alleviation challenges facing smallholder farmers.

Although farmers uses different approaches in their practice of CA, this paper discusses the basin system which according to Friedrich et al. (2009) and Mazvimavi and Twomlow (2009) is a modification of the pit system once dominant in Southern Africa and a variation of the *Zai* system of West Africa {Nkala et al., 2011a}. The *"Zai"* is the basin which works by combination of water harvesting in wide shallow pits and precise and economic application of inputs directly in most optimal and economic combinations possible (Mazvimavi and Twomlow, 2009). Basins strategically accommodate scarce inputs of seed, fertilizers, manure or compost and rain-fed water and are most suitable for poorly resourced smallholder farmers. In short, basins allow implementation of precision conservation agriculture which is a series of technologies facilitating direct application of water, nutrients, and pesticides to places and at times most critical for crop growth (Godfray, et al., 2010).

Conventional farming (CF) in this paper refers to a system of agriculture that does not restrict farmers to three principles of conservation agriculture. In conventional farming, farmers prepare clean seed-beds by ploughing and turning over all the soil. Manure is also applied evenly throughout the field and not directly into basins as under precisions conservation agriculture. Crop rotation may be practiced optionally for purposes of soil fertility enhancement rather than a matter of principle. In sum CF in this case refers to all farmers' practices before and after the introduction of CA in 2007/2008 agricultural season in Ruaca. Remarkably, most farmers resolutely and cautiously stick to established alongside the newly introduced technology resulting in the coexistence of CA and CF in our research community.

1.2. Benefits of conservation agriculture

One of the reasons farmers adopt or adapt CA to their activities is the principle of energy efficiency associated with conservation agriculture. Soil conservation and ecology improvement, and reduced evaporation and run off and sustained agricultural production are some of the benefits of CA (Pieri, 1989; Khaledian, 2010). Timely land preparation, planting, weeding and harvesting under CA results in yield increases tenfold from 0.3 - 3 tons per hectare (Twomlow and Mazvimavi, 2009) and temporary immobilization of CO_2 sequestration (Follet, 2001, Khaledian, 2010). Direct seeding in CA moderates energy consumption from high levels of 55-65% given that tillage is the greatest energy consumer in agriculture (Pimentel and Pimentel, 1996, Khaledian, et al., 2010). Reduced tillage also leads to savings in fuel consumption by 50% and non-tillage by 89% in mechanized agricultural systems (Moitzi, 2006). The energy and soil saving practices of conservation agriculture and reduced tillage as discussed by Sims et al. (1983) and Fluck and Baird (1980) all in Stout (1990) are shown in Table 1 below.

Table 6: Energy and soil saving practices of conservation agriculture and reduced tillage

Practice	Explanation	Advantages
Direct Drilling	The planting of seeds and placement of fertilizer into uncultivated or fallow ground where the existing cover has been eliminated by chemicals	Fewer and Less energy intensive field operations Less time and less labor
Over drilling or zero tillage	The planting of seed into uncultivated or fallow ground without use of herbicides to remove competition	Intensified land use
Reduced or Minimum tillage	Conventional cultivation practices but with fewest realistic number of tillage operations and passes to establish an acceptable seedbed	Ability to farm on less quality land

Source: Stout, B.A. 1990:180.

1.3 Energy in agricultural crop production

Farmers manipulate the ecosystem and contribute energy with their own hands, draft animals and chemical fertilizers to produce food (Pimentel et al., 2009). Increasing energy requirements coupled with higher energy prices for both direct and indirect inputs such as fuel, heating, seed, fertilizer, pesticides, insecticides and farm machinery underline trends in agricultural energy use efficiency (Moitzi et al., 2006). However, competing needs for higher productivity and food security override energy use efficiency in developing countries where traditional environmental mining practices like slash and burn agriculture are common (Pimentel, 2009). Total energy inputs comprise both direct and indirect energy consumption in land preparation, planting, weeding, harvesting, transportation and storage. Fuel or electricity contributes direct energy input while indirect energy input is from fertilizers, seed, pesticides and farm machinery (Pervanchon et al., 2002, Khaledian, 2010). Non-mechanized agriculture in developing countries like Mozambique depends on indirect energy inputs which can be as low as 1 $GJHa^{-1}$ compared to as high as 301 $GJHa^{-1}$ in mechanized systems.

This paper, motivated by the assertion of labor and energy efficiency in different agricultural systems examines and analyses energy efficiency between conservation agriculture and conventional farming systems. We assume that different agricultural systems will employ different energy inputs resulting in different outputs thereby defining the efficiency of each technology (Pimentel et al., 2009). This paper acknowledges the importance of a universal accommodation of inputs and outputs in energy analysis (Khaledian, 2010) guided system boundaries, materials and energy flows and associated energy equivalents (Jones, 1989, Khaledian, 2010). Although a number of energy efficiency analysis studies in crop production have been conducted (Moitzi, 2006, Pimentel, 2009, Khaledian, 2010) to our knowledge none have focused on developing countries hence this paper seeks to fill the gap by focusing on Mozambique. This study will improve technology selection among smallholder farmers in vulnerable production systems with positive mitigatory impacts on productivity, food insecurity, poverty and climate change.

3. Materials and Methods

In Mozambique and Southern Africa in general land preparation is done from June – November and should be completed 3 weeks before the onset of the first rains usually expected at the end of October beginning of November. Under CA, farmers dig planting basins 8 – 15 cm deep using hand-hoes in which planting will be done within 2 days following rains exceeding 25 mm intensity. For each day lost after such rains come, estimates show that losses of 2.5 x 50 kgs of grain per day are incurred (Oldrieve, 2009). During planting, full soil and seed contact is observed to improve germination while simultaneously making optimal use of mulch to ensure moisture conservation for good germination.

3.1. Research setting

The high magnitude of CA interventions and high farmers' motivation and willingness to learn through participating in CA projects influenced the choice of Ruaca as the study area. CA projects were introduced in 13 districts in central and northern regions of the country. The researcher explored and discussed the performance of CA projects with local extension officers and staff from a non-governmental organization involved with CA projects in Ruaca. Two plots belonging to one farmer who practiced both CA & CF were selected for the study. Both plots were closer to each other and the homestead which made observations and study very manageable. The plots measured 2160 m^2 each (70 m x 30 m) and employed almost similar direct and indirect inputs. The study focused on maize as a staple crop in Mozambique. Direct observations and interviews were employed in data collection on the quantity of seed, fertilizer, manure and amounts of human and animal labor expended on each activity and quantities of output. Table 2 gives a summary of the major characteristics of the two experimental plots on which the research focused.

Table 7: Characteristics of experimental plots in Ruaca, Mozambique

Characteristic	Plot 1	Plot 2
Cropping System	Conservation agriculture using the hand hoe and basins	Conventional farming using cattle for draft power
Plot size	2160m^2	2160m^2
Crop planted	Maize (early and late maturing varieties, *Matuba*)	Maize (early and late maturing variety, *Matuba*)
Soil type	Sandy loam	Sandy loam
Water source	Rain-fed	Rain-fed
Soil fertility	Cattle manure & inorganic fertilizers	Cattle manure and inorganic fertilizers

Although most of the observations relate to the 2009/2010 agricultural season, output data for 2006, 2007, and 2008 was collected from the farmer's records. According to the farmer similar amounts of inputs are used each year thereby discounting the need to repeat quantification of the same inputs every year. From 2007 onwards farmers were taught about the importance of keeping records on all activities including inputs and outputs in order to determine sustainability of agricultural activities.

3.2. Schematic view of CA and CF plots

The sketch in Figure 1 shows how CA and CF are implemented by farmers on each of the different plots. This section describes farming activities according to the farmers and the researchers' observations during fieldwork.

Both plots were 2160 m^2 in area and for CA the farmer used a hand hoe to prepare planting basins 15 cm wide and 15 cm deep. There were about 119 basins that were 60 cm apart along each row totaling 4760 for the whole plot. Three seeds were planted in each basin and in situations where all three sprouted, one was removed to avoid overcrowding and stiff completion for sunlight living a total of 9520 maize seedlings in the CA plot.

The basins were 60 cm apart while rows running parallel to the 72 m long field were 75 cm apart. There were about 40 rows with 119 basins each. A rope with pre-calibrations every 60 cm was used to measure the distance between the basins. The hand hoe used for digging basins was used to measure the 15cm width and depth of the basins. The basins were preferred because they helped reduce run-off by 94% as have been said by agricultural extension workers.

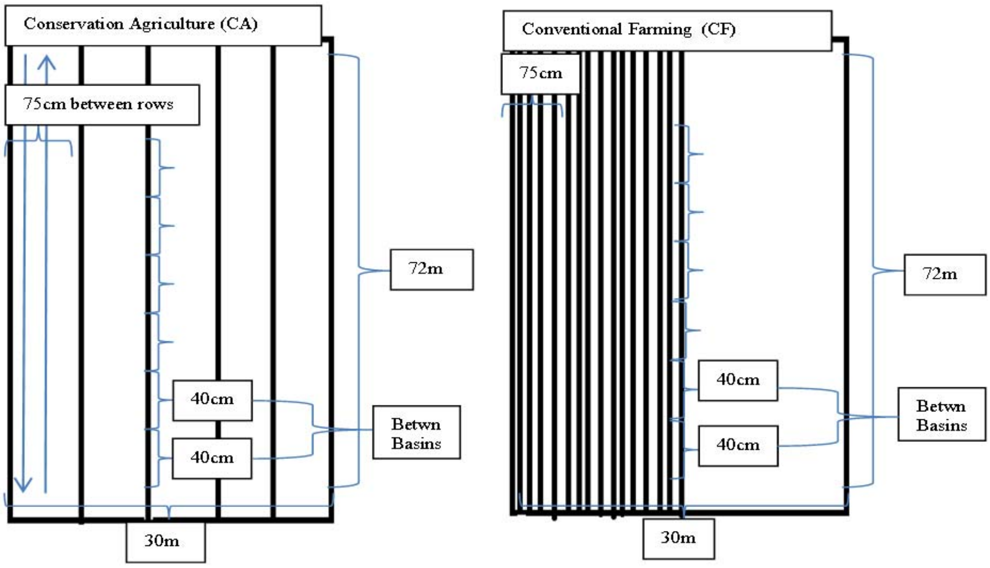

Figure 6 : Schematic representation of the CA and CF plots. Source: Authors' illustration

3.3. Mulching

The farmer used grass, leaves and crop residues for mulching[21] which they understood as important for saving soil moisture content, reducing soil erosion, preventing termites from destroying crops and suppressing weed growth. Borrowing from Oldrieve (1990) terminology, the farmer referred to mulch as "God's blanket" and crop residues as the "gold" of the field emphasizing its importance in providing permanent soil cover and improving soil fertility. Pumpkins and cowpeas were also planted as cover-crops.

The use of mechanical methods like the plough on this plot was argued to disturb soil micro-organisms understood by the farmer to be important in improving soil fertility thus hand hoes of "diggers" were used to prepare planting basins. Cattle were prevented from grazing on this particular plot in winter to ensure preservation of crop residues. Crop rotation was not observed as advised under proper implementation of CA. The farmer argued that they could not afford to gamble with planting other crops other than maize, the staple crop, on these fertile and well prepared plots. This explains the weight farmers place on maize compared to other crops like cassava, pumpkins, beans, and sorghum also grown in other parts of the fields.

[21] Mulch was said to be God's blanket while the crop residues were said to be the gold of the field because of their contribution to soil fertility as discussed in Oldrieve (2009).

3.4. Absolute quantities of inputs and associated total energy equivalents

3.4.1. Quantities of inputs utilized

The inputs included 10 kg of hybrid maize seed varieties PhB2859W (early maturing) and PhB3253 (late maturing), 78 x 50 kg bags of kraal manure[22] 1 x 50 kg phosphate fertilizer and 1 x 25 kg nitrate fertilizer all for the 2160 m^2 plot. Mixtures of top soil and liquid kraal manure were applied to improve soil fertility. During planting, a mixture of 2 x 500 g of liquid manure and 2 x 500 g of top soil was applied to each basin including two teaspoons of phosphate fertilizer, basin one week after germination. These inputs were followed up 4 weeks later by a teaspoon of ammonium nitrate per basin. Care was taken to do this following wet spell to avoid burning the crop if applied when the weather was dry. Although a 500 g tin of manure was recommended per basin, the farmer doubled this amount as he believed that 500 g was not enough to give him the desired results, further explaining how farmers redesign technologies according to their understanding and perceptions. Rainfall intensity of 25 mm was a good indicator that farmers could plant without risking poor crop germination[23]. Three (thinned out to 2 after germination) maize seeds were placed between the lower and upper layer mixtures of soil and manure; the upper layer helped cover seeds for better germination. The middle or thinnest of the three seedlings was removed to avoid overcrowding. The farmer usually works alone on the CA field but is assisted by wife or son when using cattle on the conventional farming plot and other parts of the main fields.

3.4.2. Energy Equivalents applied in the calculations

In order to determine the total energy input from the above quantities and for the resultant maize yields, this paper uses energy equivalents mainly from the *Handbook of energy for world agriculture* by Stout (1990) and other sources like, Yaldiz (1993), Singh (1997), Shrestha (2002), Ozkan (2004) and Pimentel (2009). These researchers have conducted studies assessing energy inputs in food crop production for a number of crops including corn, wheat, rice, soya beans, potatoes, cassava, tomatoes, citrus and apples in developing and developed countries using various energy equivalents. The energy equivalents shown in Figure 2 below are based on Stout (1990) which was calculated using Pimentel and Pimentel (1979) data.

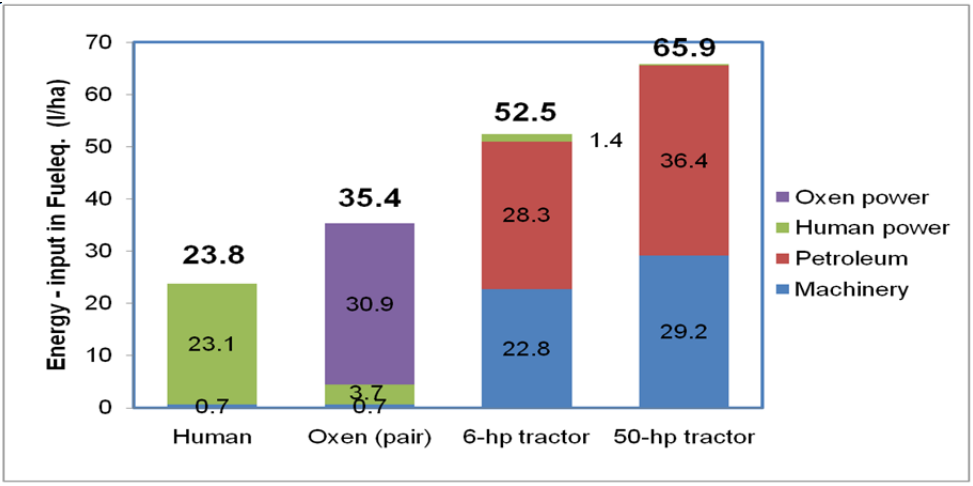

Figure 7: Energy equivalents used to calculate total energy input and energy output. Source: Stout, B. A. 1990: pp178 using data from Pimentel and Pimentel, 1979.

---

[22] The kraal manure was mixed with water and left for two weeks in a special concrete tank before being removal and application in the field.

[23]The farmers actually measure the amount of precipitation on a daily basis and keep records as part of their training within the CA project.

According to Stout (1990) each oxen is assumed to consume 20 000 kcal of feed per day and works for 5 hours in the field pulling the plough. Basic information on energy inputs and crop yields based on dry mass kilogram of maize were used to calculate the metabolizable energy converted to MJ Kg^{-1}(Ozkan, 2004). The energy ratios were found by dividing the total energy equivalent of the inputs into the total energy equivalent of the yield for the maize crop.

Table 8: Energy equivalents of inputs and outputs in agricultural production

Input (Unit)	**Unit**	**Energy equivalent (MJ $unit^{-1}$)**	**Reference/Source**	
			Author	**Year**
Oxen	Hour	5.0	Stout/Pimentel	1990 /1979
Human power	Hour	2.3	Yaldiz/Stout	1993/1990
Nitrogen fertilizer	Kilogram	66.1	Shrestha/Ozkan	1998/2004
Phosphorous fertilizer	Kilogram	12.4	Shrestha/Ozkan	1998/2004
Manure	Kilogram	0.3	Yaldiz/Ozkan	1993/2004
Seeds	Kilogram	1.0	Singh/Ozkan	2002/2004
Maize	Kilogram	19.1	Panzeri et al.	2011

4. Results and Discussion

4.1. Labor input analysis

The total labor input is the product of the number of hours worked and the energy contribution in mega joules per hour. According to Stout (1990), the energy contribution of labor is 2.3 MJ/hour as shown in figure 2. The different energy input equivalent estimates for the various inputs as shown in figure 2 and Table 3 have been used to determine the total energy input contribution per input and the total energy value is the product of that estimate and the total quantity of input employed. The energy inputs equivalents for the hoe and plough have been assumed to be negligible because of their low and equal values for both CA & CF and we make a strong assumption that this does not affect the final input energy contribution.

On the CA plot the labor input is the total number of hours the farmer employed in land preparation, planting weeding and harvesting. The farmer is assumed to work for 8 hours a day and on the 2160 m^2 the farmer spent 15 x 8 = 120, 1 x 8 = 8, 1 x 8 = 8, 5 x 8 = 40, 10 x 8 = 80, 1x 8 = 8 and 5 x 8 = 40 hours in land preparation, planting, fertilizer application, weeding, harvesting, transporting and shelling, respectively giving a total of 304 hours.

Table 3: Labor distribution by activity per area in Hours

Activity	**Time taken (Hours)**			
	Conservation agriculture		**Conventional farming**	
	Plot 2160m^2	**Hectare** 10000m^2	**Plot** 2160m^2	**Hectare** 10000m^2
Land Preparation	120	556	250	1157
Planting	8	37	14	64
Fertilizer Application	8	37	24	111
Weeding	40	185	180	833
Harvesting	80	370	48	222
Transport	8	37	9	42
Shelling	40	185	27	125
Total (Hours)	**304**	**1407**	**552**	**2556**

The labor on the CF plot comprises total number of hours including guiding the cattle in land preparation (250), planting (14), and fertilizers application (24), weeding (180), harvesting (48), transporting (9) and shelling (27) giving us a total of 552. Land preparation, planting, weeding and harvesting involved the farmer, his wife and their son; albeit working for shorter hours than when farmer is working alone on the CA plot. The span of oxen spent 12 hours each during land preparation and 5 hours during planting giving a total of 34 hours for the 2160 m^2. The energy equivalent for the oxen as stated in Stout (1990) is 5 $MJHa^{-1}$

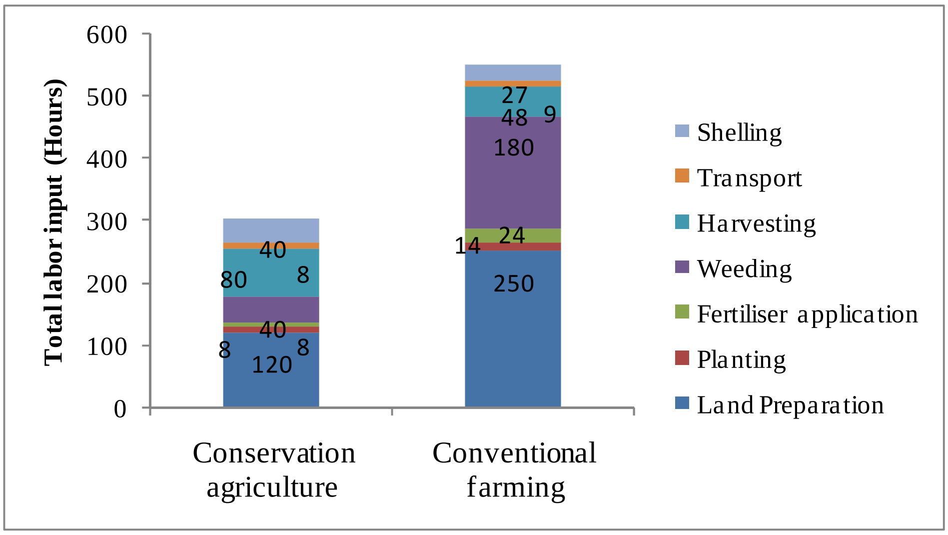

Figure 8: Labor input by activity (Hours)

4.2 Energy input Analysis

First we note that conventional farming (CF) expends more energy in land preparation through the use of more inputs than in CA as Stout (1990:179) states that "*tilling the soil requires a considerable amount of energy whether accomplished by human, animal or tractor power*". In conventional farming this includes oxen ploughing almost every part of the field being guided by at least two people who in turn expend some energy in doing so. Use of hand hoes in CA is not as demanding and one person can work alone in virtually all activities of land preparation, planting, weeding, harvesting, transportation and storage. Since planting under CF is done after every third row it would imply that conventional agriculture already uses three-times more energy as conservation farming. According to the farmer despite, more inputs of human labor and oxen required in conventional farming his yields have always been lower on the CF plot as shown in Table 3. This implies more productivity and less energy per unit of output in conservation agriculture in comparison with conventional farming. Table 2 and 4 summarize various energy inputs and outputs respectively, for each of the agricultural technologies on each of the 2160 m^2 plots used in this investigation.

Table 9: The Quantity of inputs and associated energies per hectare

Name of Input	Total Quantity used	Units	Energy equivalent per unit (kg, hour)	Total Energy Input	Total Energy Input MJHa^{-1}
Seed	10	kg	1.0	10	46
Manure	3900	kg	0.3	1170	1171
Human Labor	304	hours	2.3	699	3237
Fertilizer (Phosphate)	50	kg	12.4	620	2870
Fertilizer (Ammonium)	25	kg	66.1	1652	7650
Total				**4152**	**14974**
Name of Input	**Total Quantity used**	**Units**	**Energy equivalent per unit MJ/(kg, hour)**	**Total Energy Input**	**Total Energy Input Ha^{-1} (MJ)**
Oxen	68	hours	5.0	340	157
Seed	10	kg	1.0	10	46
Manure	3900	kg	0.3	1171	1171
Human Labour	400	hours	2.3	920	4259
Fertilizer (Phosphate)	50	kg	12.4	620	2870
Fertilizer (Ammonium)	25	kg	66.1	1652	7650
Total				**4713**	**16153**

The energy input per hectare has been determined by finding the equivalent from energy input per plot and multiplying value per plot by 10000 and dividing by plot area.

However this would seem to be the trend even if basins were not used due to more soil disturbance and weed problem in general

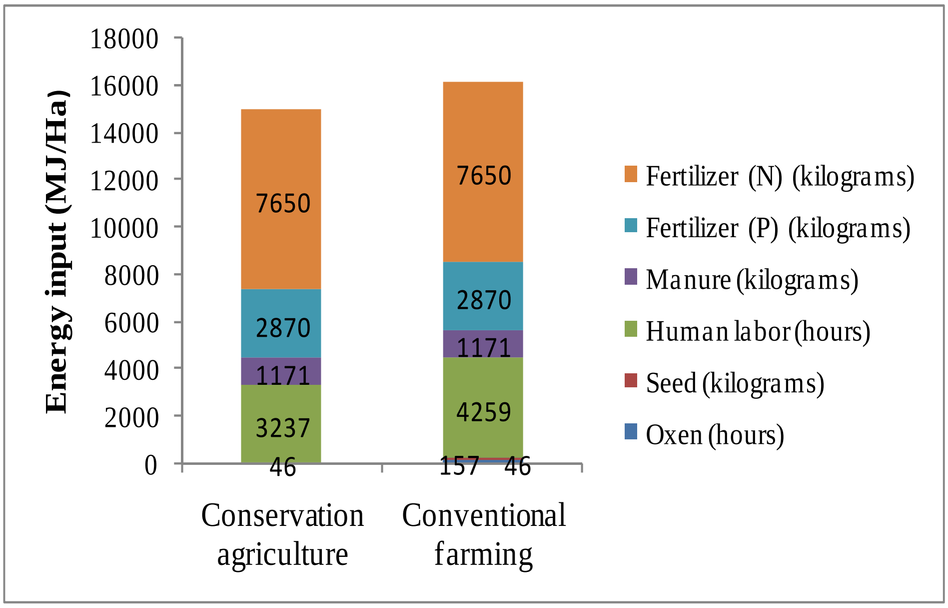

Figure 9: A labor energy inputs for various activities between CA and CF

The reduced inputs are also due to low crop residues in Mozambique as most farmers face challenges in obtaining grass, leaves and other materials for mulching.

4.3. Maize Yields

Maize yields on the experimental plots from 2006 – 2010 is shown in the Table 3. After shelling grain is packaged in 20 kg buckets or 50 kg bags hence the farmer's continuous reference to these measures rather than kilograms or tons. For purposes of standardization and necessity of making easier comparisons we have made conversions from yields per plot to yields per hectare after making strong *ceteris paribus* assumptions that per unit inputs and outputs do not change as the area planted increases.

Table 10: Output from conservation agriculture on the 2160 m^2 plot 2006 - 2010 (Kilograms)

Agricultural Season/Year	**Quantity of Output**		**Unit (20kg buckets and 50kg bags)**	**Total output (Kgs)**		**Comment**
	CA	**CF**		**CA**	**CF**	
2006	6	6	Buckets 20kgs	120	120	No CA Yet
2007	10	6	Bags	500	300	Year started
2008	20	8	Bags	1000	400	2nd year
2009*	14	5	Bags	700	250	3rd year
2010*	9	4	Bags	450	200	4th year

Source: Primary Data. *The farmer said in 2006 he was still practicing slash and burn agriculture rather than CA while reduced yields in 2009 and 2010 were due to less rainfall experienced despite having done all that was necessary in the fields.

4.4: Energy Output Analysis

Figure 4 gives a clear comparison of outputs between conservation agriculture and conventional farming from 2006 – 2010. Throughout this period the maize yield per hectare were higher for CA than for conventional farming although the two systems exhibited similar trends in either general increases or decreases in output associated with that particular season.

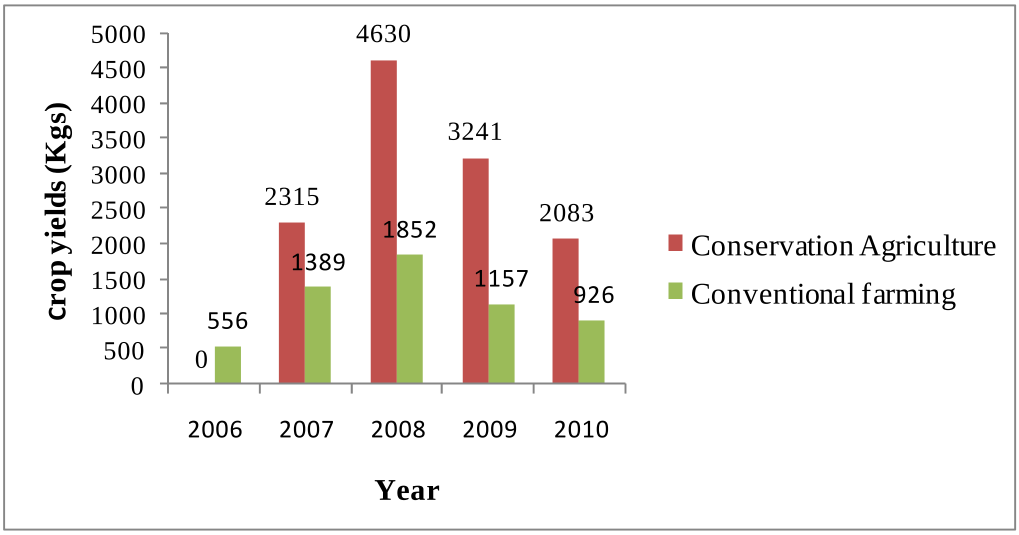

Figure 10 : Crop yields from 2006 - 2010 (Kilograms per Hectare)

Table 11: A comparison of total energy output between CA and CF

CONSERVATION AGRICULTURE					
Year	**Output ($Kg\ Ha^{-1}$)**	**Output (Kgm^{-2})**	**Output ($KgHa^{-1}$)**	**Energy Equivalent ($MJKg^{-1}$)**	**Total Energy Output Mega Joules**
2006	-	N/A	N/A	19.1	**N/A**
2007	2315	0.23	0.023	19.1	**44217**
2008	4630	0.46	0.046	19.1	**88433**
2009	3241	0.32	0.032	19.1	**61903**
2010	2083	0.21	0.021	19.1	**39785**
CONVENTIONAL FARMING					
Year	**Output ($HgHa^{-1}$)**	**Output (Kgm^{-2})**	**Output ($KgHa^{-1}$)**	**Energy Equivalent ($MJKg^{-1}$)**	**Total Energy Output (Mega Joules)**
2006	556	0.06	0.006	19.1	**10620**
2007	1389	0.14	0.014	19.1	**26530**
2008	1852	0.19	0.019	19.1	**35373**
2009	1157	0.12	0.012	19.1	**22099**
2010	926	0.09	0.009	19.1	**17687**

Figure 3 shows the energy output comparisons between conservation agriculture and conventional farming. The energy calorie energy equivalent for maize has been derived from the nutritional calorie value of maize as stated in nutritional guides. The figure shows insignificantly minor differences in energy output between the two systems given the quantity of maize produced. In 2008 the agricultural season was comparatively better with just adequate rainfall rather than the droughts and floods that have gained notoriety in Mozambique in the last 10 years. In addition 2008 farmers were going into the second cycle of CA so farmers could have mastered a few techniques regarding the principles of CA although other factors leading to conventional agriculture performing once again better than CA come into play in 2009 and 2010. This further shows that conservation agriculture is a skills and knowledge intensive technology whose adoption and adaptation can be done successfully by some and not all farmers. However these yields remain rather low implying that up-scaling through full adoption or adaption of CA is necessary for realization of optimal benefits of this technology.

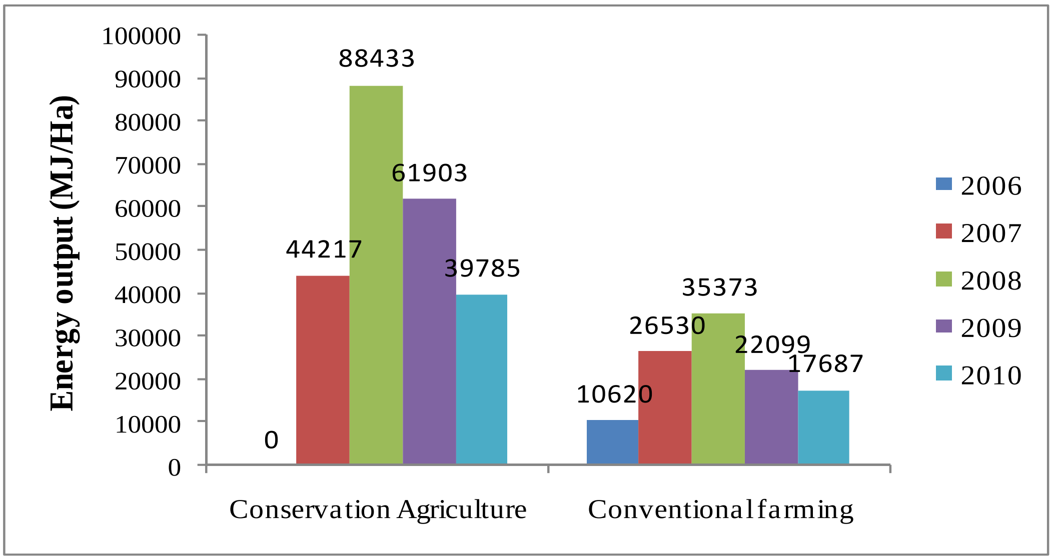

Figure 11: Energy output comparisons between CA and CF ($MJHa^{-1}$)

4.5. Energy output (EO)-energy input (EI) ratio analysis

In this section we discuss the energy ratio analysis in order to determine energy efficiency between the two agricultural systems. As shown in Table 4, assuming the farmer maintains the same level of inputs in all the years, conservation farming seems to be more energy efficient compared to conventional tillage. This can be attributed to the labor intensive nature of low agricultural productivity systems in Mozambique. The introduction of conservation agriculture reduced labor input in land preparation, planting and weeding especially in later years.

Table 12: Energy output to energy input ratio analysis

Conservation Agriculture				**Conventional Farming**			
Year	**Energy Input (EI)**	**Energy output (EO)**	**EO/EI**	**Year**	**Energy Input (EI)**	**Energy output (EO)**	**EO/EI**
2006	-	N/A	-	2006	16153	10620	**0.7**
2007	14974	44217	**3.0**	2007	16153	26530	**1.6**
2008	14974	88433	**5.9**	2008	16153	35373	**2.2**
2009	14974	61903	**4.1**	2009	16153	22099	**1.4**
2010	14974	39785	**2.7**	2010	16153	17687	**1.1**

During all the years' energy efficiency in conventional farming is below one meaning that the farmer is using more energy than he is actually realizing from the output which further explains the lack of sustainability of this system compared to conservation agriculture. The farmer despite using cattle for draught power experiences losses mainly as a result of low output.

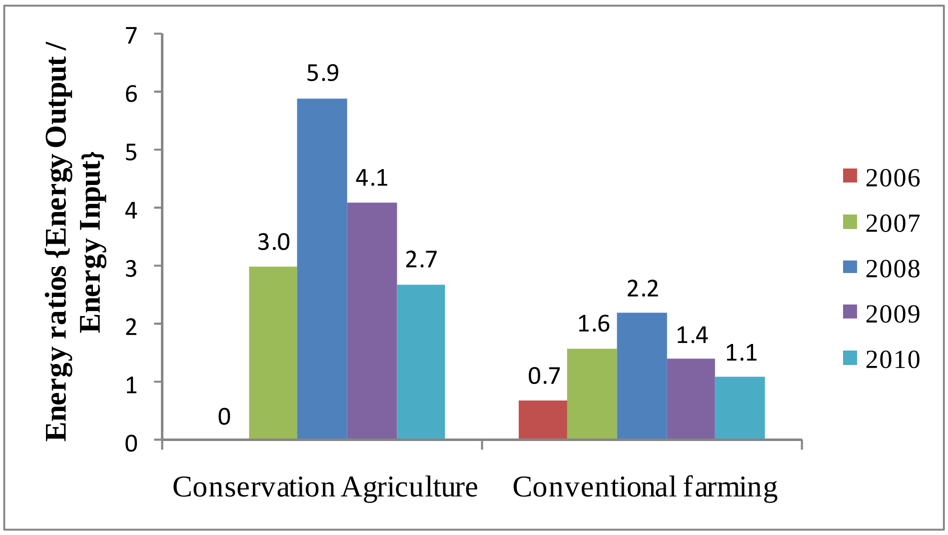

Figure 12: Energy output (EO): energy Input (EI) ratios for CA and CF - 2006 - 2010

4.6. Implications on Livelihoods

The results indicate apparent energy savings in conservation agriculture which could be exploited for the benefit of livelihoods by channeling some energy into other equally important activities. Smallholder farmers do work very hard expending so much energy sometimes that does not justify the amount of output to be realized at the end. This paper therefore provides evidence in support of CA as a technology that allows the farmer to go that extra mile without having to employ additional resources which in real terms implies should translate to better livelihoods for the farmers and their families.

5. Conclusion

Conservation agriculture results in less energy input compared to conventional tillage due to a number of energy saving activities especially in land preparation, ploughing and planting. Our results compare very well in terms of energy efficiency of sustainable agricultural systems as those of Dalgaard et al. (2000) where organic agriculture proved to be energy efficient than conventional tillage although the later showed higher energy output. The answer to our contrary findings could lie in soils that have been over degraded and rendered unsuitable for farming even with use of soil fertility enhancing inputs like manure and fertilizers. This however does not completely dismiss the idea that the proper implementation of CA requires more inputs in the first 3-5 years but given the existing scenarios and conditions of farmers this is not the case. If farmers are allowed to continue operating within their given domains, the technology could result in instant energy input saving although the full potential benefits of the technology may take longer to realize.

Acknowledgements. The reviewers of various drafts of this article and financial support from the University of Natural Resources and Applied Life Sciences (BOKU) in Vienna, Austria, through the Center for Development Research (CDR) and the International Centre for Tropical Agriculture (CIAT) in Harare, Zimbabwe, are gratefully acknowledged. Other support from the CIMMYT and the Institute of Development Studies at the National University of Science and Technology (NUST) in Bulawayo, Zimbabwe are greatly appreciated.

References

Canacki, M., M. Topacki, I. Akinci and A. Ozmerzi. 2005. Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. *Energy, Conversion and Management* 46(2005): 655-666.

Dalgaard, T., N. Halberg and J. R. Porter. 2000. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. *Agriculture, Ecosystems and the Environment* 87(1): 51-65.

Derpsch, R. 2005. *The extent of Conservation agriculture adoption worldwide – Implications and impacts*, in: *Third World Congress on Conservation Agriculture: Linking livelihoods and Conservation"*. Nairobi. October 3-7, 2005.

Fluck, R. C. (Ed). 1992. *Energy in World Agriculture: Energy in Farm Production*, Elsevier Science Publishers, Essex, England.

Fluck, R. C. and Baird, C. D. 1980. *Agricultural Energetics*. AVI Publishing Company. Westport, Connecticut, USA.

Food and Agriculture Organization (FAO). 2001. *The economics of soil productivity in Africa*. Soils Bulletin. Rome. Italy.

Food and Agriculture Organization (FAO). 2004. Conservation of natural resources for sustainable agriculture: training modules. FAO land and water Digital Media Series CD-RM 27. http://www.fao.org/ag/ca/.

Food and Agriculture Organization (FAO). 2007. *Workshop on Conservation Agriculture in Southern Africa*. Harrison's Conference Centre, Johannesburg. South Africa.

Fowler, R. and J. Rockstrom. 2001. Conservation Tillage for Sustainable Agriculture, An agrarian revolution gathers momentum in Africa. *Soil and Tillage Research* 61:93 – 107.

Friedrich, T. and A. H. Kassam. 2009. *Adoption of Conservation Agriculture Technologies: Constraints and Opportunities.* Invited paper, IV World Congress on Conservation Agriculture, 4 – 7 February 2009, New Delhi, India.

Friedrich, T., A. H. Kassam, and F. Shaxson.2009.*Conservation Agriculture. In: Agriculture for Developing Countries. Science and Technology Options Assessment (STOA) Project*. European Technology Assessment Group. Karlsruhe, Germany.

Friedrich, T., A. Kassam and F. Taher. 2009. *Adoption of Conservation Agriculture and the Role of Policy Institutional Support.* Plant Production Division, Food and Agriculture Organization of the United Nation, Rome, Italy.

Giller, K.E.E., E. Witter., M. Corbeels and P. Tittonell. 2009. Conservation Agriculture and Smallholder Farming in Africa: The Heretics' view. *Field Crops Research* 114(2009): 23-34.

Godfray, H. C. J., J. R. Beddington, I. R. Crute, L. Haddard, D. Lawrence, J. F. Muir, J. Pretty, S. Robinson, S. R. Thomas and C. Toulmin. 2010. Food Security: The Challenge of feeding 9 Billion People. *Science* 327: 812.

Hobbs, P. R. 2007. Conservation Agriculture: What is it and why is it important for future sustainable food production. *Agricultural Science* 145: 127-137.

Hobbs, P. R., K. Sayre, K. and R. Gupta. 2007. The role of conservation agriculture in sustainable agriculture. *Phil. Trans. R. Soc. B* 363: 543 – 555.

INE (Instituto Nacional de Estastica), 2010. Anuario Estastica. Maputo, Mozambique.

Jones, M. R. 1989. Analysis of the use of energy in agriculture – approaches and problems. *Agricultural Systems* 29: 339 – 355.

Kassam, A., F. T. Friedrich. Shaxson and, J. Pretty.2009. The spread of Conservation Agriculture: justification, sustainability and uptake. *International Journal of Agricultural Sustainability* 7 (4), 292-320.

Khaledian, M. R., J. C. Maihol., P. Ruelle, I. Mubarak and S. Perret. 2010. The impacts of direct seeding into mulch on the energy balance of crop production system in the SE of France. *Soil and Tillage Research* 106(2010): 219-226.

Khaledian, M. R., P. Ruelle, J. C. Maihol, L. Delage and P. Rosique.2006b.Evaluating direct seeding on mulch at a field scale.*Opt. Mediterranean* 69:125 – 129.

Lorecowicz, E., J. Uziak and B. Huyghebaert.2009.*Farm machinery and process management in sustainable agriculture. V International Scientific Symposium Proceedings.* Department of Machinery Exploitation and Management in Agricultural Engineering, Faculty of Production Engineering, University of Life Sciences, Lublin, Poland.

Mansoor, B. L, K. P. Zahra, A. A. Mohammed and M.Nadimi.2009.*Energy Coefficient for Irrigated Wheat Production in Iran. CIGR Proceedings, Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems.* Rosario, Argentina.

Mazvimavi, K. and S. Twomlow. 2009. Socioeconomic and institutional factors influencing adoption of conservation agriculture by vulnerable households in Zimbabwe. *Agricultural Systems* 101:20-29.

Moitzi, G, Szalay, T., Schüller, M., Wagentristl, H., Refenner, K., Weingartmann, H and Liebhard, P. 2009.*Energy efficiency of wheat production in different soil tillage systems in the semi-arid region of Austria, XXXIV CIOSTA CIGR V Conference 2009.* Reggio Calabria, Italy.

Moitzi, G., D. Damm, H. Weingartmann, and J. Boxberger 2010. *Analysis of energy intensity in selected Austrian dairy farms with focus in concentrate level in feeding in: the 9th international symposium "Prospects for the 3rd millennium agriculture" University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.* Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.

Moitzi, G., K. Meier, S. Falb, J. Schrabauer, and H. Wagenstristl. 2010. Energy Efficiency in Arable Farms - a Comparative Analysis. Scientific papers series. *Management, economic engineering Agriculture and Rural development* Vol. 10 (1) 2010.

Moitzi, G., L. Lande r& H. Weingartmann. *Saving of fuel and working time in field operations through steering assistance and automatic guidance system in tractors, University of Natural Resources and Applied Life Sciences, Vienna, Department of Sustainable Agricultural Systems,* Division of Agricultural Engineering, Vienna, Austria. (*unpublished*)

Nkala P., N. Mango and P. Zikhali.2011a.Conservation Agriculture and Livelihoods in Central Mozambique. *Sustainable Agriculture,* 35 (, p757-779.

Nkala P., N. Mango, M. Corbeels, G. J. Veldwisch and J. Huising.2011b.The Conundrum of Conservation Agriculture and Livelihoods in Southern Africa. *African Journal of Agricultural Research* 6(24), p5750 – 5770.

Oldrieve, B. 2009.*Trainer's Manual. Farming in God's Way*. Harare. Zimbabwe.

Ozkan, B., A. Kurklu and H. Akcaoz. 2004. An input-output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. *Biomass and Bioenergy* 26: 89-95.

Panzeri, D., V. Cesari, I. Toschi and R. Pilu. 2011. Seed calorific value in Different Maize Genotypes, Energy Sources, Part A: Recovery, utilisation and environmental Effects, 33: 1700 – 1705.Pervanchon, F., C. Bockstaller and P. Girardin. 2002. Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. *Agricultural Systems* 72: 149 – 172.Pimentel, D. and M. Pimentel. 1979. *Food, Energy and Society*. Edward Arnold publishers. London

Pimentel, D. 1992. *Energy inputs in production agriculture*. Pages 13-29.In *R.C. Flock, ed. Energy in World Agriculture*. Amsterdam: Elsevier.

Pimentel, D. and M. Pimentel. 1996. *Food, Energy and Society*. Edward Arnold publishers. London *(Reprinted).*

Pimentel, D., X. Huang, A. Cordova, and M. Pimentel. 1998a. *Impact of a growing population on natural resources: the challenge for environmental management*. In *L. Hens and D. Devuyst, eds. Environmental Management in Practice: Analysis, Implementation, and Policy*. Brussels, Belgium.

Pimentel, D. 2009. Energy inputs in food crop production in developing and developed nations. *Energies*: 2:1-24.

Schüller1, M., G. Moitzi, H. Weingartmann, and P. Liebhard. 2011. *Fuel consumption, CO2 emissions and energy efficiency of soil tillage systems in Austria, paper presented at the Efficient and safe production processes in sustainable agriculture and forestry XXXIV CIOSTA CIGR V Conference 2011*.

Shrestha, D. S. 1998. *Energy use efficiency indicator for agriculture*. http://www.usaskca/agriculture/caedac/PDF/mcrae.

Sims, R.E.H., P. Henderson, G. A. Martin, I. G. McChesney, N. Rennie and C. J. Studman. 1983. *On-farm energy supply and conservation*. Report Number 98, New Zealand Energy Research and Development Committee, University of Auckland.

Singh, J.M. 2002.*On farm energy use pattern in different cropping systems in Haryana, India*. International Institute of Management, University of Flensburg, Germany.

Singh, H., D. Mishra and N. M. Nahar. 2002. Energy use pattern in production agriculture of a typical village in arid zone, India – part I. *Energy, Conversion and Management* 43: 2275 – 2286.

Stout, B. A. 1990. *Handbook of Energy for World Agriculture*. Elsevier Scientific Publishers limited. Essex, England.

Uri, N. D. 2000. Perceptions on the use of no-till farming in production agriculture in the United States: An analysis of survey results. *Agriculture, Ecosystems and Environment* 77(3): 263 – 266.

World Bank. 2006. *Mozambique Agricultural Development Strategy, Stimulating Smallholder Agricultural Growth.* Agriculture, Environment and Social Development Unit. Country Department 2.African Region. Report No. 32416-MZ

Yaldiz, O., H.H. Ozturk, Y. Zeren and A. Bascetincelik. 1993. *Energy use in field crops of Turkey*. International Congress of Agricultural Machinery and Energy, Kusadasi, Turkey.

Appendix I: Curriculum Vitae

Peter Nkala

Centre for Development Research (CDR)
University of Natural and Life Sciences (BOKU)
33 Gregor Mendel Strasse
1180 Vienna, Austria
peter.nkala@boku.ac.at

Institute of Development Studies (IDS)
National University of Science and Technology (NUST)
Ascot, Bulawayo, Zimbabwe
nkalap@nust.ac.zw

Tertiary Education

2008 – 2012	Doctoral Candidate, University of Natural and Life Sciences, Vienna, Austria, Tentative date for graduation, March 2012
1999 – 2001	Master of Science in Economics (MScEcon), Department of Economics, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe in collaboration with African Economic Research Consortium (AERC), Nairobi, Kenya
1996 – 1999	Bachelor of Science Honors in Economics (BSc(Hon)Econ), Department of Economics, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe

Employment history

Since August 2011	**Director**, Institute of Development Studies (IDS), National University of Science and Technology (NUST), Ascot, Bulawayo, Zimbabwe

Accomplished engagements

2006 / 2008	Coordinator/Lecturer MA & MBA Economics Programmes, Catholic University of Mozambique, Beira, activities included organizing students' registration, lectures, and supervision of dissertations working with various individual student supervisors.
2002 – 2006	Chairperson/Lecturer, Department of Banking, National University of Science and Technology(NUST) ensuring smooth running of the Department of Banking, Teaching undergraduate and postgraduate economics courses & supervising student dissertations. Programme Coordinator: Diploma in Development and Disaster Management – this diploma is offered by the center for continuing education and is coordinated by the department of banking at NUST. Academic Advisor and Counselor: Part IV Banking Students. Faculty of Commerce Representative to the Research Board
Feb – March 2005	Visiting Lecturer, Catholic University of Mozambique (UCM) Teaching and Examining Master of Science Economics and Master of Business Administration Managerial Economics and Research Methods.
March- Aug 2002	Scientific Officer, International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Matopos Research Station, Bulawayo, Zimbabwe
Sept 2001 – Feb 2002	Ethnographer/Research Assistant, Zimbabwe Community Health Intervention Research (ZICHIRE), Milton Park, Harare, (M.A.R.C.H.) project
Oct 199 – Jun 2001	Teaching/Research Assistant, Department of Economics, University Of Zimbabwe
Jan – March 1998	Research Assistant, Intermediate Technology Development Group (ITDG), Harare, Zimbabwe.

Other Responsibilities

Aug 2007 – 2008	Board Member – National Furniture industries (Pvt) Limited, Bulawayo, Zimbabwe, elected to the Board with effect from August 2007. Duties – together with other board members to provide advice to company management regarding business management and economic issues critical to

successful operation of the enterprise in a very volatile economic and business climate in Zimbabwe.

Participation in Conferences and Workshops

- Research Methods Training of Trainers Workshop – Catholic University of Mozambique Faculty of Education and Communication, *Nampula*, Mozambique, 21 -25 February 2011.
- Workshop on Teaching and Research, Catholic University of Mozambique, Faculty of Engineering, , *Chimoio*, Mozambique, 14 – 18 February 2011.
- Research Methods Workshop organized by International Federation of Catholic Universities, Catholic University of Kabgayi, Kigali, Rwanda, May 2010.
- Summer School on Organic Agriculture, organized by Mendel University, Bruno, Czech Republic, August 2008.
- Tropentag 2008 Conference – University of Hoheinham, Stuttgart, Germany, October 2008.
- UNCTAD workshop on Trade and Poverty, Dar-es-Salaam, Tanzania, 19-23 November 2007.
- UNCTAD Training Course on Key Issues on the International Economics Agenda, Second Regional Training for Africa, Cairo, Egypt, 04-22 February 2007.
- University of the Free State & NUST, Sphere Training Workshop, NUST Council Chambers, Bulawayo, Zimbabwe, 03-07 July 2006.
- UNCTAD Training Workshop on Commodities Production and Trade, Dares Salaam, Tanzania, 16-20 January 2006.
- UNDP/CPU, National Conference on the Plan of Action to Strengthen Disaster Risk Management, 25-29 July 2005, Troutbeck Inn Hotel, Inyanga, Zimbabwe.
- Southern Africa Trade Research Network, (SATRN) Researchers Workshop, Livingstone Zambia, May 2005.
- SATRN, UNCTAD, WTO Researchers Workshop, Windhoek Country Club, Windhoek, Namibia, November 2004.
- SATRN, BIDPA Researchers Workshop on Commodities Trade, University of Pretoria, South Africa, 19-23 April, 2004.
- Trade and Investment Policy Strategies (TIPS), DIPRU Annual Forum 2003, Indaba Hotel, Sandton, Johannesburg, South Africa, September 2003.
- ILO Researchers Workshop on Financial Sector Liberalization, Hotel Marina, Cotonou, Benin, 29-31 October 2003.

Research &Publications

- The Conundrum of Conservation Agriculture and Livelihoods in Southern Africa, co-authored with Nelson Mango, Marc Corbeels, Gert Jan Veldwisch - submitted to the African Journal of Agricultural Research, October 2010 *(Published in Vol 6 (24), pp5520 – 5528,26 October 2011)*
- Conservation Agriculture and Livelihoods in Mozambique: The case of Nhanguo, Pumbuto and Ruaca : co-authored with Nelson Mango and Precious Zikhali, paper submitted to the Journal of Sustainable Agriculture, October 2010, *(Published in Volume 35, Issue 7, pp 757-779)*
- Increasing the Rural Livelihood Benefits from Natural Plant product Ventures in Southern Africa, a case study *of Mel da Mozambique and SOMEL,* - project done with colleagues from the Catholic University and University of Eduardo Mondlane in Mozambique, in collaboration with Stellenbosch University (SA) and Pennsylvania State University (USA) 2007, *(published by Stellenbosch University)*
- A Structural analysis of the Sources and Dynamics of Fluctuations in the South African Economy, Co-authored with T. Ndlela, Paper presented at the Trade and Industrial Policy Strategies (TIPS) 2003 Conference, from 8-10 September 2003, Indaba Hotel, Johannesburg, South Africa, *(published as TIPs conference proceedings 2003).*
- The Impact of Used clothing on the Clothing and Textile industry in Zimbabwe, On-going research being carried out for WTO, Geneva, Switzerland, 2005, *(published as an ILO monograph)*
- An Assessment of Orphaned and Vulnerable Children in Bulilima and Mangwe Districts in Matabeleland South Province, a Baseline report prepared for SNV Bulawayo, March

2006

- Challenges and opportunities faced by Rural Businesses in a hyperinflationary environment, Paper prepared for the Entrepreneurial Development Centre Consultative Conference – 28th September 2005, NUST, Council Chambers, Bulawayo *(unpublished)*
- Financial sector reforms and access to financial services by cross border traders in Small to medium scale enterprises (SMEs) in Zimbabwe, Southern Africa Trade and Research Network (SATRN), May 2005, Livingstone- Zambia *(unpublished)*
- The Impact of Financial Sector reform on Poverty Alleviation: the Case of Development Finance Institutions in Zimbabwe, ILO/Reserve Bank of Zimbabwe sponsored research – Principal Researcher(2003), Cotnou – Benin *(unpublished)*
- The Social Sector and National Budget: A Focus on social welfare, Education, Agriculture and the informal sector, Poverty Reduction Forum, Zimbabwe, and Paper presented at the Budget Series Workshop, 26 February 2004, Rainbow Hotel, Bulawayo, Zimbabwe *(unpublished)*
- Valuation of Water and an Analysis of Socio-Economic and Environmental Impacts of Water Development Projects in Zimbabwe: The Case of Mtshabezi Dam, University of Zimbabwe, 2001 *(University of Zimbabwe, Dept of Economics)*

Areas of Research Interest

- Agricultural Economics &Livelihoods
- Development Economics
- Development and Disaster Management
- International Trade
- Agriculture Economics
- Environmental Economic
- Financial Economics
- Poverty Alleviation
- Financial Liberalization.