2 ACCA

SECOND AFRICA CONGRESS ON CONSERVATION AGRICULTURE

9th- 12th October 2018 | Johannesburg, South Africa

Making Climate-Smart Agriculture Real in Africa with Conservation Agriculture

Supporting the Malabo Declaration and Agenda 2063

Condensed Papers Book

Making Climate-Smart Agriculture Real in Africa with Conservation Agriculture

"Supporting the Malabo Declaration and Agenda 2063"

Condensed Papers Book

"Propelled by declining rural labour force, increasing feminization of agriculture, ageing farming population, low interest of youths in agriculture, increasing energy costs, declining farm incomes, an increasing starving population, climate change and high levels of post-harvest losses; a new desire is emerging to adapt and promote sustainable and appropriately mechanized Conservation Agriculture in Africa. Supported by Agenda 2063 (**The Africa We Want**) to banish the hand hoe by 2025, and the framework for Sustainable Agricultural Mechanization in Africa across Agri-food Chains, a new unstoppable wave to modernise Africa's agriculture using science, technology, innovation and indigenous knowledge is on the rise.**"**

ACT News Alert Editorial, June 2018

"Conservation Farming (Agriculture), put first things first by attending to the needs of the soil—by seeing to it that the starting off place, the base, is put into sound health and kept that way. Any other approach, no matter what it may be, always has and always must lead eventually to agricultural disaster."

Hugh Hammond Bennett, 1935

The Second Africa Congress on Conservation Agriculture

"Intends to bring together expert knowledge, information, and insights from practitioners from across different sectors and interests groups from the public, private and civil sectors under one platform to discuss and strategically agree on scaling-up CA as an integral part of the growing food and agriculture systems in Africa."

2ACCA Functional Organizing Sub-Committees

The 2ACCA organisation and logistics process is largely supported by individuals, volunteers and friends of the African Conservation Agriculture Network (ACT). They all have and will continue helping in many different ways; assisting and encouraging the 2ACCA Secretariat, reviewing submitted papers and posters, chairing technical sessions, assisting the media team, providing translations, liaising with the participants and the public, and many other tasks.

The ACCA initiative is supported by the following committees:

International Steering Committee: This Committee is the overall multi-partner body to coordinate and lead on all policy and key decisions on the Congress. The Steering Committee provides leadership and guidance to all the work in the Task Teams and Sub-committee including regular monitoring and facilitating linkages and complementarities across the various work streams. Martin Bwalya (NEPAD) is the chair of the Steering Committee and Joseph Mureithi (KALRO Kenya and ACT) is the Vice Chair. Other members of the International Steering Committee are listed here below.

The 2ACCA Secretariat: The Secretariat functions are undertaken by the main ACT office in Nairobi and include: General coordination of the preparatory works; Overall secretarial and administration support to all Congress preparation task team and committees; One-stop centre for information and queries on the Congress; Maintain and manage all formal Congress related communications. The ACT Executive Secretary and CEO Saidi Mkomwa Chairs the Secretariat whose members are listed here below.

Scientific and Technical Committee: This Committee is responsible for elaborating the details of the Congress content and programme. The committee leads the decisions on the congress theme, sub-themes and congress structure as well as preparations of an architecture to guide self-organised side-events; information kiosk and poster sessions. The Committee spearheads commissioning of Congress studies and analytical works as well as reviewing of condensed papers and posters submitted to the Congress and preparation of the Congress report. The ICAAP-Africa Chair Amir Kassam leads the Scientific and Technical Committee whose members are listed here below.

The **National Organising Committee** is the host-country team that is responsible for the logistical arrangements, including securing the Congress venue, organising field visits, security arrangements as well as overseeing the local protocol needs. Klaas Mampholo, Department of Agriculture, Forestry and Fisheries (DAFF) chairs the Organizing Committee whose members are listed here below.

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Foreword

Second Africa Congress on Conservation Agriculture

Making Climate-Smart Agriculture Real in Africa with Conservation Agriculture
"Supporting the Malabo Declaration and Agenda 2063".
www.africacacongress.org

The International Steering Committee of the Second Africa Congress on Conservation Agriculture (2ACCA) and the Rebuplic of South Africa host welcomes farmers, policy makers, development partners and practitioners to Johannesburg to delibaerate and make CSA real in Africa through conservation Agriculture.The 2ACCA, as the forum for the continental Conservation Agriculture Community to support the transformation of African agriculture, is organized and consolidated as one of the most important meeting on the continent dealing with agricultural change as desired by the Malabo Declaration and Agenda 2063.

The choice of South Africa, the country which has made appreciable strides in promotion and adoption of Conservation Agriculture with the largest area of crop land under CA (65%) in Africa, provides a great opportunity to explore the application of CA practices and principles for both food security and supporting a growth agenda.

The main objective is to bring together expert knowledge, information, and insights from practitioners from across different sectors and interests groups from the public, private and civil sectors under one platform to discuss and strategically agree on scaling-up CA as an integral part of the growing food and agriculture systems in Africa. This involve taking stock, reflecting and organizing further action on what is necessary for Africa's Agriculture transformation in line with Agenda 2063 and how to effectively promote Conservation Agriculture to make the transformation a reality for all farmers. The diversity of knowledge and stakeholders at the Congress will enable the desired multi-disciplinary and cross-sectoral development of Conservation Agriculture as a core production component of climate-smart agriculture; and for the sustained mobilization of policy, institutional and community support to accelerate the widespread adoption and management of CA as a core element of the expanding climate-smart food and agriculture systems in Africa. Key demanded services from this congress are under the seven sub-themes of the congress as follows:

1. Mainstreaming of the CA paradigm within institutions, sectors and governments' systems in Africa
2. Research and technology development for scaling up of CA systems, practices and innovations in different rainfed and irrigated farming systems in Africa
3. Enhancing CA related education and training-learning capacity at systems and structural, organizational and individual levels to accelerate and expand the uptake of CA systems and practices
4. Investing across institutions and sectors, including in mechanization and commercialization, for widespread adoption of CA systems in Africa
5. CA knowledge system management and information sharing capacity development for impact

Your presence, your voice and support will demonstrate the strong commitment that the time for Africa to feed itself has arrived.

Therefore, ISC wish to rreming you that we (Africa) must not loose sight of the fact that sustainably productive and high quality soil is essential to the sustainable production of food we want to feed Africa.

We look forward to meeting you in Johannesburg.

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Introduction

With huge agricultural thrust in Africa, the importance of CSA cannot be overemphasized in the pursuit of development impact and transformations based on the continental context and trends. In reality, most African farmers (small, medium and large scale) attempting to intensify production sustainably use CA as the primary entry point in identifying and adapting locally compatible farming practices, input combinations, and timing of various farming operations in embracing farming systems and practices that are climate-smart.

Conservation Agriculture is considered as a tool to produce more and sustainably while ensuring soil health. It gives the opportunity to use different mechanization levels, from hand tools to animal power to motorized. CA can be practised in diverse conditions, from the Sahel to humid tropics, from drought tolerant cereals such as pearl millet to maize and plantation and tree crops such as bananas and cocoa, leading to the promotion of agro-forestry in predominant forest ecosystem areas. Each context brings different challenges regarding the implementation of CA, and many technologies can be adapted, including traditional ones. Technical solutions should be innovated through close partnerships between farmers, private sector industries, extension services and researchers. This approach has already permitted the development and adaptation of CA for small and big farms, in various agro-ecological zones and socio-economic contexts, and for many farming systems.

Field level experiences, supported increasingly by scientific evidence, continue to demonstrate that CA is enabling widespread empowerment of farming and rural communities in Africa as well as countries globally to sustainably increase agricultural productivity while enhancing agricultural value in mitigating climate change. Recent global and continental agreements and trends provides a common and enhanced collective "energy" that can motivate and support increased front-line action on scaling-up the adoption and spread of CA as a core component of climate-smart agriculture in line with the Sustainable Development Goals.

The First Africa Congress on Conservation Agriculture (1ACCA) held in Lusaka, Zambia in March 2014, focused on the theme *Conservation Agriculture: Building Entrepreneurship and Resilient Farming Systems*. The proceedings of the 1ACCA were published as a book by CABI under the title: *Conservation Agriculture for Africa: Building Resilient Farming Systems in a Changing Climate*. The 1ACCA reaffirmed that restoration of soil health and intensification of agriculture through CA should become the cornerstone in transforming the way farming is done in Africa, representing a major contribution to achieving NEPAD-CAADP's goal of 6% growth of the agriculture sector.

The 1ACCA released the Lusaka Declaration in line with the AU's Agenda 2063 which agreed on ten resolutions centred on: (i) policy, political commitment and leadership; (ii) private sector engagement; and (iii) training, extension, research and innovation, and knowledge support. Governments, development partners, private sector, farmers, education and training institutions, research institutions, regional economic communities and non-governmental organizations are among the stakeholders called upon to support and facilitate the implementation of the resolutions in order to enhance the adoption and scaling-up of CA across Africa.

To foster the sharing, learning and building of public, private and civil sector support for CA-based CSA development, ACT is collaborating with the Government of South Africa, African Union Commission, the NEPAD Agency, Regional Economic Communities, International NGOs, Norwegian Agency for Development Cooperation (NORAD), European Union (EU), Food and Agriculture Organization (FAO) of the UN and various bilateral and multilateral partners to organise and host the 2ACCA in **Johannesburg, South Africa,** from **9th to 12th October 2018** under the *theme "Making Climate-Smart Agriculture Real in Africa with Conservation Agriculture: Supporting the Malabo Declaration and Agenda 2063"*. This is intended to concentrate the various stakeholders to identify the best solutions for all regions in Africa to support the Malabo Declaration and Agenda 2063. The 2ACCA, as the forum for the continental Conservation Agriculture Community to support the transformation of African agriculture, is organized and consolidated as one of the most important meeting on the continent dealing with agricultural change as desired by the Malabo Declaration and Agenda 2063.

The purpose of the 2ACCA initiative is to facilitate diverse and open sharing of experiences and information on CA thereby fostering learning and widespread awareness and interest in the uptake and spread of CA. This includes CA's role in: enhancing sustainable agricultural productivity, strengthening environmental and social resilience, and fostering efforts to provide for food and nutrition security as well as jobs and economic opportunities, especially for rural communities, including youth and women. The 2ACCA initiative provides "neutral space" for networking, collaboration and partnership to support the scaling-up of CA systems as the sustainable basis for CSA development across Africa.

The 2ACCA initiative brings together expert knowledge, information, and insights from practitioners from across different sectors and interests groups at all levels of agriculture development from the public, private and civil sectors. This diversity enables the desired multi-disciplinary and cross-sector "treatment" of CA for climate-smart agriculture – a feature essential for the success of CA scaling-up as an integral part of the growing food and agriculture systems in Africa.

The 2ACCA is organized to achieve the following specific objectives, in the context of the Malabo Declaration, the Agenda 2063, the SDGs, the Paris COP 21 and Marrakech COP 22 Agreements, and UNCCD strategic framework:

(a) Facilitate **interactions and sharing** among various interest groups to enhance an integrated and holistic knowledge base on promoting demand-driven and locally compatible CA systems and practices.
(b) Examine and showcase lessons on **policy, institutional support and technological interventions** as well as **information support** in participatory initiatives to accelerate and expand **sustainable uptake** of CA systems and practices.
(c) **Mainstreaming of CA into continental, regional and national frameworks** towards realization of Africa's commitments to Agenda 2063, SDGs, COP21 Paris Agreement, COP 22 Marrakech Agreement including the 4 per Mille and Triple A initiatives, and Land degradation neutrality (LDN) targets.
(d) Showcase advances in science and technology in **supporting innovations in CA systems and practices** adapted within local agro-ecosystems and their socio-cultural and political economy circumstances.
(e) Assess recent successes and consider pathways for **comprehensive capacity, skills development and institutional building** of all stakeholders in the food and agriculture supply and value chains across Africa.

Congress Theme and Sub-Themes

The aim of 2ACCA is to bring together expert knowledge, information, and insights from practitioners from across different sectors and interests groups at all levels of agriculture development in the public, private and civil sectors. This diversity of knowledge and stakeholders is essential:

a). to enable the desired multi-disciplinary and cross-sectoral development of CA as a core production component of climate-smart agriculture; and
b). for the sustained mobilization of policy, institutional and community support to accelerate the widespread adoption and management of CA as a core element of the expanding climate-smart food and agriculture systems in Africa.

This is in line with the Malabo Declaration, AU's Agenda 2063 and the SDGs.

Hence, the Congress is being organised under the following theme and sub-themes

Congress Theme:

Making Climate-Smart Agriculture Real in Africa with Conservation Agriculture: *Supporting the Malabo Declaration and Agenda 2063*

Congress Sub-themes (in the context of Agenda 2063, SDGs, CC-COP 21, 22 and 23):

Sub-Theme 1: **Mainstreaming of the CA paradigm within** institutions, sectors and governments' systems in Africa

Sub-Theme 2: **Research and technology development for scaling up of CA systems, practices** and innovations in different rainfed and irrigated farming systems in Africa

Sub-Theme 3: Enhancing **CA related education and training-learning capacity** at systems and structural, organizational and individual levels to accelerate and expand the uptake of CA systems and practices

Sub-Theme 4: **Investing across institutions and sectors**, including in mechanization and commercialization, for widespread adoption of CA systems in Africa

Sub-Theme 5: CA knowledge system management and information sharing capacity development for impact

Congress Keynote Papers

Linking to Agenda 2063, the SDGs and COP21 and 22 Agreements, the 2ACCA places a special focus on highlighting experiences and lessons related to unblocking the necessary "frontline actions" to scale-up sustainable adoption and spread of CA systems and practices. This includes efforts at household, community, sectoral, national and global levels, aimed at transforming current food and agricultural systems into those that are climate-smart and sustainable ecologically, economically and socially.

While taking note of both large-scale and smallholder commercial farming supply and value chains, as well as the partly subsistence smallholder farming systems, the Congress put special focus on youth and women, in terms of farming, on-farm and off-farm rural and urban employment, economic integration, enterprise opportunities, improved livelihoods, and quality of life. In light of this, 2ACCA addresses comprehensive and integrated scope to the issues of climate-smart farming systems and the scaling-up of commercially viable CA systems and practices across supply and value chains. This ensure that farming practices are based on economically viable commodities, linked to effective input and output markets, and advances in entrepreneurship and business enterprise.

CA's potential impact on increasing-stabilising productivity and improving ecosystem services is important in catalysing enhanced performance of agriculture – even in rural smallholder systems, thereby expending opportunities for smallholder farmers to connect to input and output markets (i.e. to handle the increased surplus as well as to access inputs). In this way, CA will be marking an impact on multiple fronts on the Agenda 2063 and SDGs goals and targets

With still a huge agricultural thrust, the importance of CSA cannot be overemphasized in the pursuit of development impact and transformations based on the continental context and trends1. In reality, most African farmers (small, medium and large scale) attempting to intensify production sustainably use CA as the primary entry point in identifying and adapting locally compatible farming practices, input combinations, and timing of various farming operations in embracing farming systems and practices that are climate-smart.

This theme aims to bring focus on implementation and achieving results in the form of widespread and sustainable adoption and uptake of CA across Africa. It is in the results that accrue from practicing CA that the 2ACCA aims to demonstrate the value of CA in building agriculture that is climate-smart and transformed – i.e. additional to enhanced and sustainable productivity, also be directly impacting on improved agro-ecosystems and social resilience as well as through enhanced carbon sequestration and decrease in methane and nitrous oxide emissions fosters reduced GHG emissions, thereby playing a role in mitigating climate change.

The organizers of the 2ACCA strive to a Congress that, in both content and process, be attractive and worth-the-while not just to the CA networks, but other players and interest groups/organizations that may be important for enhanced CA value chain development and adoption. The congress hosts leading regional and international speakers showcasing the latest updates on sustainable agriculture and ecosystem management.

Some of the speakers shared their keynote address papers compiled and subsequently presented as follows:

[1] The changing global context, and in our times the modern information revolution; globalization; changes in technology, production, trade, knowledge and labour markets; the opportunities presented by global demographic trends, urbanization and the growing global middle and working classes in the South; the move towards multi-polarity with strong elements of uni-polarism remaining, global security and the impact of climate change. Humanity today has the capacities, technology and knowhow to ensure a decent standard of living and human security for all inhabitants of our earth

Mainstreaming of the Conservation Agriculture Paradigm in Africa

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Keywords: Malabo Declaration, Agenda 2063, policy, institution, political economy

Introduction

This paper elaborates on: (a) why Africa should consider Conservation Agriculture (CA) to be its preferred paradigm for climate smart agriculture (CSA); and (b) that Africa should focus its agricultural development investments and policy efforts to mainstream CA-based CSA within agricultural institutions, across agricultural sectors, and in government systems to support agricultural development as envisaged by Agenda 2063 and the Malabo Declaration. At the practical development level, mainstreaming CA means that all relevant stakeholders, comprising agricultural development institutions, sectors, and government systems must: (a) strategically align themselves to provide effective support to promoting the adoption and spread of good quality CA systems; (b) develop and sustain capacity for CA research, education and extension, including that of CA service providers along the value chains across agriculture sectors; and (c) mobilize in government systems policy support for investments, infrastructure development, mechanization and incentives for the commercialization of CA-based CSA. This is a major task for all CA stakeholders across Africa within the context of the Malabo Declaration and Agenda 2063 implementation.

Political Economy of Conservation Agriculture

Given the history and nature of the political economy of agriculture development globally and particularly in Africa, the inherited national and international institutional and policy support strategies still continue to push forward agricultural development strategies based on re-cycled Green Revolution agriculture. This agriculture is the conventional tillage-based agriculture which is known as 'business as usual' agriculture. This largely explains why the adoption and spread of CA as the foundation for CSA, as well as the institutional mainstreaming of CA, cannot be expected to occur automatically throughout Africa. Indeed, the full potential of CA to address issues ranging from poverty and food security to global climate change cannot be fully realized until the constraints to increasing its wide-scale uptake across Africa are resolved. Experience from countries that now have significant extent of agricultural land under CA systems show that there can be a long gestation period of some 15 years or more during which pioneer farmers, extension agronomists and researchers are able to champion the cause and generate the needed proof of concept and application to lay the foundation for effective expansion and exponential growth in the uptake and spread of CA. Figure 1 provides an example of the historical situation in Brazil since the early 1970s when the first farmer, Mr. Herbert Bartz, decided to adopt CA and transform his farm. It was after some 15 years of strongly supported pilot programmes in research, farmer associations, and agro-industries that the institutional mainstreaming of CA in Brazil began to occur with government support and with all stakeholders working together to mainstream CA. Today, Brazil not only has the largest absolute area under CA, some 32 M ha, but is also reaping large-scale economic, environmental and social benefits from it, including serving as a significant component of the global 'bread basket'.

Farmers, researchers and extension agronomist in Africa also have been working on CA since the early seventies, particularly in east and southern Africa and in west and north Africa, and there is now substantial accumulated empirical and scientific evidence to show that CA systems adapted to local biophysical and socio-economic conditions can be made to work profitably and sustainably on all farm sizes and with different farm power sources. This is in line with the global scientific and empirical evidence and experience which has led to global CA area to increase since 2008/09 at an annual rate of 10.5 M ha of cropland to 180 M ha in 2015/16, corresponding to about 12.5% of global cropland area.

Justification for Mainstreaming the Conservation Agriculture Paradigm

CA area in Africa has spread over more than 1.5 M ha, corresponding to an increase of over 210% since 2008/09. This has benefited several million smallholder family members in more than 20 countries across Africa, and the rate of adoption of CA systems in Africa and globally is expected to increase in the coming years as more policy and institutional attention and support is directed towards it promotion at the grassroots level. What is now needed is for African governments to make a firm and sustained commitment to encourage and support the CA paradigm as the desired CSA for achieving the agricultural development vision of the Malabo Declaration, specifically the Vision 25x25, and the goals set by Agenda 2063. This should be expressed in government and institutional policies which are consistent and mutually reinforcing across the spectrum of government responsibilities, including the mainstreaming of CA in public advisory, research and education services and sufficiently flexible to accommodate variability in local ecological and socioeconomic characteristics. Any financial and structural assistance and incentives needed by farmers can be justified by the recognition of the public goods' value of environmental and socioeconomic benefits generated by CA-based land use.

CA represents a different 'paradigm' of agriculture, comprising a fundamental operational change in agricultural production systems management, both technically and managerially. Transforming to CA management from tillage agriculture is similar to changing from the 'flat earth' mind-set to 'round earth' mind-set. It is a totally different way of farming and managing agro-ecosystems. It requires a deeper awareness of ecosystem functions and the societal services they offer in agricultural landscapes so that they are least disrupted when landscapes are altered or used for agricultural production. A large range of productivity, economic, environmental and social benefits that accrue from CA land uses, most of which are not possible in tillage-based agriculture, provide an indication as to why so many farmers globally, as well as in Africa, have adopted CA systems. They also provide a justification as to why CA deserves greater attention from the development community, including the government, corporate and civil sectors. CA needs therefore, to be promoted not merely based on the commercial value of farm produce, but also the transformative yet unseen ecosystem and sustainability enhancing societal services in addition to the regenerative nature of CA systems.

Based on the global empirical and scientific evidence, including from Africa, it can be shown conclusively that conventional tillage-based agriculture at any level of development and type of farm power is unable to maintain soil health and functions in crop fields and over agricultural landscapes. Due to continuous mechanical soil disturbance, leaving soils bare and without biomass substrate to feed the soil life, and poorly diversified cropping, all tillage-based agricultural systems over time lead to soil erosion and land degradation, loss of soil and ecosystem health, increased biotic and abiotic stresses and damage, and poor adaptability to climate change. These weaknesses contribute to a significant loss in attainable agro-ecological land and crop potentials, and sub-optimal actual crop yields, factor productivity and profit, and poor system resilience. There is also a loss in ecosystem functions and societal services such as clean and regulated water supply; carbon sequestration in soils; nutrient, carbon and water cycling; and pollination services,

CA systems, underpinned by three interlinked principles of: no or minimum mechanical soil disturbance; soil mulch cover; and diversified cropping, are known to be regenerative in terms of soil health and capable of reversing land degradation and minimizing soil erosion. They also offer greater resilience to biotic and abiotic stresses, and are climate smart. Thus, established CA systems generally confer a range of productivity, economic, environmental and social benefits to all land-based production systems and to producers, whether they operate on a small scale or on a large scale, and to society at large. These include: (i) Higher stable production, factor productivity, and profitability with lower production input and capital costs; (ii) Greater capacity for climate change adaptation and reduced vulnerability to extreme weather conditions such as drought, leading to more reliable harvests and reduced risks; (iii) Enhanced soil and landscape health as well as ecosystem functions and services; (iv) Reduced greenhouse gas emissions and increased soil carbon sequestration.

Institutional Capacity and Policy Support for Mainstreaming Conservation Agriculture

Despite all the known advantages of CA systems and the known disadvantages of conventional tillage-based agriculture, currently, most of the knowledge and development service institutions in the public and private sectors in Africa tend to align themselves in supporting the conventional tillage-based production systems. Also, there is limited policy experience and research-training-linkages-expertise to assist the small-scale and large-scale farmers in the different ecologies and national contexts in the transformation of conventional tillage systems to CA systems. Consequently, a concerted effort is needed to create and sustain enabling policy and institutional environment to more effectively promote the adoption of CA across Africa. Without this strategic policy and institutional alignment to support the spread of CA, mainstreaming of CA across Africa will not be possible. There is now a strong need to move away from current situation dominated by NGO driven pilot projects, and from research experimentation on CA scaling which will not provide an adequate basis for a meaningful Pan-African adoption, even in 40-50 years, to government supported CA capacity development strategies, plans and programmes involving all stakeholders. This requires a systematic CA capacity development within the government and private sectors in terms of: (1) structures, systems and roles, (2) staff and facilities, (3) skills, and (4) tools that would include the R&D, training, and extension /outreach departments of all national governments. In countries where such support is available (e.g. Brazil, Argentina, Paraguay, Uruguay, USA, Canada, Spain, Italy, Kazakhstan, China, Australia), the rate of uptake and spread of CA has been faster and wide spread, after an initial gestation period of some 15 years.

Key limiting factors that constrain CA adoption and up-scaling are: lack of adequate knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support. Where a country or state is not currently generating the knowledge needed for transforming production systems towards CA systems, it must rely on successful experience outside its borders and support a network of on-farm operational research conducted by pioneer farmers, backed by public and private sector advisory services, NGOs and research establishments. This is an area of value proposition for pan-African networks such as ACT. The engagement of the agricultural machinery sector is necessary to facilitate the supply of needed equipment. Commercial CA farming for the smallholder African farmers is possible, but with a pre-requisite investment in farmer organization and linkages to markets, initially not of interest to the private sector dealing with production inputs. Also, social capital development in terms of CA farmer associations is seen as an important pre-requisite to the adoption of sustainable behaviours and technologies over large areas. Where such social capital is high in formalized groups, people have the confidence to invest in collective activities, knowing that others will do so too. Farmer participation in technology development and participatory extension and innovation approaches have emerged as a response to such new thinking.

Policy support and cohesion to meet these aims is critical as most governments have a variety of institutions involved in natural resource management (e.g. agriculture, forestry, national parks, energy, water). The fragmented nature of their mandates often inhibits full effectiveness. On the other hand, a commonality of underlying concern with the care of land, underpinning policy cohesion, will facilitate the needed interdisciplinary collaborations to be undertaken with farmers and other land-users. Agricultural development policy should therefore have a clear commitment to CA as a basis for sustainable CSA as many nations have now done and more are beginning to so. All agricultural development activities dealing with agricultural production 'intensification' and commercialization should be assessed for their compatibility with ecosystem functions and their desired services. Tillage-based production systems do achieve some production objectives, but in many situations will not fulfil the requirement of long-term economic sustainability and enhanced ecosystem services. An alternative policy driver is promoting smallholder CA as a "sustainable livelihood programme", incentivised for the good of the planet, by Government strategies, programmes, policies and skills, and involving public-private-producer sectors. Any environmental management schemes for agriculture (e.g. certification protocols, payments for environmental services) that do not promote the integration of CA principles and practices into farming systems are unlikely to be economically, environmentally and socially sustainable.

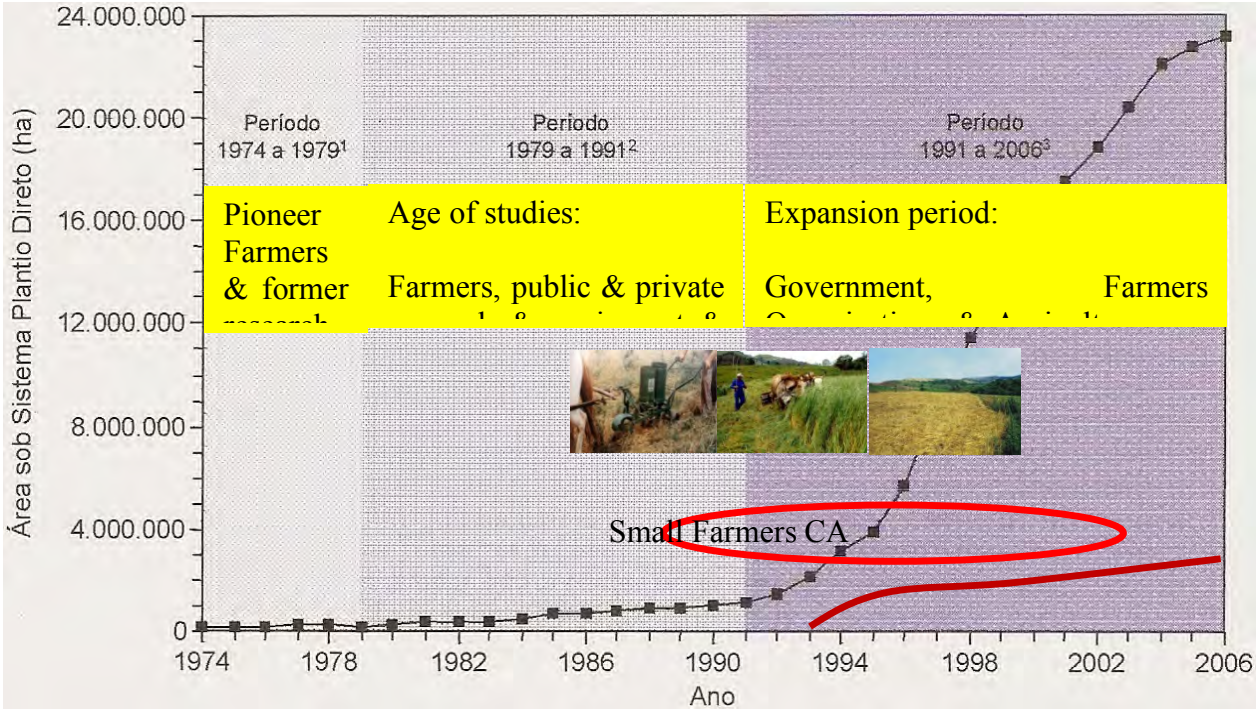

Figure 1: A historical change of land area under CA in Brazil in hectares

Research and Technology Development Needs for Scaling Up Conservation Agriculture Systems, Practices and Innovations in Africa

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Keywords: smallholder agriculture; opportunities for food production; CA research needs

Overview on state of African Agriculture

Although net agricultural production across all regions of Africa has experienced significant increase, African agriculture has performed below its potential over recent decades. The increases in production are not commensurate with increases in population and at the current rate of population growth African agriculture has to provide adequate food and nutrition security for at least two billion people by 2050. Presently food imports by African countries exceed USD 35 billion annually. This presents a significant opportunity for the agriculture and food sector, including farmers and institutions that support agricultural development, to promote sustainable intensification of agriculture. The negative impacts of climate change particularly shift in weather patterns, rising frequency of droughts and floods and incidences of pests and diseases will continue to threaten Africa's future food and nutrition security. To many African farmers and professionals, conventional tillage agriculture and recycled Green Revolution is not providing a credible and sustainable way forward. A different approach is needed which includes Conservation Agriculture (CA) at its heart, supported by all stakeholders benefiting from both global knowledge about CA as well as new knowledge generated through research and innovation in Africa. This is premised on the understating that CA already covers more than 180 M ha globally, and in Africa there is already more than 1.5 M ha of CA, of which some 1 M ha are managed by about two million smallholder farmers.

The need for research on CA tailored to biophysical and socio-economic situation in Africa

Research on CA must take cognizance of the following facts about Africa. The smallholder farm sector which is the bedrock of agricultural production and livelihood for the majority of inhabitants in rural Africa is under threat from exploitive subsistence agriculture where farmers use few if any of the purchased inputs. Many years of extractive farming and inadequate measures to ensure sustainability has degraded core resources of production at landscape level resulting in destitution and vulnerability of whole communities (Kassam et al., 2017). Farmers' ability to invest in mitigation of degradation under the unsustainable conventional tillage agricultural land use is greatly diminished leading to increased low productivity, further degradation and poverty. This state of affairs poses a real threat to African food and nutritional security and genuine sovereignty.

Intensification under conventional intensive agriculture, leads to higher frequency of tillage whose adverse consequences on soil quality and doubt that CA can drastically reduce the rate of land degradation over relatively short periods of sustained use. In addition, CA can enable farmers to mobilize greater crop and land potentials in terms of productivity as well as ecosystem services such as clean and regulated water supply, runoff and erosion control, improved cycling of water, carbon and nutrient, and pollination services.

The second notable consideration is that Africa has exceptional endowment and opportunity for food production; the continent is home to over half of the world's uncultivated arable land, a diversity of food and commodity crops, an abundance of sunshine and an expanding consumer base that creates a promising market for food products.

The third observation is that agricultural growth remains the most powerful way to reduce poverty in developing countries. In general, significant reductions in poverty have occurred in countries, which have increased agricultural productivity most rapidly (Janvry and Sadoule, 2010). The Comprehensive Africa's Agricultural Development Programme (CAADP) adopted by the African Union Commission and the Science Technology and Innovation Strategy for Africa (STISA) emphasizes need for a paradigm shift to innovation-led and knowledge-based African agriculture

(STISA-2024 and AU Agenda 2062). For this to happen, African agriculture must embrace new agricultural science and innovation that would enable the best quality CA systems and practices to be adopted across Africa.

The need for research and innovation as a vehicle for scaling up of CA systems

Existing knowledge and experience lead to a consensus that adopting conservation agricultural systems and best practices at landscape level is perhaps the best way to mitigate degradation caused by conventional tillage and restore degraded soils as well as achieve climate change adaptability and mitigation. CA is applicable over a wide range of farming systems and agro ecological conditions but adoption and implementation face many challenges including significant knowledge gaps. Given the diversity of land use systems especially in smallholder areas, it is improbable that a 'one fit all' CA intervention can be found for all situations. In Africa, research-extension-farmer linkages are weak and yet they are a prerequisite for efficient technology transfer and adoption in African farms. Africa must therefore invest in research and training for technology development and transfer of CA practices and innovations for various farming systems to achieve appreciable CA adoption rates as reported in other parts of the world.

Essential Research for scaling up of CA systems and best practices

In order to change mindsets and promote buy-in of CA interventions by farmers and policy makers, the scientific community must address key niche and site-specific challenges associated with CA as has been done in the rest of the world outside Africa. As resources for research and development are limited in many African countries, there is urgent need to link private and public sector for better leveraging of resources and dedicated research and technical support to enhance understanding of CA niches and factors that would promote adoption. How that is to be done remains a challenge that is worthy addressing by African professionals and policy makers. The following aspects of CA will need further research to enable CA to be a truly farmer-led knowledge driven innovation.

Firstly, CA depends on integrated weed management. While herbicides can help in the integrated weed management strategies, most of the two million farmers practicing CA do so with little reliance on herbicide (e.g. Owenya et al., 2011; Lalani et al., 2017). Better research is needed to help farmers control weeds with minimum use of herbicides. Our scientists also need to fill knowledge gaps on herbicide formulations and combinations to manage weeds that are unique to African environments.

Secondly, CA is pillared on maintenance of permanent soil cover. Maintenance of a permanent or a semi-permanent soil cover may be done through growing of live crops (cover crops and intercrops) or leaving dead mulch (crop residues and biomass) to serve as protection of the soil from sun, rain and wind. However, residues by nature create challenges with management; crop residues, especially loose residues create problems for seeding equipment making it generally harder to achieve good stand establishment thus highlighting the critical importance of suitable equipment for success with CA, Residues also tend to harbour pests and diseases, and sometime immobilize surface applied nutrients particularly nitrogen. CA interventions succeed where suitable no-till seeding equipment is available to drill seed through residues at the proper depth for good germination. It is urgent that CA equipment is perfected and made available for CA farming system. The quantities and types of ground cover (dead or living) required to maintain a favourable and sustainable ecological balance is largely undetermined. System compatibility research is critical particularly on live soil covers e.g. the dolichos to forestall proliferation of invasive species such as Striga. Exploratory research on plant species with possibility of multiple uses as ground cover and animal feed is critical for mixed farming systems. Permanent soil cover depending on type and quantities may create unique microclimates and unexpected shifts in biota and chemical ecology. These are areas that are yet to be explored and illuminated. Economic evaluation research on primary and secondary benefits of CA on the farm and beyond the farm gate is necessary to inform policy on mechanisms for compensating contributions to ecosystem health by CA practitioners.

Thirdly, the CA pillar of minimum soil disturbance, while having significant benefits including reduced machinery time, savings on fuel and maintenance and drastic reductions on drudgery, also has implications for research. In the short term all the advantages of CA may not become apparent as crops may not benefit from mineralization of increased soil organic matter. CA is associated with higher microbial biomass and activity in upper soil layers and this concentration may lead also to build up of pathogen inoculums. The depth of knowledge on these dynamics is

lacking under the typical smallholder settings where farmers hardly attempt to control weeds, pathogens, diseases and insect pests. Understanding the role of CA enhancers i.e. proper crop nutrition and protection from all pests is a crucial area of research.

Conclusion

Clearly, there is a compelling need for change and appropriate interventions to mitigate degradation. The absolute imperative is that farmers must shift from outdated traditional methods to modern well-tested and knowledge-based methods of land use. Making this transition will be difficult without the creation of an enabling environment. Viability of CA as a best bet option must be demonstrated by producing and replicating a convincing frequency of successful CA outcomes in situations that closely mimic the farm environment. Our continent therefore must invest more in research needed for the fine-tuning of CA technologies to customize for local conditions and generate package of good-practices.

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The Potential of Climate Change Mitigation through Conservation Agriculture in Africa

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Introduction

In this condensed paper, we address the high potential of Conservation Agriculture (CA) for mitigating climate change in Africa.

The African continent is the lowest contributor to global greenhouse gas emissions (GHGs) among the continents, but the most vulnerable to the impacts of climate change (UNFCCC, 2016). According to the Intergovernmental Panel on Climate Change (IPCC) temperatures across Africa are expected to increase by 2-6 ºC within the next 100 years (IPCC, 2014). The effects will not be limited to a rising average temperature and changing rainfall patterns, but also to increasing severity and frequency in droughts, heat stress and floods (Niang et al, 2014; Hummel, 2015; Rose, 2015). These climatic risks have a direct negative impact on the natural resources supporting agricultural production processes with a detrimental impact on food security (Awojobi and Tetteh, 2017, Abebe, 2014; Science for Environmental Policy, 2015). The agricultural sector in Africa has been impacted by flooding, droughts, land degradation and deforestation, leading to human migration within Africa and to out migration out of Africa.

Agriculture is not only impacted upon by climate change but also contributes to global warming. The sector needs to adapt to the changes in climatic conditions and also help in mitigation. Agriculture which is part of the AFOLU sector (Agriculture, Forestry, and Other Land Use) is unique, since its climate change mitigation potential is derived from both an enhancement of removals of GHGs, and a reduction of emissions through management of land and livestock (Smith et al., 2014). A well designed and executed soil management system, has the potential to increase yields (e.g., in sub-Saharan Africa), while also providing a range of co-benefits such as increased soil organic matter (Keating et al., 2013; Kassam et al., 2017).

Africa remains a food deficit region yet it has potential to become a future 'bread basket', and the sustainable intensification of agricultural output, with a focus of soil and water conservation and optimum use of production inputs is part of the solution (Conway, 2012).

Conservation Agriculture (CA)

According to the Food and Agricultural Organization of the United Nations (FAO, 2018a), CA is a farming system that promotes continuous no or minimum soil disturbance (i.e. no tillage), maintenance of a permanent soil mulch cover, and diversification of plant species. It enhances biodiversity and natural biological processes above and below

the ground surface, so contributing to increased water and nutrient use efficiency and productivity, to more resilient cropping systems, and to improved and sustained crop production.

Conservation Agriculture is based on the practical application of three interlinked principles:

(1) Avoiding or minimizing mechanical soil disturbance involving seeding or planting directly into untilled soil, eliminating tillage altogether once the soil has been brought to good condition, and keeping soil disturbance from cultural operations to the minimum possible.
(2) Maintaining year-round biomass mulch cover over the soil, including specially introduced cover crops and intercrops and/or the mulch provided by retained biomass and stubble from the previous crop.
(3) Diversifying crop rotations, sequences and associations, adapted to local environmental and socio-economic conditions, and including appropriate nitrogen fixing legumes; such rotations and associations contribute to maintaining biodiversity above and in the soil, add biologically fixed nitrogen to the soil-plant system, and help avoid build-up of pest populations. In CA, the sequences and rotations of crops encourage agrobiodiversity as each crop will attract different overlapping spectra of microorganisms and natural enemies of pests.

The characteristics of CA make it one of the systems best able to contribute to climate change mitigation by reducing atmospheric GHGs concentration. On the one hand, the changes introduced by CA in the carbon dynamics in the soil lead directly to an increase in soil C (Reicosky, 1995; Lal, 2008). This effect is known as 'soil's carbon sink'. At the same time, the drastic reduction in the amount of tillage and the mechanical non-alteration of the soil reduce CO_2 emissions arising from energy saving and the reduction in the rates of the mineralization of soil organic matter. CA adoption requires a much lower level of capital investment and production inputs and is thus more readily applicable to smallholder farmers in developing countries (Kassam et al, 2017).

Soil carbon sequestration is a process in which CO_2 is removed from the atmosphere and stored in the soil carbon pool. This process is primarily mediated by plants through photosynthesis, with carbon stored in the form of soil organic carbon (SOC) (Lal, 2008). In terms of climate change mitigation, CA contributes the increase of SOC, whilst reducing the emissions of carbon dioxide. On the one hand, the decomposition of the crop biomass on the soil surface increase soil organic matter and soil organic carbon. On the other hand, emissions are reduced as a result of less soil carbon combustion due to no-tillage, and less fuel burning because of fewer field operations. The sum of the first two processes, results in an increase in the carbon sink effect in the soil, leading to a net increase of soil organic carbon; this is measured in tonnes of carbon in soil per hectare and year ($t\ ha^{-1}\ yr^{-1}$).

Numerous scientific studies confirm that soils are an important pool of active carbon, and play a major role in the global carbon cycle. Since soils occupy about 30% of the global surface area, a major shift from tillage based farming to climate smart systems, such as CA, would have a significant impact on global climate and food security.

Material and Methods

The results presented in this paper are based on a literature review of scientific articles published in peer reviewed journals. The terms "Conservation Agriculture", "Africa", "climate change mitigation" have been consulted at the scientific databases *sciencedirect.com* and *webofknowledge.com*. Among the papers reviewed, those focused on the application of the interlinked three principles of Conservation Agriculture have been selected.

This review has been carried out based on the different climatic zones of Africa (Figure 1) and focused on CA management practices, carbon sequestration based on current area of CA adoption in African countries, and potential of carbon sequestration based on conversion of conventional agriculture to CA across Africa. No data for carbon sequestration in desert areas is presented, as no articles with a carbon sequestration rate of CA have been found, and there is little expectation of a significant carbon increase in those environments as a result of farming activities.

The description of the applied methodology to obtain potential areas of CA is as follows. Country statistics of crops were obtained from FAOSTAT (FAOb, 2018). Among the annual crops, those best adapted to no-tillage CA systems

were selected: cereals, pulses, sunflower, rapeseed, cotton, among others. Most of the woody perennial crop areas were found suitable for CA production.

In climate change international agreements, emissions are referred to carbon dioxide; however, soil carbon studies refer to carbon. For transforming carbon into carbon dioxide, the coefficient of 3.67 was used. The atomic weight of carbon is 12 atomic mass units, while the weight of carbon dioxide is 44, because it also includes two oxygen atoms that each weigh 16. So, to switch from one to the other, one tonne of carbon equals 44/12 = 3.67 tonnes of carbon dioxide.

Results and Discussion

Farmers in almost 20 African countries are promoting and supporting CA, including in Algeria, Ghana, Kenya, Lesotho, Madagascar, Malawi, Morocco, Mozambique, Namibia, South Africa, Sudan, Swaziland, Tanzania, Tunisia, Uganda, Zambia and Zimbabwe (Kassam et al., 2018). CA has also been incorporated into the regional agricultural policies, and increasingly, has been 'officially' recognized as a core element of climate-smart agriculture (FAO, 2016, 2017; Kassam et al., 2017).

The latest figures of adoption of CA for annual crops in Africa (season 2015/16) totaled to 1.5 M hectares. This corresponds to some 211% increase from 0.48 M ha in 2008/09 (Kassam et al., 2018). This significant increase is because of the many years of research showing positive results for CA systems, plus increasing attention being paid to CA systems by governments, NEPAD (New Partnership for Africa's Development), and NGOs such as ACT (African Conservation Tillage), and the private sector, international organizations and donors.

Average rates of carbon sequestration by CA in agricultural soils for each climatic zone in Africa are presented in Table 1. The total carbon sequestration estimated for the whole of Africa, of 1,543,022 t C yr^{-1} is shown in Figure 2. On average, the carbon sequestered for Africa due to CA is thus around 1 t C ha^{-1} yr^{-1}, corresponding to a total amount of 5,657,747 t CO_2 yr^{-1}. This relatively high figure is because degraded soils are 'hungry' for carbon, as the degradation caused by years of tillage and crop biomass removal has resulted in a drastic reduction of soil's organic matter (Reicosky, 1995; Jat et al., 2014; Kassam et al., 2017). However, the increase of C is not permanent in time, and after a number of years, a plateau is reached. The time to reach the plateau is considerable, and may take over 10-15 years before a deceleration in the rate of carbon increase is observed (González-Sánchez et al, 2012). Therefore, even if after 10-15 years C sequestration rates are lower, carbon is still being captured in the soil, which supports the value of long term engagement with CA. Also, even when top soil layers may be reaching plateau levels, deeper soil layers continue to sequester C through the action of earthworms and biomass provided by deeper root systems.

In Figures 3 and 4, the potential area that could be shifted from conventional tillage agriculture to CA is presented, for both annual and permanent crop systems.

Multiplying the rates of C sequestration presented in Table 1 by the potential areas per country and per type of crop (Figures 3 and 4) permits estimates of the potential carbon sequestration following the application of CA in the agricultural lands of Africa. Where more than one climate affects a single country, the climate of the major cropping area has been selected, i.e. Algeria's rate of C sequestration has been that of the Mediterranean, as most of its cropland is affected by that climate. In cases where there were two co-dominant climates, two rates of C sequestration have been applied.

Finally, Figure 5 shows the total amount of potential carbon sequestration for Africa, for each climatic region, with respect to current carbon sequestration status. In total, the potential estimate of annual carbon sequestration in African agricultural soils through CA amounts to 145 M t of C per year, that is 533 M t of CO_2 per year. This figure represents about 95 times the current sequestration rate. To put this figure into context, according to the United Nations Framework Convention on Climate Change, South Africa, the world's 13th largest CO_2 emitter, national emissions by 2025 and 2030 will be in a range between 398 and 614 M t CO_2–eq per year (UNFCCC, 2018).

In summary

Currently, the total amount of African carbon sequestration due to CA adoption of 1.5 M ha is over 5.6 M t CO_2 $yr^{-1.}$ The potential effect of the application of CA on carbon sequestration is to increase this to 533 M t of CO_2 per year, nearly a 100 times greater.

Conservation Agriculture is thus more than a promising sustainable agricultural system, as it can effectively contribute to mitigating global warming, being able to offset agricultural CO_2 emissions.

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Figures and Tables

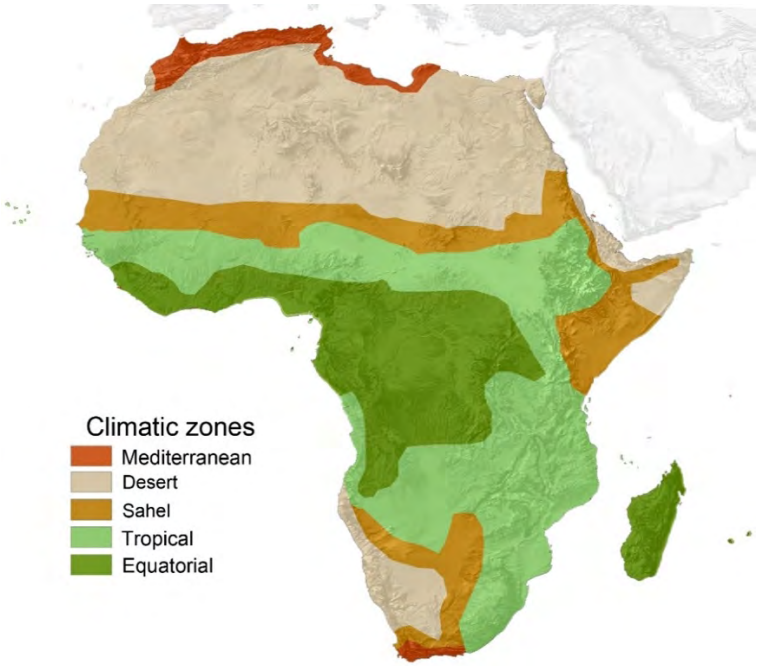

Figure 1. Climatic zones of Africa. Source: Authors' diagram based on Ngaira (2007) and www.gifex.com

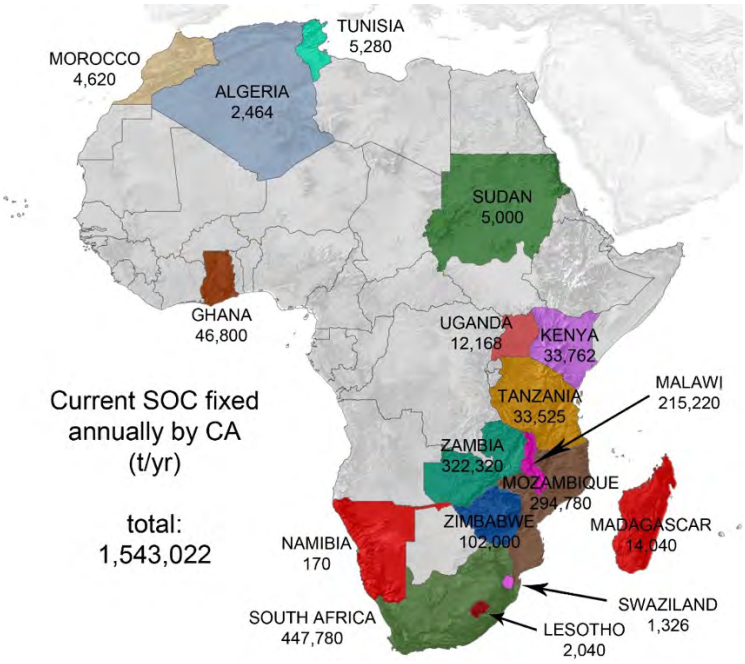

Figure 2. Current soil organic carbon (SOC) fixed annually by CA cropland systems compared to systems based on tillage agriculture in Africa. Authors diagram.

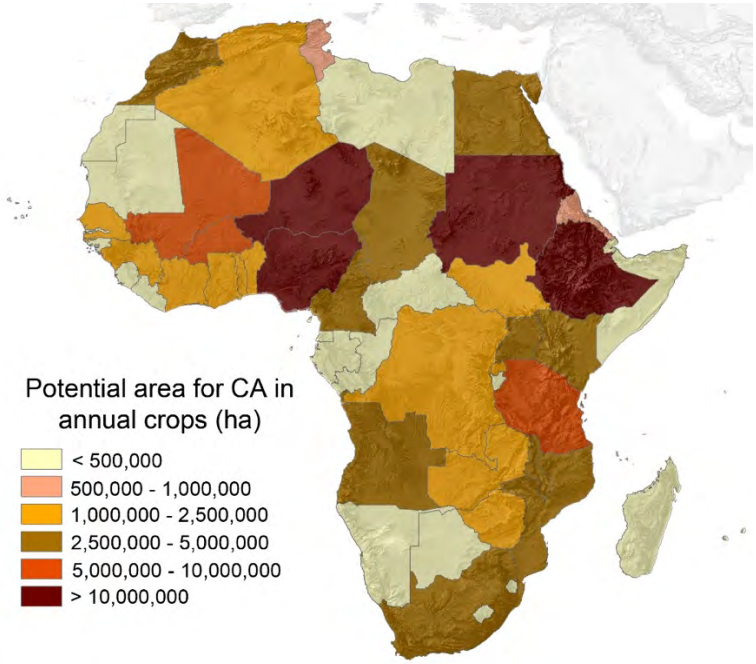

Figure 3. Potential application surface of CA in annual crops in Africa in 2016. Source: Authors diagram based on FAOSTAT, 2018.

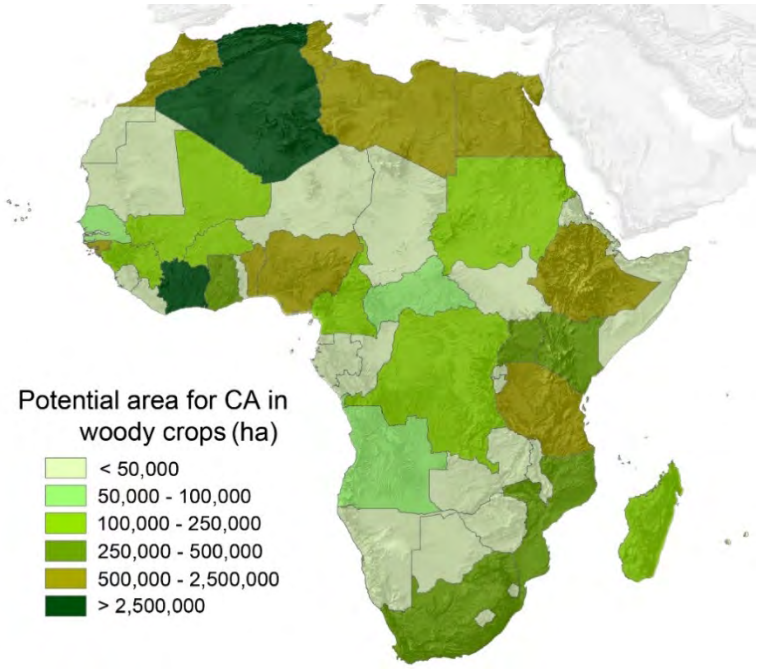

Figure 4. Potential application surface of groundcovers in woody perennial crops in Africa in 2016. Source: Authors diagram based on FAOSTAT (2018).

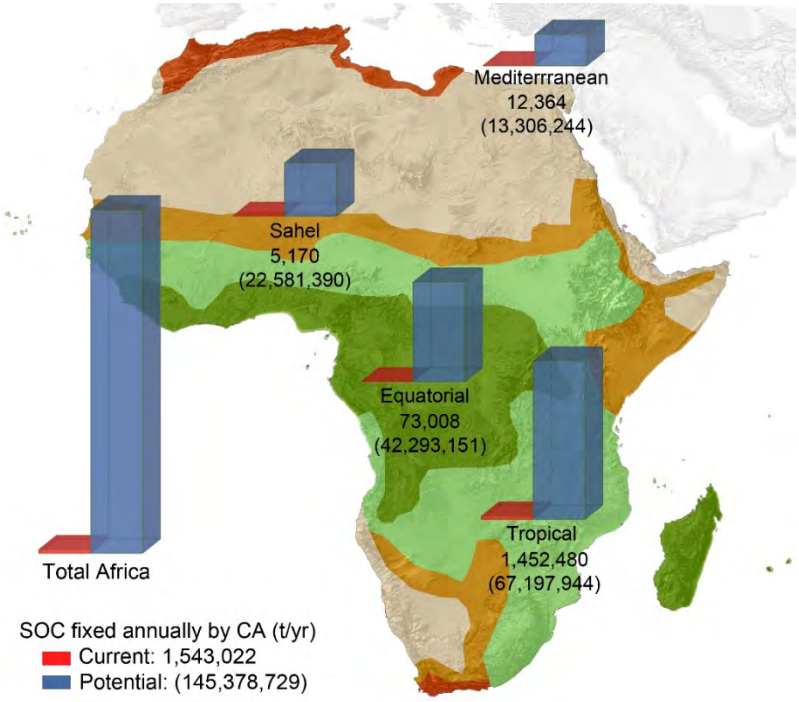

Figure 5. Potential soil organic carbon (SOC) fixed annually by CA cropland systems compared to systems based on tillage agriculture in Africa. Authors diagram.

Table 1. Carbon sequestration rates in Conservation Agriculture (CA) for each climatic zone. Source: Authors diagram based on the papers reviewed and listed in the references.

	Carbon sequestration rate for CA in annual crops (t ha^{-1} yr^{-1})	Carbon sequestration rate for CA in woody crops (t ha^{-1} yr^{-1})
Mediterranean	0.44	1.29
Sahel	0.50	0.12
Tropical	1.02	0.79
Equatorial	1.50	0.26

Enhancing Systemic Conservation Agriculture Related Education, Training and Skills Development to Accelerate and Expand its Uptake in Africa

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Introduction

Conservation Agriculture (CA), amongst other avenues for environmental action, is considered one of the recipes for reducing the large "environmental footprint" of agriculture while achieving sustainable production intensification. Yet, this new transformational agriculture wave, just like 'the Green Revolution', is again benefiting other continents leaving behind the neediest (Africa), where only about 1% of the 180 million hectares global area under CA are in Africa. Currently, CA is practiced on 1.5 million hectares in over 20 countries in Africa. Although CA has been shown to be relevant and appropriate for all farmer types and mechanization levels, its low adoption in Africa as compared to other continents is of concern to ACT and other continental organizations. ACT (2017) has put forward ten reasons for this slow spread of CA in Africa. It is evident from these constraints on the paramount and pivotal role of education, learning, skills development, systemic capacity development, and innovations in accelerating not only the adaptation and adoption of CA, but also enhance smallholder farming in Africa. Agenda 2063 – The Africa We Want – vision and roadmap, commits to speed-up actions to catalyse education and skills revolution and actively promote science, technology, research and innovation, to build knowledge, human capital, capabilities and skills to drive innovations and for the African century. This paper examines the role of education, training and skills development in CA in Sub-Saharan Africa in the context of the region's agricultural transformation systems.

Conservation Agriculture Educational and Training Pillars

(i) Conservation Agriculture-related agricultural transformation

The agriculture workforce is increasingly requiring higher skill levels and qualifications in response to a range of economic, environmental and market challenges. These challenges include: more onerous quality assurance standards, the use of more complex and ICT technologies on farms, natural resource constraints, increased climate variability, and biosecurity requirements. It is vital that the agriculture sector and employers develop a culture that promotes and values education and training. Thus, it is necessary for the agriculture sector to identify its agricultural education and training requirements and priorities for the existing workforce. CA education, training and skills development is a critical component of the total effort to bring about agricultural transformation, but it is not sufficient by itself. Programmes and strategies for CA education, training and skills development can be effective, when they are nested in a supportive environment of broader agricultural development goals and policy, which accord a high priority to and are consistent with the aims of poverty alleviation and sustainable development.

(ii) Conservation Agriculture value chain and competence-based education

The International Standard Classification of Occupations classifies skill specialisation in terms of four conceptual areas: (i) the field of knowledge required; (ii) the tools and machinery used; (iii) the materials worked on or with; and (iv) the kind of goods and services produced (ILO, 2012). In the context of this paper's intent, this presupposes identification of education, training and skills development processes entrained to the CA value chain in which knowledge, tools, materials, outputs and outcomes are elaborated. Further, the identification of skills to inform

occupations is a prerequisite in the design, development and implementation of competence-based CA curricula for different learning cycles (primary to tertiary) (DoA, 2007). Mulder and Kupper (2006) observed that agricultural education for many years has been aimed at increasing subject knowledge of learners. However, as a consequence of the restructuring of the agri-food complex, which consists of chains and networks, in which various specialists are working who are not trained in the agricultural disciplines, different kinds of competencies are needed. There is attendant need to combine content-related and educational knowledge to support the further development and innovative function of agricultural education in emerging thematic areas such as CA.

(iii) Education and training specialists for CA

In countries where teachers are not registered according to their specialist areas, there is no means to measure whether there are adequate numbers of agriculture teachers and trainers to satisfy the need to update the skills of large and growing workforces, including a need to incorporate sustainable agriculture course content and update curricula in schools and adult education training. To this end, teaching and training personnel in agriculture-related curricula need re-tooling for them to command necessary emergent agriculture discipline content such as CA knowledge, aptitudes and skills. In fact, the changing role of knowledge in the contemporary society, which obliges the ability to acquire the appropriate knowledge and translate it when needed at the spot, has become more and more important. Agricultural universities remain well poised to contribute towards re-tooling current crop of teachers and tutors through for instance, training of trainers' initiatives. Teachers are vital to the success of CA education in schools and they also play a key role in influencing students' attitudes towards sustainable agriculture.

Conservation Agriculture Training in Formal and Non-Formal Education

(i) Conservation Agriculture in schools and vocational education:

There should be a greater focus on improving the agricultural literacy of all learners in primary and secondary schools and supporting existing schools to deliver high quality agricultural education programs. It is not sufficient to use agriculture as an elective or for it to provide context for teaching subjects such as geography, mathematics and science. Accurate and balanced curriculum in agriculture, comprising tenets of conventional and Conservation Agriculture systems, should be promoted within the discipline-based learning strand, which contains the subject areas that students are expected to develop a knowledge and understanding of. School farms help to enhance learner's engagement in agricultural education. There is a need to support schools to maintain existing farms and agricultural facilities and to link with local farmers and industry. An effective approach to meeting skills needs of practicing young farmers has been through the Junior Farmer Field School, advocated by FAO, and piloted in several African countries with varying levels of adoption. The ILO (2011) suggested that short, intensive vocational training courses, tailored to the specific needs are the most effective way of delivering retraining for specific new tasks or job opportunities. NEPAD and CAADP (2013) reported on a project that integrated sustainable vocational training for the agriculture sector into the Comprehensive Africa Agricultural Development Programme (CAADP) aimed at young people across Africa and market needs. The project illustrates an implementation process to establish expertise required for developing successful CA value chains using farmer training centres or technical and vocational training (TVET) centres.

(ii) Conservation Agriculture in tertiary education

The constraints to attaining the full potential of CA performance are known (and have been for a while) but there has not been an appropriate response in research, education and training curriculum content to address required improvement in the entire CA value chain. There is urgent need, through tertiary R & D, to position CA as a market-driven agribusiness, which can be profitable as opposed to being addressed only as a production enterprise. Given the multiple dimensions of agricultural transformation and the broad range of knowledge, research and capacity building needs for this purpose, the contribution of higher education in this respect cannot be underestimated.

Tertiary institutions are well positioned to use their resources to assist the public and private sectors to develop strategies to address the opportunities provided by CA training. These resources include a range of academic programmes that are relevant to present and emerging needs of higher-level professional and technical personnel for

agricultural transformation, including needs of teachers and trainers and designing curriculum and learning content of middle level institutions. These also include, in the case of agricultural universities, their ability to coordinate and support research that improves the understanding of economic, environmental and social issues, problems and opportunities in current and emerging practices. Tertiary institutions could also support vocational and entrepreneurship skills development and develop need-based value-added services in various CA functional areas, including where agriculture has been reported to have a negative image as a career choice in the eyes of youth (Mafunzwaini et al., 2003).

(iii) Conservation Agriculture learning community

Mulder and Kupper (2006) suggests that if critical sustainable agriculture and natural resources messages are to be widely disseminated in society, the content of these must be researched and packaged for primary, secondary, vocational and adult education. The principal components of lifelong learning (learning society) considered in the context of this paper include second chance non-formal basic education; vocational and technical training; adult literacy and continuing education; and access to library and reading room and community multi-media centre. To function effectively and to become the building blocks for lifelong learning in a CA learning society, these must have technical support in designing programmes, training personnel, and evaluating the effectiveness of activities (Ahmed, 2014). The means must include e-Learning facilities and skills and the ability to produce and deliver CA online courses and CA-based MOOCs (Mass Open Online Courses). Such programmes could be designed to provide learners with an understanding of sustainable agricultural systems, and would be the requirement for learners to design, develop and manage their own agricultural business along the CA value chain.

Turning CA Educational, Training and Skills Development into Jobs

(i) Employment information services

Skills and capacities of people as human capital is one asset that must be put to work in synergy with other capital assets – physical, social, natural and financial – toward achieving the defined development objectives. The linking of skills and jobs does not happen in a vacuum, isolated from all the forces at play in relation to economic transformation. Thus, CA skills, knowledge and ability must constitute key assets within sustainable agriculture and sustainable livelihoods frameworks. It is often considered that linking skills and jobs are generic problems of the economy and the employment market. Universities are best placed to probe and embrace issues related to turning knowledge and skills into productive work (Minde *et al.,* 2015). This has been the practice in most overseas universities where they offer employment information services using designs that allow incentives for both job seekers and employers to join in establishing skills certification frameworks, which also cater to rural youth, to recognise individual skills and competencies measures, which need to be taken, with necessary adaptation for national context (World Bank, 2010).

(ii) Self-employment and young employers

There has been calls for the African agricultural university to build a new cadre of agricultural graduates who will go on to become entrepreneurs and wealth creators rather than cogs in the wheels of existing agricultural and related organizations (Davis *et al.,* 2007). In order to achieve this, the authors suggest that education, training and skills development institutions should place their students amongst research-driven networks that include university science programs, agricultural research organizations, input suppliers, extension agents, and farmers but must also necessarily rely on other network modalities that encourage innovation through the movement of knowledge and information between and among individuals and organizations. Minde *et al.,* (2015) gave examples where universities and other training institutions have established partnership programs that aim to link young people into training pathways in local industries and enhance their overall workplace knowledge, aptitudes and skills. These agricultural-related placements offer increased opportunities for graduates who will be self-employed or embrace start-ups that will offer employment to others along the CA value chain. They suggested that building agri-business career skills in the early stages of the educational system is of paramount importance for agriculture's contribution to national economies.

Priorities to support the implementation of CA education, training and skill development.

Four additional areas would need to be accepted as priorities to support and implement an effective CA education, training and skill development initiative across Africa. These are:

a. *Educational Management for CA Education, Training and Skills Development:* Educational management will need to show more entrepreneurship, courage, ambition and innovation ability (Mulder and Kupper, 2006) where CA is incorporated in agricultural education and training processes. The stakeholders of agricultural development are often many and diverse. Government agencies, NGOs and civil society organisations, local self-governments, banks and corporate sector each has a role to play in fomenting CA education, training and skills development. The major objective of the dialogue within and amongst stakeholders will be to engage in analytical thinking and consultations on understanding and diagnosing opportunities for practical sustainable agriculture interventions led by education, training and skills development (Davis *et al.,* 2017). More recently, under the aegis of ACT, cooperating partners, national and regional governments/ research and educational institutions, there has been an emergence of new mechanisms and cultures aimed at facilitating greater network formation. CA centres of excellence (CoEs) or communities of practice (CoPs) have been proposed and/or established as public research and/or training institutions dedicated to the goals and showcasing the widespread adaptation and adoption of CA (ACT, 2017; Mampholo, 2017).

b. *Information and Communication Technology (ICT) and Media:* Advances in ICT have opened new frontiers, not just in delivering learning content in new ways, but also in meeting the prevailing challenges related to sharing, exchanging and disseminating knowledge and technologies. Rasoanindrainy (2017) noted that on the continent, radio penetration is at 75%, mobile phone penetration rate at 43%, while mobile internet penetration is at 26%, with some African countries are advanced with internet users reaching more than 50%.

c. *Monitoring and Evaluation of CA Education, Training and Skills Development:* The activities, results and outcomes of CA education, training and skills development for agricultural transformation have to be monitored and evaluated to ensure that progress is being made and necessary adaptations are undertaken when the efforts are not on track. NEPAD's Agricultural Education and Skills Improvement Framework 2015 - 2025, recognises the need for quality assurance framework with appropriate monitoring and evaluation, self-assessment, accreditation mechanism, and dynamic development of training that responds to the different demands of various target groups. Furthermore, the Lusaka declaration of the First Africa Congress on Conservation Agriculture provides ACT with the mandate to handle quality assurance issues, accreditation and certification of CA training and education programmes in Africa. In this endeavour, ACT has advanced in the preliminary formation of the CA Training Accreditation and Certification Institute.

d. *Resource Mobilisation and Cooperation for CA Educational, Training and Skills Development:* A greater effort has to be made to mobilise domestic resources while better allocation and use must be a key element of the effort to close the educational resource gap in general and to direct resources to achieving agricultural transformation through CA-based investments. The long-standing target of devoting a minimum of 0.7 percent of GDP as international assistance for poor countries appears to have receded for many of the largest industrialised economies. Nevertheless, agriculture is the entry point for interventions in environmental protection in African countries. The large "environmental footprint" of conventional tillage agriculture continues to provide many avenues for environmental action. Environmental protection and climate change financing should be designed and utilised for education, training and capacity building as these provide synergy in objectives and strategies of enhancing skills and capacities while coping with vulnerabilities from land degradation and climate change; these being the tenets of CA. Resources could be deliberately devoted to incentives for CA teaching, training, action research, case studies, performance standards and assessment of CA work.

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Investing Across Institutions and Sectors for Widespread Adoption of CA Systems in Africa, with Emphasis on Mechanization and Commercialization

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Keywords: smallholder farmers, sustainable intensification, mechanization service providers

Introduction

The world is facing an unprecedented and continuing degradation of key components of agro-ecosystems, especially agricultural soils, with negative impacts on food production and future sustainability. In many developing countries, smallholder farmers are particularly susceptible to the consequences of soil and land degradation and the increasing variability and unpredictability of weather patterns caused by climate change. Yet, these very same farmers are of critical importance to producing food under these changing and challenging circumstances to meet the demand from growing populations (FAO, 2017), especially in towns and cities. There is a need to intensify agricultural production while sustainably managing, conserving and restoring natural resources. For farmers to transition to sustainable and resilient agricultural production systems it will be necessary to improve their knowledge of, and access to, appropriate farm power sources and equipment that are conducive to sustainable farming.

The United Nations' Sustainable Development Goals (SDGs), which frame development agendas until 2030, include SDG1 (No Poverty) and SDG2 (Zero Hunger) – the most important for improving the livelihoods of the rural poor. In addition, SDG12 (Responsible Consumption and Production) underlines the importance of protecting natural resources while producing sufficient nutritious food for the world's growing population. The sustainable production of food crops requires, amongst other crucial inputs, improvements in farm power, including the application of sustainable mechanization technologies to help slow, or reverse, the current trend of migration of rural youth to urban areas in search of employment opportunities.

Appropriate sustainable agricultural mechanization

Mechanization in African food and agriculture systems is desperately needed to meet many desired objectives including raising agricultural land and labour productivity, making rural employment more attractive, and achieving poverty reduction and development/growth agendas. This calls for governments to embrace mechanization along entire value chains – from production to post-harvest to processing and marketing operations – and at all levels including: technological, policy, institutional and organizational.

Smallholder farmers often do not have the necessary capital, either as savings or via access to financial credit, to invest in the expensive farm power and machinery that are essential for raising land and labour productivity. Moreover, poorly selected or misapplied agricultural machinery can damage, rather than enhance, environmental resources, especially soils.

Mechanization of Conservation Agriculture

Mechanization has a crucial role to play in enabling farmers to switch from unsustainable tillage-based systems to sustainable Conservation Agriculture (CA)-based systems. Close to 95% of the 180 million hectares under CA worldwide is large-scale commercial and mechanized farming (Mkomwa & Sims, 2018); while in Africa large-scale mechanized farms constitute about 70% of the farmed land. Under mechanized no-till direct seeding and weed management systems, CA offers advantages over conventional tillage systems in many ways. These include: (a) emergence of opportunities to rehabilitate and reclaim degraded lands; (b) timeliness of mechanized farm operations;

(c) increased cropping intensity by margins of 1.5 to 2 and; (d) cost savings from less wear and tear on machinery and reduced fuel consumption (Mkomwa and Sims, 2018). However, according to FAO & UNIDO (2008), the current level of mechanization in Africa is dominated by hand tools (65%) with animal and engine power sources contributing 25% and 10% respectively (Table 1).

Promotion and adoption of sustainable mechanization in Africa

Smallholder farmers require specialized mechanization services that are both environmentally friendly and productivity enhancing. Appropriately trained and equipped mechanization service providers can meet this critical need.

FAO with its partners (International Maize and Wheat Improvement Centre, CIMMYT, African Conservation Tillage Network, ACT, Conservation Tillage Research Centre, CTRC and others) have made efforts and invested in capacity building materials specifically designed to help train actual and potential farm mechanization service providers, in order to increase access to sustainable farm power and to raise the productivity of smallholder farmers. These efforts focus on two crucial aspects: the provision of farm mechanization services as a viable business opportunity for entrepreneurs; and the essential criterion of raising productivity in an environmentally sensitive and responsible way i.e. one that includes CA. Practical guidance on the essential business development and management skills required to successfully run a mechanization service provision business is presented, with a focus on the equipment required to offer services compatible with CA (FAO & CIMMYT, 2018).

It is foreseen that these training materials will also be of particular interest to policymakers' intent on achieving sustainable intensification in the agricultural sector. Today, in Africa, the need for investing in CA is widely accepted and, at the same time, it is perceived as intolerable that over 70% of smallholders in Africa are dependent on rudimentary hand-tools for working the land. Up-scaling CA means, in practice, mechanizing CA, and for that to happen it is important that private sector supply chains are supported to offer equipment and services compatible with the paradigm of sustainable intensification.

Of particular interest, especially in the context of smallholder farmers, is the issue of weed management in a scenario where ploughing is eliminated and therefore other means need to be explored. New developments indicate that, in the future, precision agriculture sensors will be able to detect weeds that could be then eliminated either mechanically or chemically with autonomous weeding robots. This technology could eventually constitute a real breakthrough in tackling weed management in smallholder systems (Sims, et al., 2018).

Besides building up sustainable mechanization supply chains, it is the capacity-building element that has to be the focus for supporting actions. Within rural areas of Africa, educated farm machinery operators are rarely available; there are very few training schemes for sustainable mechanization service providers and machinery operators. This is a key entry point where policies and investments need to start providing support and impact in order for widespread mechanized CA to prosper.

Policy dimension on Conservation Agriculture mechanization

The transformation of agriculture is a key strategic pillar of the African Union's Agenda 2063, the economic development blueprint for the continent. The 2014 Malabo Declaration of the African Heads of State and Government on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods was a renewal of their commitment. Commitment III of the Malabo Declaration on Ending Hunger in Africa by 2025 includes a resolve to accelerate agricultural growth by at least doubling current agricultural productivity levels, by that year. This calls for appropriate policy and institutional environments and support systems to facilitate sustainable and reliable production and access to quality and affordable inputs; supply of appropriate knowledge, information, and skills to users; efficient and effective water management systems notably through irrigation; increased development of controlled environment agriculture; and suitable, reliable and affordable mechanization and energy supplies, amongst others. Therefore, facilitating increases in agricultural productivity and strengthening food and

nutrition security through improvements in inputs, mechanization, and post-harvest management, remains a key priority for the AU and FAO (FAO & AUC, 2018).

The policy framework for sustainable agricultural mechanization is in place, what is needed is for the operational strategies to be adapted and cascaded down at national level.

Looking forward: Sustainable Agricultural Mechanization

Mechanization of agriculture in the modern era must be at the same time affordable, economically viable, environmentally friendly, and responsive to climate change challenges. The range of mechanization options available is on the increase and made more diverse with the eased access to information communication technologies.

The deployment of mechanization needs to be considered along complete value-chains; to include production, post-harvest, processing and marketing level requirements; and requires analytical consideration and inputs from political, economic, technical, social and environmental sectors.

Conclusion

Mechanization of agriculture is of crucial importance in Africa for a number of reasons including alleviation of drudgery, increase in labour productivity, and improved timeliness of farming operations, greater area under cultivation and the adoption of productivity enhancing innovations. CA and its associated mechanization confers resilience to smallholder farming systems in the sense that there is better toleration of environmental and economic stresses and shocks. This results in improved and more stable yields and profits, reduced use of inputs and better returns to investment. CA, along with other innovations such as controlled environment agriculture, also has the potential to improve rural livelihoods and stem rural-urban migration by creating new business opportunities in the agricultural sector.

However, there are constraints to the adoption of CA mechanization in sub-Saharan Africa due to the resource-poor condition of many smallholder farmers. The first step is to identify the constraints in a particular region and then to develop a strategic plan in response to them.

The best way to provide smallholder farmers with CA mechanization technology is through private sector mechanization service providers; which includes machinery manufacturers and suppliers, maintenance and repair services, extension support, access to finance and, technical and business skills training. Local manufacture of CA equipment should be encouraged and supported to ensure that equipment is best suited to local conditions. Governments' relevant departments' capacities need to be strengthened so that they play their vital roles in creating a level playing field that is not disadvantageous to local manufacture, and foster an enabling environment for facilitating acquisition of CA equipment by farmers and service providers.

It is recommended that African governments, the private sector, civil organisations and development partners substantially increase their strategic involvement and investment in advancing mechanization to deliver on the targets set out by the African Union's Agenda 2063 and the Malabo Declaration.

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Tables

Table 1: Regional farm power sources (percentages)

Region	Hand	Animal	Engine
Sub-Saharan Africa	65	25	10
Asia, Near East and North Africa, Latin America and Caribbean.	25	25	50

Source: FAO & UNIDO. 2008.

Sub-Theme 1: Mainstreaming of the CA Paradigm within Institutions, Sectors and Governments' Systems in Africa

Introduction

Mainstreaming of CA paradigm at the institutional and sectorial level and within governments' systems in bringing about the sustainable transformation of agricultural systems in Africa will set up an improved multi-level design, planning and implementation of CA in specific context and enhnace existing CA organisational landscape within different countries in Africa. Multi-sectorial approaches and active involvement of decentralised structure is one obvious success factor for widespread and sustainable adoption and management of CA systems.

The critical role of mobilizing institutional support from the public, private and civil sectors, and catalysing local and regional CA scientific and technological innovations and practices in overcoming adoption constraints is imperative and will definitely bolster the adoption in the region.

This sub-themes aims to address several issues pertaining the organizational landscapes in promotion and adoption of the technology. It attempts to answers many questions within the circles of promoter such as what are the experiences (insights and lessons) from efforts to unblock institutional factors hindering CA uptake; How can local decentralised institutions – public, civil society as well as domestic private sector be harnessed in mutual efforts to scale-up CA; Can traditional institutions and structures, such as chiefdoms, have any role in accelerating widespread and sustainable adoption of CA. What is the role and effectiveness of multi-sectorial alliances? What incentives do CA systems offer to all these constituencies and interest groups to attract their "energy" in scaling-up CA systems?

Under this sub-theme, 12 condensed papers were submitted and approved by the Scientific and Technical Committee after rigourous reviews. These papers are hereby presented as follows:

Challenges and Approaches to Mainstream Conservation Agriculture in Europe and Africa

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Keywords: Up-scaling Conservation Agriculture, Education, Advocacy, Policy

Introduction

Since the end of the last century the uptake of Conservation Agriculture (CA) globally has grown exponentially with a rate of almost 10 Million hectares per year. In 1999, the area under CA was around 40 Mha whereas an area of 180 Mha is reported for 2015/16. However, this adoption did not occur at equal rates throughout the different continents. It is especially in the New World continents where CA adoption has spread widely, with 85% of the global CA area being in South and North America and in Australia. In these three regions, CA has become a mainstream farming system with 63%, 28% and 46% of the cropland being under CA, respectively. On the contrary, in the Old World

continents, despite some growth in the uptake of CA in the recent years, adoption rates being reported are rather low, namely: 4.1%, 4.3% and only 1.1% of total cropland in Asia, Europe and Africa, respectively (Kassam et al., 2018).

Challenges to the adoption of CA in Europe and Africa

Conservation Agriculture has been promoted in both continents to address the combined problems of soil degradation and economic performance of farming. In the more recent years, CA is also seen as a promising approach to help mitigate and adapt to the impacts of climate change. Yet the process of up-scaling CA technologies lags far behind other regions in the world and the challenges encountered differ considerably between Europe and Africa. In Europe, these challenges range from the deeply embedded "tillage mindset", over to issues related with crop residues (e.g. too much to be handled by drilling equipment or delaying the warming-up of the soils in spring), the non-availability of suitable implements and inputs due to the lack of procurement, difficulties to control perennial weed infestation and some pests and diseases (e.g. slugs), the fear of yield losses in a highly productive farming environment and, increasingly, the pressure by opinion-makers and the public in general with regard to the perceived increase in the need of chemical weed control, namely the use of glyphosate (Basch et al. 2015; Friedrich et al. 2014; Soane et al. 2012).

In Africa, despite the general view that CA was capable of overcoming the severe soil degradation problems apparent all over the continent, and to improve livelihoods of resource-poor smallholders, the effective implementation of CA principles is lacking for several reasons. In many cases, especially smallholders often adopt only one or two of CA's three interlinked components, thus failing to establish CA systems and harness the full benefits of CA (Mazvimavi & Twomlow, 2009; Pannell et al., 2014; Ng'ombe et al., 2017). A recent analysis on the factors affecting adoption and intensity of CA techniques applied by smallholders in Zimbabwe (Kunzekweguta et al., 2017) comprehensively summarizes the major challenges for the uptake of CA that are certainly true for other regions throughout Africa. According to this analysis, the gender of the main decision maker of a household impacted significantly the CA adoption decision. CA promoted as a hand hoe technique is apparently less attractive to males (Farnworth et al., 2016). Farming experience seems to have a negative impact on CA adoption while farm size had a positive influence. The availability of draught power and tillage implements constrained the adoption of the three interlinked CA components, suggesting the dissemination of mechanised CA technologies to make those more attractive. The lack of access to farm inputs and service provision has also been identified as a significant constraint to CA adoption. Also, the greater the distance from public extension services, the lower was the intensity of uptake, whereas the access to advice from social networks increased the uptake of CA.

In fact, the successful adoption of CA is challenged often by specific regional or even local constraints of diverse nature. Whereas one could expect that farmers as end-users, but also other decision-makers or stakeholders would more easily surrender to constraints and refrain or desist from adoption, agricultural experts at least should be able to recognize the full picture and benefits of CA and make all reasonable efforts to endow CA and help make it work. Often however, it this latter group from where the major resistance to change arises due to the limited contextualized view and knowledge about CA.

Approaches and gaps to overcome challenges for scaling-up CA

Regarding the challenges encountered in Europe, the European Conservation Agriculture Federation (ECAF) has undertaken efforts over a period of almost 20 years to create a platform for information and knowledge exchange both within Europe but also with international institutions to accelerate and expand the uptake of CA systems in Europe, but also to identify and disseminate solutions to practical and technical challenges and to make CA work. This is achieved through an interactive exchange between ECAF and its national members, through participation in dissemination and demonstration projects (*e.g.* LIFE+Agricarbon (www.agricarbon.eu/), LIFE+Climagri (http://www.climagri.eu/index.php/en/), INSPIA (www.inspia-europe.eu/)), as well as in research projects of individual members of ECAF (e.g. iSQAPER (www.isqaper-project.eu/), INCAA (INnovative Conservation Agriculture Approaches).

In addition, and due to the fact that decision-making and developments in the agricultural sector in Europe is decisively guided by the Common Agricultural Policy (CAP). The European Commission (EC) has presented in June 1 the proposal for the Common Agricultural Policy (CAP) for the period 2021-2027 and its budget allocation. It is expected that 40% of the total budget of the CAP will contribute to climate action. Due to its proved contribution to climate change mitigation and adaptation, CA should play a major role in the coming scenario. ECAF is advocating CA practices close to political and institutional stakeholders and decision-makers at European level, such as the members of the European Parliament and the European Commission, but also at national level by supporting its national associations in advocacy actions and dissemination events. To pursue this purpose ECAF has published two reports on the role of CA. They are "Making Sustainable Agriculture Real in CAP 2020" (Basch et al., 2012) and "Making Climate Change Mitigation and Adaptation Real in Europe" (González-Sánchez et al., 2017)

Based on the existing memorandum of understanding for collaboration between ECAF and the African Conservation Tillage network (ACT), celebrated at the occasion of the 7th World Congress on Conservation Agriculture last year in Argentina, the common needs towards developing efforts to accelerate and expand the uptake of CA systems and practices in both continents could and should lead to joint approaches to enhance CA related education and training-learning capacity at systems and structural, organizational and individual levels. With regard to the practical and/or technical challenges mentioned above, ECAF and ACT should both encourage researchers to address these challenges in specifically dedicated projects and also actively participate. Together, ECAF and ACT should approach possible funding and development agencies and set up a list of topics to be addressed in future research programmes and calls for project proposal, and co-financed investment scheme, *e.g.* for mechanization.

Whereas at policy and institutional level advances have been made to bring CA as a promising farming approach on the agenda, a lot is still missing in education, training and extension at different levels. For this, education and training institutions will have to work hard to ensure that students and extension workers and farmers have an opportunity to educate or train themselves about CA at the theoretical and practical level. In this regard, available CA syllabus and educational material should be exchanged and adapted to regional and national conditions. Modern and innovative dissemination and e-learning tools could enhance the necessary knowledge exchange. Programmes and projects within the AU-EU High Level Dialogue on Science Technology and Innovation may be a source of resources to tap to achieve a close collaboration between Europe and Africa in their common goal to foster the uptake of CA. In this regard, it is timely for ACT and its partners, including ECAF, to launch at 2ACCA two important CA education related initiatives, namely: the pan-African initiative on CA curriculum development and the pan-African initiative on CA quality assurance.

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Conservation Agriculture Promotion and Ethiopian Government Engagement

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Keywords: extension, policy, scale-up

Introduction

The Government of Ethiopia has promoted anti-erosion measures and tree plantation activities mainly funded by the World Bank, World Food Program (WFP) and Food and Agricultural Organization since the 1973/74 drought (Berhe, 1996). At the same time, the establishment of a soil and water conservation (SWC) division within the Ministry of Agriculture and Livestock Resources (MoALR), focusing on drought prone areas, was the first initiative of SWC in modern Ethiopian history (Berhe, 1996). SWC activities and investment have continued in Ethiopia since the overthrow of the Derg Regime in 1991. The government of Ethiopia has made strong commitments and huge investment on SWC activities in its flagship Productive Safety Net Programme since 2005 (Andersson *et al*., 2011) and Sustainable Land Management Programme (SLMP) since 2008 with the support of World Bank and Global Environmental Facility (Nedassa *et al*. 2011). The MoALR has done soil mapping in the country and developed a soil strategy that aims to effectively and efficiently conserve soil and water resources.

Many successes have been recorded in minimizing soil degradation associated with the upscaling of programmes. However, despite these efforts, degradation of cropland in most part of Ethiopia continues, caused by the complete removal of crop residues at harvest, open grazing of livestock after harvests, intensive tillage and loss of topsoil (Girma, 2001). These conventional agriculture practices, with a minimum of three conventional tillage passes have led to 24.2 t/ha average soil loss in northern Ethiopia (Araya *et al.*, 2011).

Conservation Agriculture (CA) is important to reduce cropland degradation and increase land productivity (Araya *et al*., 2012). Since 2015, the CA Scale-Up Program of Canadian Foodgrains Bank (CFGB) has been promoting CA and its three principles (minimum soil disturbance, permanent soil cover and crop diversification) and integrated soil fertility management through non-government organizations (NGOs) in the Southern Nation Nationalities People's Region (SNNPR), Amahara and Benshangul-Gumuz Regions of Ethiopia. In 2017, these successes caught the attention of the Soil Fertility Improvement Directorate of MoALR, who subsequently requested CFGB's support to improve the execution of CA practices of the Ethiopian national and regional agricultural extension system to ensure long-term soil and crop productivity and to improve the livelihoods of farmers. This paper outlines this unique NGO-government partnership for the promotion of CA in Ethiopia.

Materials and Methods

CFGB and its partners have been implementing CA programming in close cooperation and engagement with government stakeholders and other state and non-state actors. CFGB believes in creating CA stakeholders' synergy in lower and higher levels in Ethiopia. The program has used the following key strategies to promote Conservation Agriculture and engage the Ethiopian government at all levels:

- Trained farmers in CA farming systems
- Conducted field day/demonstrations and invite key stakeholders
- Presented CA research and publications to decision makers and key stakeholders
- Organized panel discussions, debate forums and workshops at all levels of government
- Sponsored experience sharing/exposure visits (internal and international) for decision makers at the national and regional level
- Prepared policy briefs/review and dialogue with decision makers

- Produced and disseminated CA and CA related messages through radio programs in different languages
- Built capacity of agriculture and livestock resource ministries at federal, regional and woreda level including Development Agents (training, designing training modules, supporting MoALR by hiring technical person in CA)
- Established/strengthened network/platform with state and non-state actors on CA and agroecology

Results and Discussion

CFGB's CA scaling up program developed national CA implementation guidelines in Amaharic in cooperation with the African Conservation Tillage Network, MoALR and other like-minded organizations. Additionally, CFGB program staff have reviewed and contributed to the development of the climate smart agriculture field manual of SLMP of MoALR in the context of Ethiopia. About 400 MoALR staff from federal and five regions (Oromia, Amahara, Tigrai, SNNPR and Benshangul-Gumuz) participated in Conservation Agriculture training in 2017. Following the end of these training sessions, participants from four regions created Conservation Agriculture implementation plans for their regions. Over 21, 000 Ethiopian farmers have been trained in CA concepts and practices through workshops, farmer field days, and farmer-to-farmer exchanges since 2016. Over 18,000 trained farmers have started practicing CA on plots ranging from 20 X 20 meters to a half hectare. The number of CA practicing farmers are growing from time to time as they have observed benefits of CA over conventional farming system particularly on saving soil moisture, reducing erosion and increasing crop yield.

The CFGB CA hub joined forces with the Ethiopia Agroecology Platform to create a bigger network comprising local and international NGOs, government, universities, research centers, and the private sector to facilitate national and regional learning and collaboration. CA messages have also been disseminated through radio stations in three local languages with a reach of over 500,000 listeners in three regions (Amahara, SNNPR and Benshangul-Ggumuz).

The CA Scaling up programme has continued working on development and dissemination of CA training modules, radio messages, posters and videos to enhance training and engage famers and government extension staff. It has been expanding training of Ethiopian farmers in CA farming systems and strengthening networking of state and non-state actors on CA and agroecology in different levels. It plans to host national level trainings for MoALR staff to outline basic CA principles and their relevance for Ethiopia and address misconceptions, and to host conferences for Ethiopian government staff, researchers, and implementing agencies to share research results and practical experiences related to CA in the context of Ethiopia. The programme also plans to facilitate more exposure visit for Ethiopian national and regional government MoALR staff to existing CA sites to demonstrate the potential of CA in Ethiopia, and to develop and disseminate a case study of successful government CA adoption in Benishangul Gumuz, where the regional government is seeking to expand CA adoption.

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Alternative Adoption Pathways for Conservation Agriculture in Smallholder Systems in Africa

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Key words: adoption pathways, smallholder farmers, sustainable intensification

Introduction

There are several conceivable pathways towards Conservation Agriculture based sustainable intensification (CASI) of smallholder systems in Africa. However, these invariably involve one tradeoff or the other. For example, to sustain the agricultural resource base may call for expending some resources today and foregoing short term consumption in order to invest in long term soil health. Alternatively, policies that subsidize inputs in the short term must contend with the potential to crowd out investments in agricultural research and extension. While, markets are key to providing incentives for CASI, care must be taken to ensure that market based promotion of CASI adoption remains inclusive and preserves the tenets of equitable development. The multiple pathways towards CASI have to be evaluated based on these kinds of tradeoffs. One pathway can be through subsistence-based incentives where the pursuit of food security through own production drive CASI investments, especially where markets are thin. Opportunities afforded by new market outlets can also make the sale of staple crops such as maize and legumes more profitable making CASI more attractive and adoptable. In this paper we demonstrate some of the pathways that can lead households to sustainably use CASI technologies.

Materials and Methods

Broadly, the research results reported in this paper are based on various analyses that used household and plot-level data gathered under the sustainable intensification of maize legume systems for food security in eastern and southern Africa (SIMLESA) program as well as a collaborative project named the Adoption Pathways Project[2]. The broad aim of these data was to generate information on micro and macro drivers of CASI adoption such as farmers' resource conditions, community characteristics, gender relations, value chains and policies. Through econometric estimation (and post estimation simulations following probit and switching regression models), these data were used to identify key factors that were seen as likely to drive CASI adoption, especially from policy perspectives. In the results section that follow, three policy relevant pathways were identified.

[2] The Adoption Pathways Project formally known as Identifying socioeconomic constraints to, and incentives for, faster technology adoption: Pathways to sustainable intensification in Eastern and Southern Africa and was meant to complement the work in SIMLESA project The project ended in June 2016. The data from this project are now available in Open Access at http://data.cimmyt.org/dvn/dv/cimmytdatadvn/faces/StudyListingPage.xhtml?mode=1&collectionId=119

Results and Discussion

Subsistence based pathway: households having access to land and labor but limited access to agricultural markets: Evidence that this pathway is possible or even inevitable can be seen from a number of SIMLESA research results which have shown that household food security is tied to own-production. The results from Kassie, et al. (2016) showed that increases of 27%, 29%, 50% and 7% in Kcal, protein, iron and diet diversity (respectively) were possible when crop diversification was adopted jointly with improved maize varieties. These effects were especially manifest when modern seeds and maize-legume diversification occurred simultaneously (see also Hailemariam et al. 2013). This suggests that for many rural households, access to agricultural and labor markets are not the primary means of procuring food. Their food security and nutrition depends on autonomous production and crop diversification at the household level. The emphasis on crop diversification within CASI is important in this respect.

Commercial food crop pathway: through access to modern and structured markets: In areas with good infrastructure and market access, opportunities for the commercialization of food crops can be high. Diversification into relatively high value, nutrient dense legumes can support high returns to production and incentivize CASI. However, this requires good market access in order to minimize transaction costs and make the CASI technologies economically attractive. Some evidence has shown that households who were located close to markets were more likely to be net sellers of maize (Marenya et al. 2017a). It has also been reported that those farmers close to markets were more likely to implement CASI practices. Farmers who had off farm wage income or off-farm self-employment were less likely to have adopted minimum tillage and mulching as a practice in Ethiopia. Yet in Tanzania those who had non-farm self-employment were less likely to have minimum tillage on their farms. Implicitly, significant increases in yields and incomes are needed to attract more family labor to be used on their own farm production activities.

Policy and institutional pathways: The role of extension institutions: We simulated two main policy aspects involving extension and fertilizer subsidies (Table 1). The impact of extension personnel to farmer ratio (EFR) on the predicted adoption of minimum tillage combined with mulch was high across all countries (Table 1). In Kenya, the probability of adoption increased from 3.9 to 6.5 percent by increasing the EFR from 10 to 16[3]. Similarly, given the EFR increase from 6 to 16 in Malawi and 4 to 16 in Tanzania the probability of adoption increased from about 34% to about 50% in Malawi and from 10% to 21% in Tanzania.

In Table 1, we also report simulation results of what happens to adoption when extension is reduced (by setting it at the lowest level of 4 which was observed in Tanzanian) and at the same time increasing proportion of agricultural budgets allocated to input subsidies to Malawi's level of 58.9 percent (which was the highest). The results suggest the powerful impact of subsidy expenditure ratios (SER) on probability of adoption. Despite the 75% reduction of EFR in Ethiopia, the probability of adoption increased by about 4 percentage points (from 26 to 30 percent), due to increase in SER, showing the compensatory effects of subsidies on CASI adoption even under low EFR.

Conclusions and policy implications

The results suggest that lowering the costs of inputs is central to encouraging adoption of CASI practices. Since the learning and adaptation costs of CASI technologies can be a major barrier to their adoption, diverse options for lowering these costs should be put on the policy table, including short term subsidies that effectively reduce the prices of inputs considered complementary to CASI. Investing in agricultural extension systems by increasing the number of extension personnel (lowering the extension personnel to farmer ratio) and expanding the reach of publicly funded extension systems (among other providers) are important in the success of CASI. These policies would be needed to support both the subsistence- and the market-led pathways. Policy attention in support of CASI should therefore remain focused on better access to markets, solid information delivery through strong agricultural extension and

[3] EFR of 16 was observed in Ethiopia, the highest among the four countries. This level was used to simulate the effects of increasing EFR on adoption in the other countries.

creating the right policy conditions and physical infrastructure to produce favorable input and output price ratios and therefore raising the economic incentives for CASI adoption.

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Tables

Table 1: Extension Simulations

Predicted probability of CA Adoption by sample					
Panel I: Effect of increasing extension Staff to Farmer Ratio (EFR): for each country set EFR at Ethiopian level					
EFR level	Whole sample	Ethiopia	Kenya	Malawi	Tanzania
At respective country means (**A**)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
At Ethiopian mean (**C**)	0.214*** (0.019)	NA	0.065*** (0.013)	0.498*** (0.067)	0.214*** (0.057)
Chi-square tests					
A=B	NA	8.60**	7.09**	6.0**	4.61**
A=C	5.47***	NA	4.47**	5.91**	4.10**
Panel II: Effect of low EFR and high SER: For each country set EFR Tanzania's level and SER at Malawi's level					
EFR / SER level	Whole sample	Ethiopia	Kenya	Malawi	Tanzania
SER and EFR set at respective country means (**A**)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
At Tanzania's EFR *and* Malawi's SER (**B**)	0.213*** (0.023)	0.301*** (0.037)	0.092*** (0.029)	0.308*** (0.014)	0.142*** (0.019)
Chi-square tests					
A=B	3.85*	1.31	3.60*	6.50*	5.62*

Long-term Demonstrations for Accelerated Conservation Agriculture Adoption; Casestudy of Mbeya, Tanzania

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Key words: Crop rotation, no-till, profit, reduced tillage

Introduction

Conservation Agriculture (CA) that is built on the three interlinked principles of no-till or reduced or minimum soil disturbances, maintaining a permanent organic soil cover; and diversification of species with crops in associations, sequences or rotations is observed to be the solution to sustainable crop production. Although it has numerous benefits economically, socially and environmentally, its adoption in sub-Saharan Africa and Africa in general is reported to be low particularly for smallholder farms (Corbeels *et al*., 2015). Among the factors for low adoption include limited access to inputs (including no-till equipment), competing uses for crop residues, and the need for knowledge and capacity building on CA technologies. Efforts to evaluate and promote CA by Agricultural Research Institute (ARI) – Uyole started in 1999 through on station and on farm demonstrations (Shetto and Owenya, 2007). However, adoption of CA among the surrounding communities was observed to gain a steady increase around the year 2010. Survey results to assess adoption of CA for farmers surrounding the institute have indicated steady increase in number of farmers using CA technologies in crop production at the rate of 65.5%, 55.2 and 51.7% for 2017/18, 2016/17 and 2015/16 cropping seasons respectively. On the other hand, findings revealed that maize and beans production cost are low under CA with increased yield that leads to increased profit under CA practices. Most respondents reported that their shift to use of CA technologies is mostly influenced by stable as well as increased yields of crops, reduced cost of production and decreased diseases infestations.

Materials and Methods

Evaluation of CA technologies started in 1999 by on station evaluation of various tillage methods and cover crops. Main test crop was maize, currently involving maize and beans. The study was undertaken to assess adoption rate of CA technologies among smallholder farmers surrounding TARI – Uyole research institute. Various farming stakeholders involved in crop production surrounding the institute were involved in sharing their experience in crop production. A total of 58 (18 female) respondents were involved in the survey out of about 120 households that surround the institute and involved in farming. A combination of methods and tools including individual and semi structured questionnaire, group interviews and open meetings were used to collect information on CA around Mbeya municipal. Simple statistical analysis was done using SPSS software.

Results and Discussion

Proportion of farmers producing crops using CA technologies: Table 1 shows percentage of farmers producing crops using CA technologies. Results show that beans and maize were the most crops grown using CA technologies of reduced tillage that involved opening of planting furrows and holes on unploughed land using ox-rippers and hand hoe respectively, crop rotation and retention of crop residue in the last three growing seasons. Findings also revealed increased adoption rate of CA technologies at the rate of 52, 55 and 65% for 2015/16, 2016/17 and 2017/18 cropping seasons respectively. Most of the respondents reported reduced cost of production, stable and increased yields as well as reduced diseases infestations especially in beans productions to be their reasons for adoption of CA technologies. Increased per day labour cost from 2.5 USD to 3.2 USD from 2013/14 cropping season have resulted to adopt CA technologies by most farmers. However, most of the respondents indicated to practice reduced tillage and crop rotation, permanent soil cover observed to be difficult. High price of beans straw and feeding of maize stover to livestock in the area is observed to be challenging with regard to maintaining organic soil cover.

Maize and beans production benefits under conventional and CA practices: Results on maize and beans production under conventional and CA practices are shown in Table 2. Results shows that CA is more profitable compared to conventional means of production. With regard to beans production profit, findings indicated that the profit was more than two times higher in CA (USD 917.4) as compared to conventional practice (USD 376.3). Results also showed high profit of three times under CA (USD 526.9) compared to conventional practice (USD 176.6) in maize production. Such high profit was as a result of reduced cost of production and increased yield under CA that was reported by most respondents to be the result of timely production operations. Reduced production cost and increased crop yields were reported in the southern Highlands of Tanzania and southern Uluguru Mountains under CA technological options (ARI – Uyole 2003; Mwakimbwala *et al*., 2013; Mlengera *et al*., 2018).

Source of CA education: Respondents mentioned different sources of CA knowledge (Table 3). Most of them (78.9%) mentioned TARI-Uyole as the main source of CA technologies. Other sources are internet, different writings and learning in school/college/universities.

Conclusions and Recommendations

Programmes to promote CA technologies should be consistent and long term in order to build trust among smallholder farmers. Increased cost of production under conventional farming as well as labour and time saving associated with practice of CA technologies are observed to be the drivers for adoption of Conservation Agriculture.

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Tables

Table 1: Crop production percentage under CA in the last three years

Cropping season	Crops	Frequency (N=58)	Percentage
2015/16	Maize	11 (10)	19 (17)
	Beans	18 (17)	31 (29)
	Ground nuts	01 (01)	02 (02)
	Total	30 (28)	52 (48)
2016/17	Maize	10 (07)	17 (12)
	Beans	22 (19)	38 (33)
	Total	32 (26)	55 (45)
2017/18	Maize	13 (06)	22 (10)
	Beans	23 (14)	40 (24)
	Ground nuts	02 (00)	03 (00)
	Total	38 (20)	65 (35)

Note: Numbers in brackets represent non CA adopters

Table 2: Costs of beans and maize production under Conventional and CA practices

Operations	Beans production cost (USD/ha)		Maize production cost (USD/ha)	
	Conventional practice	CA practice	Conventional practice	CA Practice
Land preparation	65.2	86.2	56.8	32.5
Ploughing/Ripping	66.6	33.8	71.2	25.6
Harrowing	41.4	-	45.5	-
Fertilizer	93.2	93.2	204.6	204.6
Seeds	113.6	142.1	47.7	54.6
Planting	80.5	80.2	75.1	93.9
Weeding	78.3	56.4	92.1	62.9
Control of insect pest	51.6	30.2	34.7	24.3
Harvesting	62.2	59.9	61.0	85.2
Total production costs	652.7	623.5	688.7	583.6
Yield (t/ha)	1.5	2.3	5.6	7.1
Total revenue	1,029.0	1,540.9	865.2	1,110.6
Profit	376.3	917.4	176.6	526.9

Table 3: Sources of CA knowledge by respondents

Source	Frequency	Percent
ARI Uyole	30	78.9
Internet	02	5.3
Different reading materials	03	7.9
Schools, college /university	03	7.9
Total	38	100.0

Malawian Farmers Still Produce Less with Farm input Subsidies: Impact of Low Adoption of Climate Smart Agriculture Approaches

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Keywords: Farm inputs, subsidy, agroforestry, maize, extension, policy

Introduction

Maize is major staple for Malawi and accounts for 60% of total calories consumed (Denning et al., 2009). Although this is strategic crop the country has persistently experienced low yields as a result of continuous mono cropping, low use of chemical fertilizers (Akinnifesi et al., 2006; Ngwira et al., 2012), use of poor yielding varieties that are not drought resistant and early maturing (Denning et al., 2009; Fisher and Snapp, 2014; Smale, 1995). These problems have been compounded by low adoption of good agriculture practices aimed at improving soil structure and texture (Place and Otsuka, 2001; Smale et al., 1995). To improve outreach and increase production, the Ministry of Agriculture adopted the pluralistic demand driven extension approach in 2000 aimed at decentralizing extension services. In addition, government has made heavy investments in farm input subsidy program (FISP) since 2005 (Chibwana et al., 2012). There is a strong belief that combining FISP with Climate Smart Agriculture (CSA) approaches would be very critical in achieving sustainably high yields in Malawi. This paper looks at the impact of the pluralistic extension approach where there has been little investment versus the farm input subsidy program that has had heavy financial investments.

Methodology

Study area

Malawi has a total surface area of about 11.8 million hectares of which 20% are water bodies and a population of over 17 million (Li et al., 2017). Agriculture land accounts for 61.4% of the total land area (FAOSTAT, 2015). More than half 57.4% of Malawi's total agricultural land exists on marginally suitable land categories and is likely a candidate for rehabilitation through good agriculture practices (Li et al., 2017). Up to 70% of cultivated land is allocated to maize production (Smale et al., 1995).

Scaling up CSA

The Ministry of Agriculture adopted the pluralistic demand-driven extension policy in 2000. With government still having the largest presence in terms of extension staff on the ground (Masangano and Mthinda, 2012). For this study data on adoption of good agricultural practices (including Conservation Agriculture) was sourced from Department of Land Resources Conservation annual reports. Promotion of CSA where mostly Conservation Agriculture has been key is the core government policy direction as regards sustainable agriculture in Malawi. Entry point to CA in Malawi is reduced tillage which is followed by gradual mulching and usually crop associations. Most farmers adopt parts of the CA principles as opposed to the three principles due to limited biomass to cover fields and small land holding sizes to allow for crop rotation.

Total Factor Productivity (TFP)

As a quick solution to reduced yields the government re-introduced FISP in 2005 (Lunduka et al., 2013). Data on crop yield (maize) since FISP was introduced was extracted from the FAOSTAT website. Annual FISP evaluation reports were used to come up with data on quantities of inputs (seed and fertilizer) used in each year.

Results and discussion

The farm input subsidy policy in Malawi has not been aligned to CSA promotion efforts resulting in low adoption of the technologies (Figure 1) and a declining TFP from the FISP investment (Figure 2). In addition, financial investment in the pluralistic demand driven extension policy has been low hence not benefiting from the local research that has shown increased yields under CSA approaches like agroforestry and Conservation Agriculture (Masangano et al., 2016). Yields of up to 3 t ha^{-1} without applying any mineral fertilizer have been achieved under agroforestry and the harvest jumps up to 4 t ha^{-1} when a quarter dose of fertilizer is applied (Akinnifesi et al., 2010). The fertilizer trees add more than 60 kg N ha^{-1} $year^{-1}$ through biological nitrogen fixation (BNF); this reduces the need for mineral N fertilizer by 75% (Akinnifesi et al., 2007; Akinnifesi et al., 2010). Ngwira et al. (2012) reported yields of up to 4.5 t ha^{-1} where maize under CA was inter-planted with Lablab (*L. purpureus)* or pigeon peas (*C. cajan*), compared to 4 t ha^{-1} of maize under CA only and 2.4 t ha^{-1} under conventional practice. On the other hand, Ito et al. (2007) reported similar yields of 5 t ha^{-1} under conservation tillage. Other than increase in use of fertilizers, high TFP in crops is achieved through the use improved varieties and good land husbandry practices (Zeigler and Steensland, 2015). This shows that improved institutional, policy environment and investments for scaling up CSA are critical to realize high crop yields in Malawi.

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Figures and Tables

Figure 1. Total hectares under CA in Malawi. Source: Ministry of Agriculture Irrigation and Water Development (2014)

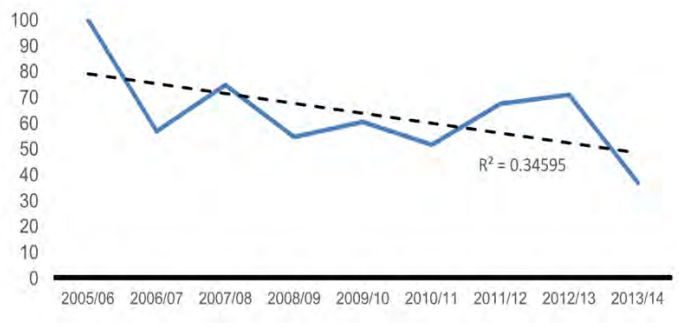

Figure 2. Maize Total Factor Productivity since reintroduction of input subsidy, 2005-06 = 100 (base year). Data from FISP annual reports and FAOSTAT (2015)

Effect of Conservation Agriculture Planting Methods on Increasing Yield of Maize: The Case of Southern Highlands Tanzania

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Keywords: direct seeding, field capacity, jab planting, ox ripping, tractor ripping.

Introduction

Conservation Agriculture (CA) is currently widely recognized as a viable approach for sustainable agriculture due to its potentially comprehensive benefits of economic, environmental, and social sustainability. In response to the aforesaid, Tanzania Agriculture Research Institute (TARI) at Uyole Centre initiated intensive research on CA technology practices since 1999. The research started on-station and widened the geographical coverage of CA trials and promotions on-farm from two to 18 villages (Mkomwa *et al*., 2007) in Southern highlands of Tanzania. An on-station study was undertaken to evaluate influence of CA planting methods on labour, weed and maize yields The study results show that use of tractor ripper, ox-direct seeder and ox-ripper had high yields of 8.5, 8.5 and 7.6 t/ha respectively compared to hand hoe (4.7 t/ha).

Materials and Methods

This paper is based on the findings obtained from on-station demonstrations undertaken for the cropping season 2016/17. The study evaluated five planting methods that are hand hoe, jab planter, ox ripping, ox-direct seeding and tractor – ripping arranged in a randomized complete block design replicated three times. The main crop was maize planted at a spacing of 0.75 x 0.3 m, di-amonium phosphate (DAP) basal fertilizer 60 kg P/ha and urea was top dressed at the rate of 120 kg N/ha in two splits. Weeds were controlled by herbicides. Data collected included agronomic data, time for operations and maize grain yield and were analysed using Genstat software (V13).

Results and Discussion

Generally, significant effect was observed regarding to the planting methods on agronomic characteristics of maize planted under CA (Table 1 and Figure 1).

Field capacity (ha/hr). Results in Table 1 show that significant effect was observed on field capacity and plots planted using tractor drawn ripper ranked first (0.19 ha/h) followed by plots planted using ox drawn ripper (0.12 ha/h) and direct seeder (0.12 ha/h). Jab planter ranked the least (0.03 ha/h).

Labour input (mandays/ha). Table 1 shows that there was significant effect on labour requirements for treatments tested. Ox-direct seeder was observed to be more labour saving (3.12 mandays/ha) followed by jab planter (4.44 mandays/ha) as opposed to hand hoe that recorded 18.47 mandays/ha.

Grain yield (t/ha). Highly significant (P>5%) effect was observed on grain yield. Plots planted using ox drawn direct seeder and tractor drawn ripper recorded higher maize grain yield followed by ox drawn ripper (Fig 1).

Weed weight (t/ha). Figure 1 shows that direct seeding by jab planter and ox direct seeder recorded low weed weight with high grain yield compared to other methods.

Conclusions and recommendations

It is concluded that direct seeding using ox direct seeders and tractor ripper in Conservation Agriculture improves crop yields and greatly reduces weed infestation.

It is recommended that:

- More farmers should be capacitated to continue practicing CA technologies e.g. direct seeding on a gradual tone up to when they gain full capacity.
- Combined effort among different stakeholders needs to be strengthened for sustainable adoption of CA.
- Policy makers and the higher Government authorities should strive develop mechanisms that support CA initiatives (policy and finance) for wider adoption of tractor seeding.

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Tables and Figures

Table 1. Effect of planting methods on biomass at planting, field capacity and labour input at TARI Uyole

SN	Treatment	Biomass at planting (t/ha)	Field capacity (ha/hr)	Labour input (mandays/ha)	Weed weight (t/ha)	Grain yield (t/ha)
1	Hand hoe	15.4	0.05 c	18.47 a	2.84	4.7 d
2	Jab planter	18.0	0.03 c	4.44 c	2.05	6.8 c
3	Ox ripper	15.9	0.12 b	7.5 b	5.55	7.6 b
4	Ox direct seeder	13.4	0.12 b	3.12 d	3.51	8.5 a
5	Tractor ripper	14.1	0.19 a	7.5 b	5.61	8.5 a
	Grand mean	15.4	0.10	8.22	3.91	7.253
	CV (%)	30.7	11.3	21.7	28	2.9
	LSD	ns	***	***	Ns	***

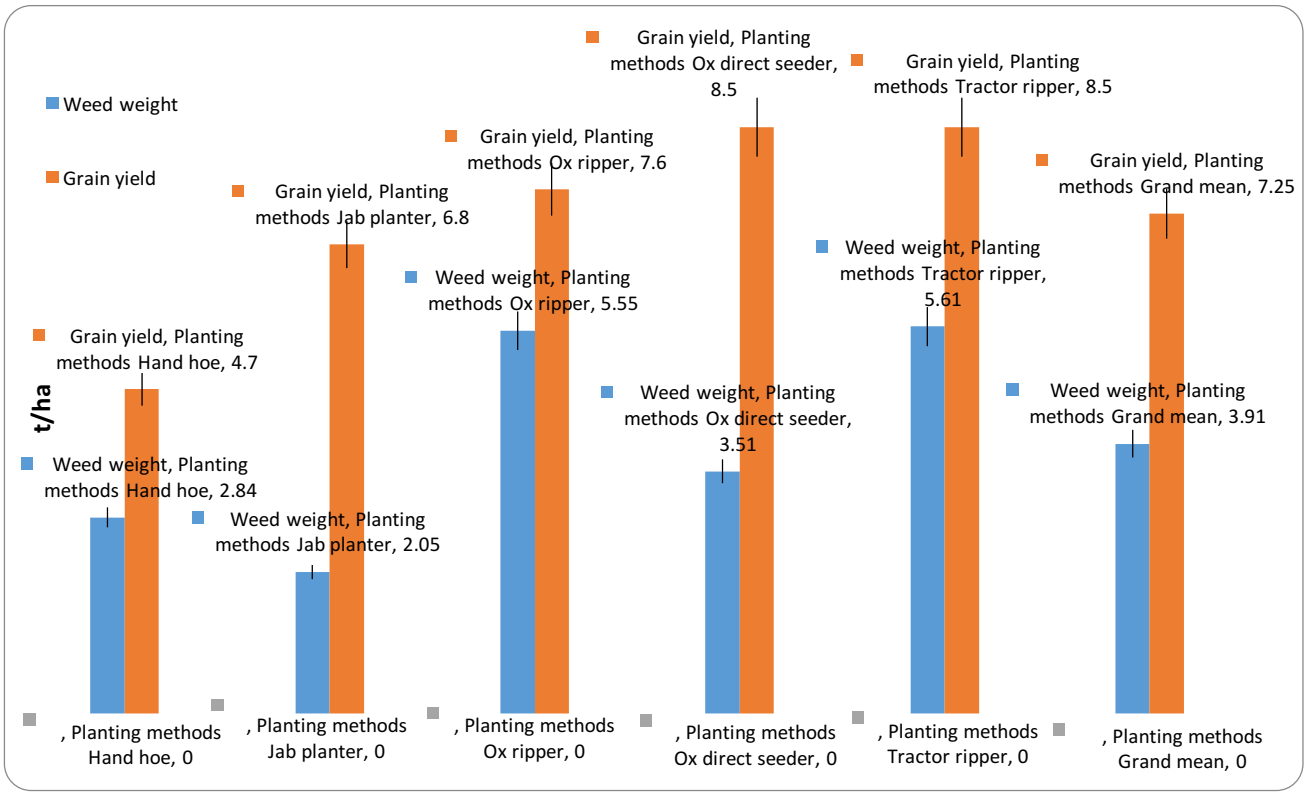

Fig.1.Effect of planting methods on weed weight and maize grain yield at TARI-Uyole

Annexes:

ARI-Uyole Trail Pictures

The project managed to lay a trial to evaluate five planting methods in a randomized complete block design replication three times.

Opening planting holes using hand hoe (left) and performance of crop in the same plot (right)

Ox-ripping (left) and performance of crop in the same plot (right)

Ox-direct seeding (left) and performance of crop in the same plot (right)

Planting using Jab planter (left) and performance of crop in the same plot (right)

Opening planting furrows using tractor drawn ripper (left) and performance of crop (right)

Tillage Effect on Agronomic Efficiency of Nitrogen under Rain-fed Conditions of Tanzania

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Keywords: sustainable intensification, Conservation Agriculture, N application rate, maize yield, soil fertility

Introduction

Nitrogen (N) deficiency is a major limitation to achieve sustainable intensification on smallholder farms in sub-Saharan Africa. This is mainly because soils have been cultivated for decades with inadequate nutrient inputs coupled with the high nutrient demands of crops such as maize resulting in nutrient mining (Smaling *et al.,* 1997). Chemical fertilisers are a key component of improved crop production technologies along with legume crops in the cropping system. Yet in this region the use of synthetic fertilisers often below optimum due to differences in both micro and macroeconomic conditions. The risk of crop failure resulting from low rainfall is a strong disincentive to the purchase and use of fertilizers on the subsistence crops often grown by farmers. Thus, strategies are needed to increase the use efficiency of the little fertilisers that smallholder farmers regularly apply, by overcoming the biophysical limitations exerted by erratic rainfall and degraded soil fertility. In the past decade, considerable effort has been invested in research and out-scaling of Conservation Agriculture (CA) as the most suitable sustainable intensification (SI) option farmers could readily utilize. In this study we assess the short-term effects of cropping system and soil type on the N agronomic use efficiency over two seasons (2014 and 2015) and in two locations in Tanzania. The underlying hypothesis is that cropping systems based on a combination of chemical fertiliser and *in-situ* organic mulch cover increase agronomic N use efficiency and may be a pathway to achieve sustainable intensification for resource-constrained smallholder farmers cultivating maize under rain-fed conditions.

Methods

The on-station experiment was carried out at Selian Agricultural Research Institute (SARI) Arusha (03º 22′ S, 36º 37′ E and an altitude of 1387 m above sea level) and the on-farm study was established in Mandela village, Mvomero district (06º 22′ S, 38º 42′) over two seasons in the long rains of 2014 and 2015. Both sites have a mean annual temperature of 25ºC and a mean annual rainfall of between 1000 and 1500 mm. The experiment consisted of two tillage systems i.e. conventional tillage (CT) and CA, with a minimum of 2.5 t ha^{-1} crop residue cover was maintained in the plots during the experiment. CT consisted of soil inversion through tillage and removal of crop residues. In the on-farm experiment, maize was grown in plots with four rates of N application i.e. 0, 27, 54 and 108 kg N/ha. In the on-station trial, 5 rates were considered i.e. 0, 20, 40, 60 and 100 kg N/ha. Maize was planted at a spacing of 75 cm between rows and 30 cm within rows to give a plant population of 44, 444 plants/ha. All plots received a basal fertiliser application of 40 kg P and 20 kg K/ha. The plots were kept weed free by using the hand hoe for weeding in the CT plots, and the use of 2.5 l/ha glyphosate (N-phosphono-methyl glycine) at planting in the CA plots. A generalized linear model (GLM) was fitted to assess the effect of N rate, tillage and site on maize grain yield. AE-N, a parameter representing the ability of the plant to increase yield in response to N applied, was calculated using the formula $AE\text{-}N = (GY_f\text{-}GY_u)/N_a$, where GY_f is grain yield of fertilised maize, GY_u is grain yield of unfertilized maize, and N_a is the amount of N applied.

Results

Maize yield increased significantly ($p < 0.001$) with increasing rate of N application, and also depended greatly on the tillage method used across the sites. Similarly, site as defined by soil fertility status was also highly significant ($p<0.001$) on maize grain yield. In the on-farm trials, AE for CT in sandy soil was low; it ranged from 3.7 kg/kg N to 13.2 kg/kg N but was high in the CA treatment i.e. 20.2 to 77 kg/kg N (Table 1). In the clay soils, the differences between tillage practices were small. Under CT, AE ranged between 21.6 to 53.9 kg/kg N, and it was 20.4 to 60.6 kg/kg N under CA. The lowest fertiliser application rate of 27 kg/ha often had the largest AE across the soil types and tillage practices. In the on-station trials at SARI, the largest AE of 24.6 kg/kg N was recorded under CA with 40 kg N/ha (Figure 1). As in the on-farm trials, the highest N application rate on-station did not lead to the largest AE. In the CT, AE ranged between 11.5 and 16.8 kg/kg N compared with a range of 15.1 to 24.6 kg/kg N for the CA treatment.

Discussion

Results suggested that a combination of crop residues retention and no-till can improve agronomic efficiency of applied N, and that the initial soil fertility status is important in determining the magnitude of crop response to applied nutrients. It is likely that the crop residues in the CA treatment increased rainfall infiltration and also reduced water loss from the soil through evaporation (Hussain et al., 1999) thereby improving nutrient uptake by the crops. In the long-term, the consistent retention of crop residues may also increase soil organic carbon, providing another opportunity for improved nutrient use efficiency. However, crop residues may also immobilize N resulting in deficiency especially in the short term. The N response results reported here are in agreement with similar research which has shown a larger response to added nutrients in poor soils than in fertile soils and that a combination of chemical and organic inputs was the best strategy to increase productivity (Chivenge et al., 2011). However, some soils maybe naturally fragile, extremely sandy, and P-fixing leading to challenges for increased nutrient use efficiency (Chikowo et al., 2010). As a result, crop responses to added nutrients vary widely due to the wide diversity in biophysical and management practices. Results from the more fertile soils suggest that nutrient management in these soils should be aimed more at replenishing nutrients taken up by the plant to increase sustainability. Crop residues retention is a promising strategy to increase nutrient use efficiency - the challenge for small-scale farmers is how to produce and retain sufficient maize residues in light of the persistent low productivity and the competition for feed with livestock (Rusinamhodzi et al., 2015). Thus, innovative pathways are needed to meet the multi-objectives of crop residue use for sustainable crop production.

Conclusion

Our hypothesis that crop residues retention in combination with no-tillage (CA) maybe a pathway to improve agronomic use efficiency of N for small-scale farmers under the rain-fed conditions of Tanzania was supported. The initial soil fertility status is also important in determining the magnitude of short-term crop response to applied nutrients. Innovative pathways are needed to achieve the multiple objectives played by maize crop residues for results reported here to be sustainable. However, efficiency of nutrient use needs to be assessed together with returns to investments as small yields may mean high nutrient use efficiency but not necessarily significant increased returns at the farm level.

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Graphs and Tables

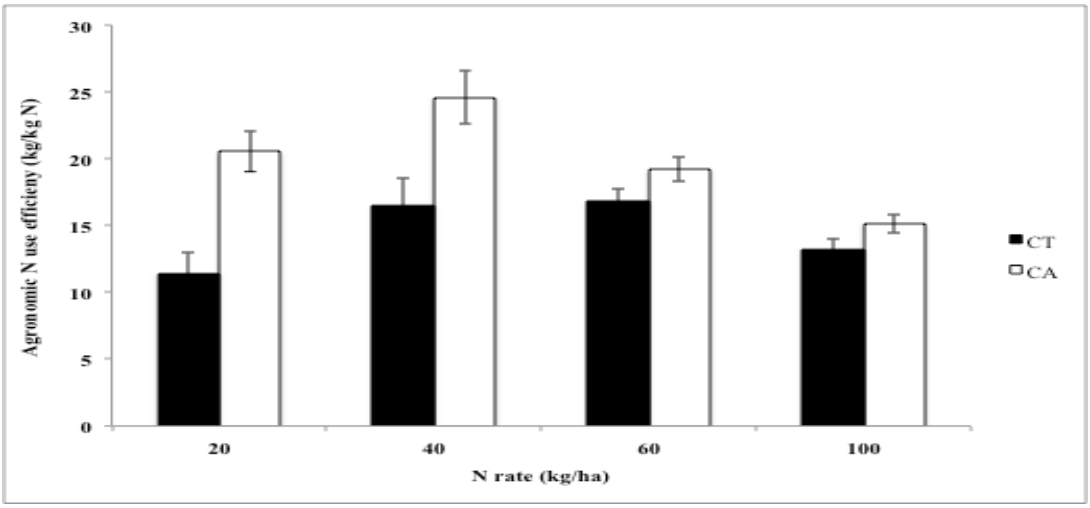

Figure 1. Average agronomic N use efficiency with increasing rates of N application at Selian Agricultural Research Institute, Arusha, Tanzania in 2014 and 2015.

Table 1. Average N agronomic use efficiency as affected by increasing N application rates, soil type and tillage method in an on-farm experiment at Mandela village, Kilosa, Tanzania**.**

N applied kg/ha	Agronomic efficiency (kg grain/ kg N)			
	Sandy soil -low fertility		Clay soil - high fertility	
	CT	CA	CT	CA
27	13.2	77.0	53.9	60.6
54	3.7	47.5	37.7	37.7
108	10.1	20.2	21.6	20.4
Standard error	2.3	13.4	7.6	9.5

Smart Agriculture from a Sudanese Perspective

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Keywords: threats, impediments, indigenous cultural practices

Introduction

In Sudan, agriculture and livestock production are the main sources of livelihood for more than 70 percent of the population. Agricultural production is practiced under three major production systems. These are: irrigated, rain fed semi-mechanized and rain fed traditional production systems. The total farmed area is 19.5 million hectares, or about 7.8% of the country. The arid and semi-arid zones cover the largest part of the of the rain-fed production systems (Malik et al., 2013). Most lands in Sudan especially in the northern and western regions are threatened by desertification and it has been classified as moderately to severely affected by desertification and environmental degradation. The long-term declining trend in land productivity is one of the most visible indicators of the ecological degradation (El Tohami, 2013[1]). Desertification and drought were identified as the most important constraints facing dry lands farming in Sudan (Boon, 1991).

Materials and Methods

This paper is dependent on the critical review of the available literature and scientific papers presented by the author to identify the impediments or threats to smart agriculture in Sudan, as well as, the personal experience to draw a green path for attaining it.

Discussion

A) **Threats to Smart Agriculture in Sudan:**

- *Deforestation, soil erosion, soil exhaustion and compaction* have lowered agricultural productivity and in most cases have taken land out for the long term (Abdel Atti, 2002).
- *Historical climate change* has reduced productivity in some areas due to decline in rainfall.
- *Ever increasing demands on resources (UNEP, 2007).* Human population growth is the underlying driver of the increased demand for natural resources (Abdel Atti, 2002).
- Blockage of the traditional migratory animal routes and to water points due to agricultural expansion (El Tohami, 20132).
- *Conflict between Sedentary herders and Nomads*. In social terms, the reported consequences for pastoralist societies is an effectively permanent loss of livelihoods and entrenched poverty (El Tohami, 2014).
- *Unstable economic policies concerning agricultural development*. They have resulted in deterioration of crop production. The farmers have been discouraged and they lack any motivation to cultivate their farms. This has definitely led to the reduction of the total production of grains and consequently resulted in food insecurity.
- *Traditional Gold Mining*. Considerable number of young famers and pastoralists nowadays abandon their lands and leave their herds in the River Nile, North Kordofan and North Darfur States. They are now engaged in traditional gold mining that provides them with better income compared to cultivation or herding (El Tohami, 2012).
- *Impose of heavy Taxes on farmers by the government* has made cultivation unattractive occupation since these taxes were exceeding the total cost of production.
- *The Agriculture Bank of Sudan lending policy (El Tohami, 1993).* This policy prevents the farmers from adopting fallowing of their lands and therefore encourages the deterioration of the soil fertility associated with drastic reduction of the productivity of these schemes (EL Tohami, 1999).

- Influx of Refugees from neighbouring countries and food smuggling threatens the food security (El Tohami, 2012).
- *Agricultural Investment in Sudan (El Tohami, 2012)*. It is faced by a lot of constraints due to the conflict of interest between the central government and the states in taking decisions on agricultural land regarding their use by Sudanese citizens or by foreign investors.
- *Foreign Investment in Sudan (UNEP, 2007)*. Complicated or cumbersome constraints face the foreign investors and discourage their investment in crop production sectors.
- *Poor marketing channels and distorted economic structure (El Tohami, 1993)***.** They are discouraging farmers because farmers are used to be exploited by monopolistic and oligopolistic forms of trade (El Tohami, 1993).
- *Informal credit* sources squeeze the mechanized rain fed farmers by giving the farmers seeds at higher prices and then exploit them by return their money in terms of sacs at lower prices according to prevailing low price after harvest.
- *Food security policies: it* is not one of the government's priorities (El Tohami, 1999).
- *Poor rural development*. It enhances the destruction of the production systems. This can be attributed to the fact that it encourages rural – urban migration and as it was mentioned before that most of the Sudanese population in rural areas are working in cultivation and/or herding (Abdel Atti, 2002).
- *Unsecured land tenure in mechanized rain- fed agricultural schemes (El Tohami, 1993). It* **enhances** land degradation. This may be due to the fact that the farmers are not willing to spend their money in conserving schemes which are not actually registered under their names (El Tohami, 2012). Therefore, lands of these schemes were degraded and soils deteriorated and consequently their productivity is declining which may lead to food insecurity (El Tohami, 2012).

B) **Pathway to develop Smart Agriculture from Sudanese perspectives:**

First, make use of the following vast areas of fertile soils all over the country which can be irrigated through surface or ground irrigation or by rains, Presence of plenty of water which is going to be increased after the building of the Grand Renaissance Dam in Ethiopia which will enable the country to use its share in River Nile agreements between Sudan and Egypt (personal experience of the author, 2018).

Secondly through adoption of the following measures:

- using sprinkler irrigation in growing wheat using ground water resources in the drier or semi-arid areas of North Kordofan and Northern states by foreign investors from Gulf countries namely Saudi Arabia and Arab Emirates (Personal experience of the author, 2018):
- adoption of indigenous cultural practices such as no tillage, agroforestry, mixed cropping, agroforestry, etc. (El Tohami, 2013[2];
- to develop a new agricultural calendar which should be adapted to extreme climatic change facing the country;
- preparation of land use map for the whole country to ensure the sustainability of agricultural activities and to avoid unneeded expansion of urban settlements on agricultural lands,
- structural and institutional changes in the national economic policy to remove the impediments imposed by irrational economic policies and regulation;
- improvement of the financial agricultural credits avoiding exploiting the farmers and squeeze them;
- development of early warning systems which is not only limited to weather forecasting but also inputs and sale price of the crops;
- to make use of the great heritage of breeding of high yielding varieties and building of new generation of experts through training and capacity building conducted by large number of scientists and professors working for the Agricultural Research Corporation even for the retired staff (Personal experience of the author, 2018).

Conclusion

Agriculture in Sudan is not smart due to anthropogenic and natural factors.

Recommendations

Smart Agriculture in Sudan can be attained by wise use of soil and water resources and through capacity building and develop a new economic policy which encourage farmers or the producers rather than exploiting them.

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Conservation Agriculture in Tunisia: Historical, Current Status and Future Perspectives for Rapid Adoption by Smallholder Farmers

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Keywords: drylands, climate change, Conservation Agriculture, soil degradation, smallholders,
Introduction

Tunisia is located in North Africa, on the border of the Mediterranean. A big part of Tunisia is semi-arid and arid, marked by hot summers and cold winters, and low annual rainfall (from 200 to 400 mm per year) for semi-arid regions, and less than 100 mm per year for arid regions. Tunisian agriculture faces the major challenges of low and irregular rainfall, accentuated by climate change. The agricultural sector remains vulnerable to climate change with an expected average annual increase in temperature of +1.1 °C in 2030 and an average of + 2.1 °C in 2050 with an increase in the frequency and intensity of extreme dry years and a moderate decrease (10%) in precipitation. It is also expected that surface water will decrease by 5% in the same horizon, which will lead to a decline in agricultural water (GIZ, 2011). Analyses of the effect of climate change on Tunisian agriculture have highlighted the vulnerability of production systems, especially in the central and southern parts of the country. The second major challenge faced agricultural sector is the problem of soil degradation. According to the DGACTA, 1.5 million ha (30 % arable land) are affected by erosion. Autumn rains in particular contribute greatly to erosion in the absence of vegetation cover. Data available shows that 47% of the total area (5.7 M ha) in the north and center of the country is affected by water erosion (OTEDD, 2011). Conservation Agriculture (CA) practices has been proposed as an adapted set of management principles that assures a more sustainable agricultural production, and can also contribute to making agricultural systems more resilient to climate change. In many cases, Conservation Agriculture has been proven to reduce farming systems' greenhouse gas emissions and enhance their role as carbon sinks in order to improve soil health and structure holds the key to improving water use efficiency (WUE) which leads to improved farm profits and benefits the farm environment. Also, CA is as an approach to farming that seeks to increase food security, alleviate poverty, conserve biodiversity and safeguard ecosystem services. In this context, this paper aims to summarize the Tunisian experience in CA (historical, current status, main results, constraints of adoption), as well as to propose perspectives for rapid adoption of CA by smallholder farmers in Tunisia.

History of Conservation Agriculture in Tunisia

CA based on direct seeding, was initiated during the period from 1970 to 1980 through an acquisition of no-till seeder from USA. In Tunisia, the serious experience of CA was started in 1999 when direct seeding was tested in 11 farms (Baccouri, 2008). In 2001/2002, a project of development of integrated rural and agricultural (PDRAI) was implemented in Siliana, Kef and Mateur regions (semi-arid regions) in the framework of an agreement between the High School of Agriculture of Kef (ESAK), Technical Center of cereals (CTC) and CIRAD (Angar, 2010). From 2001 to 2005, the French Global Environment Fund (FFEM) has funded a project on CA, which has targeted the big farms of the semi-arid regions (Kef, Zaghouan and Manouba) and sub-humid regions (Jendouba, Beja, Bizerte). Between 2007 and 2011, a new project (PADAC) on CA was started and he was financed by FFEM and managed by French Agency of Development (AFD). The CTC/INGC, ESAK and the Association for Sustainable Agriculture (APAD) were collaborated for the implementation of this project. Since 2006, interest was focused on the small farm with a first project for small farmers in Siliana, Kef (semi-arid regions) and Bizerte (sub-humid region). This project was funded by the Arab Authority for Agricultural Investment and Development (AAAID), followed in 2012 by the CANA project which was funded by the Australian Centre for International Agricultural Research (ACIAR) and was managed by the INRAT-INGC-ICARDA. This project was focused on the rapid adoption of CA by smallholder farmers in Fernana region (sub-humid region). From 2013 to 2016 a CLCA-project was implemented. This project was funded by IFAD

and managed by INRAT-INGC-ICARDA and was focused on crop-livestock integration under Conservation Agriculture for sustainable intensification of cereal-based systems in Seliana region (semi-arid region) (Angar, 2016 and Cheikh M'hamed et al. 2016). During 2015-2017, the "AC Maghreb" project, was implemented by FERT in Tunisia, in collaboration with INGC and INRAT. This project aimed to develop innovative practices related to Conservation Agriculture, through grouping farmers. During the same period (2015-2017), the project on Conservation Agriculture under rainfed condition was implemented, which was coordinated by ESAK and focused on validating a new model of technology transfer in Conservation Agriculture. Recently a new project on Conservation Agriculture "Use of Conservation Agriculture in Crop Livestock Systems (CLCA) in the drylands for enhanced water efficiency, soil fertility and productivity in MEN and LAC countries" has been launched. This project is a continuation of the CLCA project (cited above). It is financed by IFAD, managed by ICARDA and coordinated by INRAT for 4 years (2018-2022). The target area of this project are Seliana, Kef, Beja and Zaghouan (semi-arid regions).

Current State of Conservation Agriculture in Tunisia

Currently, the area under CA is about 14,000 hectares, operated by almost 200 farmers and 107 No-till seeders (Angar, 2016).

Main Conservation Agriculture systems and their characteristics

The majority of the areas under Conservation Agriculture are the semi-arid regions. Production systems in the semi-arid region of Tunisia are mainly based on cereals production (wheat and barley) combined with ruminant livestock. The characteristics of these systems are: i) Livestock make to producers the possibility to diversification of the income and represent a savings mobilized of money at any time of the year, ii) cereals provide much of the animal's needs throughout the year. The grain and straw of cereals are provided during the fall and winter and stubble during the summer season. These residues are an important food source for livestock in the summer period. However, a conflict of interest exists between mulch for covering soil and grazing.

Benefits of Conservation Agriculture in Tunisia

Results of benefits of CA recorded from several projects and studies in Tunisia showed in the table below (table 1).

Major constraints to adoption of Conservation Agriculture in Tunisia

The major constraints of CA adoption in Tunisia are: i) conflict between livestock (grazing) and maintained residue in the soil surface as mulch, ii) high cost of no-till seeder, iii) the majority of farmers are smallholders (70 % less than 10 ha), iv) weed control problem, especially in legume crops, v) soil compaction, vi) limited crop rotation (dominance of cereal monoculture), and vii) limited species for cover crop, especially in summer period

Future Perspectives and Approach for Rapid Adoption by Smallholder Farmers

The existing policy and institutional options are unsatisfying and cannot insure a rapid adoption and development of CA, especially by smallholder farmers. So, it is important in the first step to develop a national strategy for promoting Conservation Agriculture in Tunisia. This strategy should be based on: i) Encouraging the creation of Farmers' Organizations ii) Establishment of national committee on CA bringing together different stakeholder in CA, iii) Establishment of national R&D programme on CA, **iv)** Adoption of innovative technology transfer model adapted to CA, v) Creation a national network on CA that needs to be connected with an international network, **vi)** Include CA as a specialty in the training programme of technicians and agronomists engineers, vii) Adoption of CA by the big farms of the state (e.g. OTD and OEP), viii) Consider subsidies to buy seeders, and ix) Awareness creation programme by Broadcast of CA by media (e.g. radio, tv and newspapers). In the second step a more specific support is deserved for smallholders and we suggest, as measures the following: (i) limit the negative externalities by applying the principle of "degrader pays' and / or by taxing agricultural practices causing degradation; (ii) promote positive externalities by establishing payment mechanisms of these externalities (carbon sequestration, creation and maintenance of

landscapes, biodiversity protection); (iii) promote sustainable management of common property by empowering grassroots organizations (GDAP); and (iv) establish and / or strengthen the payment for public goods character of services by the establishment of incentives and controls.

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Tables

Table 1. Main results of benefits of CA in Tunisia

Main results of benefits of CA	Reference
- Reduction in the consumption of gasoil at the farm level by more than 50% and consequently a reduction of CO2 emission	(Angar, 2010)
- 20 to 40% reduction in operating costs and an increase of more than 100% in the farmer's net income	(Angar, 2010; Thabet et al., 2010)
- Reduction of erosion, especially on sloping land in the northern region of the country	(Angar, 2010)
- Improvement of water use efficiency of cereals by 10-30 % in semi-arid areas	(Jemai et al., 2013; Cheikh M'hamed et al., 2016)
- Improvement of soil organic matter by more than 1% after five (5) years of adoption of CA in most of the studied locations	
- Improvement of soil biological life	(Jemai et al., 2012,2013; Angar et al., 2011)
- Improving wheat yield in semi arid conditions	
- Introduction of new species of forage crops (vetch, triticale, etc.) and crop mixture (triticale-vetch, oats-vetch) in crop rotations was identified as a highly suitable option for the marginal wheat systems	(Errouissi et al., 2011)
- A local prototype of no-till drill was designed and manufactured	(Angar et al., 2011)
- Adoption of innovative practices (e.g. agronomy of opportunity, sowing under permanent cover crop and relay cropping)	CANA project, 2015; CLCA project 2016)
- Crop-livestock integration under Conservation Agriculture	(CANA project, 2015)
- Improving the accessibility to the field during rainy periods	(Ben-Hammouda et al., 2009; FERT, 2017)
	(CLCA project 2016)

Piecemeal Strategies Cannot Result into Effective Climate Smart Agriculture (CSA)

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Keywords: business etiquette, Conservation Agriculture, food insecurity, land use systems, mechanisation, strategic framework

Introduction

Over the period 2004 to 2015, Zambia's small-scale farmers have only managed to improve maize productivity, the predominant crop among them, on average from 1.93 to 2.24 tonnes/ha despite huge investments made in the provision of input subsidies and extension support. Low productivity has been attributed to (i) unfavourable rain performance, (ii) poor farming practices, (iii) weak extension services, and (iv) poor research and technology transfer. Productivity remains low while poverty also remains high (NAIP, 2013; SNAP, 2016).

Rural small-scale farmers continue to be challenged by food insecurity and inadequate income due to low agricultural productivity, poor agricultural practices, high dependence on rain-fed agriculture, erosion of indigenous livestock and plant genetic resources, and low private sector participation in terms of building a business etiquette and inadequate mechanisation. On the other hand, commercial farming that focuses on cash crop production including wheat, soyabeans, tea, coffee, tobacco cotton, sugar cane, floriculture and intensive livestock production flourishes. Current dominant tillage systems have led to exposed/unprotected soil and landscapes that have resulted into destruction of soil structure, loss of soil health, increased soil compaction/runoff and erosion, and loss of soil biodiversity. Unless these situations are appreciated, it becomes difficult to conclude an effective CA-led CSA agenda and participation.

Methods

Results are derived from three assessment studies of impact of CA, formulation of CSA strategies and assessment of mechanisation in the promotion of CSA approaches. Besides literature review, this work included conducting questionnaire surveys and focused group discussions among farmers, key informant interviews among technocrats and stakeholder consultations through holding of workshops.

The methodology advocates for formulation of a coordinated and encompassing CSA strategic framework, all embracing participation, pointing CSA land use systems, investment into necessary monitoring tools and mechanisation, and dealing with some cross-cutting issues.

Results and Discussion

The study indicates a demand to build a strategic framework for up-scaling CSA, with 6 key attributes for low carbon emissions: (1) linking of increasing atmospheric emissions of carbon to undesirable tillage systems; (2) facilitating change of a mind-set from conventional/inherited farming systems to CSA systems; (3) promoting the practice of reduced to no tillage systems, as a way of reducing carbon emissions; (4) enhancing soil porosity/soil health by aggregating soil particles evident under zero tillage; (5) keeping carbon under CA systems to build-up soil organic matter, and (6) empowering stakeholders with skilful opportunities to respond, take part and attain better incomes through CSA.

Necessary actions that would raise low CA-CSA action and adoption to 'full-scale' uptake requires: (1) building a committed determination/conviction and teamwork to lead the success of the CSA approach, in terms of policy, research/technology development, facilitation, and pro-active farmer participation; (2) nurturing effective coordination and communication among CSA actors on developing an appropriate strategic operational framework; (3) supporting necessary budgetary requirements and practices that promote CSA; (4) outlining a responsive step-wise facilitation change process of positive CSA thinking, characterised by demonstrated policy support, business etiquette, mechanisation, and option-oriented technical skill at both grassroots and technical level; (5) empowering beneficiaries at all levels with knowledge and skill regarding appropriate technologies/agricultural practices/support facilities that are in line with CSA; and (6) identifying sufficient mechanisms for demonstrating, exposing and disseminating information and experiences about a CSA approach that is responsive to climate change challenges.

However, as much as government may coordinate and support these actions:

- farmers need to take the ownership and drive the process – with a niche of involvement of commercial farmers being desirable; and
- relevant research and entity development support, not just by others but also one that captures farmers' experiences/trials; as well as
- strong participation by all (policy, mechanisation entities, service providers, support/business entities, extension, farmers, buyers).

From the study, salient features leading to having a good CSA results-oriented framework require: (1) demonstrating a political will that supports/avails/transfers/adapts CSA technologies; (2) lobbying/advocating a need to address climate change challenges through CSA; (3) fostering exchange visits for knowledge transfers, fundamental in farmer-to-farmer exchange; (4) facilitating on-farm-demos/schools, with financial risks and willingness; (5) building a shared appropriate research agenda; (6) increasing/improving/demonstrating desirable techniques, e.g. how to replace the traditional farming hand-hoe with mechanisation options or better income alternatives through CSA; (7) increasing precision/optimal intensification at field level for better productivity; (8) supporting small-scale practices, but also engaging the 'big' farmers to go CSA; and (9) establishing a good information dissemination network.

The study also ascribes to the need for new decision making processes that will promote innovative CSA land use systems to culture novel ideas, knowledge and skill through: (1) integration of legume/cereal rotations into livestock systems; (2) mitigating against deforestation; (3) intensive/semi-intensive livestock production; (4) agroforestry inclusion; (5) committed Conservation Agriculture agenda; (6) evidence of sustainable land management; (7) renewable energy interventions –solar, biogas, energy efficient systems; and (8) payment for environmental services interruptions – charcoal/fuelwood, wood/timber extraction, mushroom/caterpillar harvesting, agricultural expansion, infrastructure developments, ploughing/hoeing.

It was also observed that developing an appropriate CSA strategic framework also demands building up necessary (1) affordable tools to be able to commit measurable boundaries of lands, (2) affordable tools to approximate or measure mitigation carbon stocks, and (3) coming up with estimations of commitments once appropriate skills have been acquired.

Seven CSA strategic framework areas were identified which included: (1) building an efficient input supply system that raises income, productivity, and nutritional status; (2) improving livestock productivity through feeding, pasture and range management practices; (3) increasing use of sustainable land management and Conservation Agriculture practices; (4) facilitating an operational sustainable fishery management system among the fishers value chain; (5) including agroforestry/farm forestry practices; (6) advocating for management of crop insurance and weather stations, coordination of risk management activities; and (7) facilitating an enabling policy and operational environment for the uptake and sustained practice of CSA.

Other aspects important in effective CSA implementation were also observed. Gender inequalities in access to and control over resources best obtained when the household approach (of head/spouse/children) is employed at vision setting, global enterprise action planning, implementation, and at sharing the benefits together (Clare Bishop-

Sambrook et al., 2008). Most extension staff require a mind-set change to re-orient them into a common understanding of the multi-faceted CSA approach. It also demands building a cadre of knowledgeable/skilled farmers willing to share/demonstrate to others positively the CSA approach through farmer-to-farmer exchanges. Through organised interactions, extension services must develop demand-driven fora for on-field (micro-trainings) and cost-sharing formal training. Relevant entities such as farmer groups, farmer field schools, study circles, information centres, and camp/district agricultural committees/innovation platforms need to be established to effectively implement, record, share and monitor progress.

Secure land tenure was found to be an important enabling factor for adoption of legume intercropping and also agro-forestry. Promoting land use intensification among various land users is a necessity that would reduce the demand for new land clearing. Land needs to be deliberately apportioned into various land uses that can be related to adaptation and mitigation co-benefits over periods of time.

Conclusions

Production potential is constrained by continued use of traditional tillage implements and practices, in the midst of low purchasing power realms that severely limit potential for industrial development and economic growth. The majority of tools and implements used are characterised by high soil disturbance, creation of hardpans, inducement of erosion and wasting away of valuable top soil. Mechanisation within the agricultural sector is therefore seen as a means that can substantially increase yield, output and production through use of labour-saving mechanical or animal draught power technologies.

However, there cannot be successful CSA to respond to the climate challenge without CA integration. Such a demand requires integrated practices on the agricultural landscape that must include supportive policy, affordable mechanisation, crop/livestock integration, supportive agro-forestry and forestry interventions, better livestock management and Conservation Agriculture.

Deliberate supported policy and support is required to engage various pertinent business-oriented stakeholders respond pro-actively to CSA practice and promotion. Necessary recording, monitoring, measurements and verification mechanisms need to be put in place to evaluate achievements and hurdles encountered.

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Conservation Agriculture based Sustainable Intensification (CASI): Targeting by Types of Farming System

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Keywords: CA, Sustainable Intensification, Farming Systems Policy, Targeting

Introduction

Policy makers and science leaders recognize that global food production must expand 50-70 percent by 2050 in order to meet the needs of a growing global population. Recent expansion in food production over the past 50 years has been achieved at the cost of major depletion of soil, water and forest resources. In order to not to exceed planetary boundaries (Rockstrom *et al.,* 2009), such trends towards degradation need to be reversed and development drivers reshaped towards Sustainable Intensification (Godfray *et al.,* 2010) – to maintain or enhance agricultural resources while increasing productivity to meet the needs of humankind in a changing climate.

Sustainable Intensification needs to be tailored to the different contexts and types of farming systems. Farming systems are characterized by access to agricultural resources and to agricultural services including markets and the resulting livelihood patterns; and thus vary greatly across Africa, and the wider developing world (Dixon *et al.,* 2001, forthcoming 2018).

Conservation Agriculture (CA) is one of the few proven sustainable agricultural innovations that increases resource productivity in many different farming system types. Of the many definitions of CA, FAO proposes a concept that receives widespread acceptance, viz, CA is a farming system that promotes the maintenance of a permanent soil cover, no or minimum soil disturbance, and diversification of plant species (notably crop rotations and associations). CA enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased productivity, eco-efficiency and resilience. Because of these productivity and adaptability features as well as CA's ability to reduce GHG emissions and sequester soil carbon, CA is regarded as climate smart and is increasingly being promoted as a central component of climate smart agriculture (CSA). Globally, the area under CA exceeds 180 M ha of cropland and is expanding rapidly, at approximately 10 M ha per year in both smallholder and large-scale farms in a variety of different farming systems in all agricultural regions of the world. In Africa, CA has spread over 1.5 M ha across some 20 countries (Kassam *et al.,* 2018).

Conservation Agriculture based Sustainable Intensification

Agricultural development needs to be reshaped to support the uptake and spread of CSA that can contribute simultaneously to increased productivity, resilience and sustainability. These outcomes can be achieved through Conservation Agriculture based Sustainable Intensification (CASI) which combines the application of interlinked CA principles along with other complimentary practices. Ideally, CASI is implemented in a participatory and flexible fashion (as a bundle of options for adoption in a flexible sequence rather than a fixed package) to ensure good fit with the different types and stage of development of each farming system.

Thus, CASI takes into consideration minimizing soil disturbance (using special planting equipment), year-round ground cover, crop diversity, good crop establishment with improved cultivars, weed control and pest control, sound nutrient and irrigation water management, increased cropping intensity (intercropping where appropriate) and linkages to other farm enterprises including livestock. In a related fashion, Thierfelder e*t al*. (2018) lists six major areas of 'complementary practices' for functional CA-based cropping systems, viz, appropriate nutrient management, improved stress-tolerant varieties, judicious use of crop chemicals, enhanced groundcover, mechanization to reduce labor, facilitate timely planting and to provide farm power for seeding; and enabling policy and extension environments.

In the context of smallholder development, it is important to consider several non-crop aspects of farming systems. First, given the prevalence of integrated crop-livestock systems in Africa, biomass management and its influence on livestock feed needs to be considered (Rodriguez *et al.,* 2017). Second, in all developing regions, improved soil health is one desired outcome of CASI (see, for example, Parihar et al., 2018 for India). Third, because households are an intrinsic element of African and Asian smallholder farming systems and farm labour availability is diminishing, the returns to scarce labour are a critical driver of CASI adoption in many areas. Naturally, the returns to other scarce resources, for example, cash outlay for inputs, or irrigation water, can also be critical factors. Fourth, the seasonal variability of yields and returns is a critical determinant of adoption yet is generally overlooked -- notwithstanding the major role of CASI in 'de-risking' farming systems.

The Australian Centre for International Agricultural Research (ACIAR) has supported research-in-development partnerships testing CASI in Africa, South Asia and the Mekong region. In Africa the Sustainable Intensification of Maize-Legume Cropping Systems for Improved Food Security in East and Southern Africa (SIMLESA) Program tested CASI in more than 50 research hubs in eight countries of the region with substantial increased maize and legume yields, increased household incomes, and benefits to more than 250,000 farm households after 8 years of operations. In South Asia the Sustainable and Resilient Farming Systems Intensification Project (SRFSI) adoption demonstrated increased returns to labour, irrigation water and energy from about 750 on-station and on-farm trials in Bangladesh, India and Nepal (Laing *et al.,* 2017).

Farming Systems

As noted earlier, CASI technologies and support services need to be adapted to different farming system types, depending on agricultural resources, access to agricultural services including markets, and typical farm household livelihoods including the cropping pattern and livestock husbandry. In this context, a farming system is a population of farm households with similar access to resources and services, and common livelihoods, constraints and development opportunities. Dixon et al. (2001) characterized and mapped 72 broad farming systems in Africa and 5 other developing regions of the world. This farming systems framework contributed to the updating of the World Bank Rural Development Strategy in 2001, to agricultural development strategies and to the prioritization and targeting of many CGIAR Research Programs in Phase 1. Subsequently, the characterization and mapping of the 15 broad farming systems in Africa have been updated by more than 65 authors (Garrity *et al.* 2017; Dixon et al. forthcoming 2018). Farming systems can also be characterized and mapped at national levels (see, for an Ethiopian example, Amede *et al.* 2017).

Historically, conventional farming systems have been based on tillage agriculture. Thus, the differentiation of farming systems enables CASI research and development to be tailored and targeted to specific types of farming system. Clearly, some key determinants of the type of CASI include the cropping pattern, land/labour ratio, feed demand of livestock, availability of herbicides and mechanization services. Of the 15 farming systems, the Maize Mixed Farming System in east, central and southern Africa and the Cereal-Root Crop Mixed Farming Systems in west and central Africa are the two most promising engines of food production in Africa – and both have high potential for CASI. The Agropastoral Farming System would also benefit from CASI, although small-grain cereals dominate cropping and livestock are prevalent. In this manner the potential for CASI, and the appropriate type of CASI, can be determined for each of the 15 farming systems.

Conclusions

The demands of a growing global population call for productive, resilient and sustainable approaches to climate-smart agricultural development such as Conservation Agriculture based Sustainable Intensification (CASI) which has been demonstrated by the Australian Centre for International Agricultural Research in Africa and Asia with good results. Given the diversity of farming systems in Africa and also in other regions, CASI should be tailored and targeted separately by each farming system. Because of the importance of sharing knowledge of CASI across African countries, the establishment, development and effective function of the African Conservation Tillage network and its focus on transforming tillage agriculture to CA across Africa is exceptionally valuable for African development in line with AU's Malabo Declaration and Agenda 2063.

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Institutional Innovation, the Critical Missing Link in CA scaling

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Introduction

Institutions factor is the most critical success element in agriculture (Robinson and Acemoglu 2012). Institutional innovation in scaling refers to institutional change and institutional design. It therefore begins from change in context, and includes networking development, institutional arrangements, change in existing institutional capacity for transformation of agricultural scaling. Scaling is a critical element in agricultural sustainable intensification (IIRR 1998; Uvin and Miller 1994; Proctor 2003). It requires significant structural drivers, especially related to institutional innovation, given the ever-evolving contexts. True scaling is the process of achieving widespread agricultural benefits quickly, equitably, lastingly and at affordable cost is complex. Given the fragmented nature of agricultural sector in sub-Saharan Africa (Lynam and Blackie 1994), this is unlikely without institutional innovation. Success of scaling projects, programmes or schemes will be unlikely, given current institutions cannot catalyse sustained and expanded benefits, (co-benefits, spillovers) and impact (see also IIRR 2000; Proctor 2003). Benefits, co-benefits or spillovers require adaptive institutions, well networked. Most sub-Saharan scaling efforts are uncoordinated, with unregulated sources of information, weak tools, limited partnerships, dysfunctional markets, low value-addition, bureaucracy, lack of new industrial clusters that address unique rural needs e.g. quality employment, expansion of export market, deepening of sustainable intensification process etc. The broad concept of institutional innovation therefore calls for the application of innovation systems principles to organising scaling (also see World Bank 2012a).

Methodology

Case study analysis of SIMLESA – assessment of scaling institutions, and literature review are applied. Cases are purposively selected to illustrate why institutional innovation is critical. The paper uses a mix of numeric and content evidence from five scaling cases under SIMLESA funded scaling to illustrate the need for institutional innovation. Qualitative descriptions are from the former National Agriculture and Livestock Extension Programme (NALEP) of Kenya.

Results and discussions

Conservation Agriculture and the scalability issue

Conservation Agriculture (CA) is scalable; can be scaled or taken to many users, from small geographical sizes or scale to larger sites. Table 1 illustrates that no matter the approach used, CA was scalable at minimum cost. These data illustrate that the five cases of different approaches under SIMLESA funded scaling were successful based on basic interpretation of scaling as defined by IIRR (2000), Uvin and Miller (1994) and Proctor (2003).

Organisations in Table 1 estimated that adoption (of different combinations of CA) would be meaningful in five years if scaling was sustained (Misiko – in prep). However, qualities of CA portfolios were often lost under smallholder suboptimal application, when institutional knowledge support ended, and when sound policy instruments were not present. Poor portfolio application; low retention of previous crop residues, lack of mechanisation/equipment or poor herbicide rates meant CA did not always continue to function well under different settings with immediate or acceptable benefits. Besides, SIMLESA research results show that CA Portfolio performances are significantly affected by types of soils, fertiliser inputs and rainfall conditions. CA is not unique with regards to scalability challenge. These

challenges point to the need to have CA/other knowledge intensive portfolio scaling as a continuous pursuit, under strong institutional anchorage.

Beyond scalability metrics

Value for investments i.e. the worth by which (social, economic, productivity and ecological) benefits, co-benefits and spill-overs of CA exceed scaling investments, is a complex consideration. CA or Climate Smart Agriculture (CSA) portfolio co-benefits tend to be latent and cannot be completely measured within project years. Research and experience show that CA has desirable long-term benefits under climate variability, or under considerable degree of climate change risks. CA offers low degree of risk for any return in a changing climate. Logical measures of scalability cannot capture the complexity of merits of CA or CSA.

Table 1 and the foregoing analyses show that meaningful end of CA-based research initiatives must be a handover of programme portfolios to a national scaling custodian for institutionalisation (Fig. 1). SIMLESA piloted such a handover, through a competitive grant.

Analyses of SIMLESA scaling reveal several structural constraints to scaling (e.g. AGRA 2017) that a research programme like SIMLESA could not fully resolve. These are institutional gaps that hinder meaningful handover (Fig 2), and deter any transformational agricultural development.

Institutional gap

SIMLESA handover and attempts at institutionalisation shows that scaling organisations are underfunded, fragmented, mostly linear in functionality and therefore not adaptively innovative. SIMLESA hand-over to scaling community faced structural hindrances. The success in reach (Table 1) masks weak national (institutional) frameworks to inherit the scaling concept of SIMLESA and translate it into national continuous process (Table 2).

Table 2 is an in-depth analysis of institutional gaps in Kenya; there is no scaling custodian; no knowledge management support service for CA adaptive scaling and therefore no institutional support system for farmers – for scaling, and beyond mere extension.

NALEP (2000-2011) of Kenya (http://www.nafis.go.ke) shows this institutional gap is old. NALEP was similar to SIMLESA, except for the scale. Like SIMLESA (9 years life), NALEP was a medium-term investment. They both had focus beyond extension, which is what is needed to address broad issues of development such as markets, social innovation/ entrepreneurial and equity. They both were successful in meeting their broad mandate, esp. in scaling and social innovation. The enormous knowledge, investments, and success were however not institutionalised or handed over due to the absence of an effective (long term) institutional framework (Table 2).

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Figures and Tables

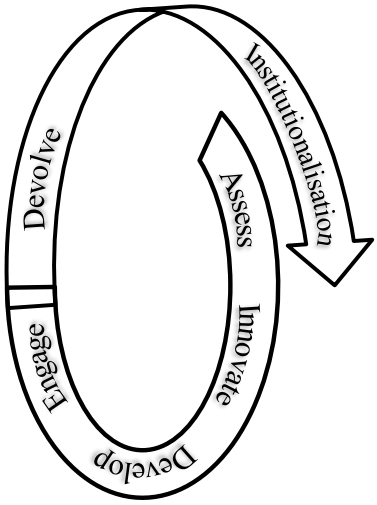

Figure 1: SIMLESA *Scaling Spiral*

SIMLESA Phase I: 2010 – 2014

Assess contexts e.g. economic, social (incl. gender), technological, institutional (constraints and opportunities). Baselines, selection of suitable technologies

Innovate to tailor CA-based portfolios (trials, PVS), for equity and scaling

Develop capacities and support – skills, institutional buy-in

Engage next-users and policy officials, established AIP partnerships

SIMLESA Phase II: 2014 – 2018

Devolve, ***transfer or handover***. SIMLESA competitive grant scheme (Misiko 2017; CIMMYT 2016; World Bank 2012b) – transform (from research to development, from CA-based to CSA practice (see also AIDED Model www.yale.edu)

Beyond SIMLESA

Institutionalisation – embed in custodian institutions, for regular scaling through co-investments, especially by governments and large development initiatives

Figure 2: Scaling is a continuous cycle of relay, in which the research-development baton must never be dropped

Table 1. selected examples of SIMLESA scaling approaches and reach

Country	Ethiopia	Mozambique	Kenya	Tanzania	Malawi
Organisation	7 Zonal Bureaus	AgriMerc	Mediae	RECODA	NASFAM
Scaling approach	Extension (T&V)	VBA and agro-dealer business model	TV (national)	Participatory (ripat.org)	Farmer clubs
Target reach	221937	62436	5000000	54000	50,000
Actual reach in 2017	165268	39462	3,103,000	16323	40,245
Est. adoption in 5 years	25%	50%	10%	25%	50%
SIMLESA cost (US$) per farmer reached	1.1	1.5	0.008	1.8	1.3

Table 2. Lessons for CA and CSA scaling: perspectives on institutional innovation

Scaling issue	SIMLESA observed issue	SIMLESA observed solution	Institutional issue
1. CSA/CA are knowledge portfolios, not technologies	Limited scaling capacities to inherit and own new knowledge New concepts, such as CSA not integrated in curricula	Close interaction between university programmes and scaling institutions i.e. mechanisms for scaling institutional fallback for knowledge management	Extension support service (or institute), a public scaling institution that rely heavily on M&E, promote innovate to scale theory of practice
2. Lack of established scaling standards	Knowledge management gap Scaling institutions inherit final products, and have little understanding of i) scalability metrics ii) new scalable possibilities Messages are incoherent – multiple small players e.g. radio programmes aired are rarely documented for validity, CA is interpreted variedly	National clearing house (similar to Plant Health Inspectorate) for CA, CSA, portfolios. Such a national extension institute/ service would enact metrics for: i) The environment (enabling factors) ii) The quality of Innovation/s being promoted iii) The target group (recommendation domains) iv) The actors/drivers of change i.e. enabling institutional landscape	Need to mentor capacity to independently authenticate portfolios and tools A national extension support service or institute would support scaling organisations to meet basic standards of transformational use of improved research portfolios A national extension support service/ institute would be a knowledge/ portfolio repository, to act as handover custodian and assist harmonise scaling efforts or lessons

			v)	Context informed impact pathways to follow	
3.	Diverse agro-ecologies, environments and farming systems	Soils, weeds, weather variability, large number of staple food Africa produces, etc. Massive scaling of new portfolios is limited	Egerton University integrated SIMLESA, and *Striga hermonthica* limiting portfolios. Acquisition of complementary portfolios		Institutional innovation; adaptive capacity to integrate different portfolios beyond one project/ single funding
4.	Fragmented investments in the agricultural sector	Non-transformational investments in production value chain development and support services	Guided investments by govt. and strategic donor investments e.g. through AIP partnerships		An extension support service to synchronise value chain projects e.g. RAB's institutional anchorage for policy instruments
		Sub-Saharan Africa's agriculture is grossly undercapitalized for poor farmers	Policy instruments e.g. 40% input by Rwanda govt. in capital expenditures for cooperatives		Mentor institutional capacity for social innovation
5.	Rapid growth in the region's rural population	There was no linkage in SIMLESA CGS, or national extension in Ethiopia between scaling strategy, with population dynamics	Good national framework based on planning documents, esp. responsive to rural demographic and social dynamics		Directly involve state planning, population development institutions in strategic agricultural research and scaling. Agriculture is key GDP source
6.	Socially skewed institutions	When capital is cheaper, it favours larger holdings	Need for innovative concepts for operationalising public private partnerships (PPP)		The concept of PPP cannot fly without strong public institutions/ support service
7.	Climate change	Extreme rains in 2018 – floods/ droughts frequencies reported to be increasing Scaling organisations did not have scaling strategies in a climate change or climate variability scenario	Functional climate models – these are not yet sufficiently well developed for Africa – no scaling institution mentioned such weak capacity for detailed planning		Opportunities for carbon trading and offsets require strong institutional arrangements. As above mentioned, a national extension support service with such capacity is critically required
8.	Nutrition gap	Nutrition indicators are rarely mainstreamed, except on project basis. These were not part of SIMLESA CGS	Nutrition security objectives should be taken into consideration in the design and implementation of agricultural scaling initiatives		A national extension support service would have adaptive capacity to catalyse nutrition integration beyond pilot research projects
9.	Weak market functionality local, national and regional markets	Paucity of farmers markets, no brand identities for farmer goods, seasonality of supply, limited-resource consumers, low collective efforts, low quality information channels	Drivers for locating farmers' markets in low-income communities (e.g. US-based Fair Food Network, Malawi NASFAM mobile markets) Monetary incentives (e.g. for produce storage) Research and educational outreach		Institutions for scaling support, regulatory, risk management, information, a framework for organizations and cooperatives
10.	Policy (awareness,	Organisations are generally not aware of/	RAB (Rwanda) interpreted policy for development		Strong national extension support service/ institute, or

	interpretation, application failures)	ambivalent/ uninterested in seeking to use/contribute to scaling policy	partners. This facilitated application of scaling related policy instruments in Rwanda	facilitative organisation that interprets policy to farmers, AIP, local scaling partners, etc.
		International research institutes poor in political, policy drives	Structural linkages to political institutions for scaling support/ buy in	Such a service would of necessity, link efforts of foundations, international institutes to *political* institutions/ support, handle policy instruments
11.	Weak scaling institutions	State and NGO institutions for scaling in Africa are particularly weak in offering learning space	National scaling instruments (e.g. CGS), designed to suit social, political, and policy contexts	
		Fragmented scaling efforts (and national extension systems are collapsing)	Strategic contribution of international foundations	Accreditation or facilitation of scaling programmes, harmonise pockets of scaling efforts, etc.
		Equity is elusive, or not sought – lack of guidance, poor enforcement or low institutional innovation	Local solutions for social innovation, e.g. reliance on strong culture, policy awareness to guide scaling	

Development of Integrated Drivers to Mainstream Conservation Agriculture in Ethiopia

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Keywords: advocacy, champions, leadership, promoting CA, scaling up, policy

Introduction

Agriculture is the main source of livelihood for millions of smallholder farmers and the major driver of the economy in Ethiopia. However, the sector's performance is highly influenced by land degradation, depletion of soil fertility, recurrent droughts due to climate variability amongst other factors. Agriculture in Ethiopia is characterized by excessive tillage, crop residue removal at harvest, overgrazing and biomass burning, which has led to land degradation, soil erosion and nutrient depletion (Michiel et al., 2001). It is reported that annual top soil loss is in the range of 42-176 tons per hectare per year depending on the biophysical characteristics and farm size of an area (Tesfay et al., 2015). In addition, agriculture is rain-fed and constrained by inadequate and variable rainfall distribution due to climate variability (Fischere et al., 2004). The combined effects of land degradation, declining soil fertility and climate variability threatened food security and agricultural productivity of smallholder farmers. The severity of the problems indicates the need for adopting agricultural technologies that reduce degradation, enhance soil health and minimize the impacts of climate variability.

CA is a promising new production system to ensure food security, particularly in a small-scale dominated farming system like Ethiopia. Yet, CA did not get the needed attention from decision makers and influential actors engaged in the agriculture sector in Ethiopia. CA's coverage in Africa has reached to 1.36 million hectares while Ethiopia is covering only 25,000ha. The current extension service highly promotes conventional agriculture with great emphasis on repeated tillage for all major crops (20 crops) grown in the country.

Ethiopia has endorsed several policies supporting Climate Smart Agriculture (CSA), including CA. The Climate Resilient Green Economy (CRGE) and the National Adaptation Plan Strategies outlined several climate change adaptation technologies of which CA is among them. Despite the existence of these policies, little emphasis was given in the promotion and dissemination of CA as a legitimate climate resilient farming technology in the Ethiopian agricultural extension system.

On the other hand, CA has been tested in different parts of Ethiopia and research results shown great potential to address problems associated with the current conventional farming system (Araya et al., 2015; Edwards et al., 2007; Tesfaye et al., 2015). This suggests the need to incorporate CA as one of the technology packages in the agricultural extension system of the country.

Accordingly, the African Conservation Tillage Network (ACT) has partnered with Canadian Foodgrains Bank (CFGB) under the Scaling up Conservation Agriculture in East Africa program (SUCA), to support CA mainstreaming within the extension system of Ethiopia. The duration of the project is 2017-2020.The major focus of this project is to improve the quality and implementation of policies that support CA. With the support of this project and other partners' contributions, efforts are being made to mainstream CA in the extension system of Ethiopia in the last one year.

This paper presents results of a case study in Ethiopia on processes of Conservation Agriculture (CA) incorporation within the agricultural extension system of the country. The results indicate the role of a proactive leadership in the government ministry, strong coalition among partners, strong research evidence and proactive dialogue and advocacy in creating acceptance and cascading of CA through the government structure.

Material and Methods

In order to enhance CA scaling up in Ethiopia, ACT, through this project, has conducted a policy environment assessment to identify barriers of implementation of existing CA supporting policies through consultations and discussions with key government decision makers and influential actors within the Ministry of Agriculture and Livestock Resources (MoALR), experts and researchers from Research centres, Non-Governmental Organizations (NGOs) and Private Sector engaged in CA. Following the initiative, the MoALR Soil Fertility Improvement directorate has established a multi-stakeholder platform to work on CA mainstreaming within the agricultural extension system.

Stakeholders that participated in the process included: Federal Soil Fertility team, Sustainable Land Management expert, Regional Soil Fertility experts, Soil health expert from Agriculture Transformation Agency (ATA), Scientists from International Maize and Wheat Improvement Centre (CIMMYT), Ethiopian Institute of Agricultural Research (EIAR), Mekelle University,

ACT Policy team, Experts from Canadian Foodgrains Bank (CFGB), CFGB supported partners and members, Sasakawa Global 2000 (SG2000) and Food and Agriculture Organization (FAO).

The team contributed to the development of a national CA implementation strategy and policy brief after a series of five workshops, several face-to-face meetings and online discussions over one-year period of time. Furthermore, ACT has conducted a one to one meeting with the Agriculture Minister, and also organized an experience sharing visit, in collaboration with CFGB and its partners, to higher officials to visit CA practicing farmers in different parts of Ethiopia.

Results and Discussion

Ethiopia is in a promising trajectory towards mainstreaming CA within the extension system. The MoALR has endorsed the national CA implementation strategy developed by the multi-stakeholder partners and is planning to cascade it at the grassroots level by building the capacity of extension workers. The drivers of change towards CA institutionalization within the extension package are described below.

Proactive leadership from Soil Fertility Improvement Directorate, MoALR

An encouraging outcome was achieved in a very short period of time due to the positive working relationships with the MoALR, the existence of strong, pro-active and enthusiastic leadership within the MoALR such as Deputy State Minister of MoALR, State Minister of Natural Resource Management and Soil Fertility Improvement Directorate. The leadership from the Soil Fertility Improvement Directorate has been very supportive of CA and has led to a formation of a multi-stakeholder forum with a continuous follow up on the progress of the work. Having champions within the Ministry is very crucial to advance CA mainstreaming agenda. In addition, MoALR has a department that deals with soil health, and the existence of this department was a plus to lead the process.

Furthermore, Ethiopia has put in place a structure from federal to community levels to realize the soil health agenda. At the federal level, there is a soil fertility improvement department owning the goal of CA. At the regional level, there are soil fertility experts supporting district experts in providing soil fertility management expertise. At kebele level, there are five extension workers assigned to reach an average of 2000 farmers though improved technology. Additionally, there are farmer-training centres that support technology demonstrations, innovations and group learnings. In general, the existence of CA champions within the top leadership, strong departmental structure with high level of experts owning CA's goal and strong system of knowledge dissemination at grassroots level has supported CA mainstreaming within the extension system. In this respect, Ethiopia is in well positioned towards mainstreaming and scaling up CA.

Strong coalition

In Ethiopia, there is a strong CA focused multi-stakeholder platform led by the Soil Fertility Improvement Directorate of MoALR. The platform is composed of actors from the MoALR (crop, livestock, natural resource management and

extension experts both from national and regional offices), ATA, CIMMYT, EIAR, Mekelle University, ACT, CFGB and CFGB supported partners and members such as FHE, TDA, MSCFSO, MCC; SG2000 and FAO. The team has been working harmoniously to support the soil fertility improvement directorate in actualizing the national CA implementation strategy and policy brief development. Scientists and researchers in the country have debated on the applicability of the technology across agro-ecology, farming system and crop types, and reached a consensus on existing evidence, knowledge and research gaps. CA implementing partners have presented practical knowledge and testimonies of farmers from different Agro-ecology and farming systems to the multi-stakeholders. CFGB supported partners (TDA, FHE and MSCFSO) have brought new paradigm shift in CA knowledge in the country, particularly on CA without herbicide and contextualized tillage practices for small grain cereals. In addition, they have empowered local leaders and experts through practical knowledge, which has helped in creating CA champions at the grassroots level. This helped CA knowledge harmonization, implementation modality and approach of CA scaling up.

Dialogue for CA inclusion

ACT has made several one to one consultation with key policy makers in the process. The visit to the MoALR has made the process effective and paved way for a successful completion and approval of the implementation strategy. During the one to one meeting, key messages were delivered to the Minister and decision makers. Engaging higher-level leaders within the Ministry, understanding their concern and interest around CA is crucial in getting buy-in for CA mainstreaming within the extension system.

Evidence based message

The research conducted by CYMMIT and scientific publication on productivity, economics, adoption, and identifying potential recommendation domains for CA (Tesfaye et al., 2015) resulted in a dialogue based on objectively verifiable knowledge and supported the CA mainstreaming process. It has also contributed to making a case to influence decision makers within the agriculture leadership. Therefore, engaging research institutions and bringing winning evidence is crucial in CA mainstreaming within the extension system. Additionally, the field visit made by higher officials has contributed to creating awareness and attaining practical knowledge from farmers. Scientific evidence supported by farmers' testimony has helped in creating champions at national levels and increased the momentum of CA mainstreaming agenda.

Effective Advocacy strategy

In the CA mainstreaming process, bottom up and top down advocacy approaches were employed. National policy initiatives such as dialogue with policy makers and knowledge harmonization within the multi-stakeholder platform was supported by grassroots initiatives of creating CA champions at all levels; farmers, experts and local leaders. These have played a great role in convincing decision makers at all levels. Thus, following bottom up and top down approach was critical for effective advocacy in CA mainstreaming and upscaling.

Conclusion

Sustainability of the current crop production systems in Ethiopia is challenged by various factors such as severe soil erosion, depletion of nutrients, declining soil fertility, alarmingly frequent droughts and chronic water deficit due to climate variability. CA has been researched and tested in Ethiopia and is found to be useful in addressing most of the current production challenges while enhancing environmental sustainability. ACT, in collaboration with the Ethiopia Ministry of Agriculture and Livestock Resource soil fertility improvement department and other stakeholders, has developed CA implementation strategy and policy brief to mainstream CA within the extension system. The drivers of CA mainstreaming are proactive leadership in the government ministry, strong coalition among stakeholders, strong local research evidence and proactive dialogue and advocacy.

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Annex

- CA Implementation strategy in local language (available from the authors)
- Policy brief both in English and local language (available from the authors)

Sub-Theme 2: Research and Technology Development for Scaling up of CA Systems, Practices and Innovations in Different Rainfed and Irrigated Farming Systems in Africa

Conservation Agriculture is more than a mere technology or practice. It is about how the science, technology and practice are applied in achieving environmental resilience in the farming ecosystem while at the same time providing for optimal productivity and harness ecosystem services. This understanding implies that adaptability to local circumstances is an integral part of what CA adoption is, and what ultimately gives CA its value, wide appeal and relevance to attract mutually beneficial institutional support from the public, private and civil sectors.

Field level experiences, supported increasingly by scientific evidence, continue to demonstrate that CA is enabling widespread empowerment of farming and rural communities in Africa as well as countries globally to sustainably increase agricultural productivity while enhancing agricultural value in mitigating climate change. Recent global and continental agreements and trends provides a common and enhanced collective "energy" that can motivate and support increased front-line action on scaling-up the adoption and spread of CA as a core component of climate-smart agriculture in line with the Sustainable Development Goals.

CA is widely identified as one key way to realise a climate-smart agriculture. Focusing on implementation, field practices and experiences, on one hand, and science and technology, on the other hand, the sub-theme aims to expose extent (how) to which expended practising of CA – i.e. reaching critical mass levels both in terms of land size and farming units involved – is an integral part of transforming our agricultural towards the inevitable climate-smart farming systems. The sub-theme brings out lessons to inform and argument further technical and policy initiatives supporting CA adoption and scaling-up. It also placed to sets the context and integrate 2ACCA into the greater continental and global goals and agenda and exposes initiatives – including related challenges and opportunities - accelerating and expanding advances to adapt and innovate CA systems and practices within defined local agro-ecosystems and communities.

Under this sub-theme, 27 condensed papers were submitted and approved by the Scientific and Technical Committee after regourous reviews. These papers are hereby presented as follows:

Deep-bed Farming System: Farmers' Perceptions on Potential Benefits in the Northern Malawi

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Key words: hardpan, high yields, manure, production costs, soil and water conservation.

Introduction

Like many African countries, Malawi continues to face food insecurity and high poverty levels as a result of increasing population, poor farming methods, soil degradation and erratic rainfall patterns (Ngwira *et al.,* 2014; Njoloma *et al.,* 2016) with climate variability expected to increase. One of the major causes of soil degradation and the resultant low crop yields is the continuous use of unsustainable conventional ridge (CR) system commonly practised in Malawi where the soil is tilled to the same depth every year. This creates a hardpan that restricts root growth and access to water and nutrients (Kassam *et al.,* 2014; Mloza-Banda et al., 2016) in addition to nutrient mining, soil erosion and desiccation (Vlek et al., 2008). Conservation Agriculture (CA) was introduced in Malawi on the basis that it reverses the destructive impacts of CR while improving crop yields for farmers despite its current low adoption across Malawi and the Sub Saharan African region (Giller et al., 2009; Ngwira *et al.,* 2014). Employing the three principles of CA (FAO, 2013), the deep-bed farming (DBF) system was introduced in the northern Malawi by Tiyeni Malawi, a local non-governmental organisation established in 2005 to counter the negative impacts of CR and improve soil and water conservation, increase crop yields and resilience of production systems to both natural and human induced changes. In 2017, a survey was carried out to understand farmers' perceptions and the observed impacts of the deep-bed farming system in relation to the conventional ridge (CR) system that influenced farmers' decisions to adopt the farming system. The results of the study suggest that the DBF method increases crop yields, reduces labour demand, reduces production costs, reduces soil erosion, improves water use efficiency and soil health among others.

Materials and methods

This study involved 36 groups of farmers from five Extension Planning Areas (EPAs) in Mzuzu Agriculture Development Division (Mzuzu ADD). These EPAs include Zombwe, Emsizini, Chikwina, Bwengu and Kavuzi. On average, the groups comprised 52% female and 48% male members with age ranging from 18 to 74 years. A sample of 111 respondents was selected using a proportionate random sampling (Ng'ong'ola, 2012; CIMMYT, 1993). A checklist of questions was then used to collect qualitative data. The interviewed farmers practise the deep-bed system where they make marker ridges across the slope and break the hardpan to a depth of 30cm by tilling the soil before making raised beds of 1m width along marker ridges across a slope in the first year. These beds are not stepped on or disturbed for a period of five years. Within these beds, box ridges are made in alternating structure while the edges of the field are closed with marker ridges planted with vetiva grass (*Vetiveria zizanioides*) or lemon grass (Cymbopogon citratus) to harvest rainwater and prevent build-up of runoff and to reduce soil erosion. Farmers are taught how to make manure using locally found raw materials. The manure is mixed with a small amount of fertiliser and applied on the beds on which crops are planted. Farmers are encouraged to plant improved crop varieties and to practise intercropping, agroforestry and crop rotation. After harvesting, all crop residues are put on the deep-bed as cover material to regulate temperature, excessive water loss and to provide organic material and encourage microbial activities in the soil.

Results and Discussion

DBF's impacts on farmers' livelihoods: About 87% of the respondents reported higher maize yields in plots where DBF system was practised compared to a field of the same size where CR is practised (Table 1). Farmers reported that they decided to request DBF training from Tiyeni Malawi because of the high yields and outstanding crop stands from

neighbouring farmers who were practising the DBF system in the first place. Another key finding on livelihoods is the reduced production costs required to implement the new system compared to CR. Farmers reported the use of locally made manure, reduced labour requirements over a period of five years, use of crop residues as soil cover that decompose to add organic matter and reduce weed growth, pests and disease outbreaks. Respondents also stated that they had acquired increased knowledge from trainings and exchange visits through field open days organised by Tiyeni Malawi.

Environmental benefits: DBF system practising farmers observed differences between their DBF plots and CR plots from the first year of implementation. Water conservation and prevention of crop wilting during dry spells were reported by 36% and 11% of the respondents (Table 1). Over 10% of the interviewed farmers linked these benefits to the reduction of soil erosion because rainwater gets harvested in the DBF fields and allowed to infiltrate. Farmers reported a difference in the soil fertility where deep-bed had been practised shown by increased crop yields and changes in soil colour.

These results suggest the potential of the DBF system to contribute to the building of sustainable farming systems that improve farmers' livelihoods while improving and sustaining the natural resource base on which agriculture depends. As farmers continue to be convinced of the benefits of the deep-bed system, many of them are extending their area under deep-bed. Unverified reports show that there are more farmers practising the method than those registered by Tiyeni Malawi. The University of Worcester is also carrying out detailed analysis of the DBF system to generate knowledge about it including how it can be adapted to suit site-specific agro ecological conditions across Malawi and beyond.

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Figures and tables

Table 1. Factors influencing the uptake and spread of deep-bed farming method

Motivating factor	Frequency	Percentage
High yields	97	87.4
Cheap production costs (more manure, less fertiliser)	48	43.2
Water conservation	40	36.0
Labour saving	26	23.4
Exploring new ways	17	15.3
Improved soil fertility	13	11.7
Prevents crop wilting	13	11.7
Erosion control	12	10.8
Inputs & implements	5	4.5
Crop diversification	3	2.7
To win pigs in the pig pass-on programme	3	2.7
Correct spacing	1	0.9

Economic and Yield Comparisons of Different Crop and Crop/Pasture Production Systems

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Keywords: alternative crops, medics, profitability, sustainability

Introduction

Rainfed agricultural production systems in the Western Cape have been based on winter cereals since the 1700s. In the Swartland, located in the west coast region of the Western Cape Province, South Africa, wheat has been the main crop for the past century and was produced in monoculture with an occasional break of bare fallow or oats pasture. The establishment of annual legume pastures was encouraged during the land improvement scheme of the 1970's & 1980's with limited success, despite extensive research showing the benefits of including such pastures (annual Medicago and annual clover species) into a farming system in rotation with wheat. In this paper wheat yields and subsequent gross margins obtained in a large-scale, long-term experiment that comprises several crop and crop/annual legume pasture rotation systems, were compared to determine the potential implications of conservation agricultural practices in systems with and without an animal factor.

Materials and Methods

The trial was implemented in 1996. It is currently in its 23rd year of production. From 1996 to 2001 minimum tillage (scarifier and adapted seed drill, crop rotation and residue retention) was used in all systems. From 2002 onwards, full Conservation Agriculture production practices (no-till, crop rotation and residue retention) were implemented for all crops in the experiment. All crops in each of the eight rotation systems were present on the field every year to be able to compare systems. Plot sizes varied from 0.5ha to 2ha depending on the system. All actions on the trial was done using normal size farm implements. Monoculture wheat served as the control. Wheat yield and system gross margin data from the 2002 to 2012 seasons were included in the analysis (excluding 2003 due to severe drought). Eight, 4-year rotation systems were compared, viz. 1-wheat monoculture (WWWW), 2-WWWC, 3-WCWL, 4-WWLC, 5-WMWM, 6-WMCM, 7-WMcWMc-1 and 8-WMcWMc-2 (where W = wheat, C = canola, L = lupin, M = medic & Mc = medic /clover mixed pasture), in a randomised block design that was replicated twice. All crops within each system was represented on the field each year. In systems E to G, sheep grazed the legume pastures during the winter production season and switched between wheat residue and pasture residue during summer. In system H sheep was taken out of the system at the start of the production season and kept on a saltbush (*Atriplex nummularia*) field for 4 to 6 weeks following which they were returned to the legume pasture. Gross margins (including all direct allocatable costs) and yields of all crops were analysed using the SAS statistical analysis program and significant differences were measure at the 95% confidence level.

Results

Average wheat yield in rotation systems containing a legume pasture tended to be significantly higher than wheat monoculture. Average yield ranged from 2854kg/ha to 4072kg/ha. System 6 (WMCM) showed the highest average wheat yield over time, although not significantly different from 5 of the other systems. By including other cash crops such as lupin and canola the average wheat yield increased by 22% over different sequences, while in systems where medics or medics/clover was included the average was 39% higher. System gross margins in 6 of the systems were significantly higher than the monoculture control.

Conclusions and Discussion

The inclusion of alternative crops in rotation with wheat improves wheat yield on a per ha base. Although the inclusion of these crops means that a lower percentage of a farm is planted to wheat it does not mean that the farm income is reduced. The improved wheat yields obtained from these rotations and income from the alternate crops and the inclusion of the animal factor where pastures were included, help to offset this loss in total wheat area.

Can Payments for Ecosystem Services (PES) tip the balance to sustainable transformative system change?

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Keywords: adoption process, peer-effect, feedback loops, Conservation Agriculture

Introduction

As much as ecosystem services (ES) are appreciated by the general public that reap their benefits, putting a monetary value to them has always been notoriously difficult. Payments for ecosystem services (PES) schemes attempt to address this issue, usually by using public resources to incentivize providers of ES to generate public goods. Experiences over the past decades show that PES are successful when beneficiaries pay more for ES than what the opportunity costs of their provision are. Further, transaction costs can be brought down when brokers are involved in the process to facilitate monetary transfers between usually large numbers of ES beneficiaries and providers. Lastly, when ES providers are smallholders they frequently need support to overcome specific economic constraints and to bear associated risks when adopting new sustainable land management practices like Conservation Agriculture (CA). Thus, PES have the potential to contribute to poverty alleviation.

Conceptual framework of PES feedback loops. Frequently unsustainable and unproductive practices like conventional land husbandry practices are surprisingly resilient to change. Contributing factors like resource constraints, risk aversion, and social norms, amongst others, tend to "lock-in" smallholders in an undesirable basin of attraction (Figure 1 left side). PES payments (like subsidies) can assist famers to overcome constraints and move to a state of greater desirability. In their most simple form, PES are direct subsidies to encourage or prevent a certain behavior (Figure 2, Loop 1). But when the payment stops, the behavior and the system is highly likely to revert back to its original state. For system transformation to work, the obstacles to behavior change need to be overcome, and to become sustainable, the adopted new behavior has to bear self-reinforcing benefits to the adopter. CA may offer the opportunity for such system transformation because a second more desirable and sustainable basin of attraction can be attained. PES have the ability to lower the threshold to change while benefits from CA continuously deepen the new basin of attraction (Figure 1 right side).

Methods and Analysis

We conducted a two-year experiment in Malawi's Shire Valley to test the effect of different incentive systems on the adoption of CA practices using a randomized control trial in an innovative PES scheme. The experiment ran from

June 2014 to October 2016 in a total of 60 villages (12 control and 48 treatment). From each of these, 30 households' heads were randomly selected for sampling (n=30x60=1800). For the purpose of this analysis we do not look at differences between treatments but only between control villages, in which no PES were offered, and treatment villages, in which we tested the effects of different PES schemes and monitoring efforts. Data on adoption rates of CA practices and associated cost estimates derive form this project. Further, we applied a simple model to estimate, from secondary data (Araya et al. 2011; Mchuru et al. 2011), the amount of sediment loading of rivers in a hypothetical catchment area. Cost estimates for dealing with sediment loads in aquifers supplying energy for generation of hydro-electric power were taken from Malawi's electricity supply company ESCOM.

Results and Discussion

Effectiveness of PES driving CA adoption. On average across various treatments, our PES scheme increased adoption rates for CA at 170% above control. In absolute terms, our intervention – which entailed no extension or CA promotional activities – was responsible for CA adoption on an additional 7% of cropped land across our villages. To put this into perspective, one should keep in mind that CA adoption rates in Malawi are reported to be low. While agronomic benefits like improved and stabilized yields are known to take 3-5 years to accrue, peer-effects emerged as a key driver for adoption in our study (Bell et al. 2018a).

Economics of sediment loading. Assuming it will take 3-5 years before CA adoption generates the full set of economic and ecological benefits, the latter constituting top soil loss reduction by around 65% (Araya et al. 2011; Mchuru et al. 2011), we obtained an estimate of the direct costs of avoiding sediment loading to be around USD 7 per ton. This estimate is, of course, sensitive to the assumptions we made on the time it takes farmers to practice CA without incentive provision. To take a conservative approach, when we assume that payments would need to be made in perpetuity, this cost rises to around USD 20 per ton. If we further assume that indirect costs (monitoring, logistics, etc.) are identical (per unit area) to those in our small-scale research study, costs would rise to USD 200 per ton. Acknowledging that not all areas pose the same risks to surface water, and assuming that only 50%, 25%, or 10% of eroded top soil reaches the river system raises these worst-case estimates to near USD 400, USD 800, and USD 2,000 per ton, respectively.

Proof of concept. Our estimates to avoid one ton of sediment loading range from USD 7 and USD 2,000 per ton, while ESCOM estimates its own costs of sediment management (which involve equipment rental, dredging, and scheduled shutdowns) on the order of USD 150,000 per ton of sediment (Millennium Challenge Corporation - Malawi 2017). Under even our most conservative assumptions, the cost of avoiding sedimentation in the first place by encouraging CA as a land management practice is orders of magnitude lower than costs currently being borne by ESCOM. Conceptually, this closed the feedback loop from provision of ES to provision of incentive to support (left side of (Figure 2) and provides the grounds for the systemic transformation shown in Figure 1 (right side). As the scheme matures, over a 3-5 year period, self-reinforcing benefits are predicted to emerge to lock the system into the more sustainable state. Clearly, ESCOM would benefit from lower siltation, but over time, adopters would also increasingly benefit for two reasons, both self-reinforcing. Firstly, the improvement in soil structure over progressive seasons reduces input needs and potentially boosts yields and, at the same time, it reduces the risks and costs that inhibit adoption. Second, peer effects imply that the additional incentive required to encourage new adopters is less and less important as Conservation Agriculture fills the landscape, and observations of (or suggestion from) neighbors reshapes attitudes about the practice. Our paper (Bell et al., 2018b) suggests that PES have the ability to effect system transformation from an undesirable and unsustainable state to a desirable and sustainable state by employing self-reinforcing feedback loops that eventually may allow the withdrawal of the incentive scheme without risking reverting back to an undesirable, unsustainable state.

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Figures and Tables

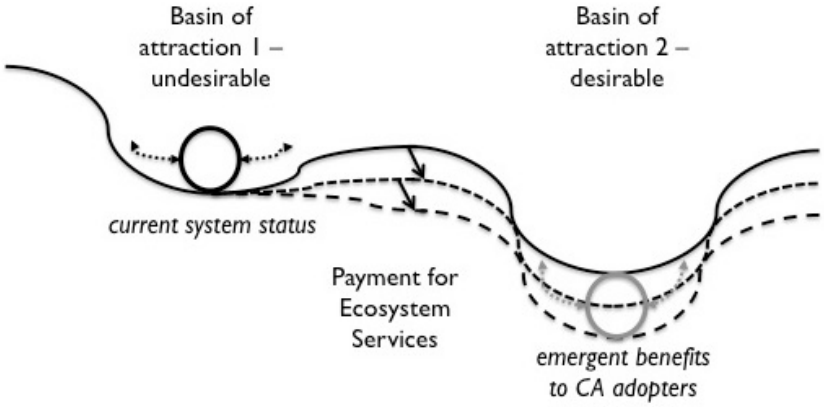

Figure 1: PES can help shift the provision of ES from an unsustainable basin of attraction to a sustainable state by removing/reducing barriers to change.

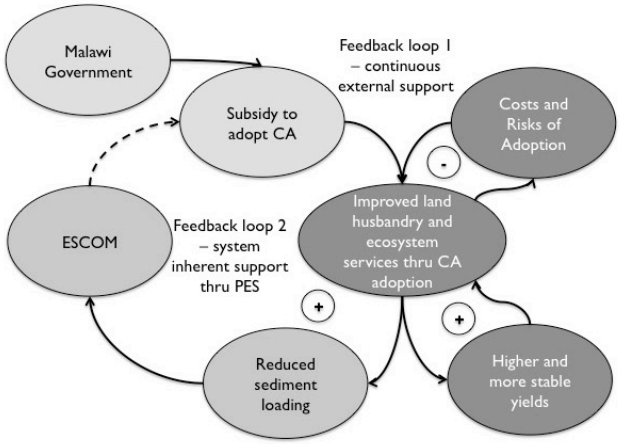

Figure 2: A model for PES feedback loops. Loop 1 encourages continued support from the public sector while feedback loop 2 utilizes the willingness to pay for ES by their beneficiaries.

Impact of Conservation Agriculture Practices on Maize Yield and Soil Properties in the semi-Arid Laikipia County, Kenya

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Keywords: Conservation Agriculture, cover crops, mulching, soils, semi-arid, soil moisture,

Introduction

Inadequate and erratic rainfall coupled with infertile soils are key factors limiting agricultural production (Liu *et al.,* 2010). The arid and semi-arid lands (ASAL) form 79 per cent of the entire land area in Kenya with varying degrees of aridity; ranging from semi-arid, arid and very arid agro-ecological zones (Jaetzold *et al.,* 2006). Conservation Agriculture (CA) has potential to support crop production under tropical conditions while mitigating natural resource degradation (Sainju and Ventrella, 2009) but minimum tillage alone without mulching is less effective particularly in areas where the rainfall amounts are low or high but variable due to the ability of the mulch to conserve soil moisture by decreasing the evaporation from the soil surface (Jalota and Prihar, 1990). Retention of crop residues to act as mulch protects the soil from the impact of rain drops while minimizing soil disturbance, it enhances soil biological activities as well as soil air and water movement. The realistic effects of CA on crop yield largely depends on the specific CA practices, regional climate characteristics and cropping systems. Cover crops could also be used to increase cropping systems resilience to climate change challenges. The use of *Lablab purpureus* as a cover crop produces more dry matter than cowpea especially during drought and this translates to nitrogen and improved soil physical conditions (Waweru, 2013).

Materials and Methods

In order to enhance technology adoption, the project used the Mother-Baby trial design. In Mother-Baby Trial Design**,** the "mother" trials (numbering 12) were testing the full set of all the six CA treatments. The full list of treatments is follows: T_1= Farmer practice: Conventional ploughing (ox or hand), no residue retained; T_2= Conventional plough practise with fertilizer, no residue retention; T_3= Minimum tillage with no fertilizer and no residue retention; T_4= Minimum tillage with fertilizer and no residue retention; T_5= Minimum tillage, without fertilizer, with residue retention and T_6= Minimum tillage with fertilizer and with residue retention. The test crop in this experimentation was maize while Dolichos (*Lablab purpureus)* was intercropped with maize in all plots to act as the cover crop. Each plot measured 10 m long and 10 m wide. Maize cultivar Duma 43 was planted using an inter-row and intra-row spacing of 0.75 m by 0.3 m, respectively. The data that was taken include dry matter for grain and dry stover yields. Rainfall in the trial sites was recorded. Each of the 12 farmers was treated as a replicate. Initial soil characterization and final soil samples were taken and analyzed for macro- and micro-nutrients.

Results and Discussion

Rainfall

Rainfall data from the rain gauges installed showed that as expected, rainfall differed from season to season but there were more rain deficit seasons than surplus/adequate ones. Rains in Laikipia fall in two distinct seasons designated Long Rains (March-August) and Short Rains (October-December). The rainfall data showed that rainfall was different across the 12 administrative locations where this research was undertaken. Apart from the SR 2015 cropping season

that was termed as the *El Nino* rain-type season, all the other seasons received sub-optimal quantities that mainly tapered off at the critical grain filling stage of the maize crop growth and development. Jaetzold et al., (2006) have observed that rainfall in Laikipia county is locally and geographically influenced by Mt. Kenya and the Aberdare Ranges.

Soils

Results of soil analysis revealed that after six consecutive seasons (three years) of experimentation, CA practices impacted differently on soil properties that were determined (Table 1). The CA practices had some positive effect on a number of soil mineral components including phosphorus, potassium and calcium whereas manganese and copper showed increases but not uniformly across the county. The elements where no noticeable change was recorded include pH, organic carbon, nitrogen plus the rest of the minor elements which was not a surprise given the high values shown in the initial soil characterization.

Maize grain yield

Field experimentation commenced in full during the March/April or LR 2014 cropping season. In this initial or preliminary LR 2014 cropping season, all the six treatments were laid out except for the fact that no residues (maize stover) were applied in treatments T_5 and T_6 since the later were supposed to be generated *in situ* in the plots (Table 1). Maize performance during the LR 2014 and SR 2014 seasons was sub-optimal while the remainder of the seasons recorded normal or near-normal yields. Barron et al. (2003) have cautioned that maize growing in Laikipia county is normally faced with greatest risk owing to its lengthy growing period and its sensitivity to unevenly distributed rainfall. The lengths of the long and short rainfall seasons are 55-90 days and 62-85 days, respectively, which means that the lengths of the rainy seasons are shorter than growing periods for most crops grown in Laikipia including maize that require 125 days to mature (Waweru, 2013). In the final cropping season of LR 2016, The average yield for the 12 sites in the county was 2.19 t ha^{-1} which signifies a fair cropping season. Data collected over the four consecutive cropping seasons indicate that the use of full CA package of minimum soil disturbance (using ox ripping), coupled with mulching with crop residues plus use of mineral fertilizer resulted in a -two to -threefold increase in maize grain yields above the farmer practice where neither fertilizer nor CA were used (Table 2). Inorganic fertilizers have the advantage of quick release of nutrients to crops and have little residual effect of the applied nutrients (Gitari and Friesen, 2001).

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Tables

Table 1: Impact of CA treatments on soil nutrient status in Laikipia, Kenya

Soil Parameter	Experimental Treatment							
	T_1	T_2	T_3	T_4	T_5	T_6	CV (%)	SED
Soil pH	5.79	5.72	5.80	5.86	5.86	5.97	10.1	0.37
Total Nitrogen %	0.15	0.14	0.15	0.16	0.14	0.14	19.3	0.018
Org. Carbon %	1.50	1.43	1.54	1.59	1.36	1.40	29.1	0.27
Phosphorus (Olsen) ppm	21.00	23.00	11.00	17.7	26.00	44.00	71.5	10.86
Potassium me%	1.00	0.89	1.11	1.09	1.19	1.28	34.5	0.24
Calcium me%	4.06	4.44	4.56	4.50	4.86	5.24	25.9	0.75
Magnesium me%	2.53	2.40	2.60	2.62	2.18	2.01	21.9	0.33
Manganese me%	0.38	0.46	0.56	0.53	0.57	0.49	47.3	0.15
Copper ppm	0.94	1.10	1.00	1.20	1.30	1.58	54.1	0.41

Table 2: Effect of CA with fertiliser treatments on maize grain yield in Laikipia, Kenya

Treatment Coding	Treatment Description	Maize Grain Yield (t ha^{-1})	
		Lr 2014	Mean for Sr 2014-Lr 2016
T_1	Farmer Practice (FP), no fertilizer, no residue retention	0.083	1.067^{a}
T_2	Farmer Practice (FP), full rate fertilizer, no residue retention	0.517	1.471^{a}
T_3	Minimum tillage, no fertilizer, no residue retention	0.158	1.143^{a}
T_4	Minimum tillage, no fertilizer, no residue retention	0.191	1.579^{a}
T_5	Minimum tillage, full rate fertilizer, total residue retention	0.034	1.685^{ab}
T_6	Minimum tillage, full rate fertilizer, total residue retention	0.570	2.192^{b}
$SED_{0.05}$		0.229	0.340

Incorporating Conservation Agricultural Practices into Small Holder Farming Systems for Sustainable Livelihoods

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Keywords: Technology, Traditional Knowledge Systems, Zai pits, Organic fertilisers, Cereal-legume crop rotations

Introduction

Conservation Agriculture (CA) has been defined as the foundation for a sustainable intensification of crop production based on the three principles of: (1) minimum mechanical disturbance of the soil; (2) permanent organic cover of the soil surface, and; (3) a diversified sequence or association of crops (Joshi, *et al.,* 2010). Adoption of various CA technologies contributes to the aptitude to understand how nature works; the ability to replicate the complementarities which exist between humans, the plants, trees, animals and the natural interlinkages on-farm, and integrating these natural processes with other technologies to achieve sustainable natural resource utilisation in achieving food security.

Given the role that smallholder farmers (SHFs) play in providing global food supply, (almost 80% of food supply in sub Saharan Africa and Asia comes from smallholder farmers), SHFs play a critical role in ensuring sustainable intensification of food production and maintaining the ecosystem balance (FAO, 2012). Currently, SHFs farming practices are less invasive and environmentally friendly, for instance utilisation of organic matter and integrated pest management, but productivity levels remain low, through common counter-productive practices such as mono-cropping (Knowler & Bradshaw, 2007). There is therefore the need to build capacity of SHFs to adopt technologies that will improve their productivity and nutritional status.

Despite the potential benefits of CA to improve productivity and sustainability of farming, adoption of CA in many sub Saharan African countries such as Zimbabwe is not widespread (Mazvimavi & Twomlow, 2009). To enhance uptake of CA technologies, it has been noted that there is need to build upon existing traditional knowledge systems within specific farming communities (Danjuma & Mohammed, 2015). Continually building the capacity of smallholder farmers on CA, specifically innovative and efficient ways that match local natural resource endowments and Indigenous Knowledge Systems is imperative.

This paper presents findings from a project that involved building the capacity of smallholder farmers in natural resource management and adoption of Climate Smart Agricultural (CSA) technologies, specifically the implementation of CA through the "Zai Pit" technology. An inclusive, consultative and bottom-up approach with SHF involvement was applied, modifying and build upon already existing practices/innovations. Zai pits are believed to have originated in the drylands of Burkina Faso from local farmers who dug planting pits about 20-30cm wide, 10-20cm deep, and 60-80cm apart across rock hard plots to break up crusted soils and thereby improving water infiltration and retention (Danjuma & Mohammed, 2015). Zai pits have also been practiced traditionally by local farmers in some drylands of other countries in sub Saharan Africa, though documentation is not as ubiquitous. Over the decades, the practice has been scaled by various researchers and organisations promoting CA, with the size and form of the pits being locally adapted to suit the different agro-ecological contexts (Mazvimavi & Twomlow, 2009).

Materials and Methods

The project was carried out in the Mutasa, Mutare and Makoni Districts of Manicaland in Zimbabwe. 106 wards across the 3 districts were covered by the project. The project spanned 3 growing seasons in 68 fields, all located in different wards. Practical Action and Sustainable Agriculture Technology (SAT) implemented the project with funding support from the DFID and management support from FAO and Palladium. Demonstration plots sized between 0.20

and 0.62ha were established in all the 68 fields. The lead farmers who participated in this study where selected by the traditional leaders and rural district councillors with input from the village/ward members. Participatory on-farm demonstration of site-specific technologies were introduced and implemented into the day to day cropping activities of the SHFs to prevent disruption of their normal routines at household level. An experimental design, the completely randomised block design was used. The treatment consisted of 40 plots with maize crop grown in zai pits incorporating organic fertilizers in the pits. 50% of the treatment plots (i.e. 20 plots) consisted of plots where the maize crop was following a legume, i.e. cereal legume rotation and the remaining 50% of the treatment plots did not have a cereal-legume rotation (Figure 1a, 1b and 1c). The control consisted of 28 plots of maize crop grown using conventional approaches in the area, i.e. no zai pits used. The zai pits used in this experiment measured (50cm x 50cm x 30 cm). Yield data was then collected to evaluate productivity of the different plots and data analysed using Genstat/Minitab statistical package.

Results and Discussions

The results indicated that the treatments under organic fertiliser in combination with zai pits produced significantly higher yields compared to the fields which did not have zai pits and were grown using conventional methods (Figure 2a and 2b).

There were slight nuances in the differences in yield between the plots as follows:

(1) Plots where zai pits were used had significantly higher yields compared to those that did not have this practice. These results were significant at the 5% level.
(2) While all plots with zai pits had higher yield than the control plots, the plots with zai pits and a cereal legume rotation had a slightly higher (though not significant) yield than those that had zai pits only.

Conclusions and Recommendations

Crop production in Sub-Saharan Africa is constrained by numerous factors including frequent droughts and periods of moisture stress, low soil fertility, and restricted access to mineral fertilisers (Nyamangara and Nyagumbo, 2011). Incorporating CA principles and practices significantly influences agricultural productivity in terms of yields realised, soil condition and health (soil microbes, carbon: nitrogen ratio, organic matter component). There is need therefore, to upscale and build capacity among small holder farming communities in order to enhance their livelihood sources and improve soil health and condition. Development of resilient, diversified, and more productive combinations and inter-linkages between crops, livestock, rangeland, agroforestry and technological systems will increase productivity, reduce hunger and malnutrition, and improve the quality of life of the rural poor (CGIAR, 2013). The majority of soils in the smallholder areas of Zimbabwe are infertile (Campbell *et al*., 1997; Nyamangara *et al*., 2009) and sustainable cultivation is not feasible without addition of plant nutrients. However, mineral fertilizers are not affordable to most of the smallholder farmers (SHFs) in Sub-Saharan Africa (SSA) including Zimbabwe (Quiñones *et al*., 1997), hence the addition of organic fertilizers in this current study. Consequently, resource-poor farmers are left with very limited options and therefore concentrate on using organic nutrient sources. However, the organic nutrient sources which are easily accessible to the SHFs are cattle manure (the main source) and plant litter (e.g. tree leaves gathered from woodlands, crop residue) which have very low plant nutrient content (Campbell *et al*., 1998). The integration therefore of organic manure and zai pits was an easily adapted technology as it built upon the reliance of SHFs on locally available organic residues as a vital plant nutrient source. The majority of these SHF areas are extensively characterized by soils with high levels of acidity, often below pH 5, and low levels of phosphorus and nitrogen (Nyamangara *et al*, 2009). This calls for interventions which will enhance natural resource management built upon locally available resources since the SHFs do not have high capital resources to purchase inorganic fertilisers. Organic soil amendments improve the soil by improving the C: N ratio and soil organic component, reducing soil erosion and improving soil fertility and also encourage formation of stable soil crumb structure, thus improving soil internal drainage, infiltration and aeration (Svotwa *et al*, 2009). CA on the other hand, reduces destruction of the natural soil texture, colloids and properties, which is further enhanced by organic matter incorporation.

In the rural Zimbabwean setting were the majority of the SHFs are situated, vegetable gardens are located in one section of the village usually close to a river or water source, some distance away from the village. This causes youth and women to travel long distances to fetch irrigation and domestic water (Pahla *et al*. 2014). Hence the need to include groundnuts in the cereal-legume crop rotation because groundnuts do not require as much irrigation water compared to leafy vegetables (Quinones *et al*, 1997) and their spreading growth architecture protects the soil. The maize stover residues which remain after harvesting the maize crop, creates mulch which increases the water retention capacity of the fields and reduce run off water loss from the field. Groundnuts leaf foliage cover further reduces moisture loss from the soil. The inclusion of groundnuts not only enhanced the nutritional value of the field crops, but will also improve the health of the communities' especially young children, women and suckling mothers (Tibugari *et al,* 2012). Maize is the staple food grown mainly for consumption and the surplus is sold, but the groundnuts are grown mainly for income generation as a cash crop sold either as dried nuts or value added by processing into peanut butter.

To maximize the potential impact and the sustainability of these proposed CA interventions, we must introduce them as part of a package, alongside environmentally friendly natural resource management techniques, appropriate CA technologies, and income-generating activities. This will ensure the interventions are sustainable and attractive within the target communities.

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Figures ad Tables

Figure 1: a. Zai pit + organic matter cereal-legume crop b. Sole cereal crop without zai pits c. Zai pit + organic matter sole maize cereal crop.

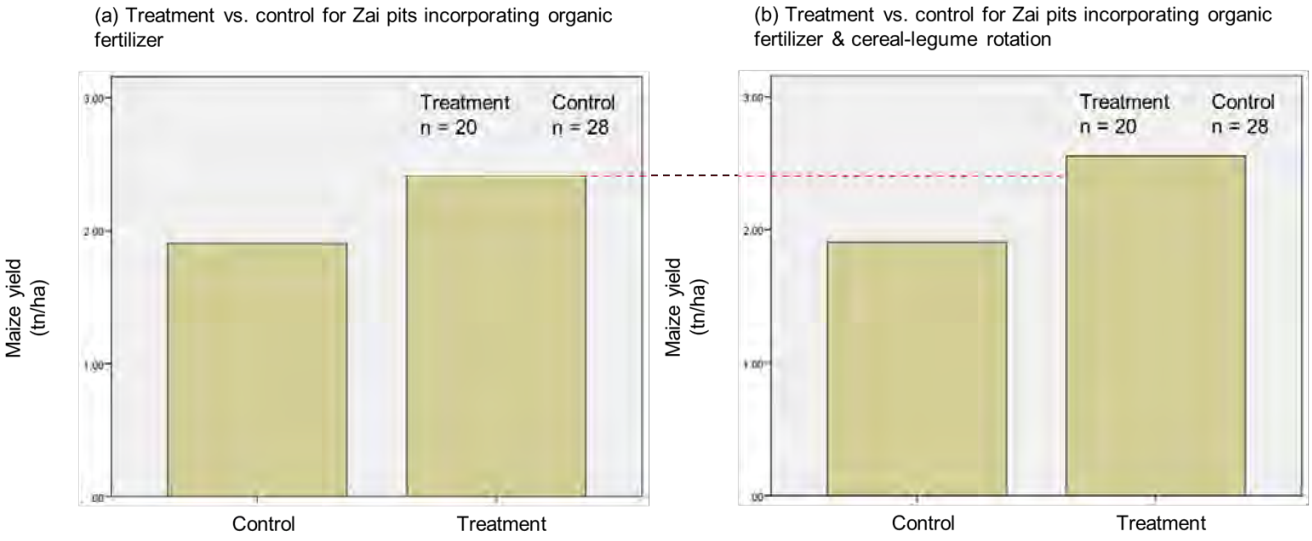

Figure 2a and 2b: Illustrates Maize yields in different treatments

Combining Tillage, Mulching and Soil Fertility Management to Reduce Within-season Climatic Risks in Smallholder Maize Cropping in Zimbabwe

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Keywords: climate change, Conservation Agriculture, rainfed agriculture, sandy soils, smallholder farming, soil fertility

Introduction

Increased incidences of intra-seasonal dry spells present one of the most critical threats to rainfed crop production and subsequently food security in southern Africa (Pascale *et al,* 2015). The situation is aggravated by the inherent poor and declining soil fertility. Most smallholder farming communities in the region including those in Zimbabwe, rely on their own production of staple food and have limited access to irrigation and fertilizers. Agronomic techniques that enhance water conservation and improve soil fertility are therefore key to increase productivity in the work of changing climate and declining soil fertility. Conservation Agriculture (CA) through its main principles; reduced tillage, permanent soil surface cover by crop residue (mulching) and crop diversity, has been promoted over the last two decades to enhance water capture for improved crop productivity among other benefits. However, adoption by smallholder farmers in Africa remains low (compared to e.g. South America) primarily due to lack of appropriate adaptation to varying biophysical and socio-economic settings (Farooq *et al.,* 2011). Under CA, improved plant available water and the subsequent crop yield benefits have largely been attributed to mulching (Hobbs, 2007). However, mulching in smallholder farming systems is limited by insufficient crop residues due to low plant biomass production and competing uses such as livestock feed, fuel and construction (Erenstein, 2002). Locally available grasses like *Hyparrhenia filipendula* (Hochst.) (Stapf) are possible alternatives to crop residues but high prevalence of termites which feed on plant materials in these tropical environments often limit the residence time of the mulch cover. This is particularly a challenge to crops like maize with long growth period of about 120 days. Given the short residence time of most mulching materials there is therefore a need for strategic mulching targeting critical crop growth stages. For example, water-deficits during the interval that spans from few days before tassel emergence to commencement of grain filling can reduce maize grain yield by over 90% (NeSmith and Ritchie, 1992). Crop yield benefits accrued from targeting mulching at such growth stages are not known. Conventional tillage (CT) which involves overturning of the topsoil (15 cm deep or more) using mainly moldboard plough remains a common and preferred farmer practice. However, there has been little attempt to integrate mulching and soil fertility management practices into CT practices. The main objective of this study was to evaluate the combined use of CA principles and soil fertility management in minimizing negative effects of intra-seasonal dry spells on rainfed maize productivity. The study sought to answer the following key research questions: (i) can mulching at different stages of the maize crop under different tillage systems increase water capture and yield? (ii) is there a significant added yield benefit of increasing fertilizer rates when mulching is applied strategically in different tillage practices?

Material and Methods

This paper is centered on the Soil Fertility Consortium in Southern Africa (SOFECSA)'s Farmer Learning Centre (FLC) concept (Mapfumo *et al.,*2013), and was conducted in Hwedza District in eastern Zimbabwe. Through participatory research approaches and diagnostic studies involving FLC participants; low soil productivity, lack of *in-situ* rainwater harvesting and utilization, as well as failure to deal with intra-seasonal dry spells during the growing season were revealed to be critical issues. The study adopted the principles CA and integrated soil fertility management to generate potential solutions jointly with farmers, following which an on-farm trial was conducted over two consecutive seasons (2015/16 and 2016/17). Two tillage practices in which the field was wholly ploughed (conventional tillage – (CT))

and reduced tillage (RT) in which ripper lines were opened, were used. For soil fertility management; fertilizer rates comprising of organics and mineral fertilizer by Mtambanengwe and Mapfumo, (2009) that represents typical rates by different resource groups in smallholder farming were used. These were high fertilizer application rate for resource-endowed (90 kg N ha^{-1}, 26 kg P ha^{-1}, 7 t ha^{-1} of manure) and low rate for resource-constrained (35 kg N ha^{-1}, 14 kg P ha^{-1}, 3 t ha^{-1} of manure) and control (no fertilizer). Mulching using locally available *Hyparrhenia filipendula* (Hochst.) (Stapf) grass was applied at 2.5 t ha^{-1} as follows: at planting only, tasseling only, planting + tasseling and no mulch (control). The field site was a sandy soil with 68% sand and 9% clay. Prior to establishment of experiments, the field was under cowpea.

Results and Discussion

In contrast to the 2015/16 cropping season, 2016/17 season was 'wetter' because of higher total rainfall received as well as shorter dry spells. During the drier 2015/16 season, conventional tillage (CT) + mulching at planting and tasselling + high rate fertiliser treatment had the greatest crop water use (155 mm) which was 37% of the in-crop rainfall received. This was about 11 % more than reduced tillage (RT) counterpart and subsequently led to greatest yield (2.63 Mt ha^{-1}) and water use efficiency (WUE) (17 kg mm^{-1}) (Fig 1 and Table 1). This difference though in a short term means more mulching benefit on CT than on RT. The results also suggest that simultaneous improvement in soil water availability and soil fertility management is critical in securing better yields under such environments. Mulching at both planting and tasseling stages of maize resulted in the best grain yield, as these practices ensured a sustained soil cover through mulching that could have simultaneously improve water infiltration and reduce evaporative soil water loss. During the 2016/17 season, longest dry spell coincided with the tasseling period. No significant differences were observed among treatments in terms of crop water use (Table 1). Highest yields of 2.66 and 3.08 Mt ha^{-1} were achieved for CT and RT, respectively, on the mulching at tasseling + high rate fertilizer treatment. Thus, about 16% more yield in RT compared to CT was achieved. For the mulching at both planting and tasseling treatment, RT outperformed CT by achieving 90% more grain yield under high rate fertilizer. Waterlogging symptoms were noted on plants in CT + mulching at both planting and tasseling plots following incessant rains early in the season. This was not the case on RT and shedding off excess water to avoid waterlogging as observed by Baudron et al., (2012) on easily crusting soils, was a possibility. Thus, RT + mulch as integral CA principles is more supportive to maize production than CT regardless of mulch during wet seasons (depicted by 2016/17) while 'CT + mulching was superior under drier conditions (depicted by 2015/16 season).

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Figures and tables

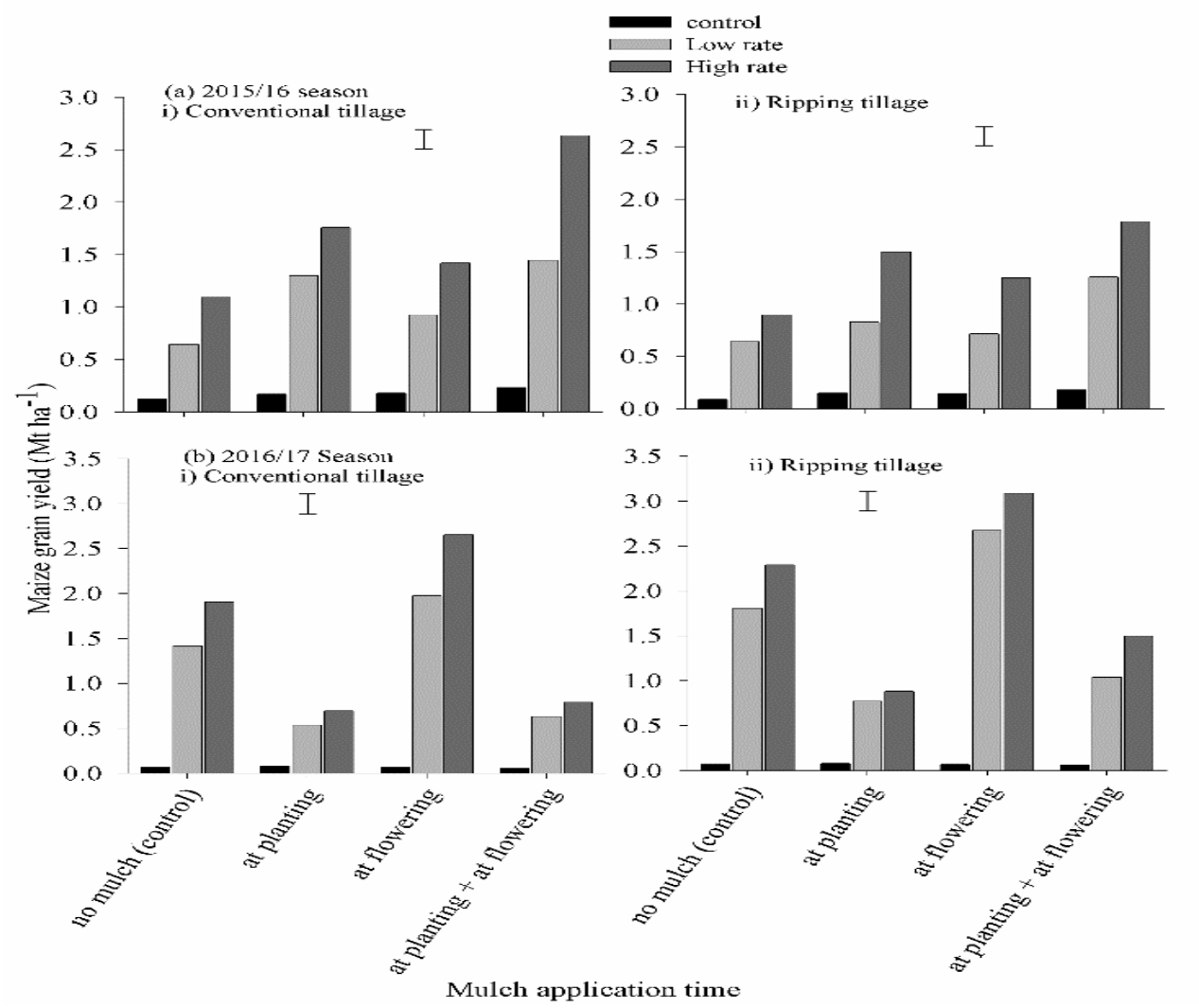

Figure 1. Maize grain yields responses to mulching at different crop growth stages and fertilization rate under conventional and reduced tillage for the 2015/16 and 2016/17 seasons in (Hwedza. Bars represent. Standard Errors of the Differences between means (SED).

Table 1. Crop water use and water use efficiency (WUE) for maize crop mulched at different growth stages under different tillage, fertiliser rates and during 2015/16 and 2016/17 season

2015/16 Season				
Fertiliser x Mulching	Water capture		Grain water use efficiency (Kg mm^{-1})	
	Conventional till (CT)	Reduced till (RT)	Conventional till (CT)	Reduced till (RT)
Low rate				
Control (no mulching)	83^{i}	81^{i}	7.76^{e}	7.92^{e}
Planting mulching	123^{e}	113^{g}	10.56^{d}	7.32^{e}
Tasselling mulching	94^{h}	97^{h}	9.84^{d}	7.39^{e}
Continuous mulching	134^{cd}	129^{de}	10.80^{d}	9.76^{d}
High rate				
Control (no mulching)	86^{i}	84^{i}	12.69^{b}	10.66^{d}
Planting mulching	138^{c}	133^{cd}	12.75^{b}	11.27^{c}
Tasselling mulching	121^{ef}	116^{fg}	11.72^{bc}	10.75^{d}
Continuous mulching	155^{a}	140^{b}	16.99^{a}	12.16^{bc}

2016/17 season				
Fertiliser x Mulching	Water capture (mm)		Grain water use efficiency	
	Conventional till	Reduced till	Conventional till	Reduced till
Low rate				
Control (no mulching)	581	579	2.44^{e}	3.12^{d}
Planting mulching	586	586	0.92^{h}	1.32^{gf}
Tasselling mulching	583	585	2.61^{e}	3.89^{c}
Continuous mulching	581	586	1.08^{gh}	1.77^{f}
High rate				
Control (no mulching)	585	581	3.26d	3.92^{c}
Planting mulching	584	588	1.19^{gh}	1.50^{f}
Tasselling mulching	585	589	4.88^{b}	5.24^{a}
Continuous mulching	584	588	1.35^{fg}	2.63^{d}
Different letters indicate significant differences within each season ($p < 0.05$)				

Tillage and Crop Rotation Effects on Wheat Biomass and Grain Yield in the Eastern Cape, South Africa

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Keywords: Conservation Agriculture, crop residues, no-till, soil degradation, soil fertility

Introduction

Soil degradation resulting in depletion of soil fertility is a problem, which undermines crop production in the Eastern Cape. Activities such as conventional tillage (CT) and the removal of crop residues have led to the depletion of soil organic matter (SOM), rendering the soils susceptible to erosional forces. Whilst Conservation Agriculture (CA) can reverse soil degradation and increase crop yields, the technology is not fully adopted by the Eastern Cape Farmers. On the other hand, earlier research findings point to the need to simultaneously apply all the principles for improved sustainable soil productivity (Karlen *et al*., 1991). Therefore, the study was carried with objective of finding sustainable entry points for the farmers by evaluating the effects of tillage and crop rotation on wheat biomass and grain yield.

Materials and methods

Experimental site: The field trial was established in 2012/13 at the University of Fort Hare research farm (UFH) in the Eastern Cape, South Africa. The UFH site (32°47′ S and 27°50′ E) is at an altitude of 508 metres above sea level. The site is in a semi-arid area and receives an average of 575 mm annual rainfall. About 30% of the annual rainfall is received in winter and the rest in summer. The site has surface layer soils of the Oakleaf form. Prior to the establishment of the trial, the land was under lucerne (*Medicago sativa*) production (Muzangwa, 2016).

Experimental design: The field trial was laid in a split split-plot design. The main plots were no-till (NT) and conventional tillage (CT); sub-plots were four crop rotations; maize-fallow-maize (MFM), maize-fallow-soybean (MFS); maize-wheat-maize (MWM) and maize-wheat-soybean (MWS). The sub sub-plots were allocated to residue management; residue removal (R-) and residue retention (R+). CT plots were ploughed, disked and harrowed to make a fine seed bed before the initial crop establishment whereas no-till plots were sprayed with glyphosate at a rate of 3 litres per ha before planting. A short season and prolific maize cultivar (BG 5785BR) was planted in summer (October-February) targeting a population of 25,000 plants/ha, recommended for dryland conditions in the central Eastern Cape Province of South Africa. The maize was spaced at 1 m between rows and 0.4 m within rows to give a plant population of 25 000 plants/ha. Planting stations were opened using hoes and three seeds were dropped per hole, and later thinned to one plant per station at 2 weeks after emergence. An early maturing, dryland spring wheat cultivar (SST015) was planted in winter (May-August) at a seeding rate of 100 kg/ha. Soybean cultivar (PAN 5409RG) was sown in summer targeting a population of 250,000 plants/ha (~100 kg/ha). Both, soybean and wheat were planted in rows spaced at 0.5 m apart and at a depth of 3-5 cm. Fertilizer was only applied to the summer maize crop at a rate of 90 kg N, 45 kg P and 60 kg K per ha in all plots for a target yield of 5 tons/ha. All the P, K and a third of the N fertilizer was applied at planting as a compound (6.7% N; 10% P; 13.3% K + 0.5% Zn) and the rest (60 kg) as limestone ammonium nitrate (LAN) at 6 weeks after planting by banding. Soybean was inoculated with *Rhizobium leguminosarium* before sowing. No irrigation was applied. Residue retention was implemented soon after harvesting each crop, whereas tillage treatments were implemented just before planting of each cropping cycle

Field and laboratory measurements: Soil samples for the study were taken after harvesting the 2015 winter wheat. Five soil cores were collected randomly to make a composite sample from each plot at three depths of 0–5 and 5-10 cm using a spade for the top layer and a graduated 7 cm diameter auger for the 5-10 cm layer. Before laboratory

work, soil samples were air-dried, sieved with a 2 mm sieve. SOC was determined by dry combustion (LECO Tru-Spec C/N, St. Joseph, MI USA). The grain yield was collected after threshing the wheat and separating grain from the straw. The grain yields were adjusted to 12.5% moisture content after grain moisture determination with a digital grain moisture meter tester model number MC-7825G (Omni Instruments Ltd, Arroyo Grande, California, U.S.A).

Statistical analysis: JMP statistical package version 13.1 (SAS Institute Inc.) was used for the analysis of variance. Treatment means were separated using Fisher's unprotected least significant difference test at 5% probability level. Correlation analyses were done to determine the relationships between wheat yield and soil parameters. Significant differences were identified at $p \leq 0.05$.

Results and discussion

Tillage had a significant ($p<0.05$) effect on wheat biomass yield. Biomass yields were higher under NT than CT in agreement with Hemmat and Eskandari (2006) who ascribed the yield increases to higher moisture conservation under NT in dry areas such as the experimental site. Higher biomass yields from NT than from CT fields are usually obtained in dry climate or in years with less rainfall because in a dry year, plants are less vulnerable to yield loss under NT rather than under CT method. There was no significant ($p>0.05$) interaction of main effects with respect to wheat biomass and grain yield (Table 1 and 2). Tillage and crop rotation effects were not significant ($p>0.05$) with regards to grain yield throughout the experimental period. Generally, higher wheat biomass and grain yields were found in the MWS rotation under NT with surface residue retention although not statistically significant. Sainju et al. (2008) also reported that retention of crop residues on soil surface and involvement of legumes in crop rotation coupled with NT practices play an important role to sustain soil fertility, improving water use efficiency, physical conditions of soils and enhance crop productivity. Soil organic carbon was positively correlated to grain yield (Figure1). Improvement of SOC (Table 3) could have contributed to better nutrient availability and crop productivity under CA. The role of SOC was earlier demonstrated by Lal (2005) who observed significant increases in wheat and maize grain yields of up to 70 and 300 kg ha^{-1}, respectively, for every 1 Mg ha^{-1} y^{-1} increase in SOC.

Conclusion

The results of this short-term study have shown that, no-till and crop rotation that included soybean with residue retention consistently favoured wheat biomass and grain yield. In particular, MWS under NT and residue retention may form part of the solution to soil degradation in the Eastern Cape agro-ecologies.

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Tables

Table 1: Tillage and crop rotation effect on the above ground wheat biomass (kg DM/ha)

Crop rotation	Tillage		Mean
	NT	CT	
MWM	4976.19	4720.95	4848.57
MWS	4983.81	4731.42	4857.62
Mean	4980.00 ^{A}	4726.19 ^{B}	4853.10
ANOVA	P-value		
Tillage	0.02 *		
Crop rotation	0.91 ^{ns}		
Tillage x Crop rotation	0.99 ^{ns}		
CV %	2.78		

NT-no till; CT-conventional tillage; MWM-maize-wheat-maize; MWS-maize-wheat-soybean, ns-not significant; CV–coefficient of variation

Table 2: Tillage and crop rotation effect on wheat grain yield (kg DM/ha)

Crop rotation	Tillage		Mean
	NT	CT	
MWM	3287.33	3145.33	3216.33
MWS	3474.00	3299.33	3386.67
Mean	3380.66	3222.33	3301.50
ANOVA	P-value		
T	0.25 ^{ns}		
C	0.22 ^{ns}		
T x C	0.90 ^{ns}		
CV %	6.5		

NT-no till; CT-conventional tillage; MWM-maize-wheat-maize; MWS-maize-wheat-soybean, ns-not significant; CV–coefficient of variation

Table 3: Tillage and crop rotation effects on SOC and P at UFH experimental site.

Treatment	SOC (%)	P (mg/kg)
0-5 cm		
CT	1.17b	51.07
No-till	1.36a	55.85
$LSD_{0.05}$	0.08	ns
MFM	1.08b	46.96b
MFS	1.28a	55.28ab
MWM	1.30a	48.77ab
MWS	1.40a	62.81a
LSD0.05	0.11	14.76

CV %	11.72	11.97
5-10 cm		
CT	1.06b	42.67b
No-till	1.25a	48.92a
LSD0.05	0.04	6.03
MFM	1.0 c	39.33b
MFS	1.22 a	49.50ab
MWM	1.15 b	41.0 b
MWS	1.25 a	53.33a
$LSD_{0.05}$	0.05	8.53
CV %	11.11	13.04

MFM, maize-fallow-maize; MFS, maize-fallow-soybean, MWM, maize-wheat-maize and MWS, maize-wheat-soybean.

Different letters in each column and factor indicate significant differences amongst the treatments.
LSD, Least Significant Difference; ns - treatment not significant at p≤0.05 probability level
CT-conventional tillage; CV–coefficient of variation

Figures

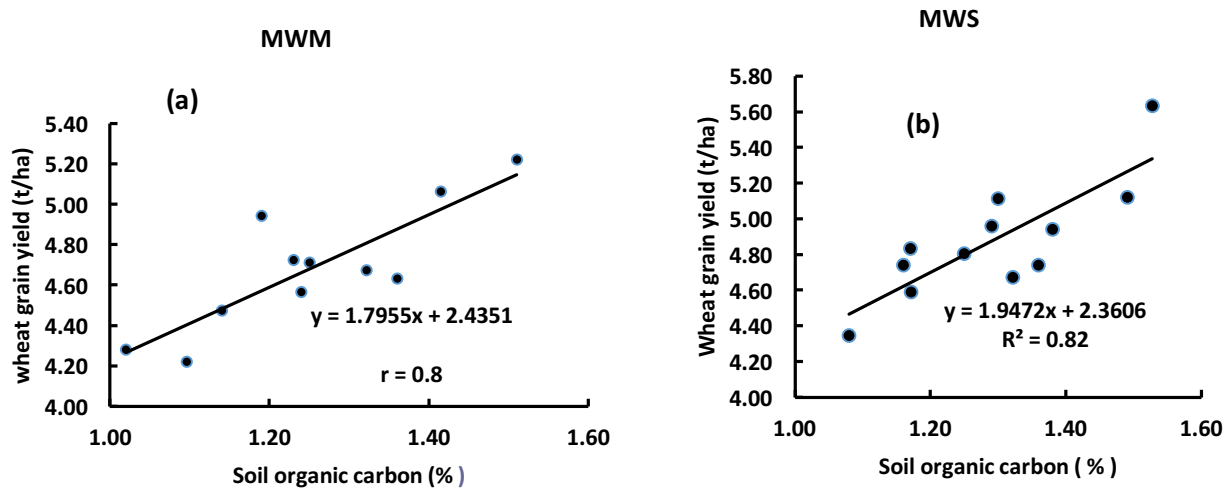

Figure 1: Relationship between wheat grain yield and soil organic carbon under maize-wheat-maize (MWM) and maize-wheat-soybean (MWS) rotations.

Multidisciplinary Approaches to Testing and Scaling Conservation Agriculture Practices in Malawi

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Keywords: Conservation Agriculture, food security, scaling

Introduction

Malawi's agricultural sector drives the economy accounting for about 30% per cent of GDP and provides nearly 80 per cent of the employment (International Monetary Fund, 2017). The country's agricultural sector is characterized with a dualistic structure i.e. high input/high productivity estate that comprises a small number of large-scale farmers, occupying about 60 percent of the fertile land and producing almost entirely for the domestic and export market; and a low input/low productivity smallholder sector, that is dominated by a very large number of farmers growing mainly low-yield food crops on small plots with minimal input use (NSO 2005; DARS 2011). The whole sector is prone to varied weather shocks and hazards including floods and droughts which have risen in frequency and magnitude in recent years, rising temperatures, deforestation and land degradation which undermines the livelihoods of farming communities and exacerbate the extent of food insecurity and rural poverty (Coulibaly et al., 2015). In response to aforementioned challenges, this paper briefly reports on the results from a research program on sustainable intensification of maize-legume cropping systems for food security in Eastern and Southern Africa (SIMLESA). The research focused on on-farm adaptive research to test the economic and production merits of Conservation Agriculture based sustainable intensification practices (CASI).

Material and methods

A series of on-station and on-farm trials were spread across six districts (to cover varying production agro-ecologies), namely Lilongwe, Kasungu, Mchinji, Salima, Balaka, and Ntcheu districts. Despite differences in agro-ecology, all study districts are characterized by rain-fed maize-legume cropping systems. This makes them vulnerable to climate change and climate variability. Participating farmers for on-farm trials were retained for the project period. Agronomic trials were carried out in 36 on-farm exploratory trials and one long term trial at Chitala research station. The on-farm trials provided platforms for farmer learning on Conservation Agriculture and sustainable intensification practices. The research was conducted in two contrasting agro-ecological zones, i.e. mid-altitude and low-altitude. In each district, activities were implemented in one extension planning area (EPA) with six farmer-replicated on-farm trials. Finally, value chain and socio-economic surveys were conducted to identify the system bottlenecks or enablers for CASI in the research sites and beyond. Farm level and market surveys were conducted to generate socio-economic datasets that lent themselves to market, adoption and policy analysis.

Results and Discussion

Yield and income analysis of technologies. Gross margin analyses from 2012 to 2017 showed that CASI outperformed the conventional maize direct seeding systems. Farming using dibble-stick was more profitable than the conventional farmers practice in the two agro-ecological regions. However, economic analysis showed that direct seeding increases labour productivity and returns per US dollar invested, across all agro-ecological regions and seasons. The results suggest the need for developing resource efficient cropping systems that increase both labour productivity and economic returns to farmers across different agro-ecologies. Maize productivity increased by 18% and 37% in mid-altitude and low-altitude agro ecological zones, respectively as shown in table 1&2. These were largely due to maize-legume rotations under CASI with good agronomic practices and these results are consistent with those of (Nyagumbo

et al., 2016). The use of CA basins on average reduced yields in Salima and Ntcheu where soils were more prone to waterlogging during periods of excessive rainfall while in Balaka the use of CA basins increased maize yield. The use of CA basins in Malawi was thus dependent on location and required special targeting to areas where the risk of waterlogging is low. Diversified crop rotations and associations of maize legume cropping systems were also demonstrated as part of the adaptive research activities. Legumes incorporated in the system also fix nitrogen and thereby increased maize yields in maize legume rotation or intercropping. These results are in line with findings from (Ngwira, Aune, & Thierfelder, 2014) and (Kankwamba and Mangisoni, 2015).

Effect on soil quality. After six years of implementation of CASI practices, soil quality changes in terms of aggregate stability were quite evident on most sites. For instance, as shown in figure 1, soils in Kasungu district that had been under CASI were much darker in colour. Soil organic carbon analysis from Kasungu and Salima districts in 2016 suggested that the soils under CASI had significantly higher top soil organic carbon status compared to the conventional practices as shown in figure 1 and 2. For example in Kasungu which is mid altitude, CASI maize sole with no herbicide and CASI maize soya rotations increased top soil organic carbon while in the lowlands of Malawi, the maize/pigeon pea intercrops and maize /groundnut rotations also increased top soil organic carbon. Consequently, the use of CASI, in particular the provision of surface residue cover, helps to improve water transmission in CA systems while in the ridge/furrow system, the poor water infiltration leads to surface ponding and consequently results in high run-off and soil loss leading to the observed high soil degradation in conventional cropping systems.

Drivers of Adoption CASI technologies. Findings from adoption surveys conducted in 2010, 2013 and 2016 show that CASI adopters increased to 51, 401 farmers from a 2, 226 baseline. The adoption rate (of at least one CASI practice) increased from 26% in 2013 to 56% in 2016 in the low-altitude, whilst in the mid-altitude area it increased from 29% to 47%. The most commonly adopted CASI options in the low potential area included minimum tillage only, minimum tillage and maize legume association and residue retention. Whilst in the high potential zones, a combination of minimum tillage, maize legume association with use of herbicides and minimum tillage residue retention plus herbicides increased significantly. The main reason for increase in adoption for the preferred CASI practices included, increased yield and ease of access to herbicides. The results suggest that higher yields from improved soil and water conservation, improved cash inflow and labour saving are the main drivers of CASI technology adoption.

Conclusion

The findings documented in this summary paper show that CASI can improve maize yields over time especially when improved varieties and good agronomic practices are part of the package. The adaptive research practices made available various CASI options for low-altitude and mid-altitude agro-ecologies in SILMESA impact districts and beyond. One of the outcomes of the research has been the institutionalization of CASI technologies into the Malawi farming systems and national agenda such as Agricultural Productivity Programme for Southern Africa (APPSA). Evidence from adoption surveys suggested that average maize yields from the communities where much of the research was done was much higher than local averages and increased from 1.2 t/ha in 2010 to 3.8t/ha by 2016. Efforts on scaling CASI technologies suggest that by 2016 some 51000 farmers were using CASI technologies in their fields. These results highlight the basic notion that scaling out CASI technologies should be the next frontier in efforts to mainstream CASI. Farm level benefits and strong extension efforts that are based on widespread adaptive research, demonstration and farmer education can help in this process.

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Tables and figures

Table 1. Average maize yields (kg/ha) by cropping system in the low-altitude districts of Balaka, Ntcheu and Salima, central and southern Malawi, 2010/11-2013/14 cropping seasons

Cropping system	Overall 4 years mean	% yield increase
Conventional practice (Farmers' check)	2397	-
CA Basins Maize -pigeon pea intercrop	2824	18
CA Dibble stick Maize-pigeon pea intercrop	2628	9
CA Dibble Maize sole	2718	12
CA Dibble stick Maize-groundnut rotation	3286	37

Table 2. Average maize yields (kg/ha) by cropping system in the mid-altitude districts of Kasungu, Lilongwe and Mchinji, central Malawi, 2010/11-2013/14 cropping seasons

Cropping system	Overall 4 years mean	% yield increase
Conventional practice (Farmers' check)	3798	-
CA + sole maize + no herbicide	3889	2
CA + sole maize + herbicides	4088	8
CA + herbicides + maize soybean rotation	4434	17
Conventional practice (Farmers' check)	3798	-

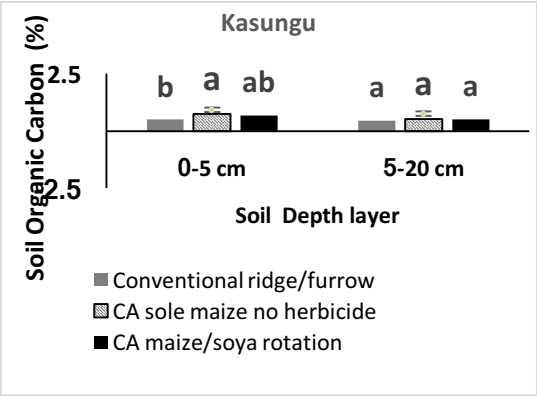

Figure 1: Soil organic carbon analysis for Kasungu, mid-attitude district

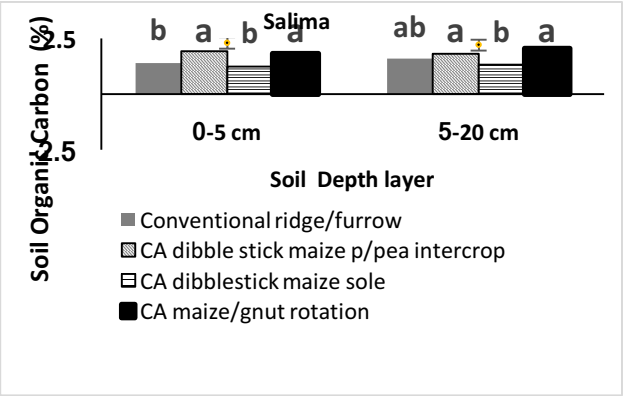

Figure 2: Soil organic carbon analysis for Salima, low-attitude district

An ex-post Evaluation of Ten Years of Conservation Agriculture Promotion in Zimbabwe

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Key words: Adoption, food security, smallholder farmers, sustainability

Introduction

Conservation Agriculture (CA), a way of farming that aims to achieve high production whilst conserving the environment through the application of three principles: minimum soil disturbance, permanent soil cover, and crop rotations or associations (FAO, 2010), has been promoted by Canadian Foodgrains Bank (CFGB) partners to address food shortages throughout Africa. One such project took place in Zimbabwe from 2006 to 2014 where CA was promoted to more than 10,000 households in five districts suffering from marginal rainfall, poor soil fertility and high levels of food insecurity. In addition to CA, community seed banks were introduced to address the challenges of input markets. While reports and evaluations done at the time of the programming were overwhelmingly positive, concerns about the potential positive bias of those who conducted these reports (Anderson and D'Souza, 2014) and questions about longer-term sustainability led to an independent, ex-post evaluation of this programming in mid-2017.

Materials and Methods

To conduct this study, CFGB engaged the National University of Science and Technology, Zimbabwe to do an ex-post evaluation of CA in the five districts of Nkayi, Chirumanzu, Gutu, Nyaminyami and Chimanimani. The consultants reviewed project documents and conducted interviews with key informants, farmers who adopted CA (including farmers who received no programmatic support), and farmers who decided not to adopt CA. Data collection methods included focus group discussions (FGD) and household surveys. In each district, sampled wards were purposefully selected to represent wards that had programming in place for a minimum of three years. A total of 305 households, 231 adopters and 74 non-adopters of CA, were interviewed in May of 2017. The objectives of

the evaluation were: 1) to assess the status of adoption of CA (the drivers and barriers to continued use of CA principles) and 2) to assess the impact and sustainability of community seed banks in improving seed availability.

Results and discussion

Adoption of CA principles. This study found that after the cessation of active CA promotion and training, minimum soil disturbance continued as a practice involving digging of properly spaced planting stations using hoes during dry seasons. This came out from the household survey where 89% of practicing respondents stated that they dug planting stations during the 2016/2017 cropping season. Crop rotation was adopted by 81% and the use of supplemental soil cover by 79%. These figures reveal a relatively high adoption rate especially for soil cover considering that other studies report soil cover as the most difficult principle due to social and environmental challenges including multiple uses of crop residues (Giller *et al,* 2009). It should be noted that crop rotation, although practiced, was partial as most of the farmers allocated a greater portion of their land to cereal.

Area under CA. The average area under CA was 0.5 ha compared to 1.5 ha under conventional tillage (see Figure 1). As a percentage of total area, CA was practiced on 23% of total arable land and conventional farming on 68%. CA plots were limited to mostly homestead fields which could be fenced and protected from livestock.

Drivers to adoption. Drivers to the practice of CA included: (i) higher yields under CA (58%); (ii) relatively simple for farmers to implement even for those without livestock and animal drawn ploughs (16.4%); (iii) improved soil fertility and moisture conservation (9.3%); (iv) training by NGOs and extension personnel and seeing other farmers also motivated 8.4% of respondents to practice CA and (v) saving of inputs through precision application of nutrients (7.9%). High yields and lack of draught power are the major drives to CA in the study.

Barriers to adoption. The evaluation revealed that some smallholder farmers who had initially practiced CA had since stopped. The perceived barriers to adoption included lack of inputs such as seed and fertilizer/manure which are promoted during training, (21%) of respondents, labour challenges (13.6), old age (13.6%), ill health (10.7%), lack of mulching material (10.7%), climate change (8.9%), lack of fencing material (7.9%) and lack of access to training or extension support (3.7%). There was generally a perception that hand -hoe based CA was more labour intensive than conventional farming and thus contributed to ill health and premature aging. There were 9.3% of respondents who felt that nothing would stop them from practising CA. The findings reveal the importance of institutional support in terms of markets and the need for labour saving no tillage methods.

Community seed banks sustainability. Sixty-seven percent (67%) of respondents indicated that community seed banks had contributed to availability of seed in their areas. However, participation in seed banks was low with 57% percent of respondents having contributed seed towards the seedbank and 43% of respondents had never contributed to the seed bank. In terms of open pollinated varieties (OPV) seed sources, only 18% of respondents had planted OPV seed from community seed banks whilst 78% used seed from own productions and 4% used OPV seed from others (Figure 2). According to key informants and discussions during focus group, the failure of community seed banks was attributed to poor quality control, poor storage, social issues (some people were not willing to have their seed mixed with others), drought and cash shortages hampered efforts to save, and lack of leadership necessary for coordinating seedbanks.

The evaluation found that CA has continued to be part of the farming system in the study districts. The yield benefits of CA have been the major driver to continued practice. However, the practice of CA is still limited to small plots sizes due to labour challenges associated with digging basins and the challenges of getting mulching material. Individual seed saving schemes are important in ensuring input availability compared to community run seed banks. Labour saving technologies, market access and finding alternative mulching material such green manure cover crops, can contribute to sustained adoption of CA.

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Figures

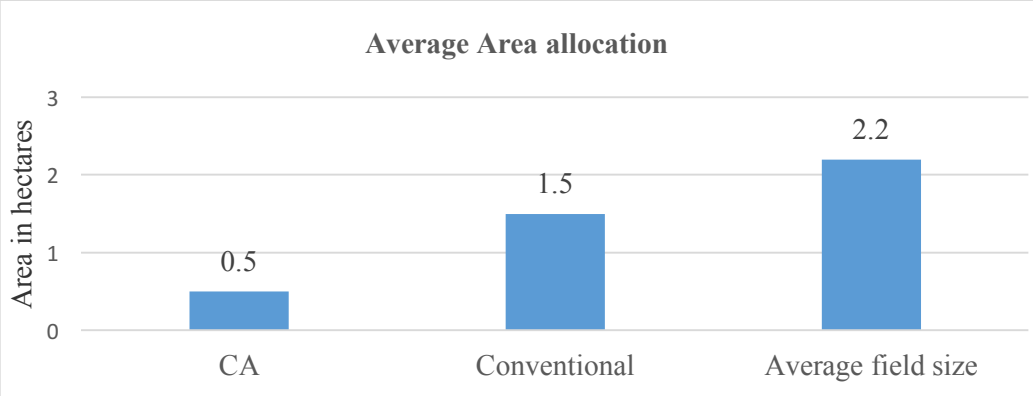

Figure 1: Average area allocation to CA and conventional

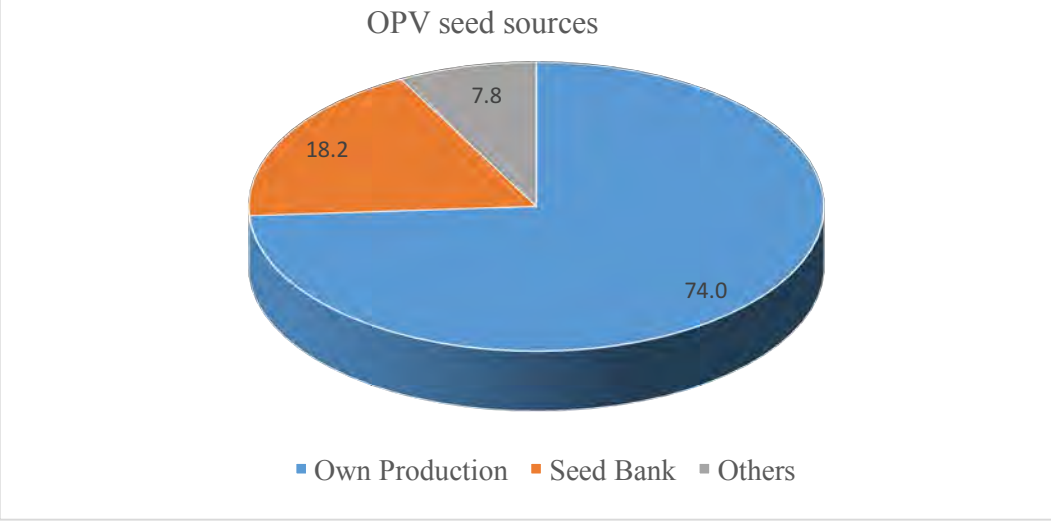

Figure 2: Sources of OPV seed

Conservation Agriculture with Legume Intercrops: evidence from Zimbabwe on economic and food security impacts

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Keywords: cowpea, lablab, pigeon pea, smallholder farmers

Introduction

Smallholder farming systems in sub-Saharan Africa (SSA) are under increasing pressure due in part to climate change and soil degradation. Current estimates show up to 40% of farming households are unable to achieve even basic food self-sufficiency (Frelat, Lopez-Ridaura et al. 2016). Farmers and researchers have experimented with Conservation Agriculture (CA) in different countries of sub-Saharan Africa for at least two decades, and over that time CA has been heavily promoted by both governments, NGO's, and researchers as a climate smart agriculture technology, and as a partial solution to food insecurity and soil degradation. While CA systems have generally resulted in significantly higher crop grain yields, this is dependent on permanent soil cover and crop rotations: the two components that are, for many smallholder farmers in SSA, the bottlenecks to adopting CA (Corbeels *et al.* 2014). This conclusion was echoed in a recent ex-post evaluation of 10+ years of CA promotion in Zimbabwe, where lack of mulch was identified as the biggest obstacle to increasing the area and number of farmers practicing CA (Nkala *et al.* 2017). One possible solution to mulch scarcity is intercropping the main cereal crop with a (leguminous) cover crop (Rusinamhodzi and & Corbeels 2011); a technology option that also has the potential to improve the food security and economic productivity of smallholder CA systems.

This paper is based on a study conducted to assess the impacts of intercropping grain legumes into CA based farming systems. Specifically, this study looked at whether a leguminous intercrop could increase the total amount of biomass produced (thus potentially reducing the need to add supplemental mulch) and improve the food security and economic impacts of a smallholder CA system. This study focused on the critical first year of intercropping/CA adoption, to determine if intercropping was beneficial for smallholder farmers in the short-term irrespective of the longer-term soil health and soil fertility benefits of intercropping.

Material and Methods

Results for this study come from three farmer managed research plots from two rural areas of Zimbabwe (Lupane (Matabeleland North) and Neshuro (Masvingo)) – both in agro-ecological zone IV (semi-arid). The two farmers in the Lupane area had sandier, lower agricultural potential soils than the farmer from the Neshuro region, who had higher potential sandy-loam soil. The experiment was initiated in late 2015 and was followed for one cropping cycle. A two-replicate split plot experiment with eight treatments was conducted on each of the three farmers' fields, all plots were planted using hand-hoe dug planting basins and micro-fertilization with composted cattle manure. The main plot treatments were mulch and no mulch, while the sub-plot treatments were legume species (cowpeas (*Vigna unguiculata*), lablab (*Lablab purpureus*), and pigeon pea (*Cajanus cajan*). The main cereal crop at all locations was maize (*Zea mays*). Experimental plots were managed by the farmers themselves; experimental data was collected by the farmers in conjunction with a research technician. Total biomass and maize grain yields were collected for all sites. Cowpea was the only legume to produce grain at all sites and these were used to calculate a simplified economic gain for the maize/cowpea intercrop. Very basic subsistence food needs for a family of six for one year was determined using Nutval – a spreadsheet used for planning and monitoring the nutritional content of food assistance (www.nutval.net). We calculated the economic value of a subsistence food package (maize, cowpeas, oil, and salt) for a family of six for one year, and determined the ability of the farmers in this study to meet these basic food needs from a 0.25 ha intercropped cowpea/maize CA field (using a combination of purchase and self-production).

Results and Discussion

Biomass production impacts: The two farms in the Lupane area received approximately 550 mm of rainfall during the study period, while the farmer in the Neshuro region received approximately 400 mm of rainfall during the study period. For the two farmers in Lupane, there was a significant increase in total biomass production when an intercrop was added to the mulched, mono-cropped CA maize crop: an estimated increase of 5,043 kg/ha (P=0.014) for the first farmer and an estimated increase of 1,843 kg/ha (P=0.049) for the second farmer. For the farmer in Neshuro, adding a legume intercrop did not increase the total amount of biomass produced but simply changed where that biomass came from (in the lablab plots, for example, approximately 75% of the biomass produced was from the lablab plants).

Economic impacts: Maize grain yields at all sites for all experimental units were higher than national averages, despite the farmer's perceptions that it was a drought year (according to FAOSTAT, the 2014 ten-year average for Zimbabwe was 706 kg/ha; the average yield across all experimental treatments for this study was over 5 tons/ha). This may have been due to the common methods used by all farmers in this study: precision planting based on recommended maize spacings; micro-fertilization of composted cattle manure placed close to the growing maize plant; minimal soil disturbance; and timely and thorough weeding. The intercropped, un-mulched maize plots as well as the intercropped, mulched maize plots both had a grain yield increase due to the intercrop = (yield of maize + cowpeas grown together as an intercrop / yield of mono-cropped maize) of close to 1 or higher (see Table 1). However, because cowpeas are generally worth twice as much on the open market in Zimbabwe as maize (at the time of the study cowpeas sold for ~0.80 USD/kg, whereas maize sold for ~ 0.40 USD/kg) adding cowpeas as an intercrop at all sites – for both mulched and un-mulched plots – yielded higher net economic benefits: for the farmers in Lupane 247 % (P = 0.09) and 241 % (P = 0.056) higher, and 197 % higher for the farmer in Neshuro (P = 0.034).

Food Security impacts: For the post-harvest period following this study (June 2016 and onwards) the Zimbabwe Vulnerability Assessment Committee reported that the Lupane area of Zimbabwe had a generally stressed level of food security (IPC phase 2) while the Neshuro area was in the more serious IPC phase 3 (crisis phase) (FEWSNET 2017). It was therefore likely at least some of the households in the Neshuro region were in need of food assistance during this period. For famers with access to and resources necessary to tend a 0.25 ha CA plot, we found that planting only maize (using CA methods but with no supplemental mulch) resulted in a significant deficit in food needs at all sites, while the addition of supplemental mulch significantly improved food security impacts for the farmers in Lupane but still produced a significant deficit for the farmer at the Neshuro site. The addition of an intercrop alone (with no supplemental mulch) allowed farmers to meet all or most of their basic food needs, while the addition of both an intercrop and supplemental mulch allowed the meeting of basic needs plus a surplus for the farmers at all sites (see Table 2).

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Table 1: Grain yield increase (expressed as ratio of maize intercropped with cowpeas compared to sole-cropped maize**) in mulched and un-mulched plots**

Site	un-mulched			mulched		
	Maize (sole-crop) (kg/ha)	Maize (inter-crop) (kg/ha)	Cowpea (inter-crop) (kg/ha)	In-crease	Maize (sole-crop) (kg/ha)	Maize (inter-crop) (kg/ha)	Cowpea (inter-crop) (kg/ha)	In-crease
1 Lupane	4426 (SE 1241)	5722 (SE 574)	407 (SE 148)	1.38	6722 (SE 1130)	9130 (SE 93)	907 (SE 315)	1.49
2 Lupane	3389 (SE 981)	5241 (SE 1019)	1000 (SE 37)	1.84	7037 (SE 74)	5593 (SE 481)	1296 (SE 111)	0.98
3 Neshuro	4124 (SE 444)	4160 (SE 889)	2200 (SE 244)	1.54	3964 (SE 516)	3876 (SE 462)	2156 (SE 67)	1.52

Table 2: Annual profit/loss calculations (USD) assuming purchase of minimum food needs for a family of six, for a variety of technology options on a CA plot of 0.25 ha.

Site	Technology (0.25 ha plot)	Total surplus or deficit
Farmer 1 (Lupane	Maize (no mulch)	-$ 214
Farmer 2 (Lupane)		-$ 318
Farmer 3 (Neshuro)		-$ 243
Farmer 1 (Lupane	Maize + Cowpea (no mulch)	-$ 9
Farmer 2 (Lupane)		$ 61
Farmer 3 (Neshuro)		$ 193
Farmer 1 (Lupane	Maize + Mulch	$ 15
Farmer 2 (Lupane)		$ 47
Farmer 3 (Neshuro)		-$ 260
Farmer 1 (Lupane	Maize + Mulch + Cowpea	$ 432
Farmer 2 (Lupane)		$ 156
Farmer 3 (Neshuro)		$ 156

The Effect of Cover Crop Utilisation on Mineral Composition of the Remaining Biomass

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Keywords: Grazing, Hay, Mediterranean, Mulch, Nitrogen

Introduction

In dry Mediterranean regions, cover crops cannot be cultivated in the summer. In order improve Conservation Agriculture systems in Mediterranean regions cash crops are substituted by cover crops. Substituting cash crops with cover crops will lead to lower profit margins. The viability of cover crops can be enhanced by utilisation as fodder in order to generate an income. Utilisation of cover crops as fodder reduce crop biomass and can lower the positive effects of cover crops. This study aims to investigate the effect of cover crop utilisation on the functional role of cover crops.

Methods

The trial was conducted in the Swartland, Western Cape, South Africa with a Mediterranean-type climate. The Swartland is a dryland production system with hot and dry summers which prevents summer crop production in the region. Three treatments were laid out in a completely randomised design, replicated 12 times in 15 x 10 m plots. The treatments consisted of three management groups, i.e. 1) grazed by sheep, 2) cut and removed as hay and 3) left as a mulch layer, with two cover crop mixtures. The first mixture was established with the aim to contain 70% cereals (forage barley and triticale) and 30% legumes (peas, medic and vetch). The second mixture was established with the aim to contain 30% cereals (forage barley and triticale) and 70% legumes (peas, medic and vetch). Both the mixtures were established after the first winter rain using a zero-tillage disc planter. Biomass samples were cut from 0.25m^2 quadrants after the growing season and analysed for chemical composition. Extensive soil data taken from each of the plots after the growing season was used.

Results and Discussion

The utilisation of cover crops as fodder reduced the amount of crop biomass regardless of the mixture ($p<0.01$). The composition of cover crops changed due to utilisation. This meant the minerals in crop biomass did not necessarily change in the same proportion as the amount of material specifically in the mainly legume mixture. Nitrogen, phosphorus and potassium content of the crop biomass was higher in the grazed plots ($p<0.05$). The unutilised plot had a higher potassium content than the plot where material was removed for hay ($p<0.05$). Total soil nitrogen levels of the grazed plots were the highest ($p<0.05$). Other than soil nitrogen no differences was observed between treatments in soil composition. High nitrogen levels in grazed plots can be the result of urine and manure from the sheep.

Conclusions

The utilization of cover crops does not have a negative influence on soil. Utilizing cover crops influence the amount of material more than the amount of nutrients in cover crop biomass. Grazing has a positive effect on cover crops in terms of soil nitrogen. When utilisation do not have a negative effect on cover crops it will increase profit margins when producers utilize cover crops.

Tables

Table 1: Mulch quality of 70% cereal and 30% legume mixture.

	Hay	Grazing	Not utilised
Cover crop (kg/ha)	1510[c]	2367[b]	4449[a]
Cover (%)	83[b]	84[b]	98[a]
Nitrogen (kg/ha)	30[c]	52[b]	72[a]
Phosphorus (kg/ha)	4[c]	7[b]	11[a]
Potassium (kg/ha)	27[c]	52[b]	74[a]
Calcium (kg/ha)	9[b]	10[b]	16[a]
Magnesium (kg/ha)	3[c]	5[b]	7[a]
Sodium (kg/ha)	2.30[b]	4.70[a]	7.60[a]
Copper (kg/ha)	0.01[c]	0.02[b]	0.02[a]
Zinc (kg/ha)	0.03[c]	0.05[b]	0.08[a]
Manganese (kg/ha)	0.09[b]	0.11[b]	0.18[a]
Boron (kg/ha)	0.02[b]	0.03[b]	0.04[a]
Aluminium (kg/ha)	1.00[a]	1.20[a]	1.10[a]
Sulphur (kg/ha)	2[c]	4[b]	6[a]
Ash (kg/ha)	176[b]	258[a]	310[a]

Key: Different letters indicate a significant difference ($p<0.05$).

Table 1: Mulch quality of 30% cereal and 70% legume mixture.

	Hay	Grazing	Not utilised
Cover crop (kg/ha)	1761[c]	2775[b]	3754[a]
Cover (%)	85[b]	85[b]	99[a]
Nitrogen (kg/ha)	39[b]	73[a]	74[a]
Phosphorus (kg/ha)	5[c]	8[b]	10[a]
Potassium (kg/ha)	32[b]	53[a]	63[a]
Calcium (kg/ha)	13[b]	20[a]	21[a]
Magnesium (kg/ha)	4[b]	7[a]	7[a]
Sodium (kg/ha)	3.10[b]	10.60[a]	8.10[a]
Copper (kg/ha)	0.01[b]	0.02[a]	0.02[a]
Zinc (kg/ha)	0.04[b]	0.07[a]	0.07[a]
Manganese (kg/ha)	0.10[b]	0.16[a]	0.16[a]
Boron (kg/ha)	0.03[b]	0.05[a]	0.04[a]
Aluminium (kg/ha)	1.10[b]	1.70[a]	1.10
Sulphur (kg/ha)	3[b]	5[a]	5[a]
Ash (kg/ha)	190[b]	271[a]	297[a]

Key: Different letters indicate a significant difference ($p<0.05$).

Improving Productivity, Resilience and Sustainability through Conservation Agriculture Based Systems in the Ethiopian Drylands

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Keywords: Conservation Agriculture, soil erosion, runoff, soil water storage

Introduction

Several farming practices in Africa have to cope with inevitable risks of soil erosion and degradation, such as intensive and repeated tillage, complete crop residue removal, aftermath overgrazing, biomass burning, use of crop straw and animal dung for fuel and deforestation. These practices have increased soil erosion and reduced soil water availability, leading to decrease in land productivity (Araya *et al.,* 2016) and weakened ability of agro-ecosystems to adapt the climate change. Conservation Agriculture (CA) can minimize the effects of soil degradation associated with soil erosion and soil fertility depletion and hydrological challenges facing smallholder farmers in the drylands of Ethiopia. However, adoption of CA is relatively low in Sub-Saharan Africa particularly in Ethiopia (Araya *et al.,* 2016). CA-based systems aim at reducing soil erosion and improving soil moisture and crop yield by minimizing soil disturbance, retaining crop residue, using crop rotations and associations, and adding *in situ* soil and water conservation tillage practices (*terwah* and *derdero*) in crop fields. In this study, the bed and furrow local tillage management structures of *terwah* and *derdero* are integral elements of CA. *Terwah* is a contour furrows at 2-4 m wide intervals while crops in *derdero* are grown on the ridges where they are protected from water logging (Araya *et al.*, 2015). Therefore, this study evaluates the effects of two CA-based systems (*terwah*+ TER+ and *derdero*+ DER+) compared to conventional tillage system on soil loss, runoff, soil-moisture storage and crop yield during the 10-yrs study period in Vertisols in northern Ethiopian highlands. The hypothesis in this study was that the CA-based systems reduce soil loss and runoff and improve soil-moisture storage for climate resilient agriculture.

Materials and Methods

This study was conducted over a period 2005-2014 in permanently kept plots in farmers' fields in the semi-arid drought prone Gum Selasa (13°14'N, 39°32'E) at an altitude of 2100 m a.s.l. in northern Ethiopia. The experimental layout was a randomized complete block design with 3 replications. The soil type under the study was a Vertisol with a slope gradient of 3%. The mean annual 31-yrs rainfall was 499 mm. Wheat, teff, barley and grass pea were grown in rotation. Glyphosate was sprayed to CA-based systems at 2 l ha^{-1} to control weeds before crop emergence, starting from 2007. Two CA-based systems were developed from traditional land management practices: (i) DER+ is a bed and furrow planting system, where beds remain undisturbed from ploughing, furrows are tilled once at planting time and 30% of crop residue is retained on the ground surface. (ii) TER+ is ploughed once at planting, furrows are made at 1.5 m interval, creating fresh broad beds, and 30% crop residue is retained. These CA-based systems were compared against conventional tillage system (CT) characterized by a minimum of three tillage (ploughing) operations and complete removal of crop residues at harvest. All ploughing was done using a local ard plough mahresha. Runoff was collected at the lower end of each plot. Soil water content was measured using gravimetric method at 5- to 6-day intervals.

Results and Discussion

Significantly different ($P<0.05$) runoff coefficients (%) and soil losses (t ha^{-1} yr^{-1}) averaged over 10 years in Gum Salasa were 14 and 3, 22 and 12, and 30 and 18 for DER+, TER+ and CT, respectively (Table 1). Soil water storage (0–80 cm soil depth) during the growing season was always highest with DER+ followed by TER+ and CT (Fig.1). This showed that CA-based systems have a significant potential as water management tools to increase green water availability mainly due to reducing loss of water in the form of runoff. Also indicates the potential of CA-based systems

to build resilience against drought and to all forms of dry spell. On the other hand, the bed and furrow structures in the DER+ systems avoided crop yield losses related to periodic water-logging or climate change induced increase in rainfall by draining the excess rainwater to the furrow from the bed where the crop grows (Araya et al., 2015). Although improvements in crop yield were observed, a period of at least three years of cropping was required before they became significant (Table 1). On average, crop yields under DER+ and TER+ increased by 30% and 16%, respectively, as compared to CT. The yield of barley in Gum Selasa was found highest in DER+ systems during drought year (2008) and long dry spells (2014).

Conclusion

CA-based (DER+ and TER+) systems reduced soil loss and runoff and enhanced soil water storage. CA-based systems are promising for smallholders' farmers on Vertisol with equal or higher crop yield during the 10-yrs study period except in 2006. The DER+ system performed better in terms of crop yield even during unfavourable weather conditions compared to the other treatments. However, the improvement in crop yield was not immediate and the full benefit of DER+ with permanent raised beds plus retention of crop residues can be expected after a minimum of three years. DER+ and to a lesser extent TER+ proved to be more sustainable for food production that can potentially contribute to building climate resilient agriculture for ensuring food security.

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Table and Figure

Table 1. Soil loss, runoff and grain yield from 2005-2014 in Gum Selasa, Ethiopia ($p < 0.05$).

Year	Treatments	Crop rotation	soil loss (t/ha)	Runoff (mm)	Grain yield (t/ha)
2005	DER+	Wheat	5b	7c	2.03a
	TER+		9ab	9b	1.97a
	CT		17a	16a	1.53a
2006	DER+	Teff	1b	14b	0.68c
	TER+		23a	25ab	0.93b
	CT		29a	29a	1.17a
2007	DER+	Wheat	10c	15c	2.76a
	TER+		27b	27b	2.2b
	CT		32a	32a	1.7c
2008	DER+	Barley	2b	14c	0.69a
	TER+		4a	19b	0.57b
	CT		6a	28a	0.53b
2009	DER+	Wheat	4b	14c	2.6a
	TER+		6b	20b	1.9b
	CT		9a	25a	1.6c
2010	DER+	Teff	5b	14c	1.53a
	TER+		8 b	19b	1.55a
	CT		17a	24a	1.42a
2011	DER+	Grass pea	4c	16c	1.76a
	TER+		9b	21b	1.66a
	CT		17a	33a	1.31b

2012	DER+	Teff	1c	23c	1.09a
	TER+		6b	30b	1.11a
	CT		15a	41a	0.88b
2013	DER+	Wheat	1c	12c	4.20a
	TER+		5b	22b	3.50b
	CT		12a	40a	2.80c
2014	DER+	Teff	4c	62c	3.00a
	TER+		19b	93b	1.22b
	CT		30a	116a	0c

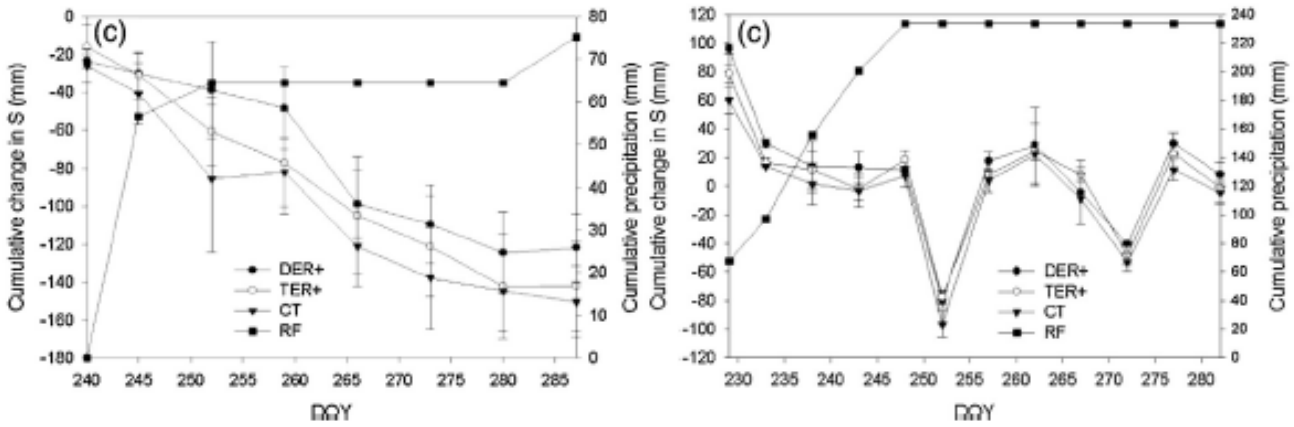

Figure 1. Cumulative change in soil water storage at 0–80 cm soil depth from each treatment throughout the growing season in 2009 (a) and 2010 (b). DER+ = *derdero*+, TER+ = *terwah*+, CT = conventional tillage system, P = Cumulative precipitation. The bars shown are the standard error of mean ($p<0.05$).

Weed Management in Conservation Agriculture in Northern Algeria

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Keywords: barley, herbicide, lentil, seeding date, weed density, wheat

Introduction

Conservation Agriculture (CA) is being promoted as an alternative to conventional cropping practices in Algeria for increasing crop yields and conserving soil resources Lahmar R., Bouzerzour H. 2010. Weeds have been identified as a major limitation to the adoption of CA and for increasing crop yields. Improved weed management has been assessed across research farm trials in Setif province figure 3, within the framework of Australian Center for International Agriculture Research funded project on Conservation Agriculture.

Weed surveys revealed the occurrence of about 50 different species mainly belonging to Poaceae, Apiacea, Brassicaceae and Asteraceae. Major weed species in the region included ripgut grass (*Bromus rigidus*), rigid ryegrass (*Lolium rigidum*), sterile oat (*Avena sterilis*), phalaris sp., *Sonchus oleraceus*, *Veronica* spp., cleavers (*Galium aparine*) pignut (*Bunium bulbocastanum*), and wild mustard (*Sinapis arvensis*) figure 7. Herbicides are the most important part of a winter annual control program Mrabet R. 2008; The herbicides that were used to control grasses and broadleaf weeds in cereals and pulses include glyphosate , pyroxsulam, clodinafop + pinoxaden, tribenuron, simazine, quizalofop, phenoxaprop and triasulfuron + dicamba.Weed control in lentils using a combination of glyphosate pre-plant, simazine pre-emergence, and quizalofop post-emergence decreased weed densities by 50 to 80% and increased grain yields from 0.8 in untreated plots up to 2.6 t/ha in the treated plots averaged over four sites. Sowing durum wheat in November combined with the application of glyphosate pre-plant, pyroxsulam, clodinafop + pinoxaden and tribenuron post emergence, resulted in up to 90% reductions in weed densities and increased grain yield from 2.0t/ha in untreated plots to 5.9 t/ha in treated plots averaged over three sites. When sowing in December grain yield of untreated plots was reduced to 2.1t/ha compared with 3.7t/ha in the treated plots.

Application of glyphosate pre-plant and diclofop, phenoxaprop and triasulfuron + dicamba post emergence in barley resulted in a significant decrease in densities of most weed species. Weed densities were reduced by 50 to 80%, resulting in increases in grain yield from 2.1 in untreated plots up to 4.3t/ha in treated plots averaged over four sites.

Material and Methods

Cropping season: 2012-2013

Implementation sites: farmer Khababa Abdelwahab. Mmunicipality Mezloug (6.3ha), Tabhirt Yazid. Municipality Ourissia (1.8 ha), Koli Rachid. Mmunicipality Ain Arnat (1.8ha) and Dahal Nouari. Municipality Beni Fouda (0.9ha); figure 4 and 8

Herbicide application for the three crops: 4 levels T_0: CHECK not weeded; T_1: Weeding Glyphosate only; T_2: Glyphosate weeding + Early weed control at three-leaf stage; T_3: Glyphosate weeding + Early weed control at three-leaf stage + Remedial Spring weeding

Notation on weeds: Identification of weeds before each weeding. Level of infestation and density of weeds / m^2 in the plots by dicots and monocots before any chemical kind weed control; Level of infestation and density of weeds / m^2 in the plots by dicots and monocots after 2, 3 and 6 weeks after each weeding;

Notations on crop: Number of emerged plants / m^2 (1 m^2 x 3 sampling plots for each treatment), Observation on seedling vigor; Yield and yield components

Results and Discussion

The study shows the level of weed infestation in the four sites is 178.5 and 236.2 plants/m². The application of only Glyphosate (360g/l) at the rate of 2.5 l/ha before sowing contributed significantly in reducing *Bromus rigidus* population, the decreasing reached 9% comparing with the plots that were not treated with Glyphosate because the application coincided with the small stage of this species. Because of their late emergence *Veronica* spp, *Sonchus oleraceus, polygonum* species escaped to the effect of Glyphosate.

Veronica sp is not controlled by all the treatments in different sites and in different crops Application of Glyphosate only allows 40% of weeds population reduction ; Application of Glyphosate + Early weed control at three-leaf stage reduces 60 to 80% of weeds population until April (new emergence of weeds); Application of Glyphosate + Early weed control at three-leaf stage + Remedial Spring weeding allows 90% of weed population reduction figure 5 and 6. The study of the dynamics of weeds (emergence, populations and growth) in the aim to develop an integrated management of weeds in CA system for this cropping season showed the major importance of the use of chemical products although before and after plants emergence. The perception of crop rotation effects is still earlier and needs repeating trials for collecting data on weed population evolution

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Figures and Tables

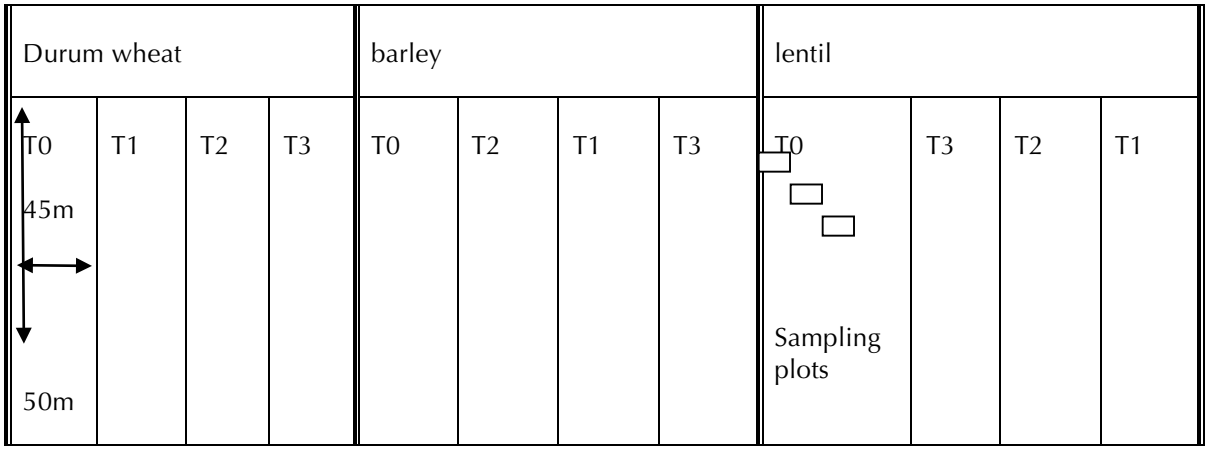


Figure 1. Experimental plan for rotation and herbicide management

Sowing date for wheat: two levels: 1st sowing was done in November, 2nd sowing was done in December

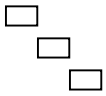
Date 1 November				Date 2 December			
Durum wheat				Durum wheat			
T0	T1	T2	T3	T0	T1	T2	T3
45m 50m	 Sampling plots			45m 50m			

Figure 2: Experimental plan for sowing date

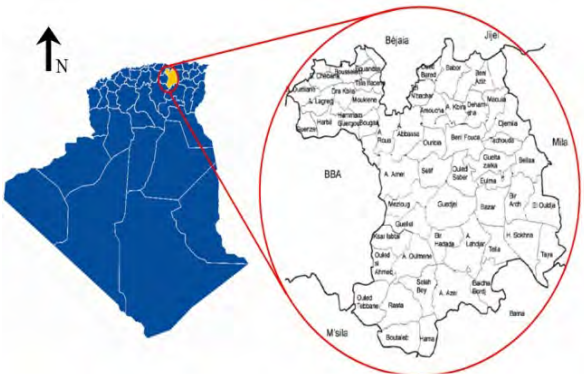


Figure 3: Setif province localization

Figure 4: Areal view of Koli's experimental weed

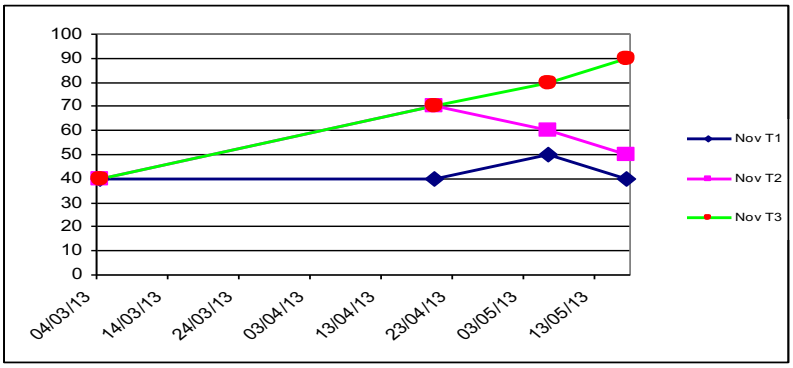


Figure 5: % of decreasing weeds density in relation with herbicide control for sowing of November (TABHIRT site)

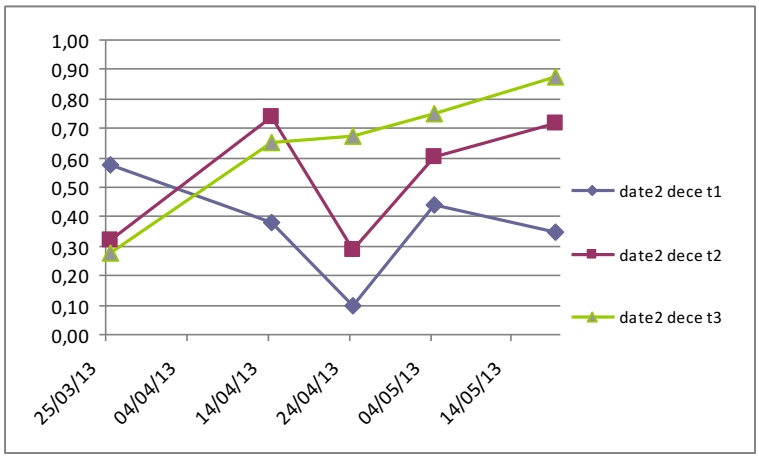


Figure 6: % of decreasing weeds density in relation with herbicide control for sowing of December (Khababa site)

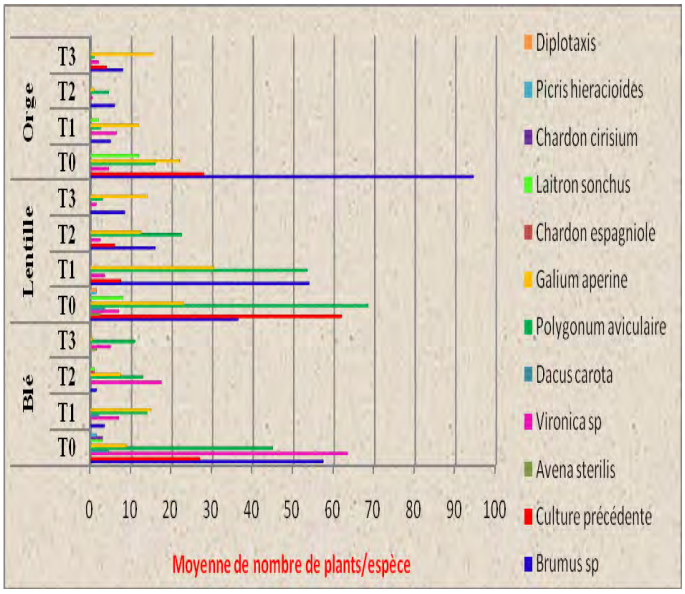


Figure 7: Main weed species recorded in khababa

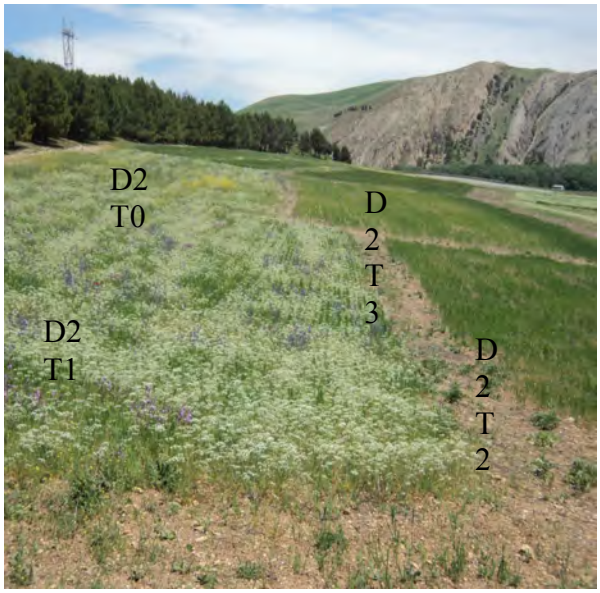


Figure 8: weeds infestation in no treated plots Tabhirt Site

Performance of Stress Tolerant Maize under Conservation Agriculture and Conventional Practices in Southern Africa

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Keywords: climate-smart agriculture, drought and heat stress, El Niño.

Introduction

In sub-Saharan Africa (SSA) "maize is life" due to its importance as a food security crop. About 40% of maize in SSA faces occasional drought stress, resulting in yield losses of 10–25% (Banziger and Diallo, 2004). Climate projections show that severe climate variability events will increase in frequency (Cai, et al. 2014; Lobell et al. 2011) and temperatures will increase by at least 2.1°C by 2050 in the maize growing environments in southern Africa, particularly in drought prone environments (Cairns et al. 2013). Therefore, there is the need to incorporate heat tolerance into the maize breeding pipeline and develop varieties for climate smart agriculture (CSA) systems to mitigate risks of climate change. Stress tolerant maize germplasm is one component of CSA that, when used in combination with other components, can sustainability increase production and resilience of agriculture systems (Setimela et al., 2017).

New hybrids from the CIMMYT breeding program now include tolerance to heat stress. After the variety development process, it is essential to confirm the performance of the best performing varieties in farmers' fields where plants experience a combination of random stresses throughout the growing season and where agronomic management practices are highly variable. In addition, it is important to assess stress tolerant maize varieties combined with additional CSA technologies to reap the benefit of several climate-smart interventions and make farming systems more resilient (Thierfelder et al., 2015). However, there have not been many studies that compare stress tolerant maize under different environments and management systems. The objective of this study was to evaluate the performance of new stress tolerant maize hybrids under conventional ridge tillage with residue removal and maize/pigeon pea intercropping and CA with residue retention and maize/pigeon pea intercropping to ascertain the impact of Conservation Agriculture on performance and grain yield stability of stress-tolerant maize varieties under farmer management during the severe 2015/2016 El Niño.

Materials and methods

Three drought-tolerant hybrids (Peacock10, CAP 9001, MH 26), two open-pollinated varieties (ZM 523, Chitedze 2 QPM) and a commercial maize hybrid (DKC 80-53) were evaluated in nine extension planning areas (EPAs) (Basale, Domazi, Katuli; Masuka, Mbonechena, Mpilisi, Mtumbwi, Ntiya, Ulongwe) in three districts (Machinga, Mangochi and Balaka) of southern Malawi. In cropping season 2015/2016, the El Niño event significantly delayed the onset of the rainy season by at least one month (Rembold et al., 2016). Trials were therefore planted in December/January 2016 rather than October/November. Farmers tested these varieties in paired plots planted side-by-side under conventional ridge tillage and Conservation Agriculture. Fields under CA were planted with a pointed stick or in small planting holes. In CA systems, the soil was covered with crop residues from previous years' maize harvest at a rate of biomass of approximately 3 t ha^{-1}. Due to land constraints farmers did not fully rotate their crops with legumes but intercropped with pigeon peas which is a common practice in Malawi. Grain yield data was analysed considering genotypes as fixed factors and farmer fields and EPAs as random effects. Mean data was subjected to singular value partitioning using the GGE biplot model to identify high yielding and stable cultivars under CA and CP across different EPAs.

Results

The CA farming system enhanced grain yields by an average of 22% as compared to CP. Mean grain yield under CA was 3.6 t ha^{-1} whereas that of CP was only 2.9 t ha^{-1}, and the two means were significantly different from each other ($P<0.001$, 5% LSD = 64) (Table 1). All the varieties produced at least 0.5 t ha^{-1} more grain under CA compared to CP, except DKC 80-53 (the commercial check variety which had not been selected for drought/heat tolerance) (Table 1). Yield benefits ranging from 12 to 31% were recorded in each variety under CA as compared to CP. The variety Peacock 10, produced at least 1t ha^{-1} (31%) more yield under CA than under conventional tillage. For all the six varieties an average gain yield increase of 0.66 t ha^{-1} was realized under CA as compared to the yield under CP (Table 1). In the biplot analysis, the varieties CAP9001, Peacock and MH 26, with mean yields of 3.8, 3.7 and 3.5 t ha^{-1} respectively, were found closer to the average environment coordinate across CA and CP farming systems (Fig 1). Furthermore, evaluating these varieties under CA showed that they are closer to the average tester coordinate (Fig 1), indicating that they are higher yielding and more stable across different management conditions. Thus the combination of stress-tolerant maize and CA improve the resilience of the overall production system. These studies highlight the need to incorporate heat tolerance as well as increased drought tolerance into African maize germplasm as well as growing these crops under more climate-smart agriculture technologies such as CA to offset predicted yield losses.

Conclusion

Grain yield and performance of released stress tolerant maize hybrids was increased when planted under CA (no-tillage, residue retention and diversification) as compared to CP. The cultivar Peacock 10 and CAP 9001 had the highest grain yields under both CA and CP, with respective grain yield increase by 31 and 25% under CA over CP. In addition, the GGE biplot identified these varieties as the most ideal cultivars in terms of grain yield and stability across locations or management systems. This study indicated the possibility of developing stress tolerant maize varieties that show good performance under CA and CP systems.

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Tables

Table 1. Grain yield and absolute differences under Conservation Agriculture (CA) and conventional practice (CP) farming systems during the 2015/2016 El Niño cropping season.

Variety	Grand mean	CA Mean	CP yield	Absolute difference	Yield gain
	t ha^{-1}	t ha^{-1}	t ha^{-1}	t ha^{-1}	%
Peacock 10	3.74	4.25	3.24	1.02	31
CAP 9001	3.81	4.23	3.38	0.85	25
ZM 523	3.19	3.50	2.87	0.63	22
MH 26	3.46	3.73	3.19	0.55	17
Chitedze 2QPM	2.67	2.94	2.40	0.54	22
DKC 80-53	2.96	3.13	2.78	0.35	12
Grand mean	3.30	3.63	2.98	0.66	22
5% LSD	0.11	0.16	0.16		

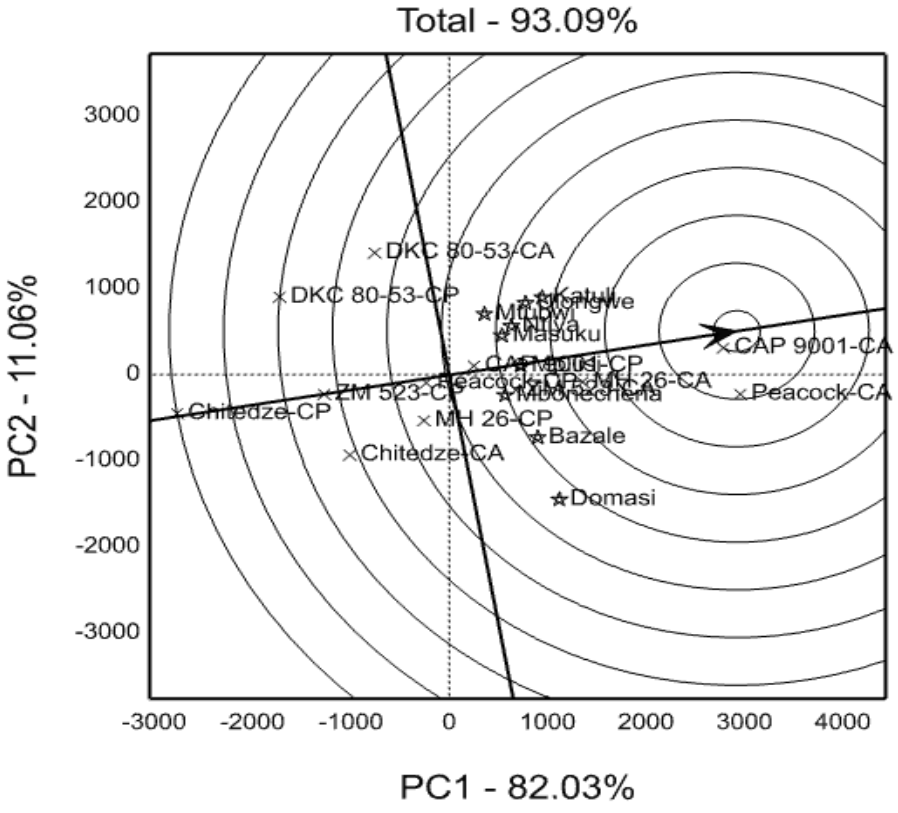

Figure 3. An average tester coordinate view showing the performance of six varieties based on mean performance and stability across CA and CP conditions during the 2016/17 cropping season. The biplot was produced based on genotype focused singular value partitioning (SVP) and the data were environment centred.

Gestion Intégrée de la Fertilité des Sols (GIFS) ; Une expérience encourageante avec le manioc au Rwanda

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Mot clés : sécurité alimentaire, étude participative, coûts de production, intensification

Introduction

Le manioc (*Manihot esculenta*) est le tubercule le plus produit dans le monde. Sa production se répartit entre l'Afrique (54%), l'Asie (28%), et l'Amérique latine et les Caraïbes (18%) (FAO, 2016). Il est généralement produit pour l'alimentation et comme source de revenu pour les petits agriculteurs ; souvent pauvres, des femmes pour la plupart et dans les zones marginales.

Au Rwanda comme tout ailleurs, malgré ses potentialités, le manioc reste cultivé traditionnellement, avec peu d'efforts d'intensification sous prétexte que cette plante peut assurer un rendement quand même d'autres plantes ne produisent rien (culture plastique) (Twilingiyumukiza *et al*, 2013). Ainsi, l'augmentation de sa production se réalise souvent par l'extension des superficies cultivées. Le constat en est qu'actuellement, la production moyenne du manioc tourne autour de 10 T/HA de tubercules (frais) (Cambridge Resource International, 2016), alors qu'avec l'intensification on pourrait atteindre 30 voire même 40 T/HA en milieu paysan. Alors que la GIFS est actuellement considérée comme un 4^{e} élément ou principe de l'Agriculture de Conservation (AC) ; la production durable à travers cette approche reste encore un grand défi posé pour la culture qui d'habitude, contribue énormément à la sécurité alimentaire pour la majorité des ménages agricoles ; environ 100 millions de tonnes en équivalent racines fraiches, la part de la production mondiale utilisée à cette fin (FAO, 2016).

Etant donné cet état, l'étude a porté une double hypothèse : les pratiques paysannes contribuent-elles à la réduction des rendements maximaux du manioc ? et le manioc répond-il positivement à l'effet de l'intensification à travers la fertilité des sols ? Alors, l'objectif était de tester les effets et impacts de la gestion intégrée de la fertilité. La GIFS étant définie comme un ensemble de pratiques comprenant l'utilisation intégrée d'intrants organiques, de fertilisants, de travaux de conservation et de protection du sol et des semences améliorées combinée avec d'autres connaissances techniques visant l'accroissement des rendements des cultures (IFDC, 2008).

Matériels et méthodes

Cette étude participative a été conjointement menée avec 40 agriculteurs en 2014 dans les districts de Ruhango et Kamonyi afin de tester les effets et impacts de la gestion intégrée de la fertilité des sols (GIFS) comparée à ceux des techniques traditionnelles (T_0). Le suivi technique a été assuré par l'organisation IBAKWE RIC sous le financement du Projet CATALIST de l'IFDC-Rwanda.

Les deux (2) parcelles dont chacune était de 5 ares ont été installées dans 40 localités (chez 40 producteurs) et l'une était parcelle test (T_1) tandis que l'autre était témoin (T_o). La T_1 contrairement à T_o, a reçu tout le paquet technologique et les intrants comme suit : 500 boutures de bonne variété (Cyizere, aussi pour T_o) soit le taux de 10.000 boutures/ha ; 20 paniers ou 10 brouettes de fumier de fond (bien décomposé), soit environ 10.000 Kg/ha ; 10 Kg de NPK 17[3] en deux applications localisées, soit 200kg/ha ; 5 Kg d'urée au moment du sarclage, soit 100 Kg/ha. La différence ou variables testés étaient essentiellement les mesures de GIFS, plus concrètement la réponse du manioc aux apports de fumier de fond, NPK et urée. Les autres opérations culturales telles que la rotation, les entretiens, les (mêmes) conditions de sols, etc. ont été maintenues communes et contribuent simplement à singulariser l'effet des fertilisants appliquées, mais bien sûr, ils jouent sur le coût de production.

Résultats & Discussion

Effets sur les rendements: nos enquêtes d'avant l'adoption GIFS ont montré que les rendements généralement obtenus dans la même région étaient de 5-7 T/ha soit une moyenne de 6T/ha de rendement en manioc frais chez les mêmes producteurs. Des résultats issus des champs tests récoltées en comparaison avec les parcelles témoins ont révélé que les rendements moyennement calculés chez les collaborateurs ont doublés, c'est-à-dire de 15,3 à 32,8 T/ha.

Effets sur le coût de production: Les coûts additionnels pour l'approche GIFS ont sensiblement monté jusqu'à 27,3% comparativement à ceux des techniques traditionnelles. Nos résultats ont montré une augmentation de 99.204Fr (environ 124 USD/ha). Ceci est attribuable aux intrants GIFS. De l'autre côté, le coût des semences est spécifiquement élevé pour les T_0 suite au non-respect des densités de plantation. Suite à une augmentation de la production, productivité induite par GIFS ; les coûts de production unitaires ont visiblement diminué (de 2,6 à 14,1 Frw/Kg). Les résultats témoignent une différence de 9 Frw/Kg (env. 0,01USD) soit 40% comme taux de diminution moyen.

Impacts sur les marges bénéficiaires: partant des prix du marché lors de l'étude, les marges bénéficiaires pour T_1 restent positives (Tableau n° 1). Les résultats sont aussi encourageants car, même si les prix des tubercules au marché chutent de plus de 50% (soit de 50 à 20 Fr le Kilo), la marge bénéficiaire GIFS reste positive (valeur 5,9 contre -3,6 de T_0). Cette situation crée également un impact positif quant à la production des cossettes et/ou des farines de manioc. Suivant nos calculs, dans la mesure où on a besoin de quelques kilos de tubercules pour faire un kilo de cossettes, l'effet sur le prix de cossettes et de la farine de manioc est encore plus grand. Si l'on considère un taux de conversion de 3,5, le prix de cossettes diminue de 84 Frw/kg (24 x 3,5) à 49 Frw par kg (14 x 3,5) ; soit une diminution de 11,2%

Impacts sur les revenus de l'exploitation : En termes de revenus nets mensuels, le manioc sous GIFS engendre des revenus supplémentaires encourageants. Avec un investissement moyen de 462.302,5 Fr (577,8 USD), un hectare de manioc sous GIFS, (si on considère le prix de 50 Fr/Kg de tubercules) pourrait procurer 1.640.100Frw/ha (2050USD) après un cycle végétatif de 17 mois ; soit 69.282 Frw/ha (86,6USD) par mois. Alors que sans GIFS, le revenu mensuel ne dépasse que rarement 23.921 Fr/ha (29,9USD) par mois

Orientations perspectives : A travers cette étude paysanne—démarche participative, 4000 producteurs ont constaté eux-mêmes que le manioc, comme le café, le maïs et autres cultures a effectivement besoin de fertilisation et mieux encore qu'il réagisse très positivement aux doses appliquées. La fluctuation des prix descendante est moins alarmante si on adopte la GIFS. L'accès aux intrants engrais reste crucial pour les producteurs et suite aux résultats intéressants obtenus, l'extension de cette approche est nécessiteuse et retombe dans les responsabilités des intervenants du sous-secteur manioc. GIFS faisant partie intégrale de l'agriculture durable, son examen dans le contexte de l'agriculture de conservation (AC) est vivement recommandé.

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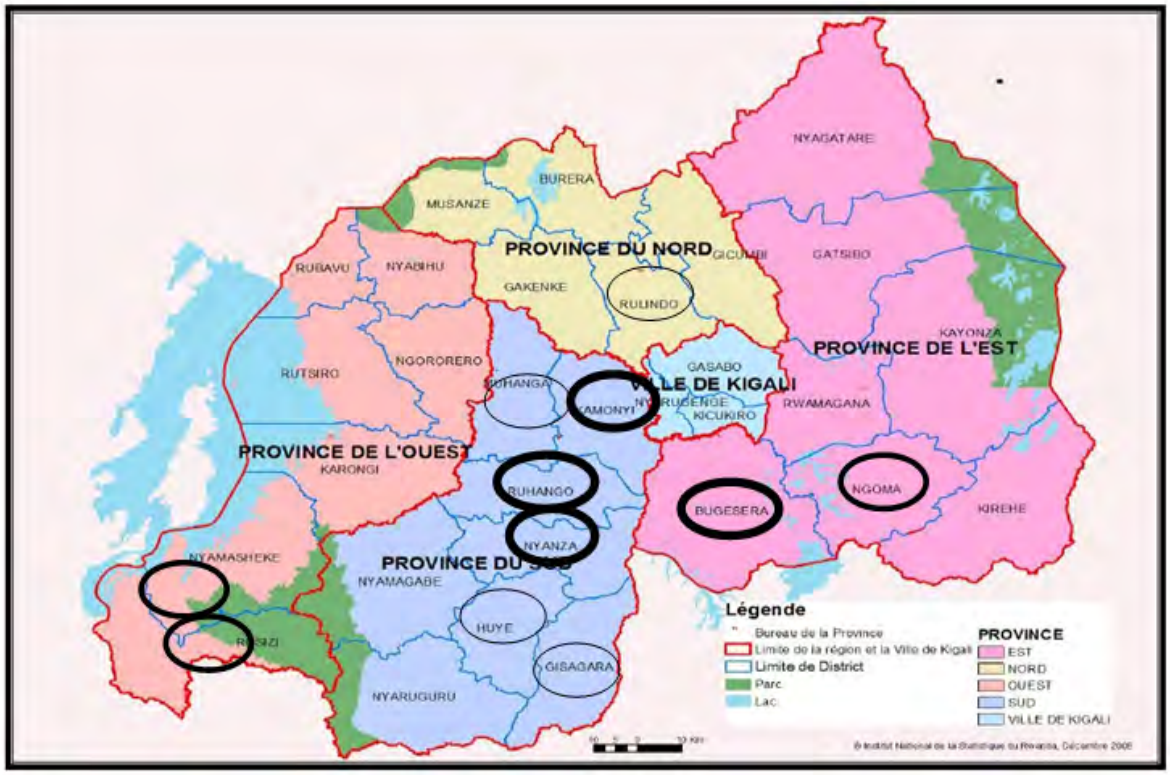
Tableau no 1-Calcul des coûts de production et des marges bénéficiaires pour l'étude comparative entre GIFS et Techniques Traditionnelles

Différents Prix de la production	20 Frw/kg		35 Frw/kg		50 Frw/kg	
Termes/Traitement	To	T1	To	T1	T0	T1
A. Durée cycle (mois)	17,3	17,3	17,3	17,3	17,3	17,3
B. Coût de production (Frw/ha)	362102	462306	362102	462306	362102	462306
C. Rendement (kg/ha)	15395	32802	15395	32802	15395	32802
D. Coût de production (Frw/kg)	23,6	14,1	23,6	14,1	23,6	14,1
E. Coût (Frw/Kg/Tubercules)	20	20	35	35	50	50
F. Valeur de la prod. Frw/ha (= CxE)	307900	656040	538825	1148070	769750	1640100
G. Marge brute en Frw/kg (= D-E)	-3,6	5,9	11,4	20,9	26,4	35,9
H. Marge brute en Frw/ha (= F-B)	-54202	193734	176723	685764	407648	1177794
I. Revenu mensuel en Frw/ha (=H/A)	-3133	11198	10215	39640	23563	68081

Figure 1 : La carte ci-dessous montre les zones les plus prometteuses pour la production de manioc au Rwanda



Source : Schrader T, Mars 2013

Développement de Systèmes Innovants Fourragers à base de Mucuna pour la Production Fourragère en Zone Cotonnière du Mali

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Mots clés : fourrage ; agriculture de conservation ; légumineuses ; maïs

Introduction

En zone cotonnière du Mali, les agriculteurs rencontrent de plus en plus de difficultés pour l'alimentation des troupeaux bovins en saison sèche. Pourtant le maintien des bovins sur l'exploitation agricole contribue à la durabilité des systèmes de culture à travers les transferts de biomasse via la fumure organique (Coulibaly *et al.*, 2007) Les cultures fourragères de légumineuses dont le Mucuna ont été introduites au Mali depuis de longue date pour l'alimentation des animaux et l'agriculture de conservation (Coulibaly *et al.*, 2013). Elles ont eu moins de succès auprès des agro-éleveurs à cause de la méconnaissance des techniques de production et d'utilisation efficace des fourrages dans l'alimentation du bétail des exploitations agricoles (Blanchard *et al.*, 2011). Dans le contexte actuel de changements climatiques, de forte pression foncière et de dégradation des pâturages, il a été constaté un retour des agro-éleveurs à introduire des cultures fourragères légumineuses dans les assolements des systèmes de cultures dans la zone cotonnière. L'objectif de l'étude était de développer des systèmes innovants fourragers à base de la culture du Mucuna pour la production de fourrage de bonne valeur nutritive en vue de l'alimentation animale en saison sèche. La diffusion à échelle des résultats des systèmes innovants fourragers à base de mucuna contribuera à l'accroissement de la productivité des systèmes de production de polyculture-élevage et à l'accompagnement des agro-éleveurs dans la phase de la transition agroécologique.

Matériel et méthodes

Dispositif de recherche

Le dispositif expérimental est un bloc de Fisher aléatoire à 2 traitements T1 (Association maïs/mucuna) et T2 (Culture pure de mucuna). Le T1 correspond à un système innovant fourrager plus productif par rapport à l'association traditionnelle des céréales au niébé. Quant au T2, il a suscité plus d'intérêt chez les grandes exploitations détenteurs de fonciers pour nourrir les bœufs de labour et même envisager des actions de production de lait d'embouche bovine et ovine.

Les sites de recherche sont des villages situés dans la zone cotonnière. Les isohyètes varient de 700 à 1200 mm par an. Le choix des villages est fait à partir des résultats du découpage de la zone cotonnière en régions agricoles homogènes (Soumaré *et al.,* 2006). Les 6 villages ont été choisis selon l'axe nord-sud pour le niveau 1 (3 villages) et est-ouest pour le niveau 2 (3 villages). Les axes sont corrélés à la diversité des systèmes de production (Soumaré *et al.*, 2008). En plus de la représentativité de la diversité des zones cotonnières, ces villages ont été choisis en fonction de la diversité des pratiques agricoles, l'intégration agriculture et élevage. Dans chaque village 5 producteurs ont conduit les essais au cours de saison hivernale 2015. Chaque agro-éleveur représente une répétition soit un total de 30 producteurs. La superficie de la parcelle expérimentale est de 0,5 ha. Elle est subdivisée en 2 parcelles élémentaires de 0,25 ha pour le traitement T1 et 0,25 ha pour le traitement T2.

Matériel végétal

Il est constitué du maïs (*Zea mays*) et du mucuna (*Mucuna pruriens*).

Itinéraire technique culturale.

Le travail du sol a consisté à effectuer un labour à plat ou en billon. Le semis du mucuna en culture pure est effectué à l'écartement de 80 cm entre les lignes et 80 cm entre les poquets à raison de 2 grains par poquet (soit 30 kg de semences par ha). Le maïs est semé aux écartements de 80 cm entre les lignes et 40 cm entre les poquets à raison de 2 graines par poquet. Le mucuna associé au maïs est semé 25 à 30 jours après le semis du maïs sur la ligne du maïs. Les poquets de mucuna sont intercalés entre les poquets du maïs (pieds de maïs) aux écartements de 80 cm entre les poquets de mucuna soit un intervalle de 2 pieds de maïs entre 2 poquets de mucuna. Le semis est fait à raison de 2 graines par poquet (soit 30 kg/ha de semence).

Opérations de fertilisation.

Pour le mucuna en culture pure, la fertilisation minérale recommandée de 65 kg de DAP/ha (Phosphate Diamonique - 18-46-0) a été apportée au sarclage 10 à 15 jours après la levée. Dans l'association maïs-mucuna, le mucuna profite de la fertilisation dédiée au maïs. L'apport a été de 6 t/ha de fumure organique plus 100 kg de NPK/ha (complexe céréale 15 N - 15 P -15 K) et 150 kg d'urée/ha (46 % N).

Opérations d'entretien des cultures.

En culture pure, le sarclage a été effectué 15 jours après la levée. La couverture rapide du sol par le mucuna permet le contrôle efficace des adventices. En association, le sarclage du maïs est effectué 15 jours après la levée du maïs. Le buttage n'est pas nécessaire à raison de la couverture rapide du sol par le mucuna, contrôlant les adventices.

Mesures et observations

La méthode du carré de rendement suivant la diagonale de la parcelle élémentaire a été utilisée. Elle a consisté à délimiter 3 parcelles d'échantillonnage de dimensions 5 m sur 5 m (soit une superficie de 25 m^2) suivant la diagonale de chaque parcelle élémentaire des 2 traitements.

Les mesures ont concerné le rendement de grain de maïs pour le traitement T1 (association maïs/mucuna et ensuite la biomasse produite pour le traitement T1 et le traitement T2 (culture pure de mucuna).

Pour l'association maïs/mucuna la récolte des épis du maïs est effectuée à la maturité. Les tiges doivent être maintenues pour servir de tuteurs au mucuna pendant son cycle végétatif. Les épis de chaque carré sont récoltés et le poids moyen des grains était estimé par pesée après séchage pendant 7 jours au soleil.

Quant à l'estimation de la biomasse, elle consiste à faucher les fourrages au stade de 50% de floraison à environ 8 semaines après le semis du mucuna. La technique de fauche du mélange des tiges de maïs et de fanes de mucuna de l'association maïs/mucuna et la biomasse de la culture pure de mucuna est identique. La biomasse fauchée est pesée à frais, puis pesée après séchage pour déterminer la matière sèche (MS) produite de l'association maïs/mucuna et la culture pure de mucuna.

Conservation du fourrage

En association, les tiges de maïs et les fanes de mucuna sont coupées ensemble. Le préfanage est réalisé par étalement et retournement des fourrages à l'ombre. Les bottes sont constituées le matin au 2ème jour après la fauche. Les bottes sont transportées avant le séchage complet pour éviter les pertes de feuilles. Elles sont ensuite entreposées sous un abri aéré ou stockées sur un hangar et couvertes de paille ou de résidus de culture contre le soleil.

Résultats et Discussions

Effets de l'association maïs/mucuna sur le rendement de maïs grain.

Le rendement moyen est de 1546 kg/ha pour l'ensemble des 6 villages de recherche avec de fortes variations entre les villages (Tableau 1). Avec l'association maïs/mucuna, les rendements étaient en moyenne de 1 546 kg/ha, donc proches du rendement de maïs grain de 2004 kg/ha obtenus dans la zone cotonnière du Mali (Coulibaly *et al.,* 2013 ; Sissoko *et al,*. 2013), de 2 270±699 kg/ha obtenu dans la zone de production de maïs au Burkina Faso (Coulibaly *et al.,* 2012) et 2670±970 kg/ha au Nord Cameroun (Nchoutnji *et al.,* 2010). Selon Coulibaly *et al*. (2013), certains producteurs ont proposé la réalisation du semis du mucuna 30 jours après le semis du maïs pour réduire l'effet de la compétition et l'étouffement des plants de maïs moins vigoureux. Traoré *et al*. (1999), avaient aussi rapporté dans la zone cotonnière du Burkina Faso que le mucuna semé moins de 30 jours après le maïs entraîne une baisse de rendement en grain du maïs à cause de la compétition pour les nutriments et la croissance rapide du mucuna qui utilise les plants de maïs pour tuteurs. Les rendements de maïs grain obtenus de l'association maïs/mucuna sont meilleurs à ceux obtenus (1 à 2 t/ha) avec la monoculture culture de maïs dans les zones de production du maïs en Afrique de l'Ouest (Boone *et al.*, 2008 ; Sissoko *et al.*, 2013) . Ces rendements de maïs présentent des perspectives d'insertion du mucuna dans les assolements à la fois pour l'agriculture de conservation et la production de fourrages pour les petites exploitations agricoles ayant un accès limité au foncier.

Effets de l'association maïs/mucuna sur la biomasse produite. La production moyenne de la biomasse maïs/mucuna est de 4883 kg MS/ha pour les villages de l'échantillon avec des variations importantes entre les villages (Tableau 1). Cette production de biomasse, de 4 883 kg MS/ha est proche de celle de 5134 kg MS/ha obtenue dans la zone cotonnière du Mali (Coulibaly *et al.,* 2013). Les différences importantes de production entre les villages s'expliquent par le non-respect par les producteurs du chronogramme des opérations culturales de l'itinéraire technique de l'innovation, en particulier de l'intervalle de semis du mucuna compris entre 25 et 30 jours après le semis du maïs.

Production de la biomasse de la culture pure de mucuna. La production moyenne est de 3994 kg MS/ha pour les villages de l'échantillon avec des variations importantes entre les villages (Tableau 1). Ces résultats sont proches de ceux de Bengali *et al*. (1994) obtenus de 1991 à 1992 avec 800 - 1000 mm de pluie/an. La culture pure de Mucuna présente des perspectives de développement de systèmes innovants fourragers et d'agriculture de conservation pour les grandes exploitations agricoles. La mobilisation du soutien institutionnel du secteur public, du secteur privé et de la société civile est souhaitable au développement d'un système semencier de mucuna et autres cultures fourragère pour la diffusion à grandes échelle en Afrique.

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Tableaus

Tableau 1 : Rendement grain de maïs et production de biomasse des traitements de la campagne agricole 2015-2016 dans les villages du volet R/D du PASE II

Village	T1 : Maïs/Mucuna			T2 : Culture pure mucuna	
	Effectif EA	Maïs grain kg/ha	kg MS/ha*	Effectif EA	kg MS/ha
Nafégué	5	2229	5968	5	4537
Ziguéna	4	1349	7000	5	4480
Benguéné	-	-	-	5	2348
Kafara	5	2351	3612	5	4745
Kokélé	5	1047	6305	5	5817
Katabantankoto	4	507	1217	4	1548
Moyenne		1546	4883		3994
Probabilité		0,001	0,001		0,001
cv%		22,4	23,5		32,8

Légendes : EA. Exploitation agricole ; MS. Matière sèche ; *Biomasse de tiges de maïs et de mucuna

Effects of Conventional and Conservation Tillage on Soil Compaction in Omuntele and Ogongo Constituencies of Namibia

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Keywords: Namibia specific conservation tillage, ripper furrower, penetration resistance.

Introduction

This study was part of a wider study that compared the differences between two conventional tillage (CV) treatments (i.e. tractor-drawn disc harrow (TDH) and animal-drawn mouldboard plough (AMP) and two Namibia Specific Conservation Tillage (NSCT) treatments (tractor-drawn ripper furrower (TRF) and animal-drawn ripper furrower (ARF). The objective was to measure penetration resistance in the farmers' pearl millet fields in two Constituencies (Ogongo and Omuntele) in order to complement the on-station trials. Thirteen farmers were targeted because they used the NSCT technology in their fields. The NSCT technology was introduced into the Northern Communal Areas (NCA) of Namibia as a way of ameliorating the negative impacts of the conventional tillage (CV) methods traditionally used by farmers in the region. The NSCT technology is a method that uses animal-drawn and tractor-drawn ripper-furrowers to rip and make furrows in one operation and emphasizes the use of ripper furrowers in place of mouldboard and disk ploughs and also emphasizes incorporation of mulch, manure and crop rotations as explained in detail by Mudamburi (2016) and Mudamburi *et al*. (2018). Results of trials carried out by Mudamburi (2016) and Mudamburi *et al*. (2018) under on-station field conditions at Ogongo in the NCA showed that the NSCT technologies resulted in better agronomical and technical performances (higher yields, more moisture, lower penetration resistance (PR), better effective field capacities, and reduced specific draught forces) compared to the CV technologies. For this study there are significant differences ($p=0.030$) between NSCT and CV for Omuntele farmers' fields. NSCT actually reduced compaction in the farmers' fields.

Materials and methods

In order to be able to compare CV and NSCT technologies on soil compaction in Namibia, a study to collect penetration resistance measurements on farmers' fields was carried out in Ogongo Constituency of Omusati Region and Omuntele Constituency of Oshikoto Region between 2012 and 2013. There were nine farmers from Omuntele and 4 farmers from Ogongo. The soils in the farmers' fields were sandy soils. A cone penetrometer (hand-held, Eijelkamp) was used to measure penetration resistance following the recommendation of ASABE (2006). The cone penetrometer has a base area of 2 cm^2 and a diameter of 15.96 mm. Penetration resistances were measured in 10 cm increments starting at 10 cm to greater than 20cm at ten randomly selected places in the two middle rows of farmer's fields that were conventionally tilled and those where the NSCT was practiced. The resistance was read in N (Newtons) and noted for the corresponding depth in the soil profile. The penetration resistance was calculated using the following equation 1:

$$PR = \frac{\text{Manometer reading (N)}}{\text{Base area of cone } (m^2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: PR = penetration resistance in N/m^2 and reported in MPa

Analysis of variance (ANOVA) using Genstat was used to test for any significant differences in penetration resistance among NSCT and CV methods. Probability levels of 0.05 were used to determine the level of significance among the means.

Results and discussion

On-Farm Penetration Resistance in Omuntele and Ogongo Farmers' Fields

The PR measurements were taken on fields of Omuntele and Ogongo farmers. There are significant differences (p=0.030) between NSCT and CV for Omuntele farmers' fields. Only 3 of the 9 farmers (33%) had fields with PR values less than 2 MPa. The maximum penetration in the NSCT fields of two out of the nine (22%) farmers was between 15 and 16 cm, and in the CV fields of seven of the nine (78%) farmers, the maximum penetration was between 8 and 18 cm. Six of the nine (67%) farmers had fields with PR above 2 MPa under NSCT only. The PR values of the NSCT fields of eight of the nine (89%) farmers were lower than the PR values under CV. The PR values of the CV plots of all nine farmers were above 2 MPa. In Ogongo all of the four sampled farmers' fields had maximum penetration at 15 cm and less than 15 cm. Only one farmer out of the four had PR values less than 2 MPa; the other three had PR values greater than 3 MPa. This suggests that most of the farmers could have problems of root penetration in their fields, as predicted by Atwell (1993) and So *et al*. (2009). They predicted 2 MPa as the critical upper value above which root growth is severely impeded. However, all four sampled fields had lower PR levels under NSCT than under CV.

The results for both constituencies were further analysed by dividing the farmers into 2 groups, one, with fields with highest maximum penetration and the other group with lower penetration depth as shown in Tables 1 and 2. Table 1 shows mean Penetration resistance for five farmers' fields with unlimited penetrometer depth that CV has significantly high mean penetration resistance (p=0.002) whilst the opposite is true for mean maximum penetration, NSCT has a higher mean. NSCT has lower PR than CV and also shows that CV contributed to increase in PR. This shows that NSCT actually reduced compaction in the fields. All the farmers in this group are from Omuntele constituency.

Table 2 shows mean penetration resistance for eight farmers' fields only with lower maximum penetrometer depth and there are no significant differences in mean penetration resistance between CV and NSCT (p=0.365) however NSCT has a significantly higher mean maximum (p=0.026). Four out of the five farmers in this category were all from Ogongo constituency and all the fields had limited penetrometer depths. It is possible that the fields of the sample of farmers from Ogongo had hard pans. It could also be because the farmers used the animal-drawn ripper furrower that does not penetrate as deep as the tractor ripper furrower.

All PR values for NSCT methods in some of the farmers' fields were less than 4 MPa. NSCT methods had lower PR than CV methods and 31% (n=13) had PR values that are less than 2 MPa showing that the fields for the rest of the farmers (69%) could have problems of soil compaction. From this study it was thus apparent that the more flexible approach of 2–5 MPa as specified by Lampurlanes and Cantero-Martinez (2003) could be used as the critical limits above which root growth is severely impeded, as roots continued to grow and high yields were achieved in the overall study for all the tillage methods. This suggests that it is important to check how far the roots of a particular crop can penetrate, so the implement depth may be adjusted to cater for the root length of the crop.

Overall NSCT methods resulted in lower PR than the CV methods showing that the NSCT methods contributed to better reduction in soil compaction. The tractor-drawn ripper-furrower can be used to reduce soil compaction better than the conventional tillage methods such as the disc harrow and mouldboard plough. The NSCT implements in this study showed some positive attributes throughout, and this conservation tillage production system therefore holds promise and has the potential to transform Namibian smallholder agriculture into a sustainable and productive crop production strategy.

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Tables

Table 1: Mean Penetration resistance for five farmers' fields with unlimited penetrometer depth

Variable Tillage method	n	Mean Penetration Resistance (MPa)	Mean Maximum Penetration (cm)	s.e ($\bar{x}$)
CV	5	2.97	23.2	6.763
NSCT	5	1.95	50.0	0.000* (all values are the same)
Overall	10	p=0.002	p=0.04	5.488

Table 2: Mean penetration resistance for eight farmers' fields only with lower max penetrometer depth

Variable Tillage method	n	Mean Penetration Resistance	Mean Maximum Penetration	s.e ($\bar{x}$)
CV	8	3.09	10.75	0.977
NSCT	8	2.74	15.75	1.750
Overall	16	p=0.365	p=0.026	1.163

Impact of Conservation Agriculture on Soil Health: Lessons from the University of Fort Hare Long-term Trials

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Key words: carbon dioxide fluxes, crop rotation effects, residue retention, no-till, smallholder, soil fertility.

Introduction

Conservation Agriculture (CA) involving minimum soil disturbances, soil mulch cover and crop diversification is a climate smart technology to mitigate the impact of climate change and reduce soil degradation in agricultural fields (Thierfelder *et al.,* 2017). CA provides increased adaptation and resilience to the effects of climate change by increasing soil organic matter (SOM), sequestering soil organic carbon (SOC) and reducing greenhouse gas emissions (Thierfelder *et al.,* 2017). The associated increase in SOM slows down and counters the process of soil degradation. SOM is consequently linked to the improvement of SOC as well as the general soil health and crop productivity. However, its adoption and success amongst South African smallholder farmers has been limited due in part to lack of robust local evidence for its effectiveness. Therefore, two multi-location trials were set up in October 2012 at the Fort Hare research farm and Phandulwazi High School to investigate the effects of CA components on C-sequestration and CO_2-emission mitigation, soil health as well as crop yields for the provision of key CA entry points for smallholder farmers.

Materials and Methods

The field trials were carried out at the University of Fort Hare (UFH) and Phandulwazi High School (Phandulwazi) an average annual rainfall of 575 mm and 750 mm, respectively (Muzangwa, 2016). The field trials were laid in a split-split plot design. The main treatments were tillage: conventional (CT) and no tillage (NT). Crop rotations were the sub-treatments: maize (*Zea mays* L.)-fallow-maize (MFM), maize-fallow-soybean (*Glycine max* L.)- (MFS); maize-wheat (*Triticum aestivum* L.)-maize (MWM) and maize-wheat-soybean (MWS). There were two residue management treatmentss for each rotation: removal (R-) and retention (R+). Maize was planted in summer (October-February) targeting a population of 25,000 plants ha^{-1}, recommended for dryland conditions in the central Eastern Cape Province of South Africa (Department of Agriculture 2003). Spring wheat cultivar (SST015) was planted in winter (May-August) at a seeding rate of 100 kg ha^{-1}. Soybean cultivar (PAN 5409RG) was sown in summer targeting a population of 250,000 plants ha^{-1}. Fertilizer was only applied to the summer maize crop at a rate of 90 kg N, 45 kg P and 60 kg ha^{-1} K in all plots for a target yield of 5 tons ha^{-1}. All the P, K and a third of the N fertilizer was applied at planting as a compound (6.7% N; 10% P; 13.3% K + 0.5% Zn) and the rest (60 kg) as limestone ammonium nitrate at 6 weeks after planting by banding. Soybean was inoculated with *Rhizobium leguminosarium* before sowing. No irrigation was applied. Residue management treatments were implemented soon after harvesting each crop, whereas tillage treatments were implemented just before planting (Table 1). The following parameters were measured, residue biomass, reside carbon input, SOC, particulate organic matter (POM), CO_2 fluxes, microbial biomass carbon (MBC), earthworms numbers, soil enzymes (fluorescein diacetate (FDA), β-glucosidase, arylamidase and acid phosphate) and crop yields.

Results and Discussion

Carbon-sequestration: Biomass and carbon inputs for crop rotations were in the order: MWM > MWS > MFM > MFS. Contrast analysis showed increased biomass and carbon input with non-legume rotations compared to rotations with legumes. The MWM and MWS rotations as well as residue retention had greater levels of particulate organic matter. Residue retention was effective in increasing soil organic carbon in the 0-5 cm depth but not in the lower depth (5-

10 & 10-20 cm) (Table 2). Fine particulate organic matter and mineralizable carbon fractions were more sensitive to the short-term Conservation Agriculture treatments than soil organic carbon.

CO_2 fluxes: CO_2 flux, which ranged from 0.28 to 5.47 µmol m^{-2} $s^{-1,}$ fell within reported ranges under similar semi-arid and/or sub-humid temperate climates. Tillage and residue management had significant effects on mean CO_2 flux calculated over the experimental period at both sites. Tillage increased CO^2 fluxes by 20% compared to no-till, regardless of site. The mean CO^2 fluxes were significantly influenced by air temperature ($P<0.001$, $r^2 = 0.41$) and soil bulk density ($P<0.001$, $r^2 = 0.16$) and was higher in summer than winter and were highest during the first three weeks after tillage.

Biological activity: Contrast analysis showed significant ($P<0.05$) improvement of the MBC and soil enzymes with residue retention and legume rotation compared to residue removal and cereal-only rotations, respectively. Arylamidase, a nitrogen-linked enzyme, responded positively to MFS and MWS rotations. Earthworm abundance was negatively affected by tillage but greatly enhanced by residue retention under no-till.

Soil quality and crop yields: Soil Quality Indices calculated using the Soil Management Assessment Framework revealed that inclusion of soybean in rotations coupled with residue retention significantly improved the overall quality of the two site soils. Crops under no-till with residue retention performed much better under severe drought than those under conventional tillage. Residue retention was consistent in significantly increasing crop grain yields than residue removal in seasons 2 to 5.

Conclusions

The MWM and MWS rotations in conjunction with residue retention under NT, offer the greatest potential for biomass and carbon inputs, and consequently carbon sequestration in the Eastern Cape sub-humid and semi-arid agro ecologies. After five cropping seasons, the greatest benefits were realised from the MWS crop rotation under NT with residue retention. Residue and inclusion of soybean in crop rotations are key in increasing crop productivity in the short-term.

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Special gratitude to the Department of Agriculture Forestry and Fisheries (DAFF) through Zero Hunger Project, the South African National Research Foundation (NRF) and the Govan Mbeki Research and Development Centre (GMRDC), University of Fort Hare for funding the study.

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Tables

Table 1: Summary of the crop rotation treatments.

Crop rotation †	Summer ‡ 2012/13 (Season 1)	Winter 2013 (Season 2)	Summer § 2013/14 (Season 3)	Winter 2014 (Season 4)	Summer 2014/15 (Season 5)
MFM	Maize	Fallow	Maize	Fallow	Maize
MFS	Maize	Fallow	Soybean	Fallow	Maize
MWM	Maize	Wheat	Maize	Wheat	Maize
MWS	Maize	Wheat	Soybean	Wheat	Maize

† Crop rotation treatments were MFM, maize-fallow-maize; MFS, maize-fallow-soybean, MWM, maize-wheat-maize and MWS, maize-wheat-soybean.

‡ Summer season month are October, November, December, January and February

§ Winter season months are May, June, July and August.

Table 2: Tillage, crop rotation and residue management effects on soil organic carbon (%) at the 0-5, 5-10 and 10-20 cm depths at the Phandulwazi and University of Fort Hare experimental sites.

Factor	Phandulwazi			University of Fort Hare Research Farm		
	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm
Tillage †						
CT	0.84	0.67	0.67	1.17	1.15	1.03
NT	0.97	0.66	0.67	1.15	1.04	0.98
LSD	ns	ns	ns	ns	ns	ns
Crop rotation ‡						
MFM	0.97	0.67	0.67	1.15	1.09	0.97
MFS	0.95	0.69	0.65	1.16	1.05	1.04
MWM	0.84	0.64	0.66	1.16	1.15	1.07
MWS	0.86	0.66	0.69	1.18	1.10	0.95
LSD	ns	ns	ns	ns	ns	ns
Residue management §						
R-	0.90	0.64^{b}	0.65	1.13^{b}	1.06^{b}	0.94
R^{+}	0.91	0.69^{a}	0.69	1.20^{a}	1.14^{a}	1.04
LSD	ns	*	ns	*	*	ns
CV (%)	22.61	10.96	10.22	8.79	9.31	11.39

Different letters in each column and factor indicate significant differences amongst the treatments.

LSD, Least Significant Difference: *, α=0.05 and ns means not significant (P>0.05)

† Tillage treatments were CT, conventional tillage, no-till,

‡Crop rotation treatments were MFM, maize-fallow-maize; MFS, maize-fallow-soybean, MWM, maize-wheat-maize and MWS, maize-wheat-soybean

§ Residue management treatments were R^{+}, residue retention and R-, residue removal.

Long-term Impact on Soil Compaction under Conservation Agriculture in South Africa

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Keywords: cone penetrometer, conventional tillage, dry bulk density, dry land, no-till

Introduction

In any agricultural set-up, soil compaction has been shown as a considerable factor to reduce crop productivity (Hamblin, 1985). The adoption of large machinery for agricultural crop production, increased axle loads, and changes in farming operations, have resulted in soil compaction problems since early 20th century. The reduction in compaction with conventional tillage has resulted in yield increases, which have been attributed to lowering of mechanical impedance to root growth penetration (Hamblin, 1985). While tillage facilitates inversion of the soil by energy–intensive field operations, the soil disturbance during this process may also cause loss of soil moisture, soil degradation and wind erosion especially when it is done in windy and dry season like winter time in dry land areas in South Africa or similar as such. Interest in Conservation Agriculture, its effect of reducing operational input cost and protective effect on soil moisture and erosion, has grown in the past several decades with the growing concern of increased fossil fuel cost and impact to environment and climate change under conventional tillage.

No-till together with crop rotation and maximum mulch cover has been refereed as the most popular Conservation Agriculture practice among South African farmers. Such a practice results in minimum soil disturbance (MSD) which has attendant benefits. The MSD contributes to reduction or prevention of soil loss by erosion; and the degradation of soil physical, bio-chemical and biological attributes (du Toit, 2007). In addition, MSD results in improved soil moisture conservation due to avoidance of soil inversion and the presence of crop residues on the surface, which results on reduced loss of soil moisture through soil surface evaporation. However, MSD has been reported to result in soil compaction caused by heavy machinery traffic, particularly in early years of no-till practice. Cases of soil compaction, while not quantified scientifically, has been observed by commercial farmers in South Africa who often use large-scale mechanised no-till equipment (Nel, 2014). For small-scale farmers, the subsoil compaction may be caused by sediment settling before significant bioorganic matter is accumulated generated as a build-up of bio-char and other organic matters. Top soil and subsoil compaction in particular occur in a wide range of soils. This is a major challenge in CA when it is mainly referred as no-till and associated practice. In order to embrace CA, changes in soil physical properties that occur over time need to be investigated and documented.

Owing to the foregoing, the objective of the work reported in this paper is to evaluate the extent of soil compaction under practical farming circumstances in sandy and clay soils that have been subjected to conventional and Conservation Agriculture practices in summer rainfall areas of South Africa. The soil compaction results between the conventional tillage and no-till CA are measured and compared.

Materials and method

The investigation was initiated on two experimental sites, in the regions of Erfdeel (site 1) and Buffelsvallei (site 2) in North West Province of South Africa during the crop season of 2014-2015. The soils in these two experimental sites are categorized as sandy loam and clay loam respectively. The classification and summarized composition parameters of the soils are as shown in Table 1 (Nel, 2014). Both of the experimental sites had accommodated in the previous six years with research on comparison between conventional tillage (CT) and Conservation Agriculture under the management by Grain Crop Institute of the Agricultural Research Council in South Africa (Figure 1). On each site, two experimental plots were selected with yearly monocrop of maize planted, but treated under conventional tollage and no-till CA respectively. The conventional tillage practiced at these sites consisted of primary

tillage of mouldboard ploughing in depth of 300 mm, while no-till CA was practiced side-by-side in parallel (Nel, 2014).

Cone penetration resistance, dry bulk density and soil moisture content are used to evaluate and compare the extent of soil compaction. Cone penetration resistance in kPa was obtained directly by using a hand operated automatic-data logging cone penetrometer, as shown in Figure 3, developed in accordance with the ASAE Standard S313.2 (ASAE, 1999). The penetration resistance was measured up to 800 mm in depth, but only in the area between rows of maize crops. Measurements were repeated in the field of each plot and eight effective tests from randomly chosen spots were recorded for statistical purpose by computerized data logger integrated with the penetrometer. The measurement was carried out in early May before the maize was ready for harvesting.

At each of the penetration test spots the soil dry bulk density and moisture content were also measured to supplement the penetration data for the study. Bulk density measurements were conducted by taking soil samples from the test plots at the two experimental sites. To investigate the subsoil compaction and possible formation of 'plough/hard pan' the soil samples in undisturbed status were taken in the depth ranging from 250 to 350 mm by using a cylindrical soil sampler with 100 mm in length by 70 mm in effective diameter. The soil samples were weighted and dried in an oven at 105ºC for over 6 hours and the weight of solid soil was measured again after oven drying. Then the parameters of dry bulk density and weight-based soil moisture content were obtained accordingly.

Results and discussion

On experimental site 1 at Erfdeel, the graphical test results of penetration resistance vs depth are shown in Figures 1 and 2 for CT and no-till CA respectively. With standard statistical analysis, the characterized results from the cone penetration tests are summarized as in Table 2.

Averagely the peak value of the penetration resistance occurs at the depth just below 300 mm where a 'plough/hard pan' might have formed. However, the results show that the average maximum cone penetration resistance under CT is significantly lower (>34%) than that under no-till CA. The depths at maximum penetration value remain very similar in both CT and no-till CA. The penetration tests at experimental site 2 (Buffelsvallei) did not generate enough meaningful test data because the soil at this site was too hard for the tests to be done as per the recommended procedure by the ASAE Standard S313.2 (1999).

Subsoil compaction and 'plough/hard pan' can negatively influence the root development for maize crop. In this study undisturbed soil samples were collected from the 250 - 350 mm depth range using a standard soil core sampler. The results are as shown in Table 3. The results indicate that the average dry bulk density under CT is lower than that under no-till CA. The difference in soil bulk density at the two sites was attributed to the differences in the soil texture at sites 1 and 2. The soil texture analysis (Table 1) indicate that site one had significantly greater percentage of sand and significantly lower percentage of clay, respectively than site 1. In general, high percentage of clay is particularly associated with propensity to compaction while high percentage of sand is associated with low compaction levels. Subsequently the results presented in Table 3 are consisted with the expected outcome.

The results for the soil moisture content was obtained for the two tillage treatments are as shown in Table 4. As can be seen from Table 4 the average moisture content under conventional tillage is lower. This was considered to be due to the higher degree of soil disturbance associated with conventional tillage than that under conservation tillage. Disturbing the soil during conventional tillage results in reduced surface cover, bringing the wetter soil at lower layers to the surface and increasing the soil porosity. This results in increased loss of soil water thorough evaporation. The results presented in Table 4 are therefore consisted with the documented findings in many previous similar work undertaken. Generally, convention tillage has been reported to conserve the soil moisture less.

Conclusions

Conclusions the following conclusions are drawn.

1. A layer of subsoil compaction exists at the depth of 300 mm to 320 mm under both CT and no-till CA.
2. The maximum penetration resistance under CT on average are significantly lower than that under no-till CA due to the yearly tillage effect.
3. The soil bulk density under CT, hence the compaction on average is slightly lower than that under no-till CA.
4. The soil under no-till CA is more susceptible to compaction even after a practicing period of more than six years, particularly under sandy soil conditions.
5. No-till CA maintains better soil moisture for sandy soil.

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Tables and Figures

Table 1. Soil classification and texture at the experimental sites (0 – 600 mm depth range)

	Experimental site 1 (Erfdeel)	Experimental site 2 (Buffelsvallei)
Soil type	Avalon, Sand	Hutton, Sandy loam
Clay content	3.25	17.50
Silt content	0.00	2.25
Sand content	96.25	80.25

Table 2. Mean soil penetrometer resistance at site 1 (Erfdeel)

Parameters	Conventional tillage	No-till CA
Average maximum cone penetration resistance (kPa)	2639 ± 354	4012 ± 373
Average depth at maximum cone penetration resistance (mm)	320 ± 39	341 ± 38

± - Standard deviation

Table 3. Average dry bulk density for the two tillage treatments at the two experimental sites

Tillage type	Experimental site 1 (Erfdeel) (kg/m^3)	Experimental site 2 (Buffelsvallei) (kg/m^3)
Conventional tillage	1340 ± 42	1432 ± 34
No-till CA	1366 ± 39	1573 ± 54

Table 4. Mean soil moisture content at site 1 (Erfdeel)

Tillage type	Conventional tillage	No-till CA
Average soil moisture content (%),	2.43 ± 0.17	3.58 ± 0.25

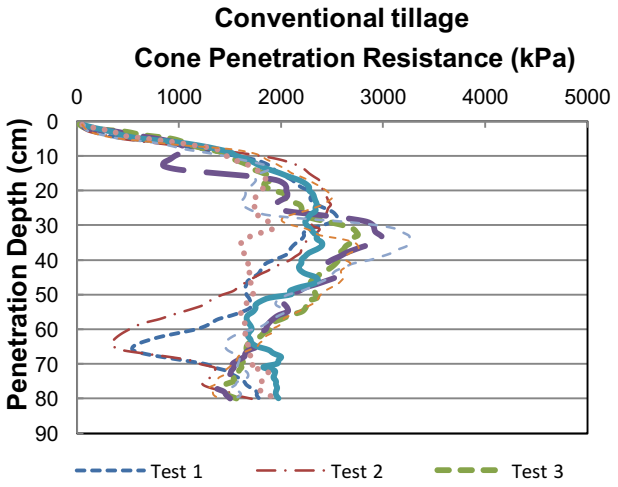

Figure 1. Variation of soil cone penetrometer resistance with depth under CT at site 1 (Erfdeel)

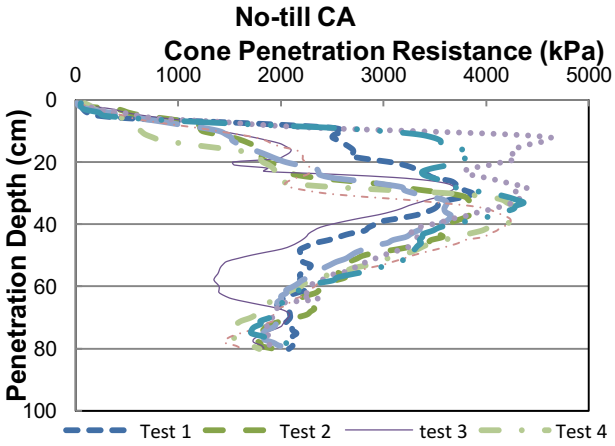

Figure 2. Variation of soil cone penetrometer resistance with depth under no-till CA at site 1 (Erfdeel)

Effect of Seeding Depth on Winter Survival and Yield of Wheat under Conservation Agriculture in Uzbekistan.

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Key words: Seeding depth, no-till, cold and survival

Introduction

Appropriate seeding depth is important for crop establishment in the harsh climatic conditions of Aral Sea Basin (Karakalpakstan Autonomous Republic in Uzbekistan where winter temperature can drop to -45^{0}C. Average Winter temperatures in Karakalpakstan range from -10 to -25^{0}C. Snow is usually not present on the soil surface, which negatively effects winter survival rate in conditions of Karakalpakistan. Deep seeding delays emergence and results in poor crop establishment while shallow seeding makes seeds and seedlings more susceptible to winter damage in Karakalpakstan Earlier studies (Qilichev and Khalilov, 2008) revealed that moldboard ploughing for seedbed preparation for winter wheat when replaced with broadcasting wheat seeds into standing cotton crop and subsequent shallow mixing with surface soil, resulted in seed depth of around 1-2 cm. Nurbekov (2008) reported that 4 cm seed depth through no-till seeding offered an effective option against harsh winter temperatures for crop establishment and could replace broadcasting method in irrigated conditions. Conservation Agriculture (CA), emphasizes minimum soil disturbance by no-till seeding, for the development of sustainable agriculture in Uzbekistan. This is because CA has been shown to be relatively better in coping with climate change impacts in areas with continental environments such as Central Asia (Gonzalez-Sanchez *et al.,* 2017).

Deeper than optimum seed placement also results in crops that suffer from delayed maturation and lower yields (Barayev, 2008). Such negative effects from deep seeding in Northern Kazakhstan conditions are more pronounced with late seeding dates because of slower and delayed seedling emergence in cold soils (Dvurechenskiy, 2010). This paper is a report of a study on the effect of different seeding depths on winter survival rate and yield of wheat under CA system in the region of Aral Sea Basin of Uzbekistan.

Material and Methods

The experiment was initiated in the autumn of 2005. Winter wheat was planted at the beginning of November and harvested at the end of June. In 2006 and 2007 the crops were planted in mid-October and harvested in June. The soils at the experimental site is sirozems with bulk density in the range of 1.4 to 1.6 g cm^{-3}. Treatments were five seeding depths, (1 cm, 2 cm, 4 cm, 6 cm, and 8 cm) under both traditional tillage(TT) and no-till (NT) with soil covered with crop residue and stubble from previous crops. Seeding rate was 200 kg ha^{-1} for each treatment in all years. Seeding was done using a no-till seeder with disc openers. The experiment was laid out in randomized complete block design with each treatment replicated 4 times. Plot size was 200 m^2 (25×8 m). Field observations were recorded on winter survival rate, tillering, plant height, thousand-kernel weight, grains per spike and yield. The data was statistically analysed using GenStat programme 18th edition.

The number of seedlings in each plot was recorded two weeks after full field germination and again in the first week of November (second and third years) and at the end of November (first year of the experiment). Snow was removed from the experimental plots as needed to expose the seedlings to frost. In the first week of April, plants were again counted in each plot and winter survival as a measure of frost tolerance was determined using the following formula: Winter survival rate (%) = (Number of plants after winter ÷ Number of plants before winter) × 100.

Results and Discussion

Average maximum and minimum temperatures during winter period 2005-2006, 2006-2007 and 2007-2008 were 0.7, -13.4, and 1.2^{0}C and -1.5, -15.6 -2.9°C, respectively in December, January and February. The severe frost conditions occurred in 2007-2008 from 01 January to 05 February. Sharp frosts were observed in 2006 and 2008 when average decade temperatures decreased down to -25 and -31^{0}C respectively. The lowest air temperature (-31.0 ^{0}C) was recorded during January 2008. The crop was at the tillering stage before the onset of low winter temperatures. At that time, the snow cover was 5-7 cm.

Winter survival rate: The highest winter survival rate (81.3%) *was* recorded with seeding depth of 4 cm under the no-till technology in 2007 while lowest survival rate (28.5%) was recorded with seeding depth of 0 cm under traditional tillage in 2008. Seeding depth greatly affected winter survival rate in this study where frost conditions in 2006 and 2008 were more severe compared to 2007. Winter survival rate ranged from 54.2 to 68.9%, 49.9 to 81.3% and 28.5 to 60.2% in 2006, 2007 and 2008 respectively (see figure 1).

Grain yield: Winter wheat yield was higher in the treatment involving the no-till seeding method compared to traditional tillage seeding. Winter wheat grain yield was significantly influenced by the treatments (P<.001) across three years. Maximum yield was recorded in 2007 and overall three years yield was in the range 966-3,570 kg ha^{-1}. The highest yield was recorded with seeding depth of 4 cm under no-till treatment in 2007. Grain yields increased by 20% and 10% under no-till seeding with seed depth treatments of 4 cm and 6 cm, respectively, compared with the seed depth treatment of 2 cm. Under conventional tillage with seed depth treatments of 4 cm and 6 cm, yields increased by 16% and 12%, respectively. The yield increase in wheat under no-till seeding treatments can be attributed to benefits of crop residue cover in protecting the soil surface from extreme temperatures, reduced soil erosion and suppression of weeds. Optimum seed depth management can play an important role in reducing risk of frost damage in winter wheat as reported by Whaley et al. (2004). Our research results are in agreement with above findings. Through this study, it has been demonstrated that deeper seeding depth of 4 cm is an effective practice to minimizing the risk from frost damage, and this finding has not been reported previously.

Conclusions

Shallow planted wheat is also more susceptible to soil heaving due to freezing. Wheat planted more than 4 cm deep may result in seedling death due to pre-mature leaf opening or poor tiller development and lower winter survival. Uniform seed placement and seeding depth are important in promoting good crop establishment and health in the fall. In year 2008, low yields resulted from severe low temperatures and absence of snow cover during the winter season, which poses a severe limitation to winter wheat growth and development. Seeding management under Conservation Agriculture system was better than traditional tillage system. These findings show that winter wheat production under Conservation Agriculture can contribute to yield stability across years while at the same time buffering the crop from effects of climate change in Uzbekistan.

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Figures and Tables

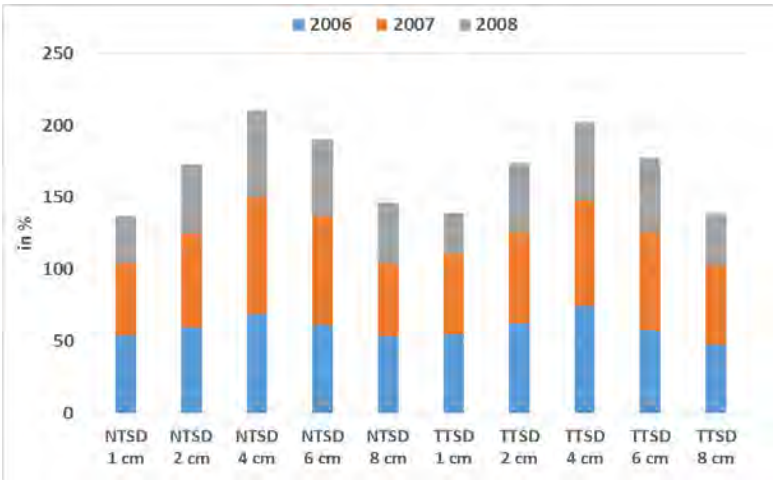

Figure 1: Frost tolerance measured as percent winter survival of winter wheat 2006-2008.

Table 1: Winter wheat yield variations with seed depth (2006-2008)

Tillage method	Seed depth (cm)	2006		2007		2008	
		Yield, kg ha^{-1}	+-%	Yield kgha^{-1}	+- %	Yield kgha^{-1}	+- %
NT	1	2,504	93	2,816	91	1,534	75
	2	2,680	100	3,074	100	2,048	100
	4	3,068	114	3,570	116	2,455	120
	6	2,801	104	3,229	105	2,247	110
	8	2,304	91	2,369	77	1,887	92
TT	1	2,374	88	2,523	91	966	51
	2	2,552	100	2,753	100	1,909	100
	4	2,915	114	3,152	114	2,216	116
	6	2,382	93	2,916	105	2,133	112
	8	2,052	86	2,472	89	1,460	76

Bringing Our Soils Back to Life – the case of Conservation Agriculture

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Keywords: no-tillage, shifting cultivation, slash and burn, sub-Saharan Africa

Introduction

A critical look at the food security dilemma in Sub-Saharan Africa deepens our fear of future food insecurity as we continue to destroy our soils. It is predicted that the world population will reach 10 billion by the year 2055 (UN 2017) and that the greater percentage will be contributed by Africa. In Sub-Saharan Africa several factors including unfavourable farming practices contribute to extensive soil mismanagement and therefore a gradual reduction in the arable land area. The irony of this is that the declining land area has to feed the ever-increasing human population. Indications are that when the soil becomes mismanaged to such a point, life on it will just be sitting on the edge of extinction (Buffett 2001and Buffett 2013).

Traditionally, farmers have been using shifting cultivation in which case cropped lands could be fallowed for up to 15 years or more to restore such lands to arable status. However, over the last two decades, increasing pressure on arable land in several parts of the sub-region has rendered the shifting cultivation practice unsustainable for soil regeneration. Forest/fallow soils are noted to be stable and productive due to minimal disturbances. The soils are permanently covered by plant canopy or litter fall and also have a diversity of plant species. Conservation Agriculture (CA) aims at replicating these forest land conditions on the arable land so that the continuously cropped land can be nearly as productive as the long fallowed lands found in the shifting cultivation system. This implies that the old paradigm of agricultural production and management (Derpsch, 1999) must be changed to one that simulates the closed-nutrient recycling of the forest so as to support sustainable crop production.

Methods

At the Howard G. Buffett Foundation Centre for No-Till Agriculture (HGBF|CNTA) at Amanchia, Ghana, we set up a long-term demonstration in 2013 to illustrate the benefits and evidence of CA so that the technology could sell itself to farmers. Three plots of 15m x 6 m each were established with each plot having a 2 m by 6 m wide soil collection area down the slope of 9%. The treatments consisted of the traditional slash and burn, mulch covered no-till and mulch covered no-till with a vegetative barrier mid slope. All plots were treated similarly except for the land preparation method which constituted the three treatments. Planting was always done with a dibbling stick on the bare soil in the slash and burn plot and with the same dibbling stick on the mulch covered no-till and no-till with barrier plots.

Results

Data gathered so far shows that:

Conservation Agriculture can greatly reduce soil loss (table 1).
Mulch on the soil surface reduces the impact of rain drops on the soil surface to prevent the detachment of soil particles and further reduces the speed of runoff to prevent soil movement.

CA moderates soil temperature and conserves soil moisture (table 2).
Organic soil cover serves as an insulator to prevent the soil from excessive heating and thus reduces soil moisture evaporation.

CA enhances soil life by creating ideal living conditions for them and provides food for their survival.

Table 3 presents the number of earthworms washed off from the various plots following a 48 mm rainfall immediately after land preparation in 2013. The higher number of earthworms lost per m^2 at the beginning of the study and the possible earthworm losses with the massive soil loss each year on the slash and burn plot reflected in the very low earthworm population on that plot five years later as shown in the table 3. The higher numbers of earthworms on the two no-till plots compared to the near zero on the slash and burn plot testify to the enhanced living conditions created by CA for the soil organisms.

Soil carbon

Starting from an initial value of 12,350 kg/ha of soil Carbon (Table 4) in the first 10 cm depth of soil, the no-tillage and no-tillage with barrier plots had attained 29,640 and 36,140 kg/ha of carbon representing gains of 17,290 and 23,790 kg/ha respectively in five years. Within the same time period, the traditional slash and burn plots gained only 4,810 kg/ha. Table 4 clearly indicates that CA has the capacity to sequester appreciable amounts of carbon even beyond the very active 10cm depth of soil. The adoption of CA will therefore have a lot of value in building Carbon-rich soils faster.

Effective Cation Exchange Capacity (ECEC)

A higher carbon content of the no-till soil is a reflection of higher amounts of soil organic matter which upon decomposition results in higher quantities of humus in the soil. The humus in organic material has charged sites that will attract and store anions like Nitrate. Research has shown that Nitrate anions together with other anions do not have many spaces in the soil where they can adsorb (stick) to be stored for later use by plants. This is because most of the electrostatic charges on the clay colloids are negatively charged. This means that they will attract and store cations, however, they will repel the negatively charged anions. This is the reason why anions like Nitrate, Sulfur and Boron are readily leached from soils with low organic matter. Starting from a low ECEC content of 7.13 cmol/kg (Table 5), the ECEC of the slash and burn plot remained low after 5 years even in the top 10 cm soil depth whereas the no-till and no-till with barrier plots had values pushed up to the moderate ECEC content of 13.63 and 14.02 respectively due to the higher organic matter content of the no-till plots.

Crop yield

CA can sustain crop yields (table 6). The combined effects of reduced erosion, moisture retention, temperature moderation, enhanced biological life and improved fertility leads to sustainably better crop yield over the years.

Conclusion

As noted from the above data, committing ourselves to understanding and adhering to farm practices governed by minimal disturbances to the soil, permanent soil cover and crop diversification as required by CA, we can surely bring our soils back to life to sustain food production.

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Tables

Table 1 Soil loss as affected by land preparation practice (Amanchia, 2013)

Land preparation	Soil loss (kg/ha/yr)
Slash and burn	17,784.8
No-Tillage	77.8
No-Tillage with barriers	33.3

Table 2 Soil temperature and moisture as affected by land preparation practice (Amanchia, 2014)

Practice	Soil surface T^{oC}	% moisture at 5 cm soil depth
Slash and burn	45.7	17.0
No-Tillage	32.2	40.3
No-Tillage with barriers	34.6	43.0

Table 3. Number of earthworms/m^2

Land preparation practice	No. of earthworms/m^2 washed off site following 48 mm of rainfall in 2013	No. of earthworms/m^2 to a depth of 5 cm in 2017
Slash and burn	60	3
No-till	5	225
No-till with barriers	4	250

Table 4 Amount of soil carbon sequestered in five years by land preparation methods

Soil depth	Initial Carbon content (kg/ha)	Carbon content (kg/ha) five years later		
		Slash and burn	No-till plot	No-till with barrier plot
0 – 10 cm	12,350.00	17,160.00	29,640.00	36,140.00
10 – 30 cm	5,980.00	8,320.00	19,630.00	20,280.00

Table 5 Effective Cation Exchange Capacity (ECEC) as affected by land preparation method

Soil depth	Initial ECEC (cmol/kg)	ECEC (cmol/kg) five years later		
		Slash and burn	No-till	No-till with barriers
10 – 10 cm	7.13	9.11	13.63	14.02
10 – 30 cm	5.27	6.73	9.38	11.71

Table 6 Crop yield (t/ha) on the erosion control demonstration plot

	2013		**2014**		**2015**		**2016**	**2017**	
Practice	Maize	Cowpea	Maize	Cowpea	Rice	Maize	Maize	Soybean	Maize
Slash and burn	1.5	0.6	1.35	0.6	0.89	0.86	1.4	0.91	2.64
No-Till	4.5	0.85	5.2	1.0	2.20	4.8	5.0	2.33	6.21
No-Till with barriers	4.8	0.8	5.0	1.1	2.15	4.6	4.8	2.68	6.92

Effect of Legume Cover Crops and Imazapyr Herbicide coated Seed on Weeds and Green Maize Yield

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Key words: Conservation Agriculture, *Lablab purpureus* L., Imidazolinone resistant maize, sustainable cropping systems

Introduction

Maize a native of Central America spread worldwide, thanks to selection and hybridization it grows in a wide range of climatic conditions. Research into agronomic practices to optimize grain yield has been a priority for many governments in Africa because of the critical role played by maize in food security. In Africa and Kenya in particular, there is an increasing high demand for green maize (Ochieng 2017; Tunoi and Too, 2017). Mature green maize is sold as fresh cobs, roasted cobs, boiled cobs, githeri (cooked mixture of maize and beans) and irio (mashed mixture of githeri, vegetables, bananas and potatoes). Roasted and boiled green maize has gained prominence, and, is preferred by many in Kenya as a healthy nutritional snack. It is sold at a cost range of 0.3-0.5 $ per comb in strategic areas along most urban bus stops. The maize crop residues are sold as fodder at 120$ per ha in central Kenya (Personal communication). Maize grain production constraints include manual weeding which is limited and, an expensive common practice, unstable grain prices making it hard for the producers to plan, competition by cheap imports from commesa countries and heavily subsidized farmer competitors, grain infestation and destruction by storage pests and disease causing pathogens, poor monoculture practices leading to degraded soils and handling costs including harvesting, shelling, transport and storage.

To intervene many farmers are opting for green maize production (personal communication). It fetches more returns compared to grain maize (Tunoi and Too, 2017). This study proposed integrated weed management with cover crops to reduce weeding cost; avoid herbicides that could be detrimental to the environment and biodiversity; and, reduce need for expensive chemical fertilizers. Hence, the objective of this study was to evaluate the effect of dolichos (*Lablab purpureus* L.) and open pollinated imazapyr herbicide coated imidazolinone-resistant (IR-maize) on weeds and green maize yield for food security and nutrition, and fodder to generate income. A three-year field study was conducted by Kenya Agricultural and Livestock Research Organisation at Kiboko site to evaluate the effect of dolichos bean (*Lablab purpureus* L.) and imazapyr herbicide coated open pollinated IR-maize (variety WS 303) on weeds and yield of mature-green maize. IR-maize tolerates imidazolinone herbicides enabling new maize innovative weed management and increased maize yields (Mwangi et al., 2015).

Materials and methods

Study area

Field trials were conducted at Kenya Agricultural Livestock Research Organisation (KALRO) Kiboko in Makueni County.

Treatments and experimental design

Plant materials: Imazapyr herbicide coated IR - maize at the rate of 30 g ha^{-1}, open pollinated variety (OPV) (WS 303) and uncoated IR - maize (WS 303). Black dolichos (*var*. HB 1002); and, brown dolichos (*var*. Rongai). At the site, weeds were identified, slashed and sprayed with glyphosate at the rate of 1.6 kg ai ha^{-1} (equivalent of 400 ml per 20

liters) using a 20 L knapsack sprayer with a low volume nozzle. Twenty-four (24) plots were demarcated, each measuring 4 x 5 m and furrows were made at a spacing of 90 cm. Six treatments including IR-maize coated, IR-maize coated + brown dolichos, IR-maize coated + black dolichos, IR-maize uncoated, IR-maize uncoated + brown dolichos and IR-maize uncoated + black dolichos were laid out in a randomized complete block design (RCBD) replicated four times. Maize was planted at a spacing of 90 × 45 cm and 2 seeds per hole. Two rows of dolichos were planted between two rows of maize with intra-row spacing of 45 cm. During planting, compound fertilizer (NPK 23:23:0) was applied at 60 kg ha^{-1} P_2O_5 (equivalent to 13.8 kg N ha^{-1} and 6.02 kg P). After planting, all treatments were irrigated for 3 hours to field capacity (320 - 355 mm) and after every 3 days (at uniform intervals) between 6.00 pm - 6.00 am. This ensured adequate water expected to dissipate herbicide from coated IR-maize and meet water requirements for crop optimal yields. All treatments were top-dressed 21 days after planting (DAP) with nitrogen (N) fertilizer at 31.2 kg N ha^{-1} in the form of calcium ammonium nitrate (CAN 26% N) fertilizer at 120 kg ha^{-1}. Weeds were controlled using glyphosate at 1.6 kg ai ha^{-1} (equivalent of 400 ml per 20 liters) and the experiment repeated in the same plots.

Data collection and analysis

Weeds assessment was done at 21 and 42 DAP. This was to show the effect of herbicide coated IR- maize and cover crops on weed species composition and weed density (count m^{-2}) within the critical period of weed control in maize. A meter squared quadrat was placed randomly in each plot. Within the quadrat, growing weed species were identified, counted and recorded. The whole maize plant was cut from ground level, tied with sisal twine, weighed using a spring balance and weight recorded, ears were counted, and cobs weight recorded. Bivariate correlation effect of herbicide coated IR-maize, cover crops and weed species composition was compared 21 and 42 DAP in 2010 and 2011. The data for weed and maize were subjected to Analysis of variance (ANOVA) using GenStat statistical package, Version 12.0. Where treatment effects were significant, means were compared using Student Newman Keuls (S-N-K) test at 5% significance level.

Results and discussion

Weed diversity: Analysis of variance (ANOVA) showed that weed species were significantly ($P < 0.05$) different across the field. There were18 weed species. The period of assessment (DAP) had significant ($P < 0.05$) difference on the number of weed species (counts m^{-2}). There were significantly more weed species (7.3 plants m^{-2}) compared to 5.5 plants m^{-2} 21 and 42 DAP respectively (Table not shown). Results indicate that most of the species were early emerging annual weeds.

Weed density and assessment period: ANOVA showed a significant ($P < 0.05$) effect of assessment time period on the density (count m-2) of 10 individual annual weed species (*Bidens pilosa*, *Boerhavia diffusa*, *Euphobia hirta*, *P. parviflora*, *Oxygonum sinuatum*, *Sonchus oleraceae*, *Tridax procumbens*, *Trichodesma zeylanicum*, *Dactyloctenium aegyptium* and *Eleusine indica*). The weed species density (count m^{-2}) 21 and 42 DAP in 2011 were significantly higher than in 2010 respectively except for *D. aegyptium*, *E. indica* and *O. sinuatum* (Table not shown).

Results showed that weed density were significantly ($P < 0.05$) different among species and *Paraknoxia parviflora* (*Stapf ex Verdc.*) density was significantly ($P < 0.05$) higher than all other species (Table not shown).

Effects of herbicide coat and cover crop on weeds: This study showed that herbicide coated IR-maize and cover crops interaction had no significant difference on weed density (number of weeds m^{-2})

Cover crops effects on weeds: Dolichos effect 42 DAP was weed species specific (Table 1). Cover crop shading effects 42 DAP, resulted to increased density of *Oxygonum sinuatum* probably because it had more seed mass, which supported its growth requirements. This study indicated that shading effect contributed to suppression of *P. parviflora* and *Portulaca quadrifida* in the maize field. Observed stunting of weeds indicates a possible loss of species potential to reproduce over time and or reduced speed at which weed patches could expand across the field. Cover crops suppressed different weed species through physical impediment and hindering germination (Mwangi et al., 2015).

Effects of coated IR-maize and dolichos cover crop on maize yields: Results (Table 2) showed that Uncoated IR-maize with black dolichos produced significantly ($P < 0.05$) higher yields than with brown dolichos probably due to the high biomass of black dolichos (10 - 22 t ha^{-1}) and additional leaf litter (1.7 t ha^{-1}). More biomass produced by black dolichos probably had greater weed suppression effect compared to brown dolichos low biomass (4 - 10 t ha^{-1}) and leaf litter dry matter (0.7 t ha^{-1}). The black dolichos had the highest yield in coated / non coated IR- maize probably because it produced the higher biomass and leaf litter per unit area than brown dolichos. Coated IR-maize with no cover crop plots had significantly ($P < 0.05$) lower numbers of green fresh ears yield in both 2010 and 2011.

Conclusion

The study demonstrated that the diversity of weed species was significantly ($P < 0.05$) more 21 DAP than 42 DAP. In addition, weed density 21 days after planting (DAP) was significantly ($P < 0.05$) higher compared to 42 DAP, and significantly ($P < 0.05$) higher in 2011 than in 2010. Integrating cover crops with herbicide coated seed technologies managed specific weed species 21DAP. Cover crops suppressed most annual broad-leaved weeds 42 DAP. Total number of green ears was higher in herbicide coated and uncoated IR maize integrated with dolichos, which was associated to cover crop effects including biomass, shading the soil and suppression of 10 weed species. Integrated weed management increased yields of green maize; and, therefore is a good option for increasing productivity that will contribute to meet high demand of green maize, and fodder for income generation. Further studies are required to evaluate 1) chlorophyll concentration in maize leaves to explain the deep green color observed in legume cover crops conclusively, treatments and 2) effect of cover on the soil temperature amplitude in similar regions.

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Tables

Table 1: Effect of cover crop on the mean density (plants m^{-2}) of *Portulaca quadrifida L.*, *Paraknoxia parviflora* (Stapf ex Verdc.) and *Eleusine indica* L. Gaertn at KALRO-Kiboko, Kenya

	Mean density of weed species (Plants m^{-2})		
Cover crops	Portulaca quadrifida	Paranoxia parviflora	Eleusine indica
Black dolichos	0.23^{b}	5.63^{b}	0.20^{b}
Brown dolichos	0.06^{b}	6.09^{b}	0.31^{a}
No cover crop	0.38^{a}	12.02^{a}	0.17^{b}
Standard Error	0.08	1.74	0.05
Significance level	$P < 0.05$	$P < 0.05$	$P < 0.05$

Means in the same column followed by the same letter do not significantly differ at ($P < 0.05$) according to Student Newman Keuls test.

Table 2: Comparing maize yield (green maize, grain and components t ha^{-1}) in 2010 and 2011 at KALRO-Kiboko, Kenya

	Maize dry matter (t ha^{-1})		Ears (count ha^{-1})		Grain yield (t ha^{-1})	
	2011	2010	2011	2010	2011	2010
No cover + uncoated maize	6.3^{a}	4.2^{a}	27625^{a}	28920^{a}	3.0^{a}	2.0^{b}
Uncoated maize + Black dolichos	5.8^{ab}	6.5^{a}	25875^{a}	27094^{a}	2.9^{ab}	3.3^{a}
Uncoated maize + Brown dolichos	5.4^{ab}	4.7^{ab}	26625^{ab}	27880^{ab}	2.6^{ab}	2.2^{ab}
Black dolichos + coated maize	4.9^{bc}	6.2^{a}	21125^{bc}	22120^{bc}	2.3^{bc}	2.5^{ab}
Brown dolichos + coated maize	4.0^{c}	5.5^{ab}	19875^{c}	20812^{c}	1.9^{c}	2.5^{b}
No cover + coated maize	2.0^{d}	1.4^{c}	18706^{d}	19588^{d}	0.9^{d}	0.6^{c}
CV %	14.9	25.4	14. 8	14.8	19.5	25.8

Means in the same column followed by the same superscript letter are not significantly different (at $P < 0.05$) according to Student Newman Keuls test.

Crop Residues in Conservation Agriculture (CA) based Cropping Systems of Southern Africa

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Key words: immobilization, mulching, nitrogen fertilizer, rainfall variability

Introduction

Conservation Agriculture (CA) based cropping systems have shown great potential for improving crop productivity on smallholder farms (Wall *et al.,* 2013). Currently, there is limited information on the appropriate quantities of maize residues and mineral N fertilizer that should be applied in CA-based cropping systems in order to increase crop yields on smallholder farms. In this study it was hypothesized that different maize residue levels with or without mineral N fertilization will increase grain yield, and the effect of different maize residue levels on grain yield is dependent on seasonal rainfall pattern. The objectives were to determine (1) the effect of different maize residue levels with or without N fertilization on maize grain yield, and (2) the effect of different maize residue and N fertilizer levels on grain yield under different seasonal rainfall patterns.

Material and Methods

The study was carried out in Malawi, Mozambique, Zambia and Zimbabwe. In Zimbabwe, the research was established at Domboshawa Training Centre (DTC), University of Zimbabwe Farm (UZ) and Makoholi Research Station (Makoholi); in Zambia at Monze Farmer Training Centre (MFTC) and Msekera Research Station (MRS); in Malawi at Chitedze Research Station (CRS), and in Mozambique at Sussundenga (SRS) and Ntengo Umodzi Research (NUR) Stations. The six main treatments were CA-based seeding with different levels of maize residues applied at the

onset of each cropping season: 0, 2, 4, 6 and 8 t ha^{-1}. In Malawi and Zimbabwe, each maize residue level plot was sub-divided into three to accommodate the N level sub-treatments. The N level sub-treatments were 0, 30 and 90 kg N ha^{-1}. Plot size was 7.2 m (8 rows) x 6 m at all sites. Maize was spaced at 0.90 m x 0.25 m with 1 plant per station giving a target plant population of 44 444 plants ha^{-1} at all stations except CRS and NURS where plant spacing was 0.75 m x 0.25 m (53 000 plants ha^{-1}). Plots were kept weed free. Daily rainfall and grain yield data were collected. Maize grain yield was calculated on a hectare basis at 12.5 % moisture content. Data were analysed using the linear mixed models in Genstat (version 6.1) and general linear mixed models in R (R Core Team, 2017).

Results and Discussion

Residue effect on grain yield was dependent on seasonal rainfall pattern at most of the sites. On sandy soil, residue cover significantly influenced grain yield in 2010 and 2011 only (Figure 1). Under poor rainfall distribution, grain yield increased with increase in residue level applied on sandy soil. This result is consistent with previous studies under semi-arid and sub-humid conditions of Africa (Mupangwa *et al.,* 2007; Kitonyo *et al.,* 2018). The different residue levels x rainfall interaction significantly (P = 0.022) influenced grain yield on clay soil. In 2008, mulching suppressed yield while in 2009, grain yield increased with increase in soil cover levels up to 4 t ha^{-1}. At the semi-arid Makoholi, grain yield was higher under 6 and 8 t ha^{-1} treatments compared with 0-4 t ha^{-1} in 2010 and 2011 seasons which had poorly distributed rainfall. At the Zambia sites, residue level x rainfall interaction significantly influenced grain yield. In 2011, a growing season characterized by rainfall concentrated in the first two months, 6 and 8 t ha^{-1} residue levels suppressed grain yield at MFTC (*results not shown*). At MRS, grain yield decreased with increase in residue level in 2014 which received >1 000 mm seasonal rainfall (*results not shown*). In Malawi, different residue levels had no significant effect on yield. In Mozambique, residue levels influenced (P = 0.003) grain yield at SRS in 2011 only and in that year 4 t ha^{-1} treatment had significantly lower yield compared with 2 and 6 t ha^{-1} treatments. At NURS, residue levels x rainfall interaction had a significant effect on grain yield. In 2013 with 1 240 mm of rainfall, 8 t ha^{-1} significantly reduced grain yield. In 2014 with lower seasonal rainfall, grain yield increased with increase in soil cover from 2 to 8 t ha^{-1}.

The residue level x N fertilizer interaction significantly influenced grain yield in 2014 at UZ site (Figure 2). Under 0 kg N ha^{-1} treatment, grain yield decreased with increase in residue level. There was also a significant residue level x N interaction across the years at the UZ site. Without N fertilizer, 6-8 t ha^{-1} residue levels had significantly lower grain yield compared with 0 t ha^{-1} control. With 30 kg N ha^{-1}, significant grain yield gain was achieved under 2 t ha^{-1} compared with the control. The 90 kg N ha^{-1} had significant grain yield gains under 2, 4 and 6 t ha^{-1} treatments compared with the control. At semi-arid Makoholi, N fertilization increased grain yield with 90 kg N ha^{-1} having a higher yield than the 30 kg N ha^{-1}. At Chitedze residue level x rainfall interaction significantly (P = 0.0217) influenced grain yield across the years. Grain yield was lowest in 2014 with 775 mm of rainfall compared with 2012 and 2013 that had 854 and 860 mm, respectively.

Conclusion

The different maize residue levels had a similar effect on maize yield in most cropping seasons. Smallholder farmers could therefore apply 2-4 t ha^{-1} or even less, to derive the other benefits of mulching. Results of this study highlight that residue soil cover with maize stover with a wide C: N ratio is insufficient for a productive CA system. The rotational component and increased N input through leguminous crops could be options to overcome nitrogen immobilization. The results suggest that immobilization of soil N and hence low maize yield is dependent on soil type and seasonal rainfall pattern with wetter seasons experiencing more soil N immobilization. Smallholders practising CA, therefore, need to invest in more mineral N fertilizer in seasons with high rainfall to offset soil N immobilization. Nitrogen fertilizer increased maize yield in the CA systems tested. Application of 30 and 90 kg N ha^{-1} can offset N immobilization on sand and clay soil, respectively. Smallholders could therefore target investing in 30 kg N ha^{-1} in most cropping seasons and 90 kg N ha^{-1} in wetter seasons particularly on clay soils.

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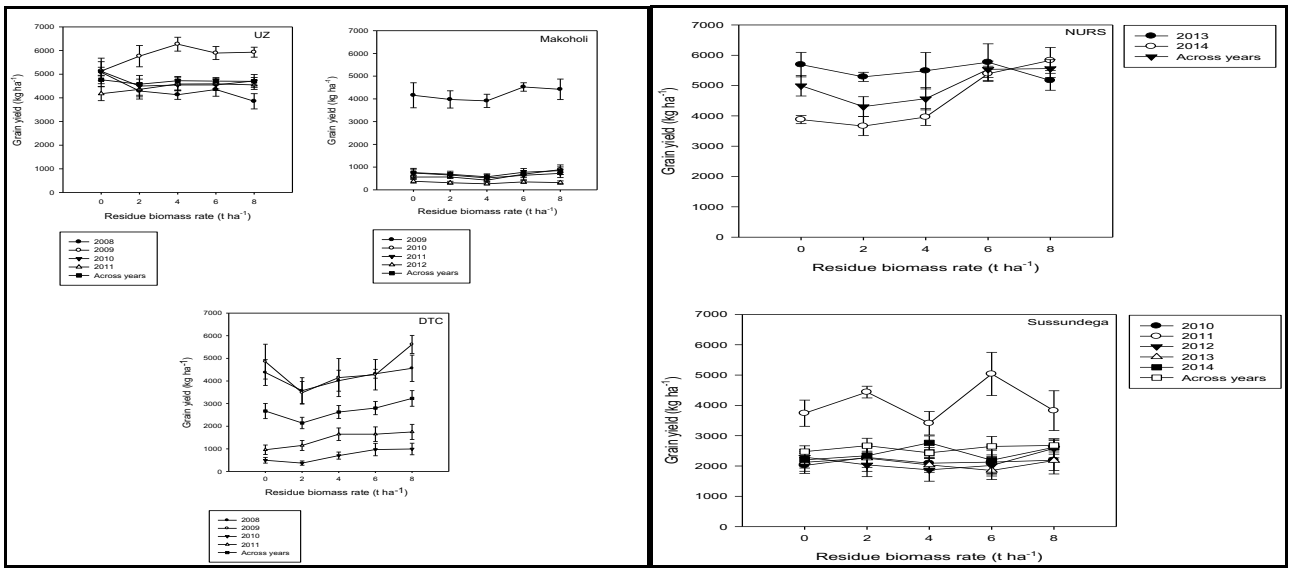

Figure 1. Maize grain yield responses to different residue levels from 2010 to 2014 at DTC, UZ, Makoholi, MFTC, MRS, NURS, SRS experimental sites. Vertical bars represent standard error of means (SE) for each year and across years.

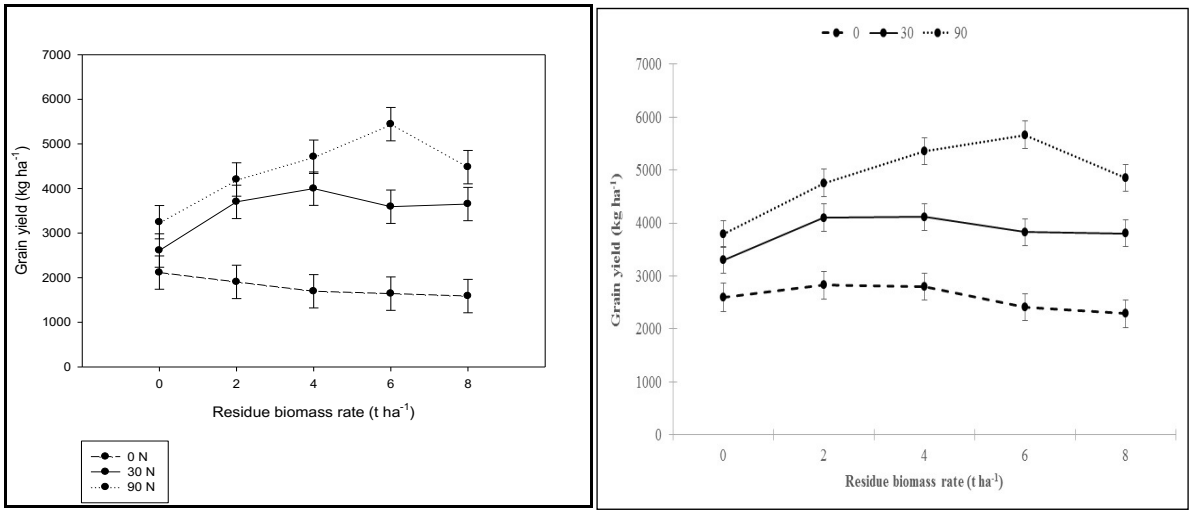

Figure 2. Interaction effects of residue biomass levels and N fertilizer on grain yield in 2014 season (*left*) and across three seasons (*right*) at University of Zimbabwe. Vertical bar represents standard error of means (SE) (n = 9).

Increasing Adaptation to Climate Stress by Applying Conservation Agriculture in Southern Africa

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Keywords: no-tillage; sustainable intensification; cover crops, resilience,

Introduction

Climate variability and change will increasingly affect smallholder farming systems in southern Africa. Already, farmers have to cope with erratic rainfalls, delayed onsets of rainy seasons, floods, droughts and heat stress. By the year 2050, average temperatures will increase by 2.1-2.6°C (Cairns *et al.,* 2013) and the most affected crops will be maize and wheat (Lobell *et al.*, 2008), two of the main staple food crops in southern Africa. Heat stress is projected to be the most devastating factor (Burke *et al.,* 2009). Since 2004, CIMMYT has rolled out a large research for development program on Conservation Agriculture (CA) to adapt smallholder farming systems to the vagaries of climate and declining soil fertility (Thierfelder *et al.,* 2017; Thierfelder *et al.*, 2015). This paper aims to summarize some of the key findings from long-term Conservation Agriculture research and highlights avenues and adjustments needed for future CA systems in Africa.

Methods

The work was carried out in more than 30 on-farm locations of Malawi, Zambia, Mozambique and Zimbabwe where clustered validation trials were incrementally established from 2004 onwards. The sites stretched from southern Zimbabwe and Zambia to Central Mozambique, Southern and Central Malawi and Eastern and Northern Zambia and covered cropping systems from 450mm to more than 1600mm of rainfall, from very sandy to loamy clay soils. The on-farm clusters had 4-9 on-farm replicates, with farmers being the replicate, while testing at least two CA systems against a conventionally tilled practice at a particular site and season. The main CA systems tested where either manually planted maize-based system, seeded with a dibble stick or in planting basins, or established in animal traction systems using a ripper or an animal traction direct seeder. All comparisons at each trial location received the same fertilizer level and variety although the rate and variety changed depending on specific site recommendations and farmer preference. All sites had initially maize as test crop and were incrementally adjusted with climate-smart agriculture options using different rotation and intercrops as well as drought-tolerant maize varieties. All CA systems had crop residues retained at a rate of at least 2.5 t ha^{-1} or above while conventional systems had their residues removed, mimicking current conventional practices. Yield and rainfall data was collected from each location to better understand the maize response of CA treatments in different cropping seasons. On-farm results were subjected to a meta-regression analysis using drought and heat stress as stress factors affecting both CA and conventionally tilled systems across the whole region.

The on-farm trial results where further supported by the results of six on-station LT trials, strategically located in the region, where CA systems are tested more rigorously under controlled conditions and where additional soil quality indicators (infiltration, soil moisture, soil carbon etc.) were captured. All supporting data were used to assess the adaptive capacity of CA systems to withstand climate stress.

Results & Discussion

CA systems across numerous on-farm locations supported both drought and heat stress better than conventionally tilled systems in southern Africa. However, we found through a meta-regression analysis that this effect is stronger under more marginal sandy soil conditions as opposed to more fertile and clay-rich soils and with increasing rainfalls

and soil moisture content (Figure 1). These results confirm previous findings that support the argument that CA may offer greater resilience under climate stress (Steward *et al.,* 2018; Nyamangara *et al.,* 2014) especially on lighter textured soils (Nyamangara et al., 2014), which form the majority of soil types in southern Africa. Greater yields become apparent in most tested CA systems after 2-5 cropping seasons (Thierfelder et al., 2015). The reason for an enhanced adaptive capacity can be found in greater soil moisture conservation due to increased infiltration, moisture retention under mulch and a more favourable soil pore structure in CA systems (Thierfelder and Wall, 2009). Gradually improving soil quality in CA systems in response to no-tillage, residue retention and diversification have been measured under controlled conditions in on-station long-term trials.

However, while providing greater adaptive capacity to climate stress it was observed that current CA cropping systems as practiced in smallholder farms are insufficient to maintain and/or increase soil fertility (Thierfelder *et al.,* 2018). Farmers struggle to maintain sufficient crop residues for groundcover due to intensive crop-livestock interactions in Zimbabwe and Zambia and associated trade-offs. Also the long dry season and volatilization of nitrogen reduce potential fertility benefits of CA systems and rarely contributed to improvements in soil carbon and available soil nitrogen at the onset of the new cropping season. Future CA interventions therefore need to focus more on increasing the biomass production on smallholder farmer's fields for both feed and for mulching. This could be achieved through adequate fertilization and use of animal manure, optimal plant population, growing of drought-tolerant crops, increased diversification and groundcover by leguminous intercrops (pigeonpea, lablab and cowpeas) or introducing tree-based components in CA cropping systems (e.g. *Gliricidia sepium* (Jacq.) Kunth ex Walp) to increase biomass production on-site (Thierfelder et al., 2018).

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Figures

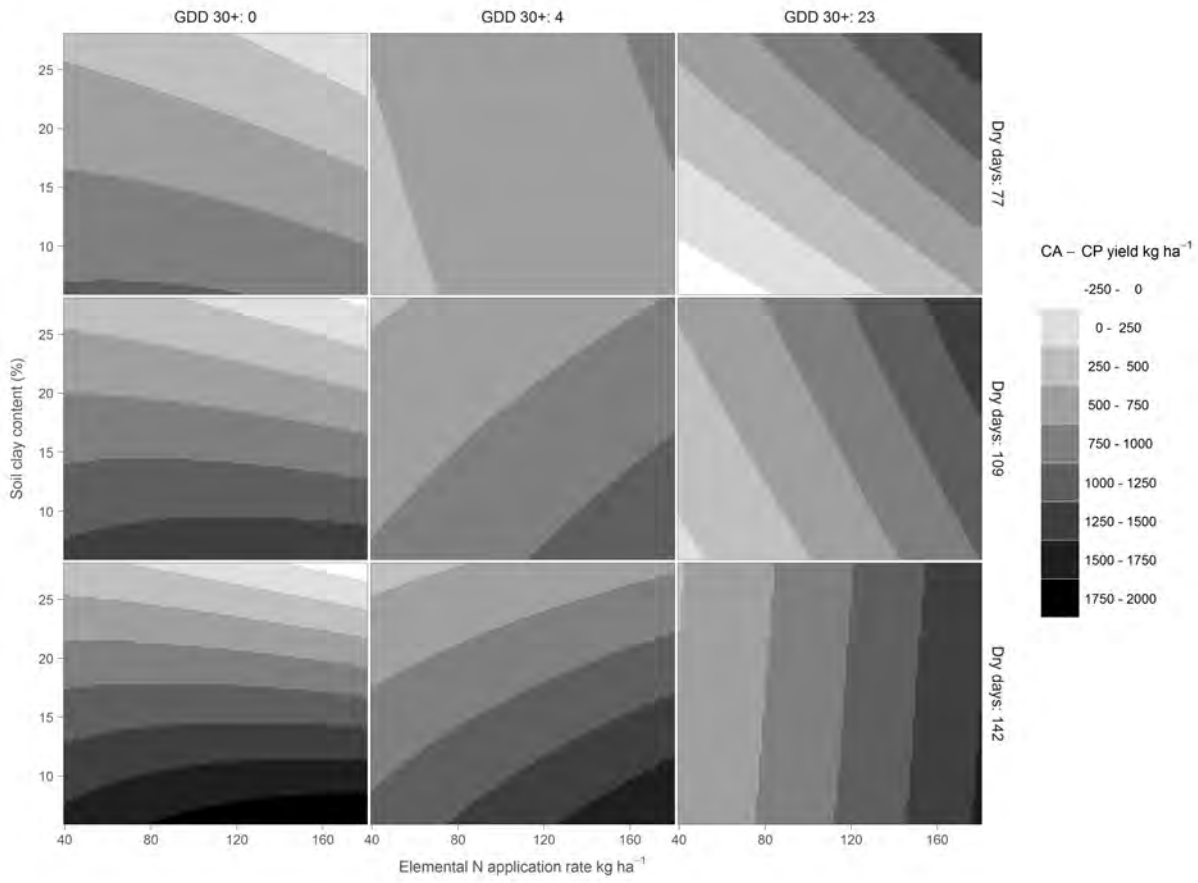

Figure 1: Maize yield benefit of CA (as CA yield minus CP yield) with soil clay content (x-axis) and nitrogen fertilization rate (y-axis) panelled by anthesis growing degrees above 30°C (columns) and total days with <5 mm rainfall for the growing season (rows). Increasing yield benefit is indicated by darker shading. Yield are predicted by an LMER model with random-effects for variety and location. Predictions are made for rotation present in CA and absent in CP, and intercropping absent overall. GDD = Growing Degree Day.

Profils Racinaires de *Brachiaria* (Trin.) *Brizantha* (Hochst.) Stapf, *B. Decumbens* Stapf *et B. ruziziensis (Germ.* & Evrard) Ndab au Sénégal

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Mots-clés: *Brachiaria*, Sénégal, plante de couverture, association culturale, système racinaire

Introduction

Le Sénégal, en particulier dans sa zone centrale, le sud du bassin arachidier, est soumis à de forts risques de ruissellement de l'ordre de 30 % des pluies. Le risque d'érosion est très élevé avec un indice de dégradation spécifique d'environ 1700 t km^{-2} an^{-1} (Perez et al., 1996). Les sols sont pauvres en matière organique. D'où la nécessité de rechercher des alternatives de lutte contre la dégradation des sols et de la baisse de fertilité des sols comme le semis direct sous couvert végétal permanent et qui a fait ces preuves à travers le monde. D'ailleurs, des travaux menés dans d'autres régions tropicales ont montré l'intérêt de l'introduction de plantes de couverture vivantes ou mortes dans les systèmes de culture (Malézieux et al. 2009). Le genre *Brachiaria* contient, à cet égard, des espèces intéressantes (Andrioli, 2004) pour participer à la lutte contre l'érosion des sols. La partie centrale du Sénégal, a une saison sèche très marquée et longue avec souvent huit mois sans aucune pluie. Or, dans les pays où le *Brachiaria* a montré son intérêt, au Brésil et aux Antilles en particulier, la pluviosité est mieux répartie dans l'année (Brunet et Brossard, 2000). Il n'est donc pas possible d'utiliser les résultats obtenus ailleurs pour élaborer des systèmes de culture avec *Brachiaria* au Sénégal, où il existe pourtant un intérêt potentiel de *Brachiaria*, notamment pour la lutte contre l'érosion et l'apport de matière organique. Mais très peu d'études y ont été menées sur ce sujet. Trois espèces du genre *Brachiaria* ont donc été testées au Sénégal afin de connaître en particulier leur capacité à résister à la longue saison sèche locale et connaître les caractéristiques de leur système racinaire pour l'accès à l'eau.

Matériels et méthodes and Methods

L'essai a été conduit durant deux années (2015 et 2016) en station dans le département de Nioro du Rip situé entre 13°35'-13°50' Nord et 16°00'-16°30' Ouest, dans le sud du bassin arachidier du Sénégal. Les précipitations enregistrées au cours de l'année ont été de 1044 mm en 2015 et de 917 mm en 2016, se rapprochant de la moyenne annuelle de la zone qui avoisine les 800 mm/an. Les sols de la station de Nioro du Rip ont une texture sableuse, une structure massive, un pH acide (compris entre 5 et 5,2), une faible teneur en carbone total et une faible capacité d'échange cationique (1,15 à 1,34 meq/100g de sol). Ce sont des sols pauvres en azote total (0,14% à 0,21%) et phosphore assimilable (20,6 ppm à 27,5 ppm) (Noba 2002). Le dispositif expérimental était composé de quatre traitements répétés dans trois blocs randomisés. Les trois espèces de *Brachiaria* étaient: *B. brizantha*, *B. decumbens* et *B. ruziziensis*. *Brachiaria* a été semé entre deux poquets de mil, en alternance, tous les 0,9 m. La préparation du terrain a consisté en un grattage avec une houe, sauf en 2016, sur les traitements avec *Brachiaria* où la couverture végétale résiduelle a été laissée sur le terrain sans travail du sol. Sur tous les traitements, on a apporté 150 kg ha-1 de 15N-15P-15K en début de culture et 100 kg ha-1 d'urée en deux apports en cours de cycle (10 et 45 jours après la levée du mil). Les semis ont eu lieu après une pluie, le 10 juillet 2015 et le 22 juillet 2016. La culture a été strictement pluviale, sans irrigation. *B. ruziziensis* n'ayant pas survécu aux huit mois de saison sèche a dû être réimplanté en début de saison des pluies 2016. Les espèces *B. decumbens* et *B. brizantha* n'ont eu besoin que de repiquages ponctuels. En 2016, il a été procédé à des coupes du *B. brizantha* (le 23/08 et le 07/09) et du B. decumbens (le 07/09) quand la biomasse, devenue trop envahissante, gênait la croissance du mil. Cette biomasse coupée a été laissée sur le sol. Des mesures racinaires ont été effectuées en novembre 2015 et en décembre 2016, plus d'un mois après la récolte du mil, quand les racines de mil étaient mortes mais celles des *Brachiaria* étaient encore vivantes. La méthode a consisté à cartographier les racines apparaissant sur un profil vertical de sol à l'aide d'une grille à mailles de 0,1 m,

suivant la méthodologie décrite par Chopart (1999), pour obtenir le nombre d'impacts racinaires (NI), par unité de surface de profil de sol (Chopart et al., 2008). La largeur de mesure était de 0,5m de part et d'autre du pied, la profondeur de mesure était de 1 m en 2015 et 1,5 m en 2016. Les mesures ont été faites sur chacune des neuf parcelles, fin 2015 et fin 2016, un mois et demi après la récolte du mil. A partir des données de base (cartes de NI par m2), on a estimé la densité de longueur volumique racinaire (DLR ou RLD pour Root Length Density en m m-3). La RLD, est estimée à partir des NI: RLD=NI*CO (Chopart, 1999). Le coefficient d'orientation CO est lié à la direction des racines plus ou moins perpendiculaire au plan d'observation. Les principes et la théorie de cette approche géométrique et architecturale sont précisés par ailleurs (Chopart *et al.,* 2008). Les modèles permettant de calculer la RLD à partir des NI ont été proposés pour plusieurs cultures tropicales: le maïs (Chopart et Siband, 1999), le sorgho (Chopart et al, 2008a), le riz (Dusserre et al., 2009) et la canne à sucre (Chopart et al., 2008b). Les résultats sont variables d'une espèce à l'autre mais les modèles s'inscrivent entre un minimum de RLD = 2* NI et un maximum de RLD = 5* NI avec une valeur moyenne de CO proche de 3. A défaut de disposer d'un modèle spécifique pour les espèces de *Brachiaria* étudiées, la valeur moyenne de CO = 3 a été retenue. Donc, pour *Brachiaria* le modèle suivant est proposé: RLD = 3*NI. La longueur totale des racines entre la surface et la profondeur maximale par m² de culture (en m m-²) a été calculée en sommant les RLD (m m-3) obtenues à différentes profondeurs. Le volume de sol utilisable pour l'alimentation hydrique du *Brachiaria* a été estimé par modélisation. On a retenu le modèle PRER (Potential Root Extraction Ratio) qui estime le rapport entre le volume de sol utile pour l'alimentation de la culture (VU) et le volume totals de sol lui correspondant (Chopart, 1999). Pour calculer VU, on estime que l'approvisionnement de la plante en eau se limite à une distance maximale (RA) autour des racines. On a retenu une valeur de RA de cinq centimètres (Blanchet et al., 1974). Pour tenir compte des compétitions entre les racines, VU dépend des distances moyennes entre les racines (DR) dans chaque unité de volume de sol. Les valeurs de DR ont été calculées à partir des RLD : DR = α (RLD0,5) -1 avec α = (4/π)0,5 (Newman, 1966).

Résultats et Discussion

En 2015, en première année de culture, les profils racinaires des trois espèces de *Brachiaria,* exprimés en pourcentage de sol potentiellement utilisable pour l'alimentation hydrique (PRER), se différencient en fonction de la profondeur. En effet, entre la surface et 20 cm de profondeur, les espèces ont des PRER proches. De 30 et 60 cm de profondeur, les PRER se différencient nettement avec le *Brachiaria Brizantha* qui a un PRER plus faible que celui des deux autres espèces. Et enfin, entre 70 et 100 cm de profondeur, *B. ruziziensis* a un PRER plus faible (Fig 1) mais ce PRER d'environ 40% à un mètre de profondeur reste néanmoins très bon. En 2016, les PRER de Brachiaria ruziziensis sont nettement plus faibles. En effet, entre la surface et 20 cm de profondeur, *B. ruziziensis* a le PRER le plus faible comparé aux deux autres espèces. Cette différence est plus marquée encore entre 100 et 150 cm de profondeur où le PRER de *B. ruziziensis* est nettement inférieur à celui des deux autres *Brachiaria* (Fig 1) avoisinant un taux de 20%. Ceci peut expliquer pourquoi *B. ruziziensis* n'a pas survécu à la longue saison sèche. Ces résultats s'écartent de ceux obtenus dans d'autres zones climatiques à plus longue saison des pluies d'Afrique tropicale, en zone de production cotonnière par exemple (Naudin et al., 2010), du Brésil (Brunet et Brossard, 2000). En revanche des résultats proches ont été trouvés en climat plus sec et à saison des pluie plus courte dans l'extrême nord du Cameroun (Dugué et al 2017) et dans d'autres régions sèches d'Afrique (Giller et al., 2009). Ces derniers auteurs considèrent qu'en Afrique Soudano-Sahélienne, l'agriculture de conservation peut avoir un intérêt dans certains cas, mais que ce n'est pas un modèle généralisable. Dugué et al. (2017) indiquent en particulier que, dans le nord du Cameroun à climat soudano-sahélien, le *Brachiaria* est utilisé de façon préférentielle pour la nourriture du bétail. Ce serait sans doute aussi le cas au Sénégal où il risque d'y avoir concurrence entre un usage comme fourrage et comme plante de protection du sol.

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Assessing Socio-Economic Factors Influencing Adoption of Conservation Agriculture in Moroto District, Uganda

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Keywords: crop rotation, crop residues, minimum tillage, smallholder farmers

Introduction

Agriculture is the backbone of economic growth for many sub-Saharan African countries (Adolwa *et al.,* 2012). It employs about 60% of the region's labor force and accounts for 25% or more of gross domestic product (UNDPI, 2014). World population of 7.3 billion in 2015 is projected to rise to 9.7 billion by 2050 (UNDESA, 2015). Global agricultural production is expected to increase by 60% in 2050, given both the food consumption and population growth (FAO, 2012a). Sub-Saharan Africa (SSA) would experience this challenge more severely (Van Ittersum *et al.,* 2016), with its population projected to approach 2.48 billion by 2050 from the current 1.23 billion (Worldometers, 2017). Agricultural production in sub-Saharan Africa is particularly vulnerable to the effects of climate change, with rain fed agriculture accounting for approximately 96% of the overall crop production (World Bank, 2015a). This is coupled with accelerated land degradation and soil fertility deterioration (Derspch, 2008).

In order for agriculture to respond optimally to the future challenges, new innovations will not only need to increase on effectiveness with which inputs are turned into outputs, but also to preserve scarce resources and decrease waste (Troell *et al.,* 2014). This can be achieved through the promotion of sustainable policies and provision of support to institutions that can provide farmers with incentives and the services required to adopt Conservation Agriculture (CA) practices and improve them over a given period of time (Kassam & Friedrich, 2009).. In Uganda although the benefits derived from CA has been promoted by government agencies and non-government organizations, its adoption is still low (Osiru, 2013). To date, empirical research on factors that enhance or hamper farmers to adopt CA is scarce. Thus, this study is intended to determine the factors that enhance or hinder the adoption of CA in Moroto District.

The hypothesis of the study is "Socio-economic and institutional factors positively and negatively influence the farmers' decision to adopt CA". The s**pecific objectives of the study are:**

- Determine the socio-economic and institutional factors, which significantly influence the farmers' decision to adopt or not to adopt CA in Moroto District.
- Examine the level of CA adoption amongst the farmers in Moroto District.
- Assess the contribution of CA on agricultural productivity amongst the farmers in Moroto District.
- Determine the constraints/challenges faced by the CA farmers in Moroto district.

Materials and Methods

Purposive sampling was used to select seven key informants in two sub counties in Moroto district, Uganda. Seven key informants were purposively selected to include two agricultural officers from the district production department, two county agricultural extension workers from GIZ. which is a development partner, and three village local councilors. The key informants were thought to be conversant with CA practices. From the two sub counties, four villages were selected based on their history of CA, included Nakodet, Nakwanga, Napudes, and Komare. A total of 80 respondents were sampled from the four villages for interviews of which 40 were adopters and 40 were non-adopters of CA. All the collected data from the respondents were first entered into Microsoft Excel to enhance proper coding of the data and then exported to the software programme, Statistical Package for Social Sciences (SPSS) for analysis using descriptive statistics (frequency distribution, means, and percentages) as well as inferential statistics.

Results and Discussion

Gender. Gender of the farmers has a positive impact on adoption of CA and it is statistically significant at the 1% level. Fifty-five (55%) of the adopters were male-headed households and 45% were female-headed households. Likewise, 62.5% of non-adopters were male-headed households and 37.5% were female-headed households. CA requires a significant input in labor for maintenance which places the male-headed households with better access to capital and labor to be more likely to adopt CA compared to their female counterparts.

Credit. Credit was found to be significant ($p<0.05$), implying that farmers who have access to credit are more likely to adopt CA than those who do not. Credit is required for hiring of labour and the purchase of agricultural inputs.

Extension services. Number of extension visits shows a positive correlation with adoption of CA and was significant at the 5% level. This is due to the fact that famers get exposed to new information, which decreases information irregularities that is associated with the new technology, and hence the majority of the farmers are aware of the technology and are willing to take risks which are associated with it.

Conclusion

Research findings revealed that access to extension services credit and gender influences the farmers' decisions to adopt or not to adopt Conservation Agriculture. Other socio-economic factors such as age, education, and farm experience did not significantly influence the adoption of Conservation Agriculture.

The level of Conservation Agriculture adoption is still low as only a few farmers are practicing crop rotation, retention of crop cover, and use of minimum tillage. Furthermore, they are farming on less than 5 acres of land. Finally, inadequate implements and inputs was highlighted by participating farmers as the main challenge faced by Conservation Agriculture famers.

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Provisional results.

Tables

Table 1. Estimated binary logistic model results for socio-economic and institutional factors affecting adoption of CA

Variables	Coefficient	S.E	Wald	df	Sig.	Exp (B)
Age	0.002	0.186	0.000	1	0.990	1.002
Gender	3.857	1.117	11.930	1	0.001***	47.327
Education	0.055	0.604	0.008	1	0.927	1.057
Credit	2.039	1.057	3.718	1	0.054**	7.684
Farm Experience	-0.202	0.470	0.184	1	0.668	0.817
Extension Services	3.436	0.896	14.710	1	0.000***	31.078
Constant	-2.863	1.472	3.78	1	0.052**	0.057

= Significant (P<0.05); * (p<0.01)

The results reveal that factors which significantly affect adoption of CA were gender of the farmer (p<0.05), access to credit (p<0.01), and extension services (p<0.01), while other factors were not significant (Table 20).

Implementing the FAO's *Save and Grow* Farming Approach for Sustainable Crop Production Intensification

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Keywords: farm typology, sustainable intensification, interventions prioritization

Introduction

Southern Africa's staple crops production has significantly grown over the last decade. This production growth has been achieved partly by an input-driven increase in yields and, for most smallholder farmers, by area expansion. The rural poor most commonly have poor access to productive resources and occupy soils naturally deficient in nutrients (Vanlauwe *et al*., 2015; Chikobola and Tembo, 2018).

This suggests that the sustainable intensification of crop production with the improved management of agro-ecosystems is an ecological as well as a development necessity from which Southern African countries will highly benefit to sustaining their development and to contributing to the Sustainable Development Goals 2 (Zero Hunger), 12 (Responsible Consumption and Production) and 13 (Climate Action).

As opposed to the prevailing paradigm of input-intensive tillage-based agriculture, FAO promotes ways to intensify crop production and achieve food security in the short term that do not erode the future productivity of agro-ecosystems. The effort to achieve food security and development, while ensuring that natural resources provide the ecosystem services on which countries' well-being relies, is known as *Save and Grow* and it is the cornerstone of climate-smart crop production (FAO, 2011). It relies on Conservation Agriculture (CA) and local specific combinations of other good agronomic management practices to make better use of farmers' available land and resources, maximize returns to scarce external inputs, and improve the overall resilience of farmers in the context of climate change.

Methodology

Options for sustainable crop production intensification will vary among farmers and will depend on each farmer's coping and adaptive mechanisms, and the degree to which each specific climate factor, resource efficiency and technology gaps are responsible for the yield gap. Would it be possible to develop a model for sustainable intensification that accounts for local-specific factors and that is replicable in other maize-based smallholder farm typologies in Southern Africa?

To address this question, with the support of the German Government, FAO has developed the Project "Implementing the *Save and Grow* approach - Regional strategies on sustainable and climate-resilient intensification of cropping systems". Zambia is the focal country for maize-based cropping systems that since 2017 is working on this Project with FAO. Country-level activities are implemented by the Zambia Agriculture Research Institute.

The Project has focused on identifying the barriers that prevent smallholder farmers from adopting CA-based sustainable crop production practices because smallholder maize producers are asset-poor and use minimum purchased inputs (i.e. seeds, agro-chemicals) as well as limited technologies (e.g. hand tools and mechanization), but they do not all face the same constraints. To overcome the limitations of conventional "discipline-oriented" analyses, the Project has developed a farm typology approach that identifies farm types that account for the heterogeneity within the smallholder farmers' population and between different locations, in terms of their access to information and institutions, their socio-economic conditions, and the biophysical environments of their farms. The resultant farm types are defined in terms of the nitrogen flow because the amount of nitrogen that farm households can provide

relative to the amount that they extract from their fields captures the extent of economic and agronomic sustainability of agricultural productivity. In this way, each farm type is associated with differing degrees of agronomic and economic sustainability and can be used to analyze the interactions between agriculture and the environment and evaluate the impact of agricultural policy on the environment.

The application of the methodology in Zambia has identified the four farm types described below and shown in Figure 1.

"Extractive" farm type: Extractive farms are those in which the quantity of nitrogen returned to the soil is less than the nitrogen removed. They are managed by resource poor people isolated from markets. Household wealth is calculated as a normalized index that includes all the asset possessed by farmers. The statistical analysis of household survey data (econometric analysis) show that key factors that push or drive farmers into this system include crop residue burning, a lack of crop diversification (particularly for legumes), and exposure to extreme weather events. Sustainability is constrained by several key factors. These include a lack of land availability, lack of access to government subsidy programmes, private markets, reliance on hand tools for cultivation and limited access to improved mechanization (both motorized and animal-traction).

"Inorganic nitrogen dependent" farm types: Inorganic nitrogen dependent farms are those in which the quantity of nitrogen returned to the soil is greater than the quantity removed, and the quantity of nitrogen returned from organic sources is less than 40%. In these systems, maize production is highly commercialized. Inorganic nitrogen dependent farmers do not retain and manage residues (due to grazing/fires, monoculture), and generally incorporate fewer organic sources of nitrogen (such as nitrogen fixing species and compost manure) into their crop rotations and on farms. They are relatively wealthy, have larger land sizes (3.58 ha), some level of mechanization (especially animal based draught power), have better access to labour, and are better educated. Access to markets is well organized in terms of farmer cooperatives and existence of a number of maize buyers. Therefore, these farmers face fewer asset, labour and market access constraints to adopting new practices. Yet, incentives created by the traditional policies (such as the provision of subsidies for fertilizer) are important barriers for farmers to diversify their production.

"Organic nitrogen dominant" farm type: Organic nitrogen dominant farms are those in which the quantity of nitrogen returned to the soil is greater than the quantity removed, and the quantity of nitrogen returned from organic sources is greater than 85%. They are clustered in regions that are prone to adverse climate events. Because of this, an approach to increasing productivity through inorganic fertilizer application is unlikely to be successful; farmers simply do not have incentives to invest in inorganic fertilizer if there is a high risk of crop loss due to adverse weather. Helping these farms to address low productivity through improved management of organic inputs is therefore an important priority. Farmers in this system retain crop residues, produce other crops in addition to maize, and -together with the "Extractive"- have the lowest rate of inorganic fertilizer application and hybrid seed use. However, they are not very productive. They produce on average 1.9 t/ha of maize. The actions required to increase productivity in this system will vary. In areas with degraded soil (where the fertility level is below that of the soil at the steady state), returning only the nutrients that have been removed by the crop is not sufficient to maintain the soil's productive capacity over time. In higher potential areas, agronomic improvements include the production of more and more diverse crop residues, crop associations and the time of planting.

"Balanced" farm type: Balanced farms are those in which the quantity of nitrogen returned to the soil is greater than the quantity removed, and the quantity of nitrogen returned to the soil from organic sources is 40-85%. Farmers in the balanced farm type often face more socio-economic constraints. Although these farmers use leguminous crops in rotation with maize, legumes are grown on significantly smaller extents than maize, which does not allow an effective recycling of nutrients. In these systems, inefficient nutrient cycling on farms and low use of inorganic fertilizers increase dependency on traditional systems, such as Fundikila (burying natural veldt) and Chitemene system (slash and burn), and on the already low nitrogen content of natural veldt. Making better use of the organic nitrogen sources already entering this farm type should be considered a priority (given grazing requirements; diverse rotations; significant cash crop production). While strategies will vary, approaches may include improving the timing of seeding legume plants relative to maize and enhancing the quality of total on-farm residues.

The validity of the methodology has been tested in the field in the districts of Mumbwa (agroecoregion II) and Kasama (agroecoregion III), which have been chosen for the validation of the methodology because of the high number of farmers, the possibility to create synergies with other existing projects and the vicinity of extension and research stations. Focus group discussions with farmers, extension officers and local multidisciplinary experts were used as a tool to "groundtruth" the farm typologies and adjust the business models based on the local needs of the farmers' communities. To guide the focus group discussions, the FAO-ZARI Project team has developed a questionnaire.

Conclusions

The methodology developed by the Project can be regarded as an assessment tool for identifying the nature of the problems that limit farmers' adoption of CA.

On the basis of the evidence of "who" are the smallholder farmers and what problems they face, Zambia, with the support of the Project, is developing workable solutions to achieve greater productivity, resource use efficiency, and profitability in Zambia's smallholder maize sector.

Farm level solutions specific to each farm typology are being developed by the Agricultural Planning Officer of the selected Provinces, District Agriculture Coordinating Offices (DACO), camp extension officers, camp focal points and farmers in collaboration with ZARI. They will be available at the beginning of the agronomic season 2018/2019 and the results on the implementation of these improved practices and technologies will be available in 2019, at the end of the agronomic season.

At the policy level, policy makers are able to prioritize different combinations of CA-based agronomic practices in coherent policy incentives.

This assessment tool will be available for use also in other countries in the region to help move smallholder farmers towards more productive and sustainable outcomes with evidence-based prioritizations of actions.

Acknowledgements

The authors wish to acknowledge the donor of the FAO Project "Implementing the *Save and Grow* approach - Regional strategies on sustainable and climate-resilient intensification of cropping systems" that is supporting advancements towards the adoption of sustainable ways to improve food security of Southern African and South Asian countries: The Government of Germany.

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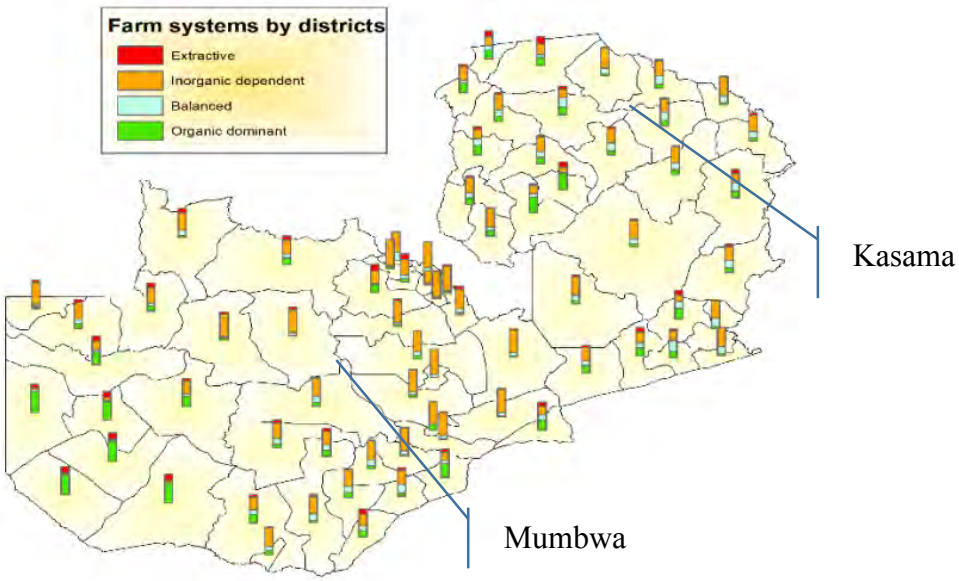

Figure 1: - Percentage of farmers in each farm typology within each district in Zambia

The role of Conservation Agriculture in Management of Fall Army Worm *Spodoptera frugiperda* in Southern Tanzania

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Key words: conservation tillage, conventional tillage, economically significant invasive pest, maize farming

Introduction

In March 2018, a randomized complete block design experiment with three replications of six tillage systems was laid on 30 meters by 10 meters plots in Sokoine University of Agriculture, Tanzania (60S and 370E, and 536 m asl). Tillage treatments included 3 conventional tillage systems (Hand Ridges, Tractor Plough and Animal Plough) and three conservation tillage systems (Hand Basin, Animal Ripping and Tractor Ripping). The aim of the experiment was to study ecosystem services that are enhanced by Conservation Agriculture. One month after planting maize (*Zea mays*), the crop was attacked by Fall Army Warm (FAW), *Spodoptera frugiperda,* an economically significant pest with potential to destroy the entire crop. This paper is based on observations following the attack by FAW and its aggressive management between April and June 2018.

FAW is an insect native to tropical and subtropical regions of the Americas. The invasive crop pest was first detected in Central and Western Africa in early 2016 (Goergen et al., 2016) and has quickly spread across virtually all sub-Saharan Africa. It was first observed in Tanzania in February 2017 and by February 2018 it had spread to most parts of country (FAO, 2018). The destructive pest attacks economically important crops such as maize, wheat, millet, sorghum, sugarcane and rice at all stages. The moth can fly up to 100 km per night and the female moth can lay up to a total of 1 000 eggs in her lifetime. In its larva stage, the insect causes severe damage to crops that can lead to 100 percent crop loss. According to an evidence note published by the Centre for Agriculture and Biosciences International (CABI) (Abrahams et al., 2017; Day et al., 2017), if proper control measures are not implemented, the pest could cause extensive maize yield losses, estimated between $3.6 and $6.2 billion per year across the 12 major African maize producing countries namely Nigeria, South Africa, Tanzania, Ethiopia, Egypt, Malawi, Kenya, Zambia,Uganda, Ghana, Mali, Angola as listed by the world atlas.

The principles of Conservation Agriculture; minimizing soil disturbance, establishing a crop cover and crop rotation; are of interest in management and control of FAW. This experiment being just at the onset, had the principle of minimizing soil disturbance well managed given the main treatment in the experiment is different tillage methods.

Materials and Methods

A field trial to study the ecosystem services enhanced by Conservation Agriculture was set up at Sokoine University of Agriculture, Morogoro, Tanzania at S 06^0 50′ 12.9″ - S 06^0 50′ 18.6″ and E 037^0 38′ 37.9″ – E 037^0 38′ 36.3″ lying 500-600m above sea level. The Randomized Complete Block Design experiment on plots of 30 m x 10 m was replicated thrice with six levels of tillage treatments namely; Animal Ripping, Handhoe Basins, Tractor Ripping (these three are conservation tillage methods), Animal Plough, Tractor Plough, and Handhoe Ridges (which are conventional tillage methods). Conservation tillage treatments were sprayed with broad spectrum systemic herbicide, Glyphosate, to control weeds before planting, and with selective 2,4-Dichlorophenoxyacetic acid herbicide to control weeds after the maize crop was established at 150ml per knapsack which is 16litres for both. Conventional tillage treatments were weeded using hand hoes. All the plots received 50kg per acre of Yaramira Cereal fertilizer, and hybrid maize seeds (C.P.201) planted on 27th March 2018 and gap filling due to rodent attack of the seed before germination was carried out 15 days later, on 12th April 2018. The maize crop was managed using insecticides sprayed one day after the first sighting of *Spodoptera frugiperda* and repeated seven days later. The insecticides consist of chlorpyrifos 50%

and cypermethrin 5%. The maize crops that had been attacked and whose whorl was affected were all counted using total count method per row in all plots, three days after the repeat spraying. Counting in all rows of all plots in all blocks was repeated about a month later when the crop was tasseling. The data was then analyzed using GENSTAT statistical software for crop scientists to carry our both descriptive and inferential analysis by comparing means of the number of FAW counted by tillage treatment, block and tillage type i.e. conservational or conventional.

Results and Discussion

Overall the total number of FAW observed reduced with the management of the pest. Conventional tillage plots were attacked early and more (Figure 2). The maize that looked healthier in the same plot and row were more attacked than the ones that looked less healthy. In relatively poor performing plots, patches that had tall normal healthy maize are mostly the parts that had been attacked by FAW. Due to heavy rains during the months of April and May, Block 3 plots had excessive moisture leading to either oxygen in-availability or nutrients leaching and therefore presented symptoms of poor nutrition including purpling and yellowing of leaves and stem. This block was the least attacked by FAW with 10% and 12% of total number of maize attacked in May and June respectively as shown in Figure 3. Block two had 23% and 28% while Block 1 had 67% and 60% of the total number of maize that was attacked by FAW.

FAW can be a difficult insect pest to control in field maize. According to (Bessin, 2004) late planted fields and later maturing hybrids are more likely to become infested. Plots that had more gaps filled, therefore had a lot of later planted maize recorded an increase in number of FAW between the first and the second count (Figure 1). While fall armyworm can damage maize plants in nearly all stages of development, Bessin (2004) observed that it will concentrate on later plantings that have not yet silked. This study observed that the plots that had much late planted maize had an increase in FAW attack in the second count.

FAW was first seen in Block one whose maize was growing much better than other blocks; the crop was healthy and tallest (compared to the other blocks) at the time FAW was first observed. The block had the largest attack which reduced by 7.4% in the second count. This block also had the least number of late planted maize 26.3% compared to 36% in block 2 and 37.7% in block 3. Block three was least attacked although it recorded 2% increase in FAW numbers.

The conservation tillage plots; Animal Ripping, Tractor Ripping and Hand Basins in all blocks had less number of FAW observed (Figure 1). Analysis of variance showed a significant difference between the number of FAW counted in May in Conventional tillage plots and conservation tillage plots (p value 0.021). Hand ridges which had healthiest looking maize at the beginning recorded about 53% of all attack observed in May. These are also the plots whose weeds had been well managed by weeding and had bare ground. The plots also recorded the highest decrease (41%) between the first and second FAW count and was the first to record 100% tasseling. Animal ripping plot in block two had healthy maize but also had lots of weeds even after spraying. It was the least attacked with 0.15% at the beginning in that block. Adjacent animal plough plot had healthy maize and well weeded and recorded a relatively higher attack of about 17%

FAW is an economically significant pest in Africa which can only be effectively controlled while the larvae are small. Early detection when egg masses are present on 5% of the plants or when 25% of the plants show damage symptoms and live larvae are still present (Bessin, 2004). Since temperatures are warm throughout the year in Africa, Spodoptera frugiperda goes through the entire life cycle from egg to adult moth in 34 - 76 days (FAO, 2017). Its eggs laid in batches of 50-200 hatch in 2 to 3 days, the larval stage lasts 14 - 22 days, pupal stage lasts 8 - 30days and the adult lives for an average of 10days and maximum of 21 days. The larval stage lasting between two to three weeks is the most destructive to crops. Proper timing of insecticide application is critical because controlling larger larvae, typically after they are hidden under the frass plug, will be much more difficult. Farmers should pay close attention to late planted fields.

Although there was no significant difference in the number of maize planted late per block as shown in Figure 4, block three had unique challenges of water retention which affected the performance of maize. Particularly the maize

that was planted late was challenged more. At the same time, the block did not respond well to weeds control compared to the other blocks despite receiving the same treatment. The number of FAW counted the second round was significantly different from the other blocks with p value of 0.005. Block three had only 12% of the total number of Maize attacked by FAW. It is important to note the overall poor performance and poor health of the maize as well as existence of more weeds in that block. This observation requires further investigation to establish whether there is a relationship between the overall health of the maize and the existence of the weeds with the attack by FAW.

Conclusions

Basing on the observations in this study, despite the fact that FAW observation and data collection was not planned but an opportunity that presented itself due to the unexpected attack by the pest, I would make a few conclusions; there is a better chance for healthy maize to recover from FAW attack is controlled early, maize planted later may experience severe attack than maize planted earlier in the same season, and lastly there is possibility that bare field where the maize crop does not have weeds or any form of ground cover are severely attacked by FAW.

There is need to collect more data and assess the trends of FAW attack in the conservation and conventional tillage systems. It is also necessary to study trends of FAW attack in maize fields with crop cover especially of a crop that FAW does not attack.

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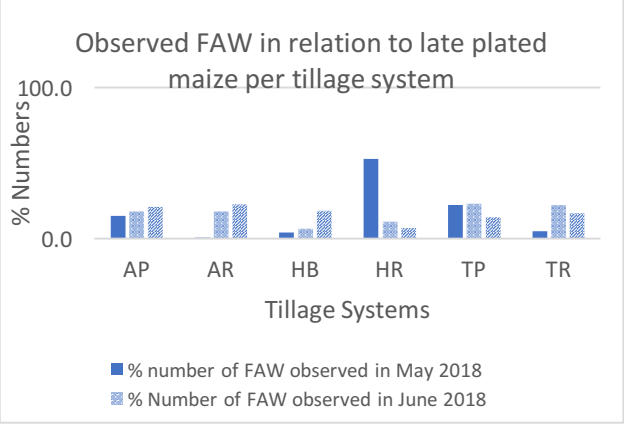

Figure 4: Number of FAW and late planted maize in different tillage systems

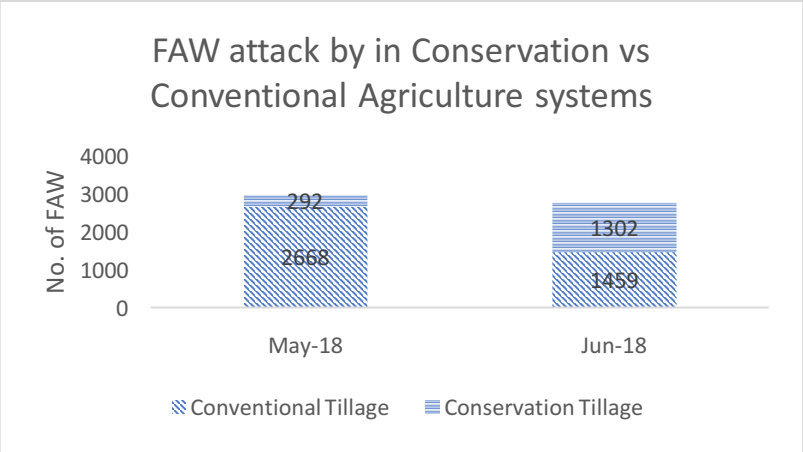

Figure 5: Number of FAW observed in different tillage systems

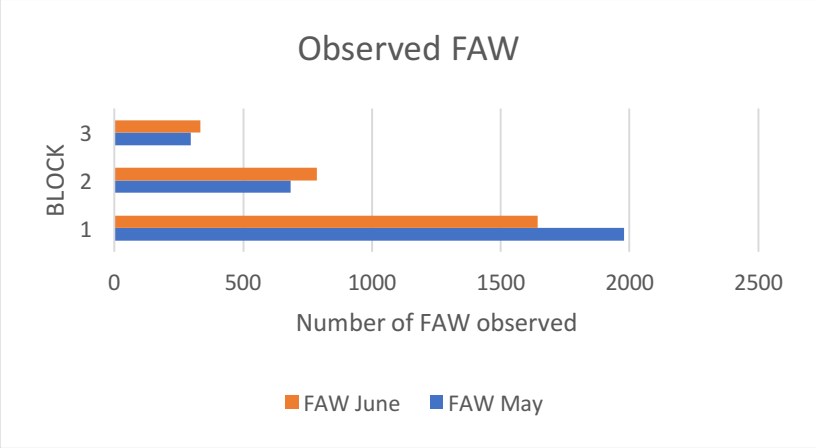

Figure 6: Number of FAW per block in May and June

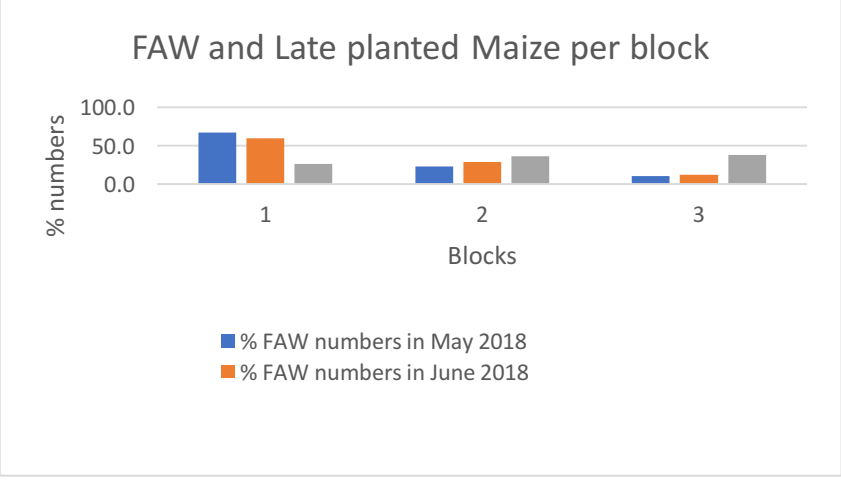

Figure 7: Number of FAW observed and Maize planted late per Block

Sub-Theme 3: Enhancing CA Related Education and Training-learning Capacity at Systems and Structural, Organizational and Individual Levels to Accelerate and Expand the Uptake of CA Systems and Practices

CA education and training-learning capacity among "last-mile" institutions will be critical in leap frogging and sustaining CA systems and practices. Enhancing CA related education and training-learning capacity and creating an enabling policy environment in support of the "last-mile" institutions and stakeholders to accelerate and expand the uptake of CA systems and practices. This sub-theme exposes experiences (insights and lessons) from frontline institutions offering CA education and training (the supply side), as well as the experiences and insights from stakeholders receiving the education and training (the demand side) and how the two are interacting in serving a robust development strategy and set of approaches to bring about education and training-learning initiatives relevant and appropriate to sustained CA adoption and wide-spread uptake

The sub-theme helps bring to the surface opportunities and challenges in grass root community level on training-learning initiatives, including related policy and institutional implications.

Under this sub-theme, 7 condensed papers were submitted and approved by the Scientific and Technical Committee after regourous reviews. These papers are hereby presented as follows:

Development of Adaptive Training Materials for Conservation Agriculture Promotion in Africa

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Key words: curriculum development, adaptation, adult education, participatory

Introduction

Conservation Agriculture (CA) practices have been increasingly promoted for small-holder farmers in Africa over the past 20 years, however, CA adoption among such farmers, has increased gradually, but lags behind much of the rest of the world (Kassam, *et al.,* 2015). Access to information and extension services has been shown as one determinant of CA adoption (Arslan, *et al.,* 2014; Brown, *et al.,* 2017). Other factors include the need to adapt CA technologies to the diversity of agro-ecological zones and cultures present on the continent (Brown, *et al.,* 2017; Liniger, *et al.,* 2011) and the need to combine CA principles with other agronomic practices which complement its benefits and provide greater short-term returns (Thierfelder, *et al.,* 2018; Vanlauwe, *et al.,* 2014).

Training materials for CA promotion have been developed by international agencies, national extension programs, and NGOs in Africa (IIRR and ACT, 2005; FAO, 2015; Dryden, 2009; CFU, 2017). However, *adaptive* training approaches, which help extensionists and farmers develop context-specific solutions from among the many possible CA approaches are lacking. This paper describes a diverse set of training materials for CA and complementary technologies, which together with a participatory, adaptive training methodology has greatly enhanced the effectiveness of CA promotion.

Materials and Methods

Canadian Foodgrains Bank (CFGB) has supported CA projects implemented by African non-governmental organizations (NGOs) since 2006. CFGB currently funds some 35 CA-related projects throughout sub-Saharan Africa. In 2015, CFGB and the African Conservation Tillage Network (ACT) organized a writeshop in which NGO partner extension staff, together with experienced CA farmers and scientists, prepared core CA modules for farmer-level training (Table 1). Each module included a Facilitator's Guide and one or more A1-size color posters to illustrate key CA concepts and engender discussion. The modules are designed to be taught individually, followed by several weeks during which the participants practice and adapt what they have learned before returning for another module. A gender specialist was engaged to review all materials to ensure gender sensitivity.

The core training modules were field-tested over a two-year period, and in 2017, a more extensive writeshop was organized to finalize the core materials and to draft additional modules on other CA and CA-complementary subjects (Table 2). These materials are now available for download in English, French, Kiswahili, Portuguese and Amharic from the ACT website (http://caguide.act-africa.org/). All materials are distributed in easily-editable formats (MS Word and MS Publisher), and users are encouraged to edit and adapt them to their local context. Additional training modules on associated technologies are being continually added and updated.

Results and Discussion

Adoption and Adaptation - Field-testing of these materials has affirmed the effectiveness of an adaptive, participatory approach to farmer training. Field staff indicate that the large-scale posters, customized with pictures from the local community are easy to use in remote locations and very effective in generating dialogue and conveying key concepts. The training calendar, which fits learning sessions into local cropping cycles, is effective in avoiding farmer information overload. The cycles of reflection and action create a powerful praxis of learning (Friere, 1970) through which farmers are empowered to adapt the ideas which they discuss, and identify appropriate solutions to their own farming constraints.

Scale-up - These training materials have been translated into at least nine languages, though the actual number is unknown since they have now spread beyond the CFGB network. This distribution will be further aided by the recent web-posting by ACT (see above) as well as the more devolved project-to-project dissemination used previously. In 2017, the successful impact of these materials, used by NGO partners in the Amahara, SNNPR and Benshangulgumuz Regions of Ethiopia, caught the attention of the Ethiopian government, which has subsequently requested CFGB train their extension personnel in CA methodologies on a national scale.

Challenges and Constraints. During field testing and the 2017 writeshop, concern was raised that many field extensionists lacked the skills to fully utilize these materials. The facilitation/question-posing approach is new for many individuals brought up in formal didactic educational systems, and extension agents need technical support and backstopping in order to adapt the materials to their own context. A more comprehensive learning strategy is, therefore, being developed to build trainer skills and capacity, and assure wider and more effective agricultural training to enhance the environmental sustainability and food security of small-scale farms in Africa.

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Tables

Table 2: Core CA Modules for Farmer Training

Module	Timing
1. Situation Analysis: Why CA? What is CA?	2 months before planting
2. Minimum Soil Disturbance with Planting Basins	1-2 months before planting
3. Importance of Soil Cover	1-2 months before planting
4. Planting with Precision	2 weeks. before planting
5. Cover crops	2 weeks. before planting
6. Weed Management in CA	2 weeks. after planting
7. Crop Residue	1 month before harvest

Table 2: Additional Modules on CA and Complementary Subjects

Module	Notes
1. Switching to CA	
2. Preparing CA Fields with Ox-Drawn Rippers	
3. CA with Root Crops	
4. Integrating CA & Livestock	Introductory module
5. Soil Conservation & CA	
6. Integrated Soil Fertility Management	Introductory module
7. Safe and Effective Grain Storage	
8. Identifying and Monitoring Insect Pests	Part of an IPM series
9. Natural Pesticides	Part of an IPM series
10. Pesticide Safety	Part of an IPM series
11. How to Experiment on Your Farm	
12. Roles and Responsibilities of a Lead Farmer	3 modules
13. Biblical Principles of Stewardship	

Leveraging Agricultural Innovation Platforms to Mainstream Conservation Agriculture Sustainable Intensification (CASI) in Rwanda

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Keywords: small holder famers, sustainable intensification, crop productivity.

Introduction

In Rwanda, agricultural production is dominated by smallholder farmers cultivating less than 2 ha, with 60% of the households cultivating less than 0.7 ha plots. The low production and food insecurity issues are explained by very low crop yields in the acidic soils of the country and frequent crop failure in the semi-humid region. The low productivity of Rwanda agriculture is basically explained by old and inherently poor soil parent materials in the tropics that result into nutrient depleted soils (Rushemuka *et al.,* 2014). The soil infertility is exacerbated by continuously soil organic matter declining and soil nutrient depletion due to soil water erosion on the intensively cultivated (twice a year) steep slopes of Rwanda. Because of a hilly bio-physical environment, the country relies mainly on rain-fed agriculture which is highly vulnerable to climate change risks. As a response to this situation, the project Sustainable Intensification of Maize-Legumes in East and Southern Africa (SIMLESA) has introduced the Conservation Agriculture (CA) as a Sustainable Intensification option. In the SIMLESA system, maize-legume (mostly beans) rotations are prioritized as part of improved agronomy in Rwanda. SIMLESA believe that Agriculture Innovation Platforms (AIPs) are instrumental to unravel the Conservation Agriculture Sustainable Intensification (CASI) complexity and to speed the adoption of CASI technologies. Here an AIP is understood as a group of actors including scientists of different backgrounds, farmers' cooperatives, local authorities and other stakeholders working in a given site, all of them around one or complex agriculture problems with a crop or any other value chain or technology as an entry point (Schut *et al.,* 2017; Adam *et al.,* 2018). In this paper, we explore the drivers that could make an AIP an authoritative approach to promote and scale up SIMLESA CASI technologies in Rwanda.

Materials and methods

In Rwanda, CASI research activities were implemented in three sites located in Bugesera, Kamonyi and Musanze districts corresponding to three Agro-Ecological Zones (AEZ). Demonstration fields were established at farmer level and adopted the split plots experimental design (Table 1). The main factors were Conservation Agriculture (CA) and Tillage Agriculture (TA). The sub factors were (T1) = manure, (T2) = Manure + fertilizers, T3 = Manure+ fertilizers + bio fertilizers.

As a second step towards large scale extrapolation, a survey on the workability of existing AIPs, as instrument of the "research in development" paradigm, was undertaken on previously established AIPs in Rwanda. This study employed qualitative methods. Data collection was accomplished through focus group discussions (FGDs) with AIPs member representatives and key informant interviews (KIIs) involving AIPs management team. Participants in the study were farmers purposively selected from the membership of nine AIPs identified after a preliminary exploration of success/failure among 18 AIPs established in Rwanda. The information recorded was about: production, sales levels of the agricultural goods and training received by members of AIPs, among other relevant information. The 9 selected AIPs were regrouped into 3 workable categories: Successful (5), Partially successful (3) and Failed (1) (Adam *et al.* 2018).

Results and Discussion

Effect of CA on Crop yields

It was noted that, in all the three districts there was no significant difference between CA and TA (data not shown). However, yield levels showed varying responses to production inputs (different treatments) across districts in both farming systems. In Kamonyi production was most sensitive to soil fertility management inputs followed by Bugesera

and finally by Musanze. In Kamonyi, maize and bean production were both significantly affected by production inputs. In Bugesera, there was no difference between treatments for bean. For maize, the results were similar to those of Kamonyi. In Musanze, there were no observed differences between treatments in maize or bean yields. The experiment showed that benefits of CA depend on fertilizers for both bean and maize in Kamonyi. In Bugesera, benefits on CA could be achieved without fertilizer for bean but required fertilizer for maize. In Musanze, benefits of CA could be achieved without fertilizers for both maize and bean. The difference in crops responses per districts/AEZ and per crop could be explained by soil fertility levels and crop nutrient requirements. Though there was not significant difference between TA and CA during this short period (four growing seasons), CA was recommended for scaling up because of many environmental and economic advantages and the expectation of improving crop yields with time. Farmer interviews indicated that farmers would require more information on CA and more customized mechanization and mechanical or chemical weeds control options and permanent sources of mulch for adoption of CA.

Drivers of AIP as an instrument of technology transfer

Raise of income for farmers, processors and traders: Each of the successful AIP cases analyzed showed evidence that benefits from business-related activities were the mainstay of these AIPs (Adam et al., 2018). In the surveyed successful AIPs farmers reported that on average the income of the AIP membership had tripled in three years. This was mainly attributed to AIPs members' skills improvement by scientists from the Rwanda Agriculture Board (RAB) along three value chains: potatoes, milk and cassava. The acquired skills were beyond the abilities of individual local actors before the intervention (Adam et al., 2018). The economic benefits were gained mainly from the sale of potatoes, milk and the sale of cassava processed flour. The AIP members have got support from various donors in a) processing; b) AIP partnerships; c) infrastructure, machines/vehicles; d) produce-marketing networks; and e) trainings, were all geared toward the generation of benefits and sustainability through business. These benefits applied to income, market access, enterprise skills, and credit access (Rahm et al.., 2018). Each support was to solve sustainably an identified problem in a given AIP.

Social innovation mentorship: The major theme of mentoring in AIP was social innovation. This project showed the most successful AIP were ones that largely embraced collective business models to encourage livelihood transformations. The various supporting programmes/ projects had especially focused on financial services (incl. credit) as the main entry point.

Equitable benefits of interest among AIPs members including gender: The surveyed AIPs reported that the equity among AIPs members were guaranteed at three levels (1) AIP membership was done on individual not household basis. In this sense, the activity remuneration was also paid to the individual regardless to his gender be it woman or man and the AIPs were made by 50% women and 50% men (2) farmer cooperatives bargaining capacity was improved and they were actively involved in the price fixation for their products (potato, milk and cassava floor) (3) farmers were empowered to do some transformations that added value to their products. For instance, farmers created points of selling potatoes. They even went a further step in branding their product and sell it in Kigali Supermarkets, thereby suppressing many intermediaries. It was the same case for milk and cassava floor. This equity along value chain and along gender is another driver of AIP success which can be use during CASI AIP mainstreaming.

Enabling policy instruments

Policy wise an AIP is difficult to apprehend because it is made by different stakeholders some of them with financial interests (e.g. farmers cooperatives, banks, agro-dealers) others without financial interests (e.g. scientists and local authorities), some are permanents other temporally. At policy level, famer cooperative is the AIP core. This is because it is the cooperative that produce and sell. Therefore, it is the cooperative that needs the government support until it becomes self-supporter if it is not for evident reasons. It is in this sense that the farmers' cooperatives received 40% price reduction on capital equipment through deliberate government policy instruments. The policy required them to attain and maintain gender equity. Moreover, famers cooperatives received transformational investments specifically targeted to social innovation (especially in agribusiness).

Innovation approach institutionalization

Over time, successful AIPs generate spillover benefits that provide evidence for institutionalization which ensures sustainability of AIP concept and their benefits. They morphed from research-supported AIPs, by integrating CBO, self-help, and mostly cooperative principles. In 2016, the combined direct service (and infrastructure) network reach of two main AIPs was over 7500 non-member households. Institutionalization helps in avoiding the pitfalls of typical cooperatives by integrating AIP principles of wider partnerships, benefits equity, niche diversification and diverse membership. They increased market access, mitigated transaction costs and leveraged better and stable (input and produce, products) prices for marginalized smallholders. The AIPs provided affordable and secure produce transport, facilitated equitable sharing of proceeds and aided responsible management of common pool natural resources including land, water and new germplasm.

Conclusion

This study has showed that AIPs are first of all about business plan (BP) for a production and sell farmers' cooperative. In this BP important functions to consider are (1) required investment and cooperative capacity to afford these (2) sustainable production constraints (3) market organization and access (4) AIP administration or organization (5) enabling and conducive government institutional framework (6) capacity building needs assessment (7) stakeholders' partnership. All these functions are equally important and all of them may apply to CASI. However, their relative importance may vary with context in presence. For instance, in Musanze where CA can be promoted without fertilizers, the market and administration/organization functions might be the most prominent. In Kamonyi, when crop yields depend on fertilizers, the production function and capacity building may come first because farmers may have limited knowledge to the use of fertilizers. In Bugesera where crop failure is frequent due to draught, the production function might be the first function to consider because famers may need earlier maturing or draught tolerant crop varieties. In the acidic soils of Rwanda, the investment function may be the number one because the production in the acidic soils needs investments in terms of lime, manure and fertilizers whose cost is most of time beyond the purchasing capacity of farmers. That is why the government subsidized the lime for 50%. This shows that an AIP is not a blue print technology transfer package. It is rather a transdisciplinary and problem-solving approach which requires a careful analyzes and understanding of each biophysical environment and socio-economic approach and bring appropriate solution. The success relevant indicator and the guarantee for continuity/sustainability for AIPs members is the equitable profitability along the value chain. All in all, the study shows that AIP can apply well to CASI research in development and technologies scaling up for high impact and transformative research.

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Tables

Table 1. Field demonstration experiment design

Conservation Agriculture	Tillage Agriculture (conventional)
T1	T1
T2	T2
T3	T3

T1= Manure; T2= Manure + Fertilizer; T3: Manure + Fertilizer + bio-fertilizers.

In this figure, the two production system being compared are CA and TA or conventional tillage Agriculture. The treatments (Ts) were intentionally not randomized to allow farmers and other stakeholders to compare them during the farmer field day organized each growing season.

Learning Conservation Agriculture the innovation Systems Way

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Keywords: innovation systems, smallholder farming, soil health, productivity, social agency, value chain

Introduction

Severe environmental degradation, low farm profitability, poverty and the increased vulnerability caused by variability in weather and climate change in current smallholder production systems have brought farming in this sector almost to a standstill (Smith, *et al.,* 2017). This calls for a paradigm shift focussing on mainstreaming sustainable agriculture systems in South Africa. Sustainable agriculture systems, such as Conservation Agriculture (CA), are social constructs or innovation processes which function as on-farm, farmer-centred Innovation Systems (IS's), embracing all the actors involved within the value chain. It is not just a model or production package to be used but is a system of continuous learning (Smith, 2014).

CA is an approach for managing agro-ecosystems to improve and sustain productivity, increase profits and food security, while preserving and enhancing the resource base and the environment. It provides potential solutions to a wide-ranging number of challenges, including economic viability, ecological sustainability and the social acceptability of farming. The success of CA under diverse agro-ecological conditions is now being documented in South Africa, mainly for large scale commercial farms (Blignaut *et al.,* 2015;Smith *et al.,* 2017;Swanepoel *et al,* 2017). There is however, still very little information available either for implementation of CA in smallholder farming systems or appropriate extension systems. This paper describes the use of an Innovation Systems (IS) approach in promotion and adoption of CA in smallholder farming systems in the KwaZulu-Natal and Eastern Cape provinces of South Africa.

Methods and Materials

For the past five years, Grain SA and Mahlathini Development Foundation have been implementing a Smallholder Farmer Innovation Programme for promotion and adoption of CA. This IS process combines elements and learnings from previous implementation experiences (Smith *et al.,* 2010) and uses a combination of a number of different approaches, processes and tools, including Participatory Innovation Development (PID) (Kruger and Gilles, 2014) and Farmer Field School (FFS) (Braun and Duveskog, 2011) approaches that enable participants to share, act, observe, reflect, plan and learn, creating a culture of learning that allows people to be innovative and interactive in managing natural resources in a sustainable manner.

Participants of this process are farmers from a locality or village who are organised into learning groups. A number of farmers in each group volunteer to undertake on-farm experimentation, which creates an environment where the whole group learns throughout the season by observations and reflections of the trials' implementation and results. They compare various CA treatments with their standard practices, which are planted as control plots. This provides an opportunity to explore all aspects of the cropping system. The whole value chain is considered including; input supply, production aspects, harvesting and storage, processing and marketing. The learning groups also form the launching point for management of group owned tools and equipment, collaborative work sharing, Village Savings and Loan Associations (VSLAs) who undertake bulk buying of inputs and setting up of local small businesses within the value chain including farmer centres, threshers and small mills. The farmer level trials are usually 100, 400 or 1000m^2 (*small areas to reduce risk)*. Farmers are trained practically in the implementation of CA; pre- planting spraying (use of knapsack sprayers) and field preparation, use of herbicides, layout of plots and planting in basins and rows using a range of no-till tools (hand planters, animal drawn planters and or two row tractor drawn planters; *depending on farmers' choice*). Aspects such as top dressing, weeding and pest control are covered during the season as well.

The first- year trial layout is pre-determined through the programme to include close spacing, inter cropping and different varieties of maize (choice of traditional, open pollinated or hybrid seed) and legumes (sugar beans, cowpeas). From the 2nd year onwards farmers start to add their own elements to the experimentation depending on their learning, questions and preferences. Cover crops (both summer and winter) and crop rotation options are introduced. Researcher managed trials are also set up, to work alongside the more enthusiastic and committed participants and to explore issues such as soil health, carbon sequestration, soil fertility, water productivity, moisture retention, run-off and specific aspects of the CA system – such as seeding and seeding rates of cover crops for example. As a minimum, 2-4 learning sessions are held yearly for each learning group, building in complexity and content every year. Review and planning sessions are held yearly for each learning group. Local farmers' days are organised, jointly with the learning groups. CA forums and innovation platforms are promoted where all stakeholders, involving government, agribusiness and civil society in a region join these forums to share, discuss and plan together. In this way more than 3 000 community members have been exposed to CA practice in their areas. External stakeholder involvement have included: Department of Agriculture and Rural Development (DARD), Department of Rural Development and Land Reform (DRDLR), Department of Environmental Affairs (DEA), the Agricultural Research Council (ARC), the University of KwaZulu Natal (UKZN), Environmental Learning Resource Centre (ELRC) – Rhodes University, Cedara Agricultural College, the LandCare Programme, Local and District Municipalities, KwaZulu Natal Agricultural Union (KwaNalu), the KZN No Till Club, Lima Rural Development Foundation, Zimele, the Institute of Natural Resources, the Farmer Support Group, Growing Nations, TWK Agricultural Cooperative, AGT Foods, FarmSave, Afritrac and Eden Equip, as examples. Each year new farmers are brought on board using a horizontal scaling model. After 3 years' farmers are graduated from the learning process, but continue in the learning groups and with their own experimentation

Results and Discussion

Results can be presented within three categories, namely, social agency, value chain development and increased productivity (Table 1).

Social agency: The SFIP has expanded in the five years of operation from working with 28 participants across two villages in Bergville, to working with 465 farmer level experimentation participants across four areas (Bergville, Midlands, Southern KZN and Northern EC), in 36 villages, with 18 Village Savings and Loan Associations (VSLAs), 18 Local Facilitators and 1 farmer centre.

Smallholder participants have increased their household food provisioning of maize and beans substantially. Initially most households had food only for 0-3 months of the year; now 53% of participants have food for 7-12 months of the year. Local sale of produce has increased from 0-10%. VSLA participation has increased form 5% to79% of participants and of these 28% are saving for inputs. All participants feel CA is cheaper than conventional farming, 78% feel that this practice has reduced their labour requirement and 39% feel that CA has reduced their weeding requirement.

Increased productivity: In addition to the implementation of intercropping, crop rotation and summer and winter cover crops outlined in Table 1, yield results have been summarised for the 4 seasons for maize and bean production (Table 2). Average yields for maize have increased systematically over the time period (from 3,74 t/ha to 5,03 t/ha for the Bergville area and from 0,95 t/ha to 2,52 t/ha for the other participating areas). The maximum yields have increased also and present maximum yields of 11,7 t/ha in Bergville and 5,2 t/ha for Southern KZN and EC reflect well the commercial yield potential for maize production in these areas (Kruger *et al,* 2017).

Effects of soil health: Soil health indicators have been monitored for 20 participants using a range of indicators, of which most are part of the Haney Soil Health Test (Gunderson, Accessed: 2018/05/20). Trends over a three-year period indicate that the Organic Carbon and Nitrogen content of the soil has increased for all 4 participants from the Bergville area, monitored over this time frame and C:N ratios have decreased for one participant only (i.e. Ms Phumelele Hlongwane), as she has most coherently implemented the diverse cropping and crop rotation process (including legumes). Soil health scores have increased significantly between 2016 to 2017 (Table 3). These results

indicate that the combination of crop rotation with crop diversity (intercropping and cover crops, including legumes) provides the best option of increasing soil health over the short term.

Conclusion

In conclusion, the IS systems approach in smallholder farming is building substantial capacity among smallholders in KZN and the EC to implement CA in their farming system and thereby greatly increasing their level of food security, social agency and soil health.

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Social agency		Value chain		Productivity	
No of female farmers	83%	Saving for inputs	28%	Intercropping – maize and beans	92%
Learning groups	36	Reduced labour in CA plots	78%	Intercropping maize and legumes (cowpeas, lab-lab, velvet bean)	17%
VSLAs – (% of participants involved)	79%	Reduced weeding in CA plots	39%	Crop rotation (3 seasons)	20%
Months of food provided through CA;		Use of planters		Cover crops; summer mix – sunflower, millet, sunn hemp,	26%
10-12	15%	Hand hoes	26%	sorghum	
7-9	38%	Hand planters	69%		
4-6	39%	Animal drawn planters	5%		
1-3	8%	Tractor drawn planters	0,5%		
Sale of crops locally; (maize, beans, cowpeas, sunflowers)	10%	Local financing of infrastructure;		Cover crops; winter mix relay cropping – Saia oats, fodder sorghum, fodder radish	31%
		Threshers	1		
		Mills	1		
Innovation platforms; including external stakeholders	5	Farmer centres	1	Fodder; provisioning of livestock through cut and carry	5%
				Seed saving	11%

Table 3: Innovation System indicators for CA implementation in KZN and EC, 2013-2017

Table 4: Yield and income values for CA trails between 2013-2017

Trial summaries

	Bergville				EC, SKZN, Midlands			
Season	2013	2014	2015	2016	2013	2014	2015	2016
Area planted (trials) - ha	2,8	7,2	5,9	13,5	0,36	0,3	0,37	1,18
Average yield maize (t/ha)	3,74	3,63	4,12	5,03 (3,09)	0,95	0,7	1,37	2,52
Min and max yield maize (t/ha)	2-4,3	1-6,7	0,6-7,4	0,3-11,7	0,3-1,7	0,3-1,8	0,5-4,4	1,1-5,2
Actual amount of maize (kg per person)	233	576	654	487	15	64	125	161
Rand replacement value (maize meal)	1 600	4 500	5 500	4 900	103	500	1 000	1 700
Average yield beans (t/ha)	1,24	0,26	0,79	1,05	1,26	0,34	0,69	1,28

Table 3: Soil health test results over three seasons for 4 participants across three villages in the Bergville area

Village	Stulwane					Ezibomvini		Eqeleni		
Participant	Dlezakhe Hlongwane		Mtholeni Dlamini			Phumelele Hlongwane		Smephi Hlatshwayo		
Soil health indicators	2016	2017	2015	2016	2017	2016	2017	2015	2016	2017
CO2 - C(ppm)	82,3	111,1	179,1	82,6	75,5	67,8	54,9	86,3	59,1	53
Organic C (ppm)	214	309	89	162,5	190,3	196,2	296,6	148	221,5	305,5
Organic N (ppm)	15,3	19	7,4	11,8	12	11,8	23,6	15,9	17,2	21,9
C:N ratio	14	16,3	12,1	13,9	16	17,4	11,5	12,1	12,9	14
Soil health calculation	9,6	17,4	16,5	8,8	12,5	7,2	13,2	10,7	8,5	13,6

Climate Smart Agriculture: Old Wine – New Bottle?

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Keywords: agroecology; Conservation Agriculture; organic farming; precision agriculture; sustainable intensification

Introduction

Climate predictions indicate an increase in weather extremes (floods and droughts), average temperatures, shifts in seasons and season duration (Fuglestvedt *et al.*, 2016). Rural farmers are especially vulnerable to these impacts because of their greater reliance on basic agricultural systems, low incomes and limited capacity to seek alternative livelihoods (Maharjan and Joshi, 2013). At the same time agriculture is faced with a three-way 'balancing act' where it must increase in (i) an environmentally friendly manner while at the same time (ii) contributing towards food security, and (iii) socio-economic development under a changing climate. This has placed emphasis on mitigating and adapting to anticipated climate change impacts on agriculture while sustainably improving productivity in response to increased food demand.

In response to these challenges, climate smart agriculture (CSA) has emerged as a leading approach to adapting agricultural systems to climate change. Although CSA was introduced as a new stand-alone technique, there are significant overlaps with existing techniques embodied within sustainable agriculture. This inadvertently confounds the task of distinguishing CSA from these pre-existing techniques. Therefore, the objective of this review was to critically assess and compare previous sustainable agriculture approaches with CSA. Approaches reviewed included sustainable agriculture, precision farming, landscape-based farming, organic farming, Conservation Agriculture and ecological farming.

Methods and Materials

A systematic review was conducted based on the Collaboration for Environmental Evidence (2013) guidelines. The databases were selected based on their relevance and credibility. Search terms used included "organic farming", "Conservation Agriculture", "precision agriculture", "agro-ecology", "sustainable intensification", and "landscape-based farming" (Figure1). Meta data was created based on the search results for the various databases, and grey literature was obtained from the relevant websites such as Food and Agriculture Organisation (FAO) as well as literature identified by experts in the field. Literature selected for this review included peer-reviewed journal articles, academic books and book chapters, academic conference proceedings, and public reports by established organizations. Identified literature was then filtered based on the following thematic areas: system productivity, soil rehabilitation, biodiversity, climate change adaptation and agricultural resilience. Publications that referred to sustainable agriculture or related terms and focused on climate smart science and agriculture were also included. Following this, about120 articles were used for the study.

Results and Discussion

There are misconceptions surrounding CSA, which question its innovation and distinction from already existing approaches such as sustainable agriculture, Conservation Agriculture, sustainable intensification, and agroecology, among others. We therefore reviewed existing literature to determine whether CSA was indeed an innovation or a rebranding of existing approaches for a new age – climate change. Throughout the history of agriculture, different

approaches have continually evolved in response to the challenges of the day. At each stage, as agricultural practices have evolved, they have maintained some part of the predecessor, whilst adding some innovation specific to current day's challenges. Similarly, CSA has evolved in response to current and future challenges posed by climate change. Like past trends, it bears semblance to previous approaches, while adding new innovations. It proposes a set of principles aimed at sustainably increasing food and nutrition security, mitigating land and eco-system degradation while concurrently adapting and building system resilience to climate change. Unlike previous approaches which often adopted a straitjacket approach, CSA attempts to be context specific and adopts a nexus approach with regards to managing synergies and trade-offs associated with adaptation, sustainably increasing productivity and mitigation. In this regard, it may offer better prospects for sustainability and aligns well with the global sustainable development agenda.

While systems such as organic farming, Conservation Agriculture, precision agriculture, landscape-based agriculture and agroecological farming have contributed towards sustainable production within high-risk ecosystems, their capabilities to provide adequate and sustainable agricultural outputs to drive human existence beyond the threats posed by increased population, climate change and increased food demand remains questionable. The premise governing most sustainable agricultural techniques are very rigid and often strictly need to be considered within the bounds of the technique. In most cases a "one size fits all" approach is assumed leaving little room to continuously adapt to the dynamic challenges faced by agriculture in the wake of climate change. Climate variability and change has resulted in volatile agricultural systems which requires an equally dynamic approach to improve productivity and adaptation. Static transformations can only reduce the adaptive capacity of agriculture. Climate smart agriculture acknowledges that cropping systems across resource poor farming situations are diverse; and their response to risk is more diverse depending on socio-economic and bio-physical scales. As a framework, it recommends several strategies across spatial and temporal scales, which are iterative and based on availability of resources.

Also, techniques under sustainable agriculture have been formulated to address specific primary objectives. For instance, OF was formulated due to scepticism of the number of agrochemicals during the green revolution; CA was established to improve soil quality after an observation of unprecedented soil erosion in north America; AE was aimed at redressing biodiversity lose; and PA was aimed at improving economic efficiency of agriculture. Besides the immediate benefits derived from each approach, secondary benefits have also been observed and these have a strong link to redressing issues pertaining to increased stability and resilience of cropping systems. These secondary benefits have loosely been linked to climate smart agriculture. However, the potential of sustainable agriculture techniques remains fragmented since, as separate entities, they are not holistic in addressing challenges posed by the dynamic interactions of climate change, agriculture and food security across multi-cultural interface. Climate smart agriculture addresses problems through a transdisciplinary lens, working in a participatory manner (innovation platform model) with stakeholders from many fields, including local NGOs, small-holder farmers and entrepreneurs (Steenwerth *et al.,* 2014). Drawing on this original framing, CSA has been applied to diverse aspects of agriculture, ranging from field-scale agricultural practices to food supply chains and food systems generally. Beyond agricultural practices and outcomes, a wide array of institutions, policies, finance, safety nets, capacity-building and assessment have all been identified as enabling CSA. Clearly there is a distinction between sustainable techniques and CSA.

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Figure 1: Conceptual framework indicating the mix of agricultural practices that fall under sustainable agricultural practices.

La Formation en Agriculture de Conservation Four une Gestion Ddurable des Ressources Naturelles à Madagascar

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L'agriculture de conservation : une solution pour lutter contre la pauvreté et la dégradation des terres à Madagascar

Madagascar est un pays agricole où 80% de la population vivent essentiellement de l'agriculture. Le riz est la principale culture suivi des cultures pluviales constituées par le manioc, le maïs, la patate douce et des légumineuses comestibles. La production agricole est généralement faible et n'arrive pas à satisfaire une population en constante augmentation. Les impacts négatifs de la production agricole sur les ressources naturelles en particulier les sols sont énormes. Cette situation est aggravée par les effets du changement climatique. Face à ce contexte Madagascar devrait:

- Assurer la sécurisation alimentaire par une agriculture familiale
- S'atteler à la recherche agronomique orientée vers l'adaptation au changement climatique
- Concourir à une mise en valeur agricole durable des sols par une approche paysage
- Contribuer à l'atteinte des objectifs de l'initiative AFR100 de restaurer 100 millions d'hectare d'ici 2030 et à la Neutralité de la dégradation des terres dans le cadre des Objectifs Durables de Développement (ODD) qui vise un total de 4 000 000 ha de terre réhabilitée

Pour cela : l'Agriculture de Conservation (AC) est une des solutions alternatives la plus prometteuse face à ces pratiques agricoles traditionnelles peu productives et dégradantes. Dans ce domaine, Madagascar a de décennies d'expérience en système de culture sous couvert végétal (SCV). Dès les années 90, des expérimentations et adaptation des techniques de SCV ont été menées dans des sites de référence dans chaque zone agroécologique. Par ailleurs, Madagascar a eu l'avantage de l'existence du GSDM (Groupement Semi-Direct de Madagascar). Ce dernier est une structure, non gouvernemental, de coordination, de suivi et d'évaluation, de l'animation de la formation et de la capitalisation des actions d'Agriculture Ecologique à Madagascar. Finalement, Madagascar a opté pour une approche paysage dans la réalisation de la restauration et protection des sols dégradés. Pour la réalisation de cette approche, un comité national de la Restauration des Paysages Forestiers (RPF) a été mis en place, qui a pour tâche de coordonner les activités relatives aux approches paysages.

Des formations sectorielles pour la mise à l'échelle de l'AC

Les informations qui suivent sont les résultats d'une documentation approfondie dans le domaine de l'AC et CSA (Climate Smart Agricuture) à Madagascar. Elles ont été renforcées par des interviews des personnes ressources.

Les acquis en matière d'Agriculture de Conservation à Madagascar

Les acquis techniques de l'AC à Madagascar portent essentiellement sur le développement des cultures Sous Couvert Végétal (SCV) dans différentes zones agro-écologiques. Il existe trois types de systèmes de SCV : le système en semis direct sur couverture végétale vivant, le système en semis direct sur couverture végétale morte et le système en semis direct sur couverture végétale mixte. A Madagascar, l'évaluation des superficies utilisant les techniques AC atteignent les chiffres de de 6325 ha en 2014 pour un nombre de 30777 adoptants.

En appui à ces techniques, Madagascar dispose, bien qu'insuffisant, de cadres supérieurs compétents en matière d'Agriculture de Conservation. De même un catalogue de matériel végétal adapté par zone agroécologique est disponible. Enfin, Madagascar dispose des fiches techniques d'Agriculture de Conservation par zone agroécologique.

Les techniques AC à Madagascar utilisent des légumineuses dont principalement : Stylosanthes guyanensis, Mucuna puriens, Dolicos lablab, Arachis pintoï, Desmodium spp. et Vicia sativa (Vesce) et des graminées en particulier Brachiaria brizenta.

Les problèmes de la diffusion de l'Agriculture de Conservation à Madagascar.

Toutefois, l'Agriculture de Conservation est confrontée à de multiples obstacles, notamment par rapport à sa vulgarisation à grande échelle. L'Agriculture de Conservation est considérée par les producteurs comme un système complexe difficile à maîtriser. De même la phase d'investissement (mise en place et fonctionnalité du système) nécessite 2 à 4 ans - une période que beaucoup de paysans ne pourraient pas supporter financièrement sans appuis externes.

A part cela, le contexte foncier se présente également comme un frein à la diffusion de l'AC à Madagascar. En effet, le faible accès à la terre conduit à la généralisation de la location ou du prêt de terre. Ces modes d'utilisation des sols n'incitent pas les producteurs aux investissements (achat d'intrants, location de main d'œuvre, achat de petits matériels).

Enfin, la diffusion à grande échelle de l'AC est inhibée par l'insuffisance de techniciens pour l'encadrement technique des producteurs. Les institutions de formation professionnelle et académique existant ne sont impliquées dans la formation des techniques d'AC que très récemment. Toutefois à Madagascar, sous la houlette du GSDM, des programmes et un référentiel de formation en AC ont été élaborés depuis 2014. Cette action est initiée dans le but de permettre à une large diffusion et pour la durabilité de l'AC à Madagascar.

La formation rurale et en Agriculture de Conservation à Madagascar

D'une manière générale, la formation rurale est sous la tutelle du Ministère en charge de l'Agriculture de l'Elevage et de la Pêche (MPAE). Le référentiel de formation des techniciens agricoles élaboré et récemment mis à jour par le MPAE est destiné à produire des techniciens polyvalents en techniques Agro-Sylvo-Pastorales capables de répondre aux besoins des paysans et des opérateurs de développement rural. Dans sa forme actuelle, le référentiel est attendu à contribuer à l'axe stratégique 4 du Programme National de Développement qui vise à instaurer un « Capital humain adéquat au processus de développement »

La formation des techniciens forestiers est sous la coordination du Ministère de l'Environnement, de l'Ecologie et des Forêts (MEEF). Le module incluant l'AC est celui de la conservation et restauration de l'écosystème forestier qui a pour objectif de doter aux apprenants les capacités techniques permettant la conservation et la restauration des forêts et des paysages. Cette formation vient en appui pour l'application et la durabilité de l'approche paysage, actuellement largement promu à Madagascar en matière d'aménagement et planification territoriale. Cette approche est construite pour une meilleure intégration de l'ensemble des écosystèmes naturels inscrits dans le paysage et les aspects socio-économique dans l'aménagement.

Les opportunités de l'AC

Les techniques d'AC présentent un intérêt indéniable et reconnu pour une production agricole respectueuse de l'environnement et propice à l'adaptation au changement climatique. Les systèmes de production basés sur l'Agro-écologie et/ou l'AC ont de fortes caractéristiques de résilience, notamment vis-à-vis des aléas climatiques. La maîtrise de ces techniques nécessite impérativement des compétences pour une large diffusion auprès des producteurs. Pour Madagascar, une base de formation a été déjà établie depuis les années 90 et continue de s'améliorer par les organismes membres du GSDM. La formation en AC à Madagascar a un triple objectif de :

- Répondre aux besoins en compétences en Agriculture de Conservation (AC) et en Agroécologie (AE) dans le domaine du développement rural.
- Proposer un certificat de spécialisation de conseiller en Agriculture de Conservation et Agro-écologie complétant une formation initiale ou continue, polyvalente de technicien agricole, reconnue.

- Pérenniser les actions en AC dans le monde rural en insérant le thème de l'AC dans le cursus scolaire depuis le niveau de base au niveau universitaire.

Les avantages de la formation en AC à Madagascar se dessinent à travers l'existence d'expérience en technique d'AC. Ces expériences sont sources de savoir et de bases de données pour le développement des compétences en AC. Par ailleurs, l'existence du GSDM est un levier opérationnel pour piloter les activités de formation en AC à Madagascar. Les efforts de GSDM portent sur actuellement à l'insertion de l'AC dans le programme scolaire de base. Enfin, la formation sur le tas des paysans constitue une des réussites des activités de diffusion des techniques d'AC mise en œuvre par les acteurs rattaché au GSDM.

Vers le recadrage de la formation rurale et de l'AC

La formation en Agriculture de Conservation tient une grande place dans le processus de diffusion à grande échelle des techniques et la restauration du paysage à Madagascar. Le référentiel de formation en AC existe déjà et une structure responsable de coordination et de mise en œuvre existe également. Toutefois, l'adoption d'une stratégie nationale est nécessaire pour une plus grande efficacité et pour adapter la formation au contexte général de la politique nationale en matière de développement rural et environnemental. Il serait souhaitable de profiter de l'existence du comité national RPF pour achever une intégration systématique des activités d'AC dans les approches paysages existantes. Le développement de la formation en AC devrait être accompagné par l'évolution de la formation agricole en général.

Les quelques recommandations ci-après visent à cadrer les formations rurales dont l'AC afin d'atteindre les objectifs de développement durable et les engagements de l'Etat malagasy en matière de conservation et gestion des ressources naturelles et de Restauration des paysages et des Forêts.

Formation agricole en générale

- Renforcement de la capacité politique et institutionnelle afin de répondre à la demande de formation et aux besoins quantitatifs et qualitatifs de formation professionnelle dans le monde rural.
- Mise à jour et mis en œuvre de stratégies nationales de la formation agricole correspondant aux défis de la production et de la gestion des ressources naturelles.
- Mise en place de dispositif national et régional de pilotage, d'orientation, de planification et de suivi-évaluation.
- Intégration de l'approche paysage et approche multisectorielle dans les modules de formation
- Financement adéquat et pérenne de la formation agricole

Formation en AC en particulier

- Les systèmes AC demandent une période d'apprentissage et les aspects formations sont fondamentaux : Il faut compter 2 à 4 ans pour former une équipe capable d'encadrer convenablement les paysans, de les accompagner dans le changement.
- La formation en agroécologie et sur les techniques d'agriculture de conservation doit être abordée à tous les niveaux possibles pour soutenir un développement rural
- Implication effective des partenaires financiers et techniques en liaison avec l'approche paysage intégrant l'agriculture et l'environnement

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Are There Similarities of African Farmers and Other Continents Implementing Sustainable Food Production, Climate Mitigation and Other Ecosystem Services?

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Introduction

This paper intends to highlight the key difficulties of farmers in conversion towards CA in Europe and Africa, and to propose some solutions to be implemented by CA community. Today Conservation Agriculture Systems in their best practices, as defined by FAO under its strictest definition including zero tillage, permanent soil cover and diverse crops and rotations, is validated by the largest (and growing) part of the best experts and scientists of agriculture in the world. In addition, they are being adopted massively and improving in both North and South Americas and Australia, and taking off in Asia. At the same time, in other geographies like Europe and Africa, adoption is still low (around 2% of farmers, with variability depending mainly on the definition), despite some positive tendencies locally.

This paper intends to highlight the key difficulties for farmers in these geographies, and to propose some solutions. Its original aspects, is that most elements come from farmers themselves, even if their interpretation also includes the views of experienced field development experts.

Method

The starting point had been an analysis made by APAD, about the difficulties for French farmers to adopt Conservation Agriculture. It had been ordered and supported by the French Ministry of Agriculture, as well as DG Agriculture of European Union. The method of this first full study was groups interviews of APAD 550 member farmers divided into 11 local groups. The results were presented to leading CA farmers and experts of other countries and continents in different congresses (WCCA Brisbane 2011, AAPRESID Congress Rosario 2012 and 2013, WCCA Winnipeg 2014, COP21 Paris 2015, COP22 Marrakech 2016, COP23 Bonn 2017). These exchanges have improved, amended the results obtained in France. key contributions came from AMAC, Association Marocaine d'Agriculture de Conservation, during several exchanges, as well as of APAD Tunisie, and ACT, African Conservation Tillage Network. It must be noticed that the inputs of other continents, including Africa, have not been done with direct interviews of farmers. But, they have been the reactions from some experts and leading farmers from CA community, during exchanges after exposure to the French synthesis. The value of this comparison comes that all inputs we got are consistent and go towards the same direction, with no critical disagreement.

Nevertheless, the asymmetry of the design makes the conclusions preliminary. To get a full scientific value and eliminate potential bias, this study would need to be disseminated under similar design in different geographies, then the data compared with similar methodology. The intention of authors is to promote this further investigation as a common project to leaders of CA movement and scientists inside of structured transcontinental projects like 4per1000, or any project aiming at transforming agricultural systems towards improved sustainable performance by mobilization of farmers. This might be proposed to international organizations in charge of improving agriculture. The first exposure to this study has shown unexpected interest of all officials and operators in France, Europe, and other places. They are a much interested in knowing the benefits of CA as understanding how farmers take their decisions, under which constraints, motivations and drivers.

The justification is that understanding the obstacles and drivers for farmers to change their systems is the number one key for policy makers, developers and donors, to get a change on the ground and accelerate it where a dynamic already exists. Even with the limitation of the methodology, these first results suggest enough similarities between geographies to support the hypothesis that there may be a basis of universal principles, as well in the biological principles of best agronomic systems, as in human behavior to transform them. This would justify further investigations and projects, to be led by CA organizations as experts, of CA as technical object, but also of farmers' sociology and mobilizations. This gives full value to complementarity between scientists, agronomists, and leading farmers, as it exists in CA community.

Results and discussion

The study and discussions around it established that the key questions arise around following points:

- What is specific in geographies? What is local, and what is universal? Human cultures, education, economics, everything is local in human communities. Soils, climates, crops, pests, everything is local in a field.
- When we look at similarities and differences, the exchanges between geographies have shown following points

Biological / ecological / agronomic aspects of farms:

Soils, climates, crops, pests, everything is local in a field. But, the natural laws and mechanisms which drive the interactions of factors are all universal. As CA is fundamentally based on understanding and mimicking nature, its principles are universal: tillage destroys all kinds of soils everywhere; bare soils are dying and threatened by erosion everywhere; a single species in a field cannot be as robust and productive as diversified mixes and successions of crops and cover crops.

These aspects rise a consensus among all specialists and leading farmers who know CA all around the world. This justifies that everyone can learn the principles from experts or farmers coming from all geographies. This is in fact how CA has disseminated from leading geographies to emerging ones.

But when farmers need to adapt to their local conditions, all details of practical technical implementation change: soils, climate, crops, pests… Ecosystems follow the same universal rules in their functions and mechanisms (like C/N cycles and photosynthesis), but the detailed components change (like vegetal and animal communities). This means that farmers need to adapt all components and all their technical actions to the new context in which they want to implement the new systems. This needs a lot of adjustments, with experiments on all factors, with multiple and complex interactions between the factors. This explains why even in the best conditions, it takes some time to get good performance from a new CA system in a new farm in a new geography.

If in most places now it is possible to describe the best ideal theoretical CA farm, it is more difficult to describe precisely the route to go to obtain the results without too much loss during transition period.

To obtain accelerated transition of more farmers towards efficient good CA farms, it is necessary to better understand the factors of success, and thus the difficulties of farmers, and the factors of success on successful cases.

Difficulties of farmers

The answers of farmers about their difficulties seem to be similar in all places:

- Lack of usable knowledge or understanding of new systems proposed. Specially, in the area of practical advices. Knowledge is provided by scientists and experts, but mostly theoretical, general, and not enough when we come to specific questions about practical implementation on the ground, especially in geographies where CA is still in emerging stage. Science in soil life is just beginning.
- Vegetal engineering with cover crops is just emerging.

- Hesitation to take the risk to change from a system they know well to another one they do not master yet, and from which they get the results only after several years of learning. They pay their learning period with their own labor and money. And often cannot afford the loss due to a mistake.
- Lack of facilitating technologies. Seeds, plant protection solutions, irrigation, fertilizers, machineries, information technologies…they need all to be available, and adapted to CA systems specifications. They are missing in most places: either because the place is not a market for supply companies, or because they are threatened to be withdrawn for political reasons.
- Policies are never adapted to transformation of farms into CA systems:
- either they do not support CA farmers, and favor their conventional competitors,
- or in most cases they prevent them to adopt CA, by limiting their technical choices, modus operandi or inputs. Many cases have been found in Europe.

Drivers to change, farmers' motivations

The answers of farmers about their personal motivations also seem to be universal: Their all want to make profit from their farm to feed their family, make extra income for education and welfare, grow and improve their operations in a professional way. As human behavior is universal, it is logical to find that drivers to change successfully are similar globally. But we may find differences in the balance between them. In Europe the study shows that two drivers to change their systems are balanced: (a) improving their economic performance through technical improvement, b) be accepted, if not recognized, by civil society.

This last point may be especially important in Europe because farmers depend of public subsidies, thus of the opinion politicians and society have from them, and also because NGO's put a lot of pressure on farmers to let them implement what NGO's promote as the best agriculture. It means that farmers opinion about what is good in agriculture is not really the driver in the debates.

There is an interrogation if this point is as much important in other geographies, but we can propose the hypothesis that it may be growing in most places, probably under growing globalization of communication and evolution of the balance between cities and rural areas.

Learning processes:

The key driver of successful change is in the mindset of farmers, in the way the understand their ecosystem, in their relation to soil, plants, animals, and in their relation to technologies, to conceive their farming systems.

Farmers understand all this easily, once exposed properly, especially when scientists explain them the theory, then when experienced CA farmers explain to them with practical examples from farms.

Both ways to acquire understanding and knowledge are complementary:

- Farmers associations of diverse geographies can connect and exchange about their needs and practices, their difficulties and how to overcome them.- Scientists and experts of CA community can give them advices and lessons, bringing their experience and testimonies.

This is internal to CA movement, may be organized and intensified.

Societal / sociological aspects

Nevertheless, the key factor remains sociological/political: the request of the society (other than farmers) about the kind of agriculture and food they want. In all countries, society is represented by elected politicians, and administrations. They decide rules for farmers, who are now everywhere in minority, and usually submitted to other citizens. And politicians are influenced by lobbies (businesses and ideologies), mass media playing a key role of relaying opinions, whatever quality or impact they may have. Farmers can have the best results on their farms, if they

are not recognized by the political power, they have no chance to get their needs fulfilled, and their operations are damaged by inadequate policies and regulations. Typical example is the ban of glyphosate decided by French government despite it makes CA in mechanized farms so difficult that most CA farmers and experts evaluate this between impossible and nearly impossible.

The impact of pressure in USA and Europe has also affected Brazil. Who's next? In the area of political influence also, farmers have common views and experiences around the world: when they explain in their fields to citizens how real lifer is, what nature does or doesn't, what is a good soil and a good production, what tools they need or can avoid, the dialog is of high quality, because based on true facts and field shared references with visiting stakeholders. And a consensus emerges between farmers and citizens about the role of each stakeholder in facilitating farmers operations to transform their farms into carbon sink.

As the debates, which impact political and business decisions are now global, and end with international regulations, policies, agreements, which have a lot of impact on farmers operations, farmers need to cooperate also globally to get what they need from society. Their first need is to obtain freedom to operate with trust, with decisions based on facts and science. Not being submitted to fake science, superstitions, rumors, unpractical or illegitimate decisions, even if popular and demagogic.

Recommendations to go further

First step would be to refine the study by complementing it with structured interviews of farmers associations in other geographies. And amend or validate the results in a scientific way, to be sure of the conclusions. Second step for CA associations is to operate as a global group, led by CA-COP. Proposed is the GCAN as Global Conservation Agriculture Network.

The structure for action plan might be to use the results of the study about needs and drivers of farmers to transition towards CA, and establish as objective to meet the needs of farmers and capitalize about the experiences. Next step is for the Global CA Network to make alliance with other groups of companies, citizens, experts, policy makers, getting a compatible and converging interest with CA farmers to improve agriculture to meet food demand and the environment challenges. GODAN, GFIA, 4per1000, Energies2050, are some of these groups having shown an interest in supporting progresses of CA farmers. In the process to get their support (of principle for the moment), the presentation of the study has been a decisive factor.

One structuring project and opportunity to work together to grow influence of CA community with influential partners is participating in Climate Conference of Parties. A practical joint project is proposed for COP24 in Poland in December.

It will be useful to get all continents represented by CA farmers and experts of regional / national associations.

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Centers of Excellence in Conservation Agriculture: Pathway for Economic and Biophysical Restoration of Degraded Smallholder Farms in Kenya.

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Introduction

Small-scale farms have been the bedrock of agricultural production and livelihood for the majority of rural Kenyans for many generations. However, subsistence level management using conventional methods - regular tillage, low soil nutrient inputs and minimal crop rotation has gradually eroded the basic resilience of the small units to the extent that they can no longer support decent livelihoods in terms of food and nutritional security. The majority of the units are currently not economically and biophysically viable due to the deteriorating soil conditions and now increasingly uncertain weather. Production of wheat and maize which are basic staples has declined steadily with yields stagnating or decreasing over the last twenty years (Fig 1). This is despite intensive promotion and cultivation of higher yielding varieties; an indication that conventional practices have limited ability to unlock the potential of improved crop varieties in low input smallholder systems. Unsustainable intensification has constrained yield increase with improved crop varieties at only 28% in Africa compared to 88% in Asia (Evenson and Gollin, 2003). In order to mitigate further degradation and to restore sustainable fertility there is a compelling need for a holistic intervention embracing all the pillars of sustainable intensification (SI). The pillars are as described by Tadele (2017); Montpellier Panel Report, 2013: - namely increasing agricultural yields without adverse environmental impact and without the conversion of additional non-agricultural land. They embrace efficiency, resilience and a contributory function to the stock of natural environmental capital.

Challenges and opportunities

A search through literature reveals a general consensus that low productivity is consequential to degraded nutrient-depleted soils with a poor soil structure and typically low organic matter (Gergesene *et al*.; 2007). A large body of literature also reveals that rapid gains in restoration of degraded farm lands are possible from sustained use of conservation agricultural (CA) practices (Johansen *et al*. (2012), Pretty and Bharucha, 2014). The social economic and biophysical benefits of conversion from traditional agriculture to CA are also well validated and documented (Pannell *et al*., 2013; Struik *et al*.; 2014; 2017). Intensification is inevitable but partial intensification through investments in improved genetics on its own cannot overcome degraded soils. Agro-ecological intensification, implying restorative management of agricultural land is necessary to improve productivity. Also critically important is socio-economic intensification to develop human capacity and to create an enabling policy and socio-economic environment beyond the farm.

The potential to produce food surpluses on smallholder farms is not in doubt but it is locked by systemic weaknesses in delivery of technological gains to the people who really need it i.e. the small- holder farmers. Based on Kenya experiences with early adopters; a fourfold yield increase is possible on small-scale farms in less than five seasons with appropriate use of CA practices (Table 1). The missing link is a vehicle to deliver technological gains in Conservation Agriculture while deliberately creating an enabling environment for adoption and value addition.

Kenya's small-scale farmers are averse to risk and have a tendency to adhere to conventional wisdom and practice. The viability of CA as a best bet option has not been demonstrated adequately. Three major weaknesses hamper uptake and sustained use of CA.

i) Poor coordination of efforts to increase awareness knowledge and practice among small-scale farmers and frontline extension personnel and hence low adoption.
ii) Lack of supporting infrastructure given that CA often requires specialized tools, often unaffordable by individual farmers. On the other hand, limited demand for CA services discourages investment in such tools.
iii) Technical backstopping capacity needs to be developed and institutionalized

The first requirement to propel farmers to decide in favor of CA technology adoption is to demonstrate CA and consistently replicating a convincing frequency of successful outcomes in situations that closely mimic the farm environment. This paper outlines the role of CA Centers of Excellence (CA-CoEs) in a comprehensive and novel approach to overcome challenges in delivery and sustained adoption of CA as the best bet option for restoration of degraded farmland.

The role of CA-CoEs as drivers of adoption of Conservation Agriculture

The CA-CoE is a multi-stakeholder platform designed to promote, upscale and sustain adoption of Conservation Agriculture as the approved method for management of agricultural land. Adoption of Conservation Agriculture is expected to contribute significantly to economic viability and food security in rural smallholder communities. In order to successfully promote adoption of well-proven and ready-to-deploy technological packages for CA, the following must happen:

i) viability of CA as a best bet option must be demonstrated by producing and replicating a convincing frequency of successful outcomes under on farm conditions.
ii) a critical mass of well-trained and equipped CA service providers within the farming communities must be created. Ideally they should be practicing farmers and
iii) building and institutionalizing capacity to deliver awareness and knowhow of the practice of Conservation Agriculture to relevant practitioners and stakeholders (farmers, policy makers, service providers and industry) and to build technical backstopping capacity.

The role of the Centers of Excellence (CoE) is therefore to leverage existing institutional capacities in private and public sector in support of promotion of adoption of CA for the purpose of fast-tracking delivery of knowledge and practice of Conservation Agriculture. The goal is to build one-stop CA referral/advisory centers and local depositories of knowledge in order to ease access to information and technical knowledge. The important function of CA-CoE is to demonstrate socio-economic and biophysical benefits of adopting CA through training and visual exposure to widespread and carefully designed farm-scale demonstrations. The collective capacities of a multidiscipline pool of agronomists, soil scientists, crop protection experts and social economic specialists will be harnessed to in building essential technical backstopping, adaptive site specific research to validate CA technologies and holistic and participatory training of stakeholders.

The CoEs will further strengthen the socio-economic foundation by promoting dialogue at the technical/political interphase with a view of enlightening political leadership and policy makers on the need and benefit of prioritizing resource allocation for up scaling adoption of CA. The Centre of excellence is designed to be alert to changing dynamics e.g. the highly feminized state of Kenya's agricultural sector and the subtle but highly determinant role of women in decision making and implementing the farm agenda. Given that the average age of active farmers is more than 60 years; the CA-CoE will be deliberate in capturing and retaining the interest of women and youth in CA programs.

In conclusion, it is tenable to note that the smallholder sector has to date relied on unsustainable tillage based agriculture. This has proved inadequate in meeting the needs of an increasing population and resisting the adversity of climate. The way out of the problem is to overhaul the land use and management system through holistic intensification that embraces and institutionalizes CA as the approved primary practice for sustainable land use. The absolute imperative is that the Kenyan small-scale farmer must move away from outdated traditional methods to well-tested and knowledge-based methods of land use.

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Tables and Figures

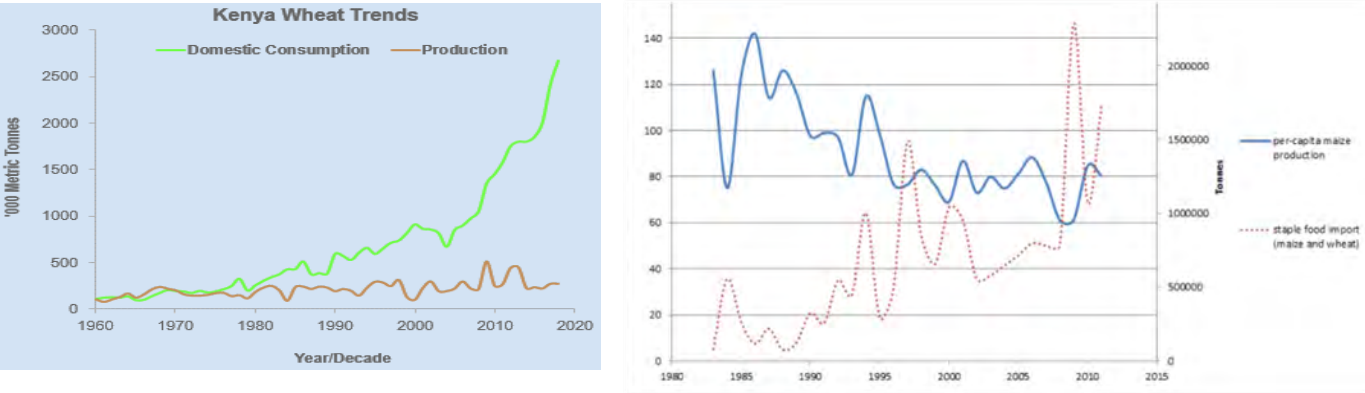

Figure 1. Kenya wheat production and imports

Table 1. Maize grain yield trend on farms of early adopters of Conservation Agriculture in Kenya

MRS. BEATRICE WAMALWA			MRS. HELLEN MASIBO	
Year	CA Practice	Yield ($t\ ha^{-1}$)	CA Practice	Yield ($t\ ha^{-1}$)
2012	Adopted CA 0.1 HA	2.7	Adopted CA on 0.4 HA planted with Maize, Dolichos, Mucuna, field beans, Green grams	5.8
2013	No till +Crop residue cover+ fertilizer	4.9	Maize, Dolichos, Ratoon Mucuna, field beans,, Green grams	7.2
2014	No till +Crop residue cover+ fertilizer	7.2	Maize, Dolichos, ratoon Mucuna, field beans, Green grams	8.1
2015	Planted without DAP, Mucuna introduced	9.0	Maize, Dolichos, Ratoon Mucuna, Grey beans,	9.2
2016	Expanded to 2 acres, with Mucuna	10.8	Maize, Dolichos, Ratoon Mucuna, field beans, beans, Green grams	10.5
2017	Expanded to 0.78 HA, with Mucuna ratoon	7.8	Maize, Dolichos, Ratoon Mucuna, field beans, Green grams	11.8

Figure 2. Kenya's per-capita maize production and staple food import (1983~2012)

Sub-Theme 4: Investing Across Institutions and Sectors, Including in Mechanization and Commercialization, for Widespread Adoption of CA Systems in Africa

Whiles bulky part of financing CA uptake should come in the small recurrent expenditures on inputs and farming services, accelerating widespread adoption and management will require massive capital investments directly in agricultural technologies and indirectly in rural and farm services and facilities including rural roads and infrastructure. Investing across institutions and sectors for widespread adoption and commercialization of CA systems in Africa

The need for farm specific set of agricultural implements for scaling - up from hand-tool level to mechanized CA is addressed through sustainable agricultural mechanization, a broad concept that promotes mechanization technologies and services along the entire value chain. Therefore, CA and sustainable agricultural mechanization are inter-linked and should be promoted together.

Ultimately, for farming to be climate-smart, it will need to be viable too. The sub-theme examines and highlights cases of large public, private, or public-private investments that is catalysing CA adoption and uptake. It also looks at facilities and services including policies and institutional support making affordable investment financing accessible to small-medium farming entities

Under this sub-theme,12 condensed papers were submitted and approved by the Scientific and Technical Committee after regourous reviews. These papers are hereby presented as follows:

Long-term Impact of Smallholders' Conservation Agriculture in Rainfed and Irrigated Systems

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Keywords: cost saving, cropping sequences, non-puddled transplanting, soil health improvement, strip planting

Introduction

Worldwide about 180 million ha (Kassam *et al.,* 2018) of various rainfed crops are being grown in Conservation Agriculture (CA) systems. Although most of the CA area is practiced on large farms with heavy machinery, however, more small farmers practice CA globally. The CA practices are well-developed for non-rice crops, the CA practice in transplanted- rice-based systems remains challenging. Bell *et al.,* (2017) reported that the application of CA practices in smallholders' cropping, reduces crop production cost, maintains grain yield and increases profit from 48 to 460% relative to conventional tillage (CT) (Miah *et al.,* 2017). Conservation Agriculture is a win-win approach that reduces operational costs, including machinery, labour, and fuel (Johansen *et al.,* 2012), while better utilizing natural resources and in many situations also increases yield (Haque *et al.,* 2016). Although CA has considerable potential, only a small percentage of smallholder farmers practice CA in Asia and Africa. Conservation Agriculture is a complete paradigm change in the way agriculture is performed which requires an acquisition of new management skills and the willingness to learn constantly. The shift of cropping practices from conventional multiple full tillage operations and crop residue removal or burial to minimum soil disturbance, crop residue retention and diversified crop rotations is likely to alter nutrient forms and availability in soils and fertilizer responses of crops, change weed dynamics, require adjustment of agronomic practices, etc. Thus, systematic long-term research is needed on the performance of CA in rainfed and irrigated conditions particularly rice-based systems.

Materials and Methods

Two long-term experiments have been conducted in Durgapur (24°28' N, 88°46' E) and Godagari (24°31' N, 88°22' E) Upazilas (sub-districts), Rajshahi (since 2010 in farmer's fields); and another long-term experiment in BAU farm, Bangladesh Agricultural University, Mymensingh, Bangladesh since 2012. These experiments provide insights into the long-term trends with practicing CA in intensive, rice-based crop rotations in Bangladesh. Three soil disturbance practices were tested: CA practice with strip planting (SP including non-puddled transplanted [NPT] of rice (Haque et al., 2016); bed planting (BP) and; conventional tillage (CT) in Rajshahi sites; and either SP or CT in Mymensingh. All experiments had low (current farmer practice, 20 cm height and about 2.5 t ha^{-1}) and increased (40 cm height and about 4 t ha^{-1}) of rice and wheat residue retention levels. The cropping sequences were lentil/mustard-mungbean/jute/irrigated rice-monsoon rice (for Durgapur); wheat/chickpea-mungbean/early wet season rice/jute-monsoon rice (Godagari; and wheat-mungbean-monsoon rice (for BAU Farm) in these experiments. The Versatile Multi-crop Planter (VMP) (Figure 1) (Haque *et al.,* 2017) was used for establishing all upland crops (lentil, mustard, chickpea, early wet season rice & mustard) in single-pass operation for SP and BP, however, 3-4 tillage operations by 2WT followed by hand-broadcast seeding and fertilizing were done for CT. In case of irrigated and rainfed rice, NPT was practiced in SP and BP; and for CT conventional puddling was followed.

Results and Discussion

Long-term trends for crop yield and profit margin: The yield of both lentil and wheat at Durgapur and Godagari sites were comparable between CA and CT in the first two years and the yield benefit of CA over CT had become apparent by the third year. However, the yield advantages of CA for mung bean and rice crop in the rotation compared to CT system were not detectable in first three years of experimentation (2010-13) at both Durgapur at Digram sites (Islam, 2016). In Durgapur site the seed yield of mustard was 22% higher ($P<0.05$) in 2012-13 (Figure 2, A1). Whereas statistically similar grain yields were recorded for Godagari site in all sixteen crops (Figure 2, A2). The rice equivalent yield for 12 crops (Figure 3), gross return and gross margin (Figure 4) were statistically higher ($P<0.05$) for CA than for CT in Mymensingh site.

Irrigation water saving: The long-term experiment of CA with aman rice-wheat-mungbean crop rotation saved 11-33 % of the irrigation water for wheat season compared to CT. In addition to significant water saving, there was more efficient irrigation water use, and higher water productivity. Water productivity of wheat was higher in SP compared to CT in three years. For example, in 2015, water productivity of wheat was 2.06 and 1.25 g grain kg^{-1} water for SP and CT, respectively (Mahmud *et al.,* 2017).

Soil organic carbon concentration: In comparison with CT, considerably higher soil organic carbon (SOC) was observed in CA at 0-10 cm soil depth after 3-4 years of cropping. Practicing CA for upland crops and NPT for rice crop accumulated an extra 4.2 and 3.8 t CO_2eq ha^{-1} in Durgapur and Godagari experiments, respectively, after 4-5 years (Alam *et al.,* 2016). The long-term effects on minimum soil disturbance and residue retention were also assessed on long-term CA experiment at BAU farm, Mymensingh. The effect of CT and CA and N fertilization on SOC concentration of the surface and sub-surface soil was assessed only after the harvest of 8th crop (wheat). A significant ($P<0.01$) increase in SOC concentration was observed in the 0-5cm soil layer between CT (1.58%) and CA (1.83%) when SOC was averaged over the residue management and N fertilizer treatments. The SOC concentration at 0 to 5 cm soil depth was significantly and positively influenced by SP, but not by residue retention nor N fertilization or their interactions with crop establishment systems. However, at 5 to 15 cm soil depth, the SOC content was not significantly influenced by any of the above-treatments (crop establishment, level of residue retention and N fertilization) and their interactions. Over time there was a stratification of SOC towards the surface layer of SP plots and with high residue retention relative to the CT and with low residue retention plots. Soil organic carbon stock (t ha^{-1}) showed the similar trend to SOC concentration, however, the differences were not significant between any of the treatments (crop establishment, level of residue retention and N fertilizer) and their interactions.

Greenhouse gas implication: The practice of CA reduced life cycle greenhouse gas emission relative to CT by about 30% (Alam et al., 2016). Cultivation of rice under CA systems offers significant greenhouse gas saving in the 100-year time horizon relative to the CT mostly due to lower emission of methane (CH_4) (Alam *et al.,* 2016).

Disease infection: On-going monitoring of disease incidence in CA plots particularly with high residue management has not yet shown significant change in the levels of infection. For Mymensingh experiment in one year, sheath blight infection (Rhizoctonia solani) occurred and was marginally higher in CA compared to CT whereas it was the opposite for bacterial leaf blight (Xanthomonas oryzae). Both the disease infections were higher in high residue retention treatment but the differences were not significant.

CA Adoption: In Durgapur Upazilla, where a concentration of effort on VMP promotion and extension of CA has occurred in the last 5 years, the adoption of CA in 2016-17 *Rabi* season was 4.5% of the total crop area. In three blocks, the CA planting reached 10-16% of all *Rabi* season crops. Hence there is evidence of early adoption by farmers where there have been programmes to build farmer awareness, practical skills and confidence in the technology and the availability of the planters and local service providers (LSP or planting service contractor with VMP) to offer planting services to farmers on a custom hiring basis (Haque *et al.,* 2018).

Farm level CA adoption benefit: Average benefits from the farm mechanization and CA adoption have been estimated from a study of 135 farmers were as follows: 34% labor saving, 31% less seed required, 6% fertilizers saving, 32% pesticide cost saving leading to up to 10% lower production cost for lentil, mustard, maize, and wheat (Miah et al.,

2017). There was a yield increase of 28% for lentil, 19% for mustard, 6% for wheat at farmers' level who adopted CA planting using the VMP, and; profit increases by 47% for lentil, 55% for maize, 46% for mustard and 76% for wheat due to adoption of CA planting using VMP (Miah *et al.,* 2017).

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Figures

Figure 8: Versatile Multi-crop Planter (VMP) Transportation (left) and in operation in the field (right).

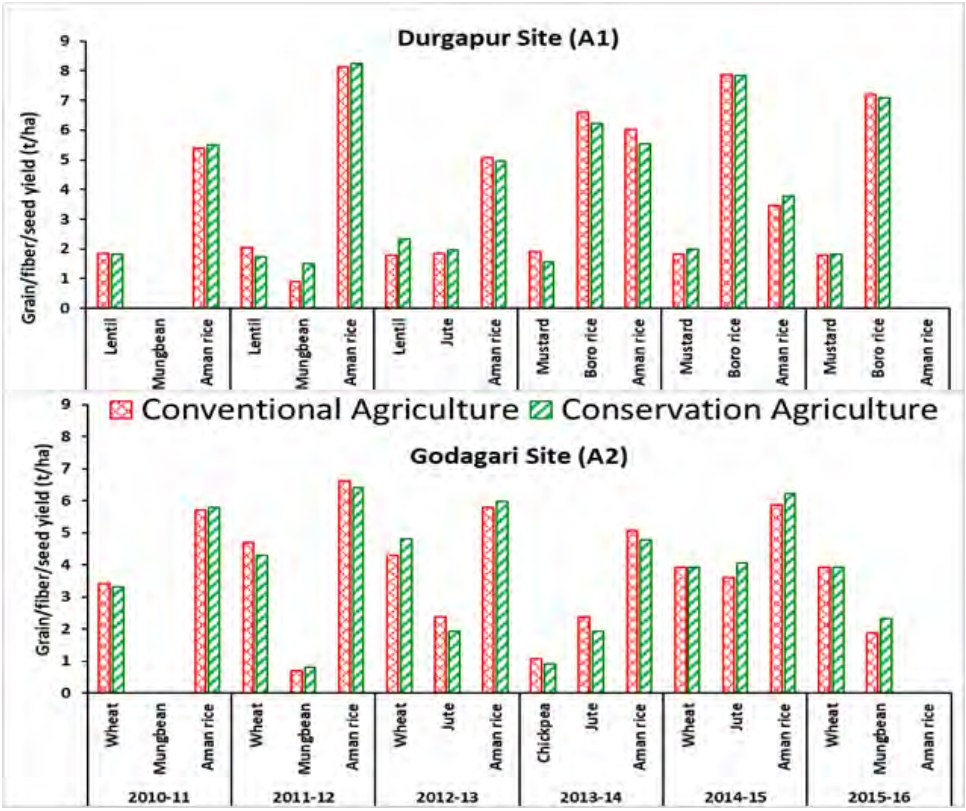

Figure 2: Long-term effect of CA on grain/fiber/seed yield in Durgapur (A1) and Godagari (A2) sites, Rajshahi, Bangladesh from 2010-11 to 2015-16

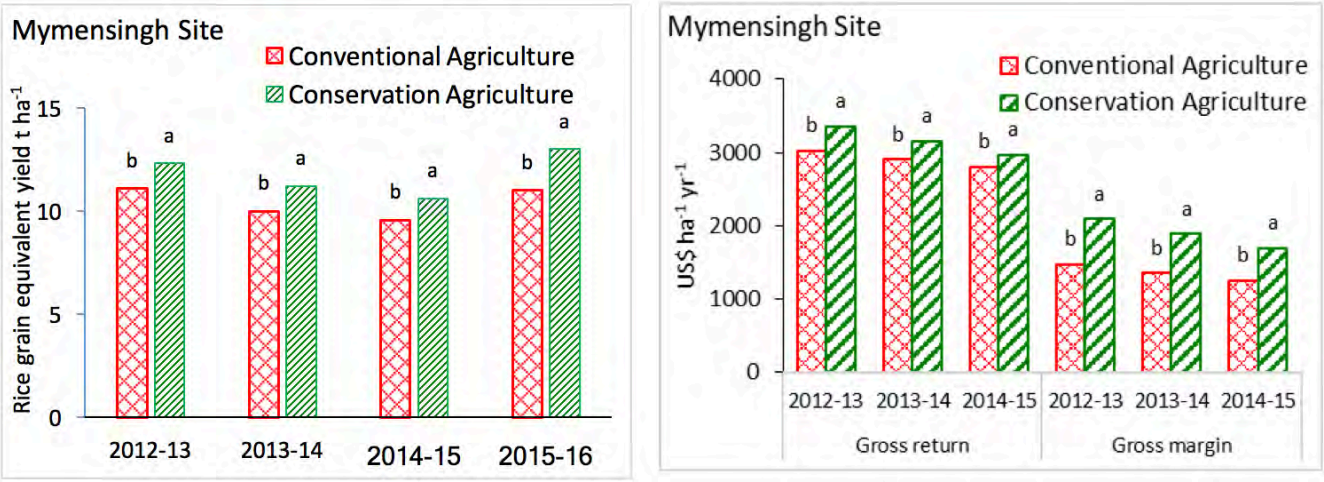

Figure 3: Long-term effect of CA on rice equivalent grain yield in Mymensingh, Bangladesh

Evaluation of Conservation Agriculture Mechanization Techniques in Maize Cultivation

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Key words: direct seeding

Introduction

The sub-Saharan region is faced with an ever-increasing demand for food for the increasing population (FAO. 2000). In Zimbabwe, the small holder farming sector constitutes the majority of the population and depends on maize (*Zea mays L.*) as the main carbohydrate source and the population in this sector is the most affected. The average national local demand for maize is 1.7^5 (1.7 million) metric tons (MT) year^{-1} which constitutes 1.3^5 MT for human consumption and 0.3^5 ton for animal feed. A 5-year national maize deficit average of 0.5^5 MT was recorded in Zimbabwe from 2011/12 to 2015/16 seasons (FEWS NET, 2017). The major limitation in maize production in the small holder sector is late planting caused by low labour and performance of hand tools coupled by high production costs among other challenges like changing rainfall patens caused by climate change. Mechanised land preparation operations are an essential component of maize cultivation under the conventional system which contributes significantly to input costs (Mitchell et al., 2010). It is therefore important to identify sustainable mechanisation technologies that do not reduce productivity, or increase costs of production, or increase labour input, and reduce land degradation.

The most common power sources for agricultural activities are humans, animals, single axle or two-wheel tractor (2WT) and the standard four-wheel tractor (4WT) in Zimbabwe. Previous work cites major benefits associated with Conservation Agriculture (CA) but there is no widespread adoption in Zimbabwe (Nyagumbo et al., 2010). Therefore, to stimulate adoption, there is a need to pursue more factual/experimental evidence of the effects of CA mechanisation on: timeliness, labour requirements, productivity and the costs of maize production.

Materials and Methods

This paper discusses results of experiments with four CA sowing treatments and one conventional tillage treatment conducted through a randomised complete block design with four replications. The treatments were as follows: (1) basins dug using a hoe; fertilizer application, seed dropping and covering all by hand; (2) two- wheel tractor powered direct seeding (2WT DS), (3) four-wheel tractor direct seeding (4WT DS), (4) animal-drawn direct seeding (Animal DS) and (5) traditional conventional tillage by animal (CT). Table 4 provides specifications of equipment used in the experiment. The two-wheel tractor direct seeding technique involved planting direct into the soil without ploughing using a single row direct seeder pulled by a two-wheel tractor driven by a single operator dropping seed and fertilizer in one operation. The animal drawn direct seeding technique involves planting directly into the soil without ploughing using a Fitarelli single row direct seeder pulled by two oxen and employing two operators. The four- wheel tractor direct seeder technique involved planting directly into the soil without ploughing using a four row direct seeder mounted on a four-wheel tractor and requiring a single operator. The conventional tillage was characterised by ploughing using an ox-drawn mouldboard plough. This was followed by planting using an ox-drawn conventional planter and two operators. Work rates were estimated by timing crop establishment tasks for each treatment using a stopwatch. Estimation of work rates, labour input during crop establishment for each treatment was recorded using a stopwatch. Maize grain yield estimated from each treatment through systematic sampling of 5 lines per treatment at a plant population of 50 plants per treatment and calculated at a plant population 37 000 plants ha^{-1}. Harvesting and weighing was done after field drying and reducing to a standardised yield at 12.5% moisture content. The cost of

production for a ton of maize grain from each treatment was calculated based on the grain yield and machinery input partial budgeting as in equation 1. Cost /ton ($ton^{-1}) = mlc÷yt (equation 1).

Where: mlc (US$) = machinery and labour hire cost (Table 3) and yt = yield (t ha^{-1}).

All the collected data were checked for errors before analysis (Park, 2010). The analysis was done using the GenStat Release 18.1. Least significant test of significance was used to evaluate differences across the five treatments.

Results and Discussion

Effect of tillage technique on work rates. The results indicate that, Basins and CT were time-consuming operations spending a total of 58 and 25 hours, respectively and Animal DS, 2WT DS and 4WT DS were 4.86, 5.55 and 2.78 hours, respectively on land preparation and planting of maize seed. However, there was no statistical differences among 4WT DS, 2WT DS, and Animal DS (Table 1). Moving from Basins to CT, 2WT DS, Animal DS or 4WT DS was increased annual planting/seed sowing capacity by 2, 10, 12 and 21 times respectively (Table 2).

Effect of tillage technique on labour input. The results indicate labour requirements of 7.3, 3.2, 0.7, 0.6 and 0.3 labour days ha-1 (Table 1) for basins animal CT, 2 WT DS, animal DS and 4 WT DS respectively. These results indicate that basins are the most labour demanding technique compared with other techniques. The result indicates that drudgery is an issue with CT where total distance travelled to establish a crop is over 100 km ha^{-1} (Table 2). Turning to Animal DS reduced the distance to less than a fifth and by less than half with Basins despite the three separate operations and the 4WT DS, the driver is seated hence no distance is walked by the driver.

The effect of crop establishment technique on maize yield. The result indicated that there was no significant differences in maize grain yield between the crop establishment techniques by CT and CA ($p = 0.478$) (Table 1). Therefore, it can be concluded that tillage technique does not affect yield. From these results, yield cannot be used as a criterion to select or evaluate a mechanisation technique.

The effect of mechanisation input on cost of land preparation. There were significant differences in production costs between the CT and CA practices, $p < 0.001$ (Table 1). The results show that the Animal DS is the most efficient practice producing a ton of maize at 23.14 % less than CT and Basins was 7.88 % less followed by 2WT DS with 4.7 % and 4WT DS being more expensive by 5.15 % than CT. Again, the Animal DS was the most efficient producing a ton of maize at 20.19 % less than the four CA practices. This was followed by 2WT DS at 1% less than average and the 4WT DS was more expensive than the average by 9.19%. The Basins were the most inefficient of the CA practices, producing a ton of maize grain at 12 % more than the average.

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Figures and Tables

Table 1. Summary statistical table

Treatment	Production cost of maize grain US$ ton^{-1}	Work rate hrs ha^{-1}	Labour days ha^{-1}	Grain yield ton ha^{-1}
Animal DS	11.56[a]	4.86[a]	0.608[a]	3.583[a]
2WT DS	17.62[a]	5.55[a]	0.694[a]	2.92[a]
4WT DS	19.44[a]	2.78[a]	0.347[a]	3.611[a]
CT	38.31[b]	25.21[b]	3.151[b]	3.245[a]
Basins	64.95[c]	58.25[c]	7.28[c]	3.304[a]
p-value	<.001	<.001	<.001	0.478
Grand mean	30.4	19.33	2.42	3.13
lsd	11.54	7.797	0.975	1.193
se	7.49	5.061	0.633	0.775
cv%	24.7	26.2	26.2	24.7

Table 2. A comparison of tillage technique annual capacities and equivalent distance travelled ha^{-1} during land preparation and crop establishment

Treatment	Annual capacity (ha)	Distanced covered (km ha^{-1})
2WT DS	3.2	41.76
4WT DS	33.6	21.24
Animal DS	67.2	9.51
CT	33.6	16.65
Basins	9.6	104.4

Source: IAE experimental data 2017

Table 3. Machinery and labour hire rates used in the experiment (US$)

Operation	Basins $ ha^{-1}	2WT DS $ ha^{-1}	4WT DS $ ha^{-1}	Animal DS $ ha^{-1}	CT $ ha^{-1}
Ploughing	0	0	0	0	75
Planting/basin digging/ direct seeding	35	50	50	40	40
Total	35	50	50	40	115

Source: Agritex and FACASI, 2017

Table 4. Specification of the Equipment Used in the Experiment

Equipment/model	Manufacturer	Type	Working width (m)	Source of power
Fitarrelli DS	Fitarrelli, Brazil	Single row mechanical DS	0.9	2 oxen
Mealie Brand	Zimplow Zimbabwe	Single bottom mouldboard	0.24	2 oxen
Fitarelli DS	Fitarrelli, Brazil	2WT drawn single row mechanical	0.9	2WT
Bental planter	Hast Zimbabwe	4-raw tractor drawn mechanical	3.6	4WT 80 hp
Hand hoe	Zimplow Zimbabwe	Multi-purpose	0.9	human
Diodong 2WT. Model ND10DE 8.75 kW	Diodong Industrial Company LTD, South Korea	Two wheel tractor	0.9	Diesel
Deutz D7206 50 kW	Deutz Manufacturing, Germany	Four wheel tractor	3.6	Diesel

Productivity and Profitability of Conservation Agriculture in Drylands of Kenya.

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Keywords: cost of production, inter-cropping, pure-stand, yields

Introduction

Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources—and with minimal impact on the environment (Hobbs 2007). Only by doing so can food production keep pace with demand, while the land's productivity is preserved for future generations. This is a tall order for developing nations where green revolution never took place and where GDP is driven by the agricultural sector that is also the highest source of employment and yet commanded by millions of its smallholder farmers and agribusiness industries. Crop and soil management systems that improve soil health parameters (physical, biological, and chemical) and reduce farmer costs are essential. This is because low production/ productivity is not being achieved due to high cost of farm inputs but also because of poor farming practices. However, today production increase must be accomplished sustainably, by minimizing negative environmental effects and, equally important, providing increased income to help improve the livelihoods of those employed in agricultural production. Hobbs (2007) identifies barriers to low crop productivity to be the inefficient use of resources at household level but more specially the human labour and farm inputs, which tend to be expensive during the crop-growing season. Lumpkin and Sayre (2010) observes that in order to confront the growing shortages of agricultural labor, a real problem even in the two most populous Asian countries (China and India), farmers need to consider the adoption of Conservation Agriculture (CA)-based technologies which, under most situations, can reduce labour requirements. Along with reductions in labor, in mechanized systems CA results in a marked reduction in the use of tractors and equipment, all of which cut fuel use, reduce both farmers' costs and GHC emissions. Generally, CA reduces tractor use by approximately 70 per cent, depending on the intensity of tillage in the conventional system (Wall et al, 2002). According to FAO, "CA aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture. Hobbs and Gupta (2004) in a rice-wheat system in relation to minimal soil disturbance, permanent ground cover, and rotation observed that yields were higher with no-till because of timely planting and better stands. Yield gains of 200-500 kg/ha were found in no-till wheat crop. Such yield gains have also been reported in other CA systems. One of the major benefits of CA, which makes it popular with farmers, is that it costs less in terms of money but also time. Farmers have estimated reduced costs of production to about US$ 60/ha, mostly due to using less diesel fuel, less labor, and less pumping of water. Since planting can be accomplished in one pass of the seed drill, time for planting is also reduced, thus freeing farmers to do other productive work.

Therefore, a study was conducted to evaluate the impact of cost reduction on a CA practices and grain yields in six semiarid counties of Kenya.

Methods

Whereas a project on increasing smallholder productivity and profitability through adoption of CA and other good agricultural practices targeted over 70,000 farmers from eight counties, this study identified 205 farmers from six counties and collected data on various cost during a production cycle for one rainfall season. The farmers involved in this study were at various stages of adopting CA practices. Some had whole farm under CA while others had only part of their farm under CA, meaning there was CA and non-CA fields within the same family farm. All these farmers were carefully identified and trained on data collection and recording regarding time taken for different operations,

labour used to undertake an activity, and cost of both the input and output variables in a crop growing season. Given the differences in rainfall reliability in different regions, in some counties data was collected during the March-May 2017 rainfall whereas in others during October-December 2017 rainfall seasons. Of the six counties, only two counties had their data collected during the October-December rainfall season. Under CA the crops were planted either as pure stand or intercrop of a cereal and a legume, while for non-CA (conventional tillage) mixed cropping was applied. Particular costs considered in the study included all costs from land preparation to harvesting i.e. cost of labour for tillage/minimum tillage, planting (main or cover crops), gapping, mulching, fertilizer applications, weeding, bird scaring, spraying (pesticide and herbicides), harvesting, threshing and storage. Besides these costs the farmer recorded the cost of inputs (herbicides, seed, pesticides, fertilize, sacks for storage, transport), management costs and recorded weights of both the grains and biomass, after removing the grains. An analysis of variance (ANOVA) using SPSS package was used to process the data.

Results and Discussion

Results from these study areas is shown in Tables 1 and 2. Cost of various farm activities and inputs are shown in Table 1 and the study shows significantly lower labour costs in CA farming than in conventional farming specifically during land preparation, planting, fertilizer application, weeding, and cost of fertilizer (quantity used). These results confirm the findings by others, that farmers who adopted CA concept under most situations observed reduced labour requirements in crop production while contributing to environmental conservation through resource-use efficiency or resource effective agricultural practices (Wall et al, 2002; Hobbs, 2007; Lumpkin and Sayre, 2010) These particular farming activities were mechanized ensuring lesser area of land getting disturbed during land preparation, planting (by using jab planter and no-till mulch planters) and chemical application. This implied comparatively lesser quantities of seed, fertilizers and herbicides/pesticide chemicals were expended. However, use of CA practices significantly had higher costs than conventionally farmed fields on labour for planting cover crops or in mulch placement (a practice that is not applied in conventional farming), and also during harvesting and threshing (possibly due to higher crop yields from CA thus more labour requirement). Another source of higher costs in CA was due to use of pesticides and purchase of packaging materials as a result of a higher yield of grains in CA than in conventional farms.

Table 2 demonstrated the impact of CA on productivity of the crops tested in the study. First, the analysis revealed that grain yield was significantly lower for CA pure-stand farms compared to the CA under inter-crop (± 4.53 kg/ha, p=0.00); and in conventional farming, the grain yield was significantly lower than in CA under intercrop (± 5.77 kg/ha, p=0.00). However, there was no statistically significant differences between the conventional and CA under pure-stand groups of farms (± 1.41 kg/ha, p=0.00).

Second, a similar pattern of statistical analysis was demonstrated on biomass assessment (i.e. crop biomass without the grains). Biomass assessment in CA farming is a critical product since these materials could be targeted for permanent soil cover or in extreme drought situations, these materials are important sources of fodder for livestock. The study showed that biomass yield was significantly lower in conventional farms compared to the CA under pure-stand (± 3.91 kg/ha, p=0.00); and also significantly lower for those applying conventional practices compared to those applying CA under intercrop (± 2.18 kg/ha, p=0.076). However, there was no significant differences between the CA under pure-stand and CA intercrop group (± 0.70 kg/ha, p=0.761). Finally, a further analysis to assess differentiation between treatments on the grand biomass yield, it was found that grand biomass yield was significantly lower for conventional farming compared to the CA under pure-stand (± 3.55 kg/ha, p=0.001); and also significantly lower for those applying conventional practices compared to those applying CA under intercrop (±4.28 kg/ha, p=0.000). However, there was no significant differences between the CA under pure-stand and CA intercrop group (±1.57 kg/ha, p=0.261).

This study demonstrated the benefits from CA concept of farming can contribute to smallholder productivity and eventually profitability besides ensuring that resources are utilized more efficiently and ecosystems are improved while supporting livelihoods of the aged, women and youths in agriculture. CA farming should be promoted given its demonstrated potential impact to lower the cost of production, increase yields and biomass for both livestock feeds and *insitu* generation of green materials for permanent soil cover to smallholders in semiarid lands of Kenya.

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Tables

Table 1: Cost of cropping activities and inputs in CA and conventional practices

	Cost (US$) in different farming practices		
Cost components	CA farms	Conventional farms	T-test
Labour for land preparation	53.7	63.6	**
Labour during planting	44.8	47.4	**
Labour for gapping and thinning	15.3	14.7	
Labour for planting soil cover crops/mulching	24.5	9.3	***
Labour for fertilizer application	23.9	42.9	**
Weeding/herbicide application	77.5	98.5	***
Labour for bird scaring	72.9	69.9	
Labour for pesticide spraying	26.2	22.9	
Labour for harvesting main crop	46.6	34.4	**
Labour for harvesting cover crop	19.0	15.3	
Labour for threshing main crop	25.6	19.8	*
Labour for threshing cover crop	5.1	5.4	
Cost of grain seeds	37.3	34.9	
Cost of fertilizer	135.2	140.3	*
Cost of pesticides	26.0	22.7	*
Cost of packing materials	11.9	6.0	**
Cost of transport	24.8	13.9	
Management costs	423.0	235.4	
Total Cost	1069.4	854.4	**
***=99%. **=95%; *=90%			

Table 2: Yield (Kg/ha) from different farming practices

	N	Grain yield (Kg/ha)	Biomass (Kg/ha)	yieldGrand biomass Yield (Kg/ha)
Conventional	100	1278.19	1861.99	3140.18
CA under pure-stand	74	1838.68	4154.86	5993.54
CA under intercrop	31	2694.25	3494.09	6188.35
p-level		0.00	0.0004	0.001

The Business Case for Conservation Agriculture for Smallholder Farmers in Ethiopia

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Keywords: Ethiopia, labor, resilience yield

Introduction

Ethiopian which is predominantly smallholder and rain fed in nature sustains livelihoods for more than 80 per cent of the population besides contributing to income, rural employment and foreign exchange earnings. In the face of changing climate with episodes of extreme droughts and floods undermines, the ability of cropping systems to sustain yield is highly compromised by low productivity leading to economic vulnerability and poverty. Soil degradation and erosion are prevalent in most parts of the country due to unsustainable cultivation practices, grazing and deforestation. In 2010, a project to increase farm-level food security, productivity was initiated. The project named Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) sought to protect natural resources by integrating conservation agricultural practices (minimum soil disturbance, multiple cropping of maize and legume, weed control) into sustainable intensification practices. In a series of on-station and on-farm adaptive research studies, the project tested and developed innovations for resilient and productive, sustainable smallholder maize-legume cropping systems for scaling out. This paper summarizes part of the resulting evidence base.

Materials and methods

Exploratory trials were established on research station and on-farms spread across regional states of Oromia, Amhara, Southern Nations Nationalities and Peoples (SNNP), Benishengul-Gumuz, and Somali Region. The data were collected using standardized template on land preparations practices, soil moistures, weed control, yield and costs. The trials assessed the effects of Conservation Agriculture based sustainable intensification (CASI) technologies on farm under farmers situations. The exploratory trials also served as learning centers for smallholder farmers and also for generating crop productivity and soil quality data. Long term on-station trials were established at agricultural research centers to generate comprehensive data on crop productivity, soil quality improvements and, soil and water conservation. Both the on-farm and on-station trials tested and evaluated CA tillage using an animal traction ripper (minimum tillage), crop residue retention and crop associations (rotations and intercropping), and improved maize and legume varieties. All trials were managed by local scientists in collaboration with international scientists.

Results and Discussion

Impacts on soil and biophysical aspects. CASI technologies enhanced water infiltration by 17% while soil organic carbon (OC) increase averaged 7% (Liben et al., 2018). Soil loss and water run-off measurements reconfirmed the superiority of CASI practices over conventional tillage systems. Water use efficiency in intercropped systems depended on the legume crop grown and the seasonal rainfall amount and its distribution. CASI based tillage reduced

soil loss by 79% and run-off by 59% respectively compared to the conventional ploughing practice at Bako (Table 1).

Effects on crop productivity. Based on on-farm and on-station results and averaged across SIMLESA sites, maize grain yield was increased by 17% under maize-legume rotation and 14% under maize-legume intercropping. Using CASI, common bean yield increased by 38% to 41% under water stressed conditions compared to sole cropping (Leben et al. 2018). Moreover, crop diversification reduced maize production risk when improved maize varieties were planted and/or chemical fertilizer was used. It also reduced the risk of crop failure, improved productivity and increased diversification of food sources for the farmers in the Central Rift Valley and Bako under Ulfisols.

Drought risk reduction. CASI provided extra resilience during growing seasons that had soil moisture stress. For instance, common bean rotation and intercropping with maize under CASI gave consistently higher maize yield than a similar cropping system under conventional practices in the Central Rift Valley of Ethiopia during a low rainfall during cropping season such as in 2012. Similar positive effects were documented at Bako (a high rainfall area) in western Ethiopia in the same year. Moreover, CASI practices resulted in higher maize yield compared to conventional practices in a drought year (Liben et al. 2017 and Abebe et al 2014).

Effect on labor. Based on survey data from Northwestern Ethiopia, study shows that minimum tillage practices reduce male and female labor use in maize production by 14.1 and 8.9 person-days per ha compared to an average of 26 person-days of labor under conventional tillage system required for weed control and management in maize cropping systems. In addition, demand for oxen draft power decreases by 13.9 pair of oxen days per ha. This could be attributed to use of one-pass furrow tillage for crop establishment and herbicide use in weed control. Thus, need to support farmers in in having access to credit facilities to pay for purchased inputs during the cropping season.

Financial benefits: CASI practices found to be more be financial profitable. As the practices of CASI increase the financial returns also boosts. For instance, CASI practice maize legume rotation under zero/reduce tillage had only a net income of 29 USD/ha while a more compressive application of maize-legume rotation, reduced tillage, and improved varieties resulted in a higher financial return of 323 USD/ha (Figure 1). Generally, CASI plots gave a higher financial return as compared to the conventional plots (Table 2).

Effects on food security. CASI Adopter farmers from Southern Ethiopia reported an increase in household food security by 32.6% and attain 49% of return on investment in maize and beans production through growing common beans twice using intercropping and relay cropping in the same season (Legesse et al 2017). In addition, the production of BH-546 (a hybrid maize variety) across locations compared to the already adopted BH-540 resulted in an additional of 1.9 tons of maize produced per ha.

Conclusion

The research in reported here has shown that CASI technologies generated a considerable body of evidence that demonstrates how a suite of CASI technologies can enhance productivity and incomes and protect biophysical resources in the longer-term. However, the optimal combinations of practices needed in different agro-ecologies in order to realize the benefits of CASI, will vary. The evidence generated by SIMLESA has contributed to mainstreaming CASI technologies in extension services. Policies and infrastructure that allow for timely provision of agricultural inputs (fertilizers, herbicides and improved seed) especially to poorer farmers are crucial to the uptake of CASI technologies. With more that 80 percent of the population involved in agricultural production, and with ongoing degradation of natural resources, CASI offers a pathway to sustainability and resilience for Ethiopia's farmers.

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Tables and figures

Table 1. Effects of Conservation Agriculture-based cropping systems on soil erosion at Bako Agricultural Research Centre (BARC) in Ethiopia.

Practice	Soil loss (ton $ha^{-1}yr^{-1}$)	Percent reduction in soil loss (%)	Sediment concentration (g/l)	Percent reduction in run off (%)	Productivity (t/ha)	Labour cost (USD‡)
Sole maize under conventional tillage (CP)†	18.92	0	66.7	0	2.66	125
Sole maize, mulch and minimum tillage (CA)	9.56	49	48.57	27	2.73	127
Maize-common bean intercropping and conventional tillage	4.69	75	38.23	43	3.07	166
Maize-common bean intercropping under CA	4.04	79	28.8	57	2.86	171

Note: †CP-Conventional practice practice; CA-Conservation agricultural practice where minimum tillage was applied.
‡ 1USD= 18.52 Birr (Ethiopian currency in July 2013)

Source: Abera Degefa, 2014

Table 2. Gross margin analysis in maize production by tillage package (North Western Ethiopia)

Items	Total plots *(N=590)*	CASI plots *(N=158)*	Conventional plots *(N=432)*
	Mean(SD)	Mean(SD)	Mean(SD)
Revenue			
Revenue from maize production *(USD/ha)* [a]	477(292)	50(346) ***	439(260)
Variable costs			
Seed cost *(USD/ha)*	26(77)	35(134) **	23(27)
Fertilizer cost *(USD/ha)*	206(104)	249(88) ***	190(105)
Herbicide cost *(USD/ha*	13(32)	49(46) ***	0
Labor cost *(USD/ha)*	79 (45)	62(37)	86(46) ***
Oxen-days *(USD/ha)*	38(24)	15(19)	46(20) ***
Total Variable costs *(USD/ha)* [b]	355(158)	7398(187) ***	339(143)
Gross margin (USD/ha) [(a-b)]	120(285)	174(368) ***	100(245)

Note: Average maize grain price was 0.232 USD/kg; opportunity cost of labor and oxen-power was estimated at 1.61USD/AE/day and 1.86 USD/pair of oxen/ha, respectively
***, **, and* aresignificantlydifferentfromtheothergroupmeanat1%,5%and10%, respectively

Source: SIMLESA/ Conservation Agriculture and Smallholder Farmers in Eastern and Southern Africa (CASFESA) baseline data

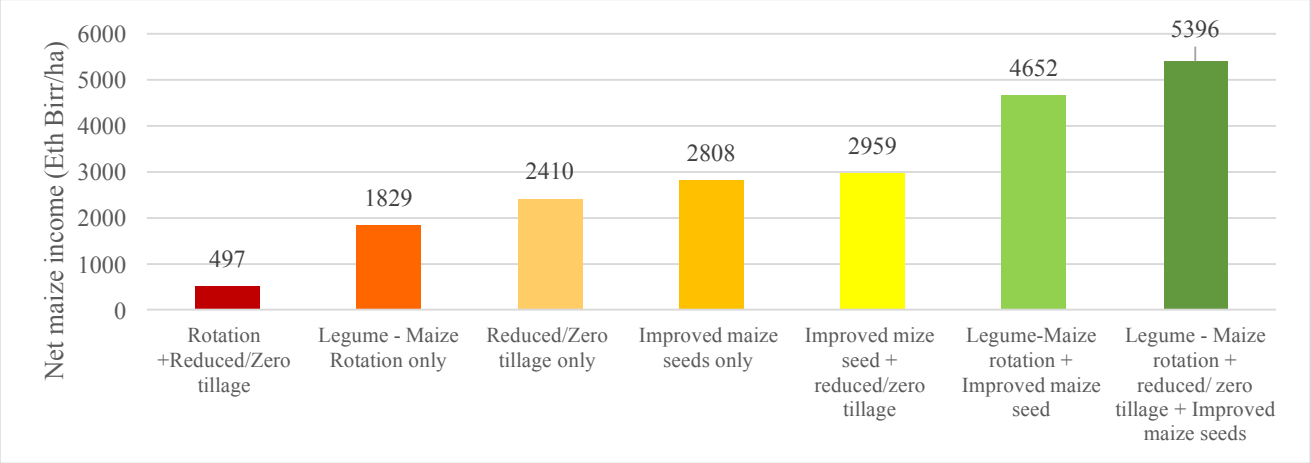

Figure 1. Net maize in come under different combinations of CASI-based SI practices in Ethiopia (SIMLESA Survey data); 1USD=17.29 Birr at the time of field survey

Assessing the Application and Practice of Conservation Agriculture in Malawi

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Keywords: on-farm trials, labor costs, factors affecting adoption, development of guidelines

Introduction

On-farm trials were conducted from 2004/05 to 2016/17 in Malawi to compare the benefits of Conservation Agriculture (CA) with conventional ridge tillage (CRT) practices in different agro-ecologies. Early experiences from these trials formed the basis to promote CA with smallholder farmers. The focus of this paper is 1) to document results of the on-farm trials; and 2) to assess key barriers and drivers affecting adoption of CA by smallholder farmers.

Materials and Methods

On-Farm Trials: On-farm trials were established in different agro-ecologies to compare maize and groundnut yields under CA with CRT. Each trial included 3 plots of 0.1 ha each: 1) sole maize under CRT without residues, 2) sole maize under CA with residues, and 3) maize intercropped with cowpeas or pigeon peas under CA with residues. In later years, groundnut yields were evaluated in rotation with maize by splitting the original plots into two. All plots were treated the same in terms of maize variety and spacing, date of planting, type and amount of fertilizer. Weed free conditions were maintained by hoe weeding in the CRT plots while CA plots included use of glyphosate before planting. Labour costs were based on a sample of 6 plots per treatment.

Summed over years, maize yields were assessed across a total of 624 plots per treatment. Yields of the legume intercrop were not taken into account in this paper.

Surveys to Assess Drivers and Barriers to Adoption: Early results from on-farm trials with CA provided a basis to develop preliminary recommendations for promoting the practice with farmers in areas where TLC was operating. Despite clear benefits and farmer interest in adopting CA, uptake was much lower than expected. This prompted Total LandCare (TLC) to undertake surveys to identify the underlying drivers and barriers to adoption (Mwale et al., 2014a&b). The surveys included interviews of 1360 smallholder households, practicing CA and not, spanning all 3 regions of Malawi.

Results and Discussion

Crop Yields from On-Farm Trials: Maize yields from season two were significantly higher across all sites for both CA treatments relative to CRT (**Figure 1**). Yield increases varied from 11% to 70% with greater differences in years of low rainfall (see also **Figure 2**). Groundnut yields were significantly higher under CA relative to CRT due primarily to the ability to halve the row spacing, which was not possible with ridging (see **Figure 3**). The reduced row spacing allowed for a more optimum plant population which effectively doubled yields. It also doubled ground cover, which likely reduced water runoff, although this was not measured.

Overall, the higher yields of cereals and legumes under CA indicate positive impacts on household food security, nutrition and income, especially in years of low rainfall.

Labour Costs: Labour data from the on-farm trials reflected a savings of 47% and 33% for sole maize and intercropped maize respectively under CA vs. CRT. The lower savings for intercropping is due to labour for planting and harvesting the legumes.

Drivers and Barriers to Adoption: Surveys by TLC identified several key benefits consistently reported by farmers across sites (Mwale *et al.,* 2014a &b). They included increased food security and yields, savings in labour, improved soil moisture during dry spells, improved soil health and increased income or savings in input and labour costs. Despite these benefits, uptake of CA has been slow in Malawi, which prompted TLC to assess barriers to adoption. The results revealed five key challenges for undertaking CA: 1) lack of adequate knowledge; 2) lack of labour or tools; 3) belief that CA offered no distinct benefit; 4) limited biomass to cover the soil, and 5) resistance to change. Details of the surveys are provided in the full paper.

Development of Guidelines for Implementing CA: Results of on-farm trials formed the basis to develop, print, and distribute practical guidelines for implementing CA in Malawi (Bunderson *et al.,* 2017; Ligowe *et al.,* 2013; Thierfelder *et al.,*2013, 2014, 2015; NCATF 2016).

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Figures and Tables

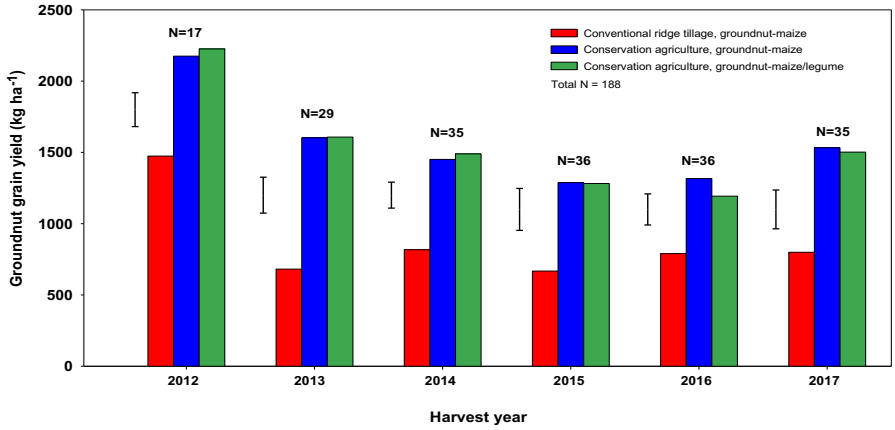

Figure 1: Mean Maize Yields under CA vs. CRT, 2004/05 to 2016/17 (p is significant between CA and CRT except 2005/06). Error bars are the Standard Error of the Difference (SED) of the means at p<0.05.

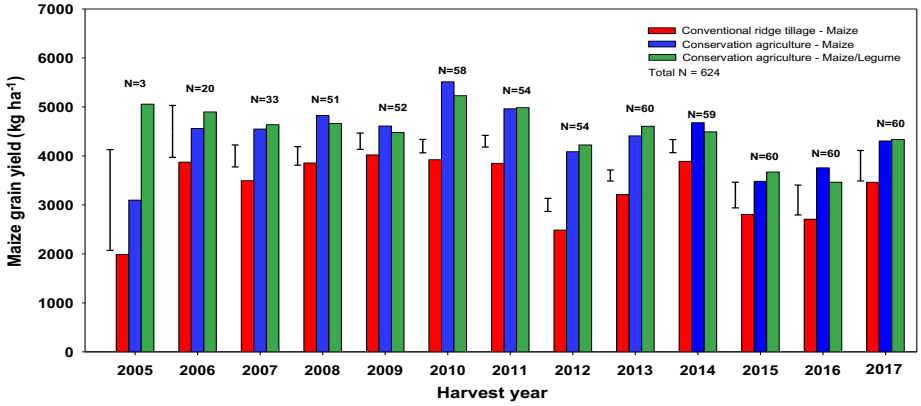

Figure 2: Mean Maize Yields under CA vs. Conventional Ridge Tillage (CRT) in a year of Low Rainfall, 2011/12. Error bars represent the Standard Error of the Difference (SED) of the means at p<0.05.

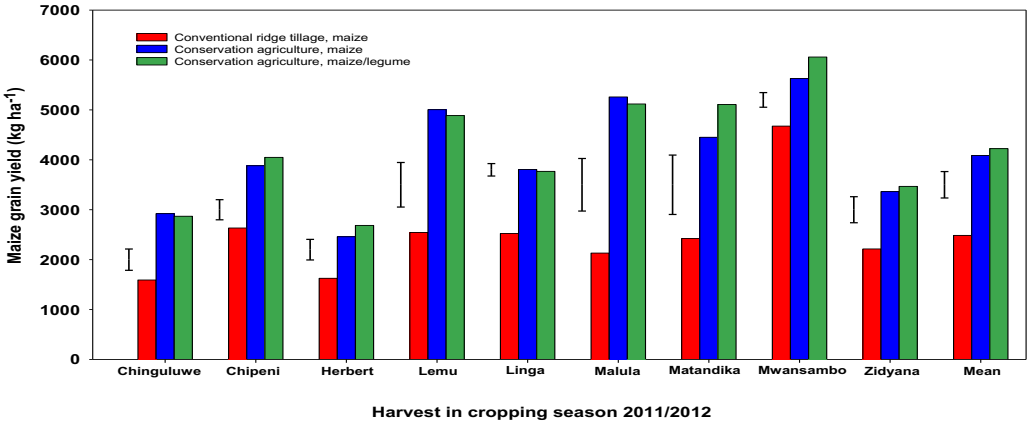

Figure 3: Mean Groundnut Yields after CA and Conventional Ridge Tillage.
Error bars represent the Standard Error of the Difference (SED) of the means at p<0.05.

Un Semoir de Semis Direct Sous Couvert Végétal à Traction Animale Adapté aux Conditions du Sénégal

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Mots-clés : conception, plante de couverture, semoir de semis direct à traction animale, Sénégal

Introduction

En Afrique de l'Ouest, la conception et l'adaptation locales de semoirs de semis direct de traction animale faciles d'utilisation et accessibles aux petits producteurs sont un des éléments favorables à l'adoption du semis direct sous couvert végétal (SDCV). C'est dans ce sens que l'équipe de FERT et AFDI Touraine a mis au point un prototype de semoir à traction bovine à 2 rangs pour appuyer les petits producteurs (Vadon et al., 2010). Mais malheureusement, jusqu'à présent, ces semoirs de semis direct introduits et testés au moins une fois dans la sous-région à l'image du semoir brésilien (Fitarelli) (Ashburner, 2004 ; Bozza et Kourouma, 2004 cité par Sissoko et Autfray, 2007) n'ont pas répondu aux attentes des agriculteurs à cause des densités de semis et à des doses d'engrais non régulières et à la maniabilité (Fert et Afditouraine, 2014). Aussi, les tests du prototype de l'AFDI (Agriculteurs Français et Développement International) n'ont pas été concluants à cause de sa lourdeur pour les animaux de trait et qu'aussi les adaptations faites pour son allégement et sa facilitation pour sa fabrication locale par les forgerons n'ont pas donné satisfaction (Sissoko et Autfray, 2007). Suite à ces expériences, des suggestions d'adaptation des semoirs aux conditions locales ont été faites pour le Sud du Mali par Sissoko et Autfray (2007) « *Il conviendrait également dans une optique d'avoir des semoirs plus simples et moins coûteux, sans épandeur d'engrais qui alourdit le système, de transformer le semoir local pour un semis de coton, du mil et du sorgho, en s'inspirant du semoir Fitarelli : rajout d'un disque à l'avant pour trancher la végétation, d'un soc juste derrière pour ouvrir la raie de semis, transfert du réservoir de semences au milieu, confection de roues plus haute*s ». Plus de 200 000 semoirs super éco sont utilisés au Sénégal avec les chevaux et les ânes au Sénégal, et quelques dizaines de milliers au Mali (Bordet *et al.,* 1988), c'est pourquoi les suggestions ci-dessus nous ont amené à proposer d'adapter le super-éco au système de semis direct sous couvert végétal permanent (SDCVP). L'objectif de l'article se limite à la conception locale d'un semoir de semis direct à partir du bâti du super éco. Ce qui signifie, un matériel qui peut facilement être fabriqué par les artisans qui fabriquent aujourd'hui les matériels de traction animale, et qui sera compétitif d'un point de vue prix avec les autres matériels de semis direct à traction animale importés. Les résultats sur les performances au semis en conditions réelles en particulier sur les rendements des cultures, seront les prochaines étapes d'évaluation de ce semoir de semis-direct.

Matériels et méthodes

L'étude a suivi le processus de la méthode « Expérimentation-Modification » (Havard, 1998) faisant intervenir plusieurs partenaires (demandeurs, constructeurs, centres d'expérimentation, etc.) et comprenant plusieurs phases successives (figure 1). Quand les conditions ne sont pas réunies pour passer d'une phase à la suivante, il est nécessaire de revenir en arrière (recommencer une partie du processus), (voir les flèches 1, 2, 3 et 4 sur la figure 1). Les dernières étapes (fabrication présérie, suivis et industrialisation) ne sont pas abordées dans cet article.

Un cahier des charges a été établi pour décrire les caractéristiques techniques (tableau 1) et opérationnelles du semoir de semis direct sous couvert végétal local. Le semoir de semis direct sous couvert végétal (semoir SDCV) doit pouvoir semer directement sur un sol avec une couverture végétale. Il doit pouvoir couper la couverture végétale pour permettre le passage du soc semeur et ensuite fermer la ligne de semis pour recouvrir les semences. Et enfin, il doit posséder un bâti suffisamment rigide pour supporter les efforts demandés pour les semis sous une couverture et avoir

un coût de production inférieur aux coûts des autres semoirs de semis direct à traction animale présents en Afrique de l'Ouest et proche du coût du semoir super éco.

Le logiciel Solidworks de conception assistée par ordinateur (CAO) a permis de réaliser les plans annotés des pièces et de leurs assemblages : dimensions, nom du concepteur, nom de son établissement, date de réalisation du plan et l'échelle utilisée. Le logiciel Solidworks génère des esquisses (draft de dessin) et des fonctions (coques, dépouilles, bossage, enlèvement de matières, répétitions etc…) appliquées sur les esquisses afin de leur donner une forme ou un volume. Il intègre un outil bibliothèque renfermant toute la boulonnerie les roulements, les chaînes etc… qui peuvent être utilisées dans l'assemblage du prototype.

Des enquêtes exploratoires auprès les établissements spécialisés dans la vente de matière première métal et les structures étatiques comme la douane sénégalaise ont été visités. C'est ce qui nous a permis d'avoir les éléments économiques afin de pouvoir estimer le cout de production du semoir SDCV.

Les tests de performance ont été effectués à la station de recherche de l'ISRA[4] à Nioro du 26 au 27 juillet 2016 en saison pluvieuse sur un sol "dior" (sablo-limoneux), préalablement humidifié sur 20 cm de profondeur coïncidant avec une pluie utile d'au moins 15 mm. Un dispositif en bloc complétement randomisé de 12 parcelles élémentaires de 10 m de côté soit 100 m2 chacune, dans lequel avec trois répétitions de chacun des quatre traitements dont les traitements de couverture végétale contenaient trois espèces de brachiarias importées du Brésil à Barreiras situé à l'Ouest de l'Etat de Bahia (*Brachiaria ruziziensis*, *Brachiaria decumbens* et *Brachiaria brizantha*) a été implanté. Dans les parcelles témoin labouré, on a fait passer le semoir super éco et dans les parcelles en culture associée (mil+ brachiaria), on fait passer le semoir SDCV.

Résultats et Discussion

Une des principales exigences de la méthode ''Expérimentation-modification'' est de favoriser un dialogue permanent entre la recherche d'appuyer ou suivre l'artisan dans l'exécution correcte du contenu du cahier des charges élaborées jusqu'à la fabrication d'un prototype (figure 1). Ce dialogue permanent a abouti à des propositions d'amélioration du prototype, et donc à quelques modifications du cahier des charges : i) renforcer le châssis du semoir pour résister aux sollicitations, aux obstacles et aux chocs dus à la présence de résidus de récolte, de souches et pierres qui peuvent déformer le châssis, ii) changer les roues plombeuses du semoir super éco par des roues plombeuses lestées et montées à l'extérieur.

Une conception d'un prototype de semoir SDCV répondant au cahier des charges a été réalisée dont les caractéristiques techniques ont été décrites et son prix de revient a été évalué. Sur la base de ce cahier des charges, une maquette numérique (figure 2) réalisée avec le logiciel Solidworks a été présentée à l'artisan retenu pour sa fabrication. Les modifications suivantes ont été faites au cahier des charges :

Semoir doit être conçu à partir du bâti du semoir super éco très utilisé au Sénégal et être suffisamment rigide pour supporter les efforts demandés pour les semis dans une couverture végétale ;

Le bâti du semoir a été renforcé par un fer plat 30 x 10 au lieu du fer plat 30 x 8 et rehaussé en remplaçant les roues motrices de 40 cm de diamètre par des roues de 50 cm de diamètre en fer plat de 40 x 6 afin d'éviter les obstacles (couverture vivante ou morte, débris etc…). Mais augmenter la hauteur des roues du semoir qui entrainent le système de distribution se traduit par une réduction des densités de semis. De nouveaux disques semeurs ont été fabriqués pour obtenir les densités de graines recommandées avec l'utilisation de la nouvelle roue motrice.

[4] ISRA : Institut Sénégalais de Recherches Agronomiques

Semoir doit pouvoir semer directement sur un sol avec une couverture végétale, c'est-à-dire qu'il doit couper la couverture végétale pour permettre le passage du soc semeur, et ensuite fermer la ligne de semis pour recouvrir les semences ;

Un disque coupeur crénelé (tôle acier de 2) de diamètre 28 cm a été fixé à l'avant train du semoir grâce à une fourche en fer plat de 30 x 6 permettant de couper les débris et d'ouvrir le sillon facilitant le travail du soc semeur. Ce dernier a été renforcé par une tôle de 4 plus forte et plus rigide que celle du semoir super éco (tôle 2). Ce soc semeur est capable de résister aux chocs et aux déformations avec une extrémité en forme de bec permettant d'attaquer et de pénétrer facilement le sol sous couverture végétale. La configuration de la roue plombeuse lestée de 5 kg montée de l'extérieur vers l'intérieur en forme de V remplit aussi la fonction des rasettes. Elle assure ainsi la fermeture du sillon de semis, et tasse la terre sur et autour du sillon de semis.

Semoir doit demander des efforts de traction compatibles avec ceux des animaux de trait disponibles

L'élimination des rasettes diminue l'effort de pénétration en profondeur du sol et réduit la puissance de traction nécessaire pour tirer le semoir. Les chevaux et les ânes au Sénégal ne sont pas assez puissants pour tirer le semoir. Ce sont des paires de bovins qui seront utilisées.

Semoir doit pouvoir être fabriqué et assemblé dans les ateliers des artisans locaux pour la majorité des pièces et accessoires ;

L'ensemble du semoir a été fabriqué par l'artisan à l'exception du mécanisme de distribution du semoir super éco. Le disque distributeur, bloqué en position sur le plateau par deux ergots, un ressort et un écrou molleté, entraîne dans son mouvement rotatif les graines vers la lumière de sortie, où elles sont éjectées dans la goulotte de descente par un éjecteur fixé sur la cloison.

La collaboration entre l'ISRA et un artisan a permis de fabriquer avec les matériaux disponibles localement un prototype de semoir SDCV à partir du semoir super-éco et répondant au cahier des charges élaborées. Ainsi, ce semoir mis au point dispose des mêmes composants comme les autres semoirs de semis direct à traction animale comme le semoir de semis direct Fitarelli ou du semoir de semis direct à traction animal équipé de deux disques d'ouverture (Sims et al., 2018) à l'exception du système d'épandage d'engrais. En effet, le semoir de semis direct à deux disques ouvreuses incorporé à un système d'épandage d'engrais est équipé de deux disques ouvreuses, d'un disque coupeur de résidus de paille et d'un système de fermeture des grains et des engrais déposés dans le sillon en forme de V (Sims et al., 2018). Bon nombre de semoir de semis direct sous couvert à traction animale ont été conçus sur ce même principe de fonctionnement comme l'ont évoqués par certains auteurs dans leurs travaux comme Bourarach (2011).

Le cheval utilisé sur le sol labouré déploie un effort de 43,7 daN compris entre 40 et 45 daN et sur les parcelles ayant un couvert végétal des efforts de 70 à 80 daN (tableau 2), et qui sont nettement au-dessus des efforts de traction du cheval pour un travail continu (Vall, 1998). C'est pourquoi, ce semoir ne peut être ni tiré par un cheval ou un âne.

Le coût de fabrication artisanale du semoir SDCV (205000 Fcfa) (tableau 1) est inférieur au coût du semoir super éco sorti de l'usine SISMAR[5] (237000 Fcfa) (MAER[6], 2015). Son coût reste aussi inférieur à celui du semoir AFDI (300000 Fcfa) mais est supérieur au coût de fabrication du semoir/épandeur de semis direct de marque brésilienne (Fitarelli) (120000 Fcfa) (Sissoko et Autfray, 2007).

[5] SISMAR : Société Industrielle Sahélienne de Mécanique, de matériel agricole et de Représentation.

[6] MAER : Ministère de l'Agriculture et de l'Equipement Rural

Ce semoir doit maintenant être expérimenté en conditions réelles. La fabrication du semoir SDCV construit par un artisan local n'est pas encore standardisée. Aussi, nous envisageons d'étudier la standardisation de la fabrication du semoir avec un industriel qui fabrique au Sénégal les matériels de traction animale (SISMAR). Son coût de production, bien qu'inférieur à certains semoirs de semis direct importés, s'avère encore trop élever pour les agriculteurs du Bassin Arachidier. Des mesures incitatives (subventions, exonération de taxes) seront certainement nécessaires pour envisager sa diffusion.

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Figures and Tableaux

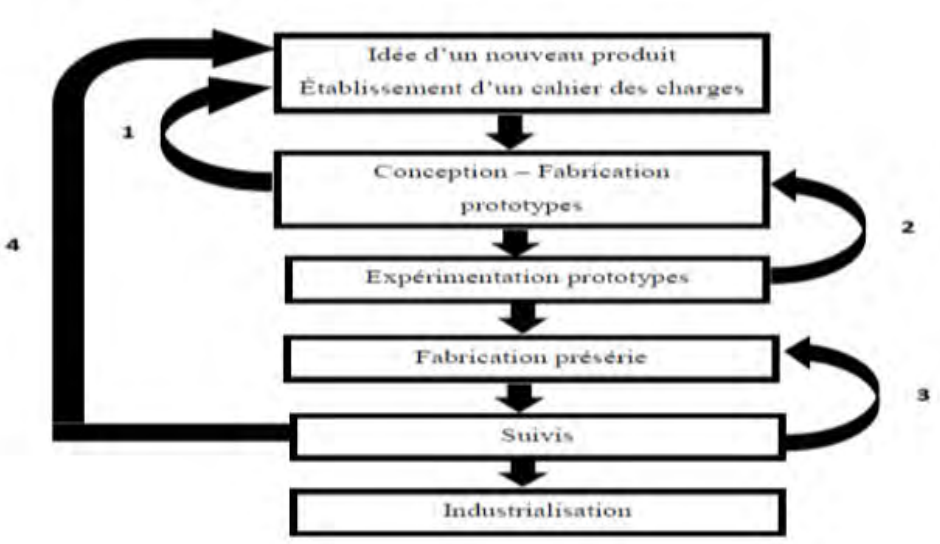

Figure 1. Description des différentes étapes de la méthode « Expérimentation-Modification » (Havard, 1998)

Figure 2. a (à gauche) et b (à droite). Figure 2 a. Vue latérale du prototype de semoir SDCV sous Solidworks. Figure 2 b. Le prototype réalisé par l'artisan retenu

Tableau 1. Coût de production du semoir de semis direct sous couvert végétal permanent version Super Éco

Matière première	Type	Partie du semoir	PU en TTC	Quantité	Unité	Montant en TTC
Fer plat	30 x 12	Gorge	2068,97	0,52	m	1075,86
	30 x 10	Cadre	1668,10	2,3	m	3836,64
	30 x 8	Soc-semeur	1362,07	1,1	m	1498,28
	30 x 6	Disque cisaille	878,45	0,42	m	368,95
	40 x 6	Roue avant	1206,90	3,14	m	3789,66
	25 x 10	Bras	879,31	2,14	m	1881,72
	25 x 6	Disque cisaille	750,86	0,15	m	112,63
	20 x 5	Contre-bras	1206,90	1,27	m	1532,76
Fer rond lisse	10	Soc-semeur	689,66	0,08	m	55,17
	8	Rayon roue avant	551,72	3,57	m	1969,66
	3	Ressort	275,86	0,15	m	41,38
Fer rond plein	40	Moyeu roue avant	7500,00	0,12	m	900,00
	20	Axe roue avant	3200,00	0,44	m	1408,00
Cornière	35 x 35	Support du traceur	1508,62	0,4	m	603,45
Tôle	5	Plaque de fond de carter	42000,00	0,8	m	33600,00
	4	Disque commande, roue plombeuse, soc-semeur	32500,00	0,6	m	19500,00
	3	Carter	27750,00	1	m	27750,00
	2	Disque cisaille	21000,00	0,88	m	18480,00
	1	Trémie	19500,00	1	m	19500,00
Tube rond	30	Poignet	1324,14	0,24	m	317,79
Boulons	12 x 100	Roue plombeuse,	400,00	3	u	1200,00
	12 x 40	Support soc-semeur	209	2	u	418,00
	12 x 30	Fixation du soc semeur sur le cadre	177,00	2	u	354,00
	10 x 30	Support roue plombeuse	130,00	4	u	520,00
	8 x 50	Fixation disque cisaille sur le cadre	110,00	5	u	550,00
	8 x 30	Fixation de la plaque fond de carter avec la trémie	66,00	4	u	264,00
	6 x 30	Fixation du fond de trémie avec trémie	43	7	u	301,00
	5 x 20	Support goulotte de descente	20,00	2	u	40,00
Vis H	8 x 20	Fixation de la plaque avec fond de trémie	150,00	2	u	300,00
	6 x 11	Fixation disque de commande avec axe des disques	100,00	1	u	100,00
Aluminium	5	Roue plombeuse	850,00	10	kg	8500,00
Roulement	6203		1500,00	1	u	1500,00
Pignon	8		750,00	1	u	750,00

Disque de commande	24		1250,00	1	u	1250,00
Electrode enrobée	Ø 2,5		25,00	20	u	500,00
Disque à meuler	Ø 115		1500,00	1	u	1500,00
Diluant	1L		700,00	3	l	2100,00
Graisse			5225,00	0,3	kg	1567,50
Peinture	1kg		2000,00	1	kg	2000,00
Coût de la matière première (TTC)						161936,44
Coût de la main d'œuvre (TTC)						15000,00
	Location					5000,00
	Electricité					15000,00
	Eau					0,00
	Transport					5000,00
	Gardiennage					0,00
	Communication					3000,00
	Autres					0,00
Fonctionnement	Coût de fonctionnement (TTC)					28000,00
	Coût de production du matériel sortie d'usine (TTC)					204936,44

Tableau 2. Résultats des essais de mesures de puissance de traction et de vitesse avec le semoir de semis direct sous couvert végétal permanent et un cheval selon les différents traitements

Variables mesurées	RuzSDCV	DecuSDCV	BrizSDCV	Labour-super éco
Vitesse (V) (km/h)	3,53[a]	3,6[a]	3,56[a]	3,31[a]
Valeur de P	0.872			
Force (F) (daN)	78,15[b]	71,11[b]	80,74[b]	43,70 [a]
Valeur de P	0.0001			
Puissance (P) (Watt)	760 [b]	710 [b]	800 [b]	400[a]
Valeur de P	0.0005			

Les traitements ayant la même lettre ne sont pas significativement différents selon le test de Tukey (p-value > 0,05).

Légende :

RuzSDCV : *Brachiaria ruziziensis* + Semoir Semis direct version super éco ; DecuSDCV : *Brachiaria decumbens* + Semoir Semis direct version super éco ; BrizSDCV : *Brachiaria brizantha* + Semoir Semis direct version super éco.

Smallholder Conservation Agriculture Mechanization Prospects in Chobe District, Botswana.

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Keywords: crop rotation, ripping, smallholder farming, two-wheel tractor, weeding,

Introduction

There is a Nigerian Proverb that states, "A farmer who would not work inside the rain, would not work under the sun and would have nothing to harvest at the end of the farming year". True to this saying, there is an elite squadron of farmers in Chobe West in Botswana, who are determined to produce crops despite a number of challenges, which are facing the arable sub-sector. Some of the challenges according to National Development Plan 9 (2003) are endemic drought, unfavorable agriculture conditions (poor soils), low rainfall, poor farming practices, low adoption of technologies to enhance productivity, and lack of security of land tenure. The Bio-Chobe project, which was funded by the United Nations Development Programme (UNDP) in 2015, donated agricultural machinery and implements in the premise to increase food production and security in Chobe district. The aim of the project was to mitigate increasing threats to bio diversity in Chobe district including climate change and poaching. As part of the Bio-Chobe project, scaling out activities were facilitated by supplying farmers with Conservation Agriculture (CA) equipment and were encouraged to adopt modern farming practices such as minimum tillage, crop cover and crop rotation to reduce the impact of climate change.

Material and Methods

During the 2016/17 crop cultivation season, the Department of Crop Production in Chobe District carried out Conservation Agriculture demonstrations. The purpose of the demonstrations was to transfer technologies towards farmers that would enable them to combat Climate Change in Agriculture. A gender mixed farmer group of 30 farmers volunteered to experiment the ripping technology that is achieved by penetrating the soil profile to a desired depth with a tine implement to enhance profile water holding capacity through breaking compaction layer that inhibit entry of water in to the soil and weed control using herbicides. A total area of 60 hectares was ripped, which was minimum soil disturbance, and weeds were managed using herbicides. Glyphosate, a broad spectrum herbicide applied pre planting at the rate of 1L/ ha, Atrazine at 3L/ha, 2,4D cocktail for post plant broad leafed weeds at the rate of 0.5L/ha and S-Metolachlor at 3L/ha for control of pole emergence perennial grasses. Out of the total area, 52 ha was planted with maize (*Zea mays*) using a mechanical planter. Participating farmers were guided by the local extension officers and the farm mechanization officers from the department of crop production. Subsequently the success of these demonstrations led to a series of events, which were the farm walks and further farmer training to embrace more farmers and to reemphasize on the concept of CA so as to attain better adoption. Among the farmer training the Chinese made 12 HP, single axle two-wheel tractor (2WT) from UNDP was the solution to address shortage of farm power and climate smart implements.

Results and Discussion

The 2WT was observed to be convenient for small fields. It was driven by a single person who either walks behind it or rides on the attached implement from the sluts depending on the implement that was attached. The configuration of the 2WT consists of a simple and compact structure mounted on two driving wheels. A 12 HP engine drives a single axle directly which in turn drives the wheels. It has 8 gear combinations, 6 forward and 2 reverses for an operator to select from. The DF-12L module weighs 353 kg. The 2WTs having suitable hitching points to attach with compatible implements such as single row planter, a single row ripper, a boom sprayer, rotovator, a plough and

trailer. The 2WT is fuel-efficient due to the fact that it is attached to a single unit of a ripper-planter. In this case, the 2WT goes through the field just once, reducing the number of field operations from two to one. This is advantageous for subsistence farmers who could save crop cultivation costs. The name "walking tractor" is a combination of two verbs, walk and pull. According to Macmillan (1971) "The word 'traction' and tractor comes from word to draw or pull'. Hence, the name "walking tractor" was conceived.

Farmer perception

Farmers were very impressed by the tenacity of crop stand in the fields, the plant health status and usage of hybrid seeds in the farm walk. In the farmer's training programme, they were impressed by machinery calibration, usage of organic fertilizers and rain forecast to complement agriculture.

Mr. Chibeya Longwane, a subsistence horticultural farmer from rainfed area of Muchenje (Mabele/ Kavimba Extension Area) made the following comments concerning the 2WT; the 2WT is generally observed to be a viable option for small-scale irrigated production (horticulture). "The 2WT is a wonderful machine. When used for ripping and planting, it was quite clear the tractor's power is very accessible and available at any given time," he said. The tractor drawn power is very good compared to work animals. Animals have to graze or be fed in order for them to work both in off and on season. Lonnemark (1967) argues that time of planting has an influence on yield; planting at the correct time gives higher yields than planting early or too late. He further argues that, farmers are unable to complete cultivation within optimum planting timeframe, particularly when the land is dry. He suggests that in that condition, it is better to hire tractor (e.g., 2WT) service to improve quality and timeliness of field operations. It is a normal trend that farmers shift from animal draft power to tractor power due to a number of factors. Mr. Longwane while operating the walking tractor was able to rip and plant two ha in a day; one ha in early morning hours and the remaining 1 ha in the late afternoon. In between the operation, he rested to prepare himself for the next scheduled operation. In total, he ripped and planted seven ha. The work rate of the 2WT was about 3 hours per hectare to rip and plant. At this rate a total of 7 ha was worked over several days working 3 hours; then resting for 1 hour before completing another 1 ha in 3 hours. The average working depth was 15 cm. Mr. Longwane concluded by stating that "The 2WT is a versatile machine; it can be used for Smart Agriculture as well as conventional tillage. It is very convenient for farmer because it is faster than work animals".

During the 2015/16 farming season a total of 77 ha was ripped by 30 smallholder farmers. Ten (10) ha had weeds managed with a hand hoe, while 63 ha had weeds managed by a combination of post spray and hand hoe techniques. As detailed in table 1, only three ha was fully controlled by post spray technique.

By 2016/17 farming season, there was an increase in harvest amongst target farmers. More smallholder farmers were attracted to CA technologies. There was an increase in the amount of area that was ripped from 77 ha to 97 ha. The technology of post spray and hand hoe increased from 63 ha to 80 ha. One of the successful farmers Mr. Jacob Mahere testified that, he has managed to harvest 3,920 kg of sorghum and 2,660 kg of maize. The gross yield of the cereal crop was 3.29 tons/ha. This is a substantial high amount compared to Convectional Tillage which yields 1.5 tons/ha of cereals.

Under the 2017/18 season, ripping technique adoption remained steady at 97 ha. More farmers moved from weed control by hand hoe to post spray technique. There was an increase from three ha to 97 ha. In the field of ripping technique, the walking tractor assisted three farmers to rip and plant 2.25 ha. This was a huge milestone in Conservation Agriculture in the district.

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Tables

Table 1: Percentage of adopters within the trained farmers practicing aspects of CA in Chobe District.

No	CA Technique	Percentage practicing			Total CA practicing
		2015/16	2016/17	2017/18	
		(30)	(30)	(30)	
1	Ripping	77	97	97	
2	Weed control-hand hoe	10			
3	Post spray + hand hoe	63	80		
4	Spray	3		97	
5	Crop rotation		20		
	Area (hectares under CA	60			
	Average household area (ha)	9.25			67%

Mechanised Cassava Production and Harvesting on Ridges – A Conservation Agricultural Approach

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Keywords: cassava, mechanised production, ridges, harvesting,

Introduction

Cassava (*Manihot esculenta* Crantz) is an important food security crop with its roots providing dietary carbohydrates for over 800 million people (FAO, 2013). Africa is the leading cassava producer in the world with Nigeria, Ghana and DR Congo as the top three producers on the continent. However, Africa's share of the global cassava export market is negligible. Unlike Africa, Asia encourages the development of cassava crops for industrial and energy purposes. In China, cassava has been listed as one of the main raw materials that can be used for ethanol production and animal feed in future (Chengyu *et al*., 2010, Zhiguo *et al* 2008). Challenges to commercialise cassava in Africa include small, fragmented and dispersed farms, aging labour force, aversion of the youth to agriculture, low level of mechanisation technology inputs (Kolawole *et al*., 2010), the predominant random and haphazard planting rather than planting on ridges and drudgery in manual harvesting when the ground is hard (Amponsah, *et al*., 2014, Bobobee, *et al*., 2014). The most difficult and time consuming operation in cassava production is harvesting (Yulan, *et al* 2012, Agbetoye 2005, Nweke *et al*., 2002). Mature cassava stems even when planted in rows on the flat do not follow a straight line and they tend to confuse the tractor operator during harvest leading to increased root damage. Planting on ridges give higher root yield (Ennin, *et al*., 2009). Ridges serve as guides during mechanised operations such as weeding, spraying and harvesting even in the most severe erosion and dry soil conditions (Bobobee, *et al*., 2014). The furrows improve rapid flood water evacuation during heavy rains and retain moisture during periods of low precipitation. Ridging enables mechanise cassava farming to expand in areas where cereal crops are failing. Cassava is tolerant to erratic and hot weather conditions and can thrive on marginal lands, where other crops fail. Stepping-up mechanisation and engineering inputs among smallholder farmers will expand cassava production for food security, animal and fish feeds, industrial use and export crop to make cassava a multi-billion-dollar commodity in Africa.

Objective The main objective in this study was to promote mechanised cassava production and harvesting on ridges as a conservation agricultural and climate-smart approach. Specificobjectives included the demonstration of planting cassava on ridges and on the flat to compareroot damage, introduction of mechanical harvester and drudgery evaluation in manual andmechanical harvesting in Ghana and South Africa.

Materials and Methods

Sites. Cassava field experiments were established on ridges and on the flats for mechanised operations in two countries, Ghana and South Africa from 2009 to 2015. The Ghana study sites were located at Anwomaso (6°41'56.75"N, 1°31'25.85"W) 274m above sea level in the Kwame Nkrumah University of Science and the Technology (KNUST) in the forest zone, and Akatsi (6° 8'40.50"N, 0°49'22.05"E,) 57m above sea level in the southeast coastal savannah. These locations were selected based on their potential for higher cassava production levels on commercial basis (Bobobee, et al., 2014). Soils in Anwomaso are mainly Forest Acrisols and Akatsi has Savanna Cambisols (FAO/UNESCO, 1998).

In South Africa, two project sites were selected in Limpopo and Mpumalanga provinces. The Limpopo field was located at the University of Venda Experimental farm, Thohoyandou in the sub-tropical Vhembe district (22° 58′ 57″ S, 30° 26′ 25″ E), at an elevation of 595 m asl. The climate at Thohoyandou is characterized by moderate temperatures

(15° C- 24.5° C), high relative humidity (52.3 -81.1%) and moderate to high rainfall regime (1069.3 mm). The Limpopo field has *Shordlands* soil series with high clay content and classified as Nitisols (FAO/UNESCO, 1998). The Nelspruit site (25° 27′ 21″ S, 30° 59′ 49″E) in Mpumalanga is characterised by deep, well-drained loamy sand soils of the *Glenrosa* series and classified as Cambisols (FAO/UNESCO, 1998). The Nelspruit site is located on the Agricultural Research Council's Institute for Tropical and Sub-tropical Crops (ARC-ITSC) orchards. Both areas (Univen and Nelspruit) are dominated by a Savannah biome with a vegetation type of sour lowveld bushveld.

Seedbed preparation field layout and crop establishment. The fields (one ha minimum) at all sites were deep ploughed to be free from hidden obstructions and ridged according to Bobobee *et al*., (2014). Ridges were constructed with an average height of 0.3m and spaced 1.2m apart (crest to crest) to accommodate the tractor track width (Figure1). Intra-row plant spacing was calculated for an optimum plant population density of 10,000 plants/ha. Cassava stakes were cut into 20-25 cm length with 8-10 nodes and planted at an inclined angle of about 30-60° to the vertical with half of the length buried in the soil.

Soil mechanical analysis. Soils were sampled at random locations at the corners and mid sections of the fields to measure soil penetration resistance, bulk density and moisture contents in the 0-40 cm layer at 10 cm intervals as reported by Amponsah, *et al.,* (2014).

Crop care and farm sanitation. All the fields planted were on long term fallow lands and no organic or inorganic fertilisers were applied to the cassava in either country. In addition to the pre-emergence chemical weed control on all fields using glyphosate, weeding was mainly by manual hoeing very regularly depending on weed infestation levels. Farm boundaries and access roads were occasionally sprayed with herbicides. Fields were maintained clean close to harvesting time to minimise residues clogging the harvester.

The TEK mechanical cassava harvester. The fully-mounted mechanical cassava harvester with a slatted conical mouldboard without any transport system (Figure 2) developed in Ghana was used to operate on the "dig and expose" principle. Mechanical harvesting was done using the TEK mechanical harvester and compared with manual harvesting, which was done with bare hand, the hoe and cutlass to determine root damage and capacity. Harvesting of the cassava was done at the various sites at 15 months after planting (15 MAP) during the dry season, a period more favourable for mechanical cassava harvesting but quite difficult for manual cassava harvesting. Before harvesting mechanically, the cassava plants were manually coppiced to a stalk level of about 20 cm to allow the stems to serve as handles in pulling the harvested roots. Coppicing also allows the tractor to pass over the plants without damage, and to help the operator to move in a more accurate path during harvesting. As previously mentioned, the plots were maintained clean from weeds prior to harvesting to prevent debris from blocking the digging unit of the harvester and increasing implement draught. When the soil is moist and sticky, the slatted conical mouldboard sieves the soil clods and reduces adhesion. This helps accelerate the harvesting process and increases the efficiency of the harvester.

Drudgery evaluation in harvesting. The heart rates of manual workers and tractor operators were measured at rest before work, during work and after work (recovery) at a sampling rate of 5s interval. The mounting, installation and performance of the heart rate sensor and monitor are shown in Figure 3 and described in greater detail, by Bobobee and Girma (2007). Since heart rates and energy consumption are strongly correlated, corresponding energy consumption values were used to calculate the mandatory rest periods required for each operation.

Root damage. Cassava root damage caused by the harvesting method and tools was assessed quantitatively after harvesting and percentage damage computed. From both the farmers and processors perspectives, cassava root damage was assessed when the roots do not come out whole after harvesting but with cuts and bruises that could render them unsuitable for storage. Cassava roots deteriorates within 2-3 days after harvesting (Bayoumi *et al*, 2008) and in an even shorter time for root tubers with bruises or cuts.

Results and Discussions

Soil physico-chemical properties. The soil chemical and mechanical properties at land preparation at all sites and at harvest at the Ghana and South Africa were analysed and found to be strongly acidic up to 60 cm depth. With such acidity levels, important soil nutrients such as Potassium and Phosphorus will not be easily available for plant growth (Brady and Weil, 1996). Relatively high root yields were obtained at 15 MAP confirming that cassava can be cultivated in poor soils with pH ranging from 4.4 – 6.0 without adverse yield loss, which agrees with the findings of O'Hair, (1995), Philippine Root Crops Information Service, (2005) and Okigbo, (2007) that cassava can survive in poor soils.

In South Africa, soil organic carbon was generally higher (<3%) at the Venda site but lower (<1%) at Nelspruit sites within all horizons (0-60 cm). Low Cation Exchange Capacity (CEC) (1.9 - 18 me/100g) and very low (<5 me/100g) indicate low to moderate levels attributable to plant uptake as well as to leaching and soil erosion.

The mechanical cassava harvester. The harvester uproots one plant/second compared to 5-10 minutes/plant by manual harvesting. This translates into a work rate of harvesting one hectare in two hours by one tractor operator and a team of 10 workers or fewer, compared with 80-104 manual harvesters per hectare per day (Figure2). Root damage with mechanical harvesting is lower than manual harvesting when the soil is hard. Mechanical harvesting leaves the field effectively pulverised and in friable soils, makes the field ready for ridging and planting. The savings in labour and fuel costs when using the ridging technology and the mechanical harvester makes the investment in the technology profitable, user and environmentally-friendly and sustainable. Farmer education and tractor operator training in farmers' environments, on demonstration farms and farmer field days are proposed to create awareness on mechanisation technologies for cassava and other root and tuber crops on the continent.

Drudgery evaluation in harvesting. Figure 3 shows the heart rate profiles of manual worker and tractor operator when engaged in cassava harvesting. The profiles for the manual harvesting were 60% higher than for mechanical harvesting. From the Figure 3, the highest heart rate for the tractor operator corresponds to the average resting heart rate profiles for the manual harvesters, confirming the high drudgery levels in manual harvesting. The higher the heart rate, the higher the energy consumption and to protect the worker, longer rest periods to recuperate are needed.

Root damage. After mechanical harvesting, mean root damage in Ghana were 10 – 12% and 19% for ridged and flat fields, respectively as shown in Fig. 4. The lower root damage on the ridges compares favourably with results of 10-23% obtained by Bobobee *et al.,* (1994) and Kolawole *et al.,* (2010) with other mechanical harvesters. Generally, higher root tuber damage values could be attributed to high residue cover and moisture content at harvest that make the harvester to float and decrease its penetration especially in non-scouring soils .

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Figures

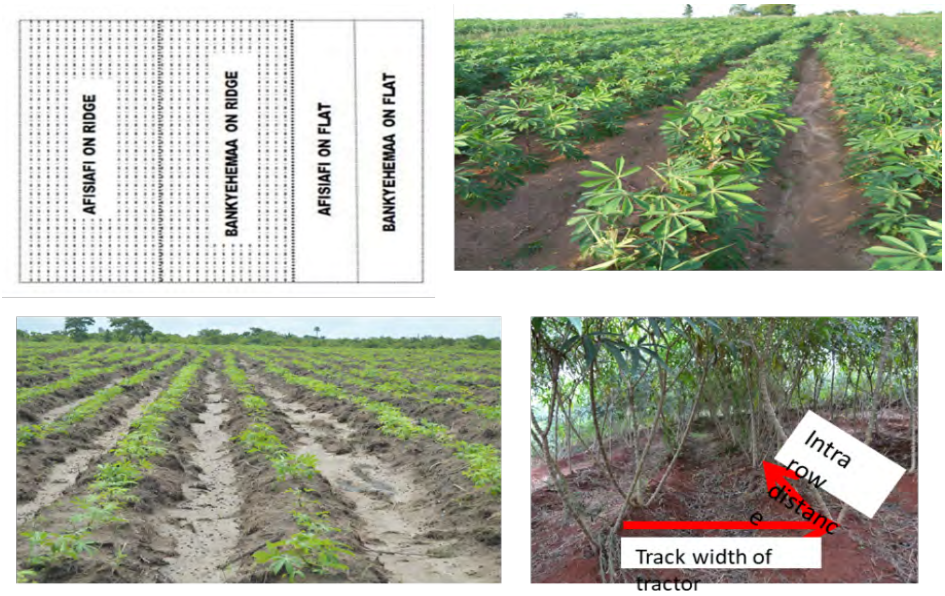

Figure 1. Field layout on ridged and flat landforms on cassava farms in Ghana and South Africa.

Figure 2. Manual and mechanical cassava harvesting operations

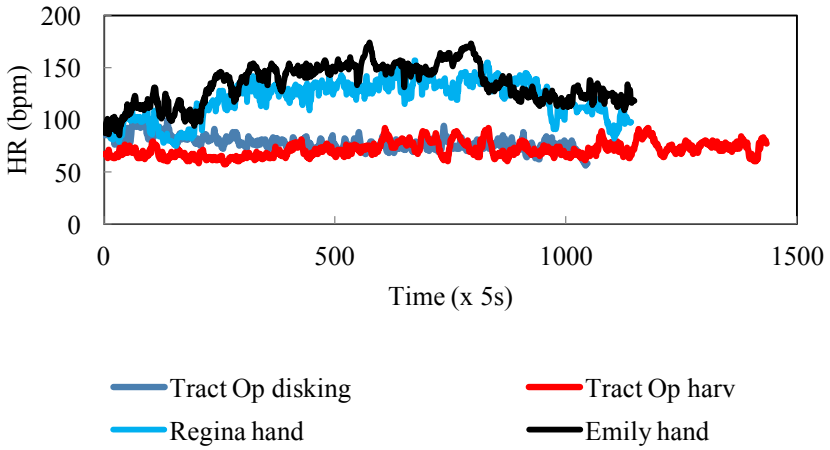

Figure 3. Heart rate profiles for manual and mechanical cassava harvesting in Nelspruit, South Africa

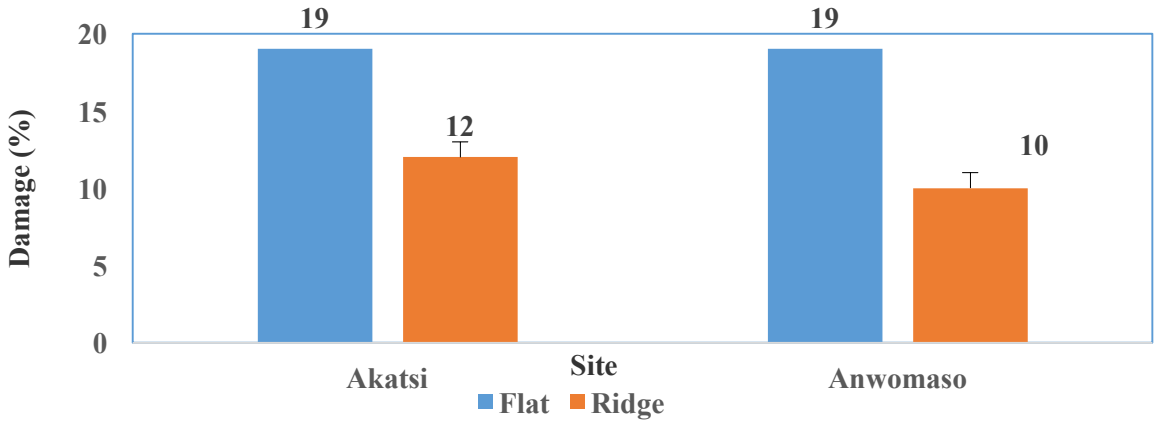

Figure 4. Land forms and root damage in Ghana

Innovating commercial farming systems for Conservation Agriculture promotion in the North West Province of South Africa

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Keywords: commercial, innovation systems, on-farm trials, soil health, crop rotations, cover crops

Introduction

In virtually all South African arable land, crop production systems based on intensive and continuous soil tillage of over many decades, have led to the loss of 46% of South African soil organic carbon (SOC). This triggered a downwards spiral of soil degradation leading to a reduction of vital soil biological activity and destruction of soil structure, severe levels of soil erosion and a considerable decrease in soil health. South Africa's soils have, over the last 60 years, been over-exploited to the point where about 70% of the country's food-producing lands are critically and severely degraded. There is general agreement among key role players in South Africa, such as government, research institutions and producer's organisations (such as Grain SA), that this negative situation can be changed through the adoption and implementation of CA. For the wide scale adoption of CA, or so-called mainstreaming, a change in paradigm is required by farmers, researchers, extension officers, agricultural businesses and policy makers. To spread this new paradigm an approach embracing and empowering all these actors involved within the value chain is needed. The so-called on-farm, farmer-centred Innovation Systems (ISs), now widely accepted as the most appropriate paradigm to mainstream CA, embrace not only the science suppliers, but the totality and interaction of actors linked to the on-farm CA innovation system (Hall *et al.* 2006). This paper serves to present some experiences and results of using a farmer-centred IS approach to promote and research CA among grain farmers in South Africa for the last five years (2013 to 2018), with a specific focus on a series of on-farm trial results on commercial farms in the Ottosdal area in the North West Province of South Africa.

Methods and Materials

This programme follows a farmer-centred IS process that uses local social structures or farmer groups as platforms to launch various projects. The IS model strongly relies on interactive, in-field discovery learning, using on-farm, farmer-led experimentation as one of the main tools. Various projects have been implemented in partnership with commercial farmer groups in key grain production regions in South Africa. Project teams were put together, which included researchers that were made responsible for the following work packages: soil, agronomy and cover crops. To test and adapt specific CA treatments or practices that were jointly identified by each of the project teams, a series of trials were designed and established on various farms. For the purposes of this paper, the following trials are presented that produced the most significant results:

Plant population and row widths: The aim is to compare the yields of maize, soybean, sorghum and sunflower grown in narrow crop row widths (0.52 m) and higher plant population densities with traditional locally used wider row widths and lower population densities. From 2014/2015 to 2016/2017, 19 trials were done on several farms using an Argentinian planter with row widths of 0.52 m representing the so-called Argentinian system, while the planter of the farmer was used to plant according to his usual densities with row width of 0.76 or 0.91 m.

Local conventional crop systems vs CA crop systems: The aim was to compare the yield of maize in conventional and CA production systems with both 0.52 and 0.91 m spaced rows in the CA systems. Annual field trials were done on farms in which commercially available equipment are used. The current conventional system used on the farm was the control which was compared with one or two row widths in no-till.

The testing and screening of cover crops: A complete randomised block design experiment with a criss-cross strip-plot layout with 17 crops (7 winter annuals and 10 summer annuals, including cash crops) was implemented over four seasons (2015-2018). The following data was collected: biomass, residue cover, canopy cover and water infiltration.

Regenerative trial with cover crops: This trial was initiated to investigate a biological soil rehabilitation process on a degraded field through the establishment of a ten species cover crop (CC) mix, as part of a CA system. The hypothesis was that high crop diversity, in this case summer and winter CC multi-specie mixtures, will enhance and speed-up the biological (ecosystem) processes in the soil to quickly restore the productive capacity of the soil.

Livestock integration trial: The economic viable use CCs in a rotation system was investigated with the integration of livestock. The hypothesis was that livestock management systems are needed that uses the principles and practices of short duration or high utilization (density) grazing, also called mob grazing, to profitably introduce CCs, but also having a range of environmental outcomes.

Results and Discussion

Argentinian versus local row widths and populations: Taking an overall look at maize it is clear that most of the time a similar or higher yield can be expected from the narrow 0.52 m row with a high plant population Argentinian system, than with the local 0.76 to 0.91 m rows with lower plant population densities, even during seasons with drought (see **Figure 1**).

Local conventional crop systems vs CA crop systems: The systems were not replicated in these trials and clear statistically based conclusions cannot be made. However, the demonstrative impact on farmers was high. Taking into account that these trials were done as the first or second year of no-till on these farms, relatively lower no-till yields were expected. However, the results of the no-till systems is encouraging, especially those of the no-till with narrow (0.52 m) spaced rows with a high plant density, which had similar or higher yields than that of the tilled systems.

The testing and screening of cover crops: Biomass production in terms of quantity was dominated by C4 plant species (see **Figure 2**). The annual grasses followed by summer legumes could convert available resources most successfully. From the winter functional groups, the radish dominated in term of biomass production. All summer CC generally had a very positive impact on cash crops. Cash cops average production was the highest (above average) on the summer mixtures, cowpeas and millet. Winter CC's affected cash crop yields negatively due to the high soil water use before the new summer growing season, however, they have various other benefits, such as green fallow in winter, assist with animal production, increase SOC and improve biodiversity.

Regenerative trial with cover crops: Very high cash crop yields were achieved in the first season after high diversity CA systems were implemented on a degraded soil (see **Figure 3**). This demonstrated that CA can facilitate the successful recovery of some critical soil ecosystem functions and the restoration of degraded soils in fairly short periods.

Livestock integration trial: Summer multi-specie CC's planted for livestock integration produced 13.11-ton ha^{-1} biomass (dry matter) before grazing. Cattle (cows and calves) utilised 2.0-ton ha^{-1} biomass (3 % DM need) and left 9.3 ton ha^{-1} on the soil surface, while 1.8 ton ha^{-1} was unaccounted for. A 100 kg weight growth per cow and 64 kg per calve were achieved over a grazing period of 50 days realising a gross income of R4,308 per cow/calve combination and a net margin of R6,128 ha^{-1} ($486 ha^{-1}).

Figures

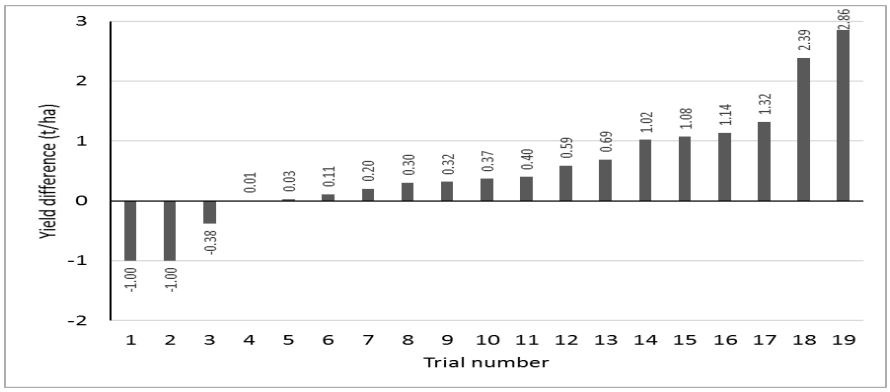

Figure 1: The yield difference of maize in Argentinian (0.52 m) and local (0.91 m) row widths and plant population densities of 19 field trials done from 2013/2014 to 2016/17. Positive values represent cases where the yield of the Argentinian system was higher than that of the local system and the other way around.

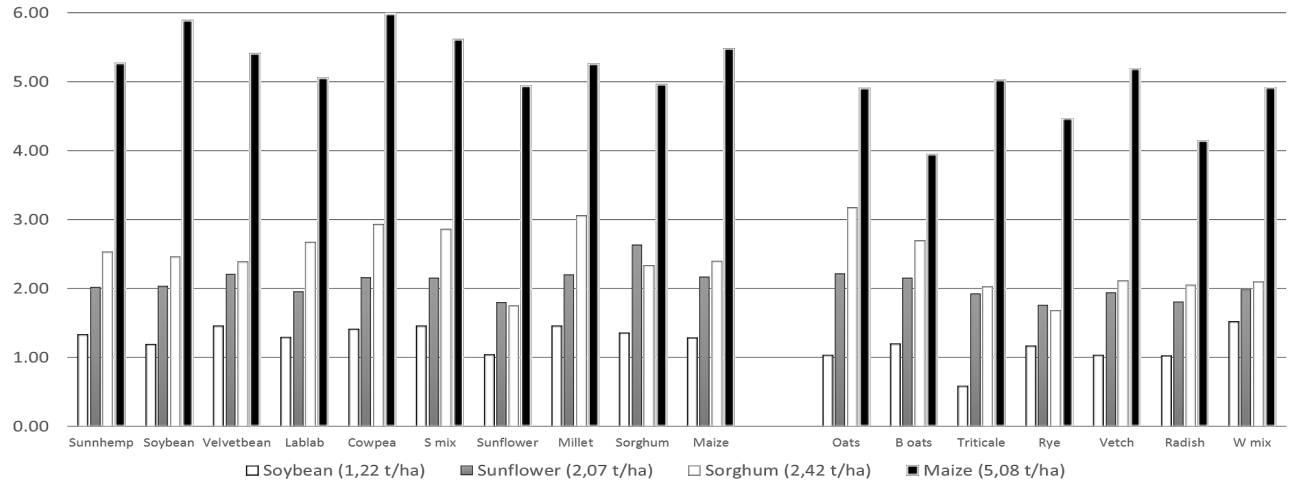

Figure 2: Yields of cash crops after cover crops on screening trial at Ottosdal, 2015 – 2017

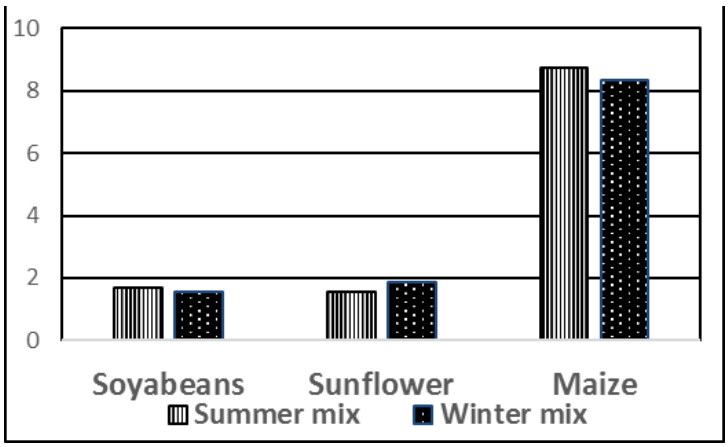

Figure 3: Cash crop yields after multi-specie cover crops, Ottosdal

The Potential of Conservation Agriculture for Enhancing Incomes, Resilience and Sustainability in Mozambique

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Keywords: impact, exploratory trial, smallholder systems

Introduction

Mozambique has been ranked the 3th country most prone to the extreme risk of climate change impacts in Africa according to the World Bank, 2015. The cumulative impact of increasing frequency and severity of climate-related hazards (droughts, floods, in-season dry spells) is devastating on agricultural production and livelihoods of insufficiently prepared communities. In 2010, an adaptive research program was initiated to test Conservation Agriculture based sustainable intensification practices (CASI) suitable for smallholder systems. The practices tested under CASI system were: CA jab planter, CA basins, CA maize-legume rotation and CA maize-legume intercrop. This paper documents some of the evidence on the impact of CASI from this research.

Material and methods

The research was implemented across three provinces of Mozambique (Manica, Sofala and Tete) with a total of 1,651,000 ha of arable land. These locations were selected because of strong maize and legume research programs with trials under National Agricultural Research Institute (IIAM). The main approach involved building public and private partnerships to scale out technologies while bringing together different actors in technology value chain for policy discussions. During the project period, several on-farm and on-station exploratory trials were set up to assess the effects of (CASI) technologies under farmer conditions. Adopting farmers were maintained for the entire period of the research program. Similarly, on-station trials were maintained at the National Research institutes under the management of both local and international scientists. The participating institutes remain key in generating and collating crop productivity and soil quality data for various agro-ecological zones. Panel data was collected through household surveys conducted in 2010, 2013 and 2016 by the Agricultural Research Institute of Mozambique (IIAM) in collabouration with the International Maize and Wheat Improvement Centre (CIMMYT). Data from the on-farm experiments were used for the gross margin analysis and ex post cost-benefit analysis (CBA) to assess the economic viability of the promoted CASI options.

Results and Discussion

Income impacts. The gross margin analysis showed that CASI benefits are context and site-specific, varying by agro-ecology and season. CASI benefits were most apparent in downside risk mitigation as indicated by the higher net benefit from direct seeded maize treatments in the low potential areas (Figure 1). The economic analysis of on-farm trial further showed that the manual CASI system, especially dibble stick increases labour productivity and returns per US dollar invested in both regions across all the seasons. The gross margins for the rip-line CASI system showed that maize-legume rotation is more profitable than the conventional practice in all cropping seasons. The suitability and economic attractiveness of CASI systems centers on profitability and labour savings in the low potential region. In the high potential area of Mozambique, dibble-stick CASI, maize legume rotation proved to be the best CASI option in terms of profitability, climate risk reduction and labour saving. Results of the cost-benefits analysis using on-farm trials revealed positive Net Present Value (NPV) and an Internal Rate of Return (IRR) higher than the discount rate for CASI options. The conventional practices resulted in a negative NPV thus the use of CASI practices are economically viable for smallholder farmers in Mozambique (Table 1).

Impact on risk. Adaptation strategies for climate change induced impacts vary strongly across agro-ecological regions, even within one location due to the variation in the effects, access to advisory services, to early warning information, to agricultural innovations and household resource endowments (Thierfelder, 2017). Further analysis revealed that integration of Conservation Agriculture practices with medium and short-duration drought tolerant varieties in the low potential drought-prone districts would be appropriate. In high potential to medium agro-ecological zones of the central region, investments in sustainable intensification such as minimum tillage, crop rotation, intercropping and mulching with increased use of improved maize seed and fertilizer, would be the best option.

Impact on yield and productivity. Results from 6seasons of trials found that that CASI increased maize yields by 37%, cowpea yields by 33% and soybean yields by 50% across farms in Manica province and 46% in Tete province well above the 7% yield increase target set by the Ministry of Agriculture. Generally, CASI maize yield increases ranged between 19 and 38 % (Table 2). The studies showed that all CA systems tested had significantly higher maize yields than conventional hand-hoe tillage systems (1497 kg ha^{-1}) in both Gorongosa and Sussundenga districts in Central Mozambique. Of these, CA in maize-cowpea rotation had the highest yields (2063 kg ha^{-1}). Also, the studies showed that maize yields depend strongly on the planting density. The optimum plant population for maize were 44,000 plants per hectare but in observed densities were often much lower than optimum.

Impact on labour. The adoption of CASI significantly reduces labour required for farming activities. The use of CASI in the high potential areas reduced labour by 15 to 27 man-days per hectare across 3 seasons, and the labour reduction was around 16 to 28 man-days per hectare in low potential areas compared to conventional practices. The labour and time saved for both men and women could be allocated to other household and off-farm activities for income generation.

Impact on Soil moisture. Soil moisture results from Angónia indicate that CASI generally provided for conditions allowing for increased soil moisture (80%) relative to the conventional ridge and furrow system. CASI in legume intercropping/rotation treatments also maintained relatively higher soil moisture levels than the sole maize CASI-based cropping systems. Results showed that that yield differences between CASI and farmer practice were dependent on seasonal conditions and crop management. CASI tended to produce superior yields in seasons with dry spells or 'below normal rainfall seasons' while the margin of differences between CA and farmer practice is rather low or similar in 'normal seasons'.

Conclusion

Research findings reveal multiple benefits of CASI practices including yield increase, soil fertility, moisture, and reduced soil erosion, thus positively contributing towards ensuring food security. In this context, 36 exploratory trials compared locally adapted CASI practices (no till, fertilizer application, legume rotation, ISFM, new maize and legume varieties) with conventional systems (i.e. continuous maize, no fertilizer, deep tillage) were aligned with necessary ecosystem services for the society such as clean water conservation, erosion control, carbon sequestration, nutrient cycling. Adoption of CASI practices has the potential to increase cash flow due to increased crop diversification and labour savings thus should be promoted along the entire value chains from seed development, input and output markets for improved livelihoods**.**

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Tables and figures

Table 1: Cost-benefit analysis of selected CSA technologies and practices

Agro-ecological zone	CASI	NPV (Ha^{-1}) (30%), USD $	Net incremental benefits for CSA option (%)	IRR	Payback Period (years)	Change in Labour (man-days Ha^{-1})
Low Potential	Conventional practice	-10.41		25	1	
	dibble-stick CA, drought tolerant maize varieties, cowpea intercrop	466.16	153	179	2	29
	Drought tolerant maize, soybean rotation	681.02	126	114	3	-18
High Potential	Conventional practice	813.58		52	1	
	dibble-stick CA, soybean rotation, common bean relay	2442.69	172	489	2	-23
	dibble-stick CA	1251.87	84	369	4	-31

Table 2. Low potential area yield increase in 6 years of CA practices

Cropping systems	Maize grain yield (kg/ha)	% increase
Conventional practice	1497[a]	0.0
CA jab planter	1784[b]	19.2
CA basins	1789[b]	19.5
CA basins maize-cowpea intercrop	1802[b]	20.4
CA basins maize-cowpea rotation	2063[c]	37.8

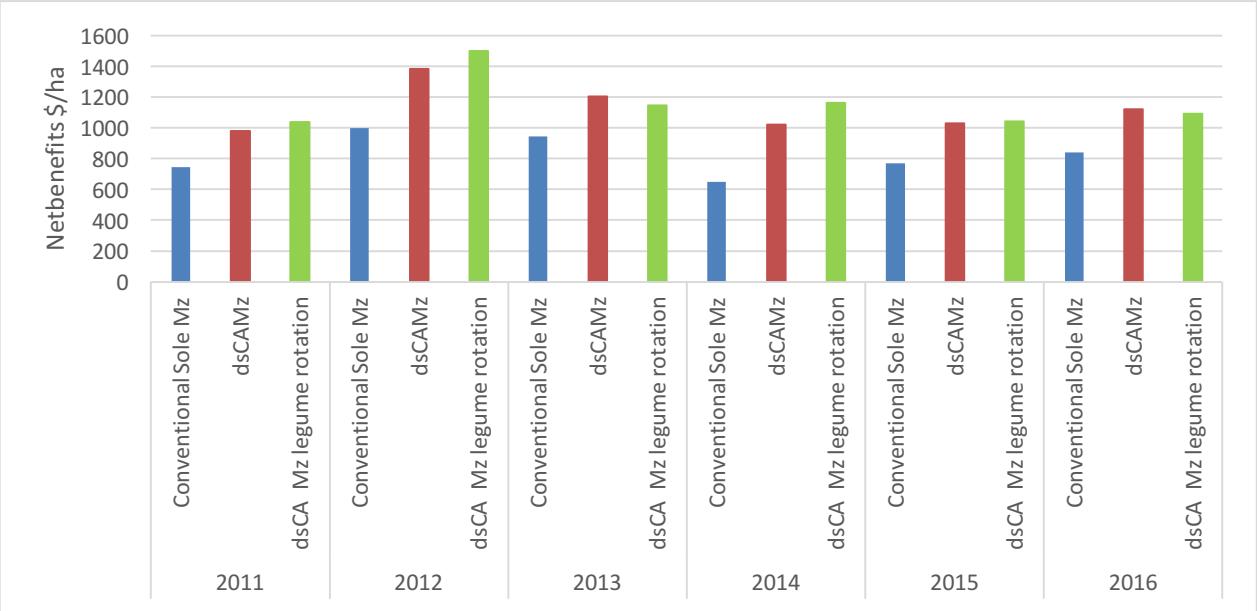

Figure 1: Net-benefits under different CASI (manual) technologies in high potential ds CA = dibble stick Conservation Agriculture

Conservation Agriculture: Enhancing Resilience and Sustainability in Uganda

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Keywords: sustainable intensification, rip lines, permanent planting basins, Conservation Agriculture

Introduction

Despite its importance, agriculture in Uganda is characterized by low production and productivity due to poor land management, soil nutrient mining, and total dependence on rainfall. The production system is also predominantly small scale characterized by low use of external inputs (such as improved seeds, agro-chemicals and fertilizers) and rudimentary production tools. All these, coupled with impacts of climate change and variability including, extended and severe droughts, floods, storms, and pest and disease epidemics have increased vulnerability of farming systems and predisposed rural households to food insecurity and poverty. In order to bridge crop yield gaps and support sustainable intensification of crop production for food, nutrition and income security to improve rural livelihoods and adaptation to climate change, a research program focusing on sustainable intensification of maize-legume cropping systems for food security in Eastern and Southern Africa (SIMLESA) was initiated. The broad aim was to test Conservation Agriculture-based sustainable intensification (CASI) in Uganda. The project goal in the context was to unlock the potential of the maize-legume production systems as a strategy for addressing food and nutrition security, incomes and long term environmental management through improved productivity.

Materials and methods

The research was carried out on-farm in two rural districts: Nakasongola in central Uganda and Lira in the north, from 2015 to 2017. The two districts had a combined population of 635,800 persons in 2017 (UBOS, 2017), primarily comprised of smallholder farmers. Working with farmer groups, the research team established demonstrations and trials, which demonstrated, tested and contrasted CASI with conventional methods in the maize-legume production systems. Conventional methods of production often involve intensive tillage, causing soil and moisture loss leading to land degradation and declining land productivity (NARO, 2017). Through demonstrations, the project promoted sustainable intensification practices and other climate change adaptation technologies including some newly introduced Conservation Agriculture (CA) practices, such as Permanent Planting Basins (PPBs) and rip lines. Permanent Planting Basins, used for planting many types of annual crops, are small pits dug in the ground about 15cm wide, 35cm long, and 15cm deep (about the size of a man's foot) (NARO, 2017). Rip lines, on the other hand, are narrow slits or furrows made in the soil by a chisel shaped implement pulled by oxen or a tractor; they are about 15 – 20 cm deep.

Crop-livestock-household-soil-weather inter-linkages were exploited through minimum soil tillage by use of herbicides and ox-rippers, soil moisture retention by covering soil with crop residues, and soil fertility was improved through judicious use of chemical and organic fertilizers and crop rotations. The project also used the Farmer Group approach which has since evolved into Agricultural Innovation Platforms (AIPs). An AIP is a forum established to foster interaction among a group of agricultural stakeholders around shared interests (Schut *et al.,* 2016; Makini *et al.,* 2013).

Results and Discussion

Impacts on yield: The potential maize yield in Uganda is estimated to range from 3.8 to 8.0 t ha^{-1}, while that of beans is 2.0 t ha^{-1}. Baseline information (Nanyeenya et al., 2013) indicated that average maize and bean grain yields on smallholder farms, which on average are less than 1 ha, were less than 30% of their potentials. This could be attributed to poor soil conditions (low soil fertility, compacted soils, and moisture stress), poor quality seed, and a low nutrient and water-use efficiency. However, CASI practices e.g. PPBs and rip lines present an opportunity to disturb the soil

as little as possible; keep the soil covered as much as possible; promote mixing and rotation of crops; and offer precision management of nutrients, capture of rainwater and conservation of soil moisture thus increasing productivity. CASI technologies in combination with improved seeds, proper fertilization (inorganic fertilizers and/ or manure) and optimum seeding rates increased bean and maize grain yields by 42 and 78 percent, respectively, as compared to the conventional practice (Table 1). However, these yields were still well below the potential yields of beans and maize in Uganda. In addition, PPBs and the ripper technology have demonstrated reduction in labour requirements (Table 2) compared to the conventional means of production. The total workdays for all field operations from bush clearing to sowing, where 1 workday is equivalent to 4 hours of effective working, were 87.2, 43.5 and 33 for conventional, PPBs and ripper technology, respectively. The ripper technology and PPBs reduced labour requirements by more than a half compared to the conventional means of production. These findings are corroborated by FAO (2001) where it was observed that there is decreased demand for labour under Conservation Agriculture during land preparation at 50 to 60 %. That notwithstanding, the ripper technology requires medium level of investment from smallholder farmers, since it involves utilization of animal power or tractors. On the other hand, PPBs requires low level of investment from smallholder farmers, but arduous compared to the ripper technology.

Challenges and drivers of CASI practices: The project interventions have increased agricultural productivity among supported farmers. However, adoption and scaling up is still low due to inadequate extension services, substandard infrastructure, and agricultural inputs. To circumvent this, the project has introduced Technical Service Units (TSUs), Agricultural Innovation Platforms (AIPs), and produced communication materials such as brochures and a Conservation Agriculture demonstration implementation guide. A Technical Service Unit (TSU) is a farmer group mainly comprised of youths; the group is trained and equipped with CA tools and implements with the purpose of providing quality and standard CA services.

Moving forward there is need to effectively disseminate the conservation farming information generated using these platforms to introduce input credit systems from big agro-input companies to local dealers, create linkages of potential agro-input dealers to financial institutions that offer long term and friendly agricultural loans and linkages and networking between individual farmers, farmer groups and cooperatives/ associations as major producers of raw materials. There is also need to encourage vertical diversification into livestock to exploit the crop-livestock-household-soil-weather inter-linkages and promotion of sustainable land management interventions at the catchment level.

Conclusion:

The research findings showed that adoption of ripper technology using animal power in combination with improved seed and fertilizer requires medium level of investment from smallholder farmers. However, the technology reduces drudgery since it reduces labour requirements by more than a half compared to conventional means of production. Consequently, the ripper technology is expected to increase the area under CASI, thereby increasing production, productivity, and sustainability. Although the PPB practice requires low level of investment from smallholder farmers, it is arduous compared to the ripper technology. Permanent Planting Basins in combination with improved seed and fertilizer as a substitute of the conventional means of agricultural production, increases land productivity, reduces the drive for area expansion, and checks land degradation, thereby increasing sustainability. Cognizant of these findings there is need to encourage local governments in Uganda to include CASI in their work plans.

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Tables

Table 1: Average bean and maize grain yields as a response to different tillage practices[†].

Tillage practice	Bean Yield		Maize yield	
	(kg ha^{-1})	SE	(kg ha^{-1})	SE
Conventional	359c	±138	1536b	+879
Conventional + Fertilizer	560abc	±138	2481ab	+879
PPB	512abc	±138	3328ab	+918
PPB + fertilizer	784ab	±138	4963a	+918
Ripe line	438bc	±148	2086b	+963
Ripe line + fertilizer	884a	±148	3921ab	+963

[†] Yield means for a particular crop followed by the same letter are not significantly different according to LSD at $p = 0.05$. (Mubiru et al., 2017)

Table 2: Labour requirements for land preparation (workdays per hectare)

Activity/ operation	Conventional		Permanent Planting Basins (PPBs)		Rip line	
	Work days[a]	Oxen days[b]	Work days[a]	Oxen days[b]	Work days[a]	Oxen days[b]
Bush clearing	17.5	5	17.5	5	17.5	5
First ploughing	37.5	2	0	0	0	0
Second ploughing	18.7	1	0	0	0	0
Spraying herbicide	0	0	2	0.333	2	0.333
Making planting station	9	0	18	0	9	1*
Sowing	4.5	0	6	0	4.5	0
Total	87.2	8	43.5	5.333	33	6.333

Adapted from Nyende et al. (2007)

[a]1 workday = 4 hours of effective working; [b]1 oxen day = 6 hours of effective working
*simultaneously making planting lines and sowing

Participatory Testing the Scalable Conservation Agriculture-Sustainable Intensification Practices in Kenya

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Keywords: technology validation, participatory evaluations, maize-legumes, cropping systems

Introduction

Kenya's agricultural production is predominantly smallholder with approximately 4.8 million households farming on less than two hectares each. Although crop production varies among households, low soil fertility, climate variability, pests and high cost of inputs are among the most common challenges faced by smallholder farmers (Micheni, 2015). The problems are compounded by low adoption of appropriate farming methods, lack of access to extension services, low rainfall and land degradation (SIMLESA 2015). To address the above farming challenges, a research program focusing on sustainable intensification of maize-legume cropping systems for improved food security in Eastern and Southern Africa (SIMLESA) was implemented for nine years (2010-2018) in Eastern and Western Kenya.

Materials and methods

Four on-farm sites in Eastern Kenya (Embu, Meru and Tharaka-Nithi Counties) and a similar number in Western (Siaya and, Bungoma Counties) were selected and characterized to define their farming systems and agricultural production challenges/opportunities. Forty-eight farmers were recruited to host the initial Conservation Agriculture-sustainable intensification (CASI) based exploratory trials established and managed from 2010. The trials were seasonally conducted to assess the effect of adopting CASI technologies on soil and maize and legumes productivity in ecologies in semi-arid or/and sub-humid areas. The tested land management options were three CASI-based tillage systems ("furrow/ridges (FR)", "zero tillage (ZT)" and "zero tillage+desmodium (ZT+Des") against the conventional tillage (CT) practice. The trial farmers were sensitized to form agricultural innovation platform (AIPs) initiative to spearhead the testing, evaluation and scaling-out of the community endorsed CASI options under maize-legumes cropping systems in 8 SIMLESA program sites. One of the core responsibility of the AIP initiatives was to evaluate/promote using the "mother-baby" approach the CASI and maize-legumes farming practices. Apart from biophysical (soil and crop productivity), labour, gender studies were conducted towards identifying constraints/opportunities for adoption of CASI-based options.

Results and Discussion

Soil productivity. Adaption of FR tillage system coupled with the right crop fertilization positively improved soil pH, carbon and biology (Table 1). For example, practicing CASI farming methods, the soil pH averaged at 4.9, against 4.8 (1:3 soil: water) determined in October 2010 when the study was established in Eastern Kenya. The almost 0.1 increase in pH value may have been attributed to the use of non-acidifying fertilizers and buildup of soil organic carbon through crop residues retention on the soil surface in the maize-legume plots. Reference to soil biology, fungi population were significantly ($p \leq 0.05$) higher under FR tillage practice than under the CT methods. But nematode population were significantly higher under FR than under ZT (Table 1). The initial soil bulk density (BD) from 0–15cm soil depth was 1.2 kg m^{-3}. The parameter was lowered to 1.0 kg m^{-3} by adapting FR and ZT+Des tillage practices. The average low BD value under the CASI treatments was attributed to buildup of the soil organic carbon and subsequent soil moisture retention throughout the period of experimentation.

Maize grain yields. Irrespective of the tillage practice, maize grain yields averaged at 4.2 and 4.5 t ha^{-1} from maize–legumes intercrop and sole maize, respectively (Figure 1).

Land Preparation/weeding labour use. At least two hand weeding events were conducted on the CT treatment. The weeding costed US$ 178 and US$ 89 on the first and second weeding event, respectively (Figure 2). The FR required approximately US$ 89 for initial construction and US$ 24 for annual repairs of furrows/ridge structures and herbicide application. The zero tillage systems (i.e. ZT or ZT+Des) required an average of US$ 43 for seasonal herbicides and residue application. The labour cost was further reduced under the CASI-based treatments because of herbicides use for weeds control. The low labour requirements under the ZT and FR tillage practices showed that more labour could be released for off-farm activities.

Gender implications for CASI adoption. Gender differences in adoption patterns of CASI-based practices showed that the males and females were equally likely to adopt ZT and FR CASI tillage practices for maize-legume production. The apparent increase in the uptake of CA SI tillage by farmers suggested that it is more labour saving.

Conclusions

Practicing CASI farming methods, positively improved both the soil quality (chemical, physical and biology). The same farming methods also improved crop productivity (growth and yields). The CASI practices were more preferred by both the male and female farmers, particularly due to land preparation and weeding labour saving.

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Tables and figures

Table 1. Effect of tillage practices on soil biology (bacteria, fungi and nematode populations)

Treatment	Bacteria (cfu x 10^6)	Fungi (cfu x 10^6)	Nematodes Count (g^{-1} soil)
Conventional tillage	261.44a	23.500b	139.47ab
Zero tillage	248.28a	33.250ab	90.43b
Furrows/ridges	242.03a	50.44a	150.89a
Mean	250.58	35.73	126.93

Means with the same letter in the same column are not significantly different ($p \leq 0.05$). cfu = colony forming unit.

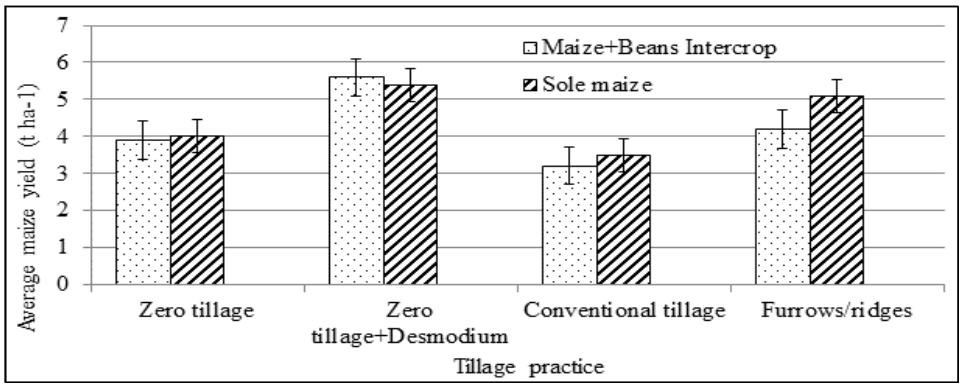

Figure 1. Effect of tillage practices on average maize grain yields

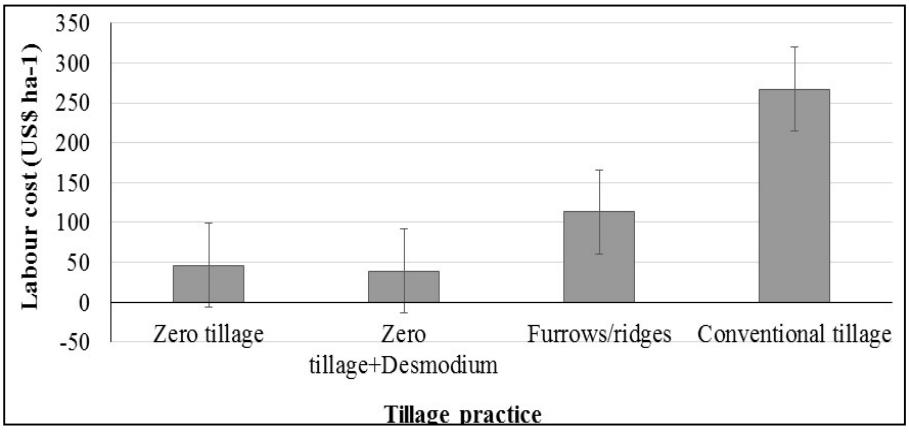

Figure 2. Effect of tillage practices on average land preparation and weeding labour cost

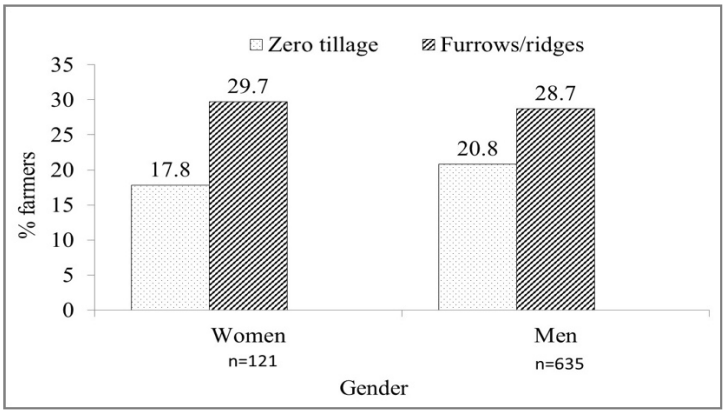

Figure 3. Percent (%) farmers using Conservation Agriculture-sustainable intensification (furrows/ridges and zero tillage) in Kenyan SIMLESA sites by 2013

Sub-Theme 5: CA Knowledge System Management and Information Sharing Capacity Development for Impact

Although Conservation Agriculture (CA) holds great promise and hope for farmers in Africa, the spread of the technology has been slow across the continent due to communication, technological and policy barriers. Some of the specific challenges includes: lack of knowledge and information about the technology among farmers and other stakeholders across Africa; lack of supportive policies and funding to support technology transfer; lack of a clear networking mechanism among proponents of the technology.

Proper communication and knowledge management strategies will contribute towards achievement of sustainable agriculture adoption. This is because when the rural farmers lack access to CA knowledge and information that would help them achieve maximum agricultural yield, they grope in the dark. Thence, the greatest input will be a more knowledgeable farmer in CA technologies and approaches, who is supported by a strong policy environment driven by a strong network of CA stakeholders. Regular, deliberate engagement with stakeholders on valuable CA related knowledge transmitted to a wider population via channels and champions they understand will gradually bring change in farming method applying these new techniques.

Networking – formal and informal – is vital to consolidate or open up new partnerships and alliances including exposing opportunities for possible joint action and collaboration. The 2ACCA sets the stage to enlighten, invigorate, and motivate participants to explore new ways of generating, configuring and disseminating CA scientific and technical information to create new partnerships and discover new models of collaboration to illicit and promote transformational changes. Avenues for bringing together, collating and distilling scientific evidence, knowledge and information to trigger future formal and informal contacts and partnerships in promoting the adoption and spread of CA and all the service sectors for the development of sustainable food and agriculture systems will be explored.

CA knowledge system management and information sharing capacity development is critical for CA impact and achieving Agenda 2063 goals and SDGs in Africa.

Under this sub-theme, 9 condensed papers were submitted and approved by the Scientific and Technical Committee after regourous reviews. These papers are hereby presented as follows:

Application of Logit Models in Assessment of Technology Adoption: A study of Adoption of Conservation Agriculture (CA) by Smallholder Farmers in Zimbabwe.

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Key words: logit model, rate of adoption

Introduction

There is significant household, district and national food self-insufficiency and food insecurity particularly in small poor rural households of Zimbabwe. These farming households are characterized by significant decreases in agricultural productivity and national food production, as well as decreases in overall economic activities (ZimVac, 2012). For example, although maize productivity increased during the early years of independence in 1980, it started declining during the mid-1990s showing accelerated declining trends in the 2000s (Rukuni *et. al.,* 2006) to current levels of 1.5 to 2.5t/ha (FAO, 2015). Productivity losses have been due to several factors, among them declining land productivity, insufficient rainfall, soil infertility, inappropriate farming techniques and poor marketing infrastructure access to inputs, and agricultural policies as well as policy inconsistencies (CIAT; World Bank, 2017). This has led to the introduction of new technologies to act as mitigation against these effects. For example, Conservation Agriculture techniques have been introduced in some rural districts of Zimbabwe to act as an adaptation against the effects of drought, low soil fertility and other effects of climate change.

According to Moyo (2013), Conservation Agriculture is a way of farming that conserves, improves and makes more efficient use of natural resources through integrated management of available resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It is based on three principles- minimum soil disturbance, mix and rotation of crops and keeps the soil covered as much as possible. Although Conservation Agriculture has led to increased average yields, when applied to farming conditions by smallholders, for instance using a hoe to create planting basins, this technique has not been widely adopted by smallholder farmers. This study was conducted to evaluate the rate of adoption of the Conservation Agriculture. Studying of adoption behaviour of any technology supplies information on the pattern of adoption, gaps and barriers to adoption and identifies opportunities foregone by adopting the technology. A profile of non-adopters and reasons for non-adoption can assist in repacking the technology to meet the needs of producers and identify other needs of such services that might enable adoption.

Methods and Materials

Data used for the study was drawn from 15 districts of Zimbabwe where Conservation Agriculture has been introduced as an innovation with funding from a group of non-governmental organisations (NGOs) under the Department for International Development (DFID)'s Protracted Relief Program (PRP), European Union (EU) and European Commission Humanitarian Aid Office (ECHO) from 2006 to 2010. The districts sampled were Bindura, Murehwa, Seke, Masvingo, Chirumhanzu, Mt Darwin, Nyanga, Nkayi, Insiza, Gokwe South, Chipinge, Chivi, Binga, Hwange and Mangwe. Data were collected through formal interviews from 416 smallholder farmer respondents randomly selected from districts where conservation farming was implemented. Structured and non-structured questionnaires were used to gather information from respondents. The study used a univariate logit model to analyse the adoption behaviour of smallholder farmers to conservation farming in Zimbabwe. The Statistical Package for Social Sciences (SPSS) software used to run the logit model. This study considered conservation adopters as farmers practicing at least two of three of the following principles: minimum soil disturbance, mix and rotate crops and keep

the soil covered as much as possible. Farmers who practiced one or no principle of Conservation Agriculture were considered as non-adopters.

Results and Discussion

Results showed that 77.4% of respondents adopted at least two of three Conservation Agriculture principles. The most common practices among farmers were crop rotation and minimum soil disturbance where farmers used hoes to dig out planting basins. About 20% of the respondents practiced mulching alone while 2.6% of the respondents did not practice of the three principles of Conservation Agriculture.

The adoption of Conservation Agriculture was influenced by the following socio-economic factors; farming experience, experience with Conservation Agriculture, access to input markets and asset ownership and not by gender, age, educational level, extension visits, and family labour availability ($p<0.05$). The relationships between rate of adoption of Conservation Agriculture and socio-economic as well as institutional factors are discussed below.

The dummy variable representing gender though not statistically significant has a negative correlation with rate of adoption of conservation farming. This sign is contrary to *a* priori expectation, and this indicates that being male is likely to reduce the uptake of CA while at the same time implying that females are likely to take up conservation farming technology as compared to males. Two possible reasons could explain the behaviour of having more females engaging in CA. Firstly, most of female-headed households do not have adequate draught power to do conventional farming and eventually end up preferring to do CF to mitigate the risk. Secondly, female-headed households tend to be early adopters of community initiatives than their male counterparts who in most cases take their (incomplete) and observe the benefits first. Farmer's age and education though not significant were found to be negatively and positively related to rate of adoption of Conservation Agriculture, respectively.

An inverse relationship existed between the farming experience and the rate of adoption of Conservation Agriculture. An increase in the time farmers are exposed to farming by 1 year, the rate of adoption of the technology decreases by a factor of 0.596. This negative relationship is contrary to a priori expectation, and findings by other researchers such as Adeogun*et. al*., (2008).

Extension visits, family labour availability, and access to input market were also not significant but increase the rate of adoption of conservation farming as hypothesized. As anticipated, access to output market was found to be significant and positive. This means that farmers with access to output market would adopt the CF technology while farmers with limited access to output markets would not adopt Conservation Agriculture. Lack of information about product as well as prices might contribute to low adoption as the farmer is not fully aware of the incentive to produce more. Adeogun *et. al.,* (2008) found a positive relationship between distance from the market and adoption of crop production technologies such as hybrid varieties. Access to output market is a significant predictor.

Cattle ownership though not statistically significant, influences rate of adoption of CA positively. This is in contrast to what was hypothesized. Farmers with more cattle are likely to adopt Conservation Agriculture faster. Cattle ownership reduces the level of risk associated with adopting a new technology. A very strong relationship exists between assets ownership and rate of adoption of Conservation Agriculture.

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Tables and Figures

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Gender	-.261	.195	1.789	1	.181	.770
	Age	.015	.009	2.945	1	.086	1.015
	Education level	-.013	.027	.225	1	.635	.987
	Asset ownership	.298	.133	5.027	1	.025	1.347
	Farming experience	-.044	.010	19.039	1	.000	.957
	CA experience	-.182	.061	8.842	1	.003	.833
	Extension visits	.003	.005	.317	1	.573	1.003
	Farming labor availability	.050	.104	.232	1	.630	1.051
	Access to input market	.339	.191	3.143	1	.076	1.403
	Access to output market	.497	.195	6.490	1	.011	1.644
	Livestock ownership	-.001	.017	.006	1	.938	.999
	Constant	-1.279	.754	2.881	1	.090	.278

Livestock Integration in Conservation Agriculture

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Keywords: crop rotation; grazing; hay; manure; soil health

Introduction

The three components of Conservation Agriculture (CA) are (1) permanent organic matter cover of the soil, (2) Minimal soil disturbance, and (3) Diverse crop rotations, sequences and associations (Kassam *et al.,* 2009). Although CA is now practiced on 180 million ha of arable and permanent cropland around the world, it is used on less than 6% of cropland in Africa (Kassam *et al.,* 2018). Grazing livestock that removes organic cover, either mulch or cover crop, during the fallow period is one major reason for lack of success with CA in Africa. Another challenge is the practice of burning tall, over-mature grasses in the dry season to favor new, high quality grass growth for livestock at the beginning of the rains.

Most environmental and soil health benefits of CA such as reduced runoff and erosion, water and nutrient conservation, increased surface organic matter, and increased earthworm populations and microbial biomass are lost in the absence of organic 'armor' on the soil (Duiker, 2011, Jat *et al.,* 2014). To maintain cover in CA, zero-grazing or complete removal of animals from cropping systems may be recommended. Zero-grazing involves extra labor and investment in structures to keep the animals. Complete removal of livestock is undesirable, because animals provide many important things to farmers such as: Draft power for field work, processing, and transport; meat, milk and hides; are stores for capital and a buffer against food shortages in years with low crop yields, and serve social and religious functions (Powell *et al.,* 2004). Excluding pastoralists and their animals from cropland increases hardship on them and sometimes leads to violent conflict.

Fortunately, there is now recognition that grazing livestock can also make positive contributions to CA (Liebig *et al.,* 2012, Ayarza *et al.,* 1998). In this review we will discuss research from Africa showing the valuable contribution grazing livestock can make to improve soil health, increase crop diversity, and increase use of cover crops in CA.

Provision of manure and urine by grazing livestock

Livestock manure and urine provide valuable organic matter and nutrients to improve soil fertility and organic matter content. Stobbs (1969) reported an average 19% crop yield improvement over 3 years following night grazing (at higher animal density) of rhodesgrass/hyparrhenia/stylo pasture and 10% following day grazing (compared with cropping following pastures without grazing). Corralling leads to lower ammonia volatilization from urine and is therefore more efficient than storing and spreading manure in zero-grazing systems. Powell et al. (2004) reported 20%, 122%, 127% pearl millet yield increase after cattle manure from the barn and 83%, 167%, and 136% greater yield after corralling in 1st, 2nd, and 3rd season after application, respectively. The effects of manure and urine effects last many years in these trials. Unfortunately, there is not enough manure to fertilize all cropland in Africa. In western Niger, for example, only 3-8% of cropland received manure (Hiernaux *et al.,* 1998). However, combining manure and fertilizer has been found to increase the agronomic efficiency of fertilizer (Vanlauwe *et al.,* 2011), suggesting important positive interactions of grazing and fertilizer use in CA through Integrated Soil Fertility Management.

Potential to increase crop diversity with grazing

Grazing livestock can help increase cropping diversity in CA. First, perennial forages become attractive components of crop rotations – and these perennial grasses, legumes and forbs have a very beneficial effect on soil health, nutrient use efficiency and following crop yields. Foster (1971) showed that maize yields increased 142% and 50% in the first and third year and bean yields increased 59% and 64% in the second and third year, respectively, after unfertilized,

grazed, napier grass (Table 1). Higher yields were achieved after grazed grass than when grass was cut and removed. Boonman (1993) emphasized the benefits of grass ley for soil conservation, nitrogen and potassium provisioning, and soil structure improvement resulting in increased infiltration. Greater integration of perennial grasses and forbs for livestock grazing in crop production can also help reduce the use of burning of over-mature grasses. Second, the potential to use cover crops for forage can expand their use. It is challenging to motivate farmers to plant a cover crop solely for the purpose of improving the soil. If, on the other hand, the cover crop has an immediate economic value, it becomes easier to justify the expense and effort involved (Zyl and Dannhauser, 2005). Third, trees can provide high quality browse and be integrated in CA, such as in alley grazing/cropping rotations with *Leucaena leucocephala* (Atta-Krah, 1990), or tree-crop mixtures adopted on 5 million hectares in the Sahel (Reij and Garrity, 2016). Trees provide vital forage in the dry season while providing services such as wind erosion and sand blasting protection, and fire wood provision. Finally, different types of plant species can be combined in *mixtures,* such as mixes of perennials, annuals, relay-cropping, and agroforestry systems, further increasing diversity in CA cropping systems.

Future Directions for Integration of Livestock in CA

This review shows that grazing livestock can be successfully integrated in CA to improve soil health and crop productivity because of the impact of manure and urine, and greater potential to increase cropping diversity. The issue of maintenance of organic cover in CA, however, needs to be addressed. Experience has shown, that part of the crop residue, forage biomass or cover crop can be consumed by livestock while leaving enough 'armor' to protect and feed the soil. How much residue cover needs to be left will depend on climate, soil, and topography, quality of residue such as its C:N ratio, the time until the new crop has achieved full soil cover, etc. Education and demonstration is needed to teach farmers the importance of the principles of CA, and community-based solutions need to be sought where crop farmers and pastoralists co-habitate (Reij and Garrity, 2016).

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Tables

Table 1. Crop yield (kg ha^{-1}) after unfertilized napier grass or continuous cropping in Kawanda, Uganda (Foster, 1971)

	Maize		Beans	
	I(2)	III(1)	II(2)	III(2)
Continuous cropping	1580	1550	920	560
Undisturbed grass	3140	2290	1130	770
Grass cut and removed	3450	2060	1030	860
Grass grazed	3830	2330	1460	920
LSD	670	490	ND	250

1st and 2nd season within year I, II, or III

Taking Conservation Agriculture Education in Africa to another Level

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Keywords: MOOC, online learning, educational affordances, mainstreaming, open source

Introduction

New and innovative ways of delivering education and creating online Conservation Agriculture (CA) communities of practice for a regional and global student population arrived with the onslaught of web-based communication technology. A few years later, a new attitude of democratizing education spawned the dawn of free web-based courses referred to as 'massive open online courses' or MOOCs for short. Although the concept of distance learning has been around in the Western hemisphere, since 1728, with the internet the number and student size of courses delivered outside of high school and university campuses grew phenomenally. Just one of several Educational Technology (EdTech) companies offering MOOCs, Coursera.com, has 30 million subscribers today (Marques, 2013). This technology-based education distribution system can now offer quality Conservation Agriculture (CA) education and training opportunities to a much wider and more globally dispersed audience.

The question we set ourselves for this paper: Through MOOCs, does the general public have an opportunity to learn about CA? Is CA education represented in this unfolding teaching/learning pathway? If CA education is not presented and agriculture MOOCs are promoting conventional agriculture, could this be hindering the uptake of CA? Or could the CA farming system, if mentioned, be misrepresented?

Material and Methods

To begin answering these questions, a 'literature survey' of English language MOOCs hosted by western-based EdTech companies and international development-related institutions was conducted. We searched for MOOCs teaching about Conservation Agriculture, Direct Seeding, Climate-Smart Agriculture (CSA) and sustainable agriculture broadly defined. University websites of course and program listings were not included in the search because MOOCs are currently distinct from university courses which are offered as part of a paid for degree program and have a more extensive syllabus. Universities and international institutions do create and facilitate MOOCs which are hosted on EdTech companies, however, they are designed for a global audience who chooses not to or cannot attend university or who want a general introduction to a subject. MOOCs are offered for free. Some are 3 weeks long and some are 9 weeks long. There are several models depending upon the subject, the university and the rules of the EdTech company. University courses which are part of a degree program on the other hand, while they may be offered online, are fee-based.

The major EdTech companies host course management systems (CMS) within which universities create MOOCs. Among these companies are Coursera.com (www.coursera.com), edX.com (www.edX.org), Futurelearn.com (www.futurelearn.com). Many development-related institutions are also creating agriculture and environmental sustainability MOOCs, among them FAO, World Bank Group, and Sustainable Development Goals Academy (SDG), Inter-American Development Bank, UNITAR to list a few. It is important to point out again that, although the course material for MOOCs often come from universities, MOOCs from these companies and institutions are to be differentiated from online university agricultural courses (of which there are hundreds) which are **not** open to the public unless paid for as part of an academic programme for which a student has to apply and be accepted.

In the survey, which was intended to locate teaching material about CA in MOOC format, we also scanned the course content of many agriculture-related MOOCs to ascertain if information about CA principles and systems was included

and/or explained in any part of the course material as part of sustainable solutions to agricultural and environmental issues.

Results and Discussion

We found that there are dozens of MOOCs on agriculture, soils, sustainable development, water management, soil health, the future of farming, etc – all created by leading universities purporting to educate the student in issues of sustainable agriculture and possible solutions (e.g. Wageningen University, University of Western Australia, University of Florida, University of Lancaster, University of Reading, and others).

We were unable to locate any English language MOOC on CA per se, however, there was serendipity in coming across one CA MOOC in Spanish being offered recently from the Universidad Nacional de Cordoba, Argentina, "Introduccion a la Siembra Directa". (https://courses.edx.org/courses/course-v1:UNCordobaX+AG001x+2T2018/course)

We located several instances of CA being mentioned in sustainable agriculture-related MOOCs. For example, one mention of the need to reduce the amount of tillage occurring in vineyards was in a MOOC from University of Reading," The Future of Farming". Another instance was a case study evaluating the economics of land conservation in a MOOC from the University of Western Australia in "Agriculture, Economics and Nature" (UWA, 2018).

In the University of Reading MOOC, no explanation of CA was given rather it was mentioned as a 'minimum soil disturbance' method for maintaining soil health in vineyards. The explanation of CA and its three interlinked principles were not explained. In the University of Western Australia, CA was presented as a 'package of farming tools' (no-till, cover crops, crop rotation) which farmers tended to choose from and not to adopt in their entirety. As can be seen from the quote below, the overall impression given about CA is not positive and would not likely inspire students to want to explore more into the benefits of CA.

"While though this (CA) is being quite widely promoted throughout developing countries, particularly in Africa and South Asia, it really hasn't been that widely adopted in those countries. And this is a bit of a contrast to at least some parts of the developed world. There's quite a bit of this type of agriculture in Australia and in North America, some in South America. But in the small holder type areas, areas with smaller farmers, smaller farms in Africa-- southern Africa, particularly-- and South Asia, **the adoption of these practices has been quite disappointing…**The yields may get worse before they get better, particularly if nutrients are not added and that crop residues that are retained and left on the soil surface are not available to be used for other things." Professor David Pannell, University of Western Australia.

There were also instances within a MOOC where solutions to environmental problems such as soil erosion were being discussed and would have been a logical place to insert the benefits of CA. However, specific non-CA solutions were explained. Here are two examples: The solution for soil erosion given by the University of Lancaster is for farmers 'to flatten their fields as much as possible'. Their solution to stopping the run-off of chemical pollutants into water ways is to dig deep ditches and/or canals along the sides of the fields into which the pollutants and sledge will collect. They do not explain what to do with those pollutants once the channels are filled. ('Soils', University of Lancaster, coursera.com)

The above examples are indicative of how 'disputed' information can be disseminated through a MOOC to an audience which may be looking at the world of farming for the first time. MOOCs have the potential to broadcast globally to thousands of students a misrepresentation of the reality on the ground. Referring the comments given from the University of Western Australia, if truth be told, globally, CA is now practiced on more than 180 M ha of cropland, with South America having the largest CA area, not just 'some in South America' as Professor Pannell indicates.

Teaching content in two MOOCs from two other major and influential agricultural institutions (Rothamsted and Wageningen) discussed solutions to unsustainable land use along the lines of updating the tillage-based Green Revolution agriculture, e.g. that increasing yields and combating degradation and loss of soil health are to be found

in 'a basket' of solutions - modern seeds, modernized agro-chemicals, min-till, contour ploughing, bunding, terracing, planting trees, agroforestry practices, etc. Several of the lectures are presented outside with a back drop of a deeply plowed field. In course material from these two institutions there is no mention of CA or no-till farming system, no recognition that maybe a new system of farming might be needed or even considered.

We discovered information that is being disseminated through highly regarded agriculture departments and institutions (SDG Academy) which will be taken on board by people who have no background in agriculture nor knowledge against which to judge the Green Revolution re-cycled solutions, systems and practices with which they are being presented.

Conclusion

In conclusion, from this general internet search which found no English language MOOC-CA specific courses on offer, there is obviously opportunity for taking CA education to another level, another boundary, beyond standard institutional teaching of out-of-date agriculture, and into the EdTech realm of globally offered MOOCs. The creating of such a MOOC(s) would allow for many positive outcomes.

Making available to the CA community, particularly African CA Centres of Excellence (CA-CoEs) promoted by ACT (ACT, 2017) and their national and international collaborators, the opportunity to add CA introductory information to their curriculum in MOOC format, would offer several benefits:

1. Provide to a wide audience correct information about CA systems and their adoption process. The correct information would help to combat/expose the messages of mis-information ongoing in some current MOOCs.
2. Network among the CA-CoEs and sharing of curriculum would help graduate the next generation to be already equipped with the knowledge and practice of CA going into the public and private sector.
3. Questions could be answered by experts and encourage discussion in the general public.
4. Educating the public would also contribute to putting pressure on policy makers to change agriculture policy to support CA.
5. Provide affordable (free) agriculture education.
6. Expose students and professors to modern web-based teaching and learning methods.

We wanted to get an idea of the number of people enrolling in these MOOCs. We were informed from the companies that the number of enrolled MOOC participants and their profiles is confidential information of each university or institution thus there was no way to have information about the extent to which an education opportunity of this kind would benefit women and youth. However, when enrolling in the MOOCs in order to view the course content, one can see on the forums that there are thousands of posts from all around the globe. Thus, an assumption may be made that there is an interest in and demand for information about the challenges and solutions to environmental and agriculture issues.

MOOCs are now a powerful and impacting source of education globally. They have the potential to influence the public's attitudes towards the role that agriculture plays in environmental issues and more importantly, attitudes and knowledge about solutions to sustainable agriculture which influence policy makers. The vast knowledge and experiences from the farmers who are successfully practicing CA can be freely shared to a global audience of all ages.

African-produced MOOCs can be a pathway for African universities debuting on the global stage with proven case studies and introduction of African CA experts. Following up on these ideas would be to build on the eLearning platform that ACT created with funding from NORAD.

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Conservation Agriculture Adoption in Mid-Northern Uganda

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Keywords: CA adoption, focus group discussions, gender, education, socio-cultural factors

Introduction

The mid-northern region of Uganda, Lango, is under the traditional annual cropping and cattle farming system. The region is recognized for its potential of being the country´s grain basket and so greatly contributing to the GDP. The main cereal crops that include maize, finger millet, sorghum and rice are the staple food for people even beyond the region in addition to providing a source of income for the rural households. However, unlike the rest of Uganda, the region has high levels of inequality and poverty (UBOS, 2016; NPA, 2015); this means households have even less ability to invest in soil and water conservation measures and are thus prone to food insecurity. Moreover the country at large is vulnerable to climate related changes such as rainfall variability, long dry spells, droughts and floods (Ssentongo et al. 2018) besides land degradation and other human induced disasters (FEWS NET, 2012).

In Uganda Conservation Agriculture (CA) is considered to be one of the resilient production technologies under climate smart agriculture (MAAIF 2016). However, the extent and rate of CA adoption in the country is yet to be researched because adoption is site specific (Kassam et al. 2017, Thierfelder et al. 2016). CA adoption also remains complex because factors influencing non adoption are not well studied (Andersson and D'Souza, 2014). Seven years prior to the study, CA was introduced to three districts within the region - Lira, Dokolo and Alebtong and since then farmers left on their own upon exit of the project. The study explored the extent and reasons for CA adoption; whether adoption of CA could be due to exposure to NGOs and if this contributed to increased adoption and whether differences in density of the farmers across the region played a role in the observed adoption.

Material and Methods

Nine focus group discussions (FGDs) as listed in (Table 1) were conducted starting on 21 July 2017 and ending on 25 July 2017. The FGDs had participants that were randomly selected from each of the three districts. Except for one control group, it was necessary to conduct gender based FGDs as it was quickly realised at the beginning that women were not free to speak when placed in the same space together with the men. This was an important socio-cultural factor identified right away from the onset of the exercise. Additionally, 417 household (HH) interviews were conducted using purposive non-probability sampling as a means of reaching the targets. Sampling was selective in that the pre-defined group sought was that of farmers that were aware of CA. To verify these criteria, the respondents were asked in the initial stage and if they did not know about CA, the interview was stopped henceforth. However, the non-proportional quota sampling method was used and the minimum for each quota of gender was 150. The sample was heterogeneous and aimed at getting views, opinions and broad ideas without so much representing those numbers proportionately. The snowball technique was used by the leaders to reach the respondents because the area is hard to reach, in terms of the means of transport thus making communication difficult over and above the scattered homesteads due to unplanned settlements. For the key informants, expert sampling was used to select respondents as a way of eliciting their expertise, knowledge and insight on the performance of CA in the region and, this group also provided evidence for the HH survey.

Results and Discussions

Empirical results showed that CA adoption was due to information and knowledge gained by the farmers; CA was the best alternative for a post war conflict zone that had limited presence of agricultural extension. Although the farmers generally had low education levels and were mostly elderly people, they easily took up CA. They also described some of the outcomes of this adoption for example increased ability to pay school fees and afford further education and construction of better houses using proceeds from CA. The comparative advantage of CA came from better yields in a region that receives less rainfall as characterised by the unimodal pattern. The critical issue that needed addressing was the scarcity of equipment and a means of persuading the youth to join the venture given the high unemployment rate and idling in their communities.

Adoption barriers and drivers

Adoption results showed differences between the three districts of Lira, Alebtong and Dokolo, (Table 2). This could be due to differences in farmer densities as all three were exposed to the same CA information. The perceptions of those farmers that were practicing CA were relevant for CA uptake in the socio-cultural context of their area. CA was the best option to manage farming in that system due to the CA knowledge received by the farmers, i.e. information and knowledge increased adoption. Under harsh conditions, access to information, attitude and proper knowledge are some of factors that positively influenced CA uptake. A legacy of post-war conflict, food insecurity, poverty and livelihood stress incentivized people to absorb anything to improve their well-being. Farmer motivations did not have the support of CA extension service, which was nearly absent. The respondents clearly demonstrated that CA had the capacity to improve their economic livelihoods, improve access to basic services such as construction of better housing, education access for their relatives and starting to lift themselves out of poverty.

Focus group discussions. FGDs results showed views on the impact of CA on livelihoods across genders. Women appeared to be benefitting more from CA and the critical feature that they continued to face was lack of machinery to make their efforts more efficient and productive. Although the HH survey sample had a disproportionately larger sample of men than what is represented in the national farm labour population statistics; the women in the FGDs could recount more the positive impacts and benefits that they had gained because of doing CA. Unlike their male counterparts, women had houses being constructed (an improvement from grass thatched huts), the ability to send their children to tertiary institutions and starting small-scale business-like shops, a sign of diversifying their income. The males on the other hand explained that their proceeds were used to meet the basic needs of their households. Women and youth generally play leading roles in agriculture and it might be expected that they could influence the accelerating adoption and upscaling of CA. Gender differences in CA adoption could also be influenced by socio-cultural factors. This result was similar to the study in west Africa on gender differences in rates of adoption (Adesina and Baidu-Forson 1995) and (Koohafkan and Stewart 2008).

Reason for adoption. Adoption of CA is site specific and the adoption patterns across the country appear to be different. In Northern Uganda, CA adoption happened because farmers had access to information and they were trained in the technique of CA. This could also be attributed to the history of the area that was marred by violence and conflict and so a lack of trust of activities related to government programs. The farmers were ready to take on technologies only after they had clearly understood how they work and how they could be applied to help them improve their livelihoods. Other results showed that adoption in the same region was positively influenced and explained by sociocultural factors (Kaweesa et al. 2018).

In This is unlike in Kapchorwa and Tororo in eastern Uganda where farmers took up CA for economic benefits and improved yields (Vaiknoras et al. 2015).

According to the Multi-Level Perspective (MLP) theory innovations go through a process to change the regime. The network actors in this case were made up of CA experts, district officials, input markets, NGOs and lead farmers' representatives who were also the key stakeholders with the relevant information needed as one of the requirements for change. These networks if strengthened could influence the implementation of new or dominant policies that support CA in the long term.

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Tables

Table 1: The structure of focus group discussions held in the field

District	Sub-county	village	# men	# women	# FDGs
Alebtong	Awei, Acede Parish	OkwaloAgabo B	7	6	2
Dokolo	Bata, Alapata Parish	Anyangocoto	9	6	2
Lira	Agali, Adyaka Parish	Anyapo	6	6	2
Dokolo	Control group	Alanyi B			1
	Control group (Abia cooperative)		6	6	2
Total number of participants			28	24	9
Workshop in Lira			10	4	

Table 2: Extent of farmer adoption of CA in sampled areas within the districts

Adoption Extent	Lira	Alebtong	Dokolo
Full adoption (%)	35%	25%	40%
Overall Gender	62.4% male		37.6% female

n=417

Drivers of Conservation Agriculture Adoption for Sustainable Intensification and Enhancing Resilience of Agriculture in Tanzania

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Introduction

The agricultural sector in Tanzania is mainly dependent on smallholder production that has inherent risks related to climate change (i.e. drought, and floods), pests, diseases and archaic production technologies. The increased frequency and intensity of droughts and floods will have significant impact on cropping systems such as sequential and intercropping patterns and farmers' resilience. Subsequently, maize, sorghum and rice yields are estimated to be reduced by 13%, 8.8% and 7.6% respectively due to climate change by 2050. Unlike other agricultural technologies and practices, Conservation Agriculture practices are still novel for most Tanzanian farmers. This paper reports study on Conservation Agriculture for Sustainable Intensification (CASI) technologies tested on farm for productive, resilient and sustainable smallholder maize-legume cropping systems and summarizes part of the resulting evidence on the key drivers of adoption of CASI for scaling out, supported by enhanced capacity for innovation and research in collaboration with national and regional research institutes. The information generated is useful in designing programs in support of CA diffusion.

Material and methods

The study was conducted in five districts (Karatu, Mbulu, Kilosa, Mvomero and Gairo) carefully selected due to their variance in intensity of integration between crop and livestock production. SIMLESA established on-farm exploratory trials and on station long-term trials to test and scale out promising technologies across different agro-ecologies. Three practices namely Conservation practice (CA), Current applied recommended practice (CONV) and primitive farmers practice (FP) were compared in experimental plots at farmers' environment (fields). CA was characterized by minimum soil disturbance, use of herbicides, crop residue retention, and use of fertilizers. CONV was characterized by maximum soil disturbance, no crop residue retention, no use of herbicides and fertilizers were applied. FP was characterized by maximum soil disturbance, no fertilizer application and no crop residue retention, CA and CONV was research managed while FP was farmers managed. The three plots were established side by side. Improved (DT maize and Pigeon peas) was intercropped in all practices. Only CA and CONV practices were statistically compared, whereas FP was for farmers' visual observations and comparisons.

Soil was sampled from CA and CONV plots and analyzed for different parameters.

Best bet Conservation Agriculture based sustainable intensification (CASI) practices were selected based on research results, farmers' preferences and scaled out through a competitive grant scheme (CGS) in which private seed companies, NGO's and Farmers networks were involved as partners. Different partners were involved at different stages with ARI-Selian and Ilonga directly participating in development, evaluation and testing of improved maize and legume varieties while seed companies and agro-dealers were responsible for sustainable production and supply of seeds to farmers. The on-farm exploratory trials worked as learning centres for smallholder farmers while generating crop productivity and soil quality data during the project period. Long term on-station trials were established and co-managed by local scientists in collaboration with international scientists at partner agricultural research centres to generate more detailed data on crop productivity, soil quality improvements and, soil and water conservation.

Results and Discussion

The average yields for 4 seasons in CA and CONV has shown high yields (2 FOLD FOR PP AND 3-4 FOLD FOR MAIZE compared to the baseline yield represented by the FP (Fig. 1 and 2). There was significant difference ($P < 0.05$) between CA and CONV for both maize and pp yields (Fig. 1b and 2b) in high potential environment. This was attributed mainly by conserved moisture (Table 1) due to soil cover. In low potential environment (Fig. 1a) the pp yield was higher in CA than CONV though not significant, whereas for maize (Fig 2a) the result was opposite. The reason for low maize yield in CA in low potential environment was due to high termite infestation (data not presented) attracted by presence of mulch, exacerbated by early onset of drought. In a situation of dry condition and presence of much, termite activity become severe especially on mature dried crops, for this situation maize, which mature earlier than pp (plate 1), the reason for un expected observed low maize grain yield in CA practice in low potential environment.

The role of demographic and human capital factors on adoption of CA practices. As is typically observed in the adoption literature (Kassie *et al,* 2012), predictors of family labor endowment (family size), human capital (education, age and experience) were found to have positive and significant effect on adoption of a range of CASI practices in Tanzania. The implication here is that conservation tillage, soil and water conservation, and improved seeds are knowledge-intensive and require some farming experience and management time input which becomes easier to provide in situations where farmers have access to family labor. Ultimately, the role of education and farmer experience suggest that for those farmers lacking these, extensive extension services for effective adoption of CA is critical.

Demonstrations and farmer to farmer exchange as information source. As a critical precedent to adoption, information is crucial in the spread of CASI technologies, or any other production technology for that matter. The research reported in this paper showed that demonstrations and farmer to farmer interactions were the main sources of CA practices followed by extension services from both Government and project staff. Others were platforms used to spread information such as radio/TV and innovation platforms (Fig. 3).

Social capital. Social capital in the form of membership to common interest groups (such as farmers' group or a cooperative), was generally found to strongly influence adoption of CASI practices. For example, farmers who belonged to an agricultural related group had a higher chance of adopting zero tillage and crop rotation by about 65.4% and 50.6%, respectively (SIMLESA Adoption Monitoring Survey, 2016). Theseinstitutions present alternative remedies to market imperfections prevalent in local markets. Therefore, collective action afforded through agricultural groups may provide credit, inputs, information, and stable market-outlet services to farmers.

Access to markets. Households located closer to markets were reported to more likely adopt legume intercrops and conservation tillage practices. This implies that better market access, can influence the availability of technology, the use of output and input markets, and the availability of information and support organizations (e.g., credit institutions), as well as the opportunity costs of labor. Therefore, in programs meant to mainstream CASI, efforts to improve the functioning of value chains (to deliver inputs such as herbicides and fertilizer) and to open up markets for lucrative sale of increased production such as legumes is crucial. Farmers' assessment on the components of CASI showed that maize-legume intercrop was the most preferred practice due to bonus obtained from two crops in the same piece of land without significantly compromising the yields compared to mono crop. Zero tillage practices ranked the second due to labour saving, cost effective and season timing (Table 2).

Impact on food security. Benefit cost ratio analyses revealed that production under CASI was more profitable compared to conventional practices. The benefit cost ratio of maize-pigeonpea intercrop under CASI was 2.1 as compared to 1.4 in conventional agriculture (Table 3). These positive returns accord smallholder farmer extra income to afford better crop varieties that yield more per unit of land area thus improving food security among rural populations.

Conclusion

Sustained adoption of CASI technologies is imperative for sustainable reduction of poverty and food insecurity as evidenced by our study findings. However, the optimal combinations of CASI practices needed in different agro-ecologies are constrained by increased labor demand that escalates production costs, shortage of livestock feeds, lack of skill to use technologies and lack of equipment. The evidence generated in this paper indicates that the choice of CASI adopted is positively influenced by gender, farm size, number of CASI trainings attended by farmers and farmers' membership in farmer group/association. The results imply that, to promote adoption of a complete package of CASI, policies that increase women access to markets, CASI trainings and farmers' membership in group/association should be apriority. Agriculture being the main stay of Tanzania's economy, CASI offers a pathway to sustainable production that is resilient to changing climate and environmental degradation.

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Tables and figures

Table 1 Different soil parameters analysis in CA and CONV practice.

Pract	During flowering						
	MC %	pH	EC mS /cm	OC %	TN %	AP Mg /kg	K cmol (+) /kg
CONV	17.98	7.84	0.07	1.5	0.16	43.0	4.28
CA	19.20	7.89	0.09	1.9	0.18	11.4	3.65

Source: SIMLESA annual report 2014

Table 2: Most preferred CASI practices

Technology	Percentage	Rank
Maize-legume intercrop	56.1	1
Zero tillage	21.9	2
Crop rotation	8.7	3

Source: Adoption Monitoring Survey results, 2016.

Table 3: Average farm partial budget for different practices for different communities in Tanzania

Yield	CONV	CASI	FP
Gross yield of maize t/ha	4.5	5.0	2.0
Gross yield of Pigeon pea t/ha	1.6	1.8	0.8
Revenue			
Maize (USD)	1,154.0	1,315.0	427.1
Stover/ha	31.25	62.5	20.5
Pigeon pea USD /ha	842.1	947.4	28,0
Gross revenue USD	2,027.4	2,324.9	519.2
Variable costs			
Cultivation/ha	109.4	0.0	109.4
Fertilizer basal DAP/ha) + Top dressing (N/ha) (both 100kg)	168.8	168.8	0.0
Fertilizer for application/ha	28.1	28.1	0.0
Herbicide before planting /ha	0.0	18.8	0.0
Herbicide application /ha	0.0	28.1	0.0
Weeding /ha	234.4	78.1	234.375
Maize stover per ha	0.0	31.3	0
Total variable cost (USD)	540.6	353.1	343.8
Net benefit (USD)	1,486.7	1,971.8	175.5

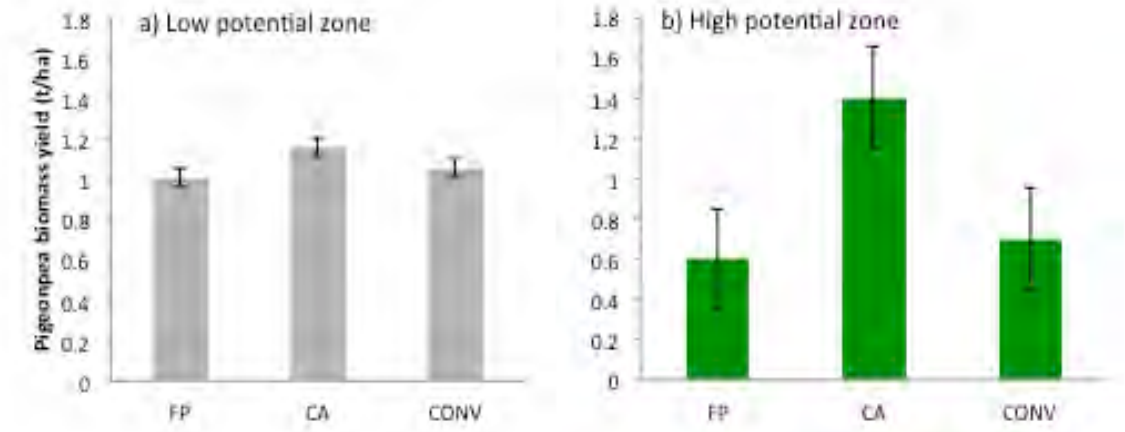

Figure 1. Average pigeon pea yield t/ha for low (a) and high (b) potential environments in Tanzania

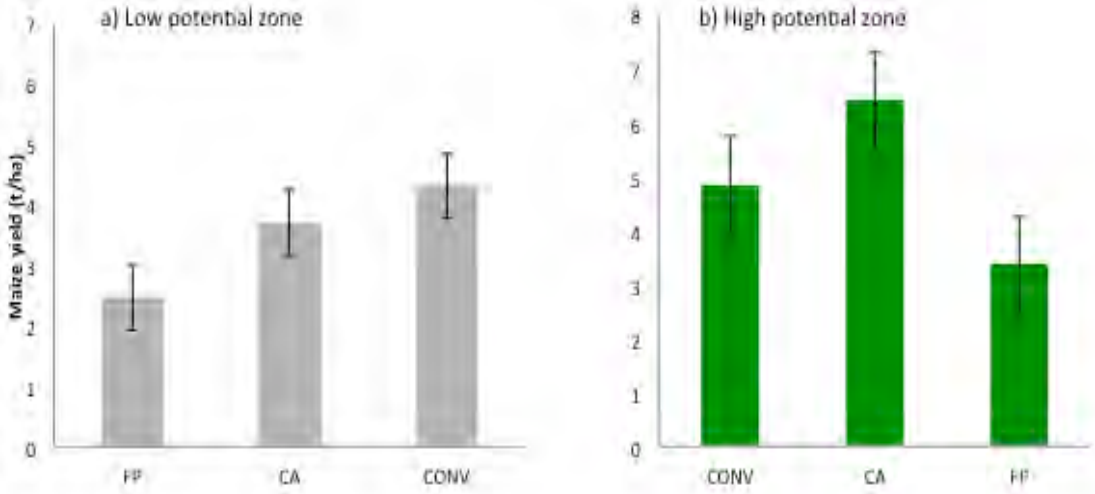

Figure 2. Average maize yield t/ha for low (a) and high (b) potential environments in Tanzania

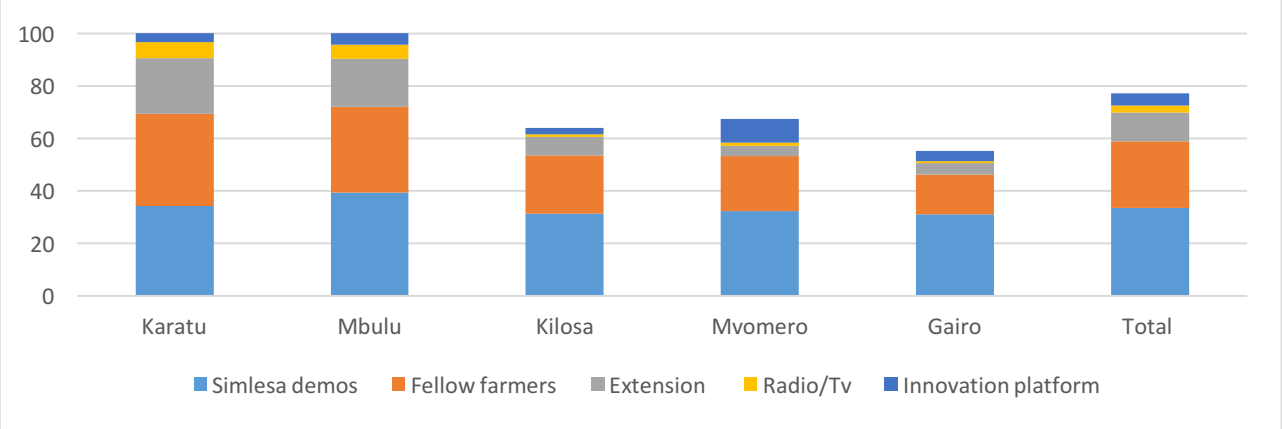

Figure 3: Sources of information about CA practices

Plate 1 Alternating rows of maize (matured and dried) and still green pigeon pea.

Lessons Learnt from Concern Worldwide's Conservation Agriculture Interventions in Malawi and Zambia, 2010 – 2018

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Introduction

Conservation Agriculture (CA) has featured prominently in agriculture development programmes in Southern Africa since 2004 due to its capacity to conserve and improve soil health, thereby improving farm productivity and resiliency to climate shocks (Thierfelder & Wall, 2010). The achievement of these outcomes relies on the application of good agronomic practices and the application of three guiding principles: 1) Minimum soil disturbance; 2) Permanent soil cover; and 3) Diversified crop associations and rotations; achievement of these three principles leads to a more resilient soil base that is more productive for farmers making CA a key component of Climate Smart Agriculture interventions around productivity and adaptation (Thierfelder, *et al.,* 2017).

Concern Worldwide is an Irish NGO founded in 1968 that currently works in 22 countries around the world, with a specific mission focused on helping people who are living in extreme poverty achieve major and sustainable improvements in their lives (Concern Worldwide, 2012). A significant portion of the interventions carried out by Concern are centered on bettering rural livelihoods, of which agriculture is often the primary livelihood activity. Concern began implementing dedicated CA projects starting in 2008 in Zimbabwe, and in Malawi and Zambia in 2010. Concern's CA projects in those countries have dealt with the challenges around implementation of CA projects with the extreme poor. This paper provides a narrative around Concern's CA activities in marginal areas of Malawi and Zambia, and how these activities evolved to lower barriers to CA adoption by the extreme poor.

Methods

The review methods used for this paper include a desk review of Concern's baseline, mid-line, and end-line evaluations conducted on our CA projects in Malawi and Zambia, project progress reports, periodic reviews of distribution mechanisms, interviews with key project stakeholders, and discussions with current staff in Malawi. Monitoring data collected by Concern and by either author dating from 2010 were also utilized in developing these narratives.

Results & Discussions

Concern's approach to poverty alleviation means targeting the poorest people in a rural landscape. In Malawi's Southern Region and Zambia's Western Province, Concern works with households that face significant hurdles in multiple contexts that constrain their adoption of improved agriculture technologies. More often than not, farmers face worn-out, infertile, drought-prone soils; erratic climate regimes; lack of access to improved seeds, fertilizer, tools or other inputs; access to livestock for both draught power and manure; limited government extension services. In addition, the poorest face intertwined aspects of hunger and off-farm coping strategies that further influence agriculture performance. In 2014/15, and again in 2015/16, poor harvests in both countries led to early exhaustion of food stocks in poor households, driving large numbers of poor into informal labour (piecework or *ganyu*) as a coping strategy, particularly in the critical months immediately prior to and during the start of the rainy season (November and December). Incapable of tending to their own fields due to both caloric deficits and sheer exhaustion, the poorest are unable to engage in the field preparation periods (basin digging, early planting, etc.) that are often crucial to successful CA implementation.

Fostering Local Adaptation within CA Promotion

Funded by Accenture, Inc., Concern's initial approaches in Malawi and Zambia utilized what were considered standard practice for CA. This included systematic and early basin-diggin, standard application of fertilizers, specific seed planting rates, and inclusions of groundnuts (*Arachis hypogaea*) and cowpeas (*Vigna unguiculata*) as annual crop rotations. In Malawi, farmers were encouraged to collect crop residues to cover (mulch) their fields. Lead farmers developed demonstration plots where CA was compared side-by-side with conventional practices and used these as training centres for 15 – 20 follower farmers, who were delivered a small input pack of seeds and fertilizers to boost their immediate production. Approaches were relative standardized, in that there were relatively strict normative definitions what CA should be.

As the project entered a second phase in mid-2013, approaches were adapted to have the lead farmers demonstration plot be more of an experimental plot. Lead farmers were encouraged to develop their own experiments with different crops, planting rates, planting dates, organic inputs, integrated pest management, and the like, where the only proscription was that overall CA principles had to be observed. As a result, lead farmers took greater ownership of techniques they had practiced, and follower farmers were able to pick-and-choose which practices to carry forward on their own farms. In Malawi, female farmers consequently began utilizing mulching in home gardens to reduce watering labour, farmers carried CA principles into their dry season irrigated gardens, and all began utilizing *Tephrosia vogelli* as a general-purpose botanical spray. In Zambia, farmers quickly adopted the practice of micro-dosing green leaves from various indigenous species (i.e., *Baphia massaiensis* as a substitute for animal manure or compost. Similar to Malawi, farmers made botanical sprays from both indigenous and exotic tree species such as *Bobgunnia madagascariensis,* and *Melia azedarach* for control of black aphids in cowpeas; the use of which carried over into their vegetable gardens.

Negotiating the last mile of seed provision

In the first phase of the project, inputs were delivered as part of a standardized pack of inputs, including fertilizer, maize, groundnuts, and soybeans (Malawi) or cowpeas (Zambia). Though Concern put significant effort into procuring and supplying the appropriate seed, extreme poor farmers lacked agency in making decisions about which crops they wished to grow, or in what quantities. Further, the logistical and financial burden of procuring and delivering seeds over vast distances added large fiduciary and opportunity costs to the project, whilst distorting or suppressing local agrodealers capabilities.

In response after 2013, Concern undertook different schemes for bringing farmers closer to the input supply. In Malawi, Concern developed a system of seed fairs and vouchers with local agrodealers. Target farmers received vouchers of fixed values that they exchange for seed inputs at local seed fairs conducted by the agrodealers. In Zambia, the lower population density and fewer agrodealers necessitated a modified approach; local farmers were engaged in the production of Quality Declared Seed (QDS) for open-pollinated species like cowpeas, groundnuts, Bambara nuts (*Vigna subterranean*), etc., which they then sold to local agrodealers. Farmers received vouchers of a fixed value that they took to the agrodealers' stores to exchange for inputs of their choice. Over subsequent years, voucher values were lowered so that farmers were weaned off external dependence for inputs. These actions fostered greater involvement of the poorest in accessing inputs, as well as providing local sources of QDS for agrodealers to exploit future sales opportunities.

Filling the hunger gap

Despite average rainfall in the 2013/2014 rainy season, baseline work conducted in Zambia in 2014 showed hunger gaps in most communities emerging a few months after the maize harvest (May), with critical food shortages amongst the poorest from September to February, unfortunately overlapping with the crucial field preparation, planting and cultivation season. Farmers with food shortages have to resort to looking for off-farm labour to meet household food demands, commonly known as piecework or *ganyu*. Focus group discussions with farmers revealed that time spent looking for and performing *ganyu* and the low labour rates precluded farmers or their households from having either sufficient time or energy to work on their own fields. Consequently, despite receiving input packages and CA training,

farmers were often physically incapable of carrying out the field preparation activities (mulching, digging basins, etc.) on time, nor were they able to hire labour as a substitute.

In response, Concern Zambia conducted a pilot exercise starting in October 2015 where 50 female beneficiaries were issued 100 Zambian Kwacha (approximately $10USD) per month for five months. Conditions were not attached to the cash distribution, but recipients had to account for how the money was spent prior to receiving the next month's allotment. The recipients of the allotment typically spent the majority of it on food purchases for the household. This had a series of positive knock-on effects; recipients obviously reported far less hunger and time spent engaged in ganyu, but also described a large expansion in available hours of labour per day. This had a number of different positive outcomes, not the least of which was an expansion of land cultivated using CA techniques. Though the sample was relatively small, it showed that a relief from the stress of food insecurity created a more enabling environment for farmers to utilize CA training on their own fields. In a similar fashion, Concern Malawi has started integrating CA trainings into their graduation model projects, which provides graduated financial support through case management to ensure sustainable departure from poverty cycles.

Essential Takeaways in CA: Remembering the Poor[est]

Concern's work in CA has extended to integration in larger-scale programmes involving all aspects of rural livelihoods, such as hygiene, nutrition, livelihoods (both on- and off-farm), socio-cultural empowerment both within and external to a household. We learnt that purported gains in productivity alone were not enough to spur full-scale adoption of CA, particularly amongst the poorest. Despite their clear desire to improve their own livelihoods, the poorest are often unable to adopt narrowly defined CA intervention packages. Though Concern has yet to "crack the nut" on how to guarantee adoption of CA amongst different agroecological and socio-economic contexts, some common threads have emerged from Concern's work in Malawi and Zambia around reducing the barriers for greater utilization of CA by the poorest:

1. Encourage farmers to experiment with different methods and crops within CA principles to develop both contextually appropriate, locally owned solutions that optimize use of local resources that do not have conflicting uses and are freely available for purposes of soil improvement and pest management.
2. Increase farmers' agency around seed selection by working on solutions that allow for better selection and storage of non-commercialized open-pollinated crops (e.g., Bambara nut, cowpeas, etc.), as well as developing appropriate "last-mile" solutions for commercialized hybrid crops such as maize.
3. Integrate programmes around household income support and management (graduation model) with CA interventions to reduce households' need to engage in *ganyu* or piecework as coping strategies that lower their initial capacity to succeed at CA.

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Moving Paradigms – Conservation Agriculture with Alternative Agronomics to Minimize Agrochemical Inputs

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Introduction

Conservation Agriculture (CA) has increasingly been adopted in many countries around the world under a wide range of agroclimatic environments and cropping-agronomy systems. Kassam et al. (2018) tracked adoption around the world to an estimated 180 million hectares in 2015/16, a doubling in the previous decade. The transition to no-tillage, permanent soil cover and diverse rotations and associations was a paradigm shift for most farmers but the rapid and widespread adoption of CA is a testimony to their innovation in finding pragmatic solutions to the barriers they were faced with whether technical or conventional thinking. Farm implementation was introduced in different circumstances than those experienced by researchers who in this case, for the most part, followed along behind the CA movement. Farms have more diverse soils, landscapes, adjacent land uses, equipment and longer periods of change management. Researchers were bound by conventions of small plots, short period research grants and, single factor experimentation rather than systems research.

In order to understand frustrations of conventional research tackling CA and to help to highlight future opportunities, we need to remember fundamental soil science and examine emergent alternative agronomic practices in the context of CA as a system at temporal and spatial scales beyond what often exists on research stations. Farmer success in achieving sustainable benefits from CA requires complementary good management of agronomy, labour and other farm resources, sometimes in new frameworks and combinations. This paper attempts to reveal some new thinking about some key agronomy components to reduce the need (or better optimize) for external agrochemical inputs.

Material and Methods

We recognize CA works as a system and the sum is greater than the parts, however to examine expected or unexpected performance of components of a system it can be helpful to consider components independently. We separately consider insect pests, weeds and fertility from CA or complementary practises such as 'sustainable intensification' or 'organic production'. We have tried to limit our review here to the more recent peer reviewed literature realizing the deficiencies or limitations of early research and the continued status-quo of applied researchers often attempting to quantify new farm practises.

Results and Discussions

Insects are the least predictable and the most difficult to study as they are impacted by short changes in climate (e.g. a strong wind, a short rainstorm) and spatial scales of field variability and surrounding lands. Regardless, early reviews of no-tillage practises found both increases, decreases and no effects of insect pests (Baig and Gamache, 2011) indicating there are both opportunities and risks to understand. Fusser et al. (2017) studied slugs and predatory carabid species in wheat fields in Germany and found that species richness of carabids increased with adjacent semi-natural vegetation to the wheat fields while slugs preferred simple landscapes. A comprehensive review of 15 studies across five countries found natural pest control was reduced as the landscape simplified (defined as the amount of tillage within 1 km of test sites) with an average reduction of 46% compared to more complex landscapes (Rusch *et al.* 2017). Chabert and Sarthou (2017) sampled CA farm fields in France which were found to have the highest hover fly populations (predator of aphids) over reduced till and proximal diversity of landscapes. They further lamented the

large range of farm field conditions that fall under the various definitions making differentiation difficult, an issue inherent in variable results of researchers. A larger study of farms in France found low pesticide use rarely decreases productivity (in 77% of farms) and they estimated total pesticide use could be reduced by 42% on 59% of the farms (Lechenet *et al*. 2017). An even larger study on the role of pollinators was completed across 33 crop systems in small and large holdings in Latin America, Asia and Africa (Garibaldi et al., 2016). They found that for small land holders, the yield gap between high and low yielding farms could be alleviated by 24% through enhanced pollination strategies and the remaining gap could be closed by deploying other technologies including CA.

Weeds and their control are another changing paradigm under CA and have been reviewed by a number of scientists, most recently by Sims et al. (2018). Monoculture-tillage systems have limited options for weed control either tillage or chemicals. The system also favours certain types of weeds while CA systems often experience a shift in weed species. Farmers need to anticipate different weed pressures in the transition years and be diligent. If seed set is avoided the 'conventional cropping' weed seed bank will become exhausted. The lack of tillage and residue cover will keep new seeds at the surface where chances of germinating seed progression are reduced. Better, the use of cover crops will provide prolonged weed competition. Cover crops such as lablab or mucuna can be used as a mulch crop further smothering weeds (Owenya et al., 2011). Diverse crop rotations and associations are also a method to change weed competition and if herbicides are used, to ensure different herbicide groups are used in order to prevent herbicide resistant weeds. Different crops provide options for residue management, growing season length and use of cover crops as well as allelopathic suppression of weeds. The push-pull system used in Africa has seen success in control of Striga. The complexity of CA systems allows for diverse options for weed management that introduce cultural options that minimize weed populations where judicial mechanical or chemical controls can be used more economically. An exciting area of innovation in managing weeds or living vegetative biomass or cover crops is the use of planting green techniques for crop establishment (Duiker, 2017). Planting green minimizes or avoids the use of herbicides by using roller crimper to subdue the vegetation and sowing directly through the rolled green biomass.

Soil fertility state and dynamics is the result of both the diversity of live and dead vegetation and microorganisms in CA systems and the resulting changes in the upper profile of the soil (changes in chemical and physical properties and their derivative characteristics). In a Pan-European study of experts examining different cropping systems impacts on the five soil functions (productivity, water regulation, carbon regulation, habitat, nutrient cycling) they found conventional practises had negative effects on soil functions while CA had overall positive effects (Ghaley *et al.,* 2018). Recently a short-term comparative study in northwest India on poor soils found CA cultural practises increased soil organic matter (and thus fertility) with available N being 33-68% higher under CA as well as some extractable micronutrients (Jat et al., 2018). After 4 years, savings in wheat agronomy was 30% for N and 50% for K. Greater reduction in N requirement, some 75%, have been reported after 10 years of CA in Portugal (Carvalho *et al.,* 2012).

Concluding Remarks

CA is a system and needs to be considered as such, not as a few new factors that have no lag, residual or interconnected characteristics. It is no longer an issue of selecting a crop type that yields a few percent more but rather understanding the interconnected physical and biological cycles as the soil changes and improves (a moving target). CA systems can magnify the influence of microsites (topographic or soil types), introduce many more organisms above and below ground and underline the importance of time scales. It helps to look at both conventional and CA agronomic paradigms from the context of the whole soil system (including above and below ground biomass) which has changed and in doing so, has shifted to new agronomic needs and opportunities.

Increasingly, it is being realized that there are biological and ecological opportunities to reduce the use of agrochemical in CA systems for effective crop protection and crop nutrition. Ability of CA farmers to minimize agrochemical use will depend on many factors including the nature of the biotic and abiotic stress conditions, availability of locally adapted biological and ecological solutions, economic environment, farmer innovativeness, research support and agricultural development priorities and strategies. Also, in situations where agrochemicals are not available, it has been shown that CA systems can be established by smallholder farmers based on the practical applications of the integrated CA principles, along with other complementary biological and ecological practices (Lalani *et al.,* 2017).

The presentation will compare and contrast global and local data and experiences with regards to potential of reducing agrochemical use in agriculture with CA systems.

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Using Improved Agronomy to Close the Yield Gap in Smallholder Farming Systems of Southern Africa: Lessons from the field

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Keywords: agronomy, Conservation Agriculture, crop rotation, planting density

Introduction

Despite advances in crop production technologies globally, smallholder farmers in Africa continue to grapple with low productivity challenges. In Mozambique and Malawi, the high cost of improved seeds and fertilizers prohibits farmers from taking up technological advancements at scale. Yet development proponents have been advocating for the adoption of Conservation Agriculture as a climate smart strategy that contributes to improved adaptation, mitigation and productivity, ultimately leading to improved food security (Steward *et al*., 2018; Thierfelder *et al*., 2017)

Conservation Agriculture (CA) based Sustainable Intensification technologies have been evaluated since 2010 through the '*Sustainable Intensification of Maize legume systems in Eastern and Southern Africa* (SIMLESA) programme in Malawi and Mozambique. Using on-farm exploratory trials, different combinations of local agronomic recommendations (including improved maize and legume varieties) and Conservation Agriculture cropping systems were tested (Nyagumbo *et al*., 2016). To assess crop yield benefits of the tested systems, maize yields were also measured from farmers' own fields adjacent to the trials and in which the farmer used their own inputs and management. This paper analyses the relative contributions of improved agronomy to maize yield increases from CA field trials carried out in Malawi and Mozambique.

Materials and Methods

Maize yields from CA based cropping systems were assembled from two communities, namely Kasungu in Malawi and Sussundenga in Mozambique. In Malawi, four cropping systems involving CA dibble stick for establishment, use of glyphosate herbicide and maize-soyabean rotations, were tested while the true farmer practice yields were measured from fields neighbouring the trials on each farm. Local district maize yield averages were also obtained for each cropping season from official district extension estimates. In Mozambique, five manual traction systems involving maize cowpea rotations and intercrops, were tested. In each location, the control treatment was the local farmer practice using locally recommended fertilizer rates. Newly released improved maize and legume varieties, were used as test crops in the trials and were provided by the project while in the farmer's true practice fields, the farmer used their own seed, fertilizer and management. The trials were farmer implemented and researcher managed. Measured maize plant populations were regressed against yield to establish the contribution of plant density for each site. Maize yields over the five and six seasons for the Mozambique and Malawi sites respectively, were compiled and analysed statistically by season using a randomized complete block design with six farmers (replicates) per site. Maize yield differences relative to the 'true farmer practice' or local averages from local district estimates from government production statistics, were simply calculated as percentages for Malawi and Mozambique, respectively.

Results and Discussion

Maize yields responded positively ($p<0.01$) to increasing plant densities on both sites (Fig. 1). The target plant population was 44 000 and 53 000 plants ha^{-1} for Sussundenga and Kasungu with plant densities ranging from 20-70 thousand and 30-60 thousand, respectively. This suggests that plant populations were below optimum densities and therefore failure to reach these targets often contributed significantly to yield losses of between 500 and 800 kg ha^{-1} for every 10 000 plants ha^{-1} drop below the optimum density. These low plant densities were often caused by poor seed quality (especially in Mozambique) or planting when conditions were not conducive for good crop establishment.

In Malawi yield results showed that differences between cropping systems were not significant in the first three years as reported previously (Nyagumbo *et al*., 2016) but became increasingly significant over time with the maize-soybean rotation system increasingly showing superiority over the conventional ridge and furrow system (Fig. 2). Similarly, in Mozambique, yield increases from CA rotations progressively became more conspicuous and amounted to 62 % compared to the control. The largest yield increases were derived from improved agronomy as opposed to CA investments (minimum soil disturbance, provision of permanent soil cover and rotations/ intercrops) when observed yield increases in the trials were compared to the true farmer practice in Kasungu. The same result was observed at Sussundenga when local district yields were compared with trial results. In Malawi the 6-yr mean maximum yield improvements over the true farmer practice amounted to 71% in the CA maize sole with herbicide and 73% of this was attributable to improved agronomy compared to 27 % from CA investments alone (Table 1). For Mozambique corresponding analyses were carried out relative to the district averages and the highest yield increases amounting to 162% were derived from the CA maize-cowpea rotation system (Table 1). Of this increase in Mozambique, the proportions attributable to improved agronomy and CA investments were 62% and 38%, respectively.

The results therefore suggest that generally yields are largely compromised by low plant populations below the optimum levels. Results from the two countries also suggest that the largest yield gains in smallholder farming systems are derived from investments in improved agronomy i.e. the use of improved seeds, fertilizer and improved management. Although CA significantly improved maize yields in both countries, such increases were smaller in magnitude compared to gains due to improved agronomy. Although the study did not isolate the different components constituting improved agronomy, the study points to the need for policy makers to invest in strategies enabling access to improved seeds, fertilizer and management as key to turning around smallholder farm productivity in the short term. Yet investments in CA technologies have their pay-offs in the longer term and therefore contribute to the overall sustainability of the farming systems.

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Figures and Tables

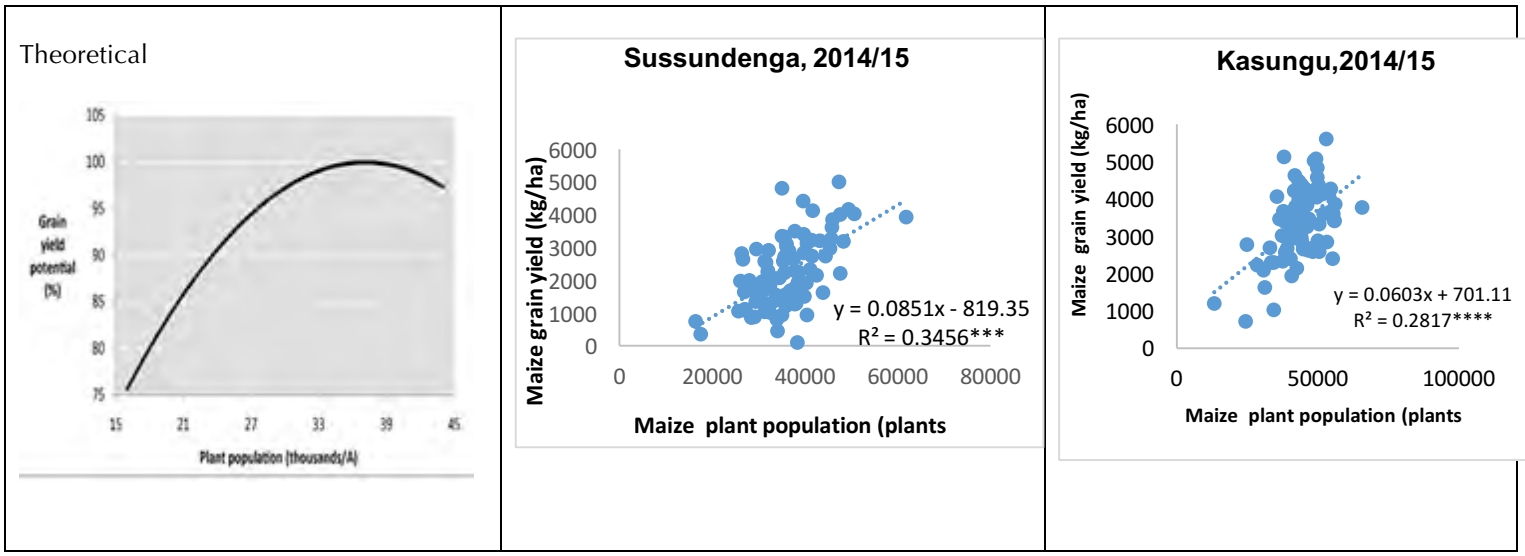

Fig 1. Maize yield response to plant population density in Mozambique and Malawi (2014/15)

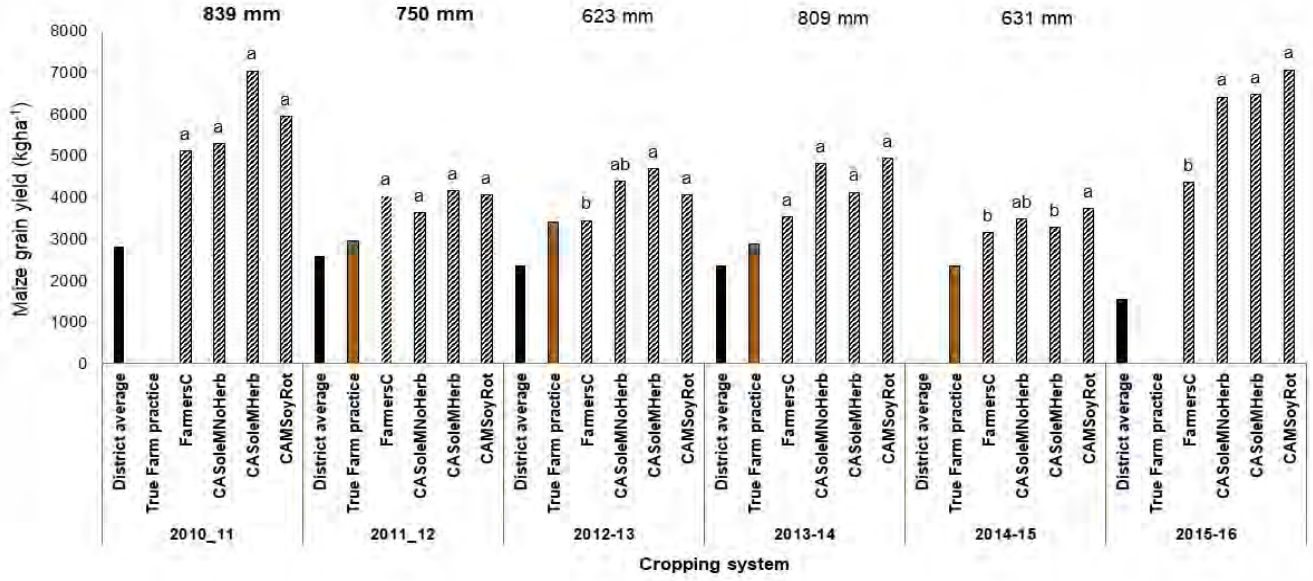

Fig 2. Maize yield effects of various CA cropping systems over 6 seasons in Malawi relative to the true farmer practice and district averages in Kasungu district, Malawi

N.B. Bars in the same season followed by different letters are significantly different at $p<0.05$. District average= average seasonal district maize yield, True farmer practice=maize yield from farmer's own field with own seeds, fertilizer and management, FarmersC = farmer check in trial using ridge and furrow practice with improved seeds, fertilizer and management, CASoleMNoHerb=Conservation Agriculture maize sole with no herbicide applied; CAsoleMHerb= Conservation Agriculture sole with herbicides glyphosate and Harness; CAMsoyRot= Conservation Agriculture maize yield in a Soyabean maize rotation with glyphosate+Harness herbicides applied

Table 1. Mean maize yields over 6 and 5 seasons since 2010 in Malawi and Mozambique and the proportions of yield increases accountable to improved agronomy and CA investments

	Maize grain yield (kg/ha)	Maize yield increase due to improved agronomy (%)	Maize yield increase due to CA (%)	Proportion of yield increase accountable to improved agronomy (%)	Proportion of yield increase accountable to CA (%)
Kasungu, Malawi					
District average	2329	-	-	-	-
True Farm practice	2892	0	N/A	N/A	N/A
Farmers check	4390	52	0	100	N/A
CA Sole Maize No Herbicide	4331	52	-2	104	-4
CA Sole Maize with Herbicide	4951	52	19	73	27
CA Maize Soya Rotation	4869	52	17	76	24
Sussundenga, Mozambique					
District average	867	0	N/A	-	-
True farmer practice	-	-	-	-	-
Farmers check	1733	100	0	100	N/A
CA basins maize sole	2048	100	36	73	27
CA jab planter maize sole	1985	100	29	78	22
CA basins maize-cowpea intercrop	1794	100	7	93	7
CA basins maize-cowpea rotation	2274	100	62	62	38

Programme and Implementation Plan of the Eastern Africa Climate Smart Agriculture Alliance

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Keywords: CSA, alliance, platform, promotion, adoption

Introduction

Agriculture is vital to the national economies of the Member Countries in the Intergovernmental Authority on Development (IGAD) and the East African Community (EAC). Progress in agricultural development has significant implications for food security and poverty reduction in these regional economic communities. Climate change and variability are major barriers in achieving that progress, with extreme weather and climate events threatening to reverse gains made in ending hunger and malnutrition (FAO, 2018). In Eastern Africa, coping mechanisms against adverse climate events have been limited, and continued climate change is expected to decrease and volatilize agricultural production (FAO, 2018). Meeting these challenges requires resilient production systems in the face of adverse climate events.

Climate-smart agriculture (CSA) is an approach that utilizes context-specific practices to improve food security through climate change adaptation and mitigation. The three main pillars of CSA are to: (i) sustainably increase productivity and incomes; (ii) adapt and build resilience to climate change; and, (iii) reduce and/or remove greenhouse gas emissions (FAO, 2013). Despite development gains from CSA, wide scale adoption in Eastern Africa remains problematic. Several barriers prevent CSA adoption, and policies and actions to remove these barriers remain a priority. Integrated and coordinated efforts among CSA actors have been identified as methods to achieve widespread CSA adoption.

The 2017 Annual Forum of the Global Alliance on Climate Smart Agriculture and the 1st African Congress on Conservation Agriculture stressed the need for integrated and coordinated efforts to promote CSA. In Eastern Africa, stakeholders meeting at the First Eastern Africa Sub-Regional Workshop on Climate-Smart Agriculture (October 2014) established the Eastern Africa CSA Platform (EACSAP) to lead the systematic scale-up of CSA initiatives. The Platform was officially launched in 2015 with the purpose of coordinating sub-regional and national activities of organizations supporting the introduction and promotion of CSA in Eastern Africa.

Following the establishment of EACSAP, the Eastern Africa CSA programme was commissioned to guide and strengthen the capacities of member states, development partners, extension agents, policy makers and smallholder farmers on the integration of CSA practices.

The Eastern Africa CSA Programme

The goal of the Eastern Africa CSA Programme is to improve adaptive capacities and resilience to climate change and variability in farmer, agro-pastoralist and pastoralist communities in Eastern Africa through the adoption of CSA practices.

The Programme builds on existing organizational structures and maintains four pillars or intervention areas: (i) strengthening institutional capacities to implement CSA practices; (ii) strengthening the national frameworks for implementing CSA; (iii) demonstrating CSA practices through innovation platforms and extension approaches such as the farmer field schools; and, (iv) making knowledge on CSA practices accessible to farmers, extension workers, policy makers and the general public. The specific objectives are to: (i) improve the knowledge base, capacity and

partnerships for CSA; (ii) improve knowledge generation, management, networking, and coordination of CSA activities; (iii) enhance the capacities of institutions and individuals on CSA at community, district, national and regional levels; and, (iv) improve the availability of standardised CSA tools, guidelines and methodologies for Eastern Africa.

Through the programme, regional economic communities are able to enhance their ability to assist Member Countries to deliver results on CSA and strengthen resilience for food security and poverty alleviation. The programme also contributes to development and implementation efforts that support National Adaptation Plans and integrate climate change into regional and national agricultural investment plans. Research institutions, civil society, and farmer associations are able to increase their awareness and skills on CSA practices, particularly on the integration of CSA into agricultural development programmes. The programme improves coordination between the regional economic communities and their development partners on CSA initiatives and reduces the scale-up burden among the implementing organizations.

During the 3rd Eastern Africa Sub-Regional Workshop on Climate-Smart Agriculture (July 2018), it was agreed that EACSAP be renamed to the Eastern Africa CSA Alliance (EACSAA) for more efficient and effective delivery. A proposed strategy will guide the organizational structure, function and activities of EACSAA to ensure successful implementation of the sub regional CSA programme.

Strategy

The purpose of EACSAA is to provide a coordination platform that supports the coordination and scale-up of CSA practices and initiatives in Eastern Africa. The vision of EACSAA is to have appropriate CSA practices adopted by farmers throughout Eastern Africa that will lead to increased productivity, food security, farm profitability and sustainable farming systems. The mission of EACSAA is to provide a platform for the coordination of CSA initiatives at a sub-regional level to address the various constraints and harness opportunities for the scale-up and wide adoption of CSA; provide strategic leadership and support to National CSA Task Forces (NCSATFs); develop sub-regional projects and programmes; and support NCSATFs in the development of country specific CSA programmes and projects with the aim to support and promote the adoption of CSA practices and techniques by farmers across Eastern Africa.

EACSAA spans eight countries in Eastern Africa: Burundi, Djibouti, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda. Membership of EACSAA is voluntary and open to all interested partners that are committed to promotion of CSA, sharing of innovative practices, overcoming barriers in the advancement of CSA, and promotion of evidence-based CSA benefits. EACSAA members agree to its purpose, vision, mission, and values and contribute to the scale-up of CSA practices in Eastern Africa.

The proposed deliverables include a widely-recognized evidence-based knowledge sharing and networking platform, support in the uptake of CSA practices among 2.5 million households, improved awareness of the need to scale-up CSA practices among key strategic partners, incorporation of CSA activities into regional and national agricultural investment plans, and increased leadership of CSA initiatives in Eastern Africa. EACSAA's resource mobilization strategy seeks to harness financing mechanisms to mobilize resources from domestic and regional public finance, private finance, public multilaterals, development finance institutions.

Governance

The 3rd Eastern Africa Sub-Regional Workshop on CSA made important recommendations on the governance of EACSAA. The proposed Chair and Co-chair of EACSAA are IGAD and EAC, respectively. The Food and Agriculture Organization of the United Nations and the United Nations Economic Commission for Africa are to serve as the Facilitation Unit (Secretariat). The specific functions of the facilitation unit are to coordinate aspects of advocacy, resource mobilization, partnerships, capacity building, and convene steering and technical committee meetings. The membership of the Steering Committee includes regional economic communities, farmer interest groups, CSA national focal points, NGOs, inter-governmental organizations, research and academia, and other development partners and acts as the decision-making body that provides strategic direction. Technical working groups are to be

convened at the discretion of the Steering Committee. An annual meeting of members ensures regular consultation and monitoring of the implementation plan. Monitoring assessments will determine the progress toward planned goals and the achievement of particular milestones.

Conclusion

The implementation and scale-up of CSA practices offers multiple benefits of enhanced food and nutrition security and mitigation against adverse climate events. It is widely recognized that to promote the scale-up of CSA at both national and sub-regional levels, there is a need for the existence of functional and effective national and sub-regional CSA coordination mechanisms to enhance the sharing of information and lessons among stakeholders. The Eastern Africa CSA Alliance was restructured in 2018 to implement the sub regional CSA programme. With the restructuring of EACSAA, it is expected that CSA practices in Eastern Africa will be scaled-up through an effective and efficient coordination platform comprised of active, multi-stakeholder partners.

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Congress Poster Papers

The aim of the posters exhibition is critical to highlights summarized issues and field experiences by different stakeholders implementing conservation. Poster submissions were invited for exhibitions during the congress with the intention to expose delegates to the latest technologies, share evidence and to challenge the current thinking and practice. They are also purposed to provide room for different organisations, especially NGOs, farmer associations, private companies, publishers, and others to present themselves and their work related to CA. All the posters submitted and approved will be displays at the exhibition area identified ad focal point of the Congress and the program is structured to maximize the opportunity for delegates to visit this area.

These posters include:

S/No.	Title of the Poster	Author(s)
1	Development of some strategic crops (wheat and yellow corn) to tolerance water and nitrogen deficit Using Conservation Agriculture	Sherif Rajab Mohamed El-Areed
2	Conservation Agriculture in Maize Legumes Systems: Perspectives from Zambia	**Kafula Chisanga,** Nswana Kafwamfwa, Petan Hamazakaza, Mulundu Mwila, Joy Sinyangwe, and Olipa Lungu
3	Development of the Conservation Agriculture based Research Programme for Roots and Tubers in the Tanzania Agricultural Research Institute	**Kido Mtunda**, Mariam Kilima and Saidi Mkomwa
4	Field Method for Detection and Evaluation of Soil Compaction	**Weyer Th.** and Boeddinghaus R
5	Livestock and Conservation Agriculture integration: A challenge or an opportunity?	Kirima, John. K.
6	Conception d'un prototype de semoir de semis direct sous couvert végétal à traction animale adapté aux conditions du Sénégal	**Demba Diakhaté,** Ricardo Ralisch,Michel Havard, Alioune Fall, Ibrahima Sarr
7	Mapping perceptions of Conservation Agriculture practices with on-farm measurements- Is there a link?	**Baqir Lalani,** Meredith Williams, Steven Gray, Libere Nkurunziza, Jose Dambiro, Philip Grabowski and Jaqueline Halbrendt
8	Conservation des sols et besoin de changer de système de culture	**Demba Diakhaté**, Ricardo Ralisch, Michel Havard, Jean Louis Chopart, Alioune Fall, and Ibrahima Sarr,
9	Farming carbon: Mobilising farmers' groups in favour of the 4/1000 initiative	GCAN
10	Farming Forward for Climate Change: A Manifesto for Action by a network of Global Conservation Agriculture organizations	GCAN

To access all the above posters, visit the link **2ACCA Congress Posters**

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