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Operational Field Guide for Establishing and Managing Conservation Agriculture Demonstrations




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Operational Field Guide for Establishing and Managing Conservation Agriculture Demonstrations

2017

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Joselyn Kashagama and Milly Nakafeero

This guide is not prescriptive but meant to inspire field extension workers and other practitioners into exploring by using applicable combinations of methods and tools

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Foreword

High levels of land degradation in all the agro-ecological zones of Uganda have led to low levels of land productivity which pose a major threat to household and national food security. This coupled with the dynamic changes taking place in the country, especially those caused by an increasing young population and climate change has made it necessary to galvanize efforts in food production, sustainable land management, and environmental protection. Identification and promotion of appropriate production methods is viewed as one of the approaches to reverse the trend of land degradation and declining land productivity.

Conventional methods of agricultural production often involve intensive tillage, causing soil and moisture loss leading to land degradation and declining land productivity. Conservation agriculture (CA) has successfully reversed land degradation and declining land productivity trends in countries like Brazil, Zambia, and Malawi. The CA package includes disturbing the soil as little as possible, keeping the soil covered as much as possible and mixing and rotating crops.

It is envisaged that adaptation and adoption of CA can go a long way to reverse the land degradation and declining land productivity trends in Uganda. In that regard, the government of Uganda has developed a CSA programme for the country with a large component on Conservation Agriculture.

This CA Demonstration Implementation Guide is the result of initiatives by the National Agricultural Research Organization (NARO) working through its institute: the National Agricultural Research Laboratories (NARL – Kawanda) and Ngetta Zonal Agricultural Research and Development Institute (NgeZARDI) which mobilized farmers from different agro-ecological zones across the country to establish and manage CA demos/trials. The demos/trials were used to provide empirical evidence of the superiority of the newly introduced conservation farming practices relative to the conventional practices.

This demonstration guide is intended to strengthen the capacity of field extension workers and other CA practitioners in their endeavor to develop and promote conservation agriculture.

I thank all those that contributed to the development of this demonstration guide, and those charged with transforming its message into practical use. Lastly, I wish to encourage our farmers to embrace CA since it is a proven agricultural production method that will increase household food and income security as well entrench sustainable land management and resilience to climate change.

Ambrose Agona,
Director General - National Agricultural Research Organization

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The National Agricultural Research Organization (NARO) through her staff at the National Agricultural Research Laboratories (NARL) – Kawanda has been at the forefront of developing and promoting conservation agriculture in Uganda. NARO's interest, support and contribution to this demonstration guide have been enormous.

The Task Force on Conservation Agriculture (CA) is highly appreciated for the technical backstopping during the implementation of the demos/trials and the contributions made to the development of this guide.

The administrative and technical support of local governments in the districts of Budaka, Bugiri, Busia, Buyende, Lira, Nakasongola, and Namutumba are highly appreciated. Their cooperation and coordination of project activities helped a lot during establishment and managing the CA trials/demos under various projects.

Farmers are also highly appreciated for their commitment and diligence in managing the testing process. Without the farmers hosting the CA demos/trials all efforts would have been futile.

The Ministry of Agriculture, Animal Industry and Fisheries has made promotion of CA top on its agenda with CA mainstreamed in the Agriculture Sector Development Strategy and Investment Plan (DSIP). This initiative has attracted development partners to commit funding for promotion of CA.

The development and publication of this demonstration guide was facilitated with technical and financial support from the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the Common Market for Eastern and Southern Africa (COMESA).

Acronyms and Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ACT	African Conservation Tillage Network
AEZ	Agro-Ecological Zone
ATAAS	Agricultural Technology and Agribusiness Advisory Services
CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CLUSA	Cooperative League of the United States of America
COMESA	Common Market for Eastern and Southern Africa
CSA	Climate-Smart Agriculture
DAP	Diammonium Phosphate
DFID	Department for International Development
DSIP	Agriculture Sector Development Strategy and Investment Plan
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FEW	Field Extension Worker
FFS	Farmer Field School
GEF	Global Environment Facility
IIRR	International Institute for Rural Reconstruction
IP	Innovation Platform
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
NAP	National Adaptation Plan
NARL	National Agricultural Research Laboratories
NARO	National Agricultural Research Organization

NDP	National Development Plan
NGO	Non-Government Organization
PPB	Permanent Planting Basins
REDS	Rural Enterprise Development Services
SDG	Sustainable Development Goal
SIMLESA	Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa
SOC	Soil Organic Carbon
SLM	Sustainable Land Management
TSU	Technical Service Unit
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WB	World Bank

Organization of this Guide

This guide is organized into two modules, with an introduction that elaborates the background and objectives of the guide.

Module 1, defines conservation agriculture and conservation farming and highlights the benefits of CA relative to conventional farming. Furthermore, it highlights the factors affecting the adoption of CA.

In Module 2, describes the steps necessary for establishing and managing conservation agriculture demonstrations, starting from establishment, management, monitoring and approaches to scaling up.

Lastly, the guide chronicles case studies that provide empirical evidence of the superiority of the newly introduced conservation farming practices relative to conventional practices.

Introduction

Agriculture is vital for promoting economic growth and reducing poverty in Uganda. The agricultural sector supports the livelihoods of 73 percent of the households and provides employment for about 33.8% (UBOS, 2014) of the economically active population. The proportional contribution of the agricultural sector to the Gross Domestic Product (GDP) of Uganda currently stands at about 20.9 percent. Generally, the sector is most important in terms of food security, employment, household income, raw materials for local industry and exports to regional and international markets (Agriculture Policy, 2013). Thus, the sector continues to maintain its historical reputation as the primary driver of economic growth and poverty alleviation.

Uganda has a diverse agricultural production system within 10 Agro-Ecological Zones (AEZ) (GoU, 2004). The zones are characterized by different farming systems determined by soil types, climate, and socio-economic and cultural factors. The AEZ experience varying levels of vulnerability to climate-related hazards which include drought, floods, storms, and pests and diseases (GoU, 2007). This coupled with poor land management, soil nutrient mining and total dependence on rain-fed agriculture increases vulnerability of farming systems and predisposes rural households to food insecurity and poverty. High population growth estimated at 3.2% p.a has led to dwindling of the average household landholding to less than 0.5 ha. The predominant smallholder production system is characterized by low use of external inputs (such as improved seeds, agro-chemicals and fertilizer), poor land management practices and rudimentary production tools which contribute to low agricultural productivity.

Soil and water management is an essential element for sustainable land management and food security in Uganda. Some of the pressing problems for rural households and the landscapes where they derive their livelihoods are related to management of land and water resources. Land degradation through soil erosion, nutrient mining by crops, nutrient leaching and soil compaction have immensely contributed to food insecurity and poverty among smallholder farmers. The situation has been further aggravated by climate change. Impacts of climate change such as extended and severe droughts have resulted into reduced crop yields or sometimes total crop failure. The main drivers/underlying causes of land degradation include intensive soil preparation by plowing, burning of crop residues, inappropriate crop rotations, and deforestation. In general terms, these are referred to as conventional farming by smallholder farmers. All these whether practiced individually or in combination leave the soil exposed to climatic hazards such as wind, rain and drought. According to a report by the World Bank (World Bank, 2008), soil erosion is a major impediment in all nine cropping systems in Uganda and soil fertility in five of the nine systems and wherever there has been agricultural intensification.

Conservation agriculture (CA) is one of the solutions being advocated/promoted to address the challenges faced by smallholder farmers because it conserves soil and water, the essential elements for Sustainable Land Management (SLM) and food security. According to Mupangwa *et al. (2014)*, CA practices can potentially address the soil and water management constraints faced by smallholder farmers. Promoters of CA, argue that it makes better use of agricultural resources through the integrated management of soil, water and biological resources, combined with limited external inputs. They further argue that CA contributes to environmental conservation and to sustainable agricultural production by maintaining a permanent or semi-permanent soil cover.

The Government of Uganda through the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) with support from FAO/UNDP/COMESA; SIMLESA/CIMMYT/ACIAR/; EU; DFID; the Norwegian Government; WB/GEF; and USAID is implementing Climate-Smart Agriculture (CSA) projects to overcome climate change impacts in several AEZ across the country. Conservation agriculture (CA) is one of the elements of CSA. The over-arching goal of the various projects is “Climate Change Resilience” that provides the basis for economic development, food security and sustainable livelihoods while restoring the ecological integrity of the ecosystem. Broadly, this initiative aims at addressing issues of land productivity, climate change adaptation, and environmental conservation for improvement of livelihoods.

The CSA projects are aligned to a cross-cutting range of development goals/frameworks, for example, the national economic blue print – Uganda Vision 2040, National Development Plan (NDP), the Agricultural Sector Development Strategy and Investment Plan (DSIP), the National Agriculture Policy (2013) and the Uganda Strategic Investment Framework for Sustainable Land Management (2010). The projects are also consistent with ongoing national climate-resilient long-term visions, such as the National Adaptation Programmes of Action (NAPA), Nationally Appropriate Mitigation Actions (NAMA), United Nations Framework Convention on Climate Change (UNFCCC) National Communications, National Action Plan (NAP) and the United Nations Convention to Combat Desertification (UNCCD) implementation frameworks.

At the regional level, the projects contribute to the main pillars of Comprehensive African Agriculture Development Programme (CAADP) that include land and water management, capacity building, food security, research and technology dissemination/adoption, among others. CAADP now also incorporates climate change and adaptation, which includes sustainable intensification and resiliency of production systems and the reduction of greenhouse gas emissions caused by agriculture.

Furthermore, the projects contribute to the country's effort to address the Sustainable Development Goals (SDG) and Targets particularly SDG 1: End poverty in all its forms everywhere by 2030, SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030 and SDG 13: Take urgent action to combat climate change and its impacts by 2030. The projects integrate the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate change challenges.

That notwithstanding, government's investment in the agricultural sector is still very low compared to the recommended minimum of 10% of the national budget (Maputo Declaration, 2003).

Objectives

The Government of Uganda through the Ministry of Agriculture, Animal Industry and Fisheries with the support of development partners including FAO, COMESA, UNDP, GEF, ACIAR, the Norwegian Government, DFID, EU and USAID seeks to contribute to:
- the protection and sustainable management of land and water resources,
- applying adaptation and mitigation strategies for food security,
- reversing the trends in deforestation and adverse land use practices,
- promoting biodiversity.

By addressing these core mandates, the government and partners is seeking to increase land productivity and ensure food security for the growing population.

Specifically, this CA Demo Implementation Guide is intended to equip CA practitioners with the requisite skills for the development and promotion of CA in Uganda. The guide has been designed to enhance knowledge and awareness on CA and promote the adoption and adaptation of this farming method throughout the country. In that regard, the guide defines conservation agriculture and conservation farming by explaining the three basic principles of CA, and how they are applied in the field and their attendant benefits. It highlights the factors affecting the adoption of CA and elaborates the approaches of scaling up for crop intensification. Finally, through case studies the guide gives empirical evidence of the benefits of conservation agriculture among smallholder farmers.






Module 1: Defining Conservation Farming/Conservation Agriculture

Conservation farming is any system or practice which aims to conserve soil and water. Conservation agriculture (CA) is one of the elements of conservation farming. Conservation agriculture (CA) aims to make better use of agricultural resources through the integrated management of available soil, water and biological resources, combined with limited external inputs. It contributes to environmental conservation and to sustainable agricultural production by maintaining a permanent or semi-permanent organic soil cover (FAO, 2002). Zero or minimum tillage, direct seeding and a varied crop rotation are important elements of CA.

1.1 Principles of Conservation Agriculture

Disturb the soil as little as possible (minimum tillage): In conventional farming, farmers plow and dig to prepare a fine seedbed and control weeds. But in the process destroy the soil structure and contribute to soil erosion and declining soil fertility. In CA, tillage is reduced to ripping planting lines or making holes with a stick, hoe, or jab planter for planting.

Conservation agriculture has three basic principles:

- Disturb the soil as little as possible,
- Keep the soil covered as much as possible,
- Mix and rotate crops.

Keep the soil covered as much as possible (soil cover): In conventional farming, farmers remove or burn the crop residues or mix them into the soil with a plow or hoe. In the process the soil is left bare, so it is easily washed away by rain, or is blown away by wind. In CA, crop residues are spread uniformly on the field; crop residues spread to create a mulch cover and leguminous cover crops protect the soil from erosion, conserve soil moisture and limit weed growth throughout the year. This also helps to build the organic matter content which is essential in maintenance of soil fertility, especially in tropical soils. Soil moisture retention by residues provides an optimum environment for biological activities, which are essential in enhancing soil health. When leguminous cover crops are used they fix atmospheric nitrogen to boost soil fertility.

Several cover crops have been evaluated in Uganda and they included; *Mucuna pruriens* (velvet bean), *Canavalia ensiformis* (jack bean), *Tephrosia candida* (white hoarypea), *Dolichos lablab* (vegetable lablab) *and Crotalaria ochroleuca* (sun hemp), among others. Some of the different cover crops evaluated are presented in Table 1.

Table 1: Legume cover crops/green manures evaluated in Uganda

Type	Quantity of seeds ($kg\ ha^{-1}$)	Recommended spacing[1]	Growth habit	Comments
Mucuna pruriens (velvet bean)	25	75cm x 60cm	Annual herb	Mucuna is a very vigorous climber which improves soil fertility and farm productivity
Canavalia ensiformis (jack bean)	25	75cm x 30cm	Annual herb	Canavalia improves very poor soils and is tolerant of drought and shade. It is easy to manage and can be intercropped with almost all crops. It grows on during the dry season.
Tephrosia vogelii	25	100cm x 100cm	Perennial shrub[2]	Can grow in highlands
Tephrosia candida	2	100cm x 100cm	Perennial shrub[2]	Tephrosia vogelii is a soft, woody herb with dense foliage. It stands 0.5–4 m tall, and contains stems and branches with short and long white or rusty brown hairs. It is commonly used to deter pests and diseases, specifically fleas and ticks on animals. It is not suitable for livestock or human consumption because it is not highly nutritious and can be poisonous for fish and some other animals. Since it is a nitrogen-fixing plant, it can be intercropped with other plants and used as a source of green manure.

Type	Quantity of seeds (kg ha^{-1})	Recommended spacing[1]	Growth habit	Comments
Dolichos lablab	2	75cm x 60cm	Annual herb	Lablab is a vigorous, drought resistant climber
Crotalaria ochroleuca (sun hemp)	5	Drill seed, 75cm between row	Annual herb	Crotalaria is fast growing, matures within 3 to 4 months, and is drought tolerant and adapted to poor soils. Nitrogen fixation of crotalaria is very effective.
Crotalaria grahamiana	5	100cm x 100cm	Perennial shrub[2]	Can grow in highlands
Crotalaria juncea		100cm x 100cm	Perennial shrub	Can grow in highlands
Cajanus cajan (pigeon pea)			Perennial shrub	Multipurpose (provides soil cover and is food grain). It is ideal for intercropping. It does not compete with other crops as it has a deep taproot and a slow initial development. It is especially well suited for dry climates and for restoration of poor soils. Residues can be used as mulch for the next crop.

[1] The recommended spacing will allow good ground cover within 2-3 months (for the annual herbs). The perennial shrubs take much longer to cover the ground. The spacing can be increased if the cover crops are grown for seed multiplication. Where the cover crops are to be intercropped with a crop (e.g. maize), plant the cover crop between rows of the crop after the first weeding, and then leave the cover crops to continue growing until land preparation for the next crop when the cover crop can be incorporated into the soil or cut and left on the surface as mulch.

[2] The perennial shrubs are best for areas that are badly degraded and they should be left to grow for two or more seasons. They also grow well in highland areas.

Mix and rotate crops (crop rotation): In conventional farming, the same crop is sometimes planted every season on the same piece of land. This allows certain pests, diseases and weeds to survive and multiply, and lowers soil fertility, resulting in lower crop productivity. In CA, this is minimized by planting the right mix of crops in the same field, and judiciously rotating crops from season to season. Rotation with legumes helps to improve and maintain soil fertility. Mixing crops, for example cereals (e.g. maize) with legumes (e.g. beans, groundnuts, etc) reduces the risk of total crop failure, maximizes land utilization, and increases food security and farm profits.

To gain the full benefit of conservation agriculture, all the three principles have to be applied at the same time. However, this is sometimes not possible and from experience application of any of the principles or a combination of any two is far better than not applying any at all.

1.2 Practicing Conservation Agriculture/Farming

The CA package prescribes dry season land preparation, precision input management, crop residue retention and crop rotations involving cereals and leguminous crops. These practices aim to improve the soil structure, water retention and reduce the need for external inputs (e.g. chemical fertilizers) while at the same time improving crop yields.

It has been advised that before you start with CA, it is necessary to address various soil problems such as compacted soils and hardpans (IIRR and ACT, 2005). Soil compaction is often as a result of land degradation, which mainly occurs through deforestation, burning of grasslands/

organic residues, and continuous cultivation with minimum soil fertility enhancement leading to soil erosion and organic matter and nutrient depletion. Planting basins and rip-lines are major components of the recently introduced conservation farming package for renovation of degraded landscapes that is being extensively promoted for smallholder farming. By breaking through pre-existing hard/plow pans, PPBs and riplines improve water infiltration and root development.

Permanent Planting Basins: Permanent planting basins (PPB), as used in conservation farming, is a crop management method which enhances the capture and storage of rainwater and allows precision application of limited nutrient resources. The method is widely used to reduce risk of crop failure due to erratic rainfall. It is reported that use of PPB in combination with improved seed and crop residues to create a mulch cover that reduces evaporation losses, has consistently increased average yields by 50 to 200% depending on the amount of rainfall, soil type and fertility (Twomlow, 2012). This strategy is a good option on small plots for annual crops and where draught animal power is not an option.

Rip lines using draught animal power: Farmers who own (or can hire) oxen to pull implements can use a sub-soiler to break up hardpans. Hardpans are soil layers that act as barriers to root and water movement. The compactness of the soils in these features affects agricultural land in a number of ways, including among others, inhibiting root and water movement; facilitating runoff hence limiting water infiltration and retention; and making plowing difficult. As a consequence, they affect agricultural productivity. Subsoiling is usually necessary only in the first year. If there is no hardpan, the farmer can use an animal drawn ripper to open up a narrow furrow 15-20cm deep for planting seed. The soil between the furrows is left undisturbed.

1.3 Examples of CA techniques in reference to the three basic principles

Direct sowing with a hand hoe (Minimum tillage): Many Ugandan farmers cultivate using the hand hoe. Such farmers can practice CA by digging small planting holes in lines, at recommended spacing, leaving the rest of the soil undisturbed. The farmer can put fertilizer and compost or manure in the holes to raise the soil fertility and the water-holding capacity and thereafter sow the seeds.

Soil cover

Crop residues: - can be placed between plant rows to create a mulch cover, which protects the soil from erosion, conserves soil moisture and suppresses weeds. This way the few weeds that emerge can be pulled out by hand or by scraping lightly with a hoe.

Cover crops: - some cover crops are multipurpose, that is, they are planted to provide a soil cover, improve soil fertility and produce food and animal feed. It is advisable to plant cover crops which fit in the local cropping system. Cover crops can be grown up to six month or beyond, after which they are slashed or killed by herbicide just before planting the next crop, leaving the dead material on the ground to serve as mulch.

Crop mixes and rotations

Crop mixes should be adapted to the local conditions and household resource constraints. It is a common practice by many Ugandan farmers to mix maize with either beans or ground nuts. However, most farmers do this haphazardly without any consideration for optimum patterns. Many farmers also do crop rotations which is part of the local cropping systems. Cereal-legume rotations are desirable.

Agro-forestry systems: Branches pruned from widely spaced rows of leguminous trees are spread as mulch on the soil surface in the alleys between the tree rows, thus enriching the alleys with nutrients from the leaves as well as conserving soil moisture. The crops grown in this alley-cropping system may yield better than crops grown alone, but only if competition between trees and crops for light and water can be kept to a minimum.

1.4 Benefits of conservation agriculture relative to conventional farming

Both conventional farming and conservation agriculture have similar operations including field preparation, planting, fertilization, weeding, and harvesting. However, the point of departure is how these operations are conducted, the time spent, the cost of operations as applied in each farming method, and the accruing benefits (Table 2). Generally, conservation agriculture means less work because one does not need to plow the land and it may not be necessary to weed as many times as is the case with conventional farming. Conservation agriculture also suppresses weeds and reduces soil erosion; it improves the soil structure, water holding capacity, organic matter content and soil fertility, all leading to more stable yields and higher productivity and profitability.

Table 2: Benefits of conservation agriculture relative to conventional farming

Element	Conventional farming	Conservation agriculture
Soil moisture	Crop residues are often burnt or buried in the ground leaving the soil bare leading to soil moisture loss.	Crop residues and cover crops provide a mulch cover so there is less evaporation from soils.
Erosion	Since the soil is left bare, wind and water erosion are a common phenomenon.	Cover crops and mulch protect the soil surface from wind and rain, thus minimizing soil loss through wind and water erosion.

Element	Conventional farming	Conservation agriculture
Soil fertility	Poor management of organic matter through burying and burning depletes soil fertility. Planting the same type of crop season after season removes valuable nutrient from the soil.	Crop residues and cover crops stay on the soil surface, adding to the organic matter. Legumes in crop mixes or rotations and leguminous cover crops improve soil fertility by fixing atmospheric nitrogen.
Weeds	Leaving the soil bare allows weeds to grow unhindered. Planting the same type of crop season after season encourages certain weeds, pests and diseases to flourish.	The cover crops or mulch suppress weeds and prevent them from growing quickly.
Costs and labour	Plowing and weeding are expensive operations, take a lot of time, and are tedious and laborious work.	Less time is spent ploughing and weeding. Costs are reduced to a bare minimum since there are less operations.
Crop diversity	Mono cropping produces one crop, with the risk of failure if there are extreme weather events (floods, or drought) or pest attack. Farmers incomes and diets depend on a single crop.	Crop rotations and crop mixes produce a range of crops. They reduce the risk of total crop failure in case one crop succumbs to extreme weather events or pest and disease attacks.
Environment	Conventional farming leads to environmental degradation because it encourages soil erosion leading to pollution of water sources. It releases CO_2 in the atmosphere which contributes to global warming.	Conservation agriculture reduces soil erosion leading to cleaner water sources throughout the year. It increases the amount of carbon in the soil, acting as a carbon sink and reduces global warming.
Yield	Yields fall over time due to declining soil fertility. This has led to encroachment on forest areas, swamps, etc.	Soil moisture and fertility is conserved, so land productivity is higher and yields are stable.

1.5 Factors affecting the adoption of conservation agriculture

Although CA has been fronted as the solution to many of challenges encountered in smallholder farming, its adoption has not been swift. Practitioners of CA point to several challenges that limit its adoption. These challenges are grouped in socio-cultural, economic, and policy and institutional.

Socio-cultural impediments

- Switching to CA involves a fundamental change in mindset. The attitude of farmers or their mindset has often been cited as a major impediment to the adoption of CA practices. Many farmers believe that one can only plant in a well tilled seedbed as opposed to fields covered with crop residues as prescribed in CA. More than often, crop residues which is an essential element of CA are burnt leaving the soil bare and exposed to the elements of weather [heat, wind, rain, etc.].

- The transformation from conventional agriculture to CA requires considerable farm management skills. However, farmers do not challenge themselves to learn new skill and are inclined to doing business as usual.

- Crops such as millet and sesame which have very small seeds can be difficult to sow without disturbing the soil.

- Some farmers have refused to include cover crops into their cropping systems for the sole reason that some cover crops are not multipurpose. In addition, well known multipurpose cover crops such as pigeon peas are mythically associated with harsh weather conditions in some parts of the country, while pigeon pea is not a common food crop in these areas.

- Since the known cover crops need moisture to grow well and therefore have to be grown during the cropping season, many farmers are not willing to sacrifice a cropping season to grow cover crops instead of their food.

Economic impediments

- The transformation from conventional agriculture to CA involves investment in equipment and inputs such as herbicides, pesticides and fertilizers. The benefits of CA can only be realized if farmers can access and afford the cost of the necessary equipment and inputs. Many farmers using CA point to high costs of equipment and inputs as one of the main impediment to its adoption.

- Other challenges include crop residue management: keeping the soil covered is an important element in CA, but it has proved to be difficult. This is mainly because farmers have many uses for the crop residues, e.g. they are used as fodder and for fencing, roofing, and fuel. It has also been noted that access to cover crop seed can be a challenge.
- It is believed by some that conservation agriculture allows more weeds to grow, making weed management a serious challenge in CA plots.

Policy and Institutional impediments

- Traditional research and extension services are weak and slow in responding to the changing needs of farmers, especially in the context of a changing climate.
- There has been inadequate support in knowledge, skills and incentives, making CA non attractive to would-be adopters.
- There is limited access to credit and financing and at present there is limited access to crop insurance.

1.6 Conservation Agriculture in Uganda

In Uganda both government and non-governmental organizations (NGOs) have initiated programmes and projects geared towards developing and promoting conservation agriculture. In 2002, the GoU sought technical and financial assistance from FAO to implement a CA pilot project, which aimed at introducing the three principles of CA through an approach using Farmer Field Schools (FFS) as an integral part of improving land management and livelihood strategies of smallholder farmers. This was the first such project in the country that focused on demonstrating the applicability of CA systems in Uganda and its multiple benefits in terms of productivity (saved labour, enhanced income, product diversification), sustainable use of natural resources (biodiversity and resilient land-use systems) and environmental services (better water quality, reduced erosion).

In recent years, CA has been promoted through initiatives such as:

- SIMLESA/CIMMYT/ACIAR project being implemented in Nakasongola and Lira districts;
- MAAIF-UNDP-GEF SLM project in the Cattle Corridor districts of Kamuli and Nakasongola;
- MAAIF-NARO-WB-GEF SLM/ATAAS Project implemented in nine zones across the country;
- COMESA-UNDP-FAO project being piloted in five districts (Budaka, Bugiri, Busia, Buyende, and Namutumba) in eastern Uganda;

- The Cooperative League of the United States of America (CLUSA) in Alebtong, Apac, Pader, Dokolo, Kole, Lira, Otuke, Oyam, Amolator, Agago, Kaberamaido, Kiryandongo, and Masindi;
- Rural Enterprise Development Services (REDS) with the support of development partners including, DFID, EU, the Norwegian Government and USAID.

Local sources of CA equipment

Conservation agriculture equipment is not easy to come by, however there are a couple of institutions engaged in fabricating, testing and adapting CA equipment to the Ugandan environment (Table 3).

Table 3: Institutions that fabricate conservation agriculture equipment in Uganda

Institution	Location
Agricultural Engineering and Appropriate Technology Research Centre (AEATREC) – Namalere, NARO	Kawanda/Namalere (13km Kampala-Gulu HWY)
Tillers International	Lira, Northern Uganda
SAIMMCO (Soroti Agricultural Implements and Machinery Manufacturing Company)	Soroti, Eastern Uganda
TONNET	Kampala
Engineering Solutions	Bugolobi, Kampala






MODULE 2: Establishment and Management of Conservation Agriculture Demonstrations/Trials

2.1 Planning Conservation Agriculture Demonstrations/Trials

To enhance adoption of conservation agriculture (CA), farmers need to be exposed to its three basic principles as practiced in the field followed by training. However, it may not be cost effective to train each and every farmer individually. Successful conservation agriculture (CA) promotion has been through farmer groups and/or Farmer Field Schools (FFS). One of the best approaches when working with farmer groups or FFS is establishment of field demonstrations. The demonstrations are used as training and learning fields for both the field extension worker (FEW) and farmers.

Before a demonstration is established, the FEW will need to understand the people they are going to work with. The following section elaborates the necessary steps that should be taken to effectively engage the communities and establish successful demonstrations to accelerate CA adoption.

It is important that the FEW take time to understand and know how best to work with the people they serve. In the past, extension services in Uganda have been characterized as top-down, with FEW telling farmers what to do and what not to do. Over time it has been realized that this approach does not produce the desired results. Often times, the moment the FEW depart the farmers return to their previous practices. In contrast, participatory approaches have proved to be more cost effective.

It has been observed that although they take more time and effort, they are more effective in the long run. Suffice to note that participatory approaches require the FEW to be equipped with skills in listening, facilitating, and organizing, rather than deciding and instructing.

Characteristics of participatory extension approaches

- Avoid the problems of top-down extension.
- Aim to enable local people to take part in making decisions that affect them, rather than having their lives shaped for them.
- People discuss issues, identify and prioritize problems, seek solutions, and plan what to do, implement, monitor, and evaluate what they have implemented.

- Participation ensures that activities are based on local knowledge, values and priorities.
- Activities are small-scale and should be adapted to local skills and technology.

Advantages of participatory approaches

- They take advantage of what farmers already know in form of indigenous knowledge, and other technologies and practices that might be unknown to the FEW.
- They increase the appropriateness of the activity, since farmers can choose options they think are best suited to their particular situations.
- They build ownership and accountability among farmers for the activities/interventions, hence sustainability is enhanced.
- Community involvement enhances accountability, increases sense of ownership and improves the care/maintenance of interventions.
- They improve coordination of activities and avoid conflicts among farmers because decisions are made as a group.
- They empower farmers to make their own decisions and by building community capacity.
- They help organize effective, committed, sustainable groups which can work as a team.

Limitations and constraints

Participatory approaches tend to suffer from various disadvantages

- Time consuming.
- High expectations from farmers.
- Some people may become free-riders (i.e. they take the benefits of the activities without doing any of the work).
- Some farmers may block changes that others want, or can influence the group in undesirable ways.
- Some farmers may hinder the progress of others.

Criteria for demonstration site selection

- In case of selection of sites for demos; this should be done in a participatory manner with the involvement of the FEW and all members of the farmer group or FFS. Farmers themselves, in the group/FFS, should provide a piece of land for the CA demonstration. The land may be communal or any of the group members may volunteer to provide a piece. Such a group member will be called a host farmer.
- In order to make meaningful observations during the experimentation phase, it is recommended that the demo covers not less than 60m × 70m
- The demo/treatment plots should range between 2 and 4 and must be distinct and clear so as not to confuse the experimenting farmers.

- The demo should be located at a site with enough land to accommodate it and with enough space to comfortably host at least 30 people during training sessions, exchange visits, and field days.
- Besides benefiting group members, demos are designed to attract non-group members to appreciate and adopt the technologies being demonstrated. It is therefore imperative that the demo is located in a place easily accessible by community members.
- The site should be well protected from livestock and wild animals to avoid damage to the crops and other installments at the demo site.

Steps to follow when establishing a CA demo

- The FEW/facilitator should survey the piece of land selected by the farmers to confirm its suitability for the demo and actual measurements.
- The FEW/facilitator should design the layout as shown in **Figure 1**; during the process make sure to involve the farmers and make them understand reasons for everything that is being done in every plot.
- Once the layout is done, assemble the following items: a rope, pegs, tape measure, hammer/stone, then proceed to demarcate the entire demo with assistance of farmers
- After the demarcation, guide the farmers to prepare the plots according to the objectives of the demo.

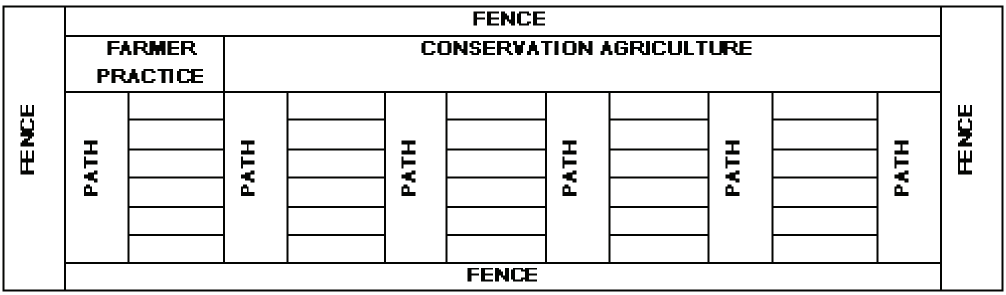
How to manage a CA demo

- It will be the responsibility of the farmers to manage the CA demo guided by the FEW/facilitator.
- The FEW/facilitator should assist the farmers to develop a management plan which is simple and acceptable to the majority.
- Management of demos by farmer groups/FFS have faced challenges due to failure to define roles and responsibilities by group members. Members also cite failure to equitably share demo outputs as another challenge often faced by groups/FFS. It is therefore important at the time of demo establishment to define the roles and responsibilities of each and every group member. Furthermore, members ought to agree on how to equitably share the outputs from the demo. Equitable distribution of outputs means that members share the outputs according to/in proportion to their contributions made in the form of time, inputs, advice, or any other contribution deemed important for the establishment and management of the demo.

How to compare practices

- Newly introduced practices/technologies need to be placed side by side with the farmer practices/technologies to establish whether the new practices/technologies are better or worse than the old ones.
- Practices/technologies are best compared when placed side by side in one field; also ensure that the field sites are not too different. For example if one side is a wetland and another is dry, the two cannot be compared.
- Ensure that all plots are treated similarly, e.g. plant and weed in the same period, apply the same amount of fertilizer/manure, etc.

Figure 1: Typical CA demo layout



How to observe and monitor demos

- Observing the trials in the course of crop growth helps to identify differences; when a crop is grown with two different techniques side by side in the same field farmers are able to see the differences easily. For example, in one treatment the maize might grow faster or be taller than in another treatment, or cobs might be bigger.
- Such observations need to be recorded so that they are not forgotten and can be analyzed in more in future.
- Farmers are encouraged to record all their observations for each treatment; this helps to share experiences with other farmers and FEW and can be used for scaling up.
- If a practice/technology is successful, one can increase the area the following season.
- In case of failure, it is very important to discuss with other farmers and extension workers/ facilitators why the practice/technology failed, and how it can be modified and adapted to improve it.

Table 4: Field observations

Factor	Farmer practice	CA
Plant health and growth		
Pests and diseases		
Soil conditions		

Records Keeping

- One of the key steps in managing a successful CA demo is keeping good, accurate records and establishing a sound record-keeping system. Records can be helpful in planning improvements and making proper management decisions. A good record-keeping system is one that will provide the necessary information and provide the information when needed. It will furnish the necessary information for understanding the activities of demo operation.
- Farmers should be encouraged to keep records right from the beginning of planning and establishing the demo. For example, records of labour requirements for land preparation, weeding; application of inputs, and harvesting (workdays per hectare) and costs of inputs (Table 5 and 6).

Table 5: Labour requirements for land preparation, planting, weeding & harvesting (workdays per hectare)

Activity/operation	Farmer practice	CA
	(Work days[a]/Oxen days[b])	
Bush clearing		
First plowing		
Second plowing		
Slashing		
Spraying herbicide		
Planting		
First weeding		
Second weeding		
Applying fertilizer		
Applying pesticides		
Harvesting		
Total		

[a]1 workday = 4 hours of effective working
[b]1 oxen-day = 6 hours of effective working

Table 6: Land preparation, planting, weeding & harvesting costs per hectare

Activity/operation	Farmer practice	CA
	(UGX)	
Bush clearing		
First plowing		
Second plowing		
Slashing		
Harvesting		
Inputs		
Fertilizer		
Pesticides		
Herbicide		
Hiring sprayer		
Spraying herbicide		
Total		

2.2 Implementation and management of Conservation Agriculture Demonstrations/Trials

Planning is hard, but implementation is even harder. This is when people put into action what they have decided to do. They form groups, build structures, manage resources, etc. The FEW's role is to assist, encourage, motivate, organize, solve problems, and provide technical support. During implementation, the farmers and FEW should decide how they are going to measure the results of their work in the form of a monitoring and evaluation plan.

2.2.1 Field Preparation and Planting

Controlling weeds and cover crops

In conservation agriculture the soil is kept covered with a crop or with crop residues. Before planting, one may need to kill the cover crop and any weeds within the plot. Cover crops and weeds can be killed by:

- Slashing,
- Using an animal- or tractor drawn knife roller,
- Applying herbicides with a sprayer.

Among the three methods used to kill cover crops and weeds, slashing is the easiest and requires the least skills. Slashers and/or machetes can be used to cut the cover crops and weeds. The best time to cut and kill the cover crops is in the early stages of the reproductive phase (when the seeds are at milk stage) before the seeds are mature enough to germinate. When the cover crops are cut during the vegetative stage it is not possible for them to regenerate and go on to compete with the planted crop. On the other hand, when the cover crops are cut in the advanced stages of the reproductive stage (when the seeds have matured) the seeds will germinate and go on to compete with the planted crop.

Knife-rollers

A knife-roller is a heavy cylindrical CA implement studded with blades. A knife-roller kills the cover crop and weeds by bending them over and shredding them; this causes the cover crops and weeds to desiccate. To use a knife-roller one needs either oxen or a tractor.

Application of herbicides

Herbicides are used to control weeds in CA. They are quick and easy to apply and in that respect allow farmers to cover extensive areas at less cost compared to conventional farming. They also allow farmers to timely planting which is essential in regard to unusually short cropping seasons due to climate change, as herbicides are quick and easy to apply. However, not many smallholder farmers use them, because unlike family labour which is often used for plowing, one needs money to buy quality herbicides which may sometimes not be available especially in rural communities, and may be costly when available. Common spray pumps include knapsack sprayers, pedestal sprayers (hand-pulled or animal drawn) and tractor-mounted boom sprayers. The choice of what to use depends on affordability and availability, and the size of the farm.

Herbicides are hazardous and need to be used carefully:

- Before using the herbicide make it a point to carefully read the instructions.
- Use protective gear to protect yourself from harmful effects of the herbicide [cap or hat on the head, goggles, nose/mouth mask, overalls, hand gloves and gum boots].
- Wash your hands, face, body and equipment immediately after handling or using the herbicide; this should be done away from water sources such as wells, ponds or rivers.
- Always store herbicides in their original containers, well out of reach of children and animals.
- Properly dispose of empty containers, as per guidelines written on the instructions.

- For the herbicide to be effective, apply when the cover crops and weeds are actively growing. Avoid applying herbicides when the weeds are stressed, for example during the dry season.
- Avoid applying the herbicide when the weeds are wet, for example very early in the morning when the weeds still have dew on them or after it has just rained and the weeds still have raindrops.
- Avoid spraying herbicides when the weather is windy to prevent the herbicide from drifting to non-targeted crops or areas.
- Before applying the herbicide check to see that it will not rain at least one hour after spraying.
- Make sure to apply the right concentration, as over doses are not only wasteful but also harmful to the environment. Under-doses are wasteful in that the herbicide will be wasted without producing the desired effect and if not properly killed, the weeds will continue to compete with the planted crop.

Table 7: Types of herbicides, their characterization and application rates

Trade/ common name of herbicide	Active ingredient	Characterization	Application rate
Agrosate, Weed master, Round up, Mamba	*Glyphosate*	It is a post-emergence, systemic, non-selective herbicide that works on both broad-leaved weeds and grasses.	5 to 7.5 litres per hectare; applied as 400 ml of herbicide per 20 litres of water.
2,4-D	2,4-Dichlorophe-noxacetic acid	It is a post-emergence, systemic, selective herbicide that kills broad-leaved weeds; it does not work on grasses and does not kill cereals. Therefore, it can be used to weed maize.	If applied together with *glyphosate* in pre-emergence application 100 ml 2, 4-D is added to 300 ml of *glyphosate*.

Amelioration of degraded soils

At the time of changing from conventional farming to conservation agriculture there may be several challenges to contend with. These include biophysical soil challenges as well as the lack of appropriate CA tools and implements. Two of the most common biophysical soil problems in Uganda are:

- Compacted soils,
- Hardpans,

Although the hand hoe is an appropriate tool for CA, there may be need for conservation agriculture specialized CA tools e.g. rippers, jab planters, direct seeders, etc. These are often not easy to access and if available many farmers may not afford their cost. Besides dealing with the biophysical soil challenges as you start with CA, one may also want to establish sustainable land management (SLM) techniques such as contour bunds and water-harvesting methods. For example, if soil erosion is a serious problem in the area, it should be dealt with before starting CA.

Compacted soils/hardpans

Compacted soils have a hard, dense layer at or near the surface. It is difficult for water to move through this layer, and for seedlings to grow well in it. Soils may be compacted when tillage destroys the soil structure by breaking down the natural system of pores and channels. Compacted soils/hardpans make it hard for crop roots to grow and to reach water and nutrients. They prevent water and air to move into the soil; this can lower yields and make crops more susceptible to drought. Also, if the soil is compacted, it is harder to till.

In Uganda, poor land management, including overgrazing and soil erosion, leads to development of compacted soil layers and often bare grounds in extreme cases. Another widespread factor is that most farmers in Uganda use the hand hoe, which only disturbs the first 15 to 20cm of the top soil. This hoeing, done consistently and regularly, can lead to development of restrictive layers/ hardpans below the 0 – 20cm of the top soil. Under these soil conditions nutrient use efficiency, especially nitrogen use is very low.

From field observations, ameliorating these restrictive soil layers leads to increased nitrogen use efficiency, greater rooting depth, and improved water holding capacity that increases land productivity leading to better harvests and food security. The long-term benefits are increased soil organic matter content, increased return on fertilizer use, and greater resilience of dryland small holder plots to erratic rainfall patterns.

Tell-tale signs of compacted soil layer/hardpans

Stunted, uneven crops – crops may grow poorly because their roots cannot reach down to nutrient/water in the soil.

Yellow leaves – yellow leaves and other signs of nutrient deficiencies (purple leaves, stunting, brown leaf edges, etc) may be caused by poor rooting systems.

Rapid wilting – crops may wilt quickly during dry periods as the surface layers of the soil dry out.

Distorted roots – This may not be visible on the surface, but if you dig up plants and examine their roots, if the roots grow sideways at a certain depth, there is probably a compacted layer/hardpan.

Water logging – puddles on the surface after heavy rains mean that water cannot drain down into the soil easily – perhaps because of a hardpan.

Loosening the soil and breaking the compacted layer/hardpan allow crop roots to penetrate deeper into the soil and reach more nutrients and water.

There are three main ways to loosen the soil and break up compacted layers or hardpans:
- Soil ripping,
- Subsoiling,
- Using Permanent Planting Basins.

Ripping

If the soil is fairly light, and if the compaction or hardpan is near the surface, you can use a ripper to loosen the soil. A ripper is a chisel-shaped implement pulled by animals or a tractor. It breaks up surface crusts and opens a narrow slit or furrow in the soil, about 15 – 20cm deep. Unlike the conventional plow, a ripper does not turn the soil over. Ripping can be done during the dry season, or at planting. Seeds can be planted in the slit/furrow by hand or using a planter attached to the ripper. Rip lines are normally established at a spacing of 75cm with in-row spacing of 30cm with one seed per hill for maize and 10cm with two seed per hill for beans.

Subsoiling

If the hardpan is deeper or if the soil is heavy, you may have to use a subsoiler. A subsoiler is a chisel-shaped implement that looks like a ripper but works at a greater depth and has narrower tines, up to 20cm long. It is designed to work at a depth of about 20 to 30cm, just below the level of the hardpan and allows water to infiltrate easily into the soil. One needs at least four strong oxen to pull a subsoiler. Sub-soilers can also be mounted on a tractor. It is recommended that you do subsoiling once, when you first switch to conservation agriculture and thereafter do it periodically, once every few years.

Do's and don'ts when ripping and subsoiling

- First observe to see if there is a hardpan and determine how deep it is by digging a pit, then use the subsoiler just below this depth.
- Never use the subsoiler when the ground is wet. Only use the subsoiler when the ground is dry to crack and shutter the hardpan.
- Follow the contours when subsoiling or ripping. This encourages water to infiltrate into the soil rather than running off.

Required tools and implements

- A ripper – a chisel-shaped implement pulled by animals or a tractor. It is best to do ripping when the soil is dry. This prevents compacting the soil further and ensures that the hardpan is broken.
- A wing – is a small implement attached to the ripper when the soil is wet to widen the planting furrow.
- Draught animals or a tractor – for smooth and effective ripping one may need two strong oxen. On heavy soils and extensive areas or for deep ripping (subsoiling) one may need a tractor.

Permanent Planting Basins

For farmers that do not have oxen or a tractor, and cannot hire them, they might have to use a hand hoe to loosen the soil and break up the hardpan. The easiest way to do this is to use planting basins. Instead of digging up the whole field, you dig basins only where you want to plant the crops. Dig the basins slightly deeper than the depth to which you normally stop when digging with the hand hoe in order to break through the hardpan.

How to make the basins

Planting basins are small pits in the ground used for planting many types of crops. They are about 15cm wide, 35cm long, and 15cm deep (about the size of a man's foot).

Planting basins are prepared during the dry season, so they are ready for planting at the beginning of the rainy season.

Required tools and implements

- A hand hoe for digging the basins – should be of suitable size, for example 10cm wide.
- A long string for marking the field – this is used for marking the correct distance between the basins. Knots are tied in the string or metallic soda bottle tops are clamped at the plant spacing required.
- Soda or mineral water bottle tops – these are used for applying fertilizer. A soda bottle top applies 7g of fertilizer while a water bottle top applies 10g.
- A plastic container – this is used to apply manure

The number of basins to dig is determined by the spacing and the number of plants you need per hectare. In conventional maize production, farmers aim for 44,444 maize plants per hectare (spacing: 75cm × 60cm; two seeds per hole). Since basins are permanent they need to be constructed in such a way that they will accommodate both cereals e.g. maize and legumes e.g. beans planted in a rotation. In that regard, the adapted spacing of basins in Uganda is 75cm × 70cm. At this spacing, with three seeds per basin the total maize plant population per hectare is 57,142 and that of beans planted at a rate of six beans per basin is 114,286 bean plants per hectare.

Applying fertilizer and manure

After digging the basins, you can then apply fertilizer and manure within the basins. This helps in precision nutrient management. Do this at the time of planting or just before planting to speed up the planting exercise.

Manure: A plastic container (*tumpeco*)– this is used to apply manure. Apply one mug-full (*tumpeco*) of compost in each basin. This adds up to 3-4 tons of manure per hectare.

Fertilizer: DAP (*diammonium phosphate*) applied at the time of planting – put either one soda bottle cap (7g) or three quarters of a mineral water bottle cap (this is done by filling some space in the cap with a thumb). This adds up to about 100kg per hectare.

After you have applied the manure and fertilizer, use a hand hoe to nearly fill the basin with soil. As a rule of thumb, always cover the manure and fertilizer to avoid contact with the seed.

Urea: Apply urea just like DAP. The best time to apply urea depends on the crop. For instance, in the case of maize, urea should be applied about 1½ months after planting or when the maize crop has reached knee-height. This is best done when the soil is moist and in the evenings.

Hard facts about planting basins

- Basins are permanent, to be used over and over again, therefore one needs to pay close attention when establishing them in order to last for a long time.
- Dig basins during the dry season and not during the rainy season; hardpans are best dealt with during the dry season.
- After digging the basin nearly fill it back with black soil; this ensures a wider area for the crop to feed from. If only partially filled the crops may be flooded.

Other methods of direct seeding

A jab planter makes planting seed easier and quicker. A jab planter is a mechanical device that is operated by hand.

It has two shafts made out of metal or wood, with handles at the top and a metallic beak at the bottom. It also has a hopper on one of the shafts to hold seed; some models have two hoppers, one on each of the shafts to hold seed and fertilizer.

How to use a jab planter

- Hold the handles apart; by doing so the slide is opened to allow the seed to fall into the closed beak.
- Jab downwards so the beak pushes into the soil.
- While the beak is still in the soil push the handles together this opens the beak and the seed falls into the hole you have made.
- Keeping the handles together, lift the jab planter out of the soil. The soil will then fall back into the hole to cover the seed.

One can control the number of seeds and the amount of fertilizers that is applied by moving a slide at the bottom of the hoppers.

Plant spacing when using a jab planter can be determined using a marked string. However, as a guide, a man's normal stride is about 60cm long. If one wants to plant at spacing longer than that, one has to take long strides between jabs. One can test himself/herself with a measure until the right distance is judged.

Using a stick

Lack of implements for direct seeding should not stop anyone from practicing CA. Farmers in Uganda and elsewhere have used sticks for direct seeding. What one needs is a hardwood stick, which should be sharpened and use the sharpened end to make planting holes. Adding a sharpened metal tip to the planting stick makes it last longer and easier to use. When planting using a stick and with the intention of applying fertilizer two holes can be made beside each other, approximately 5cm apart and one hole is used to plant the seed while fertilizer is placed in the second hole. Rule of thumb: never put fertilizer in the same hole as the seed.

Table 8: Planting method and the seed rate per hectare for maize and beans

Crop	Planting method	Spacing	Number of seeds per planting station	Total plant population per ha	Estimated Amount of seed/ha (kg)
Maize	Conventional	75cm × 30cm	1	44,333	20
		75cm × 60cm	2	44,333	20
	Rip lines	75cm × 30cm	1	44,333	20
	Basins	75cm × 70cm	3	57,000	26
Beans	Conventional	50cm × 10cm	1	200,000	80
	Rip lines	75cm × 10cm	2	266,000	106
	Basins	75cm × 70cm	6	114,000	46

2.2.2 The Conservation Agriculture Calendar

To gain the full benefit of CA, operations must be well timed because any missed or delayed step could lead to a mismatch of events with crop development stages, evoking serious consequences. Conservation agriculture demonstration plots need to be established well in time according to the rainfall patterns in the area.

In areas with a bimodal rainfall pattern, the first season commences in March and ends in May. The second season normally commences in September and ends in December.

Figure 2: Average monthly rainfall (mm) distribution at Namulonge Meteorological Station, from 1998 to 2007

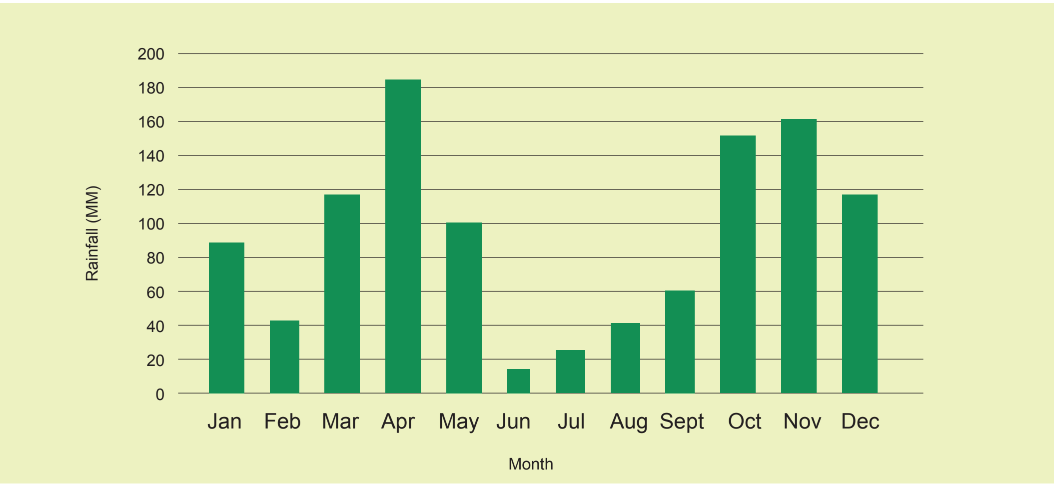


Table 9: Calendar of Conservation Agriculture activities in areas with bimodal rainfall

	Activity	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
1	Field preparation [construction of basins and rip-lines] in the dry season												
2	Herbicide application												
3	Basal fertilizer and manure application												
4	Planting												
5	Fertilizer top dressing												
6	Harvest												
7	Management in the dry season												

- Field preparation [construction of basins and rip-lines] in the dry season: January to February and July to August. The CA package prescribes dry season land preparation.
- Herbicide application – March to April and September to October [It is recommended to apply herbicides when the rain season has started and the weeds are actively growing].
- Basal fertilizer and manure application – March to April and September to October [Always cover the manure and fertilizer with soil to avoid contact with the seed].
- Planting - March to April and September to October.
- Fertilizer top dressing – April to May and October to November.
- Harvest – July to August and January to February.
- Management in the dry season - January to February and July to August [the farmer opens basins and rip lines in the same position as the previous season and the process starts all over again.

Outputs and outcomes

- Improved land management, higher crop production and productivity, greater livestock yields, and ways to measure these.
- Economic benefits, such as greater incomes, and improved livelihoods.

In areas with one long rain season, the rains start in April and end in October, lasting between 5 and 7 months. These areas also experince one dry season of about 6 months i.e. from October to March.

Figure 3: Average monthly rainfall (mm) distribution at Soroti Meteorological Station, from 1998 to 2007

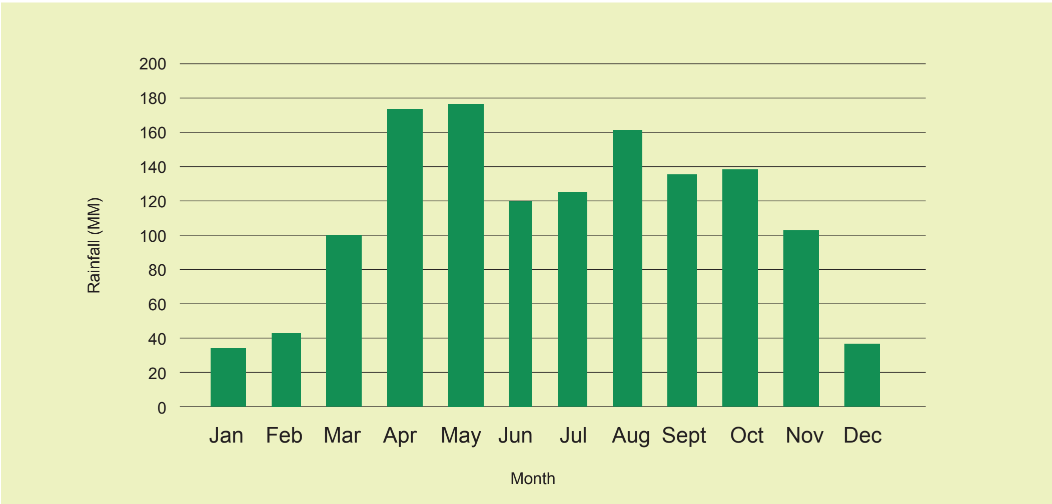


Table 10: Calendar of Conservation Agriculture activities in areas with one long season of rainfall

	Activity	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
1	Field preparation [construction of basins and rip-lines] in the dry season												
2	Herbicide application												
3	Basal fertilizer and manure application												
4	Planting												
5	Fertilizer top dressing												
6	Harvest												
7	Management in the dry season												

Table 11: Estimated costs of Conservation Agriculture operations

Conservation Agriculture Service	Cost of service per ha (UGX) †	Inputs required	Cost of inputs per ha (UGX)	Total cost [service + inputs] (UGX)	Comments
Boom spraying	61,750	5 litres of *glyphosate*	100,000	161,750	Apply herbicides when the weeds are actively growing
Sub-soiling (required inputs: oxen/ tractor, sub soiler)	148,200	-	-	148,200	It is recommended that you do sub-soiling once, when you first switch to conservation agriculture and thereafter do it periodically, once every few years (3 – 4 years or 6 to 8 seasons).
Ripping	148,200	Oxen and oxen ripper	-	148,200	Ripping can be done during the dry season, or at planting. Seeds can be planted in the slit/furrow by hand or using a planter attached to the ripper.
Construction of Permanent Planting Basins	375,000	Hand hoe			It is recommended to prepare basins during the dry season
Planting by hand	148,200	Maize: 20 kg	80,000	828,200	
		DAP: 2 bags	300,000		
		Urea: 2 bags	300,000		
		Beans: 80 kg	320,000	768,200	
		DAP: 2 bags	300,000		

Conservation Agriculture Service	Cost of service per ha (UGX) †	Inputs required	Cost of inputs per ha (UGX)	Total cost [service + inputs] (UGX)	Comments
Direct seeding	111,150	Maize: 20 kg	80,000	791,150	A direct seeder is designed to rip, plant the seed, and dispense fertilizer at the same time. This helps to save money and time.
		DAP: 2 bags	300,000		
		Urea: 2 bags	300,000		
		Beans: 80 kg	320,000	731,150	
		DAP: 2 bags	300,000		
Jab planting	111,150/=	Maize: 20 kg	80,000	791,150	Not recommended for clayey soils but rather sandy soils
		DAP: 2 bags	300,000		
		Urea: 2 bags	300,000		
		Beans: 80 kg	320,000	731,150	
		DAP: 2 bags	300,000		

† UGX 3,340 = USD 1

2.3 Monitoring of Conservation Agriculture Demonstrations/Trials

It is important that both farmers and the FEW monitor activities so they can make adjustments as they go along. At the end of the work, they should evaluate what they have done and decide on what to do next. In a participatory manner, the farmers together with the FEW can develop a monitoring and evaluation plan (including key performance indicators, targets, etc.).

Monitoring systems for conservation agriculture seek to answer both generic and specific questions (FAO, 2009). The generic questions seek to know the impact of CA on household level of food security e.g. area planted, quantity of production, income generated, number of people undertaking the practice, inputs used, etc. The specific questions are mainly on the effectiveness of CA: comparison of yields with those from conventional practices, problems encountered by farmers, adoption rate, change in soil properties, etc.

To develop a monitoring system which addresses both the generic goals and specific objectives of a CA demo, the following steps are taken:

1. List all the steps necessary for establishing a CA demo and identify the variables that can be measured in each step,
2. Define core indicators,
3. Design an operational plan for data collection and analysis,
4. Implement the plan.

Table 12 describes output and outcome indicators that can be customized to define core indicators of a particular group. It is important when defining core indicators to understand the difference between output and outcome indicators. According to FAO (2009), monitoring is often divided into looking at the process of conducting an activity, and its ultimate impact. Process is measured by describing the immediate outputs, such as the number of inputs distributed or people trained. Impact is evaluated by defining and measuring the medium and long-term outcomes of an activity. In order to claim that an activity made a difference, we need evidence of both the process and the final impact. Hence most M&E systems simultaneously keep track of both by defining separate indicators for outputs and outcomes. Where possible indicators should be disaggregated by gender.

Table 12: Conservation Agriculture Indicators

Indicator	Interpretation
Output Indicators	
1. Area of land under different CA principles (before and after demonstrations).	This indicator will provide a picture of the overall area supported by the demo, and give a profile of the amount of area under CA across demo sites and over time. This information can also be presented in map form.
2. Number of households practicing CA as a result of being exposed to the demonstrations, disaggregated by the type of land preparation method used.	This indicator captures the overall scope of CA projects in terms of number of households. The method of land preparation (e.g. hand hoes, draught power, or tractor power) is a good way of categorizing CA into its different 'tastes'. This information can also be presented in map form.
3. Number of improved farming tools available in the community and used, disaggregated by type, before and after CA demos.	Improved implements (e.g. rippers, direct planters, knapsack sprayers, pedestal sprayers) are available in many CA projects to meet specific requirements in land preparation and weed control.
4. Number of people trained, disaggregated by type of training and gender.	Training is a key element of most CA projects; this indicator will capture both the types of training offered as well as number of people by gender.
5. Percentage of farmers who prepared the land and planted on time.	The timing of land preparation and planting is very important in CA to get the maximum yields. This indicator will capture the degree to which field preparation and planting are completed on time, and therefore how much additional improvement is possible.
6. Effectiveness of weeding.	Weeding is important in CA, particularly during the first few years when the seed bank and the weed pressure are still quite high. Effectiveness of weeding will be measured on a simple 1-3 scale, where 1 means Little effectiveness; 2 - Moderate effectiveness; and 3 - Full effectiveness.

Indicator	Interpretation
7. Percentage of farmers practicing crop-livestock interaction.	Integrating livestock into production is promoted in some CA demos, depending on the farming system. This indicator will show the extent to which crop-livestock integration is actually being used.
Outcome Indicators	
8. Percent increase in yield compared to conventional methods.	Yield is a good measure of agricultural intensification.
9. Quantity of production, disaggregated by crop.	Increased production for consumption or income is one of the primary outcomes of most CA demos.
10. Number of households who benefited from increased production under CA, disaggregated by gender and level of vulnerability.	Although this indicator doesn't capture the type or degree of impact, it is a core indicator that cuts across many activities supported by development agents.
11. Proportion of cultivated land under conservation agriculture.	In addition to the number of farmers practicing CA, the proportion of land under CA in supported households is a good measure of the level of its adoption in an area and will tell us if CA is being used as core or supplemental production strategy.
12. Income generated from crop sales.	Income is an important asset for livelihood security and one of the desired outcomes of many CA demos.
13. Changes in bulk density, water retention capacity, and soil organic matter.	Soil properties are one of the primary benefits of CA. Physical properties can change quickly, but SOM and chemical properties can take two or more years to see a noticeable difference. To isolate the effects of CA practices, changes should be measured both over time as well as against control plots where conventional farming is practiced.
14. Percentage of beneficiary households practicing CA for a second year with little or no direct support.	This is one of the long-term indicators that reflect the level of sustainability of an activity. Requires a post - demo assessment.

Table 13: Top five soil properties to monitor in conservation agriculture.

Property:	**Bulk Density**
Relevance:	Bulk density is the mass of soil in a known volume. CA methods aim to reduce bulk density around the plant for better root establishment and water infiltration. Bulk density is reduced through the application of mulch, minimizing compaction through controlled foot traffic and animal exclusion, and enhanced microbiological activity. Increased bulk density is often indicative of reduced infiltration of rainwater and restricted root growth, thus poor crop performance.
Measurement method:	Soil samples of a known volume are collected at different depths and taken to a lab for drying and weighing.
Sampling:	Bulk density is most important around the plant, but to establish the effects of CA practices one also needs to sample between planting basins or rows.
Cost:	Expensive due to lab tests.
Recommended frequency:	Research has shown that bulk density within the basins or planting rows changes quickly once CA practices are adopted. Thus bulk density should be measured in year 0 (baseline), and then at one or two year intervals thereafter.
Property:	**Soil Water Content**
Relevance:	Soil water content is affected by the rate of water infiltration, water holding capacity, and evapo-transpiration. All of these factors are positively influenced by CA practices, the net effect of which should be higher soil water content relative to non-CA fields. Higher soil water content improves fertilizer use efficiency and plant productivity particularly during dry years.
Measurement method:	Soil water content is measured at different depths using devices such as a tensiometer or collecting samples and comparing the wet and dry weights.

Sampling:	Soil water content should be measured in both basins/rows and between basins and rows.
Cost:	Relatively inexpensive, no lab work needed.
Recommended frequency:	Soil water content should be measured every year until some trends are established for inference. Dry years are particularly important as this is when the differences with conventional farming may be most visible.
Property:	**pH**
Relevance:	pH (acidity) has a direct effect on the solubility of minerals and nutrients which affects the rate of nutrient uptake. Soil pH can also influence plant growth by its effect on beneficial microorganisms that decompose soil organic matter, which are hindered in highly acidic soils. Acidic soils can be easily treated with lime. The pH range in Uganda suitable for most crops is 5.2 to 7.0.
Measurement method:	Soil samples are collected in the field then taken to a lab.
Sampling:	Within and between basins.
Cost:	Cheap.
Recommended frequency:	pH can change fairly quickly with lime treatments. Sampling is recommended for year 0 (baseline) and one or two year intervals thereafter.
Property:	**Nitrogen**
Relevance:	Nitrogen is one of the limiting nutrients in many agricultural soils. It is found in organic matter but must be broken down by microorganisms before it can be taken up by plants. N is increased by chemical fertilizers, manure, and nitrogen fixing plants (e.g., legumes, certain trees). The critical value of soil N for most soils in Uganda is 0.2%
Measurement method:	Soil samples are collected at different depths and taken to a lab for analysis.
Sampling:	Between and within basins.

Cost:	Expensive due to lab tests.
Recommended frequency:	Soil N is very mobile (changes quickly depending on its state) so repeated measurements are needed to capture trends. Sampling is recommended for year 0 (baseline) and three-four year intervals thereafter.
Property:	**Soil Organic Carbon**
Relevance:	Under conventional farming, soil organic matter levels decrease over time and can only be replenished by applications of manures or recycling plant residues. Mulching and the retention of residue cover under CA promotes accumulation of soil organic matter, which is a precursor to increased levels of organic carbon in the soil and has significant impacts on soil fertility. Soil organic carbon has implication for climate change in as far as carbon sequestration is concerned. The critical level of soil organic matter in most Uganda soils in 3.0%.
Measurement method:	Soil samples are collected at different depths and then taken to a lab for analysis.
Sampling:	Within planting basins/rows. SOC is unlikely to change between basins unless mulching has been consistent.
Cost:	Expensive due to lab tests.
Recommended frequency:	Trials have show that SOC takes more than one season to show any significant change, so sampling should be done at year 0 (baseline) and then 3-4 year intervals.

2.4 Approaches to Scaling up/out

2.4.1 Exchange Visits

This is a traditional agricultural extension method with a track record of being effective in the adoption and scaling crop intensification. Exchange visits can be carried out to demonstration plots to show/learn from neighbouring farmers and communities about the benefits of different CA principles. Such visits can also be organized within or outside the community. They can be organized at the beginning to enable selected implementing farmers to learn in detail and practically the new concepts. During the visit, the visiting farmers should be given an opportunity to interact freely with the host farmers by asking questions and exchanging ideas. Exchange visits can also be organized during the implementation phase. In this case farmers exchange ideas and seek solutions to problems encountered during implementation.

2.4.2 Field Days

Field days are organized for farmers to showcase their skills in implementation of learned concepts/technologies/practices. Field days can be carried out near demonstration plots to show farmers the differences between CA principles and conventional farming techniques. They are organized to target stakeholders at all levels including; district technical staff, politicians, NGOs, traders, input dealers, processors, transporters, farmers, school children, etc. The objective of a Field Day is to expose the guests to new technologies/practices and innovations.

2.4.3 Farmer Field Schools (FFS)

The FFS model is a farmer training approach, which is based on principles of adult education. It is based on innovative, participatory, and learning by discovery approach, which enables farmers to acquire an understanding of the principles of CA. A farmer field school is a forum where farmers and trainers debate observations, apply their previous experiences and present new information from outside the community. The results of the meeting are management decisions on what action to take. Thus, FFS as an extension methodology is a dynamic process that is practiced and controlled by the farmers to transform their observations to create a more scientific understanding of the principles of conservation agriculture.

FFS can play a crucial role in establishment and management of demonstrations as well as be a crucial platform for the collection, analysis and sharing of results to encourage adoption of the CA principles.

Farmer field schools can be strengthened by providing training in group dynamics, registering the schools and developing constitutions. These additional steps build farmer's confidence and trust. Thereafter the community is able to form second-generation schools and district FFS networks. The FFS Model has the potential for scaling up CA at landscape and national levels.

2.4.4 Facilitated Adoption

Facilitated adoption is done with a specified amount of support towards the adopter. The adopter to be supported is usually selected from the Farmer Group/FFS running a group/FFS demonstration. This has two main objectives, first, targeting farmers who although willing to adopt may not have enough resource/skills, and manpower to implement on their own, these may include widows, child-headed households, the disabled, or young women and men. The second objective is to take the technologies/practices demonstrated further down to the people. Support/facilitation may be in form of inputs, implements, etc. with labour and management provided by the adopter.

2.4.5 Technical Service Units (TSU)

It is not easy to comprehensively train each and every farmer in CA implementation through demonstrations, rather it is better to select, equip and train a few groups, especially youth groups, to provide CA technical services in a community. The CA technical services include herbicide spraying, soil ripping, construction of permanent planting basins, direct seeding, etc. Key implements for functional TSU include; a pedestal sprayer, ox-ripper, direct seeder, etc.

2.4.6 Innovation Platforms (IP)

An innovation platform is described as a forum established to foster interaction among a group of relevant stakeholders around a shared interest (Makini *et al.*, 2013). The stakeholders perform complementary roles in the development, adaptation, dissemination and adoption of knowledge for biophysical and socio-economic benefits. The knowledge acquired from demonstrations could be new ideas, methodologies, procedures, concepts, practices, or technologies developed or adapted from other locations. To promote these innovations, partnerships along and beyond agricultural value chains must be nurtured to bring on board actors with a special mix of skills (World Bank, 2011).

Innovation platforms are applicable to all aspects socio-economic development. Innovation platforms in agriculture present opportunities to increase crop productivity through increased access to information, inputs, credit, insurance, markets, capacity building, etc. All these contribute to improve livelihoods among smallholder farmers.

Agricultural value chains have two characteristics that make them suitable for reaching a large number of farmers. First, they provide a mechanism for linking multiple actors around a common objective by creating space for dialogue, knowledge exchange and capacity building, and strengthening negotiation capacities. Value chains can act as a delivery mechanism for government and private extension services, credit, and subsidy programmes. Second, they provide market-driven demand that may provide a demand-led strategy for adaptation of CA technologies and practices.

The challenges to scaling up, using this mode, are (1) climate change information is too general from a private sector perspective, (2) benefits, timing and incentives for multiple actors need to be aligned, and (3) information and financial support need to be coordinated (CCAFS, 2015).

Steps to be followed in formation of Agricultural Innovation Platforms (AIP);

The following steps may guide the establishment of AIP.

1. **Initiation and Visioning phase:** This phase includes engagement with stakeholders and setting vision for the group. Other considerations are site selection, determination of the agenda and entry points. This first step comprises of a scoping study or process to determine and understand the compelling challenges of the value chains of selected commodities or systems. The process is accomplished by an initiator or broker who convenes a meeting of diverse, all inclusive stakeholders to discuss and articulate the challenges that limit the performance of the value chains of selected commodities or systems.

2. **Establishment phase:** This phase includes planning and stakeholder engagement. Selected entry points influence this phase particularly the kind of stakeholders to be engaged. Stakeholder analysis is conducted to enable the initiator to identify stakeholders willing to join the platform and their capacities to play expected roles on the platform.

3. **Management phase [including facilitation, learning, and assessing]:** This is where the management of the process takes place including learning and innovation.

4. **Sustainability [which includes the application of lessons from the process to develop a viable and long lasting system]:** This is where stakeholder dynamism occurs and issues are solved and new issues arise, some stakeholders leave and new ones join as need arises

2.4.7 Information Communication Technologies (ICT) and agro-advisory services

Experiences from researchers and practitioners suggest that ICT in combination with agro-advisory services are playing an increasing role as enablers of change. Information Communication Technologies are being recognized as part of strategies to adapt to, mitigate and monitor climate change within agricultural innovation systems. The rate of growth of mobile phone technology is particularly striking. Mobile phones are helping farmers link to one another and also to obtain early information from markets.

In order to reach more farmers and overcome the high transactions costs incurred by face-to-face interaction associated with conventional extension services such as demonstrations, the use of ICT and associated agro-advisory services is becoming increasingly important. Information Communication Technologies are effective delivery mechanisms and knowledge sharing methods that can contribute to improving access to information and awareness about CA practices and technologies, climate change, markets, etc. Information Communication Technologies encompass a full range of technologies, from traditional, widely used devices such as radios, telephones or TV, to more sophisticated tools like computers, mobile phones, the Internet or social media (FAO, 2013).

Annex I: Glossary of terms

Conservation agriculture	It is a farming method with three important elements: continuous minimum soil disturbance combined with direct seeding, maintenance of a permanent or semi-permanent organic soil cover and diversification of crop species grown in sequence or associations. It aims to make better use of agricultural resources through the integrated management of soil, water and biological resource, combined with limited external inputs. It enhances crop yields while reducing production costs, maintaining soil fertility and conserving water. It is a way to achieve sustainable agricultural production and improve livelihoods.
Conservation farming	It entails the recently introduced CA package for renovation of degraded landscapes through the use of planting stations (basins) and ripping technology.
Conventional tillage	In conventional tillage the soil on the entire surface area of the field to be planted is disturbed. This could involve one or all of the following operations: digging by hoe, plowing, disking and harrowing.
Cover crops	The main purpose of cover crops is to keep the soil covered and in the process conserve soil and water, and suppress weeds. Farmers prefer multipurpose cover crops that perform their primary functions but also serve as food or feed to those that do not. Such crops improve soil quality and fertility, control erosion, suppress weeds and control insects.
Crop rotation	The practice of growing a series of different types of crops in the same area in subsequent seasons for various benefits, such as to avoid the build-up of pathogens and pests that often occur with continuous cropping of one crop or growing different crops in a haphazard order. Common crop rotations involve sequential cropping of cereals and legumes.
Erosion	The wearing away of the land surface by running water, wind, ice or other geological agents.
Evapo-transpiration	The combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.
Intercropping	Intercropping is the practice of growing more than one crop simultaneously in alternating rows on the same field.

Mineralization	The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.
Minimum tillage:	Minimum tillage means reducing tillage operations to the minimum required to plant a crop. For hoe and ox farmers it usually involves scratching or ripping out the row where the crop is to be planted and leaving the rest of the land untouched until weeding is required. Alternatively, hoe farmers may just dig holes where the seed will be sown.
Mulch	Any material such as straw, sawdust, leaves, and plastic film that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, evaporation, freezing, etc.
Mixed cropping	Mixed cropping is the practice of growing more than one crop in a field at a given time.
No-tillage	Also referred to as ‘direct seeding’, this describes the sowing of seeds into soil that has not been previously tilled in any way to form a ‘seedbed’.
Permanent Planting Basins	Permanent planting basins (PPB), as used in conservation farming, is a crop management method which enhances the capture and storage of rainwater and allows precision nutrient application of limited resources.
pH	The degree of acidity (or alkalinity) of a soil determined by a pH meter or indicator at a specified moisture content or soil/water ratio, and expressed in terms of the pH scale.
Rip lines	In soil ripping, a narrow slit or furrow 15-20cm deep is opened in the soil surface where seeds are planted directly. Soil ripping breaks up a surface crust or a shallow hardpan.
Seed hill	A planting station prepared by digging a hole in the soil where seed is placed and covered to germinate
Subsoiling	Breaking of compact sub soils, without inverting them, with a special knife like instrument (chisel), which is pulled through the soil at depths usually of 30 – 60cm and at a spacing usually of 1 – 2 m.
Tillage	Tillage refers to all the work a farmer does to prepare land for planting.
Tines	A sharp, projecting point or prong, as of a fork.
Treatment	Refers to applications used to test technologies, practices or approaches.
Tumpeco	A plastic mug, usually with a volume of half a litre.

Annex II: Case studies

Participatory on-farm demos/trials

Introduction

Conservation agriculture has been introduced to farmers in Uganda and most farmers attest to the visible improvement in crop production/productivity. However, there has been little data collection to run statistical tests and ascertain yield differences between conventional methods (farmers' traditional practices) of production and the conservation agriculture technologies/practices.

The fertility status of soils in most parts of Uganda is generally poor. This significantly contributes to low crop productivity of most staples, including maize and beans. The low soil fertility status is in most cases caused by poor farming practices or inherently unproductive soils. It is well documented that the poor farming practices have led to rampant soil erosion, crop nutrient mining and leaching, moisture stress and loss of biota, all leading to poor soil health.

Average maize yields on smallholder farms, which on average are less than 1 ha, are less than 20% of the potential (RATES, 2003; Otunge *et al.*, 2010) and average yields of beans are less than 30% of the potential (Sebuwufu *et al.* available online). Potential maize yield in Uganda is estimated to range from 3.8 to 8.0 t/ha (Semaana, 2010) while that of beans is 2.0 t/ha.

Soil fertility can be restored through sustainable farming systems such as conservation agriculture/farming; which is expected to bridge the maize and bean yield gaps among smallholder farmers. Conservation agriculture/farming is a technology that entails basic principles such as minimum tillage; precision application of micro-doses of fertilizer (inorganic and organic); use of improved seed; use of available crop residues for soil cover (Twomlow, 2012) and appropriate crop combinations and rotations.

Planting basins and rip-lines are major components of the recently introduced CA package for rehabilitation of degraded landscapes that is being extensively promoted for smallholder farming. Permanent planting basins (PPBs), as used in conservation farming, is a crop management method which enhances the capture and storage of rainwater and allows precision application of limited nutrient resources. The method helps to reduce risk of crop failure due to erratic rainfall and extended droughts. Use of PPBs in combination with improved seed and crop residues to create a mulch cover that reduces evaporation losses, among other benefits, has consistently increased average yields by 50 to 200% depending on the amount of rainfall, soil type and fertility.

In soil ripping, a narrow slit or furrow 15-20cm deep is opened in the soil surface. This breaks up a surface crust or a shallow hardpan. Permanent Planting Basins are being targeted for households with limited or no access to oxen, while ripping is meant for smallholder farmers with oxen.

Demos/trials were established in different agro-ecological zones (AEZ) across the country. Uganda is divided into 10 AEZ (GoU, 2004); climatic variables and other factors governing land use e.g. soil types and topography define the country's AEZ. The main objective of the demos/trials was to evaluate yield responses of maize and beans to fertilizer packages and different tillage methods. Besides grain yield records, parameters such germination count, cost of inputs/ha and man-hours spent per activity were used to compare the performance and costs of the different maize and bean production management options (Table 14).

Table 14: Parameters used to assess the performance of the different maize and bean production management options

Parameter	Treatment					
	Conventional with no fertilizer	Conventional with fertilizer	PPBs with no fertilizer	PPB with fertilizer	Rip line with no fertilizer	Rip line with fertilizer
Planting date						
Days after planting to at least 50% germination						
Germination count:						
Total number of planting hills						
Germinated hills 7 days after planting						
Days after planting to at least 50% flowering						
Days after planting to at least 50% physiological maturity						
Man-hours spent per activity						
Spraying						
Digging basins						

Parameter	Treatment					
	Conventional with no fertilizer	Conventional with fertilizer	PPBs with no fertilizer	PPB with fertilizer	Rip line with no fertilizer	Rip line with fertilizer
Ripping						
Application of fertilizer						
Sowing						
Weeding						
Mulching						
Pest control						
Harvesting						
Yield						
Total yield per plot						
Yield components						
Cost of inputs/ha:						
Maize seed						
Herbicide						
Pesticides						
Fertilizers						

Case Study I: Conservation farming approaches in four districts of Eastern Uganda

Introduction

The whole of eastern Uganda like the rest of the country is grappling with impacts of climate change, including extended droughts and floods. Conservation farming approaches, including use of improved seeds together with fertilizers and tillage methods such as permanent planting basins and rip lines were introduced to four districts in the region as a measure to mitigate the impacts of climate change. The four districts namely, Budaka, Bugiri, Busia and Namutumba are located in what is historically known as the Banana Millet Cotton farming system. The districts are part of the Kyoga Plains agro-ecological zone (AEZ) that covers most of eastern Uganda and parts of northern Uganda.

Average rainfall in the area ranges from 1215 to 1328 mm annually with a bimodal pattern. The first season start from March to May while the second season starts from August to November. Dry periods are from June to July and December to February. Land in the region is mostly flat with poor to moderately fertile soils. Small scale subsistence production of mainly annual crops with some pastoralism characterizes the farming systems. The main agricultural enterprises in the region include maize, legumes, cassava and sweet potatoes.

Materials and Methods

In the first and second rain seasons of 2015, on-farm demo/trails were conducted on a total of 16 farms across four districts in eastern Uganda namely, Budaka, Bugiri, Busia and Namutumba. Eight of the farms established demos/trials on bean production while another eight established demos/trials on maize production.

The participatory Approach

Planning the trials:

At the onset it was agreed that:

- One-acre plots would be established on each of 16 farms.

The project would supply:

- Improved seed, fertilizer (DAP & urea), herbicides (glyphosate & 2,4-D), spray pumps
- Plot preparation (ox ripping, digging PPBs).
- Advice, guidance and supervision.

Each farmer would contribute:

- Land
- Her/his labour
- Proper care and maintenance
- Record keeping

The farmer would be entitled to keep the produce after recording the grain weight. The demo/trial would continue for two seasons.

Conducting the trials

On-farm trials were established to ascertain whether there are statistical yield differences between conventional methods of production and the conservation farming technologies/practices.

Treatments were:

1. Conventional practice without fertilizer.
2. Conventional practice with fertilizer.
3. Permanent Planting Basins without fertilizer.
4. Permanent Planting Basins with fertilizer.
5. Rip-lines without fertilizer.
6. Rip-lines with fertilizer.

Annexes

A baseline soil analysis was performed by taking soil samples from the 0- to 20-cm depth from each trial field. The samples were dried in open air, ground to pass a 2-mm sieve, and analyzed according to Foster (1971) and Okalebo *et al.* (2002). Texture analysis was performed using the hydrometer method (Blake and Hartge, 1986). Soil pH was measured using a soil/water ratio of 1:2.5. Extractable P, K, and Ca were measured in a single ammonium lactate–acetic acid extract buffered at pH 3.8 (Okalebo *et al.*, 2002). Total N was determined using a micro-Kjeldahl block digestion apparatus, and soil organic matter was determined by acid-dichromate digestion.

Fields were slashed and sprayed with glyphosate (500 mg/l) at a rate of 7.5 l/ha two weeks after slashing.

Seed rates

Conventional: Planting holes for maize were marked out using planting lines and digging with a hand hoe at a spacing of 75cm between rows and 60cm within rows. Each hole was seeded with two seeds, giving a total of 44,444 plants ha^{-1}. In the case of beans, spacing was 50cm × 10cm and each hole seeded with one seed to give a total of 200,000 plants ha^{-1}.

Basins: Basins were marked out using planting lines and digging planting basins of 35cm (long) ×15cm (width) × 15cm (deep), with spacing of 75cm between rows and 70cm within rows from centre to centre of the PPB, before the onset of rains. Available crop residues were laid between rows to create a mulch cover. The basins were seeded with three maize seeds per basin (57,143 plants ha^{-1}) and six bean seeds per basin (114,286 plants ha^{-1})

Rip lines: Rip-lines were ripped using an ox ripper set at a depth of 15cm, before the onset of rains. Available crop residues were laid between rows to create a mulch cover. Maize was seeded at a spacing of 75cm × 30cm with one seed per hill (44,444 plants ha^{-1}). Beans were seeded at a spacing of 75cm × 10cm with two seeds per hill (266,667 plants ha^{-1}).

A high yielding and drought tolerant hybrid maize variety PH5052 and a high yielding and drought tolerant bean variety NABE 15 were used in all the treatments.

In maize and bean trials, micro-doses of basal fertilizer (DAP) at a rate of 2 level soda bottle caps per pit (92.5 kg/ha) was applied and covered with top soil before planting the seeds. In the case of maize, nitrogen (150 kg/ha) was evenly side dressed when the maize was at knee height.

Analyzing the Data

The maize and bean grain yields were determined by harvesting the whole plot. Sub samples of grain (about 0.5 kg) were taken and weighed before and after drying to constant weight at 70°C, the data was used to determine grain moisture content at harvest and finally the dry grain yield. For grain quality, weight of 100 seeds was determined by weighing 100 random seeds.

Data was examined by ANOVA to determine significant ($P < 0.05$) treatment effects. Comparison of means were made by LSD all-pair-wise comparisons. All analyses were done using Statistix V. 2.0.

The Results

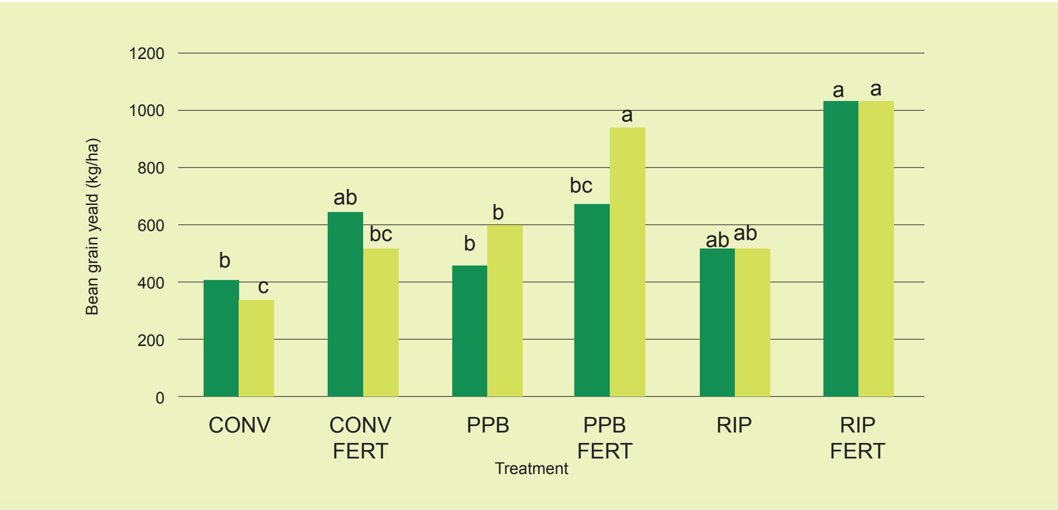
Comparing the technologies

Beans

Timing the planting of beans is very crucial because if not planted in time the crop might suffer from one or all of the following: drought, pest and disease attacks and water logging. In eastern Uganda the best time to plant beans is February to March (Budaka District) and March (Bugiri, Busia and Namutumba). It is advisable to always consult the FEW for the best time to plant your crop of choice.

Due to untimely planting during the 2015A season, the bean demos/trials in Namutumba and Busia districts were all decimated either by drought and/or pests and diseases. Some of the demos/ trials in Budaka and Bugiri districts survived but also suffered yield losses due to water logging.

Figure 4: Response of bean grain yield to different tillage practices without and with fertilizer in the first and second cropping seasons of 2015†



†Yield means in a particular season followed by the same letter are not significantly different according to LSD at $P \leq 0.05$

Table 15: Absolute bean grain yield and percent yield increases from fertilizer in the first and second cropping season of 2015†

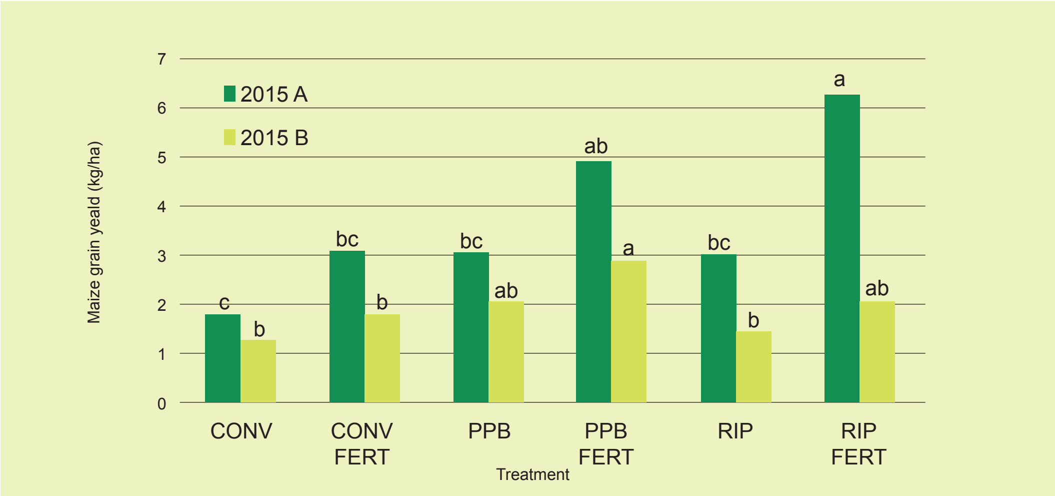
Practice/ technology	Yield (kg/ ha)	Yield increase from fertilizer	% yield increase	Yield (kg/ ha)	Yield increase from fertilizer	% yield increase
	2015A			2015B		
Conventional [Conv]	416.8b			344.7c		
Conventional + fertilizer [Conv Fert]	644.1ab	227.30	54.53	519.4bc	174.7	50.68
PPB	474.1b			593.8b		
PPB + fertilizer [PPB Fert]	668.9ab	194.80	41.09	942.5a	348.7	58.72
Rip-line	512.4ab			511.8bc		
Rip-line + fertilizer [Rip Fert]	1,034.6a	522.20	101.91	1,040.9a	529.1	103.38

†Yield means in a particular season followed by the same letter are not significantly different according to LSD at $P \leq 0.05$

In both seasons, there were significant ($P \leq 0.05$) average yield differences between tillage practices combined with fertilizer and practices without fertilizer. On average, fertilizer use in combination with the tillage practices increased bean grain yield from 483 kg ha^{-1} to 834 kg ha^{-1}, a 73 percent increase. Separately, all practices whether conventional or the newly introduced conservation farming practices in combination with fertilizer increased the bean grain yield, however the increases were not statistically significant in season 2015A, whereas in season 2015B, bean grain yields in PPB and rip lines with fertilizer were significantly higher than without fertilizer (Fig. 4). Between the two seasons, the highest average percentage yield increase (103%) was between rip-lines without and with fertilizer (Table 15); this was followed by conventional practice without and with fertilizer (53%) and least was between PPBs without and with fertilizer (50%).

Between the two seasons, average bean grain yield from conventional practice was 481.3 kg ha^{-1}; PPB 669.8 kg ha^{-1} and rip-lines 774.9 kg ha^{-1}. Apparently, the newly introduced conservation farming tillage practices increased bean grain yield relative to the conventional practice by 39 percent in PPBs and 61 percent in rip-lines. Variance of bean grain yield between the two seasons was highest with PPBs and least with rip-lines. Apparently, in the first cropping season of 2015, there was above normal rainfall which affected bean grain yield in PPBs. In contrast, bean grain yield under rip line tillage was more or less similar in both seasons.

Figure 4: Response of maize grain yield to different tillage practices without and with fertilizer in the first and second cropping seasons of 2015†



†Yield means in a particular season followed by the same letter are not significantly different according to LSD at P≤0.05

Maize

There was a significant yield difference between tillage practices with and without fertilizer. In 2015A, fertilizer application increased average maize grain yield from 2.63 ton ha^{-1} to 4.76 ton ha^{-1}, an increase of 81 percent. The highest percentage yield increase (107%) was between rip-lines without and with fertilizer; this was followed by conventional practice without and with fertilizer (72%) and least was between PPBs without and with fertilizer (61%).

Average maize grain yield from conventional practice was 2.45 t ha^{-1}; PPBs 4.0 t ha^{-1} and rip-lines 4.6 t ha^{-1}. The newly introduced conservation farming tillage practices increased maize grain yield relative to the conventional practice. The increases were 63 percent with PPB and 90 percent with rip-line tillage.

In 2015B, the average increase in maize grain yield from fertilizer application across all tillage practices was 6.48 ton ha^{-1}, an increase of 40.4 percent. The highest percentage yield increase (46.5%) was between conventional practice without and with fertilizer this was followed by PPBs without and with fertilizer (40%) and least was between rip lines without and with fertilizer (36.2%).

Average maize grain yield from conventional practice was 1.567 t ha^{-1}; PPBs 2.466 t ha^{-1} and rip-lines 1.756 t ha^{-1}. Just like it was the case in 2015A, the newly introduced conservation farming tillage practices increased maize grain yield relative to the conventional practice. The increases were 57 percent with PPB and 12 percent with rip-line tillage.

Table 16: Absolute maize grain yield and percent yield increases from fertilizer in the first and second cropping seasons of 2015

Practice/technology	Yield (kg/ha)	Yield increase from fertilizer	% yield increase	Yield (kg/ha)	Yield increase from fertilizer	% yield increase
	2015A			2015B		
Conventional [Conv]	1,801.5c			1,270.9b		
Conventional + fertilizer [Conv Fert]	3,100bc	1,298.5	72.1	1,862.5b	591.6	46.5
PPB	3,055.6bc			2,059ab		
PPB + fertilizer [PPB Fert]	4,930.2ab	1,874.6	61.3	2,872.7a	813.7	39.5
Rip-line	3,033bc			1,486.2b		
Rip-line + fertilizer [Rip Fert]	6,262.7a	3,229.4	106.5	2,024.8ab	538.6	36.2

†Yield means followed by the same letter are not significantly different according to LSD at P=0.05

Discussion

Potential versus actual grain yield

Potential bean grain yield in Uganda is about 2.0 t ha^{-1}. Apparently, the bean grain yield from the newly introduced conservation farming tillage practices was far below the yield potential. This could have been as a result of pests and diseases and water logging which were rampant due to delayed planting. Other workers (Ghaffarzadeh *et al.*, 1997) have reported poor crop performance due to excessive soil water.

Maize yield in Uganda is estimated to range from 3.8 to 8.0 t ha^{-1} (Semaana, 2010). The newly introduced conservation farming practices have apparently brought the maize grain yield within the expected range.

Lessons Learned/Conclusions

Both PPB and rip-line tillage significantly increased maize and bean grain yields relative to conventional tillage methods. A combination of PPB and rip-line tillage together with improved seed and fertilizer brought maize and bean grain yields within the expected productivity range for both crops in Uganda.

Case Study II: Participatory on-farm demos/trials in Lira District, northern Uganda

Introduction

Lira District is located in what is historically known as the Annual Cropping and Cattle Northern farming system. The Annual Cropping and Cattle Northern farming system covers parts of the North-Eastern and North-Western Savannah Grasslands agro-ecological zone (AEZ) in Northern Uganda.

Average rainfall in the area ranges from 1197 to 1371 mm annually with one long rainy season that stretches from April to mid-November. The dry period that starts from mid-November to March is usually very severe with very high temperatures. During this period, evaporation exceeds rainfall by a factor of 10. Landscape is generally flat with undulating hills with poor to moderately fertile soils in some places while other places have moderately fertile to good soils. Small scale subsistence production of mainly annual crops with some pastoralism characterizes the farming systems. The main agricultural enterprises in the region include sesame, sunflower, maize, legumes, cassava and sweet potatoes.

Conducting the trials

In the first rain season of 2015, on-farm demo/trails were conducted on a total of 24 farms across two sub counties, Lira and Aromo, in Lira District. The trials were established to ascertain whether there were statistical yield differences between conventional methods of maize production and the conservation farming technologies/practices. Treatments were:

1. Conventional practice without fertilizer.
2. Conventional practice with fertilizer.
3. Permanent Planting Basins without fertilizer.
4. Permanent Planting Basins with fertilizer.
5. Rip-lines without fertilizer.
6. Rip-lines with fertilizer.

Fields were slashed and sprayed with glyphosate (500 mg/l) at a rate of 7.5 l/ha 2 weeks after slashing. A high yielding and drought tolerant hybrid maize variety PH5052 was used in all the treatments.

The Results

Table 17: Maize grain yield in Lira District

Practice/technology	Yield (kg/ha)	Yield increase (kg)	% yield increase
Conventional [Conv]	2,810c		
Conventional + fertilizer [Conv Fert]	3,816bc	1,006	35
PPB	3,116c		
PPB + fertilizer [PPB Fert]	3,904bc	788	25
Rip-line [RIP]	5,879ab		
Rip-line + fertilizer [RIP Fert]	6,845a	966	16

†Yield means followed by the same letter are not significantly different according to LSD at $P \leq 0.05$

There was significant maize grain yield difference between the sub counties. Aromo sub county with 6,277 kg ha^{-1} produced significantly ($P \leq 0.01$) more maize grain than Lira sub county (2,513 kg ha^{-1}), a yield difference of 149%. The sub county × Treatment interaction was not significant at the 5% level, which indicated that the treatment effects were independent of the local conditions in each sub county. In that regard, treatment effects were averaged across the sub counties.

There were significant yield differences ($P < 0.1$) between tillage practices with and without fertilizer. Fertilizer application increased average maize grain yield from 3.24 ton ha^{-1} to 4.15 ton ha^{-1}, an increase of 28 percent. The highest percentage yield increase (35%) was between conventional practice without and with fertilizer; this was followed by PPBs without and with fertilizer (25%) and least was between rip lines without and with fertilizer (16%).

Average maize grain yield from conventional practice was 3,313 kg ha^{-1}; PPBs 3,510 kg ha^{-1} and rip-lines 6,362 kg ha^{-1}. The newly introduced conservation farming tillage practices increased maize grain yield relative to the conventional practice. The increases were 5 percent with PPB and 92 percent with rip-line tillage.

Case Study III: Intensification of maize-legume production in Nakasongola District, Central Uganda

Introduction

As a way of intensifying maize-legume production, there is a need of promoting maize-legume intercropping intended to diversify, maximize land use, as well as reduce production risks given the effects/impacts of climate change. In that regard, intercropping is considered a climate change adaptation strategy, given that most legumes, especially beans mature much earlier than maize. In the event of season failure the legumes which mature earlier than maize, would be expected to reach maturity, helping farmers to avoid total crop failure. This practice also has another added advantage of catering for the starch and protein needs of households. However, there is still need to establish intercropping patterns that offer maximum economic returns.

Conducting the trials

In the first rain season of 2013 on-farm demo/trails were conducted on a total of 24 farms across two sub counties, Kalongo and Wabinyonyi, in Nakasongola District. The trials were established to determine the optimum maize-bean intercropping patterns that optimize economic returns. Treatments were:

1. T_1: 2 Maize rows/1 bean row (in between).
2. T_2: 2 Maize rows/2 bean rows (in between).
3. T_3: 1 Maize row/1 bean row (within the maize row).
4. T_4: 2 Maize rows + 1 bean row (within the maize row)/1 bean row (in between).
5. T_5: Maize alone (Control).

The maize and bean seeds were planted with the following fertilization regime: 100 kg ha^{-1} DAP and 150 kg top dressing with Urea.

Analyzing the Data

The maize and bean grain yields were determined by harvesting the whole plot. Sub samples of grain (about 0.5 kg) were taken and weighed before and after drying to constant weight at 70°C, the data was used to determine grain moisture content at harvest and finally the dry grain yield. For grain quality, weight of 100 seeds was determined by weighing 100 random seeds.

Data was examined by ANOVA to determine significant ($P < 0.05$) treatment effects. Comparison of means were made by LSD all-pair-wise comparisons. All analyses were done using Statistix V. 2.0.

The Results

There were no significant ($P < 0.05$) maize grain yield differences among the different maize-bean intercropping patterns (Table 18). However, patterns T1 [2 Maize rows/1 bean row in between] and T3 [1 Maize row/1 bean row (within the maize row)] had significantly ($P < 0.05$) more bean grain yield than patterns T2 [2 Maize rows/2 bean rows (in between)] and T4 [2 Maize rows + 1 bean row (within the maize row)/1 bean row (in between)].

In terms of combined revenue from maize and beans, pattern T1 [2 Maize rows/1 bean row in between] had significantly more revenue than all the other patterns except pattern T3 [1 Maize row/1 bean row (within the maize row)]. The combined revenue from pattern T3 [1 Maize row/1 bean row (within the maize row)] was not significantly different from all patterns except that of maize alone. The pattern T5 [maize alone] had the least revenue, which was significantly different from all the other patterns except pattern T4 [2 Maize rows + 1 bean row (within the maize row)/1 bean row (in between)].

Discussion

Since the maize spacing and population remained the same in all treatments, there was no apparent competition among the maize plants. This was probably why intercropping maize with beans did not affect maize grain yield relative to maize grown as a sole crop. In that regard, intercropping maize without a doubt is more productive than sole cropping (Lithourgidis *et al.*, 2006; Andrew and Kassam, 1976) as it maximizes land utilization, and increases labour utilization efficiency, food security and farm profits. While intercropping maize with bean apparently offered no competition against the maize crop in terms of light, water and nutrients, this was not the case with the bean crop. The significant bean grain yield differences could have arose due to competition among the bean plants in the different maize-bean intercropping patterns. The best patterns in terms of bean grain yield were those with lower bean plant population. This is corroborated by Francis et al. (1986) who reported that soybean or dry bean yields were reduced between 10 and 30% because of competition for light, water, and nutrients.

During technology verification workshops, farmers selected the maize-bean intercropping patterns with lower bean population, which also turned out to have the best bean grain yield and combined revenue from maize and beans. Besides better revenues, the choices were attributed to ease of establishment because patterns with higher bean plant populations demanded more labour to establish.

Lessons learnt/conclusions

Intercropping maize with beans is more productive than sole maize cropping as it maximizes land utilization, and increases labour utilization efficiency, food security and farm profits. Bean grain yield in maize-bean intercropping is affected by high bean plant population due to competition for light, water, and nutrients, thus the need to determine the optimum maize-bean intercropping patterns. Maize-bean intercropping patterns with lower bean plant population were more popular among farmers because of ease of establishment before even considering the added advantage of higher bean grain yield and higher combined maize and bean revenues.

Table 18: Maize-bean intercropping patterns, their attributes, grain yield and accruing revenue

Maize-bean intercropping pattern	Attributes	Maize yield (kg/ha)	Bean yield (kg/ha)	Combined revenue from maize and beans (UGX/ha) †
T1: 2 Maize rows: 1 bean row in between 	Easy to establish	5,942**a**	257**a**	4,398,780**a**
T2: 2 Maize rows: 2 bean rows (in between) 	Easy to establish	5,703**a**	151**b**	3,971,260**b**

Maize-bean intercropping pattern	Attributes	Maize yield (kg/ha)	Bean yield (kg/ha)	Combined revenue from maize and beans (UGX/ha) †
T3: 1 Maize row: 1 bean row (within the maize row) 	Easy to establish	5,601**a**	277**a**	4,221,760**ab**
T4: 2 Maize rows + 1 bean row (within the maize row): 1 bean row (in between) 	Not easy to establish (need more labour)	5,486**a**	125**b**	3,767,520**bc**
T5: Maize alone 	Easy to establish	5,702a	-	3,590,500**c**

† UGX 3,340 = USD 1

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