Mechanization of smallholder Conservation Agriculture in Zambia: lessons learnt and future directions

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Summary

Conservation agriculture (CA) mechanization options for smallholder farmers include ripping and direct seeding with draught animal and tractor power. The hand-dug basin conservation farming option is also available for very small land holdings. In supporting CA mechanization, FAO has been promoting a donor-supported, e-voucher system which gives lead farmers the ability to purchase CA services from appropriately trained providers equipped with CA equipment (both draught animal and tractor powered). CA has now taken off in Zambia and the provision of appropriate CA services via commercial contractors has been a vital ingredient of the success. Involvement of the private sector in the provision of equipment and the extension of loans on a subsidy-free basis is the preferred system for the future.

1. Introduction

Farm categories and production

There are currently an estimated 1-1.2 million farmers in Zambia, most of whom are smallholders who use simple technologies (hand hoes and oxen) with minimal purchased inputs (Siegel and Alwang, 2005). Productivity is low and the main crops produced are rain-fed maize, groundnuts, roots and tubers, primarily for home consumption on farm areas under five hectares. More commercially oriented emergent farmers use animal traction (and, increasingly, tractors), hybrid seed and fertilizer to grow rain-fed crops.

Maize is the most important food and cash crop for the majority of smallholder farmers. It is also the most important crop for national food security and as such enjoys government subsidies. Despite this, productivity and profitability of maize remain low among smallholder farmers. This has been attributed to a number of factors including drought, lack of access to yield enhancing technologies, the use of inappropriate farming techniques which degrade soils and reduce their capacity to sustainably support crop production.

Conservation Agriculture

In Zambia, CA emerged to mitigate the impact of frequent droughts. Since the mid-1990s, several programmes were implemented by the Ministry of Agriculture and Livestock (MAL), the Conservation Farming Unit (CFU), Golden Valley Agricultural Research Trust (GART), the World Agroforestry Centre (ICRAF) as well as a number of NGOs. Programmes have focused on the promotion of CA as an avenue for increasing productivity, reducing soil degradation and lowering production costs.

The MAL in Zambia has a vision to scale out CA to 600,000 smallholder farmers by 2015 as it is seen as a sustainable approach to increasing farm productivity and production (www.conservationagriculture.org). However, scaling out CA has been limited due to the need for constant intense extension to support adoption, as well as poor access to CA equipment and machinery by the majority of small-scale farmers.

2. Sustainable crop production intensification

Smallholder farmers in rainfed agriculture generally believe that soil tillage is needed to control weeds and maximize crop yields. However there is abundant evidence that this can cause the degradation of physical, chemical and biological soil properties (Johansen *et al*. 2012). In Zambia the negative effects of conventional (hoe-or plough-based) agriculture are a major concern as discussed by the CFU of the Zambia National Farmers' Union (ZNFU) (CFU, 2006). CFU discusses the impact on agricultural soils of practices such as burning residues and ploughing. Continuous ploughing, widespread annual burning of vegetation prior to the rains, maize mono-cropping and the liberal use of soil-acidifying fertilizers can degrade the land to a state where farming is no longer possible. Although the sector still manages to produce 80 percent of the nation's food requirement, this form of production is manifestly unsustainable. In 1999 the Government of Zambia declared CA and related technologies a priority for promotion.

Basic principles of CA

CA is now a well-known concept and is being practised on over 125 million hectares worldwide. It is based on three basic principles which are aimed at enhancing soil health, fertility and structure:

- **Minimum soil disturbance**. In practice this means no-till, or at most producing a narrow seeding slot in the soil.
- **Permanent organic soil cover** with living or dead plant material. This means leaving as much crop residue as possible on the soil surface; incorporating cover crops into the cropping sequence; and/or associating crops particularly legumes, with cash or food crops.
- **Practising rotations and associations**. Rotating different types of crops (especially legumes and non-legumes) has long been recognized as a natural way to combat pests and diseases. Rotations are recommended both for crops and cover crops. Crop associations are recommended for soil fertility enhancement both in annual and perennial crops.

CA and soil enrichment trees

Farmers have recognized the value of leguminous fertilizer trees for many generations. *Faidherbia albida* (locally known as *musangu*) is an indigenous nitrogen-fixing acacia species which has the remarkable trait of reverse leaf phenology. This means that it sheds its (N-rich) foliage during the early rainy season as annual crops are being established; and only re-grows them at the end of the wet season. The integration of trees like faidherbia in CA production systems provides extra benefits to the farmer. With rising fertilizer prices, today 69 percent of Zambia's smallholder farmers produce maize without mineral fertilization (Garrity *et al*. 2010). Although early sowing enables crops to benefit from the initial soil nitrogen flush, the incorporation of faidherbia trees in conservation systems represents

an additional source of nitrogen and other nutrients for food and cash crops (Figure 1). The result is an agroforestry system which remains green throughout the year and so has justly earned the name of evergreen agriculture (World Agroforestry Centre, 2009).

Figure 1. Maize grown in association with *Faidherbia albida* can give yields of over 2 ton/ha compared to the 1 ton/ha to be expected in the absence of the tree's nutrients. Photo: Dennis Garrity.

3. Conservation Agriculture approaches

There are several approaches and soil tillage systems for practising CA, each of which might be more appropriate to particular farming profiles, farmer categories or farming systems:

Conservation farming with hand-dug basins

Smallholder farmers in Zambia have been encouraged to adopt a hand-dug planting basin system (Figure 2) called conservation farming (CF).

Applying precise amounts of fertilizer (and lime when needed) to the basins undoubtedly has a positive effect on yields. Also the depressed soil surface level tends to accumulate water and help to resist drought. Maintaining crop residues on the soil surface, and controlling the weeds with surface scraping by hoe, protects the soil surface, improves soil structure and water infiltration. However digging the basins each year results in excessive soil disturbance and movement, destroying the system of natural channels built up in the soil profile and having a negative effect on soil biota. Furthermore the labour requirement is not to be underestimated; CFU estimates the requirement at 60 person-days per hectare. Because of this it seems reasonable to expect that only farmers without access to draught animals will find the system attractive.

Figure 2: CA basins, Mapepe, Zambia. Photo Sina Luchen.

Conservation agriculture with ox-drawn equipment
In Zambia the CFU recommends modification of the basin CF technology for farmers having access to draught animal power (CFU, 2006). With the use of a chisel-tined ripper (e.g. the Magoye ripper) rip lines are opened up in the dry season (Figure 3); at the start of the rains these lines can be ripped again to a depth of about 20 cm. At this time fertilizer (both organic and inorganic) and lime (if needed) are applied by hand to the rip line and covered by light hoeing from the rip line sides. Once the full rains arrive, the crops are planted by hand into the prepared furrow.

With the availability of ox-drawn precision planters (which can also apply fertilizer) the move to CA becomes easier. Animal powered direct planters are available from Brazil, although there are currently serious efforts to encourage commercial manufacture of locally adapted machines in several African countries (Sims *et al*. 2012).

Figure 3. Riplines on a farm in Kayuni, Monze. Photo Sina Luchen.

4. CA mechanization options for smallholder farmers

The following options are those being promoted and adopted:

Ripping with draught animal power. Ripper tines are locally manufactured in Zambia and are fairly easy to attach to a mouldboard plough frame (replacing the plough body). While this option offers opportunities for smallholder farmer expansion of the area under CA, access to draught animal power may be limited.

Increasingly popular is the concept of agricultural contractors. These are generally tractor operators equipped with three-point mounted rippers who offer ripping services to farmers in their localities. Box 1 gives an outline of one scheme operating in Zambia, we return to the AFGRI example later in this paper.

Box 1. AFGRI Smallholder mechanization scheme, Zambia

The AFGRI Smallholder Mechanization Project equips smallholder farmers with tractors and rippers and, according to local market potential, with trailers, slashers, maize shellers and sprayers.

Smallholders take out a loan from AFGRI to purchase the tractor and associated equipment and are contractually obliged to pay the loan back over a three-year period. They do this by offering ripping, transport and other services to farmers in their neighbourhoods.

AFGRI shares the risk involved in lending to borrowers with meagre collateral. The John Deere Company assumes 10% of the risk, as does the Conservation Farming Unit (CFU). The borrower pays a 20 percent deposit, leaving AFGRI with a 60 percent share.

CFU's interest in the scheme is to promote CA and that is why they have insisted on the ripper being supplied as a priority. CFU is active on CA training for contractors and also plays a key role in selecting potential candidates.

A Swedish funded non-profit company MUSIKA is also interested in smallholder mechanization as a means of stimulating economic growth in the rural sector. Its strong point is training in financial skills and this is what the company brings to the project. MUSIKA does not share the risk of extending credit lines to smallholder farmers.

Pre-contract training is offered for CFU-selected potential beneficiaries. This includes training on CA principles from CFU and on business skills in calculating costs, margins and charge rates from MUSIKA. Legal advice is also offered so that the contract and the obligations are fully understood. After full explanation, clients have a one week cooling-off period to reconsider the contract before signing and paying the 20 percent deposit.

Post-contract support is provided by CFU, MUSIKA and AFGRI. Part of the leasing agreement is that the tractors enjoy full service backup for 3000 hours or 3 years. During their service visits, the AFGRI technicians offer advice and guidance on tractor operation and maintenance.

Aspiring CA service provision entrepreneurs receive initial orientation on the tractor that they will acquire under AFGRI's lease-buy scheme for smallholder farmers.

No-till planting can be achieved with manual, draught animal and tractor-powered planters, although manually operated jab planters, popular in many other countries, do not seem to have been attractive to Zambian smallholder farmers. Draught animal powered (DAP) planters have been well received with Brazilian makes making the greatest impact. GART has been working on the design of an inclined-plate, chisel tined animal draught direct planter which has been manufactured in small batches by Saro in Lusaka (Figure 4).

Figure 4. GART prototype DAP no-till planter

Tractor-mounted direct planters are available on the market in Zambia. Again it is Brazilian equipment which is favoured and again it is Saro who is importing them. Tractor-mounted planters are only suitable for smallholder farmers if the service can be offered by a well-trained private sector contactor.

The control of weeds and the management of cover crops are important aspects of CA and there are three types of control: biological (with cover crops), mechanical and chemical using herbicides. Mechanical control measures include slashing with machete, surface scraping by hand hoe and the use of the animal-drawn knife roller.

Weed control poses one of the major challenges to CA among smallholder farmers in Zambia. The weed burden under CA regimes gradually declines if weeds are constantly removed before they can set seed. Cover crops will suppress weed growth and the non-inversion of the soil means that the weed seed bank available for germination is reduced year on year. Early, frequent and thorough control of weeds, both during the growing season and in the winter period, is perhaps the greatest secret to successful CA farming.

Farmers have long understood the importance of crop rotations – and they are an essential component of CA. Rotations are needed to prevent the build-up of crop-specific pests (especially nematodes) and diseases, to explore different soil strata for water and nutrients, and most importantly the inclusion of legumes in the rotation will add nitrogen (Thierfelder & Wall, 2010). The challenge for Zambia is that maize is still routinely grown as a monoculture.

Crop associations (especially of cereals and legumes) are another excellent way to improve soil fertility and increase overall yields. Alternate lines of maize and pigeon pea, for example, add the benefits of nitrogen fixation and deep rooting for nutrients and water exploration and maintaining better soil structure at depth, without incurring the reluctance of farmers to devote whole fields to non-maize crops

5. Improving access to CA equipment

Farm machinery is usually an expensive item for a smallholder to acquire, but this does not mean that mechanization of CA should be beyond their reach. The provision of CA services by well trained and equipped service providers is one answer to redress this situation (FAO, 2011). Market appraisal, choosing the right equipment, learning how to operate and maintain the machinery and ensuring that the business is profitable are all areas where guidance may be required. The service providers will also require access to other stakeholders, including finance providers, mechanical repair services and spare-parts dealers.

FAO-implemented CA projects; increasing smallholder access to CA equipment
Candidates suitable to be farmer-contractors are initially identified by MAL extension staff in consultation with the community. Final validation is done by FAO and MAL in collaboration with ZNFU.

The e-voucher system
The use of e-vouchers promotes farmer-driven and market friendly development (FAO, 2012); the system is used to stimulate the demand for CA services from the newly equipped service-provision entrepreneurs; so how does it work in Zambia?

E-vouchers are issued to lead farmers and can be used both for CA services and for approved inputs such as herbicides, fertilizer and seed, as well as CA tools. The e-vouchers are redeemable directly by the mechanization service providers and at competing agro-dealer outlets. Box 2 gives an example of how the system works for one tractor-owning contractor.

Box 2. Tractor-powered CA service provision

Mathias Ndhlovu of Kanakantapa camp, Chongwe district was selected by MAL in August 2011 to receive a tractor and associated implements (no-till planter, boom sprayer, ripper, trailer and maize sheller) as part of the FISRI equipment loan scheme. The cost of the tractor and equipment is to be repaid over a 3-year period and demand is guaranteed by the issue of e-vouchers to lead farmers. He reported that, to date, loan repayment has not been a problem, however it could possibly be more difficult after the cessation of the e-voucher scheme.

The main service demanded has been for ripping and last season Mathias attended 191 farmers in 4 camps. He ripped a total of 180 ha in the 2011 season. Because of time constraints, he was only able to use the planter and sprayer on 47 ha and that was only in Kanakantapa camp.

Apart from the e-voucher system used to pay for CA services, last year Mathias ripped 60 ha at Kw300,000 (USD58) per hectare. To date this year he has ripped 28 ha. He employs two tractor drivers who work in shifts. Initially he worked at night as well as in the day, but he has encountered a cultural barrier against this practice and so he no longer does it.

Mathias and one of his tractor drivers received technical training (from Saro and MAL) in the use of the equipment and business skills at Monze Agricultural College.

Mathias, a retired teacher, has a diverse portfolio of enterprises. He owns 4 ha and rents 12 more to grow maize and irrigated vegetables. He also has a 70,000 bird laying flock and is about to install a biogas production plant to run an electricity generator for the poultry enterprise and domestic use.

Mathias Ndhlovu with his Indian-made TAFE 60 hp tractor.

Box 3 gives an insight into how one agro-dealer in Chongwe district manages the e-voucher scheme.

It seems that the demand for CA services is such that the e-voucher system can now be phased out. It has served as a very useful stimulus to promote both the input supplier and contractor service provision model, but now it is time to recede from the market. Box 4 gives an example of how DAP service providers are providing a profitable CA service in one village.

Box 3. The e-voucher scheme; an agro-dealer's view

Assistants at Kumawa Agro-Dealer in Chongwe gave the following account of how the system works for them.

When a participating farmer is issued with an e-voucher it is registered with his or her ID card. On presentation at the store this is checked via mobile phone at the time of the transaction to verify that the e-voucher holder is, in fact, the rightful owner. After successful verification, the transaction is made and, again by mobile phone, cash is immediately transferred to the merchant's bank account. In the current project, FAO pays the transaction costs.

The number of agro-dealers in Chongwe district has grown from one pre-FISRI to eight today. In the particular case of Kumawa, which also has branches in Chipata, they have achieved a 15% increase in turnover as a result of the e-voucher system.

It is, they say, that simple and that successful.

Box 4. CA with DAP in Lukoshi Village

Lukoshi village in Chongwe district has four trained contractors offering CA services (no-till planting and herbicide application); each one attends 19 client farmers. The MAL village extensionist ensures that up-to-date CA information is made available to all and that the lead farmers are given training on CA principles and equipment.

The problem of late arrival of the CA equipment in 2011 meant that each contractor was only able to attend to 15 client farmers with one acre planted to maize on each farm. Herbicide application (of glyphosate) was achieved with an average of just eight clients per contractor.

Contractors charge Kw1000 per 100 m line of planting (which approximates to USD21/ha with a 0.9 m inter-row spacing). This compares with USD57/ha for ploughing, and explains why demand is so high for the no-till planting service. Another point in favour of CA is that an acre can be planted in an hour whereas ploughing can take between four and six hours.

During the visit a single woman farmer said that she found it difficult to plough and plant on her own and that the hire service was the ideal solution to her predicament. She added that the yield on her plot had risen from 100 50 kg bags to 250 bags with the switch from ploughing to CA. Although, of course some of this will be due to greater fertilizer use and better fertilizer placement.

A contractor's new Fitarelli DAP no-till planter is inspected in Lukoshi village

6. Recouping the investment

This section examines two methods of recouping the loan investment made by farmers in CA machinery, the AFGRI model and the ZNFU model.

AFGRI

Smallholders wishing to avail themselves of the AFGRI tractor and CA machinery package take out a loan repayable over three years, currently there are 28 participating service providers.

ZNFU

The ZNFU set up a revolving fund in 2010 in order to collect funds emanating from the sale of CA equipment. The central idea was to recoup funds from the recipient farmers

and to channel them into future purchase and distribution of appropriate CA equipment to new CA service providers.

There are two classes of entrepreneur farmers who are targeted by the project, one group is provided with tractors and their associated equipment; and the other are farmers who are provided with DAP powered no-till planters and knapsack sprayers.

CA contractors using tractor power
The value of the equipment package for each participating farmer is approximately USD52,230. This is to be paid back over a three-year period with three instalments per year. ZNFU levies a 12 percent charge for administering the fund.

CA contractors using draught animal power
A total of 232 DAP-owning CA contractors have been supplied by the Project with CA equipment comprising a no-till planter and a knapsack sprayer. Of these 180 packages have been supplied on a repayable loan basis and 52 have been bought for cash.

7. Conclusions and Recommendations

CA has taken off in Zambia, it is well supported by the GoZ and promoted by international donors and NGOs. CA should be mechanized, either with tractor or draught animal power.

To achieve sustainability it is always best to involve the private sector in the provision and servicing of CA equipment. Importing machinery new to a country, and without the essential back up services is a short-term technical fix but with little prospect of long-term sustainability.

Credit arrangements and loan recovery should be in the private sector. The AFGRI model is admirable as it is run on entirely commercial lines. Roles and responsibilities are clearly spelt out at the outset and compliance with repayment schedules has been 100%.

Managing a revolving fund is fraught with difficulties. It is extremely difficult to deal with payment defaults as there is no mechanism for asset recuperation and disposal to realize its value. The revolving fund as operated is eventually bound to run out of funds for several reasons; i) a 12 percent levy is charged for administering the fund – this means that the total fund is necessarily diminishing in size; ii) no provision is made for inflation so that funds being recuperated for a particular piece of equipment will not be sufficient to buy equivalent machinery in future years; iii) the valuation of the CA equipment does not always appear to take into account all the costs of transport, import and storage; and iv) it seems that not all CA contractors understand fully their obligation to supply services and repay the loans.

The use of e-vouchers is an excellent way for donors to kick-start the establishment phase of CA service contractors. But as the scheme matures and information about service provision becomes more widely known, then the vouchers should be phased out. This has now happened in Zambia.

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