Environments **2015**, *2*, 139-166; doi:10.3390/environments2020139

OPEN ACCESS

environments

ISSN 2076-3298

www.mdpi.com/journal/environments

Review

Mechanization of Conservation Agriculture for Smallholders: Issues and Options for Sustainable Intensification

Brian Sims [1,*] and Josef Kienzle [2]

[1] Agricultural Engineer, Engineering for Development, 3 Bourneside, Bedford, MK41 7EG, UK

[2] Agricultural Engineer, Plant Production and Protection Division, FAO, Viale delle Terme di Caracalla, 00153, Rome, Italy; E-Mail: Josef.Kienzle@fao.org

* Author to whom correspondence should be addressed; E-Mail: BrianGSims@aol.com.

Academic Editor: Yu-Pin Lin

Received: 3 March 2015 / Accepted: 17 April 2015 / Published: 6 May 2015

Abstract: Conservation agriculture (CA) is an increasingly adopted production system to meet the goals of sustainable crop production intensification in feeding a growing world population whilst conserving natural resources. Mechanization (especially power units, seeders, rippers and sprayers) is a key input for CA and smallholder farmers often have difficulties in making the necessary investments. Donors may be able to provide mechanization inputs in the short term, but this is not a sustainable solution as a machinery input supply chain needs to be built up to continue availability after external interventions cease. Local manufacture should be supported, as was the case in Brazil, but this is a slow development process, especially in sub-Saharan Africa. A more immediate solution is to equip and train CA service provision entrepreneurs. With the right equipment, selected for the needs of their local clientele, and the right technical and business management training, such entrepreneurs can make a livelihood by supplying high quality CA and other mechanization services on a fully costed basis. Elements of the required training, based on extensive field experience, are provided. To catalyse the growth of CA providers' business, the market can be stimulated for an initial period by issuing e-vouchers for services and inputs.

Keywords: CA mechanization; smallholders; supply chains; local manufacture; service provision; training needs; market stimulus

---

1. Introduction

Smallholder agriculture is the mainstay of food production in the world's developing countries and is the key to ensuring long-term global food security [1]. With the global population on course to exceed 9 billion by 2050, the need to meet the growing demand for more food is immediate and pressing. The world's 500 million smallholder farms currently produce around 80 percent of our food and it is they who will have to bear the brunt of the need to increase food production by over 60 percent compared to 2007 levels. Currently many of these smallholder farms have limited access to production inputs and so achieve low levels of productivity. One key production input, mechanization, is frequently neglected in farm productivity improvement efforts, in fact it has been described as the neglected waif of agricultural and rural development [2].

Increasing food production whilst conserving the planet's natural resource base will not be a simple task. A second Green Revolution, which was able to more than double global food production in the second half of the last century, is now very unlikely. Rates of growth in the yields of the world's major food cereals (wheat, rice and maize) are now falling and this is due in no small part to the degradation of agricultural land. Increase in food production via a process of sustainable intensification will, necessarily, require the implementation of more natural resource-friendly production methods, for example reduced- and no-till farming, and this will require a major diffusion of novel mechanization technology.

Cropping intensity can be raised in a variety of ways as a result of adopting a conservation agriculture (CA) system. Plough-based tillage is intensely time and energy-consuming. Primary tillage can also only be easily accomplished when soil conditions are suitable—not too dry and not too wet. Waiting until the first rains before initiating soil preparation can waste valuable time, delay planting until late in the window, and result in reduced yields. Although highly variable, yield losses of up to one percent per day of delay after the optimum planting date can be experienced. Yield increases can also be expected after switching to CA (e.g., [3]) but improvements cannot always be expected to be immediate. Degraded soils will need time to recover their health, structure and fertility under a no-till regime and so some yield decline may be experienced before yields recover and exceed pre-switchover levels. Integrating livestock production with CA cropping is another possibility. Using leguminous cover crops to feed a livestock enterprise such as dairy goats could be a possibility if cultural preferences and market conditions are appropriate.

A current phenomenon affecting many rural economies in the developing world is the drift of healthy young males to urban centres in search of more rewarding payment for their efforts. Fifty percent of the world's global population is urban today and this is projected to rise to 70 percent by 2050 [4]. This means that those being left behind to work on the farms are women, the elderly and children and the consequence is that farm power becomes an increasingly severe constraint. Seventy percent of the power source for smallholder farms in sub-Saharan Africa (SSA) is supplied by manual labour and less than 10 percent comes from engine-powered sources. The remaining 20–25 percent of farm power is supplied by draught animals [5]. If the supply of human labour emanates principally from women, the elderly and children, it is clear that supply constraints will have a negative impact on farm productivity.

Improving smallholders' access to crucial mechanization inputs is frequently fraught with difficulties as the adoption of any innovation must be seen as a useful and profitable investment from the perspective of the farmer. This prerequisite would then trigger the necessary demand for these innovations which should lead to an increased or stabilized supply. However, very often this demand is non-existent due to the low income levels of small farmers which in turn also lead to only very rudimentarily developed mechanization input supply chains in rural areas. This situation is referred to as 'the vicious cycle of mechanization development'. It will require broad action among all actors involved in rural development and sustainable intensification programmes from the farmers' level up to and including policies to disintegrate the cycle [6].

Mechanization inputs are usually lumpy so that a smallholder with, typically, under two hectares of land, will be reluctant to be the sole investor in a machine which has the potential to operate over a much larger area. As always, there will be many demands on a farm family's financial assets and the opportunity cost of capital may militate against adoption of machinery.

The affordability of mechanization inputs in the developing country smallholder farming sector is closely correlated with their profitability. Almost by definition poor smallholder families struggling to emerge from subsistence farming will usually have difficulty in amassing the resources necessary for machinery purchase. An alternative is to borrow the money required but this can be expensive and formal sources of credit, such as banks, are notoriously reluctant to extend credit to the sector, citing the high level of risk involved.

Where specialist equipment is required for the adoption of sustainable crop intensification by means of conservation agriculture, then a further obstacle to adoption arises in the form of low availability. In many countries, and especially in SSA, local availability of CA equipment (especially planters) is extremely limited. Supply is frequently initiated by externally funded aid programmes and projects and local supply chains are generally not adequately developed. Machinery is often donated or sold at cost under attractive loan arrangements which are typified by low interest rates, long payback periods and a benign attitude towards defaulters. This can lead to the situation where farmers outside the programme target group are unable to access the machinery, even if they are convinced that it would be beneficial, as there is no local supply network. This situation is slowly improving as donor organizations realize the value of involving local dealers in the supply of machinery.

As if the global challenges of burgeoning population and food production facing the planet were not enough, we will also have to contend with the manifestations of climate change. Anthropogenic greenhouse gas (GHG) emissions have continued to increase over the period 1970 to 2010 with larger decadal increases towards the end of this period, emissions were the highest in human history from 2000 to 2010 [7]. Globally, economic and population growth continue to be the most important drivers of increases in CO_2 emissions and between 2000 and 2010 both drivers outpaced emission reductions. Without additional efforts to reduce GHG emissions they will continue to grow; baseline scenarios exceed 450 ppm CO_2e by 2030 and reach between 750 and over 1300 ppm by 2100. This will result in a rise in global mean temperatures of between 3.7 and 4.8 °C. The consequences will be increasingly violent weather events and increased uncertainty, *i.e.*, reasons for protecting agricultural soils with biomass cover to the maximum extent possible and reducing turn-around time between cropping cycles.

Mitigation scenarios which are likely to keep temperature change below 2 °C equate to concentrations in 2100 of 450 ppm CO_2e. To achieve this will require large-scale changes in energy systems to produce substantial cuts in in anthropogenic GHG emissions by mid-century (40–70 percent globally) and emissions near zero GtCO_2e in 2100. Land-use changes will also be needed and include afforestation, reduced deforestation and other carbon dioxide removal (CDR) technologies.

GHG emissions are projected to grow in all sectors [7], except for net CO_2 emissions in the agriculture, forestry and other land-use (AFOLU) sector. This is specifically due to C sequestration in forestry and C sinks in agricultural soils. Clearly agricultural soils can only be C sinks if they are not eroding or having their C oxidised by tillage—so that conservation agriculture has a clear part to play in this process.

The strategy for C sequestration with CA is to increase the overall C pool. The goal is to manage the input of biomass-C to exceed the losses [8]. Carbon can be added to soils through roots and root exudates as well as above-ground biomass and the rate of sequestration will depend on soil type and climate. However Lal [8] estimates that the SOC pool to 1 m depth is approximately 1500 Pg (10^{12} kg) and if this is increased by 0.1 percent a year then the resulting atmospheric CO_2 pool would be decreased by 1.5 Pg/yr or 14 percent of total emissions. Restoration of SOC, principally through CA and agroforestry, over the 5 billion hectares of global crop and grazing lands, will draw down atmospheric CO_2 by 40–50 ppm—a no-regrets situation as natural resources will also be managed sustainably. Continuing to lose soil carbon through erosion and oxidation is no longer an option if we are to constrain global temperature rises to within manageable limits.

This description of the situation and the threats to future agricultural production point clearly to the need for a generic switch in the model for smallholder food production at global scale. A paradigm of sustainable crop production intensification (SCPI) with greatly enhanced environmental protection is vital to produce more food whilst saving natural resources. The sector will also require an increased market orientation so that input supply chains are in place and able to offer timely services to smallholders. Market linkages will also have to be improved so that farmers can respond to market indicators (prices, locations, transport services, storage, *etc.*) and can quickly react to signals. The remainder of this paper examines in some detail the need for an agricultural mechanization supply chain for smallholder farmers as mechanization is such a crucial input to the SCPI paradigm in this world of endangered resources and increasing demand.

2. Mechanization of CA

2.1. Power Sources and Tasks to Be Mechanized

The principal mechanization requirements for smallholder CA are for no-till seeding and weed control. Equipment is available for the full range of power sources, from human and animal muscle power to two and four-wheeled tractors (2WT and 4WT) (Figures 1–5) and the wide range can be viewed at [9]. No-till planting requires the planter to be able to cut through the surface mulch and previous crop residues that will be on the soil surface or anchored into it. The planter must be able to operate without becoming blocked with an accumulation of residues. The mulch can be penetrated or cut with vertical discs, chisel tines or jab planter beaks—or even a pointed stick. Chisel point tines are suitable in low-residue cover situations. Although development of no-till planting machinery is constantly producing improvements and refinements (e.g., the 'Baker boot' inverted-T shaped opener [10]) the designs specifically for low-cost machines aimed at smallholder farmers are generally kept as simple as possible [11]. Manually operated jab planters are suitable for very small holdings and are available with both seed and fertilizer metering. For draught animal or small tractor power, disc openers, comprising two discs either offset or of different diameters arranged so that the leading disc deflects residue, will cut through residue and form a V-shaped slot in the soil. Metered seed and fertilizer can be fed into the gap between the discs via suitable tubing. Another option, not as popular as chisels or discs, is the rolling jab planter which comprises twin rotating off-set inclined star wheels which come together to penetrate the surface mulch and deliver the seed before opening to receive the subsequent seed [12]. Another example of innovation in smallholder no-till planters is the Happy Seeder (Figure 3) which lifts surface mulch with rotating flails to allow seeding with chisel openers before depositing the mulch back on the surface [13]. (Recently Happy Seeders have also been developed for 2WTs in India and Bangladesh—Figure 5, and use rotating flails to clear residue from the chisel tines.) Currently efforts are being made to address the farm power shortage in SSA through the use of two-wheel tractors (2WTs) for no-till seeding as human and animal labour becomes less available in the smallholder farming sector and the use of 4WTs is as yet not viewed as financially viable [14].

Figure 1. Jab-planter or *matraca* (Josef Kienzle).

Figure 2. Fitarelli animal-drawn no-till planter with forward vertical disc to cut surface residue and a chisel-tined opener (Christian Thierfelder).

Figure 3. Tractor-mounted Turbo-Happy Seeder with rotating flails to cut residue in front of the chisel-tines and simultaneously clean each side of the tine as the rotor spins, the rotating parts do not touch the soil [15] (Harminder Singh Sidhu).

Figure 4. Knapik animal-drawn no-till planter with double offset disc openers to better cut through heavy surface residue (Brian Sims).

Figure 5. Happy Seeder coupled to a 2WT (Harminder Singh Sidhu).

The aim of CA is minimum soil disturbance both for planting and weed control. For weed management all options should be explored including physical, biological and chemical control. Manually powered mechanical control options include shallow scraping with sharp hand-hoes, hand pulling and slashing which are suitable for very small areas (Figure 6). As holdings become larger, then animal traction and tractor power can be used for knife rolling (Figure 7). Biological control, by means of keeping the soil surface covered and competing out weeds is achieved with crop associations and cover crops undersown in the main crop before harvest and covering the soil until the subsequent main crop establishment (Figure 8). The use of cover crops is increasing in CA systems globally and has vast potential for smallholder systems where they can offer important food and forage production possibilities as well as reducing weed pressure and protecting the soil from water and wind erosion. The use of herbicides is sometimes a contentious issue when smallholder farming systems are under discussion especially as CA systems claim to be valid for sustainable intensification. Availability, quality, price and precision of application are all issues which will be disincentives to their effective use besides the philosophical or politically induced question of whether herbicides should even be an option in smallholder agriculture for weed management. However a judicious combination of mechanical, biological and chemical weed control methods may be an appropriate response in many situations and effective weed control is one of the *key* ingredients of successful CA. Chemical weed control under CA systems has often been an important step towards farmer adoption of CA due to the significant reduction in labour requirement when compared with manual mechanical control which on its own can be a valid justification for herbicide use given the enormous drudgery that is associated with mechanical weeding which is almost entirely done by women, the elderly and adolescents.

Figure 6. Effective weed control is essential for successful Conservation agriculture (CA). Mechanical control, by surface scraping, is one of the most widespread methods (Brian Sims).

Figure 7. Knife rolling can be an effective management tool both for cover crops and some weeds (Brian Sims).

Figure 8. Cover crops and crop associations can suppress weeds biologically and are preferred methods (Brian Sims).

However, if herbicides are introduced there should be a medium term aim to reduce them to the minimum as soon as the agronomic control measures are showing impact. Innovations are needed when farmers opt for chemical weed control as the conventional option is the knapsack sprayer, which is notorious for contaminating the operator. Knapsack sprayers can be mounted on a wheeled chassis, fitted with a multi-nozzle boom, and hand-pulled so removing the operator from the risk of contamination (Figure 9). Larger capacity boom sprayers are manufactured for animal traction (Figure 10). The investment costs for such equipment are, unfortunately, beyond the financial resources of many SSA smallholder farmers; and it is here that the potential of CA mechanization service providers becomes apparent. One interesting development from Zambia is the Zamwipe applicator which operates on the wick principle with glyphosate as the application herbicide. Farmers have, however, expressed some difficulties with this implement as the flow rate is not easy to control and if the application head touches the soil the herbicide is deactivated.

Figure 9. Knapsack sprayers can be modified to become hand-pulled units which not only apply herbicide more uniformly but also keep the operator well clear of the spray (Brian Sims).

Figure 10. Larger sprayer units with bigger tanks and wider spray booms are available commercially for animal traction (Brian Sims).

A modification of no-till for CA that is becoming increasingly popular in SSA is the use of rippers (either animal or tractor-drawn) to open a seeding slot (Figure 11). Use of ox-drawn CA equipment can provide an intermediate solution to expansion of land under CA. With the use of a chisel-tined ripper, rip lines are opened up in the dry season (these are usually quite shallow and no deeper that 10 cm). 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.

Figure 11. Narrow chisel-point tines can be used to rip a planting slot for subsequent planting. The inter-row area is not tilled and is managed as a CA system (permanent cover and effective weed control) (Christian Thierfelder).

Once the full rains arrive, the crops are sown by hand into the prepared furrow. The key components of the animal draught-power ripping system are as follows [16]:

- Retention of crop residues for soil cover. Soil tillage is restricted to the rip lines where the crop is to be sown.
- Shallow (hoe) weeding to avoid major soil disturbance. Rip lines are first opened in the dry season, they will then concentrate the first, light, rains and facilitate the second ripping pass at the required depth.

Fertilizer and lime are applied by hand in the rip lines at the first rains.

- Crops are sown with the first effective rains.
- Crop rotations are practised with the inclusion of nitrogen-fixing legumes and other crops such as cotton and sunflower.
- Inter-row ripping of the legume crops in the rotation when the soil is still moist can mean that preparations are well on schedule for planting the next grain crop in the coming rainy season.

The value of good transport systems is difficult to overestimate for many smallholder farming situations. Transport is vital to bring inputs to the field and, crucially, to get produce to market in good condition and on time. Offering transport services in a farmer's locality can also be a source of extra income to defray operating costs and support family livelihoods. The inclusion of transport capability with tractor-powered mechanization is especially important and it will often be the most attractive aspect of the investment.

2.2. Availability of Mechanization

Currently in many developing countries the availability of CA equipment, especially no-till planters, is via importation. Mainly due to the impetus given to Brazilian market, and so to Brazilian manufacturers during the PRONAF (National Farm Family Support) programme in the late 1990s, smallholders were empowered to invest in CA equipment and so stimulate the manufacturing sector in Brazil [17]. This means that Brazilian machines are the main source, and model, for developing countries in other parts of the world. However, more recently no-till planter models and tractors of all sizes are imported into Africa in large numbers from India, China, Bangladesh and other countries. For the most part the planters are imported by international donor-funded projects such as those implemented by FAO, CIMMYT (and other international research centres) and NGOs, and this means that their cost can be doubled or more when compared to that in their country of origin.

CA equipment prices are available from individual manufacturers and are, of course, subject to variation without notice. Table 1 gives an indication of possible costs of equipment in the country of origin.

Table 1. Some examples of indicative prices for CA equipment in the country of origin.

Equipment	Price (USD)
Jab planter for seed and fertilizer (Fitarelli)	40
Animal-drawn, single-line, long-beam no-till planter and fertilizer (Fitarelli)	500
Tractor-mounted 3-row, no-till planter and fertilizer (Fitarelli)	7000
Animal-drawn 2-row no-till planter and fertilizer (also adaptable to 2WTs) (Fitarelli)	2600
Tractor-mounted 5-row no-till planter and fertilizer (Fitarelli)	10,000
Chinese-made 10 hp 2WT	1000

However this has been the stimulus for local manufacture in many countries and has meant that there is an ever increasing volume of machines manufactured locally and able to respond to local conditions. An up-to-date account of the current situation relating to local production in SSA is given in [18].

The demand for CA equipment by smallholder farmers is country, region and site specific. Currently CA adoption in SSA is lagging behind other regions of the world [19] but there are an estimated 1.2 million hectares of CA in Africa, representing just 0.9 percent of the available arable area. So the potential for expansion is vast. Adoption of CA in individual countries can be accessed on the FAO CA website [9]. Almost by definition the demand for equipment directly by smallholders will be very low in SSA as the majority of farmers can be described as resource-poor. The investment cost will generally be too high and there is a high opportunity cost for available capital. As a result CA mechanization services will have to be supplied from elsewhere. As outlined in Section 4, the feasibility of supplying CA mechanization services is a crucial initial study to be undertaken by would-be service providers, and this may require specialist training [20].

There are no viable shortcuts for bringing suitable mechanization equipment to smallholder farmers. This is underlined by many examples of inappropriate public sector bulk procurement of mechanization inputs. Even today governments such as, for example, of Ethiopia are sourcing large quantities of implements and tractors (both 2 and 4WT) without having a solid plan for distribution, ownership handling and capacity building of potential machinery owners. Moreover, these tractors are sold with up to a 60 percent discount which equates to about half of the market price of commercial suppliers of similar equipment in the country. In addition the equipment supplied with the tractors is predominantly heavy tillage implements, not compatible with the principles of sustainable intensification and CA. One way to improve the availability of CA equipment for smallholder farmers is to encourage, equip and train local-level entrepreneurs to offer a CA mechanization service in their neighbourhood. By this means smallholders have access to the services of equipment which they, on their own, would be unlikely to be able to acquire. The concept of private sector entrepreneurial CA mechanization service provision is developed further in Section 4.

2.3. Creating Demand for Mechanization

Scaling out CA can benefit from the involvement of a range of catalytic organizations, both from the public and international donor sectors, as well as from the private sector. This can take the form of market creation and assurance through contract farming and purchasing guarantees, including partnering with the public sector extension programmes to encourage the use of environmentally friendly practices (e.g., CA). The United Nations' World Food Programme (WFP) has embarked on such an approach through its Purchase for Progress (P4P) programme in Zambia [21].

In the recent past many efforts have been made by donors and development agencies to initiate activities at pilot scale that introduce the principles of CA, often through farmer-driven methodologies and extension approaches such as Farmer Field Schools [22] or Lead Farmers [23]. Such pilot projects have provided the necessary inputs including CA equipment (principally no-till planters, animal drawn rippers and equipment for chemical weed management). The most effective of these tools, the no-till planters, were hardly available in SSA and needed to be imported (especially from Brazil). As a result there was initially an artificial, donor-driven, supply of these equipment innovations.

But there is another dimension to this. Farmers and farmer groups that have internalized and understood the benefits of CA for soil improvement and increased resilience to climatic extremes (intense rainfall events and prolonged periods of drought), and subsequently more stable and improved yields, will still remain averse to possibly risky investments. Before making a decision to acquire innovative CA-mechanization tools they will need to have a good idea of how they are to sell their produce onto a stable market at a fair price. It is this aspect of the market situation which is the focus of the P4P initiative.

In 2014 FAO and WFP in Zambia (in collaboration with the Ministry of Agriculture and Livestock—MAL) joined forces to ensure that scaling out of CA adoption in agricultural production is combined with a more secure supply of required agricultural inputs (including CA tools and equipment) through private sector dealers (Figure 12). At the same time there is a focus on strengthening farmers' business opportunities, capital financing and asset base as well as improving farmer market engagement. In practical terms this means that WFP is supporting what are called 'aggregation centres' in rural areas. These centres are private-sector driven and provide all the necessary inputs and equipment required for cleaning, storage, pest management and packaging, as well as assuring the buy-in of agricultural produce. WFP does not guarantee any purchase however, it facilitates the business links (and, for example, links to the on-going school-children feeding programme). It also facilitates the construction of warehouses in remote districts were the private sector would be unlikely to make the risky investment on its own. For the moment WFP focuses mainly on cowpeas and beans; maize is handled by the Food Reserve Agency on its own terms that are not always to the benefit of smallholder maize producers [24].

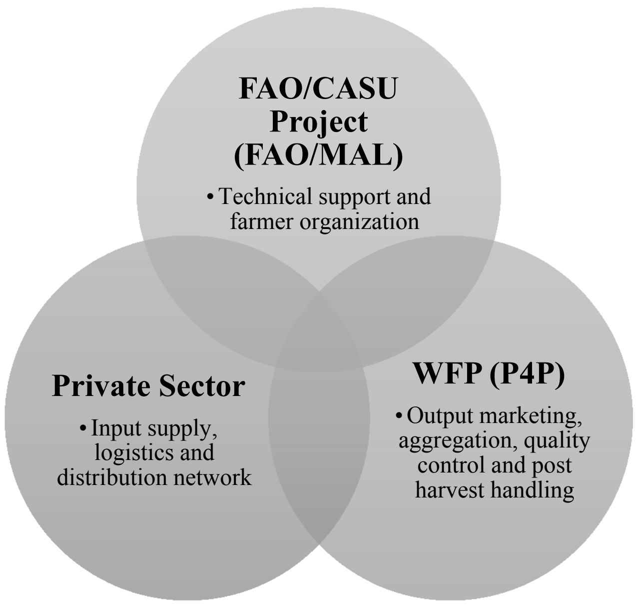

Figure 12. The CASU-P4P partnership benefits from building synergies and exploiting comparative advantages of common interests and linking input and output markets of the same value chain. CASU is the Conservation Agriculture Scaling-Up Project funded by the European Union and implemented by FAO in Zambia. Source: [25].

However, simply facilitating or unleashing the private sector is not a panacea as another example of the impact of a secured output market from the Dodoma region in Tanzania illustrates. WFP established a maize collection point in Dodoma for the local purchase of maize in Tanzania to supply the WFP food programmes in the region (Figure 13).

Figure 13. Small-scale transport service providers delivering maize to the Dodoma WFP collection point (Josef Kienzle).

The existence of this maize collection point has triggered a spike of mechanized maize farming in the area as destructive land preparation by farmers and tractor-based service providers has mushroomed out of control. The development, except for the maize collection point, is not facilitated by any project. However, as increased production is based on disc-plough mechanization and without any use of fertilizer inputs, there is now a kind of mechanized shifting cultivation occurring. Land is used for a few seasons until it is exhausted and degraded by severe erosion. Then the perpetrators move on to another piece of land that is still plentiful in this region. This example shows that there is a role for the Ministry of Agriculture or other government department for agricultural development guided towards sustainable production intensification. CA based mechanization would have led to more sustainable methods of maize production intensification. Yet, the motive for this sudden and un-controlled mechanization was the establishment of the maize output market which is an indication of how crucial the output market link is for introducing costly innovations. In this case more guidance towards the goal of sustainable maize production intensification would have been helpful; and advisable [26].

2.4. CA Mechanization Supply Chain

Agricultural mechanization is a means to increase labour and land productivity and is but one element in the array of inputs needed for a successful farming enterprise. As with any other input, agricultural mechanization has a supply chain comprising a number of stakeholders. Each of the stakeholders, with the possible exception of some of the services provided by the public sector, is active in the supply chain in order to make a living. This means that their activities must generate a surplus which will recompense them for their time and effort. Figure 14 illustrates some of the possible interactions in the chain. The roles played by the various stakeholders will be site-specific and will be very variable, some possibilities are discussed in detail in [5].

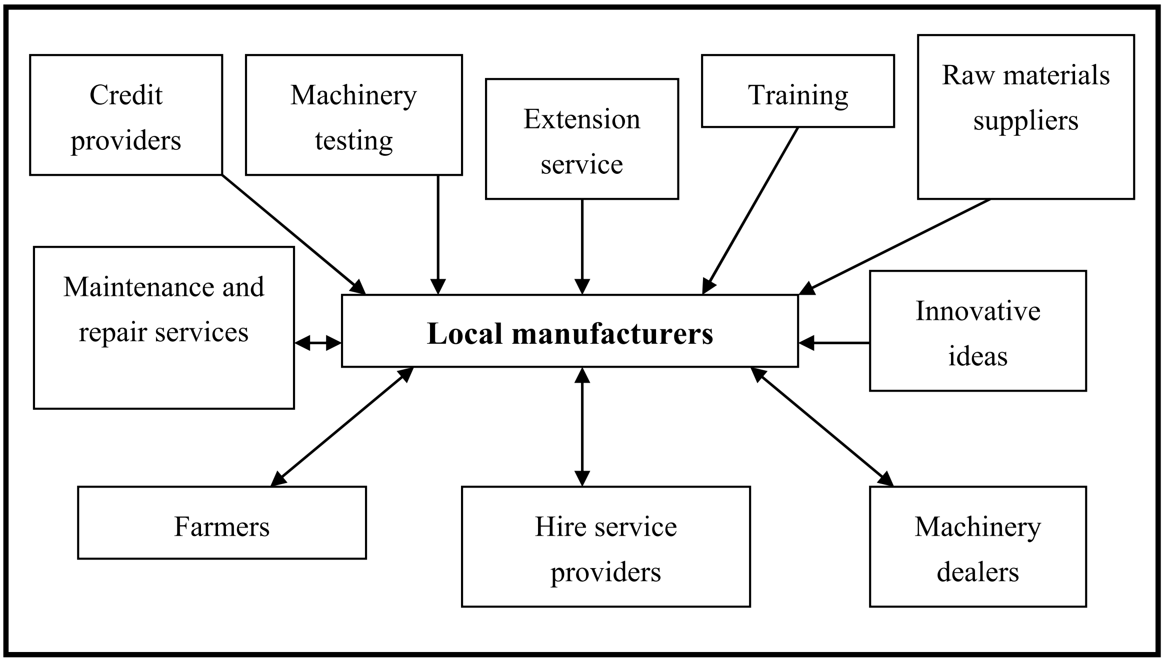

Figure 14. Mechanization supply chain stakeholder interactions from the perspective of local manufacture (Source: [5]).

3. Local Manufacture

Although, as has been noted, importation of CA equipment is a relatively easy option, it is expensive. Prices will typically double, or more, from factory (Table 1) to user when the costs of transport, import duties, exporting and importing agents' fees and local retail mark-up are taken into account. All these costs are real and necessary (although some may be exaggerated at times) and when retail prices are undercut by subsidized imports, either by governments or donor agencies, then the local market equilibrium is upset. This situation militates against sustainability and the short term benefits of subsidized imports should generally be eschewed in the interests of long-term stability. Imported equipment may not always be well suited to local conditions. For example compacted and stony terrain may be difficult to sow by no-till planters with twin offset disc openers; transport between scattered smallholder plots may require a transport mode to be supplied with the planter.

Local manufacture should be encouraged whenever possible as machinery can be produced that is appropriate for local circumstances. The development of a manufacturing industry targeting smallholder CA farmers is still in its infancy in SSA, although there is great potential. Some of the needs and the obstacles to be overcome will now be discussed, although it is clear that there is a wide range of inter-country differences, competencies and capabilities.

- *Creation of a nurturing environment for the incubation of CA manufacturing capability.* There are lessons to be learned in this regard from the Brazilian experience. From the 1980s the Brazilian government has been concerned to develop and disseminate CA equipment for smallholder farmers. This public sector support has been crucial to the success of CA for this farming sector. Appropriate machinery has been developed by consortia of private and public sector expertise and the farming community. Finance for machinery acquisition has been made available to smallholder farmers at very advantageous rates and this has stimulated the manufacturing industry to become self-sufficient. This is in stark contrast to the situation in many SSA countries where public sector investment in agricultural sector development is often very low compared to other developing regions of the world.

- *Materials supply.* Manufacturers in SSA frequently point out the uneven playing field on which they are expected to play and compete. There may be import duty on steel and machinery parts but not on imported tractors and agricultural machinery (e.g., in Kenya), which will disadvantage local manufacturers as it might be difficult for them to compete on price with their local products being made with materials subject to tax whilst imported agricultural equipment is tax free. Addressing this apparent injustice is one way that governments can work towards creating the necessary nurturing environment. Scrap steel may be appropriate for small-scale blacksmiths, but not larger scale manufacturers.
- *A lack of appreciation of the importance of critical part design and materials considerations*. Local manufacturers making an effort to break into the CA machinery market may often be at a disadvantage due to their limited knowledge of the details of design parameters for such machinery. Examples are: jab planter beaks; tine dimensions, attack angles, and materials (use of high carbon spring steel or easier to work alternatives such as Bennox steel); vertical loading on residue cutting discs; seed metering, placement, and covering; seed plates for different crops, fertilizer placement, depth control.
- *Creation of demand*. Manufacturers are reluctant to manufacture before having firm orders; at the same time farmers complain that CA technologies are not in the marketplace. This highlights the importance of development projects which, as happened in Brazil, can create the demand and maintain the interests of manufacturers until effective farmer demand can take over. Other actions have been seen to be important and these include the creation of dealer networks and their role in promotion through demonstrations and field days. The public sector's role in providing subsidies and credit in the initial stages is also important. A specific targeted subsidy system (e.g., with vouchers—see Section 4) that supports the use of CA equipment would help. However, the public sector should not attempt short cuts by offering procurement programmes without a clear plan for equipment distribution and use including capacity building for users or service providers. Such entirely public sector driven tractor and equipment procurement programmes, and subsequent public sector driven mechanization hire stations, almost entirely failed and led to the closure of these schemes and a lack of interest in mechanization development programmes by donors, international financial institutions and the UN including FAO [27].
- *Need for training to improve the skills base*. Skills need to be improved at both the user and manufacturer levels in order for equipment to be effectively designed and properly operated and maintained. Important areas are calibration, field operation, maintenance, and business skills (especially for manufacturers and hire service providers). This theme is expanded and discussed in Section 4.

One example of a government being aware of the need to support, supply and train emerging manufacturers is the Small Industries Development Organization (SIDO) in Tanzania. SIDO, part of the Ministry of Trade, Industry and Marketing of the Tanzanian Government, was established by act of parliament in 1973 to facilitate the development of the SME sector of Tanzanian industry. The support programmes that it employs to develop local manufacturing capacity comprise: technical training; managerial training (business skills and enterprise management); market access; quality control [28]. Box 1 is an example of how organizations like SIDO can encourage SMEs into the commercial market.

Box 1. Vijana Workshop, Arusha Tanzania

The Vijana Workshop was established in SIDO's 'incubation' centre in 2009. At that time two young entrepreneurs left their employment in Dar es Salaam and ventured to Arusha to start their own small business enterprise. They set up their business in SIDO's rent-free workshop accommodation centre to make small agricultural and gardening tools – using their own capital for the first year. Then, with the aid of a grant from SIDO, they expanded and took on three additional workers to help with the manufacturing of tools and charcoal burning cookers.

Their hand-tool production line now comprises rakes, fork jembes, watering cans and kitchen knives. Their main source of raw material is from local hardware dealers and they claim to be able to harden the hoe blade somewhat by heating and slow cooling in used engine oil. Customers seem to appreciate the quality of the products which are sold at a rate of several hundred per month with a 40 percent mark-up over material costs to cover labour and utilities.

Vijana Director Athumani Muhoji (right) and a colleague demonstrate two of the hand tools produced by the fledgling business.

Another example of a private sector training centre for youth is the Selam Awassa Business Group [29] in Ethiopia. This group was originally established by a Swiss couple that adopted four orphaned Ethiopian girls, one of whom is now the chairperson of the business. It is producing appropriate technology and sells onto the open market. The items are produced by apprentices who undergo a three year training cycle to obtain employable skills. The current production and services areas are: pre- and post-harvest equipment, renewable energy, water lifting devices. The aim of the centre is to develop very practical skills that are relevant for the job market (Figure 15).

Figure 15. Apprentice welder at Selam Awassa Business Group, Ethiopia (Fréderic Baudron).

The centre has all the resources and machine tools for the local production of CA equipment, especially no-till planters and pull-along sprayers (Figure 9). However their policy is only to produce for effective demand. However, the option for using this type of centre for training in maintenance of 2WTs and no-till planters is great.

The centre should be commended for its approach to especially support young people from difficult backgrounds, e.g., orphans; also 60 percent of its trainees are young women. The centre has an annual output of 100 trainees for the open market and according to their calculations, the market could accommodate 300 trainees per year.

4. Service Provision

For all the reasons discussed above it would seem that the most attractive option to improve access by smallholders to CA mechanization, would be to offer the service from well-equipped and well trained local service providers and this is the theme that will be explored now.

Service providers do not necessarily have to operate on a large scale. Neither do they necessarily need to be practising farmers, although that would be an advantage as discussed below. It seems that, with smallholder agricultural mechanization and sustainable intensification in rural areas the range or availability of reliable and skilled and appropriately equipped service providers are very limited or non-existent, especially in SSA. Yet the need for services related to farm-power intensive and time-sensitive agricultural tasks is very high. Timely, good quality and affordable services are needed in many places in rural areas [20].

For farmers who already own implements, and maybe draught animals or a 2WT, the step to becoming a service provider is not too great. However, a potential service provider should preferably be a good farmer who is familiar with, and concerned about, agricultural practices and methods that are in line with sustainable intensification and with efficient use and care of natural resources and external inputs. However for service providers themselves the most important challenge is to make a living and income out of the offered services.

For farmers to make the transition to service provision they need to be part of a network and have access to knowledge and training. They will need to be aware of, or should be equipped with, the principles of good agricultural practices and what it means in the context of the local neighbourhood where most if not all of their potential clients will be located. Potential service providers should have: (i) a reputation as reliable and knowledgeable farmers; (ii) be open to innovations in farming such as CA and its specific approach to mechanization and the use of alternative implements such as rippers and direct seeders; (iii) be able to operate, repair and maintain agricultural equipment.

In order to become a good business person and service provider an entrepreneur needs to develop the skills needed to make the business sustainable financially. As a result the following challenges may have to be overcome: (i) it may be important to focus on services that have the highest demand or that are not yet provided by another service provider; (ii) it may be necessary to acquire additional or new equipment and so the need for credit becomes clear and with it the need for a detailed business plan.

If equipment is purchased and if the investment is large, e.g., a small tractor, it is important to devise an annual plan for services that can be provided at different times of the year and for services that may be independent from agricultural seasons. Such additional services, e.g., transport or power provision for irrigation or milling can make the difference between a service business being sustainable or not.

The specifications of the equipment needed will depend on the requirements of the particular site landscape, the power source available, and the quality of the supply chain. But the minimum requirement is likely to comprise a ripper, no-till planter and sprayer plus, perhaps, a trailer. The skills that are needed, and alluded to above, will often require specific training on both technical and management aspects. Such training can be (and in practice is) provided by the public a sector or international donors (or both in combination). The following outline could form the basis of a comprehensive course:

4.1. Technical Training

This training should be hands-on and predominantly practical in the field.

- Calibration of seeders and sprayers [30] (Figure 16)
- Field operation of rippers, seeders and sprayers (Figure 17)
- Routine maintenance
- Servicing, e.g., of 2WT engines and transmissions

4.2. Management Training

Although some formal classwork will be required, as far as possible the learning process should be via practical exercises using real or realistic situations and realistic items and quantities.

- Feasibility studies
    - Market research
    - Partial budgets
    - Supply chains
    - Credit supply [31]
- Record keeping
- Accounting (balance sheets, profit and loss accounts, cash flow) [32]
- Costing of CA equipment use [33]

- Income assessment
- Business planning
- Marketing

Figure 16. Static calibration of a no-till planter (Brian Sims).

Figure 17. Field operation of a tractor-mounted no-till planter (Brian Sims).

During practical examination of market research, business planning and marketing training, the trainees and trainers may conclude that CA service providers depend on very short agricultural seasons with maybe one or two months working time. This will not usually be sufficient for a valid business plan and may not justify the investment that has to be made in the equipment. Therefore potential service providers will need to consider broadening their business into other areas for which the power source can be used. Such potential business expansion could include:

- A tractor-drawn trailer for all year round transport services of all types of goods
- A tractor-powered maize sheller or harvester (Figure 18)
- A tractor-driven water pump for water lifting and irrigation

By examining the business holistically and creating business opportunities for otherwise slack periods, potential service providers will be able to develop an inclusive all-year business model that would include the CA planting services.

Figure 18. MUST sheller/chopper developed by the Centre for Agricultural Mechanization and Rural technology (CAMARTEC), Tanzania. The machine is trailer mounted and hauled between sites by a 2WT (Wilson Baitani).

4.3. The Profitability of Service Provision

In order to evaluate the profitability of investment in CA machinery it is essential to have information on the costs of acquisition and potential annual usage. In the case of an individual farmer it is not too difficult to estimate the number of hours a year that will be spent on transport, planting, spraying, weeding and so forth. On the other hand a CA service provider will have to estimate the annual usage figures from market surveys, but there can be no guarantee that the targets will be achieved in practice. Once costs have been calculated and income estimated, then break-even areas, or hours of paid work can be visualized.

Tables 2–4 respectively give detail on the methodology of costing the use of a 2WT, no-till planter and trailer. The prices used are indicative of ex-factory values and it is essential to use figures that reflect the purchase price in a specific location. This may be double or more the price at origin**, in all cases values included in Figures 2–4 should be replaced with those applicable locally where these are available**. Further details on calculating the finances of machinery ownership can be found in [33].

Table 2. Estimating the costs of operating a 10 hp 2WT Basic information: Purchase price: USD1000; residual value: USD100; interest rate (i): 12%; useful life: 8 years; annual use: 500 h; Price of diesel fuel: USD1.00/litre.

Costs	**USD**
Annual Fixed Costs	
Depreciation (purchase price – residual value) ÷ useful life	112.5 (a)
Interest (purchase price + residual value) ÷ 2 × i%)	66.0 (b)
Sub-total (a + b)	178.5
Annual variable costs [34]	
Repairs and maintenance (130% of purchase price over useful life)	162.5 (c)
Fuel (10% × engine hp = l/h) (l/h × annual use × diesel price = annual cost)	500.0 (d)
Lubricants (1.5% × hourly fuel consumption) × annual use)	7.5 (e)
Sub-total (c + d + e)	670.0
Total hourly costs	1.7

Note: If a dedicated driver is employed to operate the 2WT then wages and other costs must be added to the annual fixed costs.

Table 3. Estimating the costs of a no-till planter. Basic information: Purchase price: USD2600; Residual value: USD260; interest rate (i): 12%; Useful life: 8 years; Annual use: 100 h.

Costs	**USD**
Annual Fixed Costs	
Depreciation (purchase price – residual value) ÷ useful life	292.5 (a)
Interest (purchase price + residual value) ÷ 2 × i%)	171.6 (b)
Sub-total (a + b)	464.1
Annual variable costs [34]	
Repairs and maintenance (150% of purchase price over useful life)	487.5
Sub-total	487.5
Total hourly costs	9.5

Table 4. Estimating the costs of a trailer for a 2WT. Basic information: Purchase price: USD800; Residual value: USD80; interest rate (i): 12%; Useful life: 5 years; Annual use: 300 h.

Costs	**USD**
Annual Fixed Costs	
Depreciation (purchase price – residual value) ÷ useful life	144.0 (a)
Interest (purchase price + residual value) ÷ 2 × i%)	52.8 (b)
Sub-total (a + b)	196.8
Annual variable costs [34]	
Repairs and maintenance (250% of purchase price over useful life)	400.0
Sub-total	596.8
Total hourly costs	2.0

Once the hourly costs of operating the tractor and ancillary equipment are known then these can be compared with output prices of saleable produce to see where the breakeven point will be for a farmer-producer. In the case of a service provider the comparison will be with rates for specific jobs which can be charged to clients in the local environment. The total income received by way of services rendered will need to exceed the machinery costs plus the minimum profit margin required by the provider.

A simple partial budget is a useful tool to gain an insight into the income that would need to be generated through the operation of a CA services provision business to keep it in the black. Table 5 indicates the required pattern of reasoning which could be applied to a specific situation.

Clearly for the enterprise to be profitable, Total benefits (B) must be greater than total costs (A)—plus the required profit margin. A, the costs of investment, will be difficult to reduce, although they are sensitive to changes in interest rate and costs of labour. However B depends entirely on the amounts paid work (‘x’, ‘y’ and ‘z’) that are obtained. Estimating likely changes to these numbers can indicate where-the the investment will be profitable under varying sets of circumstances. B will always need to be greater than A for profitability, and equal to A for break-even.

Table 5. Indicative partial budget structure showing annual the costs and benefits associated with a CA service provision business.

Costs of the investment	**Benefits from the investment**
Annual costs of:	Annual benefits:
2WT	'x' hours of no-till planting
No-till planter	'y' tonnes of maize shelling
Maize sheller	'z' tonne-kilometres of transport
trailer	*etc*.
Annual cost of labour hired for machinery operation	
TOTAL: A	TOTAL: B

4.4. E-Vouchers

The use of e-vouchers promotes farmer-driven and market friendly recovery and development according to FAO's Emergency Rehabilitation and Coordination Unit [35]. The system is used to stimulate the demand for CA services from newly equipped service-provision entrepreneurs. Another, related, approach is the use of 'cash transfers' to poor households. This enables poor families to better cover their basic needs but also allows families to use this income to invest in equipment needed for production (*i.e.*, CA equipment) and hence boost the local economies and local supply chains as well a local blacksmiths making such equipment [2].

The e-voucher system improves targeting of farmer beneficiaries, empowers farmers with wider choice, reduces operational and transaction costs for input delivery to farmers, and facilitates targeting of appropriate equipment and inputs. It also stimulates private sector participation in input and equipment service provision to farmers, resulting in increased efficiency in service delivery to farmers.

To illustrate how they work, the following is an account of the operation of an e-voucher programme in Zambia. E-vouchers (funded by an FAO project) were issued to lead farmers (LFs) and could be used both for CA services and for approved inputs such as herbicides, fertilizer and seed, as well as CA tools like rippers, ripper tines, trek chains and knapsack sprayers. The e-vouchers are redeemable directly by the mechanization service providers and at competing agro-dealer outlets identified to participate in the programme. Box 2 gives an example of how the system works for one tractor-owning contractor.

Points to be considered when setting up an e-voucher scheme include:

- Selection and verification of agro-dealers to be registered for the scheme. These will be dealers holding a certificate to indicate that the eligible products meet FAO's technical standards.
- E-vouchers will carry the farmer's name and ID number to ensure that only the intended beneficiaries are able to redeem inputs.
- The value of the voucher is not meant to pay the full cost of production of a crop or contractor service, but is a subsidy towards that cost. For LFs, the original vouchers were split into two, each valued at USD50 the first for seed and fertilizer, while the second was meant for the purchase of equipment such as chaka hoes, ox-drawn rippers (or parts for them) and knapsack sprayers. Beneficiary farmers were expected to top-up the voucher value with their own cash. The vouchers give farmers a choice in what they should buy and from whom. The voucher system provided a major boost for the business of agricultural input supply in Zambia.

Box 2. Tractor-powered CA service provision in Zambia

Mathias Ndhlovu of Kanakantapa camp, Chongwe district was selected to receive a tractor and associated implements (no-till planter, boom sprayer, ripper, trailer and maize sheller) as part of the Project 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 (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 in the use of the equipment and business skills training 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.

- The electronic cards and associated mobile transaction system are procured from a technical provider, Mobile Transactions Zambia Limited (MTZL), which at the beginning was the only supplier of such services in Zambia. Now several companies provide similar services. The responsibilities of the technical service provider are to design the electronic card, to oversee the printing of the card and to provide software and suitably modified mobile phones for use as point-of-sale devices at agro-dealers' outlets. MTZL also provided training for Ministry of Agriculture and Livestock (MAL) extension staff and the staff of agro-dealers. The cost of training of agro-dealers was charged at USD100 for each attendee in 2012. MTZL staff were always available to deal with any technical problems that arose during the operation of the e-voucher exchange.

- Selection of the implementing partner. This will normally be the Ministry of Agriculture (MAL in the case of Zambia).
- Selection of beneficiaries will be according to agreed criteria and priorities. In the case of Zambia LFs are selected by MAL field staff and they are responsible for disseminating CA technology in their camps.
- The distribution of the cards to the identified beneficiaries is the responsibility of MAL via its field extension staff network. Cards are issued against a signature to ensure that beneficiaries are *bona fide*.
- Redemption of the cards is accompanied by the recipient's ID card number to ensure that only the designated beneficiary can use the voucher.
- Payment for inputs is instantaneous through the use of the point-of-sale electronic card readers. FAO needed to open and fund a bank account for this purpose.

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

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-Project to eight today. In the particular case of Kumawa, which also has branches in Chipata, they have achieved a 15 percent increase in turnover as a result of the e-voucher system.

Once demand for CA services is healthy, the e-voucher system can be phased out. The system serves as a very useful stimulus to promote both the input supplier and contractor service provision model, but there should be planned withdrawal from the market.

5. Conclusions

- **Sustainable intensification**. The smallholder farming sector is key to producing the food requirements of an increasing, and increasingly urban, population. Increased production must be accompanied by natural resource conservation if mankind is to have a future on this planet. SCPI will include CA as a standard practice and CA requires specific mechanization inputs. Smallholder farmers are not often in a position to invest in expensive farm machinery and the best vehicle to provide them with the required services is via well trained and well equipped private sector entrepreneurial CA service providers.

- **Local manufacture**. Local manufacture of CA equipment is a desirable goal as it not only helps to stimulate the local economy, but also provides the opportunity to adapt technologies to local conditions be they crops, soils, climate, production systems, technical knowledge, manufacturing skills or material supply, amongst other factors.
- **Policy guidelines**. Governments will often need guidance on how to provide the best environment for nurturing a local CA equipment manufacturing industry. Financial support to the smallholder farming sector to assist farmers in the purchase of CA equipment will directly stimulate the local supply chain. The correction of anomalies affecting local manufacture, such as the existence of import duty on machine components and raw materials, but not on imported agricultural machinery, will need to be removed to provide an equitable environment for local industry. Training of CA equipment design and manufacturing techniques may be required (e.g., SIDO in Tanzania).
- **Demand creation.** Efforts at creating demand for CA should be on-going. Although the public sector has a major role to play (for example in organizing field days and improving extension efforts), the private sector should also be encouraged through demonstration plots, out-grower technical support, machinery fairs and the formation and consolidation of CA farmer mutual support groups.
- **Service provision**. Given the problems of affordability and availability of CA equipment, including power sources, a promising solution is to equip and train entrepreneurial CA service providers. Equipment can be centrally procured and delivered on credit to would-be service providers. Loan payments are repaid from the resulting business activity. E-voucher systems can be employed to stimulate initial demand for the services but they should be withdrawn as soon as demand is sufficiently high.
- **Training**. Service providers not only need good CA equipment, but will also often need training in the technical aspects of its correct use, calibration and maintenance, as well as training on the managerial skills of identifying and running a successful service provision model.

Acknowledgements

The majority of the international project work on which this study is based has been funded and implemented by the Food and Agriculture Organization of the United Nations. We thank the anonymous reviewers of early drafts for their constructive criticisms that have enriched the final product. We also thank colleagues who have supplied photographs for some Figures (Christian Thierfelder, Harminder Singh Sidhu, Fréderic Baudron and Wilson Baitani).

Author Contributions

Both co-authors contributed equally to all phases of the elaboration of the paper.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. FAO. *The State of Food and Agriculture. Innovation in Family Farming*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2014; p. 139.
2. FAO. Cash Transfers: Promoting Sustainable Livelihoods in Sub Saharan Africa. Available online: http://www.fao.org/resources/infographics/infographics-details/en/c/178851/ (accessed on 16 February 2015).
3. Ngwira, A.R.; Thierfelder, C.; Lambert, D.M. Conservation agriculture systems for Malawian smallholder farmers: Long-term effects on crop productivity, profitability and soil quality. *Renew. Agric. Food Syst.* **2013**, *28*, 350–363.
4. FAO. *Save and Grow. A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011; p. 102.
5. FAO. *Mechanization for Rural Development. A Review of Patterns and Progress from around the World*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2013; p. 336.
6. Kienzle, J.; Sims, B.G. Agricultural mechanization strategies for sustainable production intensification: Concepts and cases from (and for) sub-Saharan Africa. 2014. Available online: http://www.clubofbologna.org/ew/documents/3_1b_KNR_Kienzle_mf.pdf (accessed on 22 April 2015).
7. Intergovernmental Panel on Climate Change (IPCC). Fifth Assessment Report (AR5). 2014. Available online: www.ipcc.ch (accessed on 22 April 2015).
8. Lal, R. Managing soil carbon through sustainable intensification of agro-ecosystems. *Agric. Dev.* **2015**, *24*, 13–18.
9. FAO Conservation Agriculture website. Available online: www.fao.org/ag/ca/ (accessed on 22 April 2015).
10. Baker, J.C. Seeding openers and slot shape. In *No Tillage Seeding in Conservation Agriculture*, 2nd ed.; Baker, C.J., Saxton, K.E., Eds.; Food and Agriculture Organization of the United Nations and CAB International: Rome, Italy and Wallingford, UK, 2007; pp. 34–59.
11. Ribeiro, F.; Justice, S.E.; Hobbs, P.R.; Baker, J.C. No-tillage drill and planter design—Small-scale machines. In *No Tillage Seeding in Conservation Agriculture*, 2nd ed.; Baker, C.J., Saxton, K.E., Eds.; Food and Agriculture Organization of the United Nations and CAB International: Rome, Italy and Wallingford, UK, 2007; pp. 204–225.
12. Sims, B.G. Labour saving technologies for smallholder farmers; An initiative of the Gates Foundation. *Agric. Dev.* **2014**, *21*, 12–13.

13. Jat, M.L.; Kapil; Kamboj B.R.; Sidhu, H.S.; Singh, M.; Bana, A.; Bishnoi, D.; Gathala, M.; Saharawat, Y.S.; Kumar, V.; *et al*. *Operational Manual for Turbo. Happy Seeder—Technology for Managing Crop Residues with Environmental Stewardship*; International Maize and Wheat Improvement Center (CIMMYT), Indian Council of Agricultural Research (ICAR): New Delhi, India, 2013; p. 28.
14. Baudron, F.; Blackwell, J.; Sims, B.; Justice, S.; Kahan. D.G.; Rose, R.; Mkomwa, S.; Kaumbutho, P.; Sariah, J.; Mogesi, G.; *et al*. Re-examining appropriate mechanization in Africa: Two-wheel tractors, conservation agriculture, and private sector involvement. *Food Secur. Sci. Sociol. Econ. Food Prod. Access Food* **2015**, in press.
15. Blackwell, J. (Charles Sturt University, Wagga Wagga, New South Wales, Australia). Personal communication, 2015.
16. Conservation Farming Unit (CFU). *Conservation Farming Handbook for Ox Farmers in Agro-Ecological Regions I & II*; Conservation Farming Unit, National Farmers' Union, FAO: Lusaka, Zambia, 2006; p. 47.
17. Casão Junior, R.; de Araújo, A.G.; Fuentes Llanillo, R. *No-Till Agriculture in Southern Brazil*; Food and Agriculture Organization of the United Nations and Agricultural Research Institute of Paraná State (IAPAR): Rome, Italy and Londrina, Brazil, 2012; p. 61.
18. Sims, B.G.; Thierfelder, C.; Kienzle, J.; Friedrich, T.; Kassam, A. Development of the conservation agriculture equipment industry in sub-Saharan Africa. *Appl. Eng. Agric*. **2012**, *28*, 813–823.
19. Kassam, A.; Friedrich, T.; Derpsch, R.; Kienzle, J. Worldwide adoption of Conservation Agriculture. In Proceedings of 6th World Congress on Conservation Agriculture, Winnipeg, Canada, 22–25 June 2014.
20. FAO. *Hire Services by Farmers for Farmers*; FAO Diversification Booklet 19; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011. p. 83.
21. FAO Regional Office for Africa. Zambia, EU and FAO Launch Conservation Agriculture Project. Available online: http://www.fao.org/africa/news/detail-news/en/c/215584/ (accessed on 28 March 2015).
22. Sustainable Agricultural Information Initiative (SUSTAINET EA). *Technical Manual. Farmer Field School Approach*; Sustainable Agriculture Information Initiative: Nairobi, Kenya. 2010.
23. Chabata, I.; de Wolf, J. The Lead Farmer Approach: An Effective Way of Agricultural Technology Dissemination? Available online: http://www.n2africa.org/sites/n2africa.org/files/images/N2Africa%20Poster%20Isaac%20.pdf (accessed on 28 March 2015).
24. Harald, M. (Head of Programme WFP, Zambia). Personal communication, 2015.
25. Rusiga, A. (P4P Support Officer, WFP, Zambia). Personal communication, 2015.
26. Kienzle, J.; Hollinger, F. *Back to Office Report from Tanzania Mission*; Rural Infrastructure and Agro-Industries Division and Investment Center Division, Food and Agriculture Organization of the United Nations: Rome, Italy, 2007.
27. FAO. *Investment in Agricultural Mechanization in Africa, Conclusions and Recommendations from a Round Table Meeting of Experts*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011; p. 76.

28. Small Industries Development Organization (SIDO), Tanzania. Available online: www.sido.go.tz (accessed on 22 April 2015).
29. Selam Awassa Business Group. Available online: www.selamawassa.org (accessed on 22 April 2015).
30. FAO. *Testing and Evaluation of Agricultural Machinery and Equipment: Principles and Practices*; FAO Agricultural Services Bulletin 110; Food and Agriculture Organization of the United Nations: Rome, Italy, 1994; p. 102.
31. FAO. *Explaining How to Use Financial Services*; Talking About Money 6; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011; p. 24.
32. FAO. *Explaining Cash Flow and Savings*; Talking About Money 1; Food and Agriculture Organization of the United Nations: Rome Italy, 2005; p. 20.
33. FAO. *Explaining the Finances of Machinery Ownership*; Talking About Money 3; Food and Agriculture Organization of the United Nations: Rome, Italy, 2009; p. 38.
34. FAO. *Agricultural Engineering in Development: Selection of Mechanization Inputs*; Agricultural Services Bulletin 84; Food and Agriculture Organization of the United Nations: Rome, Italy, 1990; p. 105.
35. FAO. *E-Vouchers in Zimbabwe: Guidelines for Agricultural Input Distribution*; Emergency, Rehabilitation and Coordination Unit (Zimbabwe), Food and Agriculture Organization of the United Nations: Rome, Italy, 2012.