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Promoting Smallholder Adoption of Conservation Agriculture through Mechanization Services

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Abstract: The importance of conservation agriculture (CA) is discussed in the context of producing food for a growing population while, at the same time, conserving and improving the natural resource base: sustainable crop production intensification. CA requires mechanization, and the necessary equipment may be beyond the reach of the majority of smallholder farmers, especially in sub-Saharan Africa. A logical solution to this situation is to provide CA mechanization services from private sector entrepreneurs. These will be well-equipped with appropriate CA equipment and will usually benefit from specific training on the technical aspects of CA machinery operation and on the business skills needed to run a profitable venture. The technical skills to be reinforced include: equipment selection, calibration of planters, seeders and sprayers, field operation, maintenance and repair. Business skills needed include: market research and feasibility studies, business planning, calculation of operational costs, partial budgets, break-even points and cash flows. The case is made for local manufacture to reduce the costs of machinery acquisition and to encourage local adaptation. Start-up costs are discussed together with the options of obtaining finance. Guidelines for marketing and managing the mechanization service provision business are developed. These include the importance of contracts, work planning, regular maintenance schedules and record keeping. Finally the most appropriate vehicle for delivering the training and sustaining support is considered. Formal training courses are a good starting point, but can be expensive to organize and execute. Individual counselling from extension sources is a viable option when the quality of the service is high enough. Study groups of involved entrepreneurs should be encouraged and supported to overcome the problems that will inevitably arise in new business ventures.

Keywords: sustainable intensification; mechanization service provision; training; technical and business skills; local manufacture; post-training support

1. Introduction

Smallholder farmers in rainfed agriculture often believe that soil tillage is needed to control weeds and maximize crop yields. However, there is abundant evidence that tillage can cause the degradation of physical, chemical and biological soil properties and result in limited crop yields [1]. 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. Losses of up to 1000 tons of soil per hectare have been registered [2]. FAO [3] concludes that the poor use of land resources has so severely degraded the soils that it is often difficult for smallholder farmers to raise production much beyond subsistence levels. 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 [4]. The world's 500 million smallholder farms currently produce around 80 percent

of the food in developing countries, 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 by 2050. However, though the sector still manages to produce high levels of the world's food requirement, the current forms of production are manifestly unsustainable. Against this background of degraded soils, an impoverished natural environment and poor crop yields, conservation agriculture (CA) is seen as a viable option for redressing the situation.

1.1. Basic Principles of CA

CA is now a well-known concept and is being practised on over 160 million hectares worldwide. It is founded on three basic principles, which are aimed at enhancing soil health, fertility and structure; CA maintains or improves crop yields whilst paying particular attention to the conservation of natural resources. The three basic principles are (e.g., [5]):

- 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 application is premised on the integration of good agricultural practices, minimum tillage, as well as general land and water management principles, timeliness of farm operations, increased use of organic matter, judicial and proper use of mineral fertilizers and appropriate crop varieties. This approach recognizes that proper and efficient use of land and water resources is cardinal for sustainable farm productivity as new, good quality land for the use of agricultural expansion is becoming more scarce, coupled with the need to preserve enough forest land to act as sinks and reservoirs for carbon that would otherwise be oxidized and contribute to anthropogenic climate change and rainfall variability. 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 the 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 [3,6].

Having laid out the concept of SCPI, we can now look more closely at the looming storm clouds that make its application such an urgent necessity. These storm clouds comprise a rising world population, increasing greenhouse gas (GHG) concentrations in the atmosphere and degrading natural resources, especially soils.

The human population of the world, currently 7.5 billion, is set to rise to over nine billion by 2050 and reach 11 billion by the end of the century [7]. The gross inequalities that characterize the human population mean that, today, the health, lifespan and productivity of more than half of the world's people are being damaged by poor nutrition [8]; and around 800 million people face chronic hunger [9].

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 GHG emissions have continued to increase over the period 1970–2010 with larger decadal increases towards the end; emissions were the highest in human history from 2000–2010 [10]. 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, and the consequences will be increasingly violent

weather events and increased uncertainty: reasons for protecting agricultural soils with biomass cover to the maximum extent possible and reducing turn-around time between cropping cycles.

Mitigation scenarios that are likely to keep the temperature change below 2 °C include land use changes such as afforestation, reduced deforestation and other carbon dioxide removal technologies. GHG emissions are projected to grow in all sectors [10], 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 oxidized by tillage, so that conservation agriculture, especially in association with trees, has a clear part to play in this process.

The application of CA principles to smallholder agricultural production situations requires some level of mechanization. The no-till seeding, weed control and cover crop management practices required by CA call for specific mechanized processes. The availability and affordability of these options are of paramount importance if CA is to be adopted, and the acquisition of specific equipment may often be beyond the means of individual smallholder farmers. Our contention is that a cadre of well-equipped and well-trained CA mechanization service providers is an attractive solution to multiple problems. In this way, smallholder farmers gain access to CA mechanization services, and service providers can make a living by deploying equipment that would usually be too expensive for an individual farmer to afford and justify, over a number of farms. By providing access to the necessary technical and business planning skills, interested farmers (and others) could be encouraged to invest in CA machinery and offer custom hire service of benefit to many others in the smallholder farming community. The aim of the paper is to provide a basic platform for private sector entrepreneurs who are contemplating investment in sustainable agriculture mechanization service provision. Long experience has taught that it is essential to maintain basic, easily understood concepts; otherwise, there is a danger of losing the comprehension, and therefore interest, of the target recipients of the training.

2. What Skills and Equipment Do Mechanization Service Providers Need?

Operating a hire service for any form of equipment is a challenging business undertaking [11]. Potential service providers face many constraints, which range from poorly-functioning equipment supply chains and limited financial services to inadequate market demand from farmers unaware of opportunities and benefits and equally lacking in finance. With regard to conservation agriculture, the core question for any prospective service provider must be the extent to which local farmers have been exposed to the ideas and methods that underpin the system. The area under CA systems has been growing rapidly, but even so, the total is still small relative to areas farmed using tillage [12].

2.1. Market Research

Therefore, how should a farmer find out if there would be sufficient demand in an area for hiring equipment to undertake conservation agriculture practices? If the idea is even being contemplated, then there must be some activities in the area that are exposing farmers to the possibilities and benefits of adopting CA approaches. In South America where CA is most widely employed by smallholders, the uptake was driven primarily by farmers and farmer organizations, backed up by support from input supply companies, state funded research, extension services, financial incentives and some international donors.

The first step of market research that farmers might undertake, therefore, is to ensure that they participate in any meetings, discussion groups or farmer field schools relating to CA. Fellow participants will almost certainly form the core of the future clientele of a hire service. Every opportunity should be taken by the prospective service provider to talk to these potential customers, discussing what areas they have to cultivate, what crops they normally grow and what mechanized activities they anticipate needing if they adopt CA. These findings should be carefully recorded in a notebook, together with the location of each farm and the farmer's contact details.

In order to take their market research further, prospective service providers need to obtain a map of their local area—commune, district or region—whatever might be available from a land use planning office or local government. If a printed map is not available, they should try to draw a sketch map using their local knowledge of the area, noting roads, villages and farms and as many physical features as possible. Access to the Internet might enable would-be service providers to study internationally-available maps and aerial photography such as that used by Google Earth to improve the accuracy of a hand-drawn sketch map. Armed with a map, they could mark the location of any prospective customers and thus be able to work out how long it would take to travel to that location with a tractor or with draught animals. Clusters of potential customers could be identified and decisions made as to how far afield the services could be offered.

The next element of market research for a prospective service provider would be to assess what competition there might be in supplying equipment hire services to farmers using CA practices. Are others already offering such services? Are others considering it? The prospective providers must keep their "ears to the ground" to determine what they would need to do to attract customers to use their particular service. Would it be a lesser price, or more timely delivery, or better quality work? Conversations with farmers at markets, or in agricultural supply cooperatives, or merchants or simply when meeting socially are the best way of determining opinions on existing services or the lack of existing services.

When embarking on market research, it is important not to gather information for the sake of it, but to concentrate only on information of value to you as a potential service provider. Having said that, time and effort spent at this stage of the feasibility study may have a profound impact on the eventual success of the business. An analysis of the data accumulated will guide the development of a strategy on what to offer, where, to whom and under what delivery and charging arrangements. It will also help to guide the selection of particular niche markets.

Matching supply and demand throughout the year is especially important if a constant cash flow from the hire service is to be achieved. Many agricultural tasks have specific time 'windows' outside of which the job is not viable or, in the case of the planting window, may incur severe yield penalties. Good market research will identify opportunities for selling services throughout as many months of the year as possible.

2.2. Choosing Equipment

Once a market for CA services has been detected, the appropriate equipment must be selected, and in this section, the aim is to briefly describe the types of equipment that might be considered.

2.2.1. Power Sources and No-Till Planting

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). No-till planting requires the planter to be able to cut through the surface mulch and previous crop residues; the mulch can be penetrated or cut with vertical discs, chisel tines or jab planter beaks (or even a pointed stick). 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 will cut through residue and form a V-shaped slot in the soil; chisel point tines are suitable in low-residue cover situations. A further option, not as popular as chisels or discs, is the rolling jab planter [13]. Another example of innovation in smallholder no-till planters is the Happy Seeder [14], which lifts surface mulch with rotating flails to allow seeding with chisel openers before depositing the mulch back on the surface (and, more recently, with rotating flails to chop residue in front of the seeding tines). Currently, efforts are being made to address the farm power shortage in sub-Saharan Africa (SSA) through the use of 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 [15].

2.2.2. Weed Control

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. As holdings become larger, then animal traction and tractor power can be used for knife rolling. 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. Maintaining crop residues is also a critical aspect of CA and has the effect of impeding weed germination in the subsequent crop. The use of herbicides is sometimes a contentious issue when smallholder farming systems are under discussion. Availability, quality, price and precision of application are all issues that will be disincentives to their effective use, besides the 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.

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 partially removing the operator from the risk of contamination. Larger capacity boom sprayers are manufactured for animal traction (Figure 1).

Figure 1. Draft animal powered boom sprayer.

2.2.3. Rippers

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. The use of rippers can be considered an interim practice to facilitate CA before eventually moving to a full direct seeding option. 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. Ripping is a similar technique to strip tillage, except that the aim should be to reduce soil movement to a minimum, rather than deliberately cultivating a strip.

2.2.4. Transport

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 provide an income throughout the year. The inclusion of transport capability with tractor-powered mechanization is especially important, and it will often be the most attractive aspect of the investment.

2.3. Business Planning

Armed with details gathered during market research and a good knowledge of available equipment, the next step for a prospective hire service provider is to make a plan. By this stage, the farmer should be aware of what demand for services exists in the area he/she proposes to operate in and who the potential clients are. He (all references to gender represent both men and women) must have established what time-windows exist to undertake certain tasks and how these are spread throughout the year. Now, he needs to make a plan to find out if operating a CA hire service can provide him with a profitable business opportunity.

Before taking this step, it may be worth asking these key questions:

1. Does he have the technical knowledge and experience required to operate the proposed equipment effectively and to deliver a high quality service?
2. Is there a functioning input supply chain in the area that can provide spare parts and other essentials?
3. Will he be able to undertake repairs and keep the machinery working at all times?
4. If initial customers are few, is it likely that demand will grow?
5. Does he have the means to survive an uneven cash flow and periods without work?
6. Is he able to spot new opportunities, adapt to changing circumstances and show resilience when things go wrong?

2.3.1. Estimating Costs

The key question when considering a new business enterprise is: "Will it make a profit"? Profit is what is left for the farmer to use after all costs have been met from the revenue generated in a year. Therefore, what are the costs of operating a machinery hire service?

The figure that will first come to mind will be the purchase price of the equipment that is going to be used. Although this is going to be a critical figure for the farmer as he will have to raise enough to buy what he needs, it is not, of course, the annual cost of owning the equipment. The purchase price is spread over the number of years the equipment is expected to last, and the annual share of the initial cost is known as depreciation.

There are other costs involved in owning and operating machinery. You have to look after it: cleaning, sharpening, lubricating and repairing it if something breaks. You need to provide adequate shelter to protect it from the weather. Engine-driven equipment requires fuel; tractors may require a road licence; and some items need to be insured against theft and fire. You may find you need to employ extra labour to operate or repair machinery, and if you borrow money, there will be interest to pay.

Some of these costs remain fixed whether you use the machinery a lot or a little; others, such as fuel or repair bills, increase as the amount of work done increases. Spreading the fixed costs over as many hours worked as possible will clearly reduce the unit cost per hour.

2.3.2. Setting Hire Charges

In order for a service provider to know how much he can charge someone for no-till seeding, transporting their crops or undertaking any other task such as weed control or harvesting, he has to work out how much it costs to own and operate his equipment on an hourly basis.

A first, and sometimes challenging, concept to get across is how to estimate the realistic output of a tractor-implement (or draught animal-implement) combination. Details of the procedures can be found in FAO's technical bulletin on testing agricultural machinery [16], and the following is a brief overview.

Machine and field capacity: The power of the tractor's engine, as well as the tractor's weight determine its performance. Knowing the work capacity of a particular machine or tractor/implement combination is essential in determining its field capacity and to estimate its revenue earning potential. The field capacity of a farm machine is measured in hectares per hour. It is used to calculate the total number of tractors, implements and machines needed, as well as the operators required, along with the total number of hectares to be covered. Field capacities are also required for scheduling field operations on a daily, monthly and yearly basis. As an example, let us take a tractor-mounted direct planter of 3 m working width travelling at 5 km/h (the use of SI (Système international) units is often not appropriate for these kinds of field calculations).

$$\text{Field capacity} = \frac{\text{Speed (5 km/h)} \times \text{width (3 m)}}{10} = 1.5 \text{ ha/h} \quad (1)$$

Field efficiency (measured in percentage terms): This is the actual rate of work achieved divided by the theoretical maximum rate of work (field capacity). Its value is determined by the actual time the machine works productively. Small, irregularly-shaped fields lead to low machine field efficiency because the machine spends a lot of time turning and thus not working productively. Table 1 gives some indication of field efficiencies that may be achieved in practice. Actual field efficiencies achieved by a hire service, however, depend on many factors, and maximizing efficiency must always be at the forefront of management thinking.

Table 1. Typical field efficiencies for various tractor-powered operations.

Operation	Field Efficiency (%)
Tillage	
mouldboard or disc plough	75–85
disk harrow	77–90
field cultivator	75–85
spring-tooth or spike-tooth harrow	65–80
Seeding and planting	
maize planter only	60–75
maize planter with fertilizer attachment	45–65
grain drill	65–80
Harvesting	
combine harvester	60–75
Mower? reaper	75–85
baler	65–80
forage harvester	50–70
Crop care	
sprayer	55–65

Taking the example of the direct planter above and assuming a field efficiency of 65%, the actual work-rate is given by:

$$\text{Actual work} - \text{rate} = \frac{\text{Speed (5 km/h)} \times \text{width (3 m)} \times \text{efficiency (65\%)}}{10} = 0.98 \text{ ha/h} \quad (2)$$

Overall machine efficiency: This is of critical importance for the profitability of a service provision business and needs to be understood by service provision managers. It is made up of four components: (i) field efficiency as explained above; (ii) non-productive travel time; (iii) down-time caused by lack of work or bad weather; and (iv) down-time caused by service or repairs.

Taking all of these factors into consideration will give a realistic estimate of the amount of work that can be expected of a machine in any given situation.

The next thing to do is work out the annual costs of simply owning the machinery, i.e., the fixed costs. A calculation might be set out as in Table 2 (details of the methods of calculation can be found in [17]).

Then, the farmer will need to estimate how many hours of work he expects to be able to do in a typical season. If the estimate is 200 h, the fixed costs per hour will be 7156/200, which equals $35.78. The next step is to estimate the variable costs for this amount of work (Table 3).

Using these figures, the variable costs per hour are $16.68, and the total costs per hour add up to $52.46. This means that if it takes four hours to plant one hectare, the farmer needs an income of at least $209.84 per hectare just to cover his machinery costs. If, however, he can do 400 h of work, fixed costs would reduce to $17.89 per hour. The total variable costs would double as a result of the extra hours worked, but the rate per hour would remain the same at $16.68, provided the farmer continued to do all of the work himself. Therefore, the overall cost of the machinery would reduce to $34.57 per hour.

Table 2. Annual fixed costs for a tractor and associated equipment.

Fixed Costs	$
Depreciation:	
Tractor (35,000 − 8000)/8 years	3375
No-till planter (5000 − 250)/10 years	475
Trailer (6000 − 400)/8 years	700
Tractor shed depreciation (1000/10 years)	100
Interest estimated as 8% of average investment in machinery (46,000 + 8650/2) × 8%	2186
Insurance and road tax	320
TOTAL	7156

Table 3. Annual variable costs of tractor operation.

Variable Costs	$
1200 litres fuel (estimated at 6 L/h and $0.75/L)	900
Oil and filters (estimated at 15% of fuel cost)	135
Repairs and spares (estimated as 5% of purchase price)	2300
TOTAL	3335

Now, an income of $138.28 will cover the basic cost of planting, if it takes four hours to complete. Of course, the farmer will not wish to merely cover his costs, but to make a profit, as well. Therefore, he might charge someone $160 per hectare for planting their land, which is a mark-up of just over 15%.

These example calculations illustrate the importance of obtaining sufficient work to cover costs and keep the price the farmer needs to charge down to a competitive level. It shows how important market research is before starting up a mechanization hire service.

2.3.3. Partial Budgets

Once the prospective service provider has estimated the annual costs of owning and operating some CA equipment and the possible income that he can generate from hire charges, he can work out the overall effect of starting this business on his future income by completing a partial budget.

A partial budget (Table 4) is set out in a way to help someone decide if a planned change in the business enterprises is worthwhile.

Table 4. Calculating the costs and benefits of a planned change with a partial budget.

Costs of Change	Benefits of Change
Any extra costs that will be incurred Any income that will be lost	Any income that will be gained Any costs that will be saved
TOTAL (A)	TOTAL (B)

If Total (B) is greater than Total (A), the farmer should increase his profit as a result of the change. If (A) is greater than (B), he will have less profit. This type of calculation is particularly important if the farmer intends to maintain his farming operations in addition to operating a hire service.

2.3.4. Break-Even Point

Another important calculation for someone starting up a business is the break-even point, which means calculating the minimum hours of paid contract work a hire service provider must do to cover his costs and make some profit, or in other words, stay in business. This can be illustrated with the figures introduced earlier. We arrived at a possible hire charge of $160 per hectare for planting, which equalled $40 per hour. If we subtract the variable costs per hour from this, we get a figure of $23.32 per hour contribution to fixed costs. The total fixed costs for the year were $7156, so the service provider needs to find out how many contributions of $23.32 will cover this. The answer is 306.86, so let us say the hire service provider needs to complete at least 307 h of paid work to break-even.

2.3.5. Cash Flow Plans

The last and most important aspect of business planning is completing a cash flow plan. The concept of a cash flow is simple: you map when you expect to receive money in a given time period and when you expect to spend money. Combining this with any cash savings you have will show whether your plan can be implemented. If there are periods where your savings and receipts do not match your expenditure, you know you have a problem that you will need to resolve.

The idea is simple, but it is something most people find difficult because of the detailed information needed. Operating with a bank account helps because bank statements provide much of the detail required. However, every business has to have a cash flow plan even if much of the information has to be a calculated guess; plans and budgets are always estimates after all. It is only with a cash flow plan that a farmer can decide if a loan is needed to start a hire service enterprise and whether they can meet the repayments.

Table 5 is an example cash flow budget taken from [17].

Table 5. A cash flow budget for the four quarters of the year.

MONEY COMING IN	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Sales of:				
Maize			400	300
Cotton	100			500
Groundnuts			200	400
Vegetables	100	150	80	
Livestock				
Other sources:				
Contract planting	150	150		
Remittances	75	75	75	75
Loan				
TOTAL (A)	425	375	755	1275
MONEY GOING OUT				
Farm/business inputs:				
Seed	190			
Fertilizer	400	200		
Pesticides		180		
Veterinary costs	20	20	20	20
Maize bran and minerals	35	25	15	15
Tools, repairs and maintenance	10	10	10	10
Hired labour		30		50
Capital equipment				
Pair of trained oxen				
Planter				
Yoke, chain and straps				
Household expenses	160	100	160	175
Loan interest				78
Loan repayment				650
TOTAL (B)	815	565	205	998
QUARTERLY BALANCE (A–B)	−390	−190	550	277
Add or subtract the quarterly balance to or from the previous quarter's savings to get the new savings figure				
SAVINGS				
Savings at start 749	359	169	719	996

2.4. Technical Skills

The equipment that may be required for CA service provision has been outlined in Section 2.2. Anyone proposing to offer a hire service using this equipment will need to gain experience in the field operation, maintenance and servicing of all of the items. In addition, calibration skills will be needed for planters, seeders and sprayers. In the context of this paper, the term planters is applied to machines designed to drop discrete numbers of seeds (such as maize) at specified distances; seeders sow a continuous flow of smaller seeds, such as cereals. Detailed descriptions of calibration methods are given in [16].

Calibration of planters (Figure 2): At the outset, it is essential to ask farmer clients what their requirements are in terms of the numbers of seeds per hill, the distance between hills and rows and fertilizer rates per hectare. In the case of animal- or tractor-drawn planters, the drive wheel circumference is measured or calculated, jacked up and rotated manually for a counted number of revolutions (say 10) (this procedure is repeated for the range of seed rate settings provided on the machine). The seeds are collected in a suitable container placed under the seed-delivery tube

(this could be a plastic bag attached to the outlet). The distance between seeds along the row can then be calculated as follows (again, SI units may not be appropriate):

$$\frac{\text{Circumference of drive wheel (m)} \times \text{No. of turns} \times 100\ \text{cm/m}}{\text{Number of seeds dropped}} = \text{distance between seeds (cm)} \quad (3)$$

Figure 2. Calibration of a single-row no-till planter. The drive wheel is turned by hand and the seeds collected in a plastic bag attached to the seed outlet. Seeds can be counted and/or weighed to calculate seeding rates per ha.

From here, it is a simple matter to calculate the planting rate per hectare when the distance between crop rows is factored in. Furthermore, if the seeds are weighed, then the weight of seed sown per hectare can be easily calculated.

Calibration of seeders and fertilizer distributors: This is a similar procedure to that outlined for planters, except in this case, the output of seed and fertilizer is weighed, and the application rates per hectare calculated as follows:

$$\frac{\text{Weight of seed or fertilizer delivered (kg)} \times 10,000}{\text{Distance travelled (m)} \times \text{row spacing (m)}} = \text{kg/ha} \quad (4)$$

There will usually be a range of adjustments for both seed and fertilizer rates, and the calibration procedure should be repeated for specific crop and fertilizer categories over the full range of calibration settings.

Calibration of sprayers: Two important criteria for effective spray operation are the height of the boom (or nozzle) above the target and the uniformity of distribution. The fans from individual nozzles should overlap at the height of the target to achieve uniform coverage. If a patternator is not available [16], then the uniformity of the spray can be estimated visually by spraying on to a dry concrete track and watching for differential drying.

Spray output can be measured by running the sprayer over a measured track, measuring the volume of spray delivered and calculating the area covered. The application rate can then be calculated as follows:

$$\frac{\text{Spray delivered along test track(L)} \times 10,000}{\text{Length of test track (m)} \times \text{width of work (m)}} = \text{litres of spray/ha} \quad (5)$$

The width of work on a multi-nozzle sprayer is the distance between the nozzles multiplied by the distance between them.

Field operation: Once calibration has been mastered, then all machines should be used extensively under field conditions, so that the operator gains experience in the field (Figure 3). This is not, of course, confined only to successfully piloting of the machinery in the field. At the same time, extensive use should be made of the operators' manual to ensure that the machine is correctly adjusted at all times. This will include levelling the machinery both laterally and longitudinally, selecting working speed, maintaining row width, adjusting planting depth and seed coverage, and so forth.

Figure 3. Training in field operation of a tractor-mounted no-till planter.

Maintenance and servicing: To give long and faithful service, farm machinery needs not only to be operated correctly, but maintained and serviced at the intervals indicated in the operators' manual. Training courses do not always find the time to discuss these issues in the detail required. Whilst routine maintenance (lubrication, chain tension, tyre pressure, cleaning out fertilizer residues, etc.) are wholly the responsibility of the machine operator, servicing (for example of engines and transmissions) is not. Machinery servicing providers in the neighbourhood should be invited to participate in the courses and to provide details both for the need for regular servicing, especially of tractors and engine-powered equipment, and the services available to users.

2.5. Starting and Marketing a CA Mechanization Service

The market research has been done, and the prospective service provider has decided that there is potential for a contracting business to facilitate the adoption of CA by the interested farmers. The farmer has done the planning and estimated the costs and possible returns from the hire service enterprise. He has also ensured that he is competent to operate and maintain the machinery. If enough business can be secured, then the venture will be profitable. What then are the next steps?

2.5.1. Finding a Machinery Supplier

Currently, in many developing countries, the availability of CA equipment, especially no-till planters, is via importation, and Brazilian machines have been the main source, and model, for developing countries in many parts of the world. Although importation of CA equipment is a relatively easy option, it is expensive. Prices will typically double, or more, from factory to user when the costs of transport, import duties, exporting and importing agents' fees and local retail mark-up are taken into account. All of 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.

Locally-manufactured machines should be purchased whenever possible as they are more likely to be suited to local circumstances. The development of a manufacturing industry targeting smallholder CA farmers is still in its infancy in SSA, although there is great potential. The ability of a prospective contractor to find locally-produced machines will depend on the quality of its supply chain. Figure 4 illustrates, diagrammatically, the complex array of influences on local manufacturers, which may determine their ability to compete with suppliers of more expensive imported equipment:

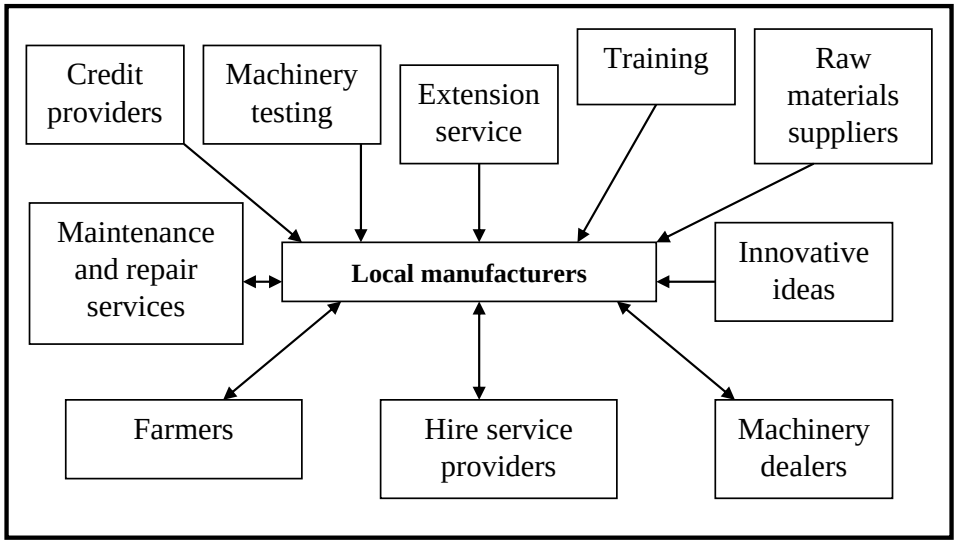

Figure 4. Mechanization supply chain stakeholder interactions from the perspective of local manufacture (source: [18]).

2.5.2. Start-Up Costs

Once the prospective service provider has identified a source of the machinery he wishes to purchase and knows how much it will cost, he can begin working out how much money is needed to launch the hire service business. This is one of the most critical pre-start up tasks. Only when these costs are known can the farmer think about how he is going to raise it.

Apart from the purchase price of the equipment and machinery, start-up costs will also include appropriate storage, road tax and insurance, initial stocks of fuel, oil and spare parts, stationery for invoices, receipts and work planning and promotional material for marketing the business. A good cash flow plan should make it clear whether or not these costs can be met from current savings or whether a loan is required.

2.5.3. Obtaining Finance

Using your own savings as much as possible to finance a new enterprise is a good strategy. It keeps costs down by avoiding interest payments and reduces the risks faced by the business. However, if a loan is required, the prospective service provider must decide whom to approach. This could be a family member, neighbour or local moneylender. In this case, the lender will decide how much they are willing to lend based primarily on their judgement of the person's character.

If the service provider decides to approach a financial institution, however, they will need to take steps to write out the details of their business plan. This will include details of the market research undertaken, the assumptions about how much hire work is available and can be expected to be done in the first year, how the service will be marketed, estimated profitability of the enterprise and a detailed cash flow plan for the first two years, which shows how much finance is required. It may be that most of these details will be provided to the institution orally during an interview, but the cash flow plan should be prepared in advance, as it is the most important part of a business plan.

Before approaching a financial institution, it is important to check out the products on offer and to ensure that loans are available that meet the terms that will suit the business. When buying machinery that will last for some years, it is usually necessary to spread any loan repayments over several years. Therefore, the availability of a medium-term loan at a reasonable interest rate is important.

An alternative to a conventional loan might be to enter into a lease agreement if such a possibility is available; machinery dealers sometimes offer this option. An operating (or true) lease calls for a series of regular payments, usually annual or semi-annual, for a period of years. At the end of a lease period, the lessee normally has the option of purchasing the machine at a price approximately equal to its fair market value. Alternatively, the machine can be returned to the dealer or leasing company or the lease may be extended.

2.5.4. Marketing

Finally, with finance secured, training completed and equipment ready to go, the new service provider must decide how to promote his business. Ideally some initial customers have been recruited, and work can commence. The most important marketing tool is always the feedback given by customers to potential customers. Delivering a prompt and efficient service of high quality is always the best way to secure further business.

However other steps may be needed to ensure the expansion of opportunities. Perhaps the new business needs a name that can appear on invoices, business cards and promotional leaflets. If leaflets or posters can be produced, these can be placed in agricultural extension offices, agricultural cooperatives, input supply merchants; any places where farmers gather. A board might be erected at the farm gate advertising the hire service business.

Travelling around the area visiting and talking to potential customers could be important. This gives an opportunity to see if other complementary services would bring in more customers or if adjustments are needed to the hire charges. Bundling of services can be a sound strategy to ensure year-round business given the seasonal nature of most agricultural operations. Price setting is a crucial part of marketing, and consideration could be given to discounts for repeat business or special offers for new customers.

The key to all successful marketing is remembering that the customer is the most important person in the marketing strategy, and it is vital to provide what the customer wants and can afford.

2.6. Managing the Business

In the simplest terms, management is about deciding what you want to do and then doing it. So far, we have focused on the first part: all of the information gathering and planning needed before a decision can be made about starting an enterprise. However, in the longer term, it is the "doing" part that will govern how successful a business is. Day-to-day management involves organizing time, organizing resources, responding to changing circumstances, making quick decisions to solve problems and implementing ways to monitor and control what is happening.

2.6.1. Contracts

When a mechanization service provider agrees to complete some work for a farmer, he is entering into a contract with that person. There will need to be agreement on what is to be done, when it is to be done and how and when payment should be made. Figure 5 is an example hire service agreement that illustrates some of these points.

Management decisions related to contracts include what to do if a crop fails to germinate or there has been some sort of collateral damage caused by the contractor. Failure to pay or requests for deferred payment will also have to be dealt with. Of course, some operators may decide to do without written agreements, but misunderstandings are more likely to arise.

HIRE SERVICE AGREEMENT

(Name of Service Provider) has agreed to provide the following services to:

(Name) _____

(Address) _____

Type of work	Area or quantity required	Estimated hours	Rate
Direct drilling			
Spraying			
Haulage			

The rates include expenses for tractor with implement, fuel and operator. If any other labour is supplied by the contractor, an additional charge will be made. All agrochemical inputs are the responsibility of the farmer.

The contractor agrees to complete the work as follows:

Operation	Estimated start date	Estimated completion date

If any delay in the work is caused by lack of suitable preparation by the farmer (e.g. access to fields), the contractor will not be held responsible for lost time.

Payment shall be made in cash on completion of the work by the contractor.

This Agreement can be cancelled by either party up to one week prior to the commencement of the operation.

....

(Signature of contractor) (Signature of customer) (Date)

Work completed:

....

(Signature of contractor) (Signature of customer) (Date)

Payment received: (Amount) ..... (Date) .....

Figure 5. An example of a custom service provision contract between the service provider and the client farmer.

2.6.2. Work Planning

When contracts have been obtained, the service provider will need to plan his work schedule so that he can meet the agreed commitments. A monthly and daily work plan will be important to ensure that work can be done as efficiently and with as little unproductive time as possible. These plans can be made in a diary or on a wall chart, such as that in Figure 6. It is particularly important to estimate accurately how long jobs will take and how long it will take to travel to and from jobs or

between them. A daily planner can assist in this process, together with the maps obtained or made during market research.

Figure 6. Annual work plans can be made on a wall chart; daily plans are needed for detailed scheduling.

2.6.3. Maintenance

In order to deliver a mechanization hire service, it is clear that the machinery and equipment to be used have to be in good working order. Steps that the service provider can take include:

- Ensuring that machinery is stored under cover as this greatly reduces its deterioration.
- Keeping operator's manuals and maintenance procedures carefully filed and accessible in the workshop or storage shed and always following the "Preventative Maintenance Guide" in the operator's manual for each piece of equipment.
- Mounting a service record chart for each machine and implement in a prominent area of the storage shed. The chart should identify maintenance intervals so it is convenient to identify, perform and record services needed.
- Using the year planner to note major repair and service operations to be carried out on each piece of machinery in the months ahead.
- Carrying a small notepad on each job to record problems and observations.

The hire service provider must ensure that he has the technical knowledge to carry out maintenance tasks and basic repairs when needed. Access to training may be important for this. Availability of spare parts is obviously important as well, and those most commonly required should be kept on hand.

2.6.4. Record-Keeping

Records are the key means by which someone can monitor what is happening in their business and thus take action if things are not going to plan. However, recording systems can become very onerous, and it is always important to remember that there is no merit in keeping records for their own sake. Records are only useful if they are used to guide decisions and aid future planning.

The first step in record-keeping is to establish a means of staying in control of pieces of paper integral to the business. If written contracts are used, these need to be neatly filed, as do daily work schedules and machinery maintenance records. Most financial transactions generate paper—invoices, order forms, delivery notes, till receipts—and simply finding a way to keep these in an orderly and searchable manner is important. Dates can be written on each item or transactions can be noted on the year planner or in diaries.

It is probably safe to say, however, that no business can achieve significant growth in its commercial operations without the information and control gained through financial record-keeping. Here are some of the benefits of having a good system of financial recording:

- You will know how much money you have received, how much you have spent and how you have spent it in any given time period.
- The records will provide a history of what has happened in your business. By comparing one year's records with the next, you will be able to see what progress you are making and identify any weaknesses.
- Records will also provide you with figures you can use for planning and budgeting and help you make decisions that will improve your income.
- Competent records will impress a loan officer or branch manager of a financial institution and thus make it easier to open an account or secure a loan if it is needed.

Therefore, learning how to maintain a cash analysis book and use the weekly and monthly totals to compare with the estimated income and expenditure in a cash flow plan are some of the most important skills for a successful business manager. If a decision has been made to permit people to defer payment for work done, a credit sales book becomes vital to ensure that money owed is always collected on time.

As a business grows and the number of financial transactions increases, it becomes more and more necessary for the owner to think about opening an account with a financial institution. This will require a new set of skills, but it enables money to be kept more securely and facilitates record-keeping by providing statements or pass books.

2.6.5. End of Year Accounts

When records have been kept, they make it much simpler to calculate whether the business has made a profit or a loss. Any business owner hopes the value of what is sold—the "output"—is greater than the cost of the inputs used. If it is not, the business is making a "loss", and there would be no merit in continuing to undertake that activity in the long term. A loss may be tolerated in the early stages of a new business, but it cannot be sustained for very long. A profit represents the income the business operator can use for family requirements. It can also be used to expand the business if so desired.

There are a number of adjustments to make to raw cash book figures to produce an accurate profit and loss account at the end of an accounting year. It is an important skill to acquire to manage a business enterprise effectively.

If the service provider has borrowed money to establish his business, it will be useful for him to know how to prepare another type of financial statement called a balance sheet. This involves answering two questions about his business activities: what assets has he got and how did he pay for them? Table 6 shows how a balance sheet is laid out.

Table 6. Balance sheet layout.

ASSETS	$	LIABILITIES	$
Stored inputs	350	Credit union loan	1000
Growing crops	900	Trader	305
Livestock	1200	*Sub-total*	1305
Tools and field machinery	1000	Own money (equity or net worth)	3045
Irrigation equipment	750		
Storage sheds	500		
Total assets	**4350**	**Total liabilities**	**4350**

On the left, you see a list of the person's assets, and on the right, you can see how they have been financed. In this example, the loans used amount to 30 percent of the total asset value, which is a sound position to be in. If debts exceed 50 percent of asset value, the business starts to be at risk if losses are incurred. A balance sheet prepared at the end of a trading year can be compared with the position at the start of the year, thus enabling any trends to be observed and rectified if their impact is negative.

3. Providing Appropriate Training for Hire Service Providers

Section 2 has outlined an array of skills that an entrepreneurial farmer would need if considering a move into providing a hire service to others wishing to adopt CA practices. It is a formidable challenge, and it is almost certain that most farmers considering taking up this role will require specialist training if they are to offer good quality, reliable services and run a profitable business.

In this section, we look at the options for providing the type of training that will be required and consider how this can be financed and delivered.

3.1. Training Courses

Pilot initiatives to introduce more sustainable farming practices are relatively common in countries seeking to improve the productivity of small-scale farmers. Such initiatives might be started by Departments of Agriculture, by NGOs or by projects funded by international donors. The budgets for such initiatives generally include an allowance for training, usually in the form of training courses or workshops.

Organizing training courses is far from simple. Ultimate success will depend on how well the initial conceptual phase is conducted, which should define the objectives of the training, the selection criteria for the participants, the themes to be covered, the methodology to be used and the preliminary programme. Once the basics are known, detailed preparation can begin. Typical tasks include:

- Selecting and contracting a training team;
- Preparing a budget;
- Choosing the venue;
- Setting the dates;
- Inviting the participants;
- Organizing accommodation;
- Preparing materials and equipment;
- Arranging transport for field work.

The length of training courses can range from half a day to several weeks. They may be residential or participants can travel daily from their homes. It is critical that the target group being offered the training is willing and able to attend for the proposed number of days. It is often difficult for small-scale farmers to take time away from their businesses, and their participation depends on course organizers choosing a convenient venue and a convenient time of year for a training course.

Another important factor to consider when planning training courses is the level of literacy and numeracy among participants. Although many concepts can be expressed simply and explained by using diagrams, successful business planning and financial management do require an ability to read and write numbers and complete simple calculations. Similarly, the calibration of seeders, fertilizer distributors and sprayers involves calculations. Calculators should always be used to aid simple calculations and ought to be supplied for use during training. If the numeracy skills of expected participants are limited, consideration should be given to offering pre-course training focused entirely on simple arithmetic and calculator use.

Training courses are not inexpensive to organize. Costs may include:

- Professional fees, travel and accommodation for the training team;

- Hiring the meeting rooms and providing computers, projectors and any other equipment;
- Travel, food and accommodation expenses for the participants;
- Materials such as paper, marker pens, cards, notebooks, pens, glue, printer cartridges, printing paper, flip charts and calculators;
- Other services such as telephone, Internet access, photocopying, translation;
- Transport for excursions or field trips and expenses these will incur.

As a result, the number of courses that can be offered and the number of participants that can benefit from training are always limited and often dependent on funding by international donors such as FAO.

An example training course timetable can be found in Appendix A. The course represented was designed for farmers considering offering a hire service using CA equipment. It lasted one week, which is almost certainly the minimum time needed to cover both technical and financial skills.

Although training courses are an excellent way of transferring new skills and knowledge in a short space of time, they are rarely sufficient on their own to enable participants to adopt and utilise the skills they have learned. A strategy for follow-up is essential, which generally depends on local extension services being able to arrange meetings and visits to discuss issues and solve problems experienced by the course participants. For this to work effectively, the relevant extension staff need to be fully involved in planning and delivering the training course. Without this, the impact of the training course may be extremely limited.

3.2. Individual Counselling

At the other extreme from a formal organized training course is individual counselling or one-on-one teaching that can be provided by local agricultural advisors. A competent advisory or extension service should have staff operating in most parts of the country. Their remit should be to assist farmers to improve their skills and knowledge and thus become more successful at supporting themselves and generating a profit.

In countries with highly commercialized agriculture, it is normal for agricultural advisors to assist farmers with budgeting and financial planning. They can sit around the kitchen table and provide advice to individuals that takes into account their unique circumstances and plans. A general advisor could also give technical advice, but is often backed up by access to specialist advisors who have greater technical knowledge. In the past, this type of individual advice was normally financed by the government, but nowadays, farmers usually have to pay for the advice and guidance they receive.

In countries that still have large rural populations and many small-scale farmers, advisory or extension services operate rather differently. They rely much more on group interaction with farmers, but nevertheless should be charged with providing individual advice when requested. Unfortunately, they are normally underfunded and rarely have any training in financial management skills, but this is something that could be rectified by those responsible for operating the agricultural extension service. Competent individual advice is essential when entrepreneurs have attended a training course and are now involved in implementing what they were taught.

Another way that individual counselling may be given to farmers proposing to invest in machinery to provide a hire service to others is when they approach a financial institution to apply for a loan. It is the responsibility of the staff in the financial institution to assess the proposal and the plans that the applicant has made and to provide a perfect opportunity for advice to be given to farmers about their budgets and business planning. Similarly, in follow-up visits to clients who have received loans, there are opportunities to give advice on record-keeping and budgetary control.

One-on-one teaching takes time, of course, and is too expensive to be used to teach people appropriate skills from scratch, but it is a very important means of reinforcing the impact of training courses.

3.3. Study Groups

Study groups provide an opportunity for people to learn together in a format that is more flexible than that of a formal training course. Most types of study groups are based on principles of participatory learning and involve members attending meetings on a regular basis over a period of time. They may be known as study circles, farmer field schools or no-till clubs.

The study circle method has been used widely in countries such as Sweden, The Netherlands and North America. More recently, it has been promoted in sub-Saharan Africa and has enjoyed considerable success in the field of agricultural development. In the African context, a study circle is a small group of people (5–15) who choose to come together to learn about a particular subject in which they are all interested. The idea may be promoted by extension staff or NGOs with experience of the approach. However, study circles are characterized by democratic values and are based on the participants taking responsibility for planning their own studies according to their needs and interests. Normally, a leader is chosen from within the group to facilitate the discussions and learning processes.

Once a study circle has been formed and agreement reached on a programme for a particular topic, resource materials and technical experts are needed for the learning sessions. If a study circle is formed within an area where CA is being promoted, local experts in the use of CA equipment should be readily identifiable. Business management expertise should be widely available, but can often be presented in a manner that is unnecessarily complicated for the audience in question.

4. Conclusions

Sustainable crop production intensification (SCPI) is an essential tool in the effort to produce more food to feed the growing world population and at the same time conserve the natural resources (especially soil and water) necessary to achieve that goal. Conservation agriculture is a good way to achieve increased land and labour productivity while preserving natural resources. The equipment required to practise CA can be expensive and not justifiable for individual smallholder farmers. Well-trained and equipped CA service provision entrepreneurs (usually farmers themselves) are a promising way forward to put CA mechanization within the reach of smallholders.

Would-be CA mechanization entrepreneurs will often need training in technical and business management skills, and this can most readily be supplied via practical training courses. However, once trained, CA service providers will require back-up and support. This support would best be supplied by well-trained and motivated extension staff. However, in practice, it will often be the case that mutual support groups will be the best way to enable practitioners to keep abreast of the latest technology, innovations and best practice. They are also a good platform for sharing problems and solving them.

If the goal of training and supporting CA mechanization entrepreneurs is achieved, then smallholder farmers will gain access to CA mechanization services, and this will give an important boost to CA adoption in regions where the financial and technical barriers have been too high.

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Appendix A

Table A1. Conservation agriculture (CA) equipment and entrepreneurship training: Karatu, Tanzania.

Time	Monday	Tuesday	Wednesday	Thursday	Friday
08:00–08:30		• Summary of Day 1 Completion of overnight tasks	• Summary of Day 2 Completion of overnight tasks	• Summary of Day 3 Completion of overnight tasks	• Summary of Day 4 Completion of overnight tasks
08:30–10:30	• Opening and introduction of participating farmer and service provider entrepreneurs	• Continuation of jab planter practical calibration work	• Measuring profitability: Accounting periods Output calculations Input calculations Profit and loss account Importance of profit	• Partial budgeting exercise: investing in a no-till planter and switching to CA	• Machinery maintenance continued • Record keeping
11:00–12:30	• Introduction to CA equipment and CA-SARD Project • Course objectives	• Animal traction no-till planter description, adjustment and calibration	• Interactive presentation	• Marketing strategies for contractors • The marketing game	• What next: forward planning by participants
14:00–15:30	• Introduction to the nature of "business" and the qualities of an entrepreneur: Aminta's story	• Pedestrian pulled sprayer calibration. Zamwipe description and use	• Adjustment, use and maintenance of ripper and subsoiler • Maintenance and care of CA equipment	• Introducing cash flow • Exercise: cash flow trees • Cash flow story	• Review and discussion of action plans • Presentation of certificates and closure
16:00–17:30	• CA Equipment: • Jab planter: construction, function and calibration (seed and fertilizer)	• Livelihood strategies • Exercise: mapping the household economy and identifying business enterprises	• How to calculate the costs of CA equipment and charges for hire services • Using partial budgets to evaluate the effect of changes on profit	• Machinery purchase and cash flow planning • Considering joint ownership of equipment	

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