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Mechanisation of Soya Bean Harvesting For Small and Medium Scale Farmers in Zimbabwe

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Abstract: *The new land holdings and cropping enterprises after the Fast track land Reform Programme (FTLRP) in 2000 have created challenges with respect to the forms of field mechanization inputs needed by the new farmers to undertake timely and cost effective production and harvesting processes without proper mechanisation. Harvesting is a time critical operation for soya bean farmers in that if undertaken late, shattering results leading to high quantitative field losses. The paper presents current soya bean harvesting practices and their respective economic and operational challenges. The use of animal or single axle tractor as a power source to pull a ground driven cutter bar for cutting soyabean, manual gathering and using threshers showed that soya bean harvesting can be mechanised cost effectively for low yield (0.8t/ha) farmers. The system is 50 times faster than manual methods of harvesting. The system improves farmers' access to the services basic technologies are existing and are currently commercially available on the market. A maximum capital of US$4200 is required to set up the complete system compared to $US 334 000 initial investment required for a combine harvester. The harvesting costs can be maintained at less than 13% of the market value of the crop. The paper presents ownership options which optimize capacity utilization leading to cost effective solutions for soya bean harvesting amongst Zimbabwe's emerging soya bean farmers.*
Keywords: *soyabean, Fast track land Reform Programme, harvesting, mechanisation*

I. Introduction

Agricultural mechanization embraces the use of tools, implements, and machines for a wide range of farm operations from land preparation to planting, harvesting, on-farm processing, storage, and marketing of products. Sources of farm power include hand tools, draft animals, and mechanically-powered technologies.

Agricultural mechanization often follows various stages, starting from the use of mechanical power for power-intensive operations that require little control (such as milling, threshing, water pumping, or land preparation, followed by control-intensive operations (such as harvesting, weeding, and adapting farming systems and cropping patterns) to increased use of mechanically powered technologies, and finally to automation of production. Development of mechanisation systems involves the appropriate and systematic selection of power sources, equipment and /or implements that perform the given operations with optimal use of resources (finance, time, inputs) and minimum human labour bringing viability to farm operations. Zimbabwe is at various levels of mechanisation with smallholder farmers still at the early stage of agricultural mechanization. Soya bean harvesting among smallholder farmers has been slow. A significantly higher proportion of soya bean farms are still manually harvested. There is need to develop mechanisation systems for soyabean harvesting that meet the above definition.

Soya bean (Glycine max) is one of the main oil seeds produced in Zimbabwe. However, Soyabean production has faced harvesting challenges especially among the medium scale famers who are poorly mechanised. This group of farmers cannot viably use human labor or buy combine harvesters to accomplish the harvesting operations. This has seen most of the soyabean crop getting lost through shattering or affected by rains because of late harvesting. This is against the economic and nutritional importance of the seed. The seed contains about 20% oil and 34-36% protein which makes it an economically important seed. It is grown for processing into edible oil and the residue from oil extraction is a high protein meal, a critical ingredient for stock feeds. It also consists of 30% carbohydrates, vitamins, minerals and excellent amounts of dietary fiber. Malnutrition, particularly, protein deficiency, is prevalent in many parts of Africa as animal protein is too expensive for most populations and has, therefore, a tremendous potential to improve the nutritional status and welfare of the families of resource-poor farmers. Many leguminous crops provide some protein, but soya bean is the only available crop that provides an inexpensive and high quality source of protein comparable to meat, poultry and eggs. Availability of large supplies of soya oil helps the food industry develop and market many new food products like soya mince, stock feeds, milk cheese as well as soya wax and the recently soya sadza, soya samoosas, soya pies and maputi. It also provides a break in the biological cycle of various cereal diseases, accounting for the part of yield increase (A-250, 2003).

Farmers and animal breeders' worldwide have benefited from the expansion of soya beans production, as people strive to improve their diet. This is being accomplished through increased animal production and the use of soya protein directly in human consumption (USDA, 2006).

1.3 Production of Soya beans in Zimbabwe

Historically in Zimbabwe, soya bean production was highly mechanized and was primarily carried out by the large commercial farmers in the high rainfall areas of the country. Commercial farmers produced 90 percent of the crop and the small scale farmers produced the remainder (Zimoil, 2011). The few small scale farmers were inexperienced and undercapitalized. The fast track land redistribution that the Government of Zimbabwe implemented has resulted in many commercial farms being subdivided into smaller A1 and A2 farms, leading to an increase in the number of smallholder farmers involved in soya bean farming whilst the crop harvesting equipment available for these small scale farmers have changed very little over the years especially in developing countries (Zimoil, 2011).

The number of small-scale commercial farmers who have gone into soya bean production increased from 75 to 189, between 1996 and 2000 (CSO, 2001). The resettlement exercise is expected to increase levels of agricultural production as under-utilised land in large commercial farms is opened up for farming activities, communal areas are de-congested and farm sizes are reduced to manageable sizes (Elich, 2005). However, mechanisation of these farms is still a challenge as the local agricultural equipment manufacturing industry has failed to develop harvesting technologies that can be adopted and be viably used by this group of farmers. Soya bean production was 50 000 MT (metric tonnes) in the 2011/12 season against an estimated national demand of 220 000MT annually. There is rising local demand for soya bean meal mainly from the expansion in the poultry and pig industries. Increased demand has increased the area under soya beans in 2010/11 from 43000 hectares to 45000 ha in 2011/12. Soya bean production is projected to increase in the 2012/13 season as local buyers are willing to pay above import parity prices for non- Genetically Modified (GM) soya bean, that is between US$500 and US$535/t compared to import parity price of US$495/ton. In order to meet this demand, there is need to develop solutions that deal with soyabean production bottlenecks which include harvesting.

1.4 Promotion Of Small Scale Soya Bean Production

After realizing the importance of soya bean, a soya bean taskforce (STF) was established to promote soya bean production in Zimbabwe. Its main duties include coordinating, educating and encouraging various stakeholders (farmers, banks, farmer unions, Non Governmental Organizations (NGOs), fertilizer/seed companies). As of August 1, 2011, with the help of the soya bean taskforce, a 15% import duty on cooking oil was re-introduced in an effort to stimulate domestic oilseed production and oil processing. This has again further increased domestic demand for soya bean. One of the major challenges faced by the taskforce in promoting Soyabean production was the unavailability of harvesting labor. Although many technologies have been developed for all sizes of farms for tillage, crop maintenance and seed placement which can be used or adopted for soyabean production, no systems have been developed for soyabean harvesting that reduce the drudgery of operation. This coupled with farm labor shortages that are experienced in Zimbabwe due to the HIV/ AIDS pandemic and massive exodus of the people, rural-urban migration creates soyabean harvesting a challenging operation. Zimbabwe recorded a 9.6% drop in farm labor in 2000 due to AIDS pandemic, The future impact of HIV/AIDS on agriculture will depend, among other things, on finding ways to reduce the amount of labour required, including introducing less labour intensive methods of production and increasing yields with non-labour inputs (FAO, 2001).

1.5 Soya Bean Harvesting

Harvesting is a process of collecting or gathering physiologically mature crops from the fields (American heritage dictionary, 2000). For soya beans, harvesting at the right time and in the correct way maximizes grain yield and minimizes grain losses and quality deterioration.

The primary objective is to separate soya bean grain from the pods and plants. The traditional methods of harvesting, that is the use of sickles and scythe are very slow; 100-200 man–hours are required to cut the crop for a single hectare (FAO,1997). In developing countries, up to 40% of the total labour required to grow a crop is expended in the harvesting and threshing operations (Regional Network for Agricultural Machinery (RNAM), 1983).

1.5.1. Harvesting Methods Used In Zimbabwe

1.5.1.1 Small Holder Practises Practises

Traditionally, soya bean harvesting involves the cutting of the crop from the field with hand sickles and knives and the transportation of cut plants to the homestead in animal drawn carts (capacity 500kg) or head baskets. This is followed by threshing which is accomplished by beating the grain using a flail on a threshing floor. Another traditional method of threshing is to make donkeys or oxen walk in circles on the grain on hard surface. The process is done off the field which means the stalks are removed from the field where they are necessary to maintain ground cover and retain the nutrients needed by the crops for growth and maturity (Caruthers and Rodriguez, 1992).

Work rates for cutting of the crop in the field are of the order of 100-200man hours/ha (Mushangaire, 2011). Figures for transportation of crop to the homestead are highly dependent on distances and cart carrying capacity. Threshing rates are 20-40kg per hour (FAO, 2007).

The major cost in manual based harvesting and primary processing of soya bean is human labour. Labour for cutting the crop (using sickles), at rates of $4/man-day equate to $50/Ha. A minimum of 100hours /Ha is assumed in the 100-200mh/Ha range (FAO, 1997).

The benefits of manual systems include the low cost and availability of equipment. The sickles are well priced at $5 each and are readily available even at village level. However manual systems are characterised with low work rates and drudgery. A large labour force makes the operation costly and low harvesting rates will limit area farmers place under the crop thereby reducing national production of the crop. For farmers growing both summer and winter crops, time to prepare land for the next crop is limited necessitating the need for fast crop harvesting methods if the growing season for the next crop is to be optimised.

1.5.1.2 Harvesting Practices In Large Scale Farming

The machinery inputs supply industry in Zimbabwe has evolved to cater for the harvesting needs of large scale farmers who use combine harvesters. Most major brands of cereal combines including Massey Ferguson, Claas, John Deere and Deutz have local dealers offering extensive national retail and after sales support networks. A 6m wide cutter bar self propelled combine in Zimbabwe is currently sold at US$354 000. Combine hire rates are US124/Ha, (dry rates) before fuel costs which are borne by the farmer.

The harvesting and primary processing systems are all undertaken within a combine harvester. The machine cuts, lifts, threshes, cleans and unloads grain into some form of transportation destined for storage facilities or markets. The combines are available in self propelled and trailed formats. Work rates for combines are a function of the cutter bar width and ground speed. A combine with a 6m wide cutter bar moving at a ground speed of 1.3m/s would have a work rate of 2Ha per hour, assuming a field efficiency of 85%.

The benefits of combine based systems include high work rates, low shedding and other weather related (qualitative) losses, timeliness of operations and low harvesting costs per hectare. However the high procurement cost of the combines (US300 000), is a limiting factor to the adoption of the technology even amongst large scale farmers.

1.6 Application Of Combine Harvesters Amongst Small Scale Farmers

The average yield for soya bean amongst small scale farmers is 0.8 ton/Ha, and the producer price is US500/tonne. Hiring a combine for US$124 (less diesel costs) per hectare equates to almost 30% of the total crop sales revenue paying for hiring the combine. Raising the average soya bean yield is a necessary precondition for small scale farmers to adopt use of combines as a viable alternative. The fragmented nature of fields amongst small farmers does not auger well for combine based systems. There is high down time as the equipment moves between fields, which cost must be passed on to the farmers. This makes the use of combine systems economically difficult for the small holder farmers.

During harvesting period, often rains and storms occur, causing considerable damage to the crops as well as germination which causes qualitative and quantitative losses. Up to 35% of the total yield per season can be lost due to pests, shattering and weather-related damages (Mushangare, 2011). Speed and accurate timing of harvesting facilitates more time for land preparation and earlier planting of the next crop. The absence of an affordable mechanized system for harvesting for small scale farmers have resulted in major losses and delayed onset of the next farming season. This reduces total returns per hectare, making it difficult to afford hiring harvesting equipment. The number of farmers venturing into soyabean production has been increasing annually although many farmers have suffered field losses due to delayed harvesting. SSF and MSF use manual methods of harvesting. However these systems are characterised by low work rates, drudgery and costful since a large labor force is required. Commercial farmers use combine harvesters which are expensive to purchase and are not always available timely when hired. These drawbacks create bottlenecks in soya production. This research exposes some of the systems that can be adopted and viably used by SSF and MSF which improve on workrates, cost and efficiency.

This paper proposes mechanisation options fro soya bean harvesting and primary processing (threshing) processes which can be promoted as interventions to reduce labor requirements in soyabean harvesting and improving the viability of mechanised soya bean production in Zimbabwe. This paper postulates that soyabean harvesting can be mechanised to improve on harvesting time and drudgery currently associated with the farm unit operations using locally available equipment that can be adopted by small holder farmers in Zimbabwe.

II. Materials And Methods

Mechanisation options (1 and 2) were developed. The following materials were used :Cutter bar mower, pair of oxen, motorised thresher, tape measure, stop watch, manual labourers, 5ha soyabean bean field (ready for harvest). The options are as detailed in section 3.A stopwatch was used to measure operation time of each option.

Current values of costs of input, e.g. labour, fuel, equipment (thresher) were search from the market prices.

III. Results

3.1 Proposed Harvesting Systems

Two options for harvesting and primary processing of soya beans are proposed based on animal and single axle tractor powered cutter bars. Gathering and threshing operations are the same for the two options and are based on manual and motorised thresher inputs respectively.

Table 1: Option 1; Animal drawn cutter based system

Activity	Technology	Specification	Performance	Costs(US$)
cutting	Option 1 Animal drawn cutter bar	m wide, reciprocating cutter bar 1 person	Work rate 3h/ha No fuel required	P=$1500/cutter bar R&M =100% of P over 5 years Insurance 5% of P Interest 20%/y Depreciation 5y Housing $150 Wages $4/md Fuel $1.3/L
	Option 2 Single axle tractor cutter bar	1m wide, reciprocating cutter bar 1 person	Work rate 3h/ha Fuel 2L/Ha	P=$1200/cutter bar R&M =100% of P over 5 years Insurance 5% of P Interest 20%/y Depreciation 5y Housing $150 Wages $4/md Fuel $1.3/L
Crop gathering	Manual labour (6 people)	6 adults		4$/md
threshing	Animal drawn motorised thresher	8Hp diesel powered, impact type thresher on single axle animal drawn platform 4 adults	Throughput 1.5 t/h Fuel 2L/ha	P=$2700/thresher Insurance 5% of P Interest 20%/y Depreciation 5y Housing $150 R&M =100% of P over 5 years Wages $4/md Fuel $1.3/L
transportation	Option 1 Animal drawn cart	Single axle, payload 500kg	Payload 500kg, speed 1m/s	0
	Option 2 Single axle drawn cart	Single axle, payload 500kg	Payload 500kg, speed 1m/s	

Md=man-day

Fig 1 (a) shows a motorised mobile thresher used to separate the seed from the pods, Fig 1. (b) shows the animal drawn cutter bar cutting stalks of soya beans. Soya bean stalk left in the field after the passing of the cutter bar is shown in Fig 1 (c). This shows the

Fig 1 (a) Thresher (b) cutter bar in operation cutting soya bean with gatherers behind.

(c) Stalks of crop left after cutting

3.2. Operating Patterns

The cutter goes into the field first and moves in a clockwise pattern. Behind the cutter people follow and collect cut plants and assemble them at three points along the lengths of the two long sides. The gathering points should be spread around the field, at least 20m apart. The distance between the gathering points should be minimised to reduce the downtime or unproductive time spent in moving the material to the points. This also reduces handling and transportation losses. At least 6 people are required to gather and collect from one hectare in 3 hours. A thresher is brought in to the collection points and starts the threshing operation. Once the cutter is through, the animals are taken off the cutter and hitched to the trailer and start to ferry grain to the point of storage

3.3 Costing

A detailed sample of harvesting cost calculations is presented in appendix 1. The main assumptions are presented in table2.

TABLE 2 HARVESTING COSTS

Cost item	**Option 1**	**Option2**
Fixed costs ($/ha)	($US/ha)	($US/ha)
Insurance (cutting, threshing and transportation)	0.7	0.5
Interest (cutting, threshing, transportation)	4	3
Depreciation (cutting, threshing, transportation)	6	5
Housing (cutting, threshing, transportation)	0.18	0.16
Sub total		
Variable costs		
Cutting Fuel	0	2.3
Cutting wages	10	5
Cutting R&M	3	3
Gathering Wages	12	12
Threshing Fuel	2.3	2.3
Threshing wages	8	8
Threshing R&M	6	6
Totals	**47**	**44**

Assumptions

Annual utilisation for equipment 80 ha of soya bean and 80 Ha of wheat harvesting, Wages rates are $ 4/day, Machine operator rates $5/day, Motorised Threshing requires 4 adults, Gathering requires 6 adults, The animal drawn cutter bar requires two adults, The single axle cutter bar requires 1 adult, Residual value of equipment is 15% of purchase price

3.4 Workrates

TABLE 3. SUMMARY OF COMPARATIVE WORK RATES AND COSTS

	Traditional manual	**Animal drawn cutter bar**	**Single axle cutter bar**	**Combine harvester (6m)**
Cutting (ha/day)	0.08	2	2	16
Gathering(ha/day)	0.33	2	2	16
Threshing(ha/day)	0.1	2	2	16
Combined(ha/day)	0.08	2	2	16
Total(threshing, gatheringandcutting)man-hours/ha	198	86	80	1
Productivity ha/md	0.005	0.023	0.025	16
Initial investment($)	5	4 200	3 700	334 000
Hire charge($/ha)	100	47	44	110

Assumptions

(i) The draft animals in option 1 are used for a maximum of 6 hours, i.e 3 hours in the morning and three late in the day.

(ii) Harvesting time for a hectare has been reduced to half a day (3 hours), which significantly lowers the risk of shattering losses from prolonged exposure of pods resulting from delayed harvesting during the afternoon.

The combine harvester based option is 640% more productive compared to human labour utilisation but the investment cost associated with it will limit its potential for adoption.

The two options have the potential to reduce the cost of harvesting and primary processing of soya beans to under $50/hectare. In the event that farmers attain low production yields of the order of 0.8t/ha, the cost of harvesting can be maintained under 13% of the crop market value

The initial investment cost associated with options 1 and 2 (US$3700-4200) makes it possible for a service provider to mobilise resources to acquire the equipment package for offering harvesting services to small and medium scale farmers. The single axle tractor option has a greater potential to be used for other operations during the year which increases capacity utilisation. An increase in annual capacity utilisation lowers the fixed costs associated with equipment ownership with potential to improve service provider margins. The sheller can be used for maize and sunflower processing operations resulting in the same effect on the fixed costs.

Options 1 and 2 allow for threshing in the field which leaves crop residues in the field. The system creates potential to improve soil structure, reduce surface water runoff and therefore soil erosion.

Back breaking work associated with cutting the crop with sickles is totally avoided. Furthermore threshing by hand which is a tiresome activity is also avoided. The two options significantly reduce the drudgery associated with traditional manual based systems leading to improved quality of life for soya bean farmers.

IV. Conclusions

It is possible to mechanise soya bean just like any other farm operations using locally available technologies. Late harvesting and thereby loss of crop in the field can be avoided if the options proposed can be adopted as a national mechanisation strategy by farmers and the government. The options reduce harvesting time significantly to 2 ha/day and therefore limit potential field quantitative and qualitative losses from shattering and weather related causes. This mechanisation model reduces the harvesting time requirements and drudgery associated with soya bean harvesting thereby improving the quality of life for farmers.

The harvesting options 1 and 2 have a potential to lower harvesting costs for soya beans amongst low yielding small holder farmers which improves viability.

Stover is also maintained in the field with potential to realize benefits associated with mulch farming.

It is possible to develop viable complete soya bean harvesting systems for small holder farmers using machines already available on the market in Zimbabwe. All processes involved in harvesting, i.e. cutting, threshing and separation can be mechanised with minimum human input. In this case, human operations have been reduced to gathering only.

4. Appendix 1

Calculations

Threshing

Motorised stationery multicrop threshers: Costing per hectare/tonne
Cost: $2500-00
Level of use of t thresher: 4 months, 2 for soya beans and 2 for wheat

Fixed costs	**Variable costs**
1. Salaries @ $0.80/hr Threshing rate: 1ton/hr Add: 1 hr for collecting and gathering at threshing points 1 hr for moving machinery from one threshing point to another round the field 6 people required for threshing, three people for bringing the stalks close to the thresher, two feeding the thresher and one operating the thresher. $2.40×36ton/month=$86.40/month Total salary =$86.40/month×6 people =$518.4÷36=$14.40/ton/ha **2. Housing** Assume: Put up a shelter at $150 and its going to last for 5 years $150 =$30/yr 5yrs Total housing /ton/ha: $30÷ (12×36) =$0.13/ha **3. Depreciation** Assume: 5 years depreciation period Residual value=$700 after 5 years = (P-R) =$(2500-700) =$360÷ (12×36) =$0.83/ha No. Of years 5 yrs **4. Insurance** @ 5% per year =5/100×$2500=$125÷ (12×36) =$0.29/ha **Σ fixed costs/ha**=$(14.40+0.13+0.83+0.29) =**$15.65/ton/ha**	**1. Fuel** Fuel consumption**:** 1l/hr 1 litre of petrol =$1.44 =$1.44 **2. Oils** @ 5% fuel cost=$0.072 **3. Repairs and maintenance** 120% of the principal value of thresher, over its commercial life of 5 years 120 ×$1900=$456÷ (12×36) =$1.06/ton/ha 5 **Σ variable costs:** $(1.44+0.072+1.6) =**$2.572** **TOTAL COST OR BREAK EVEN CHARGE/TON/HA** =Σ (fixed costs +variable costs) =$15.65 +$2.572
Total **$18.22/ton/ha**	

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