Cost Benefit Analysis of Small Scale Mechanization: Zimbabwe Case Study

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Key Highlights

- Under the conventional way of planting, farmers use animal draft to plough, raw mark, plant and apply basal fertilizer, whereas with 2WT planter they cut, plant and apply fertilizer in one pass.
- To ensure success in service provision, there is need to ensure that the different pieces of equipment need to be appropriate technology for the target group of farmers.
- The study shows a low capacity utilization with hours worked being below 20% for shelling and less than 10% for planting against the available time in a season
- Mechanization has also uplifted the lives of the service providers as they now have a guaranteed stream of income at a certain time of the year

Abstract

This paper focuses on the cost benefit analysis of small-scale mechanisation in Zimbabwe under the FACASI project. The study uses interviews and surveys to collect data for the analysis from farmers, service providers, machinery dealers and researchers. The analysis was done from the farmer's perspective using the gross margin analysis and from the service provider's perspective using NPV, IRR and BCR. A break-even analysis was done for all the machines and a payback period for each of the machines was calculated. The paper finds out that a service provider with more implements makes more profit. The results showed that for a 5-year lifespan machines have the following break-even times: 13hours for 2WT-powered sheller, 72hours for 2WT powered double row Fitarelli, 5.6hours for large self-powered sheller and 10 hours for double cob sheller with petrol engine. The study also found out that the farmers favor the planting service since it increases the profitability of their enterprise. Contrary to that, the planting business is less profitable to the service provider with the shelling business being more profitable. We conclude that service providers need to consider both social benefits and clientele built up

through offering all services which eventually translates to a more profitable mechanization enterprise.

Introduction

Agriculture is pivotal to the economy of Zimbabwe, providing 14-18 per cent of the Gross Domestic Product (GDP), 40 per cent of export earnings and 60 per cent of raw materials for industry (AMID 2012a). Zimbabwe has had several land resettlement schemes and redistribution of land. Despite all these efforts to improve the population's access to productive land, Zimbabwe's agricultural production has been declining. Some of the reasons for the decrease in agricultural production are lack of infrastructure, inputs (like fertilizers and herbicides) and appropriate technologies for use in the fields. The latest Fast track land reform in Zimbabwe led to a new crop of farmers who have land, which is too small for large 4WT yet too big for animal draft power. Additionally the increased growth in population in rural areas has led to subdivision of land leading to smaller farm sizes, which will not be suitable for 4WT hire, indicating the need for smaller machines (Jayne, Muyanga, Chamberlin, & Nkonde, 2014). Kahan et al, 2017 recommended exploring the feasibility of appropriate small-scale mechanization for smallholder farmers. In this paper, we undertake a cost-benefit analysis to explore the potential of small scale mechanized technologies to improve agricultural production.

Currently, the Zimbabwe agricultural mechanization market is dominated by around 14,000 4WTs (ZIMSTAT 2013) which falls below the national requirements of 40 000 to 50 000 tractor units needed to meet the agricultural production targets set (Simalenga, 2013). Manual shelling is dominant due to lack of mechanized implements. Increasing agricultural production and productivity is an important concern for the Government of Zimbabwe since the country's economy is and has been dependent on agriculture since independence in 1980 (Chisango and Obi, 2010). Agrarian reforms by government and donor agencies are promoting mechanization with the latest attempts being the ARDA Mechanization Program, Malaysian-South Korean Loan, RBZ National Agricultural Mechanization Program and the on-going Brazilian More Food Africa Program. Most of these programs failed due to various reasons. For example, the RBZ National Agricultural Mechanization Program failed due to poor planning and politicization of the program (Obi, 2011). Other programs failed because of inappropriate technologies, failure to maintain the equipment and lack of access to spare parts and backup services. For instance, the first attempts to introduce 2WTs in Zimbabwe failed due to the inappropriate ploughs that could not till the heavy soils that are dominant in Zimbabwe. In fact, Takeshima 2015, Biggs, and Justice 2015 conclude that without some adjustments, the 2WT is not suitable for conventional ploughing in Africa. This calls for the need to explore appropriate, affordable and multi-purpose small-scale mechanization like the 2WT (Baudron, 2014, Diao et al., 2012)

Literature review

A review of literature shows that several studies have been carried out on farm mechanization in developing countries. For instance, studies have assessed uptake of agricultural technologies by small holder farmers (Mwangi and Kariuki, 2015; Mamudu et al., 2012; Feder and Zilberman, 1985) while others evaluated the process and impact of adoption of various technologies in the agricultural sector (Gummert et al.,2013, Abdoulaye et al, 2014). Over the past two decades, studies have mostly focused on farm level profitability at the expense of the whole mechanization system (Eicher & Baker, 1982, Kahan et al 2017). In fact, most of these studies mostly focused on large-scale technologies such as the 4WT thereby limiting our understanding of the potential contribution of small-scale mechisation to the agricultural sector in developing countries. Only recently have studies started focusing on the feasibility of introducing small-mechanized technologies in view of the decreasing farm size because of population growth and land re-distribution policies. However, few of these studies have quantitatively explored the feasibility of these small-mechanized technologies in terms of appropriateness, affordability, and economic viability. Yet such information is critical for the development of the agricultural sector in developing countries.

This study performs a cost and benefit analysis on the Zimbabwean component of the FACASI project. Farm Power and Conservation Agriculture for Sustainable Intensification (FACASI) is an Austra,lian Centre for International Agricultural Research (ACIAR) funded project implemented by (International Maize and Wheat Improvement Centre) CIMMYT and the University of Zimbabwe (UZ) and the Ministry of Agriculture Mechanisation and Irrigation Development (MAMID). This study hinges on objective 2 of FACASI where the project is looking at ways of commercializing the adoption of the 2WT and small engines. The project is promoting the use of 2WT and other small-mechanised technologies to address the needs of smallholder farmers using service providers in Domboshawa and Makonde. The project has two main service provision models i.e., the individual and the group model. In order to be able to commercialize the 2WT and small mechanization business it is important to know the potential of the businesses, hence this study.

Objectives

- The objective of the study is to test the economic viability of small-scale mechanization for farming communities and service providers in a resettlement area of Zimbabwe.

Materials & Methods

Study area

The study area is located in Makonde district found in Mashonaland West Province of Zimbabwe. Makonde lies in Natural region 3. The area is a typical resettlement area with farmers having landholding of up to a maximum of 100+ hectares. Figure 1 shows the location of Makonde district in the map of Zimbabwe. Makonde district has large small farm holding with a modal size of around 3 hectares. Makonde has a maize based system with farmers also engaging in cash crop production of soya-bean and tobacco. Makonde has limited numbers of tractors for use by farmers. There is normally a rush for the limited tractors during the planting period and some delay their crop establishment because of this. Some resort to using animal draught power, which takes a long time given the size of their land to establish the whole area whilst some are limited to producing less due to lack of means to increasing production

Figure 1: Map of Zimbabwe showing Makonde District

<u>Methods</u>

Published literature and project documents related to small-scale mechanization were reviewed in order to provide some context and background to the study. This was followed by key informant interviews with Service Providers and farmers in Makonde district. A survey was then carried out with 20 SPs and 65 farmers to get insights into the economic feasibility of introducing small-mechanized technologies. For the survey, farmers and key informants were purposively selected from farmer population in the project area and from different stakeholders in the mechanization value chain, respectively. Surveys allowed for soliciting for data on farm type characterization, machinery work rates, timing of field and postproduction operations, Gross margins per hectare with and without 2WT mechanization, investment costs of 2WTs and implements, maintenance and running costs and life of equipment. Experts and service provider's records provided ancillary information that was used for verifying data collected in the field. Cost and benefit analysis of 2WT-based mechanization and other pieces of small-scale mechanization was then performed using data collected during the survey.

The cost benefit analysis was done from the farmer's perspective using the gross margins for with and without mechanization scenarios. Cost benefit analysis from the service provider's view was used to assess profitability of hire service business using the three economic indicators namely Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR). Break even analysis was used to determine the breakeven hours that service providers need to achieve before they start earning profits.

In conducting the economic analysis, the following considerations were made:

- Calculations of gross margins for maize per hectare were done for comparisons of conventional and 2WT mechanized operations.
- The prices used for inputs and outputs were from the year 2018
- A time horizon of 10 years was used to assess the profitability of the different machinery
- A 20% rate was used for cost and benefit analysis in this study.

Results

Table 1 shows mechanized activities provided by SPs and the period during which the activities are offered. During the period under consideration, SPs were mainly offering planting and shelling services.

Table 1: Calendar of activities for planting and shelling as well as the potential available hours for service provision

Crop	Activities	Period	Hours available
Maize	Planting	Nov 15 – Feb 29	896
	Shelling	May 15 - Sept 15	976

Table 2 provides summary of the estimated purchase price, working life as well as work outputs of implements. In terms of shellers, the double cob sheller costs the least while the 2WT sheller and the large sheller have the highest purchase price. Of all the equipment, the Fitarelli double row planter costs the most. The 2WT and the Fitarelli double row planter have multiple uses while the shellers are used solely for shelling maize.

Table 2: summary of the estimated purchase price, working life and work output of implements

Implement	2WT	Fitarelli double row planter	2WT Sheller	Large Sheller	Double cob sheller/petrol engine
Purchase price ($)	2,000	4500	1,000	1,000	320
Average working life (hrs.)	4,000	4,000	2,857	2,857	2875
Crop	Multi use	Multi-crop	Maize	Maize	Maize
Work rate (hrs./ ha)		2hrs/ha	4tons/hr	4tons/hr	0.7tons/hr

A comparison of costs reduction of conventional shelling and planting versus mechanized shelling and planting are illustrated in Figure 1. Under the conventional way of planting, farmers use animal draft to plough, raw mark, plant and apply basal fertilizer, whereas with 2WT planter they cut, plant and apply fertilizer in one pass. Big 4wt shellers were doing shelling in the study area, which is the conventional way on shelling. 2WT mechanized shelling and planting reduce costs by ~25% and more than 53%, respectively compared to the conventional way.

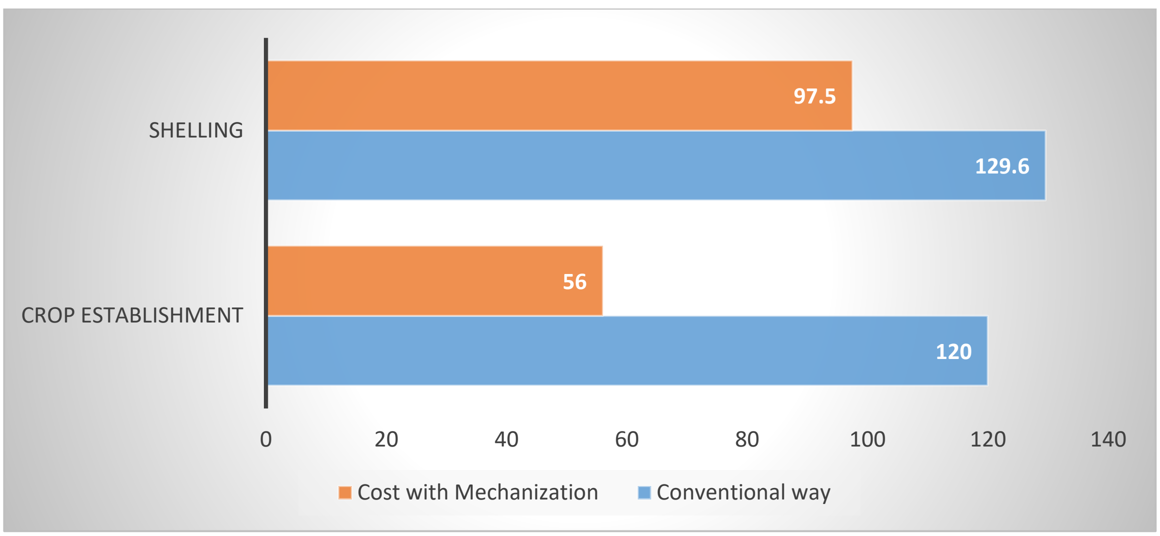

Figure 1: Cost reduction on hiring charge due to use of 2WT sheller and planter compared to the conventional way

Figure 2 depicts gross margins derived from a combination of technologies in the project area. It can be observed that the highest gross margins are realized when hiring 2WT Fitarelli planter and sheller. The conventional 4WT in combination with 4WT sheller has the least gross margins.

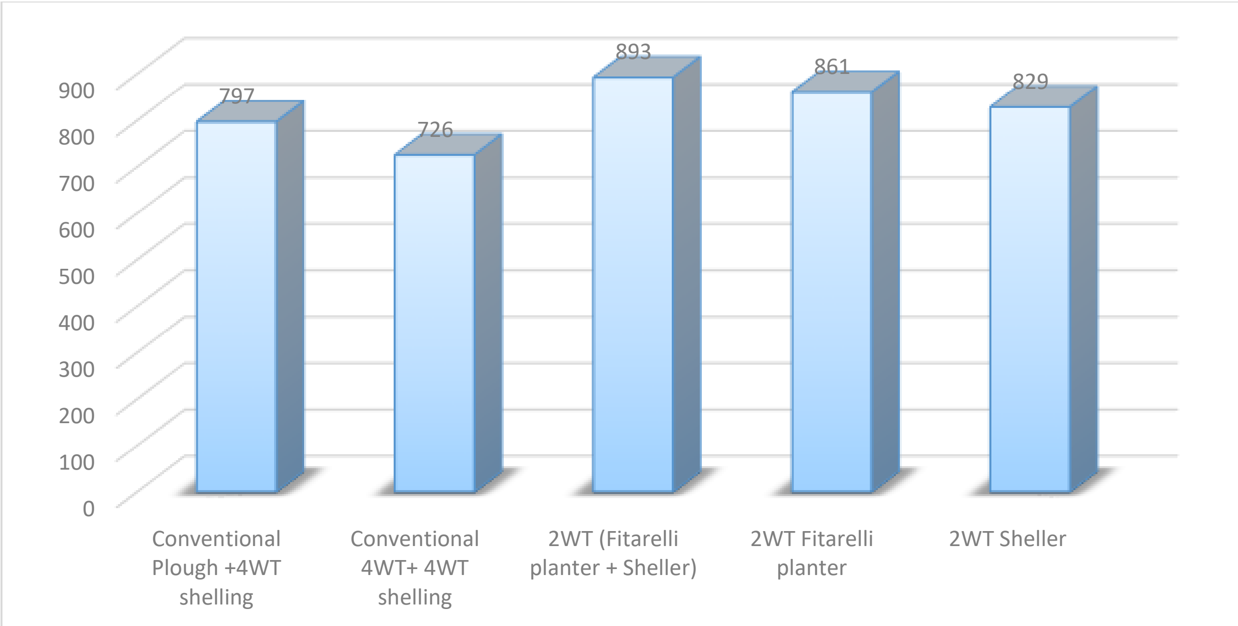

Figure 2: Comparisons of Gross margins for the conventional shelling and planting versus hiring 2WT technology

Breakeven points for machinery

Figures 3-6 show the breakeven points for 2WT driven implements across the assumed lifespan of the machinery. In all cases, the more the years a machine works the less the break-even hours needed per year for the owner to start enjoying profits.

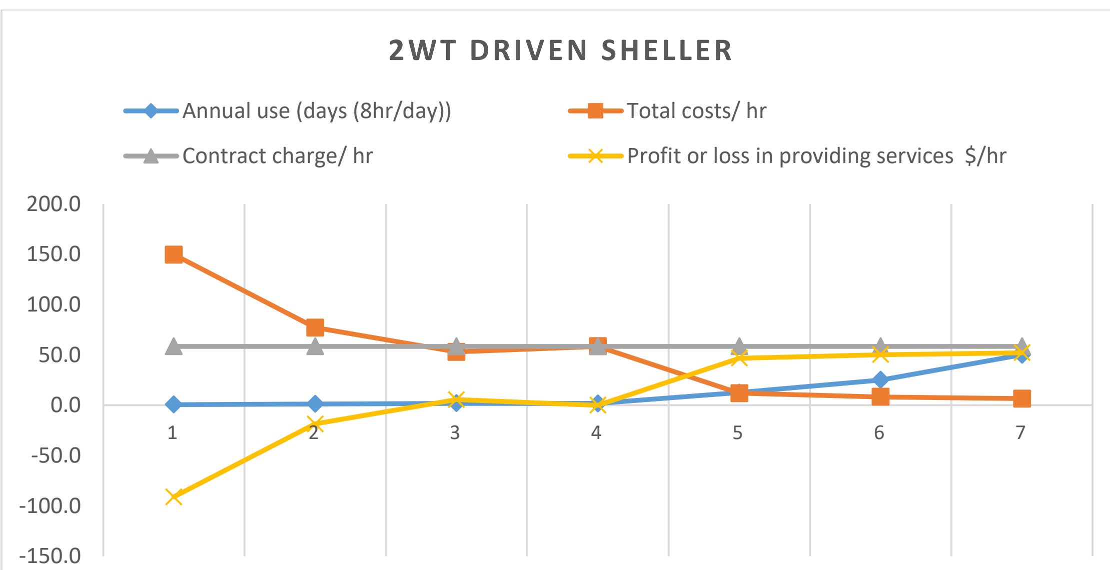

Figure 3: Break-even point for 2WT driven sheller

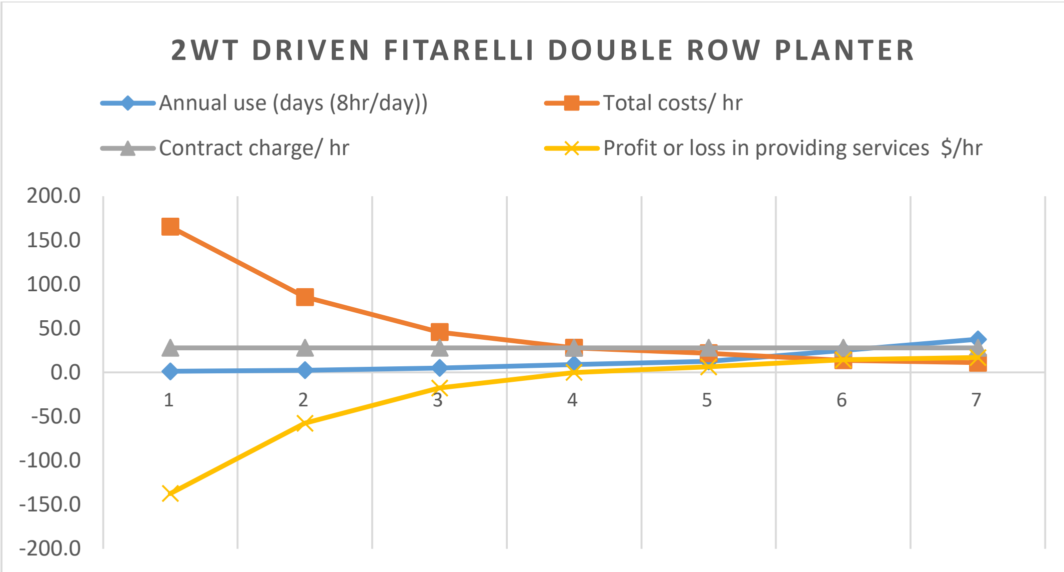

Figure 4: Breakeven point for Double row Fitarelli planter

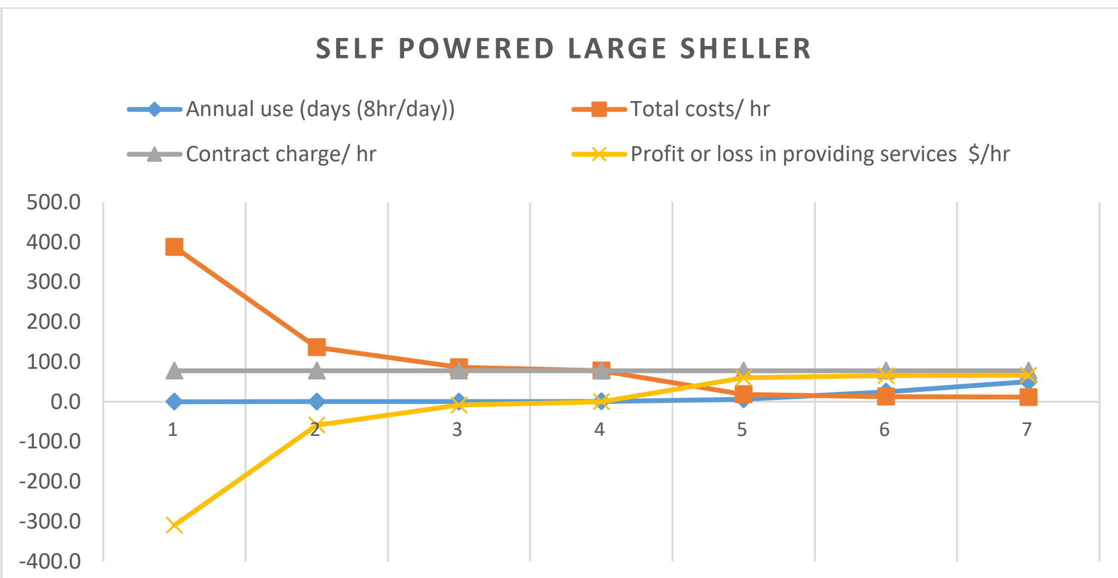

Figure 5: Break-even point for large sheller

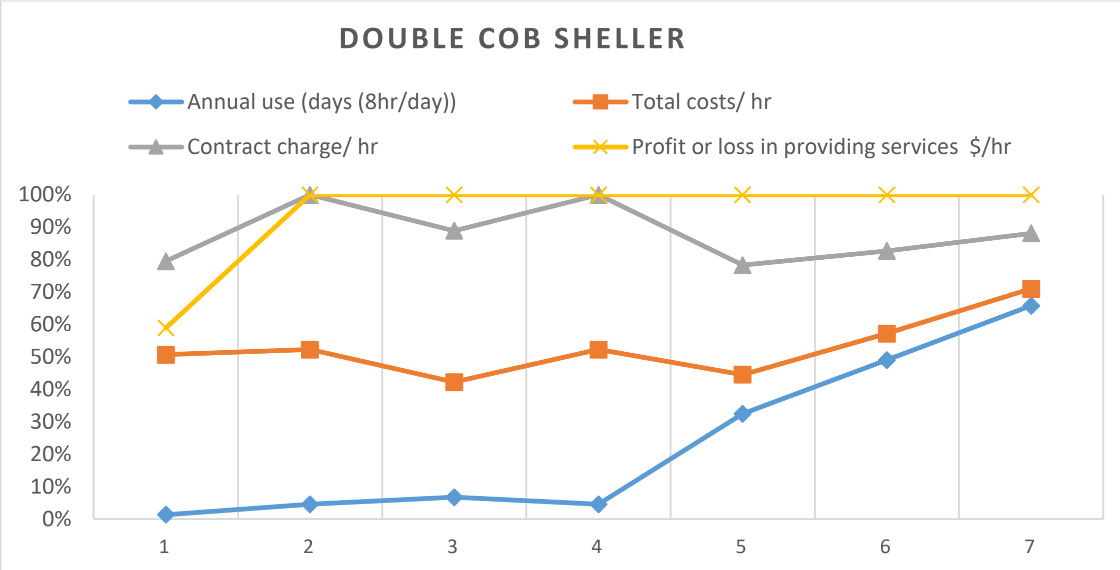

Figure 6: Break-even point for double cob sheller with petrol engine

<u>Profitability</u>

The study assessed the profitability of these business models for years the project has been running Results of the study show that, when averaged across all the years, all the business models are profitable as shown by positive NPVs and high IRR (Table 3). The maximum NPV is realized under combination of 2WT Planter and sheller while the least NPV is realized when using 2WT only.

Table 3: Average profitability of service provision

Average	2WT powered Sheller	2WT Planter +sheller	2WT Planter	Self powered large sheller	Petrol engine double cob sheller
NPV ($)	17679.2	21778.9	1763.2	4824.2	2371.8
IRR (%)	172%	106%	30%	140%	240%
B/c ratio	4.0	2.6	1.17	2.0	2.7
Increase in cost (10%)					
NPV ($)	17076.9	20395.2	748.2	4290.0	2219.7
IRR (%)	155%	94%	24%	115%	209%
Payback period(months)	0.6	0.9	2.5	8.4	4.8

Discussion

The results of this study indicated that mechanized activities in the project have different operating hours distributed across different months of the year. This implies that a service provider owning more than one type of equipment has more working hours in a year (Kahan et al, 2017). Consequently, more working hours translate to high capacity utilization of the machines especially for those business models that are reliant on 2WT-based technologies. The following discussion is going to go into detail about the findings in the results section.

Access to machinery

This study revealed that procurement costs of the different machines vary widely with the least expensive equipment costing USD320.00 (Double cob sheller/petrol engine) while the most expensive business kit attracting a total of USD7,500.00 (2WT, Sheller, Fitarelli planter, trailer). The high prices charged by suppliers of some machinery makes it difficult for these small-scale farmers to access the machinery. Thus, without financial support an ordinary farmer may fail to venture into business of agricultural service provision. However, to a salaried farmer who wants to venture into machinery business, financial products are readily available in Zimbabwe. Biggs & Justice (2015) consider 2WT as a low cost technology that is equally effective and appropriate for the smallholder fields relative to the large 4WT. The entry point, which is based on a low cost self-powered double-cob sheller, has led to high rates adoption since an ordinary farmer can access it without any financial help. Given that the gazetted selling price of maize was at $390/ton in 2018, farmers are likely to find the self-powered double-cob sheller affordable. This might explain the rapid adoption of this technology, with the suppliers running short of supplies at the beginning of every shelling season.

Cost implications of mechanization to farmers

Makonde being a new resettlement area and a highly productive region in the agro-ecological region 3 has farmers who have turned to the mechanized way of shelling. Farmers have been hiring shelling services from 4-wheel tractor driven shellers with a capacity of up to 30 tons/hour. This capacity has led to the need for farmers to hire additional labor for winnowing and packaging of the produce, to whom they also provide food. This has led to an increased cost of shelling compared to the 2WT driven sheller with an output which is manageable by fewer people at a similar cost of a 50kg bag/ton shelled (Figure 1). Moreover, conservation farmers using the 2WT double row planter has reduced the cost of crop establishment as the costs of ploughing, row marking, planting and basal fertilizer application are removed in one operation. This has significantly reduced the cost of crop establishment from $120 to $56 (Figure 1). The cost of crop establishment with a 4WT using the conventional way is also expensive indicating the cost advantage of using 2WT Technologies.

Farmers are better off hiring a package of 2WT-mechanized technologies (planter + sheller) as they get access to cheaper services that eventually gives them a better gross margin (12% increase) than conventional farming based on draught power (Figure 2). The benefit addresses

FACASI's target of improving farmer access to cheaper mechanized services. Amongst the 2WT technologies, hiring planting services in isolation has a greater benefit of 8% compared to the conventional way. Shelling benefits of 2WT are 4% owing to reduced labor and food costs compared to the 4WT shelling. Farmers enjoy other benefits from having 2WT services such as convenience and timely services since it is within their locality. Survey results indicate that farmers in some cases used to miss the season waiting for the 4WT, which will be in short supply, or using draught power, which can only do so much in a day, which ended up having adverse effects on their yields. Increased access to machinery is another benefit that farmers have, with a service provider who lives within their village.

Service provision as a business

The break-even point shows the amount of business that the service provider needs to cover before they start making profit. In this study, results show that for a 5-year lifespan machines have the following break-even times: 13hours for 2WT-powered sheller, 72hours for 2WT powered double row Fitarelli, 5.6hours for large self-powered sheller and 10 hours for double cob sheller with petrol engine. The low break-even hours for the machines shows that the small mechanization can be profitable in many areas. This result shows that the most lucrative business for service provision is shelling as it shows low break-even hours. Therefore, shelling provides the best entry point for a service provider investing into mechanization business. In fact, a service provider could explore additional business options after starting with shelling as it provides a significant income to invest in expensive machinery.

From service provider's perspective, results of the study show that, when averaged across all the years, all the business models are profitable regardless of the business model used as shown by positive NPVs and B/C ratio which is more than 1 (Table 3). Aggressive marketing of services and an established clientele base mainly drove the high performance in business. SPs highlighted that they experienced years with low business which they attributed to incessant rains leading to downtime for SPs as well as poor quality machinery, which caused serious breakdowns. Overall, all businesses models are not very sensitive to a 10% increase in the cost of the business as illustrated by the fact that business models still remain profitable even after the 10% adjustment. It is also important to note that these results show an idiosyncrasy on the business models per machine type over the years the service providers have been in business due to a cocktail of issues highlighted in this paper.

Additionally, the study also indicate that service providers with more than one business i.e., more implements, tend to be profitable in all scenarios considered. This suggests that businesses can complement each other in bad years as shown in the 2WT planting and shelling business models (Table 3). The findings of this study are consistent with Kahan et al., 2017 who observed that profitability was higher for a service provider offering a range of services compared to one offering a single service. Bundling of services increases capacity utilization of the 2WT as it is the major source of power for these services. Offering more than one service is, however, dependent on the capacity of the SP to invest in additional implements, affordability and access to the financial resources. Thus, business model performance is dependent on the actors and is context specific despite it being a group or individual business model (FACASI, 2016).To further improve profitability of the 2WT business, the 2WT can be used for other activities using the power generated by the machine. Apart from economic considerations, there is need to consider other benefits that may accrue from the not so profitable business ventures such as planting. In this regard, such ventures can provide a platform for continuous interactions with clients on different services throughout the year. Such interactions may, in the long term, help service providers to secure clients through social capital. The benefit might not be monetary but it might ensure a huge clientele base.

Looking at the businesses in isolation, shelling recorded high profitability compared to the planting business. The shelling business with a 2WT-powered business proved to be more profitable. However since the operational periods are different it is always more profitable to increase the number of operations of the 2WT to increase its profitability (Diao et al, 2016). It is important to note that buying of equipment is circumstantial, especially in a complex economic situation like Zimbabwe characterized by an unpredictable economic environment that Jones 2010 call a 'Kukiya kiya' economy. In the project, the expectation was that once the service provider successfully operates a shelling business, the next thing would be to invest in either planters or 2WT. However, results show that decision to invest did not follow a functionalist approach i.e., predetermined sequence in the purchase of follow on equipment (Crossman, 2019). Rather the study showed some SPs investing were investing in additional shellers to expand the shelling business instead of investing in other business venture such as planters and 2WT.

Targeting a niche is an important aspect of service provision. To ensure success in services provision, there is need to ensure that the different pieces of equipment need to be appropriate technology for the target group of farmers. In the Zimbabwean case, a 2WT proves to be the appropriate technology for farmers who have land that is too big for crop establishment using ox-drawn implements and too small for 4WT. The 2WT is also appropriate in communal areas where farmers have been hiring ox-drawn implements for business. Similarly, shellers of different sizes are appropriate in different farming systems. The study showed that when double cob shellers were deployed in Makonde area at the project start of the project in 2016, SPs and clients readily accepted them. The year experienced a drought that was characterized by low yields. The subsequent years had normal rains and farmers got high yields. The increased yield resulted in farmers shunning double cob shellers as they felt the shellers were now too small for their 20ton yields. In particular, during the years characterized by high yields, farmers preferred bigger shellers with a higher output. From this observation, it can be concluded that small shellers should be targeted towards smallholder farmers with yield around 10tons. These small shellers can only be used in highly productive areas for business if there are no bigger shellers competing with them. The use of big shellers in low producing areas is inefficient as there is no full utilization of the capacity of the machines thereby reducing profitability. To sum this up Binswanger 1986, said that agricultural technologies are not a one size fits all, some technologies are cost effective is some farming systems are not in another.

Low capacity utilization effects to business

Climate change or variability

The study shows a low capacity utilization with hours worked being below 20% for shelling and less than 10% for planting against the available time in a season. Climate variability and change could have contributed to low capacity utilization for planters through shortening the actual planting season. For instance, the average annual rainfall has remained the same but the distribution is erratic affecting the planting patterns. In one of the years 2017, there were incessant rains throughout the season to the extent that service providers could not continue planting as the 2WT could not operate in waterlogged conditions. In another year, rainfall events were infrequent with lots of dry spells thereby resulting in limited effective moisture to a few days after the rainfall event. Similarly, the shelling business is affected is such years as low yields will lead to reduced demand for shelling services. With low yields, it will not be economical to hire shelling services.

Economy

Another important factor affecting capacity utilization of the machines is the prevailing poor economic performance of the country. Discussions with farmers in project areas who failed to hire planting services revealed lack of financial resources to hire the mechanized services as an impediment to secure the services. The situation was exacerbated by unavailability of, and the increase in, fuel prices in 2018. Apart from affecting capacity utilization economic situation also affected farmers who had adopted no till planters and wanted to acquire Fitarelli planters from Brazil. Fifteen farmers wanted to buy planters and had local currency but could not access foreign currency for payment. The Reserve Bank of Zimbabwe had the sole responsibility of allocating foreign currency to different sectors of the economy and purchasing of planters was not at the top of its priority list of foreign currency allocation. Although there is high demand for the services, farmers cannot access the foreign currency to procure the equipment. In this regard, the government needs to intervene and encourage the private sector possibly through subsidies to invest in mechanization (Diao et al, 2016). That way, service providers can access machinery, which will trickle down to the ordinary farmer thereby improving access to mechanization. This finding is in line with what Sims and Keinzle, 2016 noted that the Chinese experience in improving accessibility and availability of mechanization to small-scale farmers involved subsidies, solid extension services, infrastructure development and a strong manufacturing sector, which prioritizes the smallholder sector.

Poor quality of machinery

Poor quality of machinery and unavailability of spare parts, led to long hours of downtime, which translated to low capacity utilization of machinery. Service providers had challenges getting spare parts like Fitarelli planter plates when they broke down thereby negatively affecting service provision. The fact that spare parts for the equipment are mostly found in Harare, which is almost 200km from Makonde would mean some considerable loss in time if SPs had breakdowns and need to replace parts. The parts were also expensive as they were not available in many shops. Gummert et al., 2013 pointed out unavailability of parts and lack of common components and standard designs of equipment as constraints on mechanization. Some local manufacturers made some shellers and some of them like the double cob shellers were imported. The poor quality of some of the machinery led to several breakages such that the SPs were always visiting the welders for repairs. This contributed to lot of downtime and high repair and maintenance costs and even a negative business for some of the businesses in the third year when they are supposed to be making more profits (Table 5). Verma et al, 1994 also highlighted fabrication, manufacturing, and importance of standardization and quality control as possible sources of bottlenecks in mechanization. In this regard, service providers need to cluster their activities and make use of agents in different areas so they do not waste time travelling across villages servicing them on different days. Service providers do not need to invest in additional machinery before they can effectively utilize the available time, this would lead to divided attention on machinery and further reduce capacity utilization.

Competition

Competition has also contributed to low capacity utilization especially for shellers. Makonde being a highly productive area, shellers including large 4WT powered shellers come in from different districts for the shelling business. This causes low capacity utilisation as the service provider's fight for their market share. Moreover, service providers with smaller machines such as the double cob shellers are most threated by competition as farmers tend to prefer the big shellers with a high capacity which takes fewer days than a small sheller. This indicates that the size of the sheller relative to the average yield and landholding of the targeted area should be considered before one invests in a sheller to be able to be competitive. As Diao et al, 2016 suggests, before one decides to venture into mechanization business the demand has to be assessed first for it to be a success, and to know the type of machinery to bring.

Benefits of mechanization

Interactions with service providers reviewed that due to the trust they have with some farmers, some employed farmers would just send seed and fertilizer to SP to go and plant in the absence of the farmer. Furthermore, some farmers indicated that they could now venture into other income generating activities, as they would have saved time in the fields. For instance, it has been established that farmers need 4 days with cattle to establish 1 ha of land yet with a 2WT they only spend 2.5hours, similarly for shelling farmers need 6 people to manually shell a ton in 2 days, whilst they only need 1.5hours to shell the same with a double cob sheller. Mechanization has allowed for intensification, which has had ripple effects in their production subsequently yielding more and being able invest into for example, buying houses, livestock etc. Mechanization has also uplifted the lives of the service providers as they now have a guaranteed stream of income at a certain time of the year. Some of the service providers have managed to invest the income they get from offering services into gardening, piggery and poultry so they do not just tie down the money awaiting the next season.

Summary

This study highlighted contrasting dimensions to planting services depending on the perspective one is looking at service. From the farmer's perspective, mechanizing planting is attractive such that farmers were advocating for more planting services in the project area. On the contrary, the shelling business is more profitable to SPs with planting being less profitable.

In this study, results show that for a 5-year lifespan machine have the following break-even times: 13 hours for 2WT-powered sheller, 72hours for 2WT powered double row Fitarelli, 5.6hours for large self-powered sheller and 10 hours for double cob sheller with petrol engine. The low break-even hours for the machines demonstrates that small mechanization can be profitable in many areas. Additionally, the study also indicate that service providers with more than one business i.e., more implements, tend to be profitable in all scenarios considered.

However, the study also shows a low capacity utilization with hours worked being below 20% for shelling and less than 10% for planting against the available time in a season. Climate variability and change could have contributed to low capacity utilization for planters through shortening the actual planting season. However, hours can be optimized by the use of multiple attachments onto the tractor as the machinery usage is subject to seasonal requirements, eg. Tillage is determined by rainfall and temperature.

Looking at the businesses in isolation, shelling recorded high profitability compared to the planting business. Private service providers would rather invest in attachments, which are more profitable to their business. From the service provider's perspective, shelling is the most profitable option. The sheller can be an independent unit as well as an attachment to a 2WD tractor, with a low entry cost (from $200) and fast return on investment.

Some service providers, possible because they are farmer/service providers or for lack of other profitable business opportunities for the 2WT may invest in planting to increase capacity utilization and increase the overall profitability of the business. However the study also showed that some SPs were investing in additional shellers to expand the shelling business instead of investing in other business venture such as planters and 2WT.

Therefore the project goal of increasing conservation agriculture through access to mechanization was not always achieved. However, from the perspective of reducing drudgery, the shellers have met the project goals, particularly for women. To increase conservation agriculture adoption, it will be important to advise service providers about the benefits of bundling products and providing full capacity utilization service provision of the machine.

The results of this research have shown that improved financial benefits through high NPVs and B/C ratio of more than one for combined businesses. The results also show that it is equally important for farmers and SPs to understand the importance of building business capital through providing a range of services to the same farmer or within their service region. The SPs will act as a 'one stop shop' for all infield and post-harvest mechanized operations.

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