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Social and Institutional Change in Agriculture (490c)

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Impact Assessment of John Deere's Approach to Promote Smallholder Mechanization in Zambia

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Abstract

Agricultural mechanization has been of long appeal in most African countries. The demand for mechanization has always been high due to a relative abundance of land and labour scarcity in agriculture in most of Africa. However, although the theoretical demand for agricultural mechanization is high, the number of tractors in use in SSA is the lowest across the world.

While tractors are used profitably and effectively on large landholdings, it is economically not viable for a smallholder to finance a tractor. During the past five years, John Deere has therefore developed a new approach to promoting smallholder mechanization in Africa. This approach focuses on the development of emerging farmers, who acquire a mechanization package that is adapted to local conditions, including a tractor and a set of machineries. To ensure maximum use of the facility, some emerging farmers provide land preparation and/or shelling services to neighbouring smallholders in addition to their own farms. This kind of smallholder mechanization model is faced with high hopes across Africa and is seen as a solution for smallholder agriculture development.

Against this background, this thesis assesses the economic and social impact of this strategy on the smallholder farmers and the local communities who receive mechanization service through this approach; describes the evolution of the John Deere Scheme over the period and its influencing factors; assesses the viability of the service provision business model; assesses the net implications of the scheme on agricultural labour. To achieve this, a mix of qualitative methods – focus group discussions at the community level and semi-structured interviews with the tractor owners, and quantitative methods – household survey with the smallholders, the use of a propensity score matching analytical method and investment analysis of the use of the acquired facility, were employed.

The outputs suggest that mechanization has significant positive social and economic impact on individual smallholders and their communities at large. The research findings identified a remarkable increase in on-farm income (per farm and per household) for participants of the scheme. Farmers re-invested these increased on-farm earnings mostly into their farming businesses; acquiring more inputs like fertilizer. They also invested into their off-farm businesses which mostly ranged from livestock aggregation and sales, operation of small grocery shops to petty trading during off seasons. Participating farmers also had enough to

invest in the education of their children and acquire more food and non-food goods. Smallholders who participated in the scheme made significant expansions to their cultivated lands and had relative slight yield increases. Due to this, the seasonal demand for agricultural labour at the community level did not reduce since land preparation and seldom processing were the two commonly mechanized farming activities. The smallholder mechanization model in Zambia seems promising if challenges related to on-farm productivity; market prices of produce; depreciation of the Zambian kwacha; and the total land area serviced per season as well as the multifunctional use of the tractor are addressed. The authors suggest a strategic and continued partnership of John Deere (the promoters of the scheme) with third sector groups like MUSIKA and CFU to help build the capacity of the tractor owners and reduce the transaction cost of service provision by organising potential smallholder farmer beneficiaries.

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List of abbreviations

ATT	Average Treatment effect on the Treated
CA	Conservation Agriculture
CF	Conservation Farming
CFU	Conservation Farming Unit
DAP	Draft Animal Power
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GART	Golden Valley Research Trust
GDP	Gross Domestic Product
GPS	Global Positioning System
Ha	Hectare
HH	Household
HP	Horsepower
JD	John Deere
MT	Metric Tonne
NA	Not Applicable
NN	Nearest Neighbour
NORAD	Norwegian Agency for Development Cooperation
NPV	Net Present Value
IRR	Internal Rate of Return
PSM	Propensity Score Matching
PTO	Power Take-Off

SB	Standardized Bias
SPSS	Statistical Package for the Social Sciences
SSA	Sub-Saharan Africa
USD	United States Dollar
ZANACO	Zambia National Commercial Bank
ZMW	Zambian Kwacha
ZNFU	Zambia National Farmers Union

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Chapter 1: Introduction

"It is only through appropriate mechanization that African farmers will be able to feed not only themselves but also the continent's burgeoning urban population…while at the same time addressing pertinent global challenges such as environmental degradation and climate change." (FAO/UNIDO, 2008:1)

1.1. Background to the study

In Africa, and especially in countries south of the Sahara, there is a great potential to increase agricultural production. Even with some degree of progress achieved on the continent in terms of agricultural production over the past few decades, the FAO, its development partners, the private sector and many African governments highlight agricultural operational efficiency and productivity as lagging (FAO/UNIDO, 2008). Investment in engineering technology inputs has been identified as a significant tool that African farmers and rural communities can use to modernize and achieve higher intensities of agricultural production. To this end, and particularly for the developing world, increased levels of farm power and appropriate mechanization techniques are now being frequently mentioned by development experts and researchers. This rekindled interest comes after the subject of mechanization had dropped off the agenda of international development organizations and donor agencies due to stalled progress, particularly in SSA, over the past three decades.

There have been renewed efforts to promote a sustainable productive revolution in Africa's agriculture over the last decade with some new scope for large-scale farming, especially in the land abundant countries on the continent (Deininger & Byerlee, 2012). However, almost 70% of farms in SSA operate less than two hectares and they typically do not realize more than 25% of their potential yields (Deininger et al., 2010). Smallholder farming systems will therefore have a crucial role to play in agricultural development in Africa (Birner & Resnick, 2010; World Bank, 2007).

Labour, rather than land, is a constraining factor in agricultural development in most African countries; there is a far lower population density compared to Asia (Boserup, 1976). The theory of induced innovation therefore predicts an important role for mechanization, even in its early stages of agricultural development (Ruttan & Hayami, 1984). Africa's farming systems however remain the least mechanized of all continents with the number of tractors remaining below two per 1,000 hectares crop land well after its introduction since the 1960's (Pingali, 2007).

Renewed emphasis on prioritizing agricultural development as a development agenda comes with a renewed interest in agricultural mechanization (FAO/UNIDO, 2008; Diao, Silver, & Takeshima, 2016). The provision of agricultural machinery services to smallholder farmers offers an opportunity for the private sector. This is unlike other services and inputs, such as agricultural extension, which requires substantial public sector involvement due to market failure (Feder, Birner, & Anderson, 2011). There is a considerable potential for win-win solutions, which provide new business opportunities for agricultural machinery companies and their dealers on the one hand, and for smallholder farmers in Africa on the other. This issue has become particularly interesting with the rise in the number of medium scale farmers who are seen to have the potential to grow smallholders with them.

Agriculture in Zambia is dominated by smallholder farmers as 95% of the farms cultivate less than 5 hectares (Sitko & Jayne, 2014). There has however been a rapid increase during the past decade in the number of medium scale farmers who cultivate between 5 to 20 hectares of land, vastly outstripping the growth rate of the total smallholder population (Sitko & Jayne, 2014). Access to agricultural machinery, such as tractors and processing machines, is still very low with only 1.8% of all households in Zambia using mechanical power in their farm operations (IAPRI, 2015).

The need for a sustainable business model for smallholder mechanization has provoked an on-going big debate on finding a mechanization strategy that works for the smallholder. In Zambia, the case under study, to facilitate the access of smallholders to mechanization, John Deere and its Zambian dealership, AFGRI, over the past 5 years have developed an approach which focuses on the development of medium scale farmers through access to a mechanization package (usually a tractor and an attaching implement of farmer's choice). This package usually comes with after sales services to these medium scale farmers. Apart from using this machinery on their own fields, most of these medium scale farmers provide mechanization services (mostly land preparation and processing) to smallholder farmers, who use tractors to prepare all or portions of their fields.

1.2. Problem statement

In light of the above, several Mechanization Schemes initiated by AFGRI have evolved over the 5-year period from which some medium scale farmers acquire a mechanization package that is adapted to local conditions, including a tractor and a set of machineries, such as disk plough, ripper, planter and a sprayer. Some of these medium scale farmer beneficiaries find a business opportunity in providing land preparation and/or processing services to neighbouring smallholder farmers. The aim of this research was to use a mix of quantitative and qualitative research methods to assess the economic and social impact of this strategy on the smallholder farmers and their farming communities which receive mechanization service through this approach.

1.3. Objectives

This study seeks to assess the economic and social impact of these Mechanization Schemes on the smallholder farmers and their farming communities which receive mechanization service through this approach.

Sub objectives

In addition to the primary objective mentioned above, the research will also attempt to address the following sub objectives:

- Describe the evolution of John Deere's Mechanization Schemes and the factors which influenced this
- Analyse the factors which influence the decision by a smallholder to participate in the John Deere mechanization scheme
- Assess the viability of the service provision business model
- Assess the extent to which tractor owners act as change agents
- Assess the impact of the mechanization strategy on the local communities taking into account the on-farm and off-farm incomes of the smallholder farmers and the contractors involved

1.4. Research questions

To meet these objectives above, the study will attempt to answer the following research questions:

- What are the impacts of John Deere's Mechanization schemes on smallholder and emerging farmers in Zambia?
- What are the social, economic, and environmental aspects of these impacts?

- Are there significant intra-household and community labour implications of these mechanization schemes on service providers, user, and non-users?
- In which ways do the John Deere mechanization service providers act as change agents for the smallholder farmers and the communities that they serve?
- Under what conditions is the John Deere service provision model profitable?

1.5. Relevance of the study

Machinery has an important role to play in improving farmers' crop management through better tillage, weed control and moisture management (Byerlee & Husain, 1993; Anderson & Dillon, 1992). However, research on mechanization on the smallholder farming systems in Africa has become a rather neglected field in the 1990s and 2000s (Diao et al., 2012). The study sought to provide empirical findings to contribute to the few available literature on the impact mechanization has on smallholder farming systems in Africa.

The study will also serve to inform John Deere as well as potential partners about the functioning and current experience of this mechanization strategy and inform future plans to expand this business model. A better understanding the underlying dynamics by which mechanization can improve the livelihoods of local communities will help John Deere to effectively support different types of stakeholder groups.

On the broader debate on finding a sustainable mechanization business model for smallholder mechanization, empirical evidence from this research will help inform policy makers and relevant stakeholders to find effective solutions which will work particularly within the sub-Sahara African region and could apply to the developing world at large.

1.6. Organization of the study

The study is organized in nine chapters. The first chapter introduces the topic and provides a background to the study. It also provides the problem statement, objectives of the study, questions that the study sought to address and its relevance. Chapter two reviews and discusses existing literature on the subject to elaborate on the topic and provides a background study on Zambian agriculture and mechanization status. The mechanization schemes implemented by AFGRI during the period of the research are discussed in Chapter three. The conceptual framework used is discussed in chapter four. In chapter five, the methodology of the research is described. It provides information on the study area, data collection method and the type of analysis used. The analysis of the data and the results are presented in chapter six while chapter seven focuses on the discussion of findings based on literature. The final chapters conclude the study and suggest policy recommendations based on findings of the study.

Chapter 2: Literature Review

In this chapter, the author will outline mechanization in Africa, impacts of mechanization, issues and challenges related to smallholder mechanization. In the latter part of the chapter the author will outline background of Zambia, agriculture in Zambia, some insights on conservation agriculture and recent efforts to promote mechanization.

2.1. Mechanization in Africa

Mechanization is the term used to describe "…tools, implements and machinery applied to improving the productivity of farm labour and of land; it may use either human, animal or motorized power, or a combination of these. In practice, therefore, it involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to draught animal power and to mechanical power technologies. Mechanization is a key input in any farming system. It aims to achieve the following:

- increased productivity per unit area due to improved timeliness of farm operations;
- expansion of the area under cultivation where land is available, as it often is in SSA;
- accomplishment of tasks that are difficult to perform without mechanical aids;
- improvement of the quality of work and products;
- reduction of drudgery in farming activities, thereby making farm work more attractive" (Sims & Kenzle, 2006:xii).

Over the recent years, the demand for mechanizing farm operations have increased due to the necessity to intensify agricultural production and likewise expansion of land for cultivation. (Houssou, Diao, & Kolavalli, 2014). In many African countries, agricultural mechanization has been of long appeal. The demand is always high and increasing due to factors such abundant land and scarce labour in agriculture. Most African countries, like many other developing countries have their economies based on agriculture which also provides employment to majority of population. However, in most African countries, agriculture is the sector that is under developed. It is one of the regions in the world with still agricultural productivity whereas agriculture had transformed progressively as commercial industry in other parts of the world (FAO/UNIDO, 2008). A distinct farm family which depends only on human power can cultivate 1.5 ha/ year which increases to 4 ha if DAP is used and over 8ha when tractor is used (Sims & Kenzle, 2006).

The number of tractors in use has increased since 1960s up until 2000 in Asia, Latin America and the Caribbean, North Africa, and the Middle East. However, this trend in SSA has been different. Initially, the number of tractors was more in SSA than Asia, North Africa, and the Middle East. Over time, SSA lagged and has the lowest number of tractor in tractor in use. "…. SSA is the only developing region where the number of agricultural workers is no more than half the average for all developing regions and the number of tractors in use is also a small fraction of the number in the other regions" (Mrema, Baker, & Kahan, 2008:12).

In SSA, the tractor hire schemes run by Government have hardly been effective (see Daum, 2014). However, the tractor schemes run by private sectors have been effective and profitable but seldom for smallholder sector in SSA. On the contrary, it has been proven to be profitable on large landholdings. For a smallholder owning 5 hectares of land, it is not feasible economically to own a tractor and with the given fact that government run hiring schemes have not been effective in poverty alleviation, increasing farm productivity, the other way could be the rental market concept, which may rise in future. (Sims & Kenzle, 2006)

There are several justifications for the use of tractor over human power and draft animal power. Mechanization allows practical and effective use of previously uncultivated land through the expansion of land under cultivation. The other justifications could be the timeliness in farm operations resulting in increasing productivity. "Timeliness is essential for multiple cropping because of the need for rapid land preparation between sequential crops, especially in irrigated agriculture or in areas with bimodal rainfall and in unimodal rainfall conditions for breaking the hardpan and exploiting the short rainy season" (Mrema, Baker, & Kahan, 2008:4). Farm drudgery is reduced with mechanization and also helps to overcome seasonal labour shortages. (Mrema, Baker, & Kahan, 2008)

Table 2-1: Examples of the positive impacts of mechanization on smallholder livelihoods

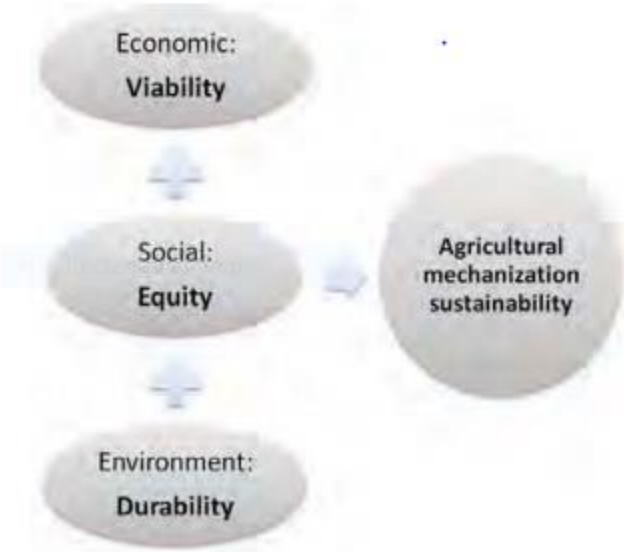
Factors affected by Mechanization	Potential Improvement
Labor Productivity	Farm family can cultivate 1-2 ha by hand; >2 ha with DAP; >8ha with tractor
Land Productivity	Increased production through better placement of seed and fertilizer, better weed control through line planting and improved timeliness

Value chain development	Holistic improved mechanization along the value chain from producer to consumer can greatly improve productivity and improve livelihoods
Timeliness of operations	Approximately 1% reduction of yield per day of delay in planting
Drudgery reduction	Reducing the need for women's power, especially hand-hoeing and transport.

Source: Sims & Kienzle (2016:4)

The issues and challenges for the adoption of mechanization could be: availability of tractors, machine and implements; repair and maintenance services, spare parts; trained operators; supplies of fuel, lubricants etc.; implements for weeding and harvesting; financial services. The other factors include: distance between the fields, plot sizes, shape and access to the field (Sims & Kenzle, 2006).

Figure 2-1: Agricultural mechanization: the principles of sustainability



Source: Houmy et al., (2013:10)

There are three aspects that could be looked at in agricultural mechanization: economic, social, and environmental. "As regards economic aspects, mechanization is an investment for farmers and they have to generate income and profit from their investment by means of greater production or increased value. The economic aspect has also to consider the commercial and financial links between farmers and other stakeholders. These are the retailers, distributors, manufacturers, importers, and service providers. The fundamental requirement for a sustainable subsector is a strong linkage between these different parties and that all of them must be able to make a livelihood from their businesses." (Houmy et al., 2013:9)

With regards to social aspects, benefits are varied. For example, mechanization reduces the drudgery in farming and saves time. Agricultural mechanization has an impact on rural employment. There is an on-going debate whether mechanization provides new employment opportunities or reduces the employment opportunities. "Many analysts consider mechanization to be a major factor in reducing employment opportunities and reducing the skill levels of ordinary labouring jobs. Other analysts however, consider mechanization to be a means of reducing rural unemployment through the development of new employment opportunities such as manufacturing, repair, and provision of mechanization services" (Houmy et al., 2013:10). Not much is found in literature on the net effect of mechanization on the agricultural labour market or on how mechanization influences the dynamics of household farm labour distribution.

With regards to environmental aspects, some of the mechanization operations have negative impacts on environment like degradation of natural resources due to intensive tillage. "It should however, also be pointed out that mechanization opens up new possibilities for the conservation of natural resources and the environment. Conservation agriculture, for example, is one of those very important concepts that have been developed during recent years." (Houmy et al., 2013:10). Conservation agriculture is further explained in detail in Section 2.2.

2.1. Overview of Zambia

Zambia is a land locked Southern African country with the total area of 752,618 square kilometres. Zambia borders with eight countries namely, Angola, Botswana, Democratic Republic of the Congo, Malawi, Mozambique, Namibia, Tanzania, and Zimbabwe. Of the total area, 31.7% is agricultural land from which 4.8% is arable land and remaining 26.9% being permanent pasture. 66.3% are forest. 1,560 sq.km of the total area is irrigated land. (The World Factbook, 2017)

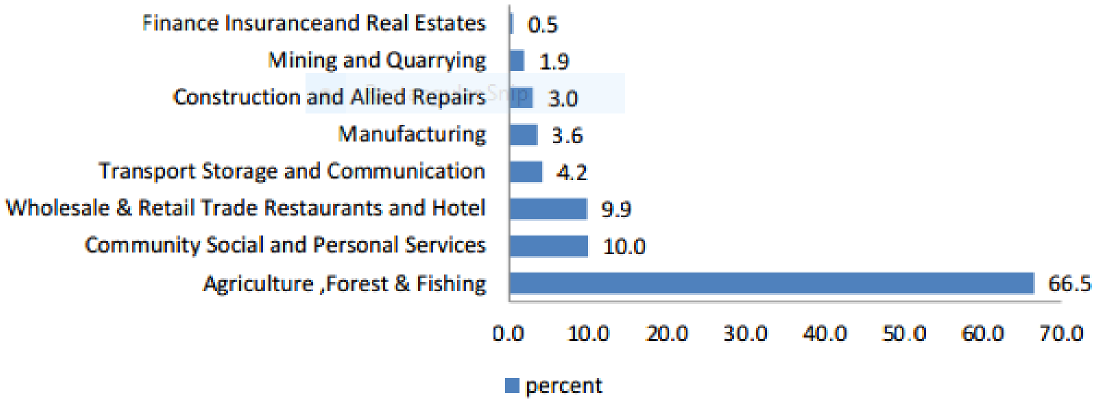
Figure 2-2: Agro-ecological zones of Zambia

Source: http://www.fao.org/ag/agp/agpc/doc/counprof/zambia/figure14.htm

There are three agro ecological zones in Zambia. Zone I cover the Southern and Western part accounting about 15% of total land area. This zone receives less than 800 mm of rainfall annually. Zone I was considered as the breadbasket of the country. However, it has not been the same for the last 20 years due to erratic rainfall. Zone II lies in the central part of the country. This zone receives more rainfall than Zone I about 800-1000mm of rainfall annually. Zone III covers the Northern part of the country receiving over 1000 mm of rainfall annually. (CEEPA, 2006)

Agriculture plays a highly significant role in the Zambian economy, providing employment for most in the informal sector. (Central Statistical Office, 2012) estimates the sector's average contribution to GDP to be 18% over the past decade. The real growth rate of the sector has however fluctuated significantly mainly due to the sector's high dependence on seasonal rainfall, reduced investments, and the failure to strategically position the sector according to its comparative advantage (Central Statistical Office, 2012). There has not been significant growth in the agricultural sector. Despite its decreasing share of overall GDP, agriculture still is the primary source of livelihood to Zambians, mostly the rural poor. In Zambia, Agriculture supports over 66% of the population's livelihood which makes agriculture the most important sector for livelihood and employment (Tembo, Solomon & Sitko, 2013).

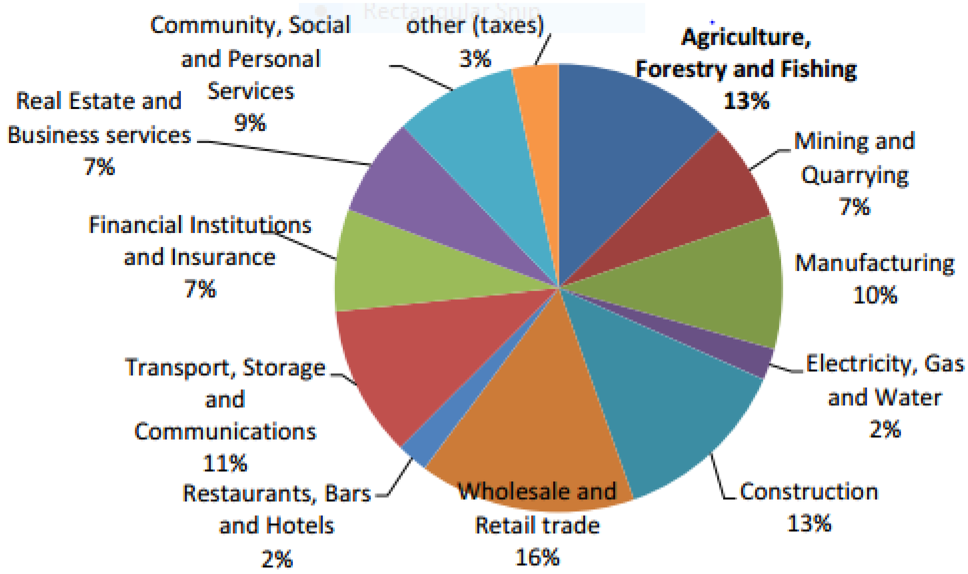
Figure 2-3: Distribution of Usually Working Population by Industry, Zambia



Source: Tembo, Solomon & Sitko (2013:3)

The economy of Zambia has had steady growth since 2001 though the contribution to GDP from the agricultural sector has declined to 12.6% (2012) from 16% (2001). This advocates that agricultural growth has not been the same as the other sectors which is alarming for the given fact that agriculture is one of the most important sectors for employment and livelihood as shown in Figure 1. (Tembo, Solomon & Sitko, 2013)

Figure 2-4: Share of different sectors in Zambian economy



Source: Tembo, Solomon & Sitko (2013:3)

The farmers in Zambia are categorized broadly in 3 categories: small, medium, and large-scale farmers. Subsistence farmers i.e. the small-scale farmers mainly produce staple food for own consumption and the surplus is marketable. The medium scale farmers, second group of farmers, produce the staple crop and other cash crops for marketing. The third group i.e. the large-scale farmers produce wide range of crops not only for local market but also for export market (Aregheore, 2009). As mentioned in (Sitko & Jayne, 2014), the government of Zambia categorizes these three major groups of farmers based on their landholdings as follows:

- Small-scale farmers are those cultivating between 0.1 hectares to 4.99 hectares of land
- Medium scale farmers (commonly addressed as “emerging farmers” in the Zambian context) are those cultivating between 5 hectares to 20 hectares or considerably more as shown in (Sitko & Jayne, 2014)
- Large-scale farmers are farmers cultivating more than 20 hectares land

“The sum total of small-scale and emerging farmers (i.e., farmers cultivating from 0.1 hectares to 20 hectares) are referred to as ‘smallholders’” (Sitko & Jayne, 2014:195).

There has been increase in emergent farmers’ number over the decade in Zambia. The ‘emergent farmers’ as mentioned above are the smallholder farmers who cultivate land from 5 hectares up to 20 hectares. “As the name implies, emergent farmers are often characterized as occupying a transitional phase between small-scale, semi-subsistence production and larger-scale, more commercial farming. Between 2001 and 2011 the population of emergent farmer households in Zambia grew by 62.2%, vastly outstripping the 33.5% growth rate of the total smallholder population. When disaggregated further, farm households cultivating between 10 and 20 hectares increased by 103.1% during the same time period” (Sitko & Jayne, 2014:195). The same study suggests that the rapid growth of the emergent farmer sector in Zambia is not a reflection of a widespread transition among small-scale farmers to a higher order of production and commercialization. Instead, it appears that much of the growth of the emergent farming sector can be explained by a legislative and public spending framework that favours both the alienation of large tracts of agricultural land by non-smallholder farmers, coupled with the disproportionate capture of agricultural public spending by a rural minority” (Sitko & Jayne, 2014:201).

“Adoption of improved agricultural technology by farmers can contribute to an economically efficient farm sector and the financial viability for farmers through improved production and productivity" (Chapoto et al., 2016:21). Table 2-2 displays the adoption of improved technology across different provinces and nationwide in Zambia.

Table 2-2: Adoption of improved technologies in Zambia

	National	Central	Copper belt	Eastern	Luapula	Lusaka	Muchinga	Northern	Northwestern	Southern	Western
Percent of Fertilizer Use	25.6	35	32.9	24.9	12.5	45.7	28.9	18.5	21.2	30.6	5.8
Percent of Herbicides Use	14.1	18.4	26.6	4.6	7.1	15.5	17.6	25.3	15.9	4	5.9
Mechanization											
Mechanical Power	1.8	2.1	1.6	0.5	0.4	10.4	0.7	0	0.1	1.1	1.1
Animal Draft Power	36.5	67.6	17.3	56.6	0.3	39.4	0.9	7.6	3.6	93.8	60.2
Percent of land cultivated that is fertilized	43.1	60.4	58.8	41	21.4	72.1	50.9	31.7	36.8	49.9	7.6
Fertilizer kg/ha	160.2	149.6	176	157.3	175.9	163.5	166.1	180.9	163.6	111.3	157.6

Source: Chapoto et al., 2016

Table 2-2 shows that the percentage of farmers using fertilizer nationwide is 25.6%, the highest use of fertilizer (45.7%) is in Lusaka province and the lowest use (5.8%) in Western Province. The percentage of farmers using herbicides is lower compared to fertilizer used. The highest use of herbicide is in Copper Belt province (26.6%) and the lowest use is in Southern Province (4%). The percentage of land cultivated that is fertilized is 43.1% nationaly, highest being in Lusaka province (72.1%) and least in Western province (7.6%). In terms of mechanization, 1.8% of household use mechanical power. The use of mechanical power is highest in the Lusaka province (10.4%) followed by central province (2.1%), while 36.5% of husehold use animal draft power nationally. The highest percent being in Southern(93.8%), Central (67.6%) and Western (60.2%) provinces. (Chapoto et al., 2016:21)

2.2. Conservation agriculture

The growing demographic pressure on farmland and its resulting effect of reduced fallow periods, land degradation, soil erosion and nutrient mining has become common problem especially in most developing countries where agriculture remains an economic driver (World Bank, 2008). There has been global efforts to develop and introduce new technologies to help mitigate the effects of climate change and land degradation in sub-Saharan Africa, with much of the discourse on Conservation Agriculture (hereon CA) (Grabowski, Kerr, Haggblade, & Kabwe, 2016).

CA, which evolved from the disastrous effects of the US dust bowl in the 1930's (Hobbs, Sayre, & Gupta, 2008), is defined in FAO (2015) as an improved, profitable, sustainable, and environmentally friendly package of agronomic practices characterized by minimum soil disturbance, permanent organic soil cover and crop diversification and rotations. The central tenet of this approach as indicated in FAO (2001), is the maintenance of a permanent or semi-permanent organic soil cover, which could be live crop or dead mulch which serves to protect the soil from sun, rain and wind, and feed soil biota. CA takes more deliberate advantage of natural processes; setting the base for better sustainable agricultural production intensification than conventional agriculture, especially when complimented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management (FAO, 2015).

Hobbs et al. (2008) documents environmental and some agronomic benefits of CA practices relative to traditional tillage to include; control of wind and soil erosion, soil physical and biological health improvement, better water infiltration, better soil organic matter build up, reduced production cost, and higher yield with timely planting. These associated benefits from the use of CA however, cannot be realized without the use of appropriate and available equipment adopted for this kind of farming system (Hobbs et al., 2008).

Despite the various theorized and documented benefits, many of which are backed by empirical findings (though fragmented) related to CA (see Thierfelder & Rusinamhodzi, 2014; Hobbs et al., 2008; Giller, Witter, Corbeels, & Tittonell, 2009), its adoption rates in regions beyond the Americas and Australia is low. Bradshaw & Knowler (2007) emphasises that efforts to promote conservation agriculture must be tailored to reflect the particular conditions of individual locales. This is reiterated by a study done by Giller et al. (2009) which recommends an urgent need to critically assess under which ecological and socio-economic conditions CA is best suited for smallholder farming in SSA. It further mentions that current circumstances, including institutional and livelihood contexts make CA inappropriate for most resource constrained smallholder farmers particularly in this region. "Concerns about performance of CA for smallholder farmers in SSA include impacts on yields and returns to labour with the latter largely dependent on the former" (Brouder & Gomez-Macpherson, 2014:2).

Current global estimates of the extent of adoption of CA is 157 million hectares (FAO, 2015), 87% of which is concentrated in five countries: The United States, Brazil, Argentina, Australia, and Canada (26.5, 25.5, 25.5, 17.0 and 13.5 million ha, respectively) (Brouder & Gomez-Macpherson, 2014). 45% of the total global area under CA is in South America, 32% in the United States of America and Canada, 14% in Australia and New Zealand, 3% in Russia and the Ukraine and 1% each in Europe and Africa (Friedrich, Derpsch, & Kassam, 2016).

CA is now beginning to spread to Sub-Saharan Africa, particularly in the eastern and southern African regions. Zambia is among the fastest adopters of the approach; only third behind the continent's leading adopters, South Africa, and Zimbabwe in sub-Saharan Africa.

In Zambia, the practice of CA involves minimum tillage (dry season land preparation with minimum soil disturbance, crop residue retention, nitrogen-fixing crop rotation and application of precise doses of mineral fertilizers (see Conservation Farming Unit, 2007a; Conservation Farming Unit, 2007b; Kabwe, Donovan, & Samazaka, 2007). The use of hand-hoe basins, ox-drawn ripping and tractor ripping are the three popular minimum tillage technologies promoted (Grabowski, Haggblade, Kabwe, & Tembo, 2014).

Several regional droughts and an outbreak of corridor disease in the early 1990s triggered an interest in CA as stakeholders worked together to develop agronomic practices and technologies that could mitigate growing problems of soil degradation and drought (Kabwe et al., 2007; Grabowski et al., 2014). High fuel costs also spurred interest in low-tillage, low external input systems as Zambian farmers discovered that low-till cultivation enabled them to reduce their fuel consumption by 75% (from 120 litres to 30 litres per hectare), dramatically improving the profitability of mechanized maize production (Kabwe et al., 2007).

Extension of the technology has attracted strong support, most notably from the Conservation Farming Unit (CFU) – originally created by the Zambian National Farmers Union (hereon ZNFU) in 1996 - and work in close relationship with the Ministry of Agriculture in Zambia, the Golden Valley Research Trust (hereon GART) and several other organizations (CFU, 2015; Kabwe et al., 2007). Since 2007 to date, after a decade of patchwork funding from a series of small donor projects, the CFU and GART have together received a five-year funding agreement from the Norwegian Agency for Development Cooperation (NORAD) to support full-scale extension of the CF hand-hoe and ripper systems to farmers in Zambia's moderate- and low rainfall regions (Kabwe et al., 2007; Grabowski et al., 2014).

Since the late 1990s, some privately held cotton companies which usually provide inputs (usually credit for herbicides, seeds and information on key on-farm management practices) on contract to smallholder growers, have actively promoted minimum tillage; two of the most prominent ones being NWK-Agri-services (formerly Dunavant) and Cargill cotton companies (Grabowski et al., 2014; Kabwe et al., 2007; Haggblade & Plerhoples, 2010). NWK encourages its distributors to have minimum tillage demonstration plots for training while Cargill buyers hold "cotton schools" to train farmers on minimum tillage and cotton production practices (Grabowski et al., 2014). Cotton farmers in Zambia are ranked among the earliest and most loyal adopters of CF mostly as a result of these interventions (Haggblade & Plerhoples, 2010). The preferred minimum tillage practice has changed dramatically in recent times with Zambian smallholder farmers rapidly moving from the use of hand-hoe basins, to the use of oxen and tractor drawn rippers (Grabowski et al., 2014)

Since 2007, the CFU, GART, extension services and the major cotton companies have all actively distributed rippers (through sales, loans and as program incentives) and conducted training in animal traction minimum tillage (Grabowski et al., 2014).

2.3. Recent efforts to promote mechanization in Zambia

Over the recent years, the interest in agricultural mechanization has been increasing in Zambia, like other African countries. Zambia hosts AgriTech Expo Zambia, a major trade fair for agricultural machinery. International agricultural machinery companies have started to invest in Zambia. AGCO, Your Agriculture Company (NYSE: AGCO), a worldwide manufacturer and distributor of agricultural equipment, farm, and learning centre near Lusaka, Zambia. The training facility is designed to accommodate a full range of customers, from small scale producers up to large, commercial farmers[1]. The Ministry of Agriculture and Livestock started a Tractor Mechanization Fund in collaboration with the FAO, and ZNFU in 2011. The Tractor Mechanization Fund uses a revolving fund concept to enable farmers' access to equipment. The farmers can purchase tractors, rippers, ripper-

[1] See http://investors.agcocorp.com/phoenix.zhtml?c=108419&p=irol-newsArticle&ID=1702132

planters, maize shellers, boom sprayers and other equipment[2]. In 2015, the German Federal Ministry of Food and Agriculture supported the establishment of the Zambian-German Agricultural Knowledge and Training Center, where field trials, demonstrations and trainings are offered in collaboration with twelve private sector partners from Europe[3]. Since 2010, John Deere and its dealer in Zambia, AFGRI, focuses on the development of "emerging farmers", i.e. the medium-sized farmers, who can afford to purchase a tractor. The approach includes mechanization package, i.e. a tractor and a set of machineries, such as ripper, disc plough, planter, sprayer etc., which is further discussed in Chapter 3:

Chapter 3: The Mechanization Schemes of John Deere and AFGRI in Zambia

In Zambia, John Deere has worked with AFGRI as its dealer. JD approach focuses on the development of "emerging farmers", i.e. the medium-sized farmers, who can afford to purchase a tractor. The approach includes mechanization package, i.e. a tractor and a set of machinery, such as ripper, disc plough, planter, sprayer etc. These emerging farmers first use the tractor to prepare their own land and then also provide mechanization services to the smallholder farmers. The smallholder farmers mainly hire the mechanization for ripping if the farmer is part of CFU, practicing conservation agriculture; and for ploughing. Besides ripping and ploughing smallholder tractors are also hired for post-harvest activity such as maize shelling. The smallholders mainly use tractors to mechanize the labour-intensive activity in crop production. The emerging farmers possessed different forms of implements and processing tools. Typically, they purchased a tractor, a ripper or disc plough and maize sheller while very few emerging farmers purchased cultivator, ridger, combine harvester and thresher to mechanize further farm activities.

John Deere supports these medium scale farmers/contractors by facilitating access to finance and by training and mentoring. John Deere's dealers provide after sales services to the emerging farmers such as servicing and maintenance. AFGRI also provide other value chain services, such as input supply and marketing of farmers' produce. Since 2010, John Deere

[2] See http://www.znfu.org.zm/tractor_mechanization

[3] See http://www.aktczambia.com/.

and AFGRI have implemented mechanization schemes to provide above mentioned support to the emerging farmers which are described in detail in Section 3.1.

3.1. Description of the Mechanization Schemes of John Deere and AFGRI

This section provides a description of the three mechanization strategies initiated by AFGRI between 2010 up till the time of the research. Within the period, the first scheme has undergone a series of evolutions to enhance the viability of the model, reduce risk of default and ensure its sustainable expansion across the country. The section again highlights the factors that influenced these evolution processes.

3.1.1. First loss guarantee

In 2010, AFGRI and the John Deere Company piloted a project in the Western part of Zambia to address medium scale farmers. The program began with four farmers. The scheme collaborated with the Conservation Farming Unit (CFU) and MUSIKA, an organization linking private businesses and smallholders.

Its set-up was straightforward: based on its longstanding field-experience, CFU suggested promising, liquid farmers and linked them with AFGRI. After making cash-down-payment of 20%, these farmers received a tractor and a ripper, which allows land preparation according to the principles of Conservation Agriculture. Some farmers also bought planters and boom sprayers depending on their budgets. The tractors were delivered with a 3000-hour service plan, three-year equipment insurance and GPS tracking, which allowed AFGRI to monitor the tractors which doubled as the only collateral asset in the agreement. All tractor-beneficiary-farmers in this arrangement received a 2 to 3-hour technical training on proper handling of the acquired machine and the use of the tractor drawn ripper by AFGRI and CFU respectively. 26 out of the total 34 beneficiaries were trained on business topics related to the provision of mechanization services by MUSIKA. These tractor owners were encouraged to use the facility to provide services other farmers though this was not mandatory.

The package was supposed to be paid within 36 months on a monthly basis. The facility was calculated in US-Dollars which allowed AFGRI offering a substantially below-market-interest-rate of 14 %.

After the pilot scheme successfully phased out with the four linkages translating into purchases, the scheme expanded to the other provinces with 13 and 17 more farmers benefitting in 2011 and 2012 respectively.

On the downside, repaying tractors became challenging for the farmers when the Zambian Kwacha started depreciating substantially by the end of 2013. Some farmers also had problems repaying monthly particularly between January and April (after planting and before harvesting) when they had little liquid capital. In combination with bad rainfall patterns this led to a situation where most tractor-receivers struggled to meet repayment schedules even as at 2016 with some tractors being repossessed.

As at the time of this study in April 2016, only 19 tractor-receivers had completed repayment; 10 were still repaying as AFGRI agreed with them on a more flexible repayment-schedule. 5 tractors had been repossessed. In the latter case, the Deere & Company and CFU each covered 10 % of the default-costs. The remaining 80% were covered by AFGRI. As repossessed tractors, can be resold, AFGRI believed default-costs can be manageable. Yet, AFRGI underestimated depreciation and the repossessed tractors were often in bad conditions as tractor-receivers were mostly first-time-owners.

These challenges led to the end of the scheme in 2013. According to AFGRI, the scheme nevertheless showed that working with medium scale farmers can be possible, made banks curious and allowed AFGRI to learn valuable lessons for future schemes.

3.1.2. Tractor for maize

In 2012 / 2013, AFGRI started promoting a new mechanization scheme to serve as an improvement from the first. The main feature behind this scheme was farmers repaying tractors with maize; Zambia's main staple crop. This scheme takes advantage of AFGRI's "Grain Management Division", which has several grain collection facilities across Zambia.

AFGRI mainly self-selected most of their potential tractor beneficiaries after screening applicants. In some cases, MUSIKA, the before mentioned organization, played a brokering role. Applicable farmers were selected mainly based on land-sizes as AFGRI calculated that farmers would need to cultivate more than 25-30 hectares of maize annually just for repaying the tractors. Farmers also had to be located within a 100-km radius of either the AFGRI sales office (in Lusaka) or a grain collection facility (in Mazabuka, Mkushi and Kabwe).

A farmer-tractor-beneficiary needed to deposit initial cash-down-payment 30% of the cost of the facility. Repayment of the difference was scheduled to adapt to the seasonal characteristics of farming; an obvious improvement to the first scheme described above. Unlike before, farmers could choose any tractor-drawn implements (e.g., also disc ploughs) as AFGRI did not collaborate with the Zambian Conservation Farming Unit on this scheme. 40 deals were successfully rolled out.

Farmers delivered a fixed quantity of grain immediately after the harvesting period (until August each season) as repayment for the machinery they obtained. This quantity was valued using the maize market price at that time. To ensure farmers repayment-capacities, meaning high maize harvests, AFGRI's Sales Division made on-farm assessment visits to farmers' cropped fields at least once during the cropping season compiled "Emergency Reports" and provided technical advice to farmers. While this concept proved to be successful, it was organizationally very tedious because of long distances and bad roads and often not all farmers could be visited.

While the scheme was matched to the characteristics of farming, some challenges remained. Most crucial being that the maize market price was still converted to US-Dollars so the exchange rate risk was still high, which made repayments difficult as the Zambian Kwacha continued depreciating during 2014 and 2015. The depreciation of the Zambian Kwacha also led to high prices of farm inputs such as seeds, fertilizers, and agro-chemicals and therefore less inputs used and subsequently lower average yields. In addition, El-Nino triggered droughts particularly in 2015, led to crop losses for many farmers.

All these factors coupled with negligence of the side of some farmers (30% as estimated by AFGRI) reduced farmer's capacities to repay. By 2016, only 2 of the 40 tractor-receivers had paid-off, 33 were still repaying and 5 beneficiaries had defaulted. For a selected number of defaults (10 – 15 farmers), MUSIKA covered 50% (a maximum 4,000 US$) of the default costs. Most of the burden of the risk of default was carried by AFGRI. The Scheme was ended in 2015 and replaced by the ZANACO scheme.

3.1.3. ZANACO scheme

Since 2015, AFGRI has partnered with the Zambia National Commercial Bank (ZANACO) and John Deere Financial to run a third scheme. The principle of this third scheme is simple; after AFGRI negotiated with potential tractor-buyers on the types of tractors and implements to be bought, ZANACO assesses the repayment capacities of these customers looking at criteria such as land size (roughly 20 hectares), turnover (roughly 120,000 ZMK, which are 12,000 US$), cash flow, historical records, regular off-farm-incomes and the possibility to make a cash-down-payment of 20 %.

The provision of mechanization services is no criteria. Based on this evaluation ZANACO offers the customers a loan. This loan is based on the market-interest-rate of around 30 %. John Deere Financial absorbs, depending on deposits and turnovers, 1 to 4 % of this rate.

The default risk is entirely captured by ZANACO. Once agreed, farmers receive a tractor-package including implements, which they are obliged to insure against certain risks. They are supposed to repay the tractor-package with four, freely choose-able annual instalments.

Unlike before, the repayments are done in Zambian Kwacha, which reduces the exchange rate risks for farmers. However, the interest rate is floating based on market fundamentals, which still compromise exchange rate risks. Until the tractors are repaid, ZANACO officially owns the tractors. By 2016, 6 deals were finalized.

Partnering with ZANACO substantially reduces the risks for AFGRI. On the downside, the interest rates are higher compared to the other schemes. Tractors are delivered with a four year service package and a 2-3 hours technical introduction to the machinery.

Chapter 4: Conceptual Framework

A conceptual framework was created based on theory of change which was used in sampling design, questionnaire design and preparing interview guidelines as a guide. The mechanization schemes are expected to have social, economic and environmental impacts which are represented in the causal chain Figure 4-1: Theory of change: The framework represents different actors, pathways; also, the factors that assist and obstruct the change or desired impact.

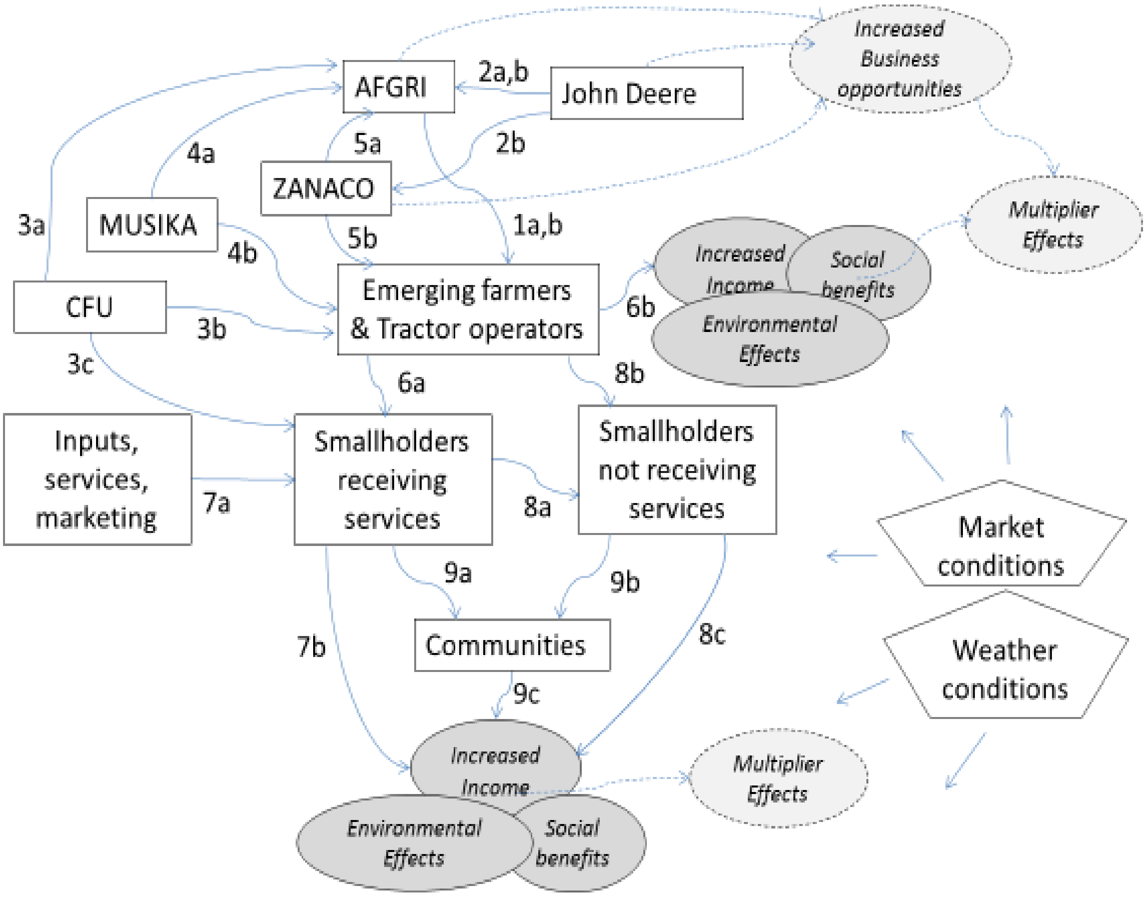
"A 'theory of change' explains how activities are understood to produce a series of results that contribute to achieving the final intended impacts. It can be developed for any level of intervention – an event, a project, a programme, a policy, a strategy, or an organization.

A theory of change can be developed for an intervention:

- where objectives and activities can be identified and tightly planned beforehand, or that changes and adapts in response to emerging issues and to decisions made by partners and other stakeholders" (Rogers, 2014:1)

Figure 4-1 presents the expected impacts mechanization. Theory of Change was used to develop a framework which shows the causal relationship between what impact we expect and how we can achieve it. It shows the result of causal chain which contribute in achieving the intended final impacts. The impacts that are considered in this assessment are marked in grey oval shapes in the diagram. Numbers indicate the different causal links next to the arrows in the diagram and explained below the diagram. "Multiplier effects" are also listed in the diagram though not discussed in the impact assessment. The framework also shows that there are factors such as market conditions and weather conditions which are not under the control of the actors involved. Basically, 'theory of change' is helpful to identify the type of data to be collected and the how it could be analysed, in an impact evaluation. In addition, also as a guide in reporting through the. framework (Rogers, 2014) In this study, Figure 4-1 was used as guideline for sampling strategy, in depth interview and questionnaire design which are further discussed under Chapter 5: .

Figure 4-1: Theory of change



Source: Birner, Daum, Adu-Baffour, Upreti, & Koller (2017)

Table 4-1: Explanation of the link in conceptual framework

Link	Explanation of the link	Assumptions to be fulfilled for impact to be achieved
1a	AFGRI sells tractors and machinery to emerging	Tractors and machinery are appropriate for emerging farmers
1b	farmers	Sufficient after-sales services are provided
1c	AFGRI provides financial support	Farmers are identified who have the capacity to repay
	AFGRI provides advice	AFGRI is able to visit farmers and to provide appropriate advice
2a	John Deere supplies equipment	Tractors and machinery are appropriate for emerging farmers
2b	John Deere Financial supports financing plans	Sufficient support is provided to AFGRI Emerging farmers are identified who have the capacity to repay
3a, b 4a, b 3c	CFU and MUSIKA help AFGRI identify farmers and support them	Emerging farmers are identified who have the capacity to repay Selected emerging farmers receive appropriate support

	CFU supports smallholder farmers	Smallholder farmers who can afford tractor services are identified, organized, and receive extension services
5a,b	ZANACO provides loans to emerging farmers	Emerging farmers are identified who have the capacity to repay; conditions of the loan allow for investment to be profitable
6a	Emerging farmers provide services to smallholders	Emerging farmers are able to identify interested smallholders; service provision is beneficial for both sides
6b	Emerging farmers are able to increase their income and realize social benefits	Investment in tractor and machinery is profitable; emerging farmers can manage associated risks; emerging farmers have capable tractor operations who have the necessary skills
7a, b	Smallholder farmers who receive services increase their income and realize social benefits	Smallholder farmers can increase their productivity or expand their cultivated land; they have sufficient access to inputs and marketing facilities; they use their additional income to increase their families' wellbeing (e.g., by investing in education)
8a, b, c	Smallholders who do not receive services benefit also; or are at least not negatively affected	Demand for hired agricultural labor (provided by smallholders) increases (due to expansion of cultivated land) or does, at least, not decline; increased income by emerging farmers and smallholders who receive services creates new income opportunities
9a, b, c	Benefits are realized at the community level	Smallholders who benefit directly or indirectly from service provision realize benefits at the community level, e.g., by increased collaboration within communities and by investing in community infrastructure
	Market and weather conditions	Market and weather risks can be managed

Chapter 5: Methodology

This chapter provides details on the study area, the sampling strategy employed for each targeted group of respondents as well as the data collection and the type of analytical methods used.

5.1. Study area

This study was carried out from April to July 2016. The study was carried out in 6 provinces which were categorized into 4 groups: Eastern province, Central and Copper Belt provinces combined, Lusaka and Southern provinces combined and the Western province.

Figure 5-1: Provinces in Zambia

Source: http://www.globalharvestinitiative.org/GAP/2015_GAP_Report.pdf

5.2. Sampling strategy

A good number of randomly selected tractor owners were interviewed, but the survey on their smallholder service beneficiaries was done from a selected number of these interviewed tractor owners. This subsection provides descriptions and reasoning behind the sampling strategy used for both tractor owners and smallholder farmers.

5.2.1. Sampling of tractor owners

The tractor owners for the interviews were sampled randomly from the list provided by AFGRI. Stratified random sampling approach was used. As mentioned above in section 5.1, the study area was divided into four regions Eastern region, Western region, Southern region (Southern Province and Lusaka) and Central region (Copper Belt and Central Province). In Western region, all the tractor owners were interviewed because of their small number i.e. two. In the remaining three groups/ regions the tractor owners were selected randomly from the given list. In the eastern five tractor owners were selected, in southern region, six tractor owners were selected and seven in the central region for in depth interviews.

5.2.2. Sampling of smallholder farmers

Fifteen tractor owners were selected from whom smallholders were surveyed. For the eastern province, three tractor owners were randomly selected. In the western province both the farmers were selected. In the central region and southern region, six and four tractor owners were selected respectively. In case an emerging farmer did not provide service to the smallholder farmers he was replaced and another emerging farmer in the same stratum was selected randomly.

For each of these selected fifteen tractor owners providing services to smallholder farmers, sixteen smallholders were interviewed from communities he served and their immediate neighbouring communities. The criteria to select these sixteen smallholders were as follows:

From an individual emerging farmer providing service, we obtained the list of farmers he/she served. In case he did not have the list and was working with CFU, we obtained the list from the CFU office or field officer stationed in the village. These smallholder farmers were grouped into three clusters: two treatment cluster (Treatment I and Treatment II) and one control. The treatment cluster is the community where the service provider/ emerging farmer provide service and other service provider may provide service, and third cluster, the control group where nobody received mechanization services.

The smallholders in different cluster were randomly selected with the help of an agricultural extension officer (camp officer), CFU field officer or village headmen, depending on the availability and convenience. From the list of farmers in each cluster, the smallholder farmers were selected randomly for the semi-structured interviews.

Photo 5-1: Research team interviewing a smallholder farmer

For each emerging farmer, 8 farmers were selected who received mechanization services which fall in the first treatment group. 5 farmers were selected in the same community who did not receive mechanization services from the selected emerging farmer. However, may or may not receive mechanization services from the other service provider. The last cluster is the control group where 3 farmers were selected randomly from the nearby community where nobody received mechanization services.

5.3. Data collection and analysis

This subsection describes the kinds and methods of data collected from the above mentioned sampled groups and communities as well as its intended use in this research. Both qualitative and quantitative analytical methods used for the research are also described extensively in this subsection.

5.3.1. Tractor owners

In depth interview was conducted with the tractor owners to generate qualitative data using open questions. The interview provided an opportunity to get in depth information on tractor owners' general background, agricultural activities, service provision and tractor specific questions etc.

A set of guiding questions were asked on different sections such as general information about tractor owners (education, land size, off farm business); ownership of tractor (the year they acquired tractor, main criteria to choose John Deere, source of information about the John Deere's scheme, finished repayment or not, number and types of breakdown faced, time and cost to fix the breakdown of the machinery, the implements and processing tools they own); service provision (reason to provide service to smallholders and type of services provided, number of farmers served, furthest distance served, minimum field size served, total area served, service charge , criteria to choose smallholder farmers); information on operator (wage, experience, has license to drive tractor or not, trainings received) and crop production and mechanization (major crops grown, area cultivated, yield, income, effect of mechanization and labour demand).

The interviews were recorded and later transcribed. The data were also entered in excel for further analysis for qualitative analysis.

Interviews with the medium scale farmers yielded rich quantitative data which was used to conduct an analysis of the profitability of participating in the scheme. Detailed information from a select six of these farmers was used for this. The selection was done to cover the first two schemes as well as different regions. The selection of these farmers was not random but rather based on their willingness to provide detailed economic information. Hence, this information is not statistically representative; the goal rather was to illustrate the range of outcomes that could be observed. The investment analysis was carried out as follows: Detailed data costs of production of the medium scale farmers' own farm operations were collected for the previous farming season. Data on yields and prices was collected for the last two seasons and the average yield of the last two years was used for the following calculations. Data on income from service provision and cost of service provision was additionally collected.

The investment calculation was carried out for a period of ten years, and it was assumed that the costs and benefits that were calculated represent the average for the ten-year period. For each year, the cash flow was calculated, using the data on the income from farm operations, costs of farm operation as well as the down payment on the tractor and the equipment and the instalments. On this basis, the Net Present Value (NPV) and internal rate of return (IRR) that were calculated. Sensitivity analyses were conducted to simulate the effect of changes in key parameters. To help understand seasonal income realized from a farmer's farming operations, gross margin calculations were also done for each of the selected farmers.

5.3.2. Smallholder farmers

Descriptive statistics was used to compare some observed agronomic, demographic, socio-economic and labour use characteristics between users of the scheme and non-users before matching using SPSS and Microsoft excel analytical tools. This was to help provide a general overview of the data, guide in data cleaning and to generate a sense of what to expect when more robust analytical methods were applied. As mentioned earlier, these smallholder farmers were selected only from regions where the above-mentioned schemes were operating. Some level of sample selection bias was therefore expected. Details of this problem and the specific analytical method used to address it are described in the subsections below.

5.3.2.1. Sample selection bias

The potential for sample selection bias occurs whenever one works with a non-random subset of some population. This could occur due to decisions taken by the researcher during research design or by the surveyed individuals, both leading to data that are not representative of the alleged population. A random assignment of human beings to a treatment group and a control group is problematic for ethical and practical reasons. One usually faces the situation whereby observation units select themselves into treatment and control groups (ex-post facto research design). In such situations, data are not necessarily representative of the population the original random sample was drawn if one is interested in measuring variables that are only observable within the treatment group.

If unobserved or unobservable factors influence both the probability that an observation unit appears in our sample and the variables of interest, our estimates will be afflicted by sample selection bias. This implicates both internal and external validity of the sample used to estimate causal conclusions to the population. In such cases, the estimation procedure applied must take the sample selection phenomenon into account. There is also the problem of evaluating the impact of a treatment on a group without existing baseline data to compare. These make it necessary to use a special kind of analytical technique known as the propensity score matching which is elaborated below.

5.3.2.2. Propensity score matching

Propensity score matching (hereon PSM) has become an increasingly used tool for correcting sample selection bias. P. Rosenbaum & Rubin (1983) defines propensity score as the estimated conditional probability of assignment to a particular treatment given a vector of observed covariates. The principal idea of PSM is to find treated and untreated cases (in these situation smallholders) that are similar with respect to a set of observed pre-treatment characteristics and match them to each other.

Under the assumptions of conditional independence of the given set of observable covariates on potential outcomes (see Sianesi, 2001a) and the need for a region of common support where for example, smallholders with similar characteristics have a positive probability of being both participant or non-participant (see Heckman, Ichimura, & Todd, 1998), the propensity score is a suitable single-index balancing score to identifying matching partners (P. Rosenbaum & Rubin, 1983) . These assumptions may be relaxed or generalized depending on the focus and research question (see as example Sianesi, 2001a; Michael Lechner, 2001).

5.3.2.2.1. Implementation of PSM

Once a researcher settles on using PSM over covariate, he is confronted with questions of implementation. The process as outlined in Caliendo & Kopeinig, 2005 begins with an estimation of the propensity score. One then should decide which matching algorithm to choose and determine the region of common support. Subsequently, the matching quality should be assessed with treatment effects and their standard errors estimated. Finally, one might also want to test the sensitivity of the estimated treatment effects with respect to unobserved heterogeneity or failure of the common support condition. Figure 5-2 summarizes these five necessary steps when implementing a PSM.

Figure 5-2: PSM – Implementation Steps

Source: Caliendo & Kopeinig (2005)

5.3.2.2.1.1. Propensity score estimation approach

Given the conditional independence assumption holds and assuming additionally that there is overlap between the treated and control groups the main impact measure of interest is the average treatment effect on the treated *(ATT_J)* according to

$$ATT_J = E[y_{1j}|JDMech_j = 1] - E[y_{oj}|JDMech_j = 1] \qquad (1)$$

where y_{1j} is the value of the outcome of farm household *j* after benefiting from the John Deere tractor service provider and y_{oj} is the outcome of the same farm household *j* if the household did not benefit from the programme.

The underlying estimation problem of equation 1 can be represented as a treatment-effects model of the form;

$$y_{jt} = \alpha_j + \tau_t + \boldsymbol{\beta}'\boldsymbol{x_{jt}} + \delta JDMech_j + \varepsilon_{jt} \quad (2)$$

$$JDMech_j^* = \boldsymbol{\gamma}'\boldsymbol{w_j} + u_j$$

$$JDMech_j = \{\mathbf{1}, \text{ if } JDMech_j > 0 \text{ and } \mathbf{0} \text{ if otherwise}\} \quad (3)$$

$$\text{Prob}(JDMech_j = 1) = F(\boldsymbol{\gamma}'\boldsymbol{w_j}) \quad (4)$$

$$\text{Prob}(JDMech_j = 0) = 1 - F(\boldsymbol{\gamma}'\boldsymbol{w_j}) \quad (5)$$

where $JDMech_j^*$ is a latent unobserved variable whose counterpart, $JDMech_j$, is observed in dichotomous form only; $JDMech_j = 1$ represents a user (ie. a farmer who decides to hire services) of John Deere tractor service provision (that is, treatment) and $JDMech_j = 0$ represents non-user of the facility (that is control); $\boldsymbol{x_j}$ is the vector variable determining the outcome of the John Deere tractor service provision scheme, $\boldsymbol{w_j}$ is the vector variable determining the probability of being a user of the JD mechanization facility or not which includes the list of explanatory variables given below; α_j and τ_t respectively captures the individual and time-specific effects; β and γ are the vectors of parameters measuring the relationships between the dependent and independent variables; ε and u are the random components of the respective equations. The functional form (*F*) may take the form of a normal, logistic or probability function.

A two-stage weighted estimation approach is used. In stage one, equation 3 is estimated by probit to obtain the propensity scores, which are then used as weights in a second stage estimation of equation 2 based on matched treatment and control observations identified in stage one.

The *ATT* of the John Deere Mechanization program estimation is defined by the use of a John Deere tractor facility at least for land preparation. The *ATT*s of the programme were obtained by estimating the models using data on a sample size of 121 JD tractor beneficiary smallholder farmers with 129 control (non-beneficiary) group of smallholder farmers for the 2014 – 2015 cropping season.

In line with an analytical approach used by (Benin, 2015) additional assumptions made with this model include:

1. Farmers in the same treatment face identical mechanization market conditions
2. Choice of service provider used is determined by the farmers' own mechanization requirements and preferences

5.3.2.2.1.1.1. Choice of variables

Based on the assumption of conditional independence, requiring that the outcome variables must be independent of treatment conditional on the propensity score, implementing matching requires choosing a set of variables that credibly satisfy this condition (Caliendo & Kopeinig, 2005). Omitting important variables can seriously increase bias in resulting estimates as shown by Heckman, Ichimura, & Todd (1997). Only variables that influence simultaneously the participation decision and the outcome variable should be included (Caliendo & Kopeinig, 2005). Selected variables should be fixed over time or measured before participation to ensure that only variables that are unaffected by participation (or the anticipation of it) are included in the model (Caliendo & Kopeinig, 2005). Data for participants and non-participants should be informative and stem from the same source (same questionnaire) in order to credibly justify the conditional independence assumption and the matching procedure (Heckman, Lalonde, & Smith, 1999).

It should however be emphasized that "too good" data is not helpful either, because, persons having characteristics with P(X) = 0 or P(X) = 1 for some values of X will either always or never receive treatment when estimating a treatment effect (Caliendo & Kopeinig, 2005). Heckman, Ichimura, Smith, & Todd (1998), recommends some level of randomness that guarantees that persons with identical characteristics can be observed in both states.

Over-parameterized models, that are models that include too many rather than too few variables, should be avoided (Caliendo & Kopeinig, 2005). Bryson, Dorsett, & Purdon (2002) identifies the problems of potentially exacerbating the support problem and increasing the variance of the estimates as two reasons why over-parameterized models especially with non-significant variables should be avoided.

Rubin & Thomas (1996) on the other hand argue that a variable should be excluded from an analysis only if there is consensus that the variable is either unrelated to the outcome or not a proper covariate otherwise, these variables should be included in the propensity score estimation.

The choice of variables should therefore be based on empirical theory and previous empirical findings (Caliendo & Kopeinig, 2005). There are also common statistical tests which can be used in making the choice of variables. These include the hit or miss method, the use of the statistical significance (see Heckman, Ichimura, & Todd, 1998; Heckman et al., 1999), the leave-one-out cross-validation method (see Black, Smith, Berger, & Noel, 2016) and overweighting some variables (see Bryson et al., 2002).

Determinants of Farm Mechanization Adoption

Several factors influence the likelihood of a smallholder farmer assessing mechanization services. As with other technological innovations, adoption of mechanized farming depends on farmers' perceptions of the commercial and practical benefits that would arise from the use of such innovation (Forbes, Cullen, & Grout, 2013) as well as on attributes of the innovation itself (E. M. Rogers, 1995; Mbosso et al., 2015). A range of personal, cultural, and socio-economic conditions also play a contributing role to a farmer's decision to (or not to) adopt an agricultural technology on part or all of his or her farming operations when viewed through a broader disciplinary lens (Pannell et al., 2006). In a meta-level analysis, Baumgart-Getz, Prokopy, & Floress (2012) shows education level, capital, income, farm size, access to information, positive environment attitude, environmental awareness and utilization of social networks are generally positively associated with the adoption of best management practices. Guided by economic theory, literature and data available, some demographic and socio-economic determinants used as explanatory variables of farmer's access to any of the JD mechanization schemes described above are discussed below:

Farming Experience

Experienced farmers are assumed to be more knowledgeable and effective with their farming occupation having seen many seasons of repeated agronomic cycles. These characteristics means they most likely will opt for more efficient farming methods and adopt innovations that will help reduce the drudgery of farming while maximizing their outputs. This variable is assessed using the smallholder's number of years of farming. It is the difference between the year of the immediate past season and the year a smallholder first started farming for himself or herself.

Off-farm business participation

This variable is to confirm whether a smallholder or any member of his or her household has been engaged in other businesses aside farming (e.g., carpentry, brick making, agro-chemicals dealing) during the past twelve months at least. Income from off-farm businesses can serve as investment capital for farm inputs and operations.

Size of household

A bigger household size could imply increase on-farm labour force; a common phenomenon found in rural agricultural households. This variable is a count of the total number of household members above the age of 5 years and can contribute labour for farming operations. In this case, a household is defined as a group of family members who eat from one bowl.

Gender of household head

The gender of the household head could play a role in a household adopting some agricultural innovations. This is a binary variable which assesses the gender of the household head. 1 represents a male household head while 0 represents a female household head.

Education level of household head

(Ryan & Gross, 1943) shows farmers with more formal education are more likely to adopt an agricultural innovation. Such farmers have a higher exposure to current information about such technologies and usually a better understanding of its accompanying benefits and possible risks. This variable measure the total number of years a smallholder has spent in formal educational institutions. The greater the number the more educated the household head.

Land owned

A farmer with full legal claim of larger arable land size has more incentive to undertake longer term projects to ensure its sustainable and productive use. This variable uses the total land area owned by the farming household before the joining the scheme.

Access to extension services

This is also a binary response variable which measures whether farmer has access to private, public and/or third sector extension service. A response in the affirmative, yes, is assigned a value of 1 while a negative response, no, is assigned a value of 0. The variable assesses a farmer's access to information.

Access to credit facilities

A smallholder's access to seasonal credit affords him or her chance to acquire the needed inputs, hired labour and mechanization services needed for good yield. This is a binary response variable which measures whether a farmer has access to credit or loan facility. Yes is assigned a value of 1 while no is assigned a value of 0.

Market access

A smallholder will ensure an increasing quantity and quality of produce when he or she is assured of ready market for it. In rural agricultural areas, informal village market points are common sales points for farmers' produce. The variable indicates the amount of travel time (in minutes) required to access nearest village market.

Network group membership

Service providers (be they for input, tractor, or extension) as well as produce aggregators are usually motivated to work with organized network groups localized within specific locations than with individuals spread across far distances. The primary reason for this is to ensure services are provided at minimum transaction cost. Farmers who are members of a network groups are increasingly likely to adopt a technological innovation when they are exposed to positive ideas and experiences from others (Gould, W. Brian, 1989). This variable captures a smallholder farmer's membership in a social or political network group like farmer cooperative. A smallholder is assigned a value of 1 if he or she is a member of a network group and a 0 if not.

Livestock ownership

As a wealth indicator, the number of livestock owned by a smallholder in an agricultural rural area can influence his or her decision to hire a mechanization service. A farmer who owns a large livestock size is considered wealthy and hence can afford the cost of hiring tractor services. Using Tropical Livestock Unit conversion factors (Jahnke, 1983) the total number of livestock owned by a farmer before participating in the mechanization scheme is calculated as an explanatory variable.

Farmer's investment behaviour

(Pannell et al., 2006) highlights a farmer's personal behaviour as one component influencing his or her decision to adopting an agricultural technology. This variable captures the percentage of amount a farmer is willing to invest in any venture of choice considering potential losses and gains.

Table 5-1: Explanatory variables associated with the Mechanization Scheme

Variable Name	Variable Description
Farming experience	Number of years of farming
Off-farm business participation	Whether farmer is involved in off-farm businesses: 1 = Yes, 0 = No
Size of household	Total count of household members above age 5
Gender of household head	Whether head of household is male: 1 = Yes, 0 = No
Education level of household head	Years of schooling
Land owned before scheme	Own land per capita – total owned land divided by total members of household
Access to extension service	Whether farmer has access to private, public or third sector extension service: 1 = Yes, 0 = No
Access to credit facilities	Whether farmer has access to credit/loan facility: 1 = Yes, 0 = No
Market access	Amount of travel time (in minutes) required to access nearest village market
Network group membership	Farmer's membership in a social or political network group like farmer cooperative: 1= Yes, 0 =No
Livestock ownership before scheme	Total number of livestock owned by a farmer, weighted using Tropical Livestock Unit conversion factors (Jahnke, 1983)
Farmer's investment behavior	What percentage of an amount a farmer is willing to invest in any venture of choice considering potential losses and gains

Choice of outcome variables

Table 5-2 summarizes the main indicators that were used to measure the economic and social impact at the smallholder level. These variables fed into the PSM analysis as outcome indicators that were influenced by a farmer's involvement in the Mechanization Scheme. Below is a brief description of each of these variables.

Net on-farm income

This indicator measures the farmer's total farm gross margins. It is further broken down per hectare (divided by crop area cultivated) and per farm household (divided by total number of household members).

Yield

This indicator measures the per hectare seasonal crop output of maize which is the most commonly grown crop in Zambia.

Household expenditure

This indicator measures the average periodic expenses (in ZMW) made by the household on the following list of items:

1. Food - average monthly expenditure made on basic food items

2. Non-food household needs - average yearly expenditure made on personal supplies like clothes, shoes, accessories etc.

3. Education – average expenditure on school fees, books, student's dress, tuition over a three-month period (termly)

4. Health - average yearly expenditure on drugs, visits to doctors, health insurances etc.

5. Recreation – average monthly expenditure on alcohol and tobacco.

Food diversity

The frequency weighted diet diversity score "Food consumption score" was calculated using the frequency of consumption of different food groups consumed by the household the day before the survey (see WFP, 2008).

Food consumption frequency

This indicator measures the number of times a household significantly cuts the size of meals or completely skip meals because there was not enough money for food or any food in storage.

The survey also included recall data from respondents on selected outcome variables. These included changes in input use, yield and livestock that occurred after accessing mechanization services. For these variables, a double difference ATT technique was used to estimate the differences in mean outcomes for these variables

Table 5-2: Outcome variables assessed

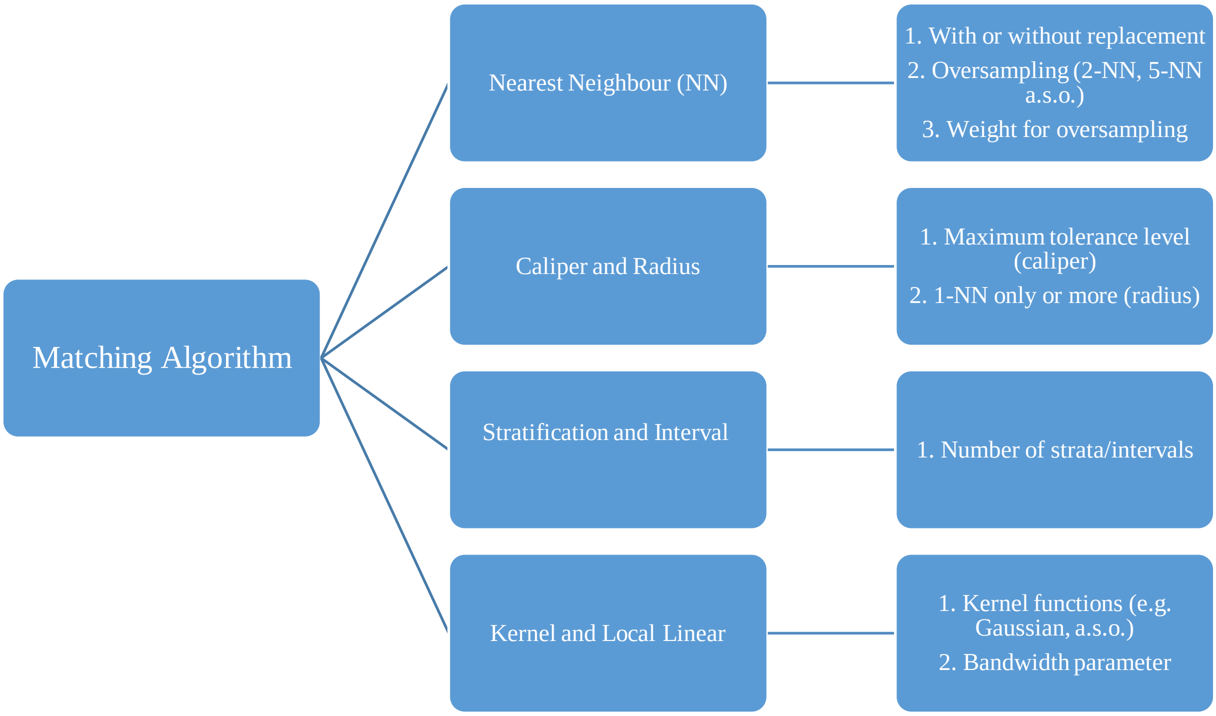
Variable Name	Variable Description
Net on-farm income • Per hectare	Farm gross margins

• Per household	
Yield	Per hectare seasonal crop output
Land ownership increment	Increase in land size owned
Farm input used • Fertilizer • Herbicides • Seeds	Changes in the quantities of farm inputs used
Household expenditure • Food, non-food household needs, education, health, recreation	Average amount of money (in ZMW) spent on daily needs over stipulated periods
Food Intake • Food diversity • Food consumption frequency	Quantity, quality, and frequency of food consumed by respondent household

5.3.2.2.1.2. Choice of matching algorithm

The specific propensity score matching method depends on the sample size, availability of treated and control observations and distribution of the propensity score. All matching estimators contrast the outcome of a treated individual with outcomes of comparison (control) group members (Caliendo & Kopeinig, 2005). Figure 2 depicts different PSM estimators and the inherent choices to be made when they are used. The general ideas and the involved trade-offs with each algorithm will be discussed in brief.

Figure 5-3: Different Matching Algorithms



NN: Nearest Neighbour, PS: Propensity Score

Source: Caliendo & Kopeinig (2005)

5.3.2.2.1.2.1. Nearest neighbour matching (NN)

This matching estimator is the most straightforward. The matching partner for the treated individual is chosen from the individual from the comparison group that is closest in terms of propensity score. Two prominent variants of NN matching proposed are the NN matching 'with replacement' (where untreated individuals can be used more than once as a match) and 'without replacement' (where untreated individuals can be considered only once as a match). For a NN matching with replacement, the average quality of matching of matching increases while the bias decreases; appropriate for data with propensity score distribution very different in the treatment and control groups (Caliendo & Kopeinig, 2005). Ordering must be randomly done when using the NN matching without replacement to prevent estimates depending on the order in which observations get matched.

A third and usually recommended variant of NN matching is the use of more than one nearest neighbour ('oversampling'). With this form of matching, there is a trade of reduced variance, resulting from using more information to construct the counterfactual for each participant, with increased bias that results from poorer matches when closest nearest neighbour is far away (Caliendo & Kopeinig, 2005).

5.3.2.2.1.2.2. Caliper and radius matching

Imposing a tolerance level on the maximum propensity score distance (caliper) reduces the risk of bad matches which happens in the case where the closest neighbour in NN matching is far away. With the caliper method, an individual from the comparison group is chosen as a matching partner for a treated individual that lies within the caliper ('propensity range') and is closest in terms of propensity score (Caliendo & Kopeinig, 2005).

Radius matching is a variant of caliper matching where all of the comparison members within the caliper are used (Dehejia & Wahba, 2002). This method has an advantage of using only as many units as are available within a caliper (*c*), allowing for more matching options. P. Rosenbaum & Rubin (1985) recommends caliper used to be one-fourth the share of the standard deviation (*s.d*) of the probability model of the propensity score ($c = 0.25*s.d$). Loos & Zeller (2014) tested a range of fractions and found P. Rosenbaum & Rubin, 1985's recommendation superior for minimizing the remaining mean standardized bias and variance after matching on the propensity score for radius matching.

5.3.2.2.1.2.3. Stratification and interval matching

Also known as the interval matching, blocking and sub classification (P. Rosenbaum & Rubin, 1983), stratification matching approach partitions the common support of the propensity score into a set of intervals (strata) and calculates the impact within each interval by taking the mean difference in the outcome between the treated and control observations (Caliendo & Kopeinig, 2005). Five classes are often enough to remove 95% of the bias associated with one single covariate (Cochran & Chambers, 1965) since under normality the use of five strata removes most of the bias associated with all covariate (Imbens, 2004).

5.3.2.2.1.2.4. Kernel and local linear matching

"Kernel matching and local linear matching are non-parametric matching estimators that use weighted averages of all individuals in the control group to construct the counterfactual outcome" (Caliendo & Kopeinig, 2005:10). This matching method has a major advantage of having lower variance due to the use of more information. There is however a drawback of having bad matches of observations used hence strongly requiring a proper imposition of the common support condition (Caliendo & Kopeinig, 2005).

The bandwidth parameter is even more important since its implementation come with trade-offs. According to Caliendo & Kopeinig (2005), high bandwidth values yield a smoother estimated density function which lead to a better fit and a decreasing variance between the estimated and the true underlying density function but could lead to biased estimates. “The bandwidth choice is therefore a compromise between a small variance and an unbiased estimate of the true density function” (Caliendo & Kopeinig, 2005:11).

5.3.2.2.1.3. Checking for sufficient overlap/common support

Treatment effects can only be estimated over the common support region. It is therefore important to check the region of common support between a treatment and comparison group. The most straightforward way as indicated in Caliendo & Kopeinig (2005) is a visual analysis of the density distribution of the propensity score in both groups. By implementing the common support condition, any combination of characteristics observed in the treatment group can be observed in the control group (Bryson et al., 2002).

Individuals that fall outside the defined region of common support are disregarded and for these individuals the treatment effect cannot be estimated. There may be concerns however whether the estimated effect on remaining individuals can be viewed as representative if the proportion of lost individuals is too large (Caliendo & Kopeinig, 2005). It may therefore be necessary to carry out sensitivity tests to inspect characteristics of discarded individuals since those can provide important clues when interpreting the estimated treatment effect.

5.3.2.2.1.4. Estimating treatment effect and assessing matching quality

As discussed in prior sections, after conditioning on the propensity score, matching procedure must be able to balance the distribution of the relevant variables in both control and treatment group. This needs to be checked (Caliendo & Kopeinig, 2005).

P. Rosenbaum & Rubin (1985) suggests looking at the standardized bias (SB) before and after matching. A bias reduction below 3% or 5% after matching is considered acceptable (Caliendo & Kopeinig, 2008). The standardized bias calculation is given by:

$$\mathrm{SB(X)} = 100 * \frac{\bar{\bar{X}}_T - \bar{X}_C}{\sqrt{0.5[V_T(X) + V_C(X)]}} \tag{6}$$

where $\bar{\bar{X}}_T$ (V_T) is the mean (variance) in the treatment group and $\bar{X}_C$ (V_C) the analogue for the control group, X is the covariant and SB is the standardized bias.

P. Rosenbaum & Rubin (1985) alternatively uses a two-sample t-test to check if there are significant differences in covariate means for both groups. Differences are expected before matching, but covariates should be balanced in both groups after matching hence no significant differences should be found. Using this matching quality assessment approach does not provide a clearly bias reduction before and after matching (Caliendo & Kopeinig, 2005).

Furthermore, one can also perform an F-test on the joint significance of all regressors. This test should not be rejected before, but should be rejected after matching (Caliendo & Kopeinig, 2005).

“The basic idea of all approaches is to compare the situation before and after matching and check if there remain any differences after conditioning on the propensity score. If there are differences, matching on the score was not (completely) successful and remedial measures have to be done, e.g. by including interaction-terms in the estimation of the propensity score” (Caliendo & Kopeinig, 2005:15).

Calculating Treatment Effect and Standard Error

Bootstrapping as suggested by M Lechner (2005) is one way of dealing with the problem of variation beyond normal sampling variation of the estimated variance of the treatment effect which also include the variance due to the estimation of the propensity score, the imputation of the common support, and possibly also the order in which treated individuals are matched (Caliendo & Kopeinig, 2005).

This is a widely-used method (see e.g. Black & Smith, 2003 or Sianesi, 2001b) and a popular way to estimate standard errors in case analytical estimates are biased or unavailable (Caliendo & Kopeinig, 2005).

Each bootstrap draw includes a re-estimation of results from the propensity score estimation stage through to the stage of estimating the average treatment effect. N bootstrap repetitions lead to N estimated average treatment effect using N bootstrap subsamples (Caliendo & Kopeinig, 2005). The downside to this method is it is very time consuming and might not be feasible in some cases.

5.3.2.2.1.5. Sensitivity analysis

The final step of a PSM addresses the sensitivity of the model. P. R. Rosenbaum (2005) proposes the use of a bounding approach to address the problem of “hidden bias” (DiPrete & Gangl, 2004) which occurs if there are unobserved variables which affect assignment into treatment and outcome variables simultaneously. The approach identifies a critical level of influence (a gamma value) a variable excluded from the model may reach, before the implication of the matching analysis needs to be questioned. This is to determine how strongly an unmeasured variable must influence the selection process in order to undermine the implications of the matching analysis (Caliendo & Kopeinig, 2005).

As discussed in section 5.3.2.2.1.3 disregarded individuals that fall outside the region of common support could carry useful information especially for heterogeneous treatment effects. This is another reason to check for robustness of estimated treatment effects (see Michael Lechner, 2008).

The gamma value is usually reported alongside the matching quality test. Rosenbaum-bounds only reflect worst case scenarios (DiPrete & Gangl, 2004) and may not be relevant when the choice of the set of observables are guided by economic theory.

PSM analyses were carried out using STATA software version 12.0.

5.3.3. Communities

To get qualitative data to assess the impact of mechanization services focus group discussion were conducted. In the location where the small holder farmers were interviewed who receive the mechanization services from emerging farmer, male and female focus group discussions were conducted separately in the same location. 13 Male and 12 Female focus group discussions were conducted in total. These focus group discussions helped to generate information and capture the effects at community level.

Photo 5-2: Focus group discussion with women group

Participatory Impact Diagrams was used to facilitate the discussions, which is a tool used to assess the positive and negative impact of development interventions. The discussion started with the round of introduction and informing farmers about the purpose of the study and the discussion session. (Kariuki & Njuki, 2013)

In each session, the participants were asked the following questions:

a) What are the positive impacts of mechanization?

b) What are the negative impacts of mechanization? and

c) What are the challenges that hinders adoption of mechanization services?

The group constituted farmers who use mechanization services as well as the farmers who do not use mechanization services. The male and female discussions were carried out separately which allowed us to consider the perspective of both men and women. At the beginning of each session, the farmers were asked some general questions on communities as the number of farm household, and out of them the number who uses manual, animal, and mechanical traction. The discussion was then preceded by placing a picture of tractor at the centre of the large sheet of paper. The participants were then asked to mention the positive and negative immediate or direct changes related to mechanization at the household and/or community level and drew the mention changes on the paper. The positive changes were drawn on the right-hand side of the paper and negative changes on the left-hand side of the paper. The participants were encouraged to discuss about the mechanisms of each of the changes and to assess whether the change affected mostly men or women, and how many household of the community. The participants were also asked the second-round effects of the subsequent changes of each direct change, which resulted in "change trees". Again, participants were asked to discuss and asses the magnitude of the change on different community members.

The focus group discussions were recorded and for analysis the discussions were transcribed. The discussions were analysed using interpretative techniques and making record of how many male and female groups discussed a specific theme.

Chapter 6: Results

The main aim of this thesis as outlined in subsection 1.3 is to assess the economic and social impact of mechanization schemes described in section 3.2 on the smallholder farmers and their farming communities. On the side of the tractor owner, it also attempts to assess the viability of the John Deere mechanization scheme service provision business model in Zambia. Results from analyses of both quantitative and qualitative data addressing these goals are presented in this chapter.

6.1. Tractor owners

This subsection presents findings related to the tractor owner. It provides information on the general profiling of these tractor owners, experiences with the schemes, service provision and results of an investment analysis on the use of the acquired facility.

6.1.1. Profile of the tractor owners

Table A - 1 in the Annex provides detailed information on each of the interviewed tractor owners who participated in the Mechanization Schemes. On the average, the farmers owned 90 ha of land. All tractor owners had school education. The minimum was 2 years, on the average, the tractor owners went to school for 9 years, which indicates that they are better educated than the average farming population. The tractor owners typically had other off-farm business; agro-dealers, transportation, timber, livestock and diary trading, grocery shops or work for the public sector (e.g., as teachers). The reasons to provide services to the smallholder farmers are as a source of income for the repayment of the tractor, business and to help the community. On the other side, some tractor owners do not provide services as organizing them could be tedious, time consuming, also to increase the self-life of their tractor since the smallholder's field are not cleared properly (contains stones and stumps) and the hiring rates are low from which they cannot benefit.

The tractor owners saved for a minimum of a year to maximum of 7 years before buying the tractor, while some took loan from ZNFU and some informal sources of credit or sold assets like land. On the other hand, few had immediate cash from their crop harvest.

Box 1 illustrates an example of a young emerging farmer who owns two tractors and post mechanization has expanded his area of cultivation.

Box 1: Example of an emerging farmer in Lusaka Province

Mr. X is 30-year-old emerging farmer in Lusaka. He acquired his first tractor in 2012 under John Deere first scheme. He got his second tractor in 2014. He chose John Deere as he considers it to be the best. To get his first tractor, he saved for 7 years from his carpentry and grocery businesses.

He owns a ripper, which he got with the tractor, disc plough, planter, and boom sprayer. He operates the tractor with his driver. The wage of the driver is 10% of the net income. He has received the training from AFGRI on operation and maintenance of the tractor. He received servicing only for the first tractor he bought in 2012 for 2 years but not for the latter one since it was not part of the scheme.

He started providing services to the smallholders from 2012. He provides services for business. He makes profit of around 30,000 to 40,000 ZMK in a season. He serves around 100 farmers within the radius of 50 kilometers. When the distance is above 50 km the farmer/customer had to buy the diesel. The minimum field size for him to provide service is 3 ha of land. Right after harvesting, he prepares his own land before providing services to others. He owns implements such ad ripper, disc plough, planter, and boom sprayer.

The major crops grown by him are maize and soybean. In 2014, he cultivated 10 hectares of land, maize in 7 hectare and soybean in 3 hectares. He also does pig farming. He has 18 of them. He is the only one in the family to work. He hires labor for harvesting and shelling.

Besides farming, he has transportation business, grocery shop and timber business. He uses one tractor for providing services and the other for timber business.

"*… before I was only managing 1 ha so after I got the tractor I went up to 10 ha*."

Photo 6-1: Compound of an emerging farmer

Source: Thomas Daum

Box 2 illustrates an example of an emerging farmer who provides services to smallholders and looking forward to having one more tractor so as he could meet the demand of smallholders.

Box 2: Example of an emerging farmer in Eastern Province

Mr. is an emerging farmer in Eastern Province of Zambia. He has studied up to Grade 6. He acquired his tractor in 2013 of 65 HP. This is his first tractor and he got the information about the John Deere scheme via CFU. He got his tractor along with a ripper as a package. The total cost of the package was 300,000 ZMK. He pays monthly installments in kind and expects to finish repayment by the end of 2016.

He started providing services from 2013. He provides service as business. He serves around 50 smallholder farmers within the radius of 20 kilometers. The smallholder farmers are selected and organized by CFU. The minimum field size he serves is 0.5 hectare. The small holders sometimes fail to pay for the services on time which is one of the challenges he faces. However, the farmers pay back after selling their produce.

He owns disc plough, ripper, trailer and sheller. He uses sheller only for himself. He has an operator. The operator has received training by CFU on operation, maintenance and use of ripper. He pays 700 ZMK per month to the operator.

He owns and cultivates 70 hectares of land. As there is high demand for ripping, he first prepares his own field and then provides land preparation services to smallholders. He cultivates only maize. In 2014/15 season, he had yield of 2600 bags of maize of 50 kg each. He also has 37 cows. He hires labor for planting, fertilizer application, weeding and harvesting. Besides farming, he runs transportation business, lodge, and grocery shop.

"*.. I would love to have another tractor… may be one just working on my own field and other one goes out. Having only one is a challenge. ……. I just need to ignore some of them (smallholder farmers because of high demand) to work well…*"

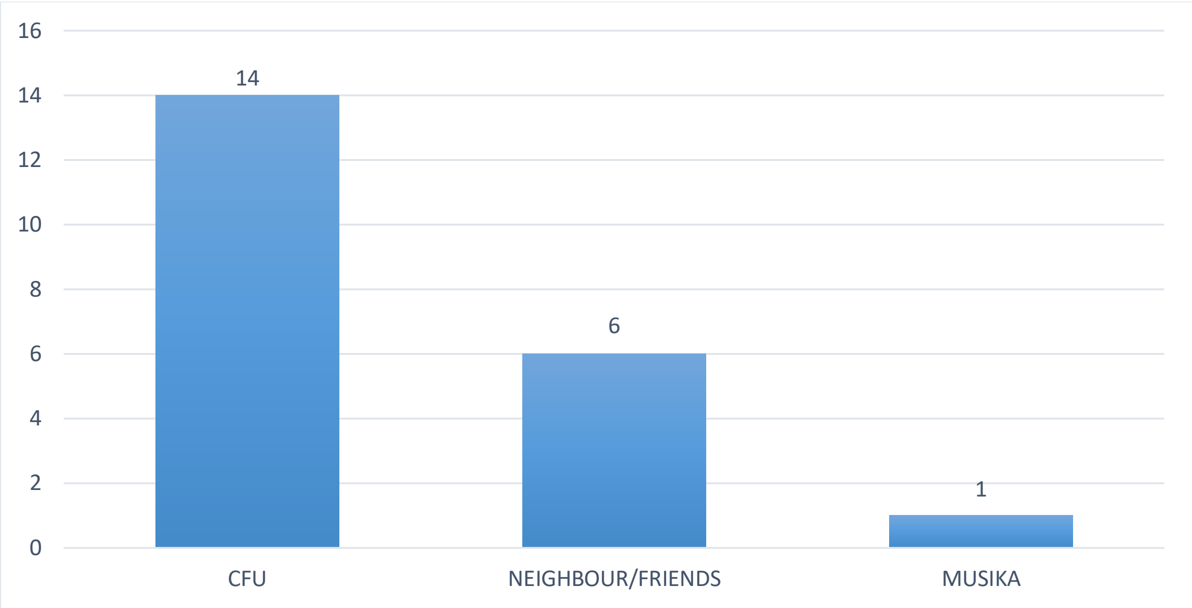
6.1.2. Experiences with the Mechanization Schemes

This section presents the findings on the farmers' experience with the Mechanization Schemes.

6.1.2.1. Motivation to participate in the Schemes

Majority of farmers could purchase their first tractor after the participation in the scheme. The farmers were asked how they got to know about the John Deere /AFGRI mechanization schemes.

Figure 6-1: Source of Information



In the first scheme, John Deere collaborated with CFU and MUSIKA, as an organization linking smallholders and AFGRI. CFU suggested promising farmers and linked to AFGRI. It was through this partner organization where tractor owners knew about the scheme.

The tractor owners chose John Deere tractors because of its strength, durability and for some, through their previous experiences with John Deere tractors. John Deere tractor being very expensive, some chose John Deere tractor also to take benefit from the scheme since it allows them to pay in instalments. John Deere scheme/approach is an opportunity for farmers who wanted to acquire tractor. The other attractions of the schemes were trainings on maintenance and operation to the farmers who acquired tractor, servicing facilities up until 3000 hours, trainings by CFU under the first scheme.

The farmers who acquired tractor have large land holdings on average 91.3 hectares of land. The common reasons for them to have tractor is to reduce drudgery of farming and to be able cultivate more land.

When asked "Why did you choose John Deere?" tractor owners replied as:

"*… John Deere tractor is durable and strong and I got used to them.*"

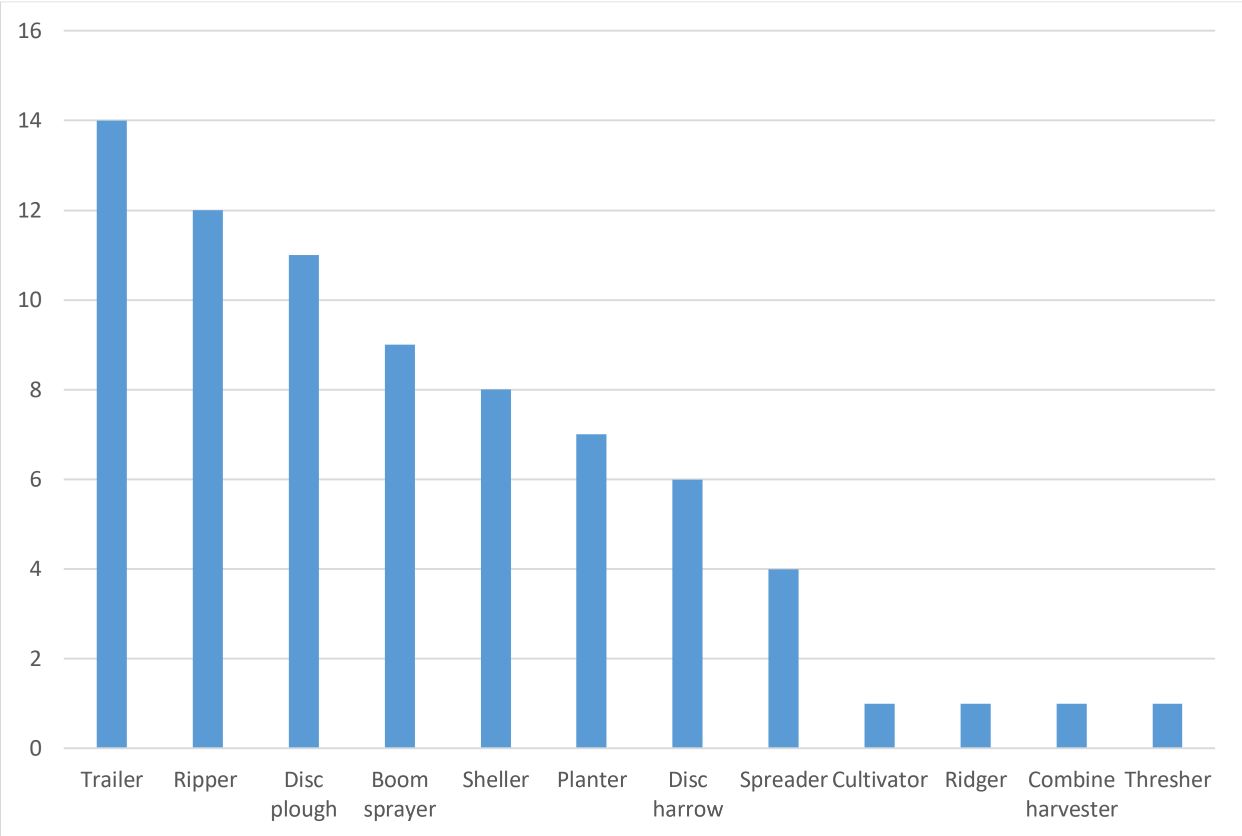
"*I need only JD because they have power, very strong…*"

"Admire John Deere since my grandfather used to have one and it served and stayed for more than 25 years…"

6.1.2.2. Implements and Processing tools owned

The Figure 6-2 shows the number of tractor owners possessing different forms of implements and processing tools. Per the graph, maximum number of tractor owners own a trailer followed by ripper, disc plough, boom sprayer, sheller, planter, disc harrow, spreader. While very few farmers owned cultivator, ridger, combine harvester and thresher.

Figure 6-2: Implements and processing tools owned by tractor owners



The type of implements farmers own depend upon the part of scheme they are in. In the first scheme, John Deere collaborated with CFU and MUSIKA, as an organization linking smallholders and AFGRI. CFU suggested promising farmers and linked to AFGRI. The farmers received tractor and a ripper which allows land preparation according to the principle of Conservation Agriculture.

However, in the 2nd scheme, farmers could choose any implements as AFGRI didn't collaborate with CFU. Similar is the case in the third scheme. Therefore, the type of implements farmers chose depends on the part of the scheme. The other implements such as boom sprayer, planter, sheller depend upon the size of farm, only the big farmers have those implements.

6.1.2.3. Breakdown, spare parts and servicing

Of the tractor owners interviewed, majority of the farmers did not face any breakdown of the tractor so far. Four of them had faced major breakdown while only few i.e. two had faced some minor breakdown.

Major breakdown were often problems with:

- Rings
- Clutch plates
- Engine
- Operator's negligence
  - Accident due to drinking alcohol and driving
  - Passing the tractor through river where by water passed through the engine.

Minor breakdown was problem with:

- PTO cable

In the case of breakdown, the spare parts are easily available at AFGRI. Though expensive the spare parts bought are of good quality and durable. Also, the tractor owners report that the spare parts are easily available for the new tractors but difficult for the old ones. The farmers are not allowed to buy spare parts else other than AFGRI.

As a part of the scheme, the tractor receivers were provided with 3000-hours servicing plan. The servicing included change of filters and change (engine, disc etc.) oil. The payment for servicing varied with different tractor receivers.

For 5 number of farmers, the servicing charge was paid at the time of servicing which varied from 2000-3000ZMK depending upon the distance of the farmer from AFGRI.

For 8 number of farmers, the servicing charge was already included in down payment.

For 1 farmer, the servicing was free for the first time then had to pay 1200ZMK every time when the tractor was serviced.

There have also been cases where farmer (only one) didn't receive servicing at all and in the other case, 1 farmer received servicing for only one year.

The tractor owners were also provided with 2-3 hours of technical training on maintenance and operation of the tractor.

6.1.2.4. Financing

Under all the schemes, tractor-owner had to pay certain amount of down payment depending upon the schemes they are part of. The emerging farmers saved for a minimum of a year to maximum of seven years before buying the tractor, while some took loan from ZNFU and some informal sources of credit or sold assets like land. On the other hand, few had immediate cash from their crop harvest.

Table 6-1: Financial arrangements of the Mechanization Schemes

Scheme	Financial arrangements	Risk management arrangements	Total number of participating farmers (until April 2016)
I: Pilot Scheme	Down payment: 20%; Pay-back in 36 months in monthly installments Interest rate: 14% - calculated in USD	John Deere and CFU covered each 10% of the default risk; AFGRI covered the remaining 80%	34
II: Tractors for Maize	Down payment: 20%; Pay-back in 36 months in form of maize after each harvest; market price of maize was converted to USD	MUSIKA covered 50% of default costs, up to USD 4,000 per case	40
III: ZANACO Scheme	Down payment: 20%; loan by ZANACO at commercial interest rate (approx. 30%); John Deere Financial subsidizes 1-4% of this rate; repayment in four annual instalments to be freely selected by the farmer	Default risk is entirely born by ZANACO	6

The tractor owners under the first scheme had to pay instalments monthly which was very stressful because of seasonality of farming. Some tractor owners also struggle to repay because of weather risk such as drought. One of the other challenges for the farmers were depreciation of the local currency. Since the scheme was based on repaying on US- Dollars, it was challenging for the farmers when the Zambian Kwacha started depreciating substantially by the end of 2013.

This scheme was an improvement to the first scheme. Under this scheme farmer had to make an upfront down payment of 30% and the remaining had to be paid in 3 farming seasons in the form of grains (maize, soybean, sunflower, and wheat). Under this scheme too, the repayment was on US-Dollars, so it was again challenging for the farmers due to the depreciation of the local currency to dollars. The other challenge was the weather pattern; there was no good rainfall due to which it was difficult for the farmers to pay back on time.

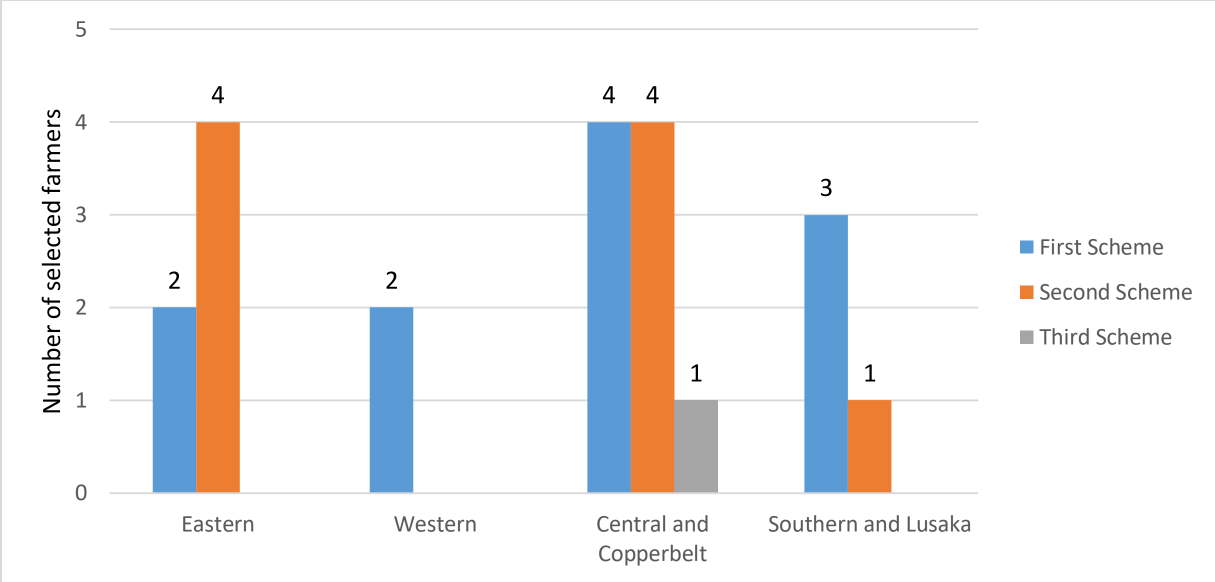
6.1.3. Service provision by tractor owners

Out of 21 interviewed tractor-owners only 12 provided service to smallholders i.e. less than 60%provide the tractor service to smallholders. This section covers the information on the patterns of service provision, motivation of service providers and their characteristics.

6.1.3.1. Patterns of Service Provision

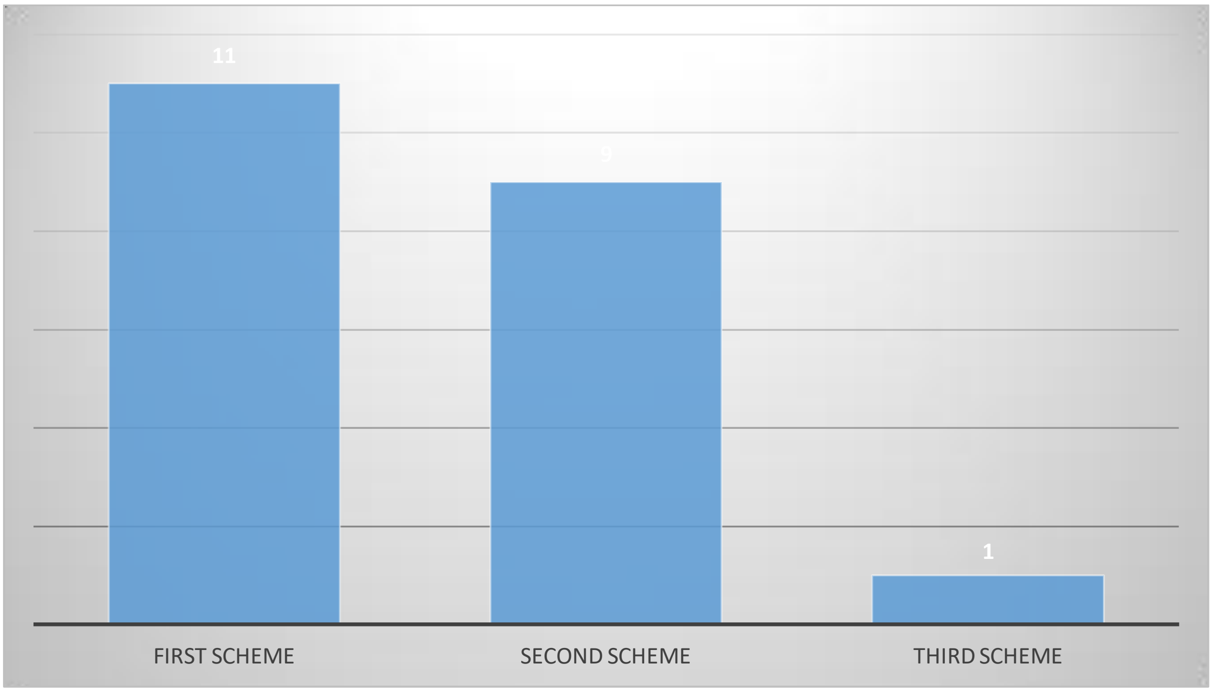
The chart shows the number of tractor owners under different schemes in 4 different provinces where the study was carried. In the Eastern Province, 6 tractor owners were interviewed out of which 2 acquired tractor under first scheme and 4 under second scheme. Similarly, there were 2 tractor owners under first scheme in the Western Province. In Central and Copper Belt region, 4 farmers each from first and second scheme were interviewed and 1 from the third scheme. Similarly, in the Southern and Lusaka region, 3 farmers under first scheme and 1 farmer under second scheme were interviewed

Figure 6-3: Number of selected tractor-owners by region and scheme



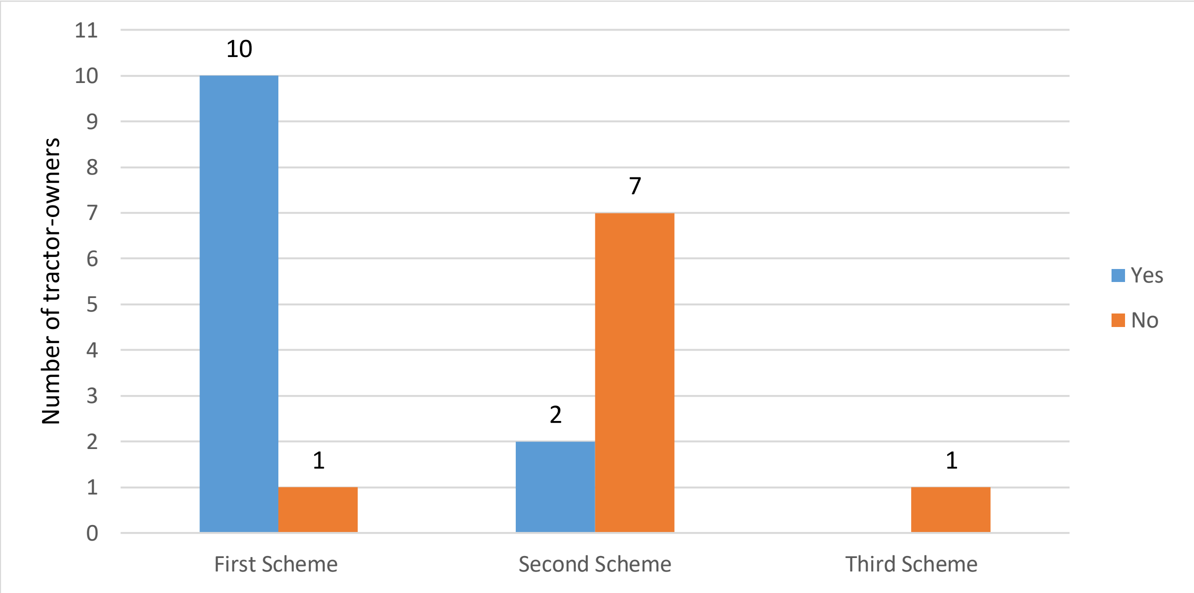
Of the 21 farmers interviewed, 11 were under the first scheme, "Pilot Scheme"; 9 under the second scheme "Tractor for maize" and only one under the third scheme "ZANACO Scheme".

Figure 6-4: Number of farmers under different schemes



The chart shows that service provision under the first scheme was the highest compared to second and third scheme. One of the reasons for this could be collaboration of John Deere with CFU under the first scheme.

Figure 6-5: Number of tractor-owners providing services, by scheme



The chart shows the count of tractor owners providing services in different provinces. Of the interviewed tractor owners in Western, Southern and Lusaka region, all provided services to the smallholders. Whereas, in the Eastern , Copper Belt and Central region the number of farmers not engaged in providing services were higher to that of providing services.

Figure 6-6: Number of tractor-owners providing services, by region

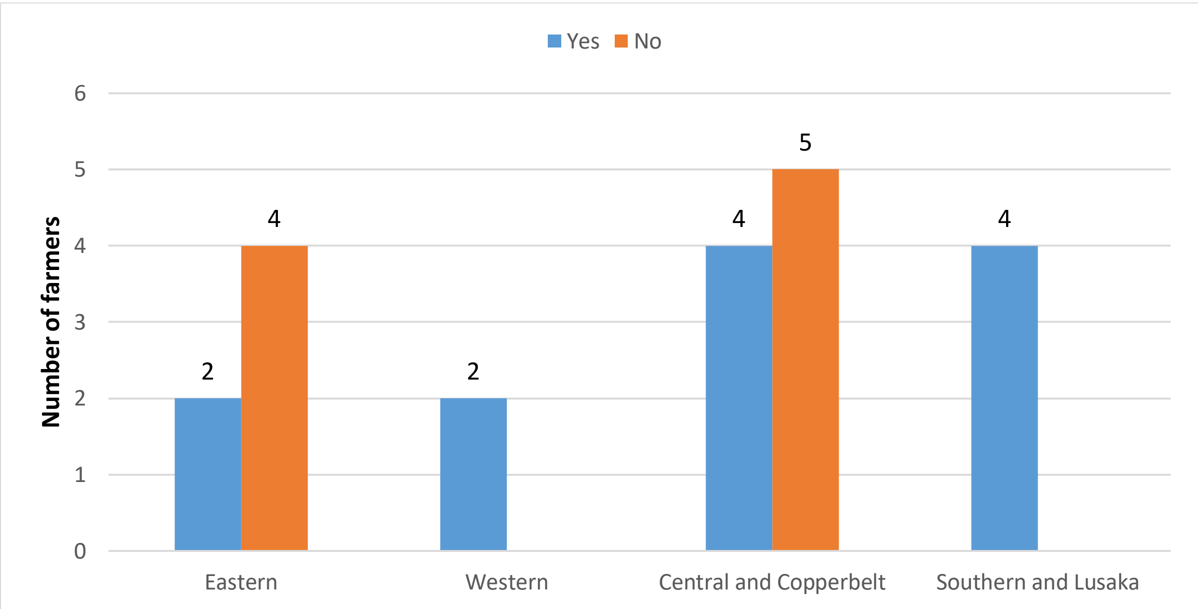


Figure 6-7 shows the relationship between education of the tractor owners and service provision. The tractor owners who are less educated (below grade 6) do not provide much services as compared to educated or more educated group. The tractor owners who are educated (between grade 6 and 11) provide services more compared to less educated. The farmers who are more educated above grade 11, all of them provide mechanization services to the smallholders.

Figure 6-7: Education level of farmers and service provision

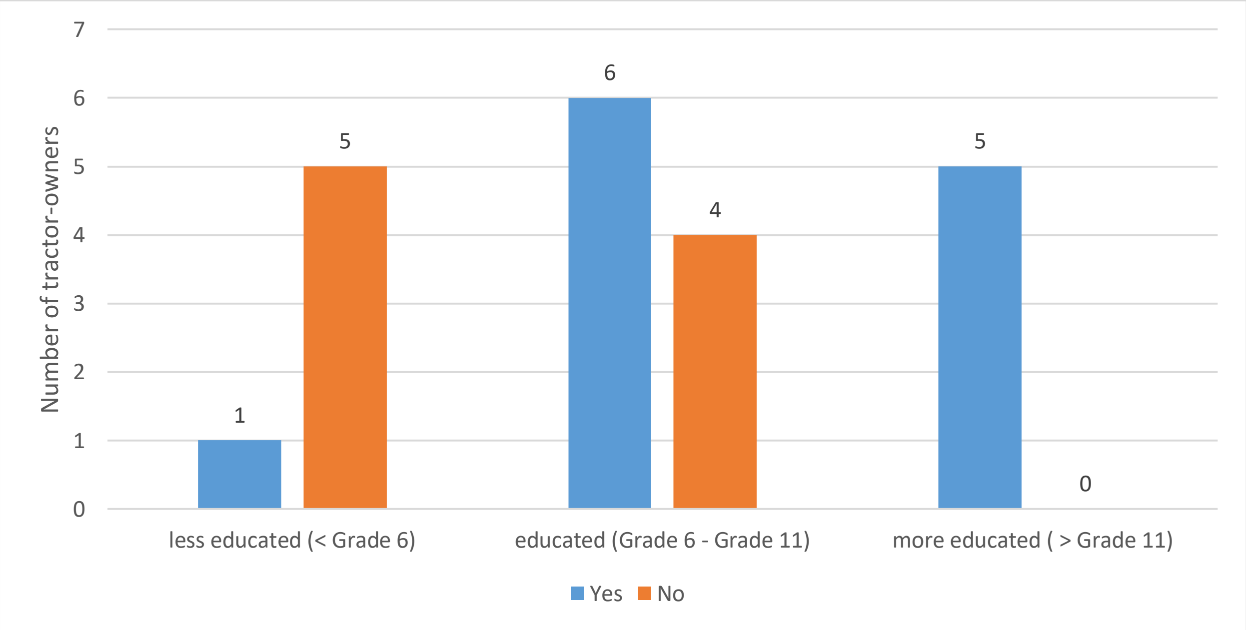


Table 6-2: Descriptive information on Service Provision

	Minimum	Maximum	Average
Number of farmers served	9	157	57
Field size served (ha)	0.4	56	5.3
Radius served (km)	0	80	44

Table 6-3: Fees charged for service provision

	No. of farmers providing that service	Minimum (ZMW)	Maximum (ZMW)	Average (ZMW)
Ripping (Fee per ha)	11	250	400	340

Ploughing (Fee ha)	2	520	900	710
Shelling (Fee per 50kg bag)	3	2	4	3

Out of the 21 interviewed tractor owners, only 12 provide services to the surrounding small holders, mainly for ripping, ploughing and shelling i.e. 57% of the tractor owners provide hiring services.

When possible, tractor owners serve smallholders who demand more than 0.5 ha of land to be served and who are close by. Nevertheless, the tractor owners serve on an average of 44 kilometres. The tractor owners offer services for an average of 57 farmers and the average land served is 5 ha.

In addition, most tractor owners first prepare their field as soon as after the harvest making sure they have enough time to serve smallholders for upcoming season especially for ripping to catch the rainfall. The fees for different services are listed in Table 6-3.

6.1.4. Investment Analysis

Result from the investment analysis is reported in Table 6-4 below. This result indicates a wide variation in the profitability of the investment. While some farmers realize significantly high positive IRR, the returns on similar investments yielded negative rates for other farmers. At a bank lending rate in the range of 30% at the time of the survey in Zambia, a medium scale farmer should achieve an IRR in that range for the investment to be profitable. From Table 6-4, it can be observed that half of the selected farmers could achieve an IRR above this level. The example of the first two farmers (A and B) shows that the investment in the tractor can be highly profitable. However, the table also indicates that not all farmers were able to use the tractor in a profitable way, as indicated by the negative IRR in the last two cases (E and F).

Data gathered suggests that the profitability of a medium scale farmer who participated in the scheme depends on four main factors. The first is the farmers' ability to achieve high productivity on their own farms. Table 6-5 shows the varied maize yields from around 1.5Mt to 3.5Mt for the six selected farmers. Second noticeable factor was the substantial differences in the prices at which farmers could sell their produce. These were influenced, as gathered from the interviews, by produce selling times, the farmer's bargaining power and their distance to major markets. The third factor was a farmer's ability to utilize the tractor not only for his/her own farming operations but also providing services for others. In this light, the total area and number of bags of shelled for land preparation and processing services respectively as well as their related service charges were crucial. The total land size serviced for the selected medium scale farmers as shown in Table 6-4 for example varied from 0 to 300 ha. The fourth factor was the depreciating value of the Zambian kwacha (ZMW) against the US dollar. This was a peculiar problem because the original cost of the mechanization package was in US dollars for which a beneficiary farmer made Zambian kwacha equivalent instalment payments within the payback period. A depreciating local currency meant a farmer had to pay more than originally anticipated.

Table 6-4: Investment calculation for sample farmers

ID	Province	Scheme	Own area (ha)	Own Farm Income (ZMW)	Area Serviced (ha)	Income from Service Provision (ZMW)	Income from shelling (ZMW)	Annual Net Income	Internal Rate of Return
A	Central	II	97	388,000	58	30,160	13,836	195,849	255%
B	Central	I	40	216,000	300	90,060	2,200	119,163	380%
C	Central	I	19	93,100	173	51,810	4,000	37,616	67%
D	Southern	I	29	64,844	30	17,400	-	22,883	28%
E	Copper Belt	II	62	146,301	0	-	-	-13,223	-24%
F	Eastern	II	60	120,120	100	30,000	-	-16,209	-28%

Note: 1 USD equals approx. 10 Zambian Kwacha (ZMW)

Table 6-5: Gross margin table for 6 tractor owners

ID (Crop)	A (Maize)	B (Maize)	C (Maize)	D (Soybean)	E (Maize)	F (Maize)
Yield (Mt/ha)	2.5	3.0	3.5	0.9	1.7	1.4
Price (ZMW/Mt)	1,600	1,800	1,400	2,600	1,400	1,300
Revenue (ZMW/ha)	***4,000***	***5,400***	***4,900***	***2,236***	***2,360***	***1,859***
Costs						
Land Preparation (ZMW/ha)	479	322	317	259	456	386
Production cost (ZMW/ha)	1,735	1,735	1,735	904	1,735	1,424
Total Cost (ZMW/ha)	***2,214***	***2,056***	***2,052***	***1,163***	***2,191***	***1,809***

Gross margin/ha (ZMW/ha)	*1,786*	*3,344*	*2,848*	*1,073*	*169*	*50*
Total cultivated area (ha)	97	40	19	29	62	60
Total gross margin (ZMW)	*173,233*	*133,750*	*54,121*	*31,126*	*10,458*	*2,980*
Total gross margin ($)	***17,323***	***13,375***	***5,412***	***3,113***	***1,046***	***298***

Note: 1 USD equals approx. 10 Zambian Kwacha (ZMW)

Five different scenarios were calculated to assess the influence changes in costs, yields and price of farmers' produce had on the IRR. This is displayed in the sensitivity analysis computation of Table 6-6. From this, it can be observed that an increase in yields or prices by 20% or cost reduction by 20% would move farms E and F into the positive range. However, they would still not meet the recommended level of an IRR of at least 30%. Farms C and D under similar conditions increase their positive IRR with farm D becoming profitable under these scenarios. Farms A and B would still remain profitable, even if the yields were 20% lower or the costs were 20% higher. An increase in own land cultivated or area of serviced land by 10 hectares increases the IRR in all cases with farmer D becoming profitable again under both scenarios.

Table 6-6: Sensitivity analysis for investment

ID	Current IRR	20% cost decrease	20% cost increase	20% yield increase	20% yield decrease	20% output price increase	10 ha own land increase	10 ha serviced land increase
A	255%	302%	208%	363%	159%	363%	291%	258%
B	380%	499%	257%	550%	209%	550%	524%	381%
C	67%	119%	41%	120%	28%	120%	156%	67%
D	28%	41%	23%	48%	9%	48%	45%	38%
E	-24%	4%	NA	21%	NA	5%	-19%	-23%
F	-28%	1%	NA	-3%	NA	-3%	-18%	NA

Note: NA indicates that for these cases, the IRR calculation (which is based on iterations) could not find a result

6.2. Smallholders

Results from the PSM method used to assess the economic and social impact of mechanization schemes described in section 5.3.2.2. on the smallholder farmers is presented in the subsections below. This section begins with some summaries of the data used for this analysis.

6.2.1. Descriptive Analysis before Matching

To help provide a general overview of the data and to generate a sense of what to expect when more robust analytical methods were applied, some general descriptive analyses were done. The following subsections provide the results of these analyses.

6.2.1.1. Commonly Mechanized On-farm and Off-farm processes

Data used for the assessment of the impact of the mechanization schemes on smallholder farmers was collected from a total of 250 farmers within 16 districts in 6 provinces. As indicated in Table 6-7, the total number of respondents included 121 farmers each of who received mechanization services from one of the tractor owners who participated in one of the three mechanization schemes (hereon referred to as participants) and 129 smallholders who did not receive such services (hereon referred to as control group). Some members from both groups hired post-harvest services (shelling or threshing) usually for their maize outputs.

Table 6-8 presents, from the survey data gathered, a summary of the distribution of the types of mechanization used by smallholders between land preparation and produce processing which the researchers identified as two operations commonly mechanized. 77% of the total surveyed farmers manually processed their harvested produce while 23% used mechanized power sources. The common way of manual processing (especially maize) was by spreading the dried harvested produce on a clean floor and beating with a stick to get the grains off the cobs. 16% of all surveyed farmers tractor-mechanized both land preparation and processing activities, 7% mechanize only processing activities and 45% mechanized neither land preparation nor processing activities.

Among the 121 participants, a share of 32% went on to mechanize their processing activities compared to 13% of the 129 farmers from the control group during the 2015 – 2016 farming season as shown in Table 6-9. Processing services are mostly provided either by hired motorized processing equipment or by businesses solely providing these services. This is shown in Table 6-10.

Table 6-7: Summary of survey data used

JD_Mechanized	Frequency	Percentage
Non-participants	129	51.6

Participants	121	48.4
Total	250	100

Table 6-8: Summary of mechanization of land preparation and processing from data

Activity	Share
Manual Processing (%)	77
Mechanized land preparation and processing (%)	16
Non-mechanized land preparation and non-mechanized processing (%)	45
Mechanized processing only (%)	7

Table 6-9: Degree of mechanization of land preparation and processing

Activity	Participants	Non-participants
Land preparation (%)	100	4
Processing (%)	32	13

Table 6-10: Source of mechanized processing service provision

Source	Share
Own motorized processing equipment (%)	0%
Hired motorized processing equipment (%)	12%
Processing services (%)	10%
Cooperative processing services (%)	0%

6.2.1.2. Socio-economic characteristics

Table 6-11 presents information about the socio-economic characteristics of the surveyed smallholder farmers. The table indicates that smallholders who received tractor services generally have similar characteristics as those who do not receive services. Most differences shown in the table were not statistically significant except for land cultivated per household member and livestock owned per household member. With these two characteristics, the table identifies household members of participant groups as cultivating almost twice as much land and owning almost double as many livestock as their counterparts in the control group. Both groups however owned between 6 to 7 hectares of arable land (see Table 6-19). Averagely, household heads of participants (who usually turn out to be the participants themselves or their spouses) were better educated than those of their control group counterparts. This difference was however not statistically significant.

These findings indicate that participation in the Mechanization Scheme was not biased towards special groups of smallholders with unique socioeconomic characteristics. However, data suggests that the schemes are implemented in areas where smallholder farmers tend to have somewhat larger holdings and higher education levels than on the national average (see (IAPRI, 2015).

A subset of the socioeconomic characteristics in Table 14 was included in probit model to estimate the propensity score used for matching. The selection was done based on economic theory, past empirical findings and supported by qualitative information gathered during the survey as discussed above.

Table 6-11: Socioeconomic characteristics of the surveyed smallholder farmers

Variable	Total (N=250)	Standard deviation	Participants (N=121)	Control Group (N=129)
Farming experience (years)	20.6	12.0	20.1	21.0
Off-farm business participation (yes/no)	0.4	0.5	0.46	0.40
Household membership	7.4	2.8	7.4	7.4
Gender of household head (male=1/female=0)	0.2	0.4	0.22	0.18
Education level of household head (years)	7.7	3.5	8.3	7.2
Land ownership (ha)	10.0	14.3	10.8	9.2
Cultivated land per capita (Ha)	0.69	0.93	0.90	0.49
Access to extension service (yes/no)	0.70	0.46	0.74	0.65
Access to credit facilities (yes/no)	0.14	0.35	0.13	0.15
Market access (minutes)	30.7	25.5	30.9	30.5
Livestock ownership before Mechanization Scheme	7.9	15.1	9.6	6.2
Farmer’s investment behavior	0.80	0.26	0.81	0.79
Age of household head (years)	48.4	13.4	50.0	47.0

6.2.1.3. Labour Hours used on Farming activities

Differences in labour use for participant farmers and the control group are displayed in Table 6-12, Table 6-13, Table 6-14, Table 6-15, Table 6-16 and Table 6-17. Expectedly, the number of labour hours that can be saved is particularly high for land preparation. The higher labour hour demand for land preparation in the control group is due to the fact that these farmers either use manual labour for land preparation, animal traction or a combination of both depending on availability of these services.

Table 6-17 also show that participants spend, on an average, considerably less time for weeding. This is likely to be the effect of a combination of the increase in the share that uses herbicides (63% among participants as compared to 24% in the control group; see Table 6-19) and better land preparation usually with either a tractor drawn plough or ripper.

Participants are also able to reduce the labour time for processing because, as highlighted earlier in

Table 6-9, 32% of their share could access shelling services against 13% from the control group. Even though no statistically significant per hectare labour hour differences are observed (as shown in Table 6-17 and Table 6-17), Table 6-16 shows participants saving labour hours on planting, fertilizer application and harvesting activities when an overall farm labour use analysis was done. This could be because of tidier and more organized fields enhancing smoother and more efficient on-farm operations.

Table 6-12, Table 6-13, Table 6-14 and Table 6-15 also show a significant use of family labour time both on pre and post-harvest activities for both participant and control groups. In comparing the two groups Table 6-16 shows control groups using more of its family labour time, notably significant during weeding and processing. These differences are statistically significant for all operations except harvesting when assessed per hectare for all crops combined. The results further show how much women and children contribute to agricultural labour use. From these tables, there is quite a high reliance on women and children labour during planting and weeding (especially), fertilizer application, harvesting and processing activities with these two-family labour groups contributing over 50% of the total work force on average. These findings confirm the important role rural families play in contributing to agricultural labour force especially in SSA.

From Table 13, the total hired labour hours used by participants is more than twice that used by their counterparts from the control group. The difference is even more profound in Table 6-16 and Table 6-17 when analysis considers significance in the hired labour time used differences between the two groups for all crops. In fact, aside land preparation and maize processing; results from these tables show participants employ a significant share of the agricultural labour force for their crop husbandry operations than their counterparts from the control group.

From these tables, it can again be inferred that even though the total time for cultivation activities and processing is reduced when smallholders use tractor services, they also increase the overall size of cultivated land. When combined with higher yield per hectare realized by this group of farmers, the total labour requirement for crop husbandry activities is not significantly reduced due to mechanization. The increased yields, which increase the labour demand for harvesting and post-harvesting activities, may also contribute to this result, since shelling is only partly adopted as shown in Table 6-8.

Table 6-12: Labour hour use per hectare for cultivating and processing maize

Labor Dynamics	**Participants**						**Non-participants**					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	**Total Labour hours/ha**	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Land preparation	**6**	0	5	3	2	1	**162**	7	144	83	52	11
Planting (maize)	**53**	4	49	19	27	3	**60**	2	57	17	36	4
Fertilizer application (maize)	**52**	6	44	20	21	3	**66**	1	63	24	31	8
Weeding (maize)	**122**	29	91	40	45	7	**361**	18	339	147	169	23
Pests/ disease control (maize)	**7**	0	7	7	0	0	**7**	0	7	7	0	0
Harvesting (maize)	**215**	54	155	73	70	12	**240**	14	212	95	104	12
Processing (hours/50-kg-maize-bag)	**3**	0	2	1	1	0	**6**	1	5	2	2	0
TOTAL LABOUR HOUR USE	***458***	***93***	***353***	***163***	***166***	***26***	***902***	***43***	***827***	***375***	***394***	***58***

Table 6-13: Total farm labour hour use for cultivating and processing maize

Labor Dynamics	Participants						Non-participants					
	Total Labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	**Total Labour hours**	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Land preparation (Maize)	**39**	5	26	11	1	13	**312**	21	279	89	21	204
Planting (Maize)	**132**	24	86	44	6	36	**119**	5	102	71	6	26
Fertilizer application (Maize)	**127**	30	90	38	6	46	**135**	3	129	66	13	50
Weeding (Maize)	**235**	74	156	64	14	78	**574**	40	530	251	38	241
Pests/ disease control (Maize)	**24**	0	24	0	0	24	**13**	0	11	0	0	11
Harvesting (Maize)	**801**	421	360	146	26	189	**496**	50	425	194	27	204
Processing (Maize)	**205**	62	127	51	15	61	**387**	162	195	85	19	92
TOTAL LABOUR HOUR USE	***1563***	***616***	***869***	***354***	***68***	***447***	***2036***	***281***	***1671***	***756***	***124***	***828***

Table 6-14: Labour hour use per hectare for cultivating and processing all crops

Labor Dynamics	Participants						Non-participants					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	**Total Labour hours/ha**	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Land preparation	**10**	1	8	4	3	1	**226**	10	201	115	73	15
Planting	**81**	29	51	20	26	4	**92**	4	86	24	55	7
Fertilizer application	**47**	7	39	18	18	3	**60**	1	60	23	29	8
Weeding	**174**	51	122	51	63	8	**375**	24	344	148	172	24
Pests/ disease control	**14**	1	13	12	0	0	**43**	0	43	41	2	0
Harvesting	**314**	63	244	105	124	15	**328**	18	278	125	135	18
Processing (hours/50-kg-bag)	**5**	11	4	2	2	0	**9**	12	8	3	3	2
TOTAL LABOUR HOUR USE	***645***	***163***	***481***	***212***	***236***	***31***	***1133***	***69***	***1020***	***479***	***469***	***74***

Table 6-15: Total farm labour hour use for cultivating and processing all crops

Labor Dynamics	Participants						Non-participants					
	Total Labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	**Total Labour hours**	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Land preparation	**61**	7	41	18	2	21	**434**	29	386	109	26	251
Planting	**311**	149	153	74	15	67	**205**	17	181	124	11	48
Fertilizer application	**145**	47	92	38	6	48	**135**	3	129	66	13	50
Weeding	**478**	162	293	131	23	139	**791**	76	711	338	51	322
Pests/ disease control	**16**	2	14	0	0	14	**32**	0	32	1	0	31
Harvesting	**1263**	582	649	290	43	316	**840**	94	698	326	45	328
Processing	**296**	92	188	71	21	96	**514**	209	275	123	28	125
TOTAL LABOUR HOUR USE	***2570***	***1041***	***1430***	***622***	***110***	***701***	***2951***	***428***	***2412***	***1087***	***174***	***1155***

Table 6-16: Labour hour differences for cultivating and processing of all crops

	Total Labour hours		**Hired Labour hours**		**Family labour hours**		**Female and Children family labour hours**		**Female family labour hours**		**Children family labour**		**Male family labour**	
	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error
Land preparation	374***	65	22	23	348***	59	117***	36	93***	36	24***	6	231***	32
Planting	-106*	64	-131**	51	28	40	45	28	50**	23	-4	8	-19	17
Fertilizer application	-10	26	-44***	15	37	21	34**	15	29**	14	6	4	2	9
Weeding	313***	103	-86**	40	418***	96	768**	387	207***	49	28**	11	183***	48
Pests/disease control	16	9	-2	1	18	9	1	1	1	1	0	0	17*	9
Harvesting	-423**	221	-488**	195	49	102	38	54	36	48	2	13	11	54
Processing	218.2411	138	117	136	88**	39	52***	20***	51	20	7	7	29	19

Note: Mean difference is the difference between mean values of non-participant group members and participant groups

*Statistical significance at the 10% level, **Statistical significance at the 5% level, *** Statistical significance at the 1% level.

Table 6-17: Per hectare (per 50kg bag) hour differences for cultivating and processing of all crops

	Total Labour hours/ha		**Hired Labour hours/ha**		**Family labour hours/ha**		**Female and Children family labour hours/ha**		**Female family labour hours/ha**		**Children family labour/ha**		**Male family labour/ha**	
	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error
Land preparation	219***	59	9	6	196***	53	84***	31	70***	25	14*	8	111***	27
Planting	11	22	-25**	14	35**	17	32**	13	29**	12	3	4	4	6
Fertilizer application	13	12	-6**	2	21**	12	16**	8	11**	6	4	3	5	4
Weeding	200***	46	-27**	16	222***	44	125***	26	110***	24	16***	5	97***	22
Pests/disease control	29**	14	-1	1	31**	14	2	1	2	1	0	0	6	23
Harvesting	14	39	-45***	11	34	36	13	21	11	20	3	5	20	17
Processing (per 50kg bag)	4***	1	2	12	3**	1	2**	9	2***	1	1	0.3	1	0.6

Note: Mean difference is the difference between mean value of non-participant group members of the scheme and participant groups

*Statistical significance at the 10% level, **Statistical significance at the 5% level, *** Statistical significance at the 1% level.

Table 6-18: Per hectare (per 50kg bag) hour differences for cultivating and processing of maize

	Total Labour hours/ha		**Hired Labour hours/ha**		**Family labour hours/ha**		**Female and Children family labour hours/ha**		**Female family labour hours/ha**		**Children family labour/ha**		**Male family labour/ha**	
	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error	Mean difference	Standard error
Land preparation	219***	59	9	6	196***	53	54***	31	70***	25	14*	8	113***	27
Planting	7	9	2	1	8	9	10*	6	9**	5	1	2	-2	4
Fertilizer application	14	14	4***	2	19	14	15	9	10	7	4	2	4	5
Weeding	239***	52	-11	11	248***	52	141***	31	125***	29	16***	6	107***	24
Pests/disease control	-1	6	-0.2	0.3	0	6	0	0	0	0	0	0	-0.3	6.0
Harvesting	24	23	-40***	12	57**	22	34**	13	34***	12	0	4	22**	11
Processing (50 kg bag)	4***	1	0	0	2***	1	1**	1	1**	1	0	0.3	1***	0.3

Note: Mean difference is the difference between mean value of non-participant group members of the scheme and participant groups

*Statistical significance at the 10% level, **Statistical significance at the 5% level, *** Statistical significance at the 1% level.

6.2.1.4. Input use and output

Table 6-19 shows that the farmers who receive mechanization services cultivate almost the entire arable land that they own, whereas the farmers in the control group cultivate only 60%. Moreover, the participants are able to start land preparation much earlier than the control group. The amount of fertilizer that the participants use is over 30% higher than that of the control group. The share of farmers who apply herbicides is 63% among participants as compared to 24% in the control group. The data also shows that the participants achieve maize yields that are 30% higher than those of the control group. This is likely to be the combined result of better soil preparation, timelier planting, more fertilizer use and had better weed control.

Table 6-19: Differences in agricultural practices, input use and output

Selected Characteristics	**Participants (N=121)**	**Control Group (N=129)**	**Difference**	**Significance (5 % level)**
Arable land owned (ha)	7.1	6.1	15%	No
Arable land cultivated (ha)	6.5	3.7	56%	Yes
% of owned land cultivated	91.8	60.3	41%	
Beginning of land preparation	30-Sep	6-Nov	.	
Fertilizer use for maize (Mt/ha)	0.26	0.19	32%	Yes
Herbicides use for maize (litres/ha)	2.3	2.4	-5%	No
Percentage of farmers using herbicides	63%	24%	162%	
Pesticides use for maize (litres/ha)	0.2	0.1	100%	Yes
Maize yield (tons/ha)	3.2	2.5	28%	Yes

Table 6-20 displays a calculation of the gross margin of maize cultivation, based on the average figures on the costs and revenues collected from the smallholders who use tractor services and from the control group. The smallholders who use tractor services have a gross margin per ha that is approximately 20% higher than that of the control group. Importantly, they can realize a return on the family labour that is twice as the return of family labour of the control group.

Table 6-20: Gross margin table for JD Mechanization service users and non-users

MAIZE	Participants	Control group
Yield (Mt/ha)	3.2	2.5
Price (ZMW/Mt)	1492	1431
Gross revenue (ZMW/ha)	***4806***	***3597***
Variable costs (ZMW/ha)		
Land Preparation	366	97
• Tractor	364	14
• Hired animal	1.7	83
Seed	243	190
Fertilizer	876	655
Herbicide	98	35
Pesticide	7	3
Hired labour	164	71
Total variable cost (ZMW/ha)	***1754***	***1052***
Gross margin (ZMW/ha)	***3052***	***2546***
Family labour (hours)	371	700
Gross margin (ZMW) per hour of family labour	***8***	***4***
Total cultivated area (ha)	4.1	2.7
Total gross margin (ZMW)	12602	6766
Total gross margin ($)	***1277***	***686***

Note: 1 USD equals approx. 10 Zambian Kwacha (ZMW)

Table 6-21 displays differences in the main indicators that were used to measure the economic and social impact at the smallholder level: farm income, expenditure and nutrition. As expected, farmers who use mechanization services have a significantly higher total farm income than the control group. The difference per hectare is not significant, but the difference in total farm income is significant. This finding suggests that the main income effect from accessing tractor services is due to the increase in cultivated land area, which is made possible by mechanizing soil preparation.

Table 6-21 also shows differences in the expenditure regarding health, education, and food. These are important indicators of the social benefits that households can derive from an increased income. Farm households that use tractor services spend, on average, slightly less on health expenditure, but this result was not statistically significant. However, service users have significantly higher expenditures on education and food, which indicates that they are able to improve education of their children and their food security.

Based on the survey data, a food diversity score was calculated, which is an indicator of nutritional quality. More diverse diets provide more micro-nutrients, which is important to combat "hidden hunger". The findings indicate that households that access mechanization services do not consume a significantly more diverse diet than the control group. This finding suggests that the additional income that the participants earn is mostly spent on food staple crops.

Table 6-21: Differences in farm income, expenditure and nutrition

Indicator	**Participants (N=121)**	**Control group (N=129)**	**Difference**	**Statistical significance**
Farm Income (ZMW)	16,999	7,323	132%	Yes
Farm income per hectare (ZMW)	2,838	2,044	39%	No
Farm income per household member (ZMW)	2,527	1059	138%	Yes
Health expenditure per year (ZMW)	270	340	-23%	No
Education expenditure per term	1,730	842	69%	Yes
Food expenditure per monthly	561	299	61%	Yes
Food diversity score	11.4	10.4	10%	No

Note: 1 USD equals approx. 10 Zambian Kwacha (ZMW)

Overall, the descriptive statistics presented in this section suggest that providing tractor services to smallholder farmers has substantial economic and social benefits. However, the descriptive statistics should be interpreted with care, because one needs to address the attribution problem, which has been outlined in section 5.3.2.1. The following section presents the results of the PSM, which was used to establish causality.

6.2.2. Results of the Propensity Score Matching analysis

As explained in section 5.3.2.2.1.1, the first step in the PSM is estimating the propensity score using a probability model (in this case a probit regression model). Table 24 displays the results of this probit analysis.

Important to know from Table 6-22 is that the overall effect of the predictor variables of the probit model is jointly different from zero with a p-value of 0.0758. This implies that at least one of the regression coefficients in the model is not equal to zero at a 10% statistical significance level, hence the selected explanatory variables of the model are associated with the decision of a farm household to access tractor services.

The table also reports the average marginal effects which predict farmer's likelihood to access tractor services because of an increase in the value of the respective explanatory variable. As shown below, the decision of a farmer to use a tractor is positively influenced by a farmer's ownership of livestock (at 10% significance level), his or her membership in a social network group like a farmer's cooperative, and level of education (each at 5% significance level). Farmers with a greater number of livestock, which also qualifies as a wealth measuring indicator, have a higher probability of accessing the John Deere mechanization facility because they can afford its cost. Starting from the sample mean livestock owned, for a unit increase in livestock owned, a smallholder farmer is approximately 0.4% more likely to access mechanization service. Farmers in social, religious and political network groups e.g. farmer cooperatives, have a 20% (approximate) likelihood of accessing the John Deere mechanization service than farmers who are not. Possible reasons for this observation are access to information about the service provision from group members and the possibility to access mechanization services as part of a group. Starting from the mean years of schooling (indicated in Table 6-11) for an additional year of schooling, a smallholder farmer is about 2% likely to access services from the John Deere service provider. Another interesting revelation from Table 6-22 is that the decision of a farmer to use a tractor is influenced negatively by the size of his household and curiously by his access to credit and land owned. These are however not statistically significant.

Table 6-22: Probit regression, reporting marginal effects

Explanatory Variables	Using samples of JD mechanized and non-mechanized respondents (dF/dx)	Standard Error
Farming experience	0.0003	0.0030
Off-farm business (yes/no)	0.0630	0.0703
Household membership	- 0.0013	0.0123
Gender of family head (male/female)	0.1148	0.0832

Years of schooling		0.0223**	0. 0103
Land ownership before scheme		-0.0010	0.0027
Access to credit		-0.0749	0.0952
Access to extension services		0.0938	0.0759
Network group membership (yes_no)		0.1986**	0.0939
Access to market		0.0007	0. 0013
Livestock owned before scheme		0. 0044*	0.0027
Farmer's investment behavior		0.0343	0.1312
LR chi2(12)	19.57		
Prob > chi2	0.0758		
Pseudo R-square	0.0565		

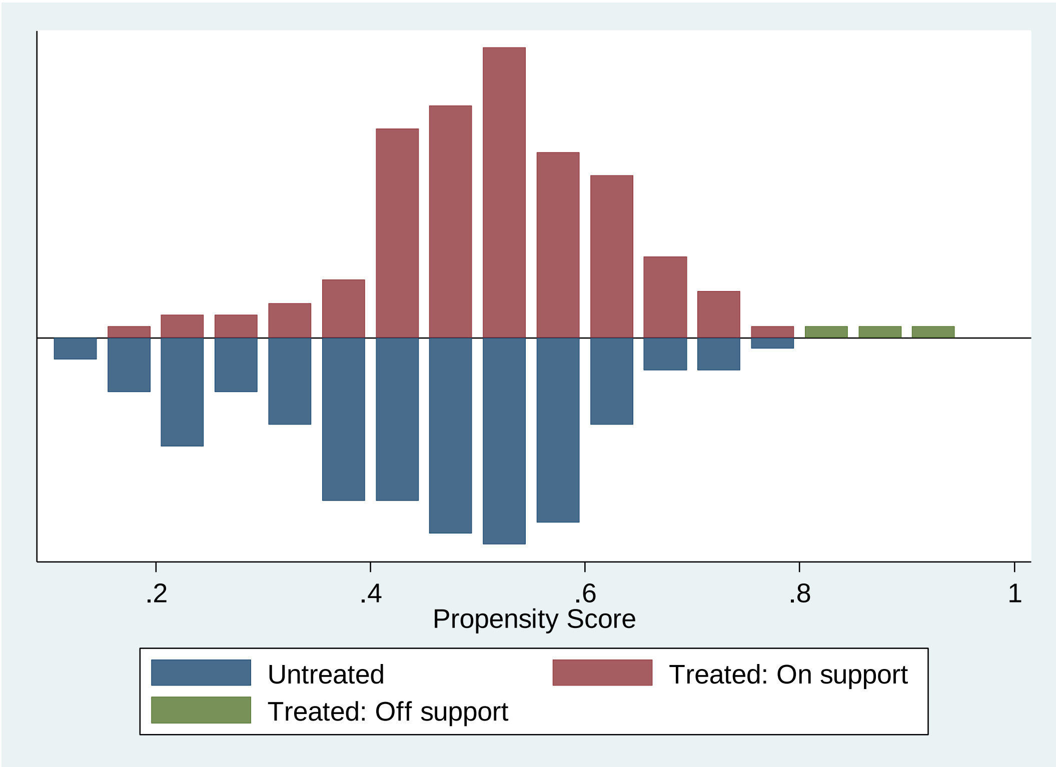
Note: *Statistical significance at the 10% level, **Statistical significance at the 5% level, *** Statistical significance at the 1% level.

In order to assess the average effect of the JD mechanization schemes on selected outcome variables – to stick with common terms, we refer to this as the Average Treatment Effect of the Treated (hereon *ATT*) – we match treated cases, i.e., beneficiaries of JD mechanization service provision to counterfactuals with similar propensity scores. Using a probit model, we estimated the balancing scores for each pairwise comparison of the JD mechanized smallholder group with their matching counterfactuals. As we are primarily interested in the use of a John Deere mechanization facility or not by a smallholder farmer, we predict the probability of opting to use the JD mechanization facility. The model's predictive power is generally high at 58.8%, and the variables included show the expected signs.

Using radius matching helps to restrict ourselves to an area of common support which is defined by the caliper width (c) set to one-fourth the share of the standard deviation (s.d) of the probability model of the propensity score (c = 0.25*s.d). As discussed in subsection 5.3.2.2.1.2. previously, this method has an advantage of allowing for more matching options by using only as many units as are available within a caliper. **Error! Reference source not ound.** displays the distribution of the propensity scores and the overlap between the groups. For this pairwise comparison, the figure also shows the cases dropped from the analysis to avoid bad matches. 3 out of the 121 treated assignments fell out of the region of common support for the data used (shown in Table 6-23).

Regarding the matched sample, we applied bootstrapping (500 repetitions) method to estimate the standard errors and hence check for distinct variations. The matching procedures resulted in a number of changes to significance levels of previously observed variations and disclose new significant differences.

Figure 6-8: Histogram of estimated propensity scores



Source: Own data, plotted using *psgraph* (Leuven & Sianesi, 2003)

Note: The region of common support falls within the range of [0.17306538, 0.95089005]. The mean propensity score is 0.48.

Table 6-23: Distribution of treated and untreated farmers that fall within the region of common support

	Common Support		
Treatment Assignment	Off support	On support	Total
Control group	0	129	129
Participants	3	118	121
Total	3	247	250

Table 6-24 reports the findings from the PSM analysis. The table displays the *ATT* which measures the difference in mean outcomes between matched smallholder farmers assigned to the treatment and smallholder farmers assigned to the control. In this case, the effect that can be causally attributed to the use of mechanization services offered by tractor owners who participated in one of the three Mechanization Schemes.

Table 6-24 indicates that using tractor services has a significant positive effect on on-farm income for the entire household and the on-farm income per household member. This effect is not only significant, but also large. The difference of seasonal net on-farm household income of approximately ZMW 10,000 indicates that the use of tractor services allowed smallholder farmers to more than double their income (see Table 6-20). The income per household member was also significantly higher, which confirms the above finding (see Table 6-20) that the users of mechanization services can improve the productivity of the family labour that they invest in farming. Net on-farm income per hectare is positively influenced using a mechanization services though not significant. Even the yield increase parameter which was significantly positive with a substantial magnitude of the *ATT* estimate could not cause a significant increase in the income per hectare parameter. Possible reason for this can be that participants hire mechanization services only for part of their fields for which they can afford. Yield increase was hence not sufficient to cover the increased cost per hectare.

The PSM analysis also shows that the increased expenditure in education, food and basic non-food household items can clearly be attributed to use of tractor services. Though not statistically significant, yearly health expenses are reduced for farmers who participate in the Mechanization Scheme.

Table 6-24: Output from *ATT* estimation of the effect of use of John Deere Mechanization service

Outcome Variable	Average Treatment effect of the Treated (*ATT*)	Standard Error
Net on-farm income (ZMW)	10,000***	3460
On-farm income per hectare (ZMW)	720	501
On-farm income per household (ZMW)	1500***	574
Yield (Mt/Ha)	0.42*	0.25
Yearly Expenditure on food (ZMW)	220***	70
Termly (4 to 6 months) Expenditure on Education (ZMW)	850**	305
Expenditure on basic household non-	760***	250

food household needs (ZMW)		
Health Expenses (ZMW)	-57	117
Expenditure on Recreation (Alcohol, Tobacco, etc.) (ZMW)	-40	25
Skipping Meals	-0.16**	0.06
Food Diversity Count	-0.08	0.7
Before and after JD mechanization difference in land ownership (ha)	0.02	0.7
Before and after JD mechanization difference in maize seed used (kg)	3.5	11
Before and after JD mechanization difference in fertilizer used (MT)	0.3***	0.1
Before and after JD mechanization difference in maize yield (MT)	0.7	2.8
Before and after JD mechanization difference in herbicides used (litres)	2.0	1.6
Before and after JD mechanization difference in pesticides used (litres)	-0.06	0.2
Before and after JD mechanization difference in livestock units owned	1.3	1.3

Note: *Statistical significance at the 10% level, **Statistical significance at the 5% level, ***Statistical significance at the 1% level

As indicated above, the survey also included recall data from respondents on selected outcome variables which include changes in input use, yield and livestock owned that occurred after accessing mechanization services. For these variables, a double difference *ATT* technique was used to estimate the differences in mean outcomes for these variables. The only significant effect was identified for the use of fertilizer. This indicates that we can attribute a causal effect on increased fertilizer use to the mechanization scheme. This result may be since farmers see an increased yield potential if they use more mechanized soil preparation techniques. The results from the recall data on the other input variables, yield and livestock differences after mechanization did not show any statistical significance.

To be able to evaluate how well the PSM performed, the reduction of the bias in the covariates included in the probit model used to estimate the propensity score is assessed. This was done by comparing the mean SB before and after matching (see details in section 5.3.2.2.1.4). Result of the mean SB comparisons for the implemented matching procedure is shown in Table 6-25.

Looking at the result of quality assessment of matching JD Mechanized and Non-mechanized farmers from Table 6-25, it appears that an extremely good matching quality was attained. The standardized bias was reduced from 16.3% before matching to 1.06% after matching; a bias reduction of approximately 93.5%. A residual mean bias of 3.7% as indicated in Table 6-25 is within the range of 3-5%, which is suggested in Caliendo & Kopeinig (2008) as an acceptable threshold for remaining bias after matching (see detailed discussion in section 5.3.2.2.1.4). The low remaining SB and the high reduction rate of mean SB proves a good balancing power and hence, good matching results.

Table 6-25: Indicators of matching quality and sensitivity analysis

	SB_{before} (%)	SB_{after} (%)	% |SB| reduction	Mean Bias	p>chi2
JD Mechanized/Non-Mechanized	16.3	1.06	93.5	3.6	1.000

6.3. Communities

In this section, the positive and the negative impacts of mechanization at community are represented as discussed by the farmers in the focus group discussions.

6.3.1. Positive impacts

Table 6-26 displays the main positive impacts that were identified in focus group discussions.

Table 6-26: Positive impacts

Positive impacts identified	Percent of male groups identifying this impact (N=13)	Percent of female groups identifying this impact (N=12)	
Agronomic impacts			
Yield increase	92%	100%	"If you do early planting and you cultivate big portion of land even the yield becomes better so you are likely to get high yield"
Early planting und retention of soil moisture due to use of ripping	92%	75%	"When you use a tractor…, moisture content is kept for longer, the germination of maize is good, germinates well…"
Improved land preparation	69%	42%	"When using tractor, depth is better than using animals…. Even when the rain goes the plants don't dry up..."
Cultivation of more land	38%	83%	"When we use tractor, we can cultivate bigger portion of land compared to animals"

Socio-economic impacts			
Increased income	92%	100%	"When you have better yields, you provide for own consumption, you will be able to find money for children's school fees, for other things… you also have money to buy farming inputs…."
Reduction of labor demand	54%	25%	"When using a tractor just one person or one manpower, using animals lots of people are supposed to do the work"
Time saved during land preparation time	38%	58%	"It is faster when you use tractor, …"
Improved health	38%	0%	"When you are using tractor, cattle have enough time for grazing… when you are using tractor at least the cattle won't be working by that time, just grazing, enough time for that… but when you are using them on the farming, you might use them from 7 to 12 or 11- they won't have enough time for grazing, resting..."

One of the most frequently mentioned positive impact was that tractor was faster and helps in early land preparation. Tractors can be used for land preparation at any time as soon as after harvest for the upcoming season. It is faster i.e. less time for land preparation facilitating early planting, crop diversification, vegetable gardening, cultivate more land, involving in off farm activities, more time for social events etc. Cultivating more land is directly proportional to more yield and income, reducing the risk of hunger during crop failure (even under erratic rainfall patterns) and there is more food availability.

Besides for land preparation tractors can be used for multi-purpose like planting, fertilizer application, weeding, harvesting, processing and transportation. Mechanization in context to ripping, is deeper and retains soil moisture for longer time promoting early planting and germination. Mechanization (referring to tractors) saves time, allows to cultivate a large area in lesser time an also cultivate more eventually leading to higher yield and income. The major sectors where the income is invested are education, buying inputs for the following season, buying assets, health, personal supplies etc.

Mechanization has made farming attractive. Youth are now interested in farming and it has reduced the drudgery of farming. There is reduced domestic labour demand so the children have more time to go school, women have free time for HH chores. On the other hand, due to mechanization and expansion of cultivation there is more demand for agricultural labour for weeding, fertilizer application and harvesting; which is an additional source of income to the agricultural labour- "piece-worker". The piece work is an additional source of income for the casual agricultural labour which majority use in buying food, education for their children and personal supplies.

6.3.2. Problematic Impacts

Table 6-27 displays the negative impacts that were identified in focus group discussions.

Table 6-27: Negative impacts

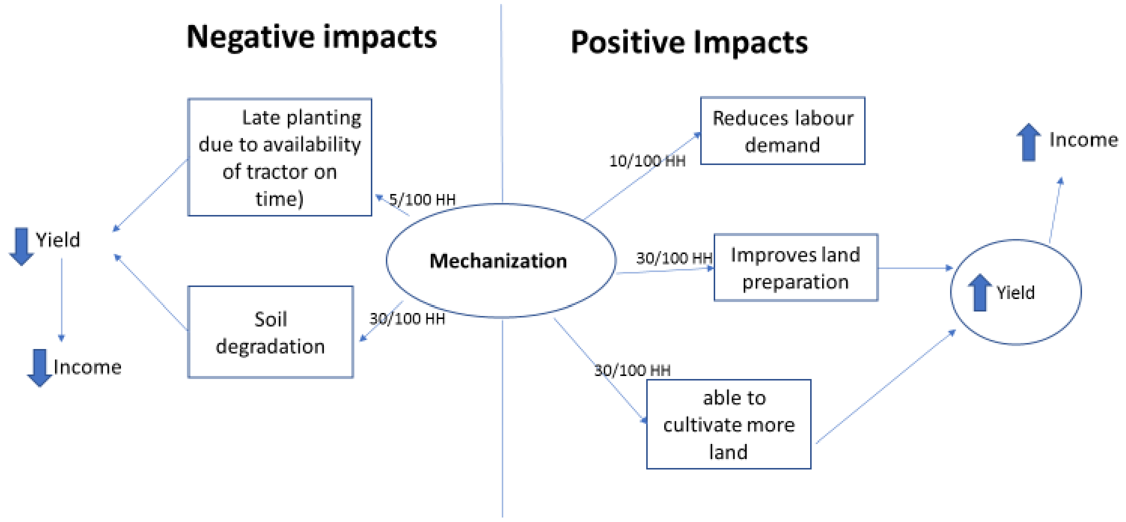
	Percent of male groups identifying this impact (N=13)	Percent of female groups identifying this impact (N=12)	
Agronomic impacts			
Yield losses because services were delivered late	31%	17%	"The tractors are not available on time since there are few tractors… At the time, we need it is not available, so forced for late planting due to unavailability of tractor..."
Soil degradation (in case of use of plough)	31%	8%	"… Soil fertility is reduced after repeatedly turning soil surface season after season…"
Socio-economic impacts			
Fewer jobs for agricultural laborers	54%	8%	"…. before start hiring a tractor, you used to hire people to come and help you in the fields. Now you have tractors around you won't be hiring the people……….so that person you used to hire will be in problem because no income for him…"
Migration of laborers	8%	0%	".. the leaders of the household migrate to towns and communities where the farm has been expanded…"
More work load for women	0%	17%	"…Women are doing more work…. because more activities after using the tractor, more activities like weeding since women tend to do more than man…"

As discussed in most of the focus group discussions, due to mechanization there were reduced jobs for the animal service providers and the casual agricultural labour especially for land preparation. Breakdown and unavailability of tractor on time favoured late planting due to which there was loss of yield and income.

The keys findings from focus group discussions are presented as impact diagram with both the positive and negative changes.

In the Zozwe village, there were total of 100 HH of which 30 HH used the mechanization services. According to the male participants, the direct benefit to almost all the households using mechanization were improved land preparation resulting to timely planting before the rains and less weeds in the field. The farmers having access to mechanization services could cultivate more land. Of the 30 HH using mechanization services, 10 HH reported that the labour demand has reduced due to mechanizing their farm. These direct benefits have attributed to increased yield and income.

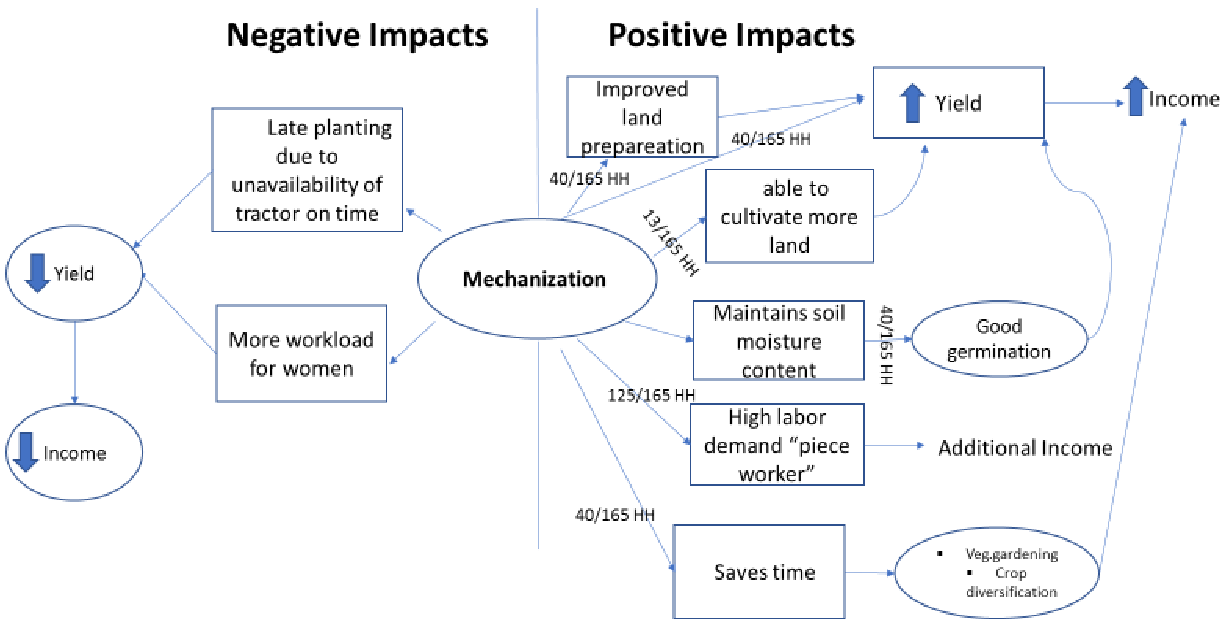
Figure 6-9: Impact diagram for mechanization drawn based on men focus group discussion in Zozwe Village



Men have reported some negative consequences. The negative consequence being unavailability of the tractor on time due to high demand for it in the community inducing late planting, thus decreasing the yield and income of the farmers. Soil fertility is reduced after repeatedly turning soil surface season after season when mechanized (especially when ploughed) which results decrease in the yield and eventually the income.

In the Kasavasa village, there were total of 165 HH of which 40 HH used the mechanization services. According to the female participants, the direct benefits to almost all the households using mechanization were improved land preparation, better germination of the crops since moisture is retained in the soil for longer due to the use of ripper and saving time (especially during land preparation) which can now be used for vegetable gardening and crop diversification. Of the 40 HH using mechanization services, 13 HH could cultivate more land or has expanded their area of cultivation. These direct benefits lead to increased yield and income. Of 165 HH, 125 HH have additional income as the demand for agricultural labour, "piece-worker" is high for activities such as weeding, harvesting and processing.

Figure 6-10: Impact diagram for mechanization drawn based on women focus group discussion at Kasavasa village



Women have reported some negative consequences though the group members were not able to quantify. Post mechanization there is more workload for women with the expansion of area under cultivation. Tractors are mostly used for land preparation, reducing the workload for men. The workload for women increased as women are more involved in planting and weeding. The other negative consequence is the unavailability of the tractor on time due to high demand for it in the community inducing late planting, thus decreasing the yield and income of the farmers.

Chapter 7: Discussion

Based on the research findings in comparison with reviewed literature, this section begins by providing a general discussion on the social and economic impact of mechanization scheme on the service providers, their beneficiary smallholders, and the communities within which they operate. The extent to which institutions contribute to this are also considered (see 7.1.). It then touches on some environmental effects associated with mechanization in the context of the study (see 7.2.). Net labour implications of mechanization at the household and community level, an area of study lagging in much of literature, are also discussed (see 7.3.). The current situation of smallholders' access to additional arable land and its relationship with mechanization are then discussed in subsection 7.4. Given the current debate on the need for a sustainable business model for smallholder mechanization, the authors, then discuss, based on findings from the research, factors that could potentially influence the viability of smallholder mechanization.

7.1. Socio-economic impact of the Mechanization Schemes

Socio-economic impacts of mechanization schemes can be realized at the level of the service provider, the smallholder farmer beneficiary, as well as directly and indirectly on the communities where the service provider operates. The subsections below attempt to discuss the dynamics at each level based on research findings and some reviewed literature.

7.1.1. Impact on service providers

The causal impact chain diagram in Figure 4 exhibits that impact on tractor owners (link 1a, b) is the first step in the impact chain of the Mechanization Schemes. The precondition for tractor owners to invest in a tractor is that it should be profitable. Tractor owners invest in tractors either to cultivate more hectares of land and/or to earn money from providing services to other farmers.

Participation in the scheme potentially has large economic benefits for the tractor owner. Section 6.1.4. shows that investing in a smallholder mechanization scheme can indeed be a profitable venture for its owner even at a commercial interest rate of 30%. Successful farmers from the Mechanization Scheme could realize an IRR of more than 100% (see Table 6-4). However, the analysis also shows a wide variation in the IRR that service providers could realize with some farmers not able to achieve positive rate of return to their investment.

Sensitivity analysis (Table 6-6) shows that, in the case of arable land availability and an increase demand for tractor services, investing in a John Deere tractor can be a significantly profitable venture. The table shows more than half of the sampled farmers achieving an IRR above the level of the current commercial interest rate of 30% under both scenarios of an increase in farmer’s own land cultivated and an increase in smallholder land serviced by 10 hectares. This confirms the importance of land to the overall profitability of smallholder mechanization (see 7.4. for detailed discussions).

As mentioned in a study by (Sitko & Jayne, 2014), most medium scale farmers in Zambia have an urban business background. 62% of these farmers among those interveiwed for this study had non-farm businesses, from which earnings many of the farmers used to purchase their tractor. Still, a considerable share (38%) of the tractor owners that AFGRI and John Deere could involve in their schemes did not have non-farm enterprises and were still able to accumulate sufficient capital to purchase a tractor. This proves that a performing average smallholder who can increase productivity and commercialize can have enough to save in order to acquire and own a tractor.

With the positive return on investment, interractions with these farmers revealed many reinvest into their off-farm businesses. Most of the tractor owners interviewed also reinvested heavily in the farming businesses in the form of acquiring more inputs and land for expansion. Some successful tractor owners have been able to aquire an additional tractor and their attachement implements to be able to service more smallholders as shown in section 6.1.1.

Tractor owners are important actors since there can be no impact on smallholders and their communities if they do not provide mechanization services. However, from 6.1.3, it is evident that not all tractor owners provide mechanization services. Out of 21 interviewed tractor owners, only 12 provided mechanization services to the surrounding smallholders i.e. only 57% of the tractor owners provide hiring services. Tractor owners who were reluctant to work with smallholders attributed it to the high transaction costs of organizing these smallholders who usually have individual farms scattered apart over far distances. Tractor owner also found it challenging manoeuvring around fields with stumps and big stones highlighting its contribution to constant major breakdowns. To scale-up the schemes and have prominent impact on smallholders and community this percentage must be increased.

In the first scheme where John Deere collaborated with CFU, Figure 6-5 shows that service provision was highest than the second or third schemes. One of the reasons for this could be CFU's important role in organizing the smallholders and linking them to the tractor owners. This sought to reduce the transaction cost on the part of the service providers who had already organized groups recommended by CFU to provide services for. Such organized farmers happen to have fields relatively close to each other and this helped reduce the fuel cost burden of traveling long distance to provide services between farms.

7.1.2. Impact on smallholders

One of the main objectives of this impact evaluation was the assessment of the social and economic impact that the Mechanization Scheme had of smallholders. As defined in section 2.1. smallholders in this context include both small-scale farmers and medium scale farmers (i.e., farmers cultivating from 0.1 hectares to 20 hectares). At the level of the smallholder farmer beneficiary, findings from the socioeconomic impact evaluation clearly showed that the Mechanization Scheme provided by AFGRI and John Deere had remarkable impacts. These are detailed in this section.

On an average, smallholders who used tractor services were able to double their income. This evidence was reliably supported not only by the descriptive statistics, but also by the propensity score matching (PSM) results (see Table 6-24) and by the focus group discussions and the Participatory Impact Diagrams. It can therefore be established that this positive income effect can be attributed to the Mechanization Schemes. This causal chain is represented by link 7b and the links that lead to 7b in Figure 4-1.

An agricultural project that aims to increase the income of smallholders is considered successful if it results in an income increase in the range of 20% and 30%. Achieving such positive results in agricultural projects especially in SSA is a challenge (cf. World Bank, 2011). Having this in mind, a 100% increase in smallholder farmer income from participating in the Mechanization Schemes of John Deere and AFGRI is considered an exceptionally remarkable success. This success is even more pronounced if one takes the number of smallholders that can benefit from a single tractor into account. Successful emerging farmers provide services to more than 100 smallholders per cropping season (see Annex 1-1). This indicates that enabling one medium scale farmer to purchase a tractor has the potential of enabling more than 100 smallholder farmer beneficiaries double their income. This potential is not fully realized yet for reasons mentioned above in section 7.1.1. Altogether, the 21 emerging farmers included into the sample served 693 smallholders, which correspond to an average of 33 smallholders per tractor.

Findings from the evaluation indicated that smallholders partly used their increased income to purchase farm inputs. There is particularly strong evidence that they substantially increase the use of fertilizer which is supported by both the qualitative findings and PSM results. As discussed below, however, smallholders may need advisory services to use their farm inputs more effectively to be able to realize a higher per hectare income on their farms. The use of tractor services was also found to be associated with an increased herbicide use. This, as mentioned earlier, may be due to the fact that CFU, which supported Scheme I, promoted herbicide use in connection with the introduction of conservation farming involving reduced tillage.

There is also strong evidence provided from the evaluation that smallholder farmers have achieved social benefits using these increased farming incomes from accessing mechanization services. They spend more on educating their children and on improving their food security; increasing their food expenses and hardly skipping meals. These findings on social benefits are also supported by PSM results and can, therefore, be seen as a causal effect of the use of the mechanization services provided under the Schemes of John Deere and AFGRI. The qualitative findings suggest a reduction in child labour among the households that use mechanization services, which is an important social benefit, as well. Overall, the findings indicate that the smallholders use their increased income from mechanization services for improving their farm operations and for improving the well-being of their families.

Results from qualitative findings indicate that some smallholders were able to invest their income into off-farm businesses. For example, farmers who trade in livestock use the profit as capital to buy more cattle or goats or pigs from their villages which they sell in larger market centres in Lusaka or Ndola at significantly higher prices during the off-farming seasons. Others who run grocery shops were able to invest in stocking their shops and earning more from this economic activity. One can therefore, assume that a multiplier effect indicated in Figure 4-1 also occurred.

Results from the evaluation also showed increase in labour productivity from accessing mechanization services. This is also an important benefit as results shown in Table 6-24 from the PSM analysis indicated a significantly positive return on household labour use. This is discussed in more detail in subsequent section 7.3.

There is strong evidence that smallholders were able to slightly increase their yields as confirmed by the descriptive analysis, PSM and qualitative findings. Therefore, the effect can clearly attributed to the use of tractor services. This link was likely the combined result of better land preparation, timelier planting, increased fertilizer use and the use of herbicides, as mentioned earlier. According to the PSM analysis it was in the range of 0.5 Mt per ha, which corresponds to a yield increase of approximately 25%.

It would have been expected that income effect on smallholders was, in part, due to increased land productivity, and not only by land expansion and improved labour productivity. However, from the PSM result, smallholders who use mechanization services were not able to achieve a higher income per hectare. This finding suggests that farmers may benefit from extension services to use their inputs more effectively. Farmers who use mechanization services are shown from the results to apply almost double the amount of fertilizer as compared to the control group. This level of fertilizer should make it possible to achieve yield increases above the 25% that the farmers realized. This finding reflects a general concern about low yield response rates to fertilizer in Zambia and other African countries, which has been extensively discussed in the literature (see, Chapoto, Chabala, & Lungu, 2016 for Zambia and Jayne & Rashid, 2013, for general review). To get access to extension services means continued partnership with organizations like CFU (link 3b in Figure 4-1). From Table 6-11, the share of farmers who access agricultural extension services was 70%, which is already rather high as compared to other African countries (see e.g., World Bank & IFPRI, 2010). Hence, there seems to be scope for improving the effectiveness of extension. Establishing a partnership with the government extension services, which is overall the major provider of extension, may be useful in this respect (i.e. strengthening the link 7a in Figure 4-1). From the result, there is hardly any major yield intensification when labour is substituted for land and capital. Farmers, deprived of ready access to arable land for expansion, may move to more marginal and not very productive lands. This might explain the low yield response. Based on this line of thought, it might be more economical for a smallholder to cultivate more land rather than target higher yields.

7.1.3. Impact at community level

To assess impact of the Mechanization Schemes at the community level, the effects of mechanization must be considered on members who use the mechanization services and also on community members who do not use mechanization services (see Figure 4-1, link 9a, 9b). Moreover, there can be impact of mechanization on smallholders and community only if tractor owners provide mechanization services.

Information gathered from the focus group discussions gave the researchers a resounding view that mechanization undoubtedly has social and economic impacts on the community and household that access mechanization services. Access to tractor services allows faster and earlier land preparation. This can lead to larger land cultivated in areas where arable land access is not constrained, higher yields and a lower risk of crop failures under good agro climatic conditions. This translates to a higher farm income, which households reportedly spend on education, farm inputs, assets, health, and personal supplies. The majority of community members benefit directly or indirectly from the scheme when increased farm incomes are used on both food and non-food goods sold within the communities. This contributes to transforming the rural economy and leads to a gradual reduction in rural poverty rates. The time saved during land preparation is reportedly used for gardening, household chores, off farm work and social events. From the focus group discussions, participating community members confirmed improving their health due to reduced drudgery from mechanized agriculture.

From the focus group discussions and descriptive analysis, it can be established that land preparation and seldom shelling (see Table 6-9) are the commonly mechanized operations. There has been a significant reduction in female and children labour demand for these activities especially land preparation for households that participated of the Mechanization Scheme. This was highlighted from the focus group discussion and supported by the labour analysis presented in section 6.2.1.3. Children from these households can now have ample time for school while women have spare time for household chores and/or attend to small businesses like vegetable gardening, petty trading and livestock trading. Men who provide the most labour force for these labour intensive activities are shown to save significantly more labour time from mechanizing these activities (see results from 6.2.1.3.). From the focus group discussions, it was gathered that men from households that participated in the Mechanization Scheme used this saved time to attend to their livestock, which is one of the important alternative sources of income in rural Zambia. They also mentioned that farming has become less tedious and is increasingly becoming an attractive area for the youth who before would venture into the bigger cities to look for alternative means of economic engagements. Some groups even mentioned that the disabled community members can also farm now.

On the downside to these benefits however, area expansion due to mechanized land preparation leads to increasing labour required for other on-farm activities which are not commonly mechanized. Weeding which usually done by women is one of these activities. A few women groups (2 out of 12) from the focus group discussions mentioned increasing workload for women from land expansion. Findings from quantitative study however, indicate a relative increase in herbicide use by households participating in the Mechanization Scheme. Spraying of herbicides is almost always a male undertaking and requires a fraction of the time used when done manually.

Despite the many benefits of mechanization in general and the schemes in particular, there were challenges which hindered the greater number of smallholders within the communities from participating in the scheme. Two of the commonly mentioned ones during the focus group discussions were related to the hiring cost and the limited number of tractors in the communities. High demand for few tractors (if any) within a community and its immediate environs causes stiff competition especially between August and October which is usually the window for land preparation. Smallholders end up planting late since tractors are only available for hiring after the tractor owner has prepared his own farmland and met the demands of those who make earlier requests. This leads to late planting and its accompanying risk of yield drops and income reduction (see Figure 6-9 and Figure 6-10). This is in line with findings from (Buriro, Bhutto, Gandhi, Kumbhar, & Shar, 2015) and (Beiragi et al., 2011) which show that delayed planting reduces maize yields and its components.

7.2. Environmental Impacts of the Mechanization Schemes

Some of the mechanization operations could have negative impacts on environment like degradation. Results from qualitative finding from this research however suggest that even though mechanization, especially deep ploughing, disturbs the soil structure, it is based on the skill level of the tractor operator. Development of the capacity of the tractor operator is therefore crucial for proper land preparation and a sustainable use of the mechanization package. Mechanization provides possibilities for the conservation of environment through conservation agriculture, promoting the use of ripper (see subsection 2.2.). The qualitative findings suggest that ripping helps to maintain soil moisture for long; enhancing better germination, plant development and eventually better yield. This is in line with Hobbs et al. (2008) who documents that, by using the appropriate and available equipment adapted for local conditions, CA practices can have a good number of environmental and agronomic benefits. Development organizations like CFU must be continually involved for farmers to practice CA and realise its short to long term benefits; in line with a recommendation by Daum (2014).

The results suggest that there is expansion of cultivated land due to mechanization which is a positive impact. However, one should also consider the underlying potential negative effect that expansion of cultivated land could lead i.e. deforestation and land degradation in the long run. Extension services to smallholders could play an important role in ensuring appropriate soil fertility management on mechanized smallholder farms.

7.3. Net implications on labour

Evaluation results confirm that accessing mechanization services increases labour productivity, which is an important benefit. From Table 6-20 of the descriptive results, it can be inferred that farmers who access mechanization services achieved double the income per labour hour than their counterparts who do not access mechanization services. The PSM results confirmed this as a causal effect of using mechanization services: There was not only a significant increase in the farm income, but also of the farm income per family member which is a measure of household labour productivity (Table 6-24). This is of particular importance because family labour is the predominant agricultural labour source in these research areas and in most parts of the developing world particularly SSA.

There have been divided views whether mechanization provides new employment opportunities or reduces the employment opportunities. Many consider mechanization to reduce employment opportunities (see Schmitz & Seckler, 1970) while some consider mechanization to provide new employment opportunities (Houmy et al, 2013). Above mentioned benefits of mechanization do not happen at the expense of loss of agricultural labour opportunities from the results seen in Table 6-16 and Table 6-17. A reduction in time required for cultivation activities and processing is compensated for by an almost twice increase in the size of cultivated land. Coupled with higher yield per hectare (approx. 25% more) the total labour requirements for crop husbandry activities are not significantly reduced due to mechanization. This is in line with Binswanger & Mcintire (1987) who argues that if land can be expanded and there is an emergence of output market, per capita labour days in agriculture will increase due to intensive cultivation. In such scenario, mechanization does not affect the agricultural labour market due to increasing labour demand. Increasing yields also mean increasing labour demand for harvesting and post-harvest activities. With mechanized shelling only being partly adopted, more agricultural labour is required for processing.

Results from the labour analysis show that participants of the Mechanization Scheme hire significantly more labourers for crop husbandry activities due to increase in their cultivated land and the cultivation of additional crops (see section 6.2.1.3.). This was supported by qualitative details from focus group discussions where participants usually agreed that mechanization has provided an income opportunity especially for the agricultural labourers known as 'piece workers' in the Zambian rural community setting. This was significantly overshadowed by employment opportunities lost during land preparation due to mechanization. Based on this outcome, an expansion of the scheme to include more smallholder farmers will have a rather positive net implication on agricultural labour demand.

In an agro-climatic zone with only a single and relatively short growing season, there is an inevitable burden on the local labour market; where cultivators are suppliers sometimes and demanders at other times, due to synchronicity of cropping operations as highlighted in Binswanger & Mcintire (1987:87). Saved labour hours from assessing mechanization services are mostly used for other income generating ventures. A common example as highlighted in the FGDs is to provide labour services on demand to other farms particularly during planting, weeding and processing periods for income. Participants of the Mechanization Scheme spend less time on most of their own farm cultivation activities as shown in results from labour analysis presented in section 6.2.1.3. . These farmers can therefore available themselves to work on other fields for income to add to already high returns from their own farms. This finding seeks to provide a solution for agricultural labour supply especially during a time where rural-urban migration of the youth constrains rural agricultural labour availability.

7.4. Arable land expansion for smallholders and mechanization

Having among the lowest population densities in SSA, making Zambia one of the most land abundant countries in the region, one would expect a rich availability of arable land for its many smallholder farmers. However, the reality is far from this expectation. Like in other parts of Africa, land in Zambia is administered through the parallel systems of customary and state land (Sitko & Jayne, 2014). Customary land which is the foundation of smallholder agriculture in Zambia is far less available now for smallholder utilization than is often assumed in the policy making circles (Sitko, Chamberlin, & Hichaambwa, 2015). These lands are administered by traditional authorities, such as chiefs and headsmen who grant legal rights to individuals to occupy and use these lands, but prohibit their sale.

There is wide mention of the great potential smallholders have to increase income from agriculture, move out of poverty and contribute to rural and agricultural development (see Birner & Resnick, 2010; World Bank, 2007) with one major factor for this being increasing access to arable land. An overwhelming 75% of the 1.6 million smallholder households in Zambia cultivate 2 hectares or less of land (Hichaambwa & Jayne, 2014). These farmers hardly produce enough surpluses to sell and are unable to benefit from government spending on agriculture through programs such as the farmer input support program (FISP) and the food reserves agency (FRA). Only about 25% of smallholders in Zambia are participants in its agricultural growth. The remaining smallholder majority who cultivate 2 hectares or less of land fail to produce enough to meet the ever growing local and regional market demands due to land constraints (Hichaambwa & Jayne, 2014). This is quite a paradox considering Zambia being among the most land abundant countries in SSA on phase value.

Emerging farmers who hold between 20 hectares to 50 hectares of farmland now control more land than smallholders in Zambia and their population has been rising considerably (see 2.1. These are usually not developing smaller scale farmers who have managed to consolidate land to expand their cultivated areas but usually individuals coming from urban towns and outside the agricultural sector (mostly have an urban business background). Sitko & Jayne (2014) argue that this phenomenon is as a result of land administration and agricultural spending policies which these actors are well-resourced and connected enough to exploit. The agricultural sector in Zambia will now have to contend with solving the inevitable problem of competition for available arable land resources between the already under resourced rural poor smallholder and the emerging farmer.

Findings from the evaluation revealed that the major mechanism behind the remarkable income increase among the smallholder farmers was the expansion of the land area that they cultivate. In the locations where the evaluation was conducted, smallholders typically own, according to the survey results, between 6 and 7 ha of arable land which are somewhat higher than the national average (see IAPRI, 2015). The findings also indicate that due to labour constraints, farmers without access to tractor services are not able to cultivate the entire land that they own. The smallholders in the control group cultivated only 60% of the arable land they own. In contrast, farmers who access tractor services were able to increase this share to more than 90% (see Table 6-19).

Getting the majority smallholders to participate in the market from the sale of production surpluses which can be ensured from high productivity and arable land expansion can cause increase in income. Access to mechanization and the Mechanization Scheme has been shown to significantly influence these yields and income of the smallholder. Income realised which is used for food and non-food goods contributes to the transformation of the rural economy which eventually leads to poverty rate reduction. If poverty rate reduction is a core goal within the Zambian policy making circles, then smart policy solutions addressing land ownership and distribution which allows for smallholder majority participation has to be considered.

7.5. Is the John Deere mechanization model viable in Zambia?

Results from the investment analysis confirm that the mechanization strategy operating in Zambia can be a significantly viable model with direct economic and social implication on the smallholder farmer. This is however heavily dependent on certain identified conditions which when met can open a window for more medium scale farmers to become participants and expand the smallholder mechanization schemes due to its viability. These are in line with findings from the cost benefit analysis component of the study by Daum (2014). In this study, the author argues that specialization in agricultural mechanization is indeed a viable business model in Ghana when conditions of optimal land serviced and service charge are coupled with high returns from maize shelling to ensure multi-functionality of the tractor. This finding was in stark contrast to Houssou et al. (2013) which stated otherwise, but only focused on the seasonal total land area serviced.

Take a typical case of a successful Zambian farmer (see Annex 1-1), who rips a total average of 340 hectares of land (40 hectares owned) each season at a service charge of ZMW 300, can make an average seasonal net benefit of ZMW 119,163. The farmer also shells an average of 550 bags (50 kg) of maize for a service charge of ZMW 4 per bag. This farmer was a beneficiary of the first scheme; acquired a tractor and ripper from AFGRI at a cost of ZMW 175,000. His total investment cost, including a maize sheller was ZMW 202,800. He produces an average of 3 Mt of maize yield per hectare and sells a 50 kg bag of maize at a market price of ZMW 90 to contracted buyers. Such a farmer was seen (from Table 6-4) to have a remarkable IRR of 380% at a current bank lending rate of 30%.

Comparing this to a less successful farmer (see Annex 1-2), who rips a total average of 160 hectares of land (60 hectares owned) seasonally at the same service charge, makes a seasonal net loss of ZMW 16,209. This farmer was a beneficiary of the second scheme; acquired a tractor and a ripper from AFGRI at a cost of ZMW 300,000. He also produces an average of 3 Mt of maize per hectare and sells a 50-kg bag of maize at a market price of ZMW 70. Such a farmer had a negative return (-28%) on his investment at the commercial interest rate of 30% (see Table 6-4).

The Zambian kwacha (ZMW, previously ZMK before its rebase in 2013) has continued its gradual line of depreciation since 2010. World Bank (2016) attributes this to falling copper prices, pressure on fiscal spending, and electricity supply shortages which has had adverse effects on Zambia's macro economy. Even at the same cost of an investment (tractor and its attachment implement) in USD, farmers who were part of the first scheme (implemented from 2010) had a significantly lower initial cost of investment relative to beneficiaries in the other schemes when converted to ZMW. Instalment payments during the 3 year payback period were also seen to be comparatively lower for beneficiaries from the first scheme.

The problem with the depreciating Zambian kwacha increased costs of imported goods and increased the demand for exported goods. Demand for farm inputs like fertilizers, herbicides and high yielding seed varieties which are imported but crucial for agricultural production is affected even with government support program (FISP) which only covers a certain limited quantity of seeds and fertilizer per farmer. This has a direct effect on the cost of production and overall cost of investment, clearly visible from comparing the examples provided above. There is therefore the need for a stable exchange rate.

High and competitive market prices of produce could offset increased cost of production and enhance the profitability of crop production under stable agro climatic conditions. The examples above show the successful farmer selling produce to contracted buyers and having higher market prices compared to the less successful farmer.

The past 3 seasons have seen most Zambian agricultural production regions being hit by periods of limited or no rainfall especially before seed emergence stage. This was brought up during the smallholder survey and reiterated during the focus group discussions. This has direct consequences on crop development and hence overall yield (3 tons/ha from the examples above) which can be increased under better conditions. Under such unfavourable conditions, some agronomic training of farmers will help them adapt and produce the maximum possible outcomes from the current situation.

Houssou et al. (2013) and Daum (2014) both argue that the use of a tractor to provide services on an optimal area of land seasonally ensures the viability of the smallholder mechanization model. But as seen from earlier discussions, organizing smallholders to reduce transaction cost of service provision and to meet this optimum is a challenge without the support of third sector groups like CFU. Table 6-4 confirms that this is not easy to achieve. To enhance returns of the use of the tractor, farmers will also need to have a multi-functional use of the facility as further identified by Daum (2014). The example cases shown above indicate the more successful farmer providing shelling services in addition to providing land preparation services contributing to a remarkably high IRR.

The peculiar case of Zambia identifies variations in a farmer's on-farm productivity, market price of produce, extent of use of the facility to provide services for other farmers, land expansion and the depreciation of the Zambian Kwacha as the five most prominent conditions which influence the profitability of the smallholder mechanization scheme in Zambia.

Chapter 8: Conclusions

The results suggest that mechanization has remarkable positive social and economic impacts on smallholders and the communities. The smallholder and the communities using the mechanization services are benefitting, at the same time there are no negative impacts to the smallholder who do not use the mechanization services. The findings suggest there was reduced labour demand during land preparation, which was not interpreted as a negative impact for agricultural labourers since there was an increased labour demand for other farming activities such as planting, fertilizer application, weeding, harvesting and post-harvest processing due to expansion of cultivated area.

The findings from the Participatory Impact Diagrams (PID) suggest that mechanization helped to improve the timeliness and quality of land preparation which contributed to increased yields and increased incomes. Early planting and retention of soil moisture (as a combined effect of using Conservation Agriculture) favoured a higher germination percentage due to the use of ripper was also frequently discussed as positive impacts. The negative effects that were frequently discussed were soil degradation (discussed in 48% of the focus group discussions) and late planting because of non-availability of tractor on time due to high demand for mechanization which resulted in yield loss and income (discussed in 39% of the focus group discussions).

John Deere and AFGRI made it possible for medium scale farmers willing to finance a tractor through the mechanization schemes where they had to make a down payment and pay in cash/kind monthly or seasonally depending upon the schemes they were part of.

However, these above-mentioned impacts can only be achieved if the tractor-owners provide mechanization services to the smallholders. The results of the study indicate that less than 60% of the tractor-owners provided mechanization services. Some tractor-owners are reluctant to work with smallholders because organizing them can be tedious and time-consuming. The organizations like CFU helps organizing smallholders for service-provider thus reducing transaction cost for the tractor-owners involved in organizing farmers.

Mechanization has overall benefitted the smallholder and the community. Farmers have expanded their land under cultivation, have higher yield and income, have more spare time for off farm business. In precise, they are better off than the farmers not using mechanization services. Agriculture mechanization has the potential to promote smallholder farming but this potential has not been grabbed fully since it is evident that only about half of the tractor-owners under the schemes provide mechanization services to the smallholders.

Chapter 9: Recommendations

Based on the findings from the evaluation, the following recommendations can be derived:

Expansion of the ZANACO Scheme:

In Zambia, John Deere and AFGRI developed mechanization approach to develop smallholder mechanization. Since 2010, John Deere and AFGRI have implemented mechanization schemes (see section 3). As known from the findings, mechanization has significant positive social and economic impacts on smallholders and the community. On the downside, tractor owners faced some challenges in the first and second scheme in repaying when the Zambian Kwacha started depreciating. Some farmers also had problems repaying monthly particularly between January and April (after planting and before harvesting) when they had little liquid capital. In combination with bad rainfall patterns this led to a situation where most tractor-receivers struggled to meet repayment schedules even as at 2016 with some tractors being repossessed. Currently, the third scheme, ZANACO scheme is implemented and is recommended to continue as it is based on a viable business model and is based on the experience of the previous two schemes. The default risk is entirely captured by ZANACO. The farmers receive a tractor-package including implements, under the scheme which they are obliged to insure against certain risks. They are supposed to repay the tractor-package with four, freely choose-able annual instalments. Unlike the previous schemes, the repayments are done in Zambian Kwacha, which reduces the exchange rate risks for farmers.

Partnership with the NGOs:

The mechanization schemes have significant impact on the smallholder and in the community. However, these mechanization schemes can only have impact when the tractor-owners provide mechanization services to the smallholders. The tractor-owners are not obliged to provide services to smallholders. The findings suggest less than 60% tractor owner provide mechanization services. The tractor owners find it tedious to organize farmers and provide services. It is evident from the findings that under the first scheme when John Deere and AFGRI collaborated with CFU the tractor owner provided more services to the smallholders and none of the farmers from the third scheme worked with smallholders. So, one way could be collaborating with NGOs at community level that can organize farmers who want mechanization services and help in providing training on the operation of machines to meet standards of use of implements and maintenance to actual operator rather than the owner.

Government Investment on Capacity building:

Investment in the capacity of the tractor-owner is very crucial to make this business profitable. The results suggest less than 60% of tractor-owner provide mechanization services. A tractor-owner can serve up to 150 smallholders. There is high potential which has not been grabbed. For the sustainability of the scheme and to benefit smallholders and the community, it is important on the part of the government to invest on the capacity building of these tractor-owner so that they can make profitable use of the tractor, up-scale the scheme, and serve more smallholders. Government could provide extension services to these tractor-owners and smallholders to make effective use of the mechanization and the inputs used. Extension services can also be provided to smallholders by collaborating with development organizations that can organize farmers who want mechanization services and help in providing training on the operation of machines to meet standards of use of implements and maintenance.

Addressing potential negative effects:

Though the study did not find major negative impacts of mechanization, there are few potential effects that could increase as the schemes expand. There may be less and less employment opportunities for agricultural labourers. For now, this is compensated by the expansion of cultivated area. But, in future this could create less and less employment for agriculture labourers (who have small farms and earn additional money by working at others' farms) when other farming activities are also mechanized. The other potential negative impacts are a higher work load for women, soil degradation and migration of labourers. The other potential impact could be due to expansion of cultivation which could lead to deforestation and land degradation in the long run. These impacts are not discussed much through the discussions but need to be carefully looked at as the schemes expand.

Learning platform:

Furthermore, John Deere and AFGRI have developed a viable business model to promote smallholder mechanization in Zambia and have provided important lessons which could also be relevant to the other African countries where John Deere works actively.

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Annex

Annex 1-1: Background information on interviewed tractor owners

Farmers' ID	First tractor?	If no, which?[1]	Scheme	Source of information[2]	Years of schooling	Land size (ha)	Maize yield (Mt/ha)	Package	Fully Repaid	Break down	Non-farm businesses
1	No	MF	1st	CFU	7	200	3.5	Tractor ripper	Yes	No	Yes
2	Yes	-	1st	CFU	12	30	NA	Tractor ripper	Yes	No	No
3	Yes	-	1st	CFU	18	30	NA	Tractor trailer	Yes	Minor	Yes
4	Yes	-	1st	CFU	6	27	NA	Tractor ripper	Yes	Yes	Yes
5	No	-	1st	CFU	7	20	5.7	Tractor ripper	Yes	No	Yes
6	No	-	1st	CFU	9	90	4.4	Tractor ripper	Yes	No	No
7	Yes	-	1st	Neighbors/ Friends	8	500	2.7	Tractor ripper	Yes	No	No
8	No	MF	1st	MUSIKA	18	100	2.8	Tractor plough	No	Minor	Yes
9	No	JD	1st	CFU	16	55	4.3	Tractor ripper	No	Yes	Yes
10	No	MF	1st	CFU	3	5	3.0	Tractor ripper	No	No	Yes
11	Yes	-	1st	CFU	18	30	NA	Tractor ripper	No	No	Yes
12	No	JD	2nd	Neighbors/ Friends	10	10	NA	Tractor ripper	Yes	No	Yes
13	No	JD	2nd	Neighbors/ Friends	8	125	6.0	Tractor plough	Yes	No	No
14	No	2 JD	2nd	Neighbors/ Friends	9	62	1.6	Tractor plough	No	No	No
15	No	-	2nd	CFU	7	90	4.5	Tractor planter	No	No	No
16	Yes	-	2nd	CFU	4	70	1.9	Tractor ripper	No	No	Yes
17	Yes		2nd	Neighbors/ Friends	10	NA	NA	Only tractor	No	Yes	Yes
18	Yes	-	2nd	CFU	2	NA	NA	Tractor ripper	No	No	No
19	Yes	-	2nd	CFU	5	NA	NA	Tractor ripper	No	No	No
20	Yes	-	2nd	CFU	5	90	NA	Tractor ripper	No	No	Yes
21	No	JD	3rd	Neighbors/ Friends	7	110	NA	Tractor ripper	No	Yes	Yes

[1] Brand of the tractor that the farmer had before; JD = John Deere; MF = Massey Ferguson
[2] Source of information about the tractor scheme; CFU = Conservation Farming Unit
Note: NA = Not available

Annex 1-2: Information on service provision by tractor owners

ID	Scheme	Service Provided	No of farmers served	Area served (ha)	Radius served	Charge for ploughing (ZMW/ha)	Charge for ripping (ZMW/ha)	Charge for planter (ZMW/ha)	Charge for shelling (ZMW/ 50 kg bag)
1	1st	Ploughing & shelling	20	59	20	520	NA	NA	4
2	1st	Ripping & shelling	120	195	20	NA	300	NA	2
3	1st	Ripping	12	-	18	NA	600	NA	NA
4	1st	Ripping	12	-	20	NA	300	NA	NA
5	1st	Ripping	113	-	50	NA	350	NA	NA
6	1st	Ripping	9	-	80	NA	300	NA	NA
7	1st	Ripping	157	250	50	NA	300	NA	NA
8	1st	Ripping	50	-	50	NA	300	NA	NA
9	1st	Ripping	30	-	25	NA	300	NA	NA
10	1st	Ripping	20	-	70	NA	250	NA	NA
11	2nd	Ripping, ploughing. planting	100	-	50	900	400	400	NA
12	2nd	Ripping	50	-	20	NA	300	NA	NA

Annex 1-3: Cash flow (Eastern_Petauke)

Farming season	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**
Average farm size owned (Ha)	50	70	60	60	60	60	60	60	60	60
Market price per 50kg bag (ZMW)	65	65	70	70	70	70	70	70	70	70
Average yield per hectare (50kg bag)	16	37	29	29	29	29	29	29	29	29
Seasonal income from farming (ZMW)	52,000	168,350	120,120	120,120	120,120	120,120	120,120	120,120	120,120	120,120
Number of beneficiary farmers (land preparation services)	50	50	50	50	50	50	50	50	50	50
Average farm area prepared per farmer (Ha)	2	2	2	2	2	2	2	2	2	2
Service charge per hectare (ZMW)	300	300	300	300	300	300	300	300	300	300
Revenue from service provision (ZMW)	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Fuel use cost on own farm size (ZMW)	11,274	18,136	15,765	15,765	15,765	15,765	15,765	15,765	15,765	15,765
Fuel use cost service provision (ZMW)	22,548	25,908	26,276	26,276	26,276	26,276	26,276	26,276	26,276	26,276
Fuel use cost travel (ZMW)	258	296	300	300	300	300	300	300	300	300
Maintenance for service provision (ZMW)	6,667	5,882	6,250	6,250	7,500	7,500	7,500	7,500	7,500	7,500
Labour cost for service provision (ZMW)	3,333	2,941	3,125	3,125	3,125	3,125	3,125	3,125	3,125	3,125
Net income from service provision (ZMW)	-2,806	-5,028	-5,952	-5,952	-7,202	-7,202	-7,201	-7,201	-7,201	-7,201

Annex 1-4: Investment analysis (Eastern_Petauke)

Years	Investment (ZMW)			Costs (ZMW)				Benefits (ZMW)		Net Benefit	Discount Factor	PV (ZMW)
	Tractor	**Ripper**	**Down payment (ZMW)**	**Maintenance**	**Fuel**	**Labour**	**Production cost**	**Ripping**	**Own farm earnings**			
0			-90,000							-90,000	1	-90,000
1	-43,333	-26,667		-10,000	-34,081	-5,000	-71,187	30,000	52,000	-108,268	0.88	-217,779
2	-43,333	-26,667		-10,000	-44,341	-5,000	-99,662	30,000	168,350	-30,653	0.77	-131,312
3	-43,333	-26,667		-10,000	-42,342	-5,000	-85,424	30,000	120,120	-62,647	0.67	-136,781
4				-10,000	-42,342	-5,000	-85,424	30,000	120,120	7,353	0.59	4,354
5				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.52	2,780
6				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.46	2,439
7				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.40	2,139
8				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.35	1,877
9				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.31	1,646
10				-12,000	-42,342	-5,000	-85,424	30,000	120,120	5,353	0.27	1,444
											NPV	**-234,163**

Annex 1-5: Cash flow (Copper Belt_Mpongwe)

Farming season	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**	**2023-2024**
Average farm size owned (Ha)	62	62	62	62	62	62	62	62	62	62
Market price per 50kg bag (ZMW)	65	70	70	70	70	70	70	70	70	70
Average yield per hectare (50kg bag)	27	40	34	34	34	34	34	34	34	34
Seasonal income from farming (ZMW)	110,503	173,600	146,301	146,301	146,301	146,301	146,301	146,301	146,301	146,301
Fuel Use Cost Own Farm Size (ZMW)	16,063	16,291	16,291	16,291	16,291	16,291	16,291	16,291	16,291	16,291

Annex 1-6: Investment analysis (Copper Belt_Mpongwe)

Years	Investment (ZMW)				Cost (ZMW)				Benefits (ZMW)		Net Benefit (ZMW)	Discount Factor	PV (ZMW)
	Tractor	Disc Plough	Fertilizer spreader	Down payment (ZMW)	Maintenance	Fuel	Labour	Production cost	Ploughing	Own farm earnings			
0				-90,231							-90,231	1	-90,231
1	-70,180				-7,000	-16,360	-5,000	-107,552	0	110,503	-95,292	0.88	-83,590
2	-70,180				-7,000	-16,592	-5,000	-107,552	0	173,600	-32,423	0.77	-24,948
3	-70,180				-7,000	-16,592	-5,000	-107,552	0	146,301	-59,721	0.67	-40,310
4					-7,000	-16,592	-5,000	-107,552	0	146,301	10,458	0.59	6,192
5					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.52	3,874
6					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.46	3,398
7					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.40	2,981
8					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.35	2,615
9					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.31	2,293
10					-10,000	-16,592	-5,000	-107,552	0	146,301	7,458	0.27	2,012
												NPV	**-215,716**

Annex 1-7: Cash flow (Central_Mkushi)

Farming season	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**
Average farm size owned (Ha)	97	97	97	97	97	97	97	97	97	97
Market price per 50kg bag (ZMW)	115	80	80	80	80	80	80	80	80	80
Average yield per hectare (50kg bag)	55	50	50	50	50	50	50	50	50	50
Seasonal Income from Farming (ZMW)	613,525	388,000	388,000	388,000	388,000	388,000	388,000	388,000	388,000	388,000
Number of beneficiary farmers (land preparation services)	18	20	20	20	20	20	20	20	20	20
Average Number of Ha Prepared	3	3	3	3	3	3	3	3	3	3
Service charge per hectare	520	520	520	520	520	520	520	520	520	520
Revenue from Land Preparation Service Provision (ZMW)	28,080	30,680	30,160	30,160	30,160	30,160	30,160	30,160	30,160	30,160
Fuel Use Cost Own Farm Size (ZMW)	29,163	33,509	33,984	33,984	33,984	33,984	33,984	33,984	33,984	33,984
Fuel Use Cost Service Provision (ZMW)	16,235	20,382	20,320	20,320	20,320	20,320	20,320	20,320	20,320	20,320
Fuel Use Cost Travel (ZMW)	309	355	360	360	360	360	360	360	360	360
Maintenance for Service Provision	3,755	3,026	2,994	2,994	2,994	2,994	3,742	3,742	3,742	3,742
Labour Cost for Service provision	4,291	4,538	4,490	4,490	4,490	4,490	4,490	4,490	4,490	4,490
Net income from service provision (ZMW)	3,489	2,379	1,995	1,995	1,995	1,995	1,247	1,247	1,247	1,247

Annex 1-8: Investment analysis (Central_Mkushi)

Years	**Investment (ZMW)**				**Costs (ZMW)**				**Benefits (ZMW)**			**Net Benefit (ZMW)**	**Discount Factor**	**PV (ZMW)**
	Tractor	**Plough**	**Sheller**	**Down payment**	**Maintenance**	**Fuel**	**Labour**	**Production Cost**	**Ploughing**	**Shelling**	**Own farm earnings**			
0			-54,000	-65,000								-119,000	1.00	- 119,000
1	-51,667				-10,500	-45,707	-12,000	-168,267	28,080	13,836	613,525	367,300	0.88	322,193
2	-51,667				-8,000	-54,246	-12,000	-168,267	30,680	13,836	388,000	138,337	0.77	106,446
3	-51,667				-8,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	137,398	0.67	92,740
4					-8,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	189,065	0.59	111,941
5					-8,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	189,065	0.52	98,194
6					-8,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	189,065	0.46	86,135
7					-10,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	187,065	0.40	74,758
8					-10,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	187,065	0.35	65,577
9					-10,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	187,065	0.31	57,524
10					-10,000	-54,665	-12,000	-168,267	30,160	13,836	388,000	187,065	0.27	50,460
													NPV	**946,969**

Annex 1-9: Cash flow (Central_Chibombo)

Farming season	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Average farm size owned (Ha)	40	40	40	40	40	40	40	40	40	40
Market price per 50kg bag (ZMW)	90	90	90	90	90	90	90	90	90	90
Average yield per hectare (50kg bag)	70	60	60	60	60	60	60	60	60	60
Seasonal Income from Farming (ZMW)	252,000	216,000	216,000	216,000	216,000	216,000	216,000	216,000	216,000	216,000
Number of beneficiary farmers (land preparation services)	190	190	190	190	190	190	190	190	190	190
Average Number of Ha Prepared	2	2	2	2	2	2	2	2	2	2
Charge per Ha	300	300	300	300	300	300	300	300	300	300
Revenue from Land Preparation Service Provision (ZMW)	90,060	90,060	90,060	90,060	90,060	90,060	90,060	90,060	90,060	90,060
Revenue from Processing Service Provision (ZMW)	0	0	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Fuel Use Cost Own Farm Size (ZMW)	9,660	10,511	9,020	10,364	10,511	10,511	10,511	10,511	10,511	10,511
Fuel Use Cost Service Provision (ZMW)	72,498	78,881	67,691	77,778	78,881	78,881	78,881	78,881	78,881	78,881
Fuel Use Cost Travel (ZMW)	276	300	258	296	300	300	300	300	300	300
Maintenance for Service Provision	7,059	7,059	7,059	7,059	7,059	7,059	8,824	8,824	8,824	8,824
Labour Cost for Service provision	10,589	10,589	10,589	10,589	10,589	10,589	10,589	10,589	10,589	10,589
Net income from service provision (ZMW)	-363	-6,770	4,463	-5,663	-6,770	-6,770	-8,535	-8,535	-8,535	-8,535

Annex 1-10: Investment analysis (Central_Chibombo)

Years (ZMW)	**Investment (ZMW)**			**Costs (ZMW)**				**Benefits (ZMW)**				**Net Benefit (ZMW)**	**Discount Factor**	**PV (ZMW)**
	Tractor	**Ripper**	**Sheller**	**Down payment**	**Maintenance**	**Fuel**	**Labour**	**Production Cost**	**Ripping**	**Shelling**	**Own farm earnings**			
0				-30,000								-30,000	1.00	-30,000
1	-48,333				-8,000	-82,434	-12,000	-69,388	90,060		252,000	121,904	0.88	106,933
2	-48,333		-30,000		-8,000	-89,692	-12,000	-69,388	90,060		216,000	78,646	0.77	60,516
3	-48,333				-8,000	-76,969	-12,000	-69,388	90,060	2,200	216,000	93,570	0.67	63,157
4					-8,000	-88,438	-12,000	-69,388	90,060	2,200	216,000	130,434	0.59	77,227
5					-8,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	129,180	0.52	67,092
6					-8,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	129,180	0.46	58,852
7					-10,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	127,180	0.40	50,826
8					-10,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	127,180	0.35	44,584
9					-10,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	127,180	0.31	39,109
10					-10,000	-89,692	-12,000	-69,388	90,060	2,200	216,000	127,180	0.27	34,306
													NPV	**572,602**

Annex 1-11: Cash flow (Central_Mumbwa)

Farming season	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**
Average farm size owned (Ha)	19	19	19	19	19	19	19	19	19	19
Market price per 50kg bag (ZMW)	70	70	70	70	70	70	70	70	70	70
Average yield per hectare (50kg bag)	70	70	70	70	70	70	70	70	70	70
Seasonal Income from Farming (ZMW)	93,100	93,100	93,100	93,100	93,100	93,100	93,100	93,100	93,100	93,100
Number of beneficiary farmers (land preparation services)	157	157	157	157	157	157	157	157	157	157
Average Number of Ha Prepared	1	1	1	1	1	1	1	1	1	1
Charge per Ha	300	300	300	300	300	300	300	300	300	300
Revenue from Land Preparation Service Provision (ZMW)	51,810	51,810	51,810	51,810	51,810	51,810	51,810	51,810	51,810	51,810
Revenue from Processing Service Provision (ZMW)	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Fuel Use Cost Own Farm Size (ZMW)	4,589	4,992	4,284	4,923	4,992	4,992	4,992	4,992	4,992	4,992
Fuel Use Cost Service Provision (ZMW)	41,707	45,379	38,942	44,744	45,379	45,379	45,379	45,379	45,379	45,379
Fuel Use Cost Travel (ZMW)	276	300	258	296	300	300	300	300	300	300
Maintenance for Service Provision	0	0	0	0	5,405	5,405	5,405	5,405	5,405	5,405
Labour Cost for Service provision	9,335	9,335	9,335	9,335	9,335	9,335	9,335	9,335	9,335	9,335
Net income from service provision (ZMW)	492	-3,204	3,276	-2,566	-8,610	-8,610	-8,610	-8,610	-8,610	-8,610

Annex 1-12: Investment analysis (Central_Mumbwa)

Years	**Investment (ZMW)**			**Costs (ZMW)**				**Benefits (ZMW)**				**Net Benefit (ZMW)**	**Discount Factor**	**PV (ZMW)**
	Tractor	**Ripper**	**Sheller**	**Down payment**	**Maintenance**	**Fuel**	**Labour**	**Production Cost**	**Ripping**	**Shelling**	**Own farm earnings**			
0			-30,000	-26,000								-26,000	1.00	-26,000
1	-49,667				0	-46,572	-10,362	-32,959	51,810	4,000	93,100	9,350	0.88	8,202
2	-49,667				0	-50,672	-10,362	-32,959	51,810	4,000	93,100	5,250	0.77	4,040
3	-49,667				0	-43,484	-10,362	-32,959	51,810	4,000	93,100	12,438	0.67	8,395
4					0	-49,963	-10,362	-32,959	51,810	4,000	93,100	55,625	0.59	32,935
5					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.52	25,406
6					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.46	22,286
7					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.40	19,549
8					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.35	17,148
9					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.31	15,042
10					-6,000	-50,672	-10,362	-32,959	51,810	4,000	93,100	48,917	0.27	13,195
													NPV	**140,198**

Annex 1-13: Cash flow (Southern_Chikankata)

Season	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**
Average farm size owned (Ha)	29	29	29	29	29	29	29	29	29	29
Market price per 50kg bag (ZMW)	130	130	130	130	130	130	130	130	130	130
Average yield per hectare (50kg bag)	17	17	17	17	17	17	17	17	17	17
Seasonal Income from Farming (ZMW)	64,844	64,844	64,844	64,844	64,844	64,844	64,844	64,844	64,844	64,844
Number of beneficiary farmers (land preparation services)	12	12	12	12	12	12	12	12	12	12
Average Number of Ha Prepared	3	3	3	3	3	3	3	3	3	3
Charge per Ha	580	580	580	580	580	580	580	580	580	580
Revenue from Land Preparation Service Provision (ZMW)	17,400	17,400	17,400	17,400	17,400	17,400	17,400	17,400	17,400	17,400
Fuel Use Cost Own Farm Size (ZMW)	7,620	6,539	7,514	7,620	7,620	7,620	7,620	7,620	7,620	7,620
Fuel Use Cost Service Provision (ZMW)	7,883	6,765	7,773	7,883	7,883	7,883	7,883	7,883	7,883	7,883
Fuel Use Cost Travel (ZMW)	300	258	296	300	300	300	300	300	300	300
Maintenance for Service Provision	0	0	0	0	-3,051	-3,051	-3,051	-3,051	-3,051	-3,051
Net income from service provision (ZMW)	9,217	10,378	9,331	9,217	6,166	6,166	6,166	6,166	6,166	6,166

Annex 1-14: Investment analysis (Southern_Chikankata)

Years	**Investment (ZMW)**			**Costs (ZMW)**				**Benefits (ZMW)**				**Net Benefit (ZMW)**	**Discount Factor (ZMW)**	**PV (ZMW)**
	Tractor	**Ripper**	**Sheller**	**Down payment**	**Maintenance**	**Fuel**	**Labour**	**Production Cost**	**Ripping**	**Shelling**	**Own farm earnings**			
0				-40,000								-40,000	1.00	-40,000
1	-46,667				0	-15,803	0	-26,204	17,400	0	64,844	-6,430	0.88	-5,640
2	-46,667				0	-13,561	0	-26,204	17,400	0	64,844	-4,188	0.77	-3,223
3	-46,667				0	-15,582	0	-26,204	17,400	0	64,844	-6,209	0.67	-4,191
4					0	-15,803	0	-26,204	17,400	0	64,844	40,237	0.59	23,823
5					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.52	17,781
6					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.46	15,598
7					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.40	13,682
8					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.35	12,002
9					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.31	10,528
10					-6,000	-15,803	0	-26,204	17,400	0	64,844	34,237	0.27	9,235
													NPV	**49,596**

Annex 1-15: Labour hour use per hectare for cultivating and processing rice

Labor Dynamics	Participants						Non-participants					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Planting (rice)	273	784	21	10	10	1	432	85	394	166	183	44
Fertilizer application (rice)	45	32	13	9	4	0	11	0	11	0	10	0

Weeding (rice)	438	311	102	25	77	1	436	107	324	104	203	18
Pests/ disease control (rice)	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting (rice)	237	146	193	20	62	0	175	46	123	41	79	5
Processing (hours/50-kg-rice-bag)	8	3	4	2	1	0	11	3	9	3	4	2
TOTAL LABOUR HOUR USE	***1008***	***1277***	***337***	***69***	***154***	***3***	***1226***	***247***	***1004***	***397***	***530***	***80***

Annex 1-16: Total farm labour hour use for cultivating and processing rice

Labor Dynamics	Participants						Control Group					
	Total labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	Total labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Planting (rice)	1498	1057	397	136	7	54	546	57	451	341	39	153
Fertilizer application (rice)	150	120	30	6	0	23	13	0	13	11	0	3
Weeding (rice)	1008	725	206	122	6	79	532	252	277	150	18	110
Pests/ disease control (rice)	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting (rice)	554	342	151	96	0	55	325	207	118	62	8	48
Processing (rice)	351	183	166	41	9	116	392	304	88	42	14	32
TOTAL LABOUR HOUR USE	***3598***	***2432***	***975***	***413***	***23***	***340***	***2120***	***840***	***1227***	***685***	***98***	***526***

Annex 1-17: Labour hour use per hectare for cultivating and processing sunflower

Labor Dynamics	Participants						Non-participants					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Planting (sunflower)	68	0	68	28	37	3	28	1	27	5	20	2
Fertilizer application (sunflower)	0	0	0	0	0	0	0	0	0	0	0	0
Weeding (sunflower)	135	0	135	34	91	10	103	9	94	65	22	7
Pests/ disease control (sunflower)	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting (sunflower)	239	38	317	76	105	5	384	3	361	160	190	16
Processing (hours/50-kg-sunflower-bag)	9	0	6	3	3	1	10	0	9	5	3	1
TOTAL LABOUR HOUR USE	***456***	***39***	***530***	***143***	***238***	***19***	***687***	***20***	***636***	***317***	***287***	***36***

Annex 1-18: Total farm labour hour use for cultivating and processing sunflower

Labor Dynamics	Participants						Control Group					
	Total labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	Total labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Planting (sunflower)	74	0	74	37	3	33	18	2	16	13	2	2
Fertilizer application (sunflower)	0	0	0	0	0	0	0	0	0	0	0	0
Weeding (sunflower)	87	0	87	43	10	34	148	30	118	26	10	83
Pests/ disease control (sunflower)	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting (sunflower)	233	26	207	107	4	96	171	10	161	74	10	76
Processing (sunflower)	79	2	77	24	14	39	104	0	82	37	5	41
TOTAL LABOUR HOUR USE	***511***	***33***	***470***	***223***	***33***	***215***	***753***	***63***	***657***	***229***	***46***	***383***

Annex 1-19: Labour hour use per hectare for cultivating and processing seed cotton

Labor Dynamics	Participants						Non-participants					
	Total labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	Total labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Planting (seed cotton)	37	2	35	14	19	2	36	0	36	9	24	3
Fertilizer application (seed cotton)	9	0	9	8	1	1	18	0	18	18	0	0
Weeding (seed cotton)	363	16	346	156	170	21	328	0	328	176	118	34
Pests/ disease control (seed cotton)	18	0	18	18	0	0	53	0	53	51	2	0
Harvesting (Seed cotton)	778	142	636	260	356	20	0	0	0	0	0	0
Processing (hours/50-kg-seed cotton-bag)	19	0	19	9	9	0	24	0	24	8	16	0
TOTAL LABOUR HOUR USE	***1230***	***161***	***1068***	***468***	***556***	***45***	***621***	***7***	***603***	***345***	***212***	***48***

Annex 1-20: Total farm labour hour use for cultivating and processing seed cotton

Labor Dynamics	Participants						Control Group					
	Total labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	Total labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Planting (seed cotton)	36	3	32	17	2	13	34	0	32	24	3	6
Fertilizer application (seed cotton)	7	0	7	1	1	5	18	0	18	0	0	18
Weeding (seed cotton)	343	26	317	153	21	144	390	0	390	137	50	204
Pests/ disease control (seed cotton)	12	0	12	0	0	12	37	0	37	1	0	36
Harvesting (seed cotton)	632	115	492	247	28	217	757	37	696	304	51	341
Processing (seed cotton)	672	0	672	336	0	79	576	0	576	378	0	79
TOTAL LABOUR HOUR USE	***1740***	***149***	***1557***	***764***	***54***	***483***	***2125***	***57***	***2029***	***923***	***123***	***865***

Annex 1-21: Labour hour use per hectare for cultivating and processing soybean

Labor Dynamics	Participants						Non-participants					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Planting (soybean)	37	9	28	18	8	1	87	6	78	31	45	2
Fertilizer application (soybean)	49	9	40	30	10	0	6	0	6	3	3	0
Weeding (soybean)	13	8	5	5	0	1	335	1	332	119	188	24

Pests/ disease control (soybean)	8	4	3	3	0	0	1	0	1	1	0	0
Harvesting (soybean)	316	81	306	120	82	15	244	15	208	100	88	22
Processing (hours/50-kg-soybean-bag)	11	1	9	5	3	2	34	1	31	14	13	5
TOTAL LABOUR HOUR USE	***439***	***112***	***397***	***184***	***105***	***19***	***870***	***31***	***801***	***351***	***389***	***63***

Annex 1-22: Total farm labour hour use for cultivating and processing soybean

Labor Dynamics	Participants						Control Group					
	Total Labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	Total Labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Planting (Soybean)	79	32	47	12	1	34	98	27	69	37	2	30
Fertilizer application (Soybean)	29	9	20	5	0	15	48	0	48	24	0	24
Weeding (Soybean)	66	58	8	0	1	8	212	9	203	92	11	100
Pests/ disease control (Soybean)	8	5	3	0	0	3	2	1	1	0	0	1
Harvesting (Soybean)	367	155	201	78	10	114	223	42	173	68	15	90
Processing (Soybean)	220	74	165	56	19	90	257	62	162	73	13	75
TOTAL LABOUR HOUR USE	***808***	***338***	***470***	***162***	***31***	***277***	***1152***	***160***	***936***	***374***	***60***	***502***

Annex 1-23: Labour hour use per hectare for cultivating and processing groundnut

Labor Dynamics	Participants						Non-participants					
	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha	Total Labour hours/ha	Hired labour hours/ha	Family labour hours/ha	Male family labour/ha	Female family labour/ha	Children family labour/ha
Planting (groundnut)	46	2	37	10	27	2	64	2	63	19	34	9
Fertilizer application (groundnut)	0	0	0	0	0	0	0	0	0	0	0	0
Weeding (groundnut)	370	19	308	114	175	19	379	10	350	123	211	16
Pests/ disease control (groundnut)	0	0	0	0	0	0	6	0	6	6	0	0
Harvesting (groundnut)	573	58	505	149	333	22	568	32	472	198	248	27
Processing (hours/50-kg-groundnut-bag)	25	0	25	14	8	3	30	5	25	6	12	7
TOTAL LABOUR HOUR USE	***1020***	***80***	***879***	***291***	***544***	***47***	***1209***	***56***	***1061***	***435***	***557***	***69***

Annex 1-24: Total farm labour hour use for cultivating and processing groundnut

Labor Dynamics	Participants						Control Group					
	Total labour hours	Hired Labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour	Total labour hours	Hired labour hours	Family labour hours	Female labour hours	Children family labour	Male family labour
Planting (groundnut)	27	5	22	15	1	6	39	2	36	23	3	10
Fertilizer application (groundnut)	0	0	0	0	0	0	0	0	0	0	0	0
Weeding (groundnut)	224	28	164	89	9	66	252	29	223	130	10	83
Pests/ disease control (groundnut)	0	0	0	0	0	0	6	0	6	0	0	6
Harvesting (groundnut)	395	111	274	176	11	87	367	17	311	171	14	126
Processing (groundnut)	67	0	64	18	5	41	248	75	166	81	23	62
TOTAL LABOUR HOUR USE	***752***	***149***	***550***	***309***	***28***	***213***	***1225***	***144***	***1022***	***485***	***69***	***469***

Annex 1-25: Probit regression, reporting marginal effects

Iteration 0: log likelihood = -173.15877
Iteration 1: log likelihood = -163.47712
Iteration 2: log likelihood = -163.37597
Iteration 3: log likelihood = -163.37582

Probit regression, reporting marginal effects

Number of obs = 250
LR chi2(12) = 19.57
Prob > chi2 = 0.0758
Pseudo R2 = 0.0565

Log likelihood = -163.37582

John Deere Mechanized	**dF/dx**	**Std. Err.**	**z**	**P>|z|**	**x-bar**	**[95% C.I.**	**]**
Farming experience	0.0003256	0.002997	0.11	0.913	20.584	-0.00555	0.006200
Off-farm business* (yes/no)	0.062702	0.070252	0.89	0.373	0.432	-0.07499	0.200394
Household size	-0.0013258	0.012329	-0.11	0.914	7.376	-0.02549	0.022838
Gender of household head* (male=1/female=0)	0.1147858	0.083225	1.36	0.172	0.2	-0.04833	0.277905
Education level of household head (years)	0.0223491	0.010271	2.18	0.03	7.68	0.002218	0.042480
Land ownership before scheme (ha)	-0.0000771	0.002651	-0.03	0.977	8.3303	-0.00527	0.005119
Access to extension service* (yes/no)	0.0938204	0.075911	1.22	0.221	0.696	-0.05496	0.242603
Access to credit facilities* (yes/no)	-0.0748862	0.095191	-0.78	0.436	0.14	-0.26146	0.111685
Network group membership* (yes_no)	0.1986321	0.093855	1.98	0.048	0.86	0.014681	0.382584
Market access (minutes)	0.000687	0.001283	0.54	0.592	30.712	-0.00183	0.003202
Livestock ownership before Mechanization Scheme	0.0043644	0.002653	1.65	0.1	7.8512	-0.00084	0.009564
Farmer’s investment behavior	0.0342892	0.131245	0.26	0.794	0.8012	-0.22295	0.291524
obs. P	0.484						
pred. P	0.4818822 (at x-bar)						

(*) dF/dx is for discrete change of dummy variable from 0 to 1
z and P>|z| correspond to the test of the underlying coefficient being 0

Annex 1-26: Stata output of probit model predictive strength

	TRUE		
Classified	D	~D	Total
+	69	51	120
-	52	78	130
Total	121	129	250

Classified + if predicted Pr(D) >= 0.5
True D defined as **John Deere** Mechanized != 0

Sensitivity		
Specificity	Pr(-|~D)	60.47%
Positive predictive value	Pr(D| +)	57.50%
Negative predictive value	Pr(~D| -)	60.00%
False + rate for true ~D	Pr(+|~D)	39.53%
False - rate for true D	Pr(-| D)	42.98%
False + rate for classified +	Pr(~D| +)	42.50%
False - rate for classified -	Pr(D| -)	40.00%
Correctly classified		**58.80%**

Annex 1-27: Result of matching quality assessment; pstest

Variable	Mean			t-test		V(T)/ V(C)
	Treated	Control	% bias	t	p>|t|	
Farming experience	20.288	20.937	-5.4	-0.41	0.679	1.03
Off-farm business (yes/no)	0.47458	0.43488	8	0.61	0.542	.
Household size	7.3983	7.2402	5.6	0.44	0.661	0.88
Gender of household head (male=1/female=0)	0.21186	0.19279	4.8	0.36	0.717	.
Education level of household head (years)	8.2034	8.1446	1.7	0.14	0.892	1.23
Land ownership before scheme (ha)	8.6518	8.3254	2.5	0.19	0.851	0.77
Access to extension service (yes/no)	0.74576	0.73156	3.1	0.25	0.805	.
Access to credit facilities (yes/no)	0.13559	0.13328	0.7	0.05	0.959	.
Network group membership (yes_no)	0.91525	0.93736	-6.5	-6.5	0.518	.
Market access (minutes)	31.195	31.999	-3.1	-0.22	0.825	0.67*
Livestock ownership before Mechanization Scheme	7.3864	7.4835	-0.6	-0.06	0.95	0.57*
Farmer’s investment behavior	0.80593	0.80201	1.5	0.12	0.903	1.27

* if variance ratio outside [0.69; 1.44]

Ps	R2	LR chi2	p>chi2	Mean Bias	Median Bias	B	R	%Var
0	0.005	1.58	1	3.6	3.1	16.3	1.06	29

* if B>25%, R outside [0.5; 2]

Annex 1-28: Stata output of *ATT* estimation of the effect of use of John Deere Mechanization service

	Net on-farm income	On-farm income per hectare	On-farm income per household	Maize Yield per hectare	Food expenditure	Expenditure on education	Expenditure on non-food household needs	Health Expenses	Expenditure on Recreation (Alcohol, Tobacco, etc.)	Skipping Meals	Food Diversity Count
Observed coefficient	10032.6**	719.3	1514.1**	0.424	222.5**	852.5**	760.6**	-56.72	-39.61	-0.155**	-0.0842
	(3549.111)	(517.8345)	(549.0867)	(0.2342232)	(73.35154)	(311.2878)	(248.0275)	(113.7731)	(23.58175)	(.0558304)	(0.7219543)
N	250	250	250	250	250	250	250	250	250	250	250

Bootstrap standard error in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Annex 1-29: Stata output of mean differences using double difference *ATT* technique

	Before and after JD mechanization difference in land ownership	Before and after JD mechanization difference in maize seed used (kg)	Before and after JD mechanization difference in fertilizer used (MT)	Before and after JD mechanization difference in herbicides used (litres)	Before and after JD mechanization difference in pesticides used (litres)	Before and after JD mechanization difference in livestock units owned	Before and after JD mechanization difference in maize yield (MT)
Observed coefficient	0.0243	3.506	0.331***	1.941	-0.0579	1.289	0.703
	(0.6252776)	(11.62327)	(0.0903259)	(1.690674)	(0.2348534)	(1.340761)	(2.951629)
N	250	250	232	107	250	250	228

Bootstrap standard error in parentheses

* p<0.05 ** p<0.01 *** p<0.001