AN ASSESSMENT OF HERBICIDE TECHNOLOGY ADOPTION AMOUNG SMALL SCALE FARMERS IN KEEMBE CHIBOMBO

BY

AMOS MVULA

UNZA 2016

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A Research Report presented to the Department of Agricultural Economics and Extension of the University of Zambia.

BY

AMOS MVULA

In Partial Fulfillment of the Requirements for the Degree of Bachelor of Agricultural Sciences

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First and foremost I want to thank God Almighty for making it possible for me to complete my studies.

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LIST OF ABREVIATIONS

ALS	Aceto Lactate Synthase
AMIZ	Association for Microfinance Institutions in Zambia
AMPA	Amino Methyl Phosphoric Acid
CSO	Central Statistics Office
GR	Glyphosate Resistance
HH	Household Head
HR	Herbicide Resistance
MAL	Ministry Of Agriculture and Livestock
MOA	Mechanism of Herbicide Action
MCL	Maximum Contamination Levels
NGO	Non-Governmental Organization
NHL	Non-Hodgkins Lymphoma
OFSP	Orange Fleshed Sweet Potato
SPSS	Statistical Package for Social Sciences
US	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSSA	Weed Science Society of America
Zamwipe	Zambian Weed Wiper
ZMW	Zambian Kwacha

ABSTRACT

Weeds are an under estimated crop pest in Africa. Plant pathology and entomology take precedency over weed science. Because weeds do not strike as violently as insects, there is a tendency to underestimate their importance. Under unweeded conditions crop losses have been measured for the following; maize (55-90%), common bean (50%), sorghum (40-80%), groundnut (80%), cassava (90%), wheat (50-80%), cow pea (40-60%).Weed competition is most serious when the crop is young. Herbicides are chemicals that can be alternatively used to control weeds. They are most effective and time-efficient weed control method. The use of herbicides ensures a decrease in weed density over time. Most significantly, 90% of acres on large plantation farms in sub-Saharan Africa are treated with herbicides, the same percentage on all crop lands in developed countries while only 5% of small holder acres receive herbicide applications.

This study was centred on small scale farmers in central province of Zambia, specifically the rural farming areas of Keembe Chibombo. The main focus of the study will be centred on shedding light on the adoption of herbicides. A technology that has proven to reduce crop yield losses attributed to ineffective weed control methods. The specific things of the study included firstly to assess the adoption rates of herbicides by small scale farmers in Keembe, Chibombo. Secondly to determine the descriptive characteristics factors affecting adoption of herbicides among small scale farmers. The structured questionnaire was the primary instrument used for data collection. Descriptive statistics were generated using Stata. Excel was used to organize outputs.

Among the factors found to have had influence to herbicide adoption included: age, education, herbicide training, and sprayer ownership, access to credit and membership to an agricultural organization positively affect adoption according to descriptive statistics. Distance where herbicides to negatively affect adoption of herbicides in the area.

On the aspect of adoption, adoption stood at 66.7% while non-adopter at 33.3%. The adoption rates where between 1995 and 1999 at 1.1%, 2000 to 2004 at 3.3%, 2005 to 2009 at 15.6% and finally 2010 and onwards at 46.7%.

Thus there is need to open up more agro chemical outlets so as to shorten distance where chemicals can be sourced. Education should be continuously be encouraged by the government in the area by building more primary, secondary schools and making it affordable for all including the tertiary level. Research should be undertaken by other researchers to establish whether there has been significant increases in yields of various crops in the area owing to the high adoption levels of chemical weed control measures.

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CHAPTER ONE:

INTRODUCTION

1.1 BACKGROUND

Weeds are an under estimated crop pest in Africa. Plant pathology and entomology take precedency over weed science. Because weeds do not strike as violently as insects, there is a tendency to underestimate their importance. Even when a farmer abandons a crop to weeds, such incidents do not attract attention. Weeds are most universal of all plant pests proliferating every year on every farm in Africa. A review of crop pests in sub-Saharan Africa indicated that weeds are the most important pests to control in all zones studied (Sibuga 1997). Broad leaf weeds and grasses dominate the spectrum, whereas sedges are minor. Weed problems are more severe in African tropical regions than in Europe and North America because weeds grow more vigorously and regenerate more quickly because of heat and higher light intensity. High humidity and high temperature conditions characteristic of sub-Saharan Africa, favour rapid ad excessive weed growth. High humidity and high temperature conditions characteristic of sub-Saharan Africa, favour rapid and excessive weed growth. Weeds reduce crop yields by competing with crops for light, water, nutrients and space. Numerous studies have documented the negative effects on yield of season-long weed competition in Africa. Under unweeded conditions crop losses have been measured for the following; maize (55-90%), common bean (50%), sorghum (40-80%), groundnut (80%), cassava (90%), wheat (50-80%), cow pea (40-60%). (Ambe et al. 1992; Akobudu 1987; Ishaya et al 2007; Chikoye et al 2007).Weed competition is most serious when the crop is young. Weeds need to be cleared from a field prior to planting a crop and again during the growing season for optimal yields to be achieved.

On the other hand the principal limiting factor to the size of African farms is the number of necessary weeding's during the period following planting (Kent et al. 2001). Johnson discovered that 80% of the small holder farmers would increase the size of cultivated land if weeds were less of a problem (Johnson 1995). Thus weeds can be considered the main constraint to agricultural production. Furthermore, increased use of fertilizer has been promoted for several years as a way of increasing yields in the region. However, the benefits of fertiliser depend on weed control. Applying fertilizer competes with labour with weeding and planting of additional crops. Crops may not respond to fertilizer applied late (Makanganise et al. 1999).

Thus today farmers in Zambia, Africa continue to realise 70% lower yields than researchers on unweeded plots. Reasons for the lag include weeding at suboptimal times and labour constraints. For example, small holder maize yield are typically 1-2 tons per hectare compared to 8-10 tons per hectare by commercial farmers and research stations in Zambia (Littenel et al. 2007, Bishop-Sambrook 2003). Herbicides are an alternative to weed control since they are quick and effective. In addition, the Environmental Protection Agency in Europe has shown that for example that atrazine has no negative effect on human life (Williams, 2013). Herbicides can be sprayed before planting to remove weeds from field, applied directly to soil at planting for residual control for germinating weed and applied to weeds during the growing season. Several benefits have been found in the usage of herbicides. For example, by reducing labour requirement for weed control, herbicide use could only allow additional resources to be invested in food crops to the benefit of food security in the country (Mavudzi et al 2001). Along with food security and better nutrition, the potential benefits of herbicide use include increased incomes and reduced drudgery. Thus herbicides have great potential of solving the weed problem in Zambia. The unfortunate part is that only a few small scale farmers have adopted this technology (Ito et al., 2007)

1.2 PROBLEM OF THE STATEMENT

Herbicides are chemicals that can be alternatively used to control weeds. They are most effective and time-efficient weed control method (Chhokar et al 2007). The use of herbicides ensures a decrease in weed density over time (Mouni et al 2013). Thus herbicide technology can be a good alternative to control weeds particularly if they are used in combination with other herbicides. They can even be 95% effective in controlling weeds and weed resistance when combined (Beckie & Rebound, 2014). This enables farmers to combine with other herbicides thus widen the weed spectrum controlled (Williams et al. 2011). Most significantly, 90% of acres on large plantation farms in sub-Saharan Africa are treated with herbicides, the same percentage on all crop lands in developed countries while only 5% of small holder acres receive herbicide applications. Most farmers use hand hoes for weeding, and a small minority use herbicides in sub-Saharan Africa (Bisanda & Mwangi, 1996). It is only slowly that herbicides are being known as an economic way to control weeds in southern Africa (Rugare and Mabasa, 2013). Furthermore, use of herbicides is environmentally friendly and have been proven by the Environmental Protection council in Europe particularly atrazine which was earlier on thought to have negative effect on humans (Williams, In addition the study is relevant to a country such as Zambia which has since independence over relied on copper. Copper prices have recently declined thus causing serious economic challenges since it has been Zambia's main export. Thus this study will exploit on the opportunities that Zambia would have in increasing its productivity in agriculture production of various crop per hectare. While the study focuses on assessing adoption of herbicides by small scale farmers, it addresses the issues of how to manage change in the farming sector. The small scale farmers are a target of many technological and policy changes. Thus this study will help us make recommendation that will possibly help small scale farmers consistent with research findings.

1.7 HYPOTHESIS

There are a lot of small scale farmers who have adopted herbicides technology in Keembe Chibombo.

CHAPTER TWO:

LITERATURE REVIEW

2.1 INTRODUCTION

A literature review is a critical and in depth evaluation of previous research. It is a summary and synopsis of a particular area of a research, allowing anybody reading the paper to establish why you are doing a particular research program. A good literature review expands upon the reason behind selecting a particular research question. It is important, however, to note that books while being an invaluable source of information, tend to give summaries and general backgrounds of research material. They do not always provide primary research material. Academic journals and magazines on the other hand tend to provide up to date information. They are usually published periodically and thus the information they contain is much more recent. Dissertations are equally a good source of information as they afford the research access to primary data derived from field studies.

In this study the assessment of herbicide adoption amongst small scale farmers was gathered from a range of sources comprising books, journals, dissertations and magazines.

The purpose of this chapter therefore is to provide a theoretical background which provides a framework for diagnosis of the problem under study in order to arrive at possible solutions to the problem at hand.

2.2 EFFECTS OF WEEDS ON CROPS

2.2.1 INTRODUCTION

Weeds are undesirable plants growing within a crop and they compete for resources such as nutrients, water and light. Without weed control, crop yields can be significantly reduced. Weeds can also cause further problems by harbouring pests and diseases, interfering with harvest operations, and increasing costs of cleaning and drying the crop produce.

Weeds are an under estimated crop pest in Africa. Plant pathology and entomology take precedence over weed science. Because weeds do not strike as violently as insects, there is a tendency to underestimate their importance. Even when a farmer abandons a crop to weeds, such incidents do not attract attention. Weeds are most universal of all plant pests proliferating every year on every farm in Africa. A review of crop pests in sub-Saharan Africa indicated that weeds are the most important pests to control in all zones studied (Sibuga 1997). Broad leaf weeds and grasses dominate the spectrum, whereas sedges are minor. Weed problems are more severe in African tropical regions than in Europe and North America because weeds grow more vigorously and regenerate more quickly because of heat and higher light intensity. High humidity and high temperature conditions characteristic of sub-saharan Africa, favour rapid ad excessive weed growth. Weeds reduce crop yields by competing with crops for light, water, nutrients and space. Numerous studies have documented the negative effects on yield of season-long weed competition in Africa. Under unweeded conditions crop losses have been measured for the following; maize (55-90%), common bean (50%), sorghum (40-80%), groundnut (80%), cassava (90%), wheat (50-80%), cow pea (40-60%). (Ambe et al. 1992; Akobudu 1987; Ishaya et al 2007; Chikoye et al 2007).Weed competition is most serious when the crop is young. Weeds need to be cleared from a field prior to planting a crop and again during the growing season for optimal yields to be achieved.

Thus today farmers in Zambia, Africa continue to realise 70% lower yields than researchers on unweeded plots. Reasons for the lag include weeding at suboptimal times and labour constraints. For example, small holder maize yield are typically 1-2 tons per hectare compared to 8-10 tons per hectare by commercial farmers and research stations in Zambia (Littenel et al. 2007, Bishop-Sambrook 2003).

Weeds compete with the cultivated crops for nutrients, moisture, sunlight, and space. They are any plants that grow where they are not wanted. They compete for shelter pests and diseases that attack the crop. They reduce crop yields and farmers' incomes. Controlling weeds can be a lot of work.

They take light, water and food away from your crops. They push the crops out of their living space. They shelter pests and diseases that attack the crop. The longer you leave them, the harder they are to control. Control them before they steal your yield.

The impacts of poor weed management practices have continued to worsen crop yield loss within the smallholder farming sector in southern Africa. This has left the majority of smallholder farmers food insecure where their average maize grain yields is as low as 0.8 tonnes ha-1 (Baudron *et al.*, 2012). Traditionally, weed management has been handled via the use of conventional tillage

Corresponding author's Name: Tarirai Muoni Email address: *tarirai.muoni@gmail.com* practices where the mould plough is the common tool used for land preparation (Colbach *et al.*, 2000). The mouldboard plough facilitates turning of the soils burying weeds and their seeds leaving the farmers' field weed free at the onset of the season. However, such weed management practices are ideal to farmers who have access to draft power that is necessary when using the mouldboard plough. Most of the resource limited smallholder farmers use hand hoes for land preparation, planting and weeding that is normally done three times per growing season (Siziba, 2008). However, hand hoe weeding is labour intensive (Mandumbu *et al.*, 2011) and Asian Journal of Agriculture and Rural Development journal homepage: Asian Journal of Agriculture and Rural Development, labour availability is limited due rural to urban migration of most youths. Thus the smallholder farms are occupied by old farmers whom some of them have been affected by the HIV/AIDS pandemic disease that reduces their ability to weed three times and before yield losses are encountered. This has left more land abandoned due to weed infestation, especially on resources poor farms. Although the conventional tillage practises facilitates easy weed management practices at smallholder farming level, it has been reported to offer more detrimental effects on the farm. Conventional tillage practices increases soil loss in the fields (Alba *et al.*, 2006; Thierfelder and Wall, 2009; Zhang *et al.*, 2003). This reduces the productivity of the plots since most fertile soils are washed away by water runoff (Thierfelder and Wall, 2012; Thierfelder and Wall, 2009). Also, conventional ploughing reduces soil moisture retention and crops are affected by moisture stress that are commonly experienced during the growing season which results in yield decrease at the end of the season (Thierfelder and Wall, 2010).

2.3 USE BENEFITS OF HERBICIDE

2.3.1 INTRODUCTION

Herbicides also commonly known as weed killers, are chemical substances used to control unwanted plants. There are two main categories of herbicides, these include selective and Non selective herbicides. Selective herbicides control specific weed species, while leaving a desired crop relatively unharmed Non selective herbicides (sometimes known as total weed killers in commercial products) can be used to clear waste ground, industrial and construction sites, railways and railway embankments as they kill all plant material they come into contact.

Herbicides are a good alternative to weed control since they are quick and effective. In addition, the Environmental Protection Agency in Europe has shown that for example that atrazine has no negative effect on human life (Williams, 2013). Herbicides can be sprayed before planting to remove weeds from field, applied directly to soil at planting for residual control for germinating weed and applied to weeds during the growing season. Several benefits have been found in the usage of herbicides. For example, by reducing labour requirement for weed control, herbicide use could only allow additional resources to be invested in food crops to the benefit of food security in the country (Mavudzi et al 2001). Along with food security and better nutrition, the potential benefits of herbicide use include increased incomes and reduced drudgery. A good example of success in herbicides is China.

China recorded consecutive record crop harvests in the six years from 2004 to 2009. The increase in crop production is largely due to unprecedented gains in productivity. China has performed the miracle of achieving self-sufficiency in the world's most populous country, where cultivatable land is very limited. Figure 1 shows the dramatic increase in yields since the late 1970s for major field crops in China. Along with policy reform and infrastructure construction, agricultural technology is considered a key factor in driving this remarkable achievement.

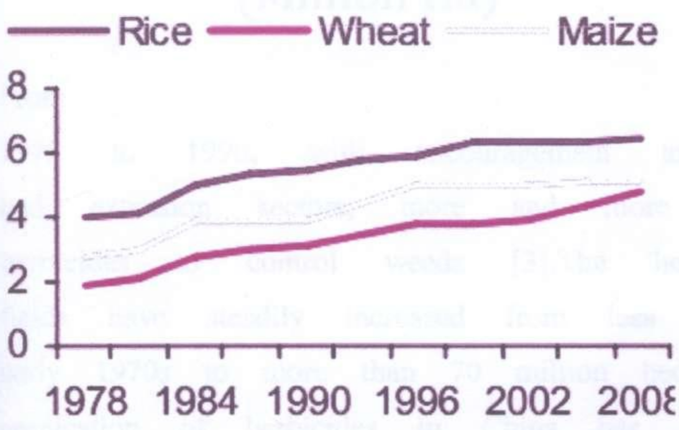

Figure 1: Crop Yields, China (Ton/Ha)

One of the main new technologies adopted by Chinese farmers in recent decades has been the use of chemical herbicides to control weed infestations. In the past, farmers weeded by hand. Since the late 1970s, with rural economic development, rapid expansion of industries and development of commerce, which caused an outflow of the farming population to industry as well as a corresponding increase in wages, chemical weed control became more attractive to farmers [2].

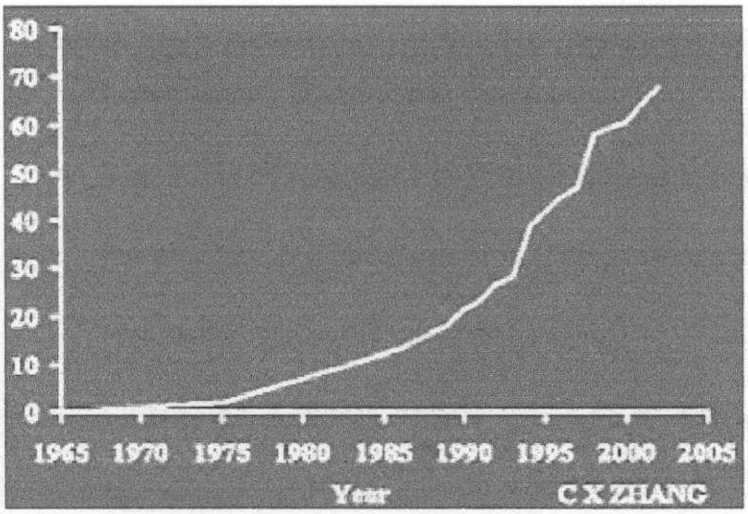

Figure 2: Herbicide Use, China (Million Ha)

From 1978 to 1990, with encouragement and promotion from the research and extension sectors, more and more Chinese farmers started adopting herbicides to control weeds [3].The herbicide application areas of crop fields have steadily increased from less than one million hectares in the early 1970s to more than 70 million hectares in 2005 [2] (Figure 2). The application of herbicides in China has increased to 72,800 tons in 2007 from 1,067 tons in 1970[4]. Herbicides are used on approximately 75% of the rice acres, 55% of the wheat acres, 44% of the maize acres, 50% of the cotton acres and 61% of the soybean acres [3]. Herbicides have contributed to increased crop yields in China by improving weed control and by facilitating the adoption of high yielding dwarf rice plants that are less competitive with weeds. Herbicides have made it possible for farmers to control weeds even with the large decline for traditional hand labourers who have moved from rural to urban industrial areas.

Thus Zambia would emulate China in its successful use of weed killers and help increase crop yields in the country.

2.4 SUMMARY OF THE BENEFITS OF HERBICIDES USE

- Less drudgery than cultural methods
- Weeds can be selectively controlled without injury to crops
- Pre-emergence applications protect crops from early weed interference
- Field labor demand is lower than manual
- Little soil disturbance – hence reduced risk of erosion
- Faster than other methods
- More effective against perennial weeds
- Less likely to be adversely affected by erratic weather conditions

2.5 FACTORS AFFECTING ADORPTION OF HERBICIDES

2.5.1 INTRODUCTION

Adoption is a special kind of diffusion in the adoption of an innovation .To adopt an innovation means to acquire a new product or innovation. The adoption process involves an interrelated series of personal, cultural, social and institutional factors, including the five stages of: awareness, further information and knowledge evaluation, trial, and adoption. Characteristics of a technology, such as simplicity, visibility of results usefulness towards meeting an existing need and low capital investment promote its eventual adoption and should be considered when transferring any technology.

The main factors affecting herbicide technology and other technologies adoption among smallholders in Sub-Saharan Africa are assets, vulnerability, and institutions (Meinzen-Dick et al.,2004).

Assets These factors deal with whether farmers have the requisite physical (material) and abstract possessions (e.g. education) essential for technology adoption. A lack of assets will limit technology adoption (Meinzen-Dick et al., 2004). Researchers, policy makers and development practitioners therefore need to put more emphasis on the development of technologies with little requirements for such material and abstract possessions (Meinzen-Dick et al., 2004). Policy makers and development practitioners should also promote technologies with low asset requirements as they are likely to have higher adoption rates among poor farmers (Meinzen-Dick.etal.,2004).

Vulnerability

Vulnerability factors deal with the impact of technologies on the level of exposure of farmers to economic, biophysical and social risks (Meinzen-Dick et al., 2004). Those technologies that have a lower risk have a greater appeal to smallholders who are naturally risk-averse (Meinzen-Dick et al., 2004). It has been conceded that traditional smallholder farmers have their reasons for not adopting untried technologies. Most of the time, such reasons are quite rational (Mazonde, 1993). These farmers are well aware, for instance, that a sudden upswing in the productivity of their fields is likely to deplete the soil nutrients, which would result in much lower returns in the following agricultural season (Mazonde, 1993).

Institutions

Institutional factors deal with the extent or degree to which institutions impact on technology adoption by smallholders (Meinzen-Dick et al., 2004). Institutions include all the services to agricultural development, such as finance, insurance and information dissemination. They also include facilities and mechanisms that enhance farmers' access to productive inputs and product markets. Institutions also include the embedded norms, www.ccsenet.org/jsd Journal of Sustainable Development Vol. 5, No. 8; 2012 73 behaviours and practices in society (Meinzen-Dick et al., 2004). Researchers and development practitioners should also consider issues that relate to the farmers' exposure to economic, agro-meteorological, biophysical and social shocks in designing technologies for smallholders. Care should be taken to avoid technologies with a high investment cost structure which smallholders cannot afford because they are poor and lack the necessary resources (Meinzen-Dick et al., 2004). Embedded norms, behaviours and practices in society can encourage or discourage adoption of a particular technology by members of that society (Meinzen-Dick et al., 2004). Clearly therefore, an understanding of local cultural practices and preferences is important if they are to benefit from agricultural research (Meinzen-Dick et al., 2004). Results of studies in sub-Saharan Africa have shown that male headed households have more access to land, education, and information on new technologies (Bisanda & Mwangi, 1996). There is a strong association between the gender of the household head and adoption of technological recommendations (Bisanda & Mwangi, 1996). In some countries female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates (Mkandawire, 1993). There is clearly a case for improving current smallholder credit systems to ensure that a wider spectrum of smallholders are able to have access to credit, more especially female-headed households (Mkandawire, 1993). This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific target groups. (Mkandawire, 1993). Synergies need to be created between government departments, non-governmental organizations, researchers, donors and local communities in implementing programs that promote smallholder farmers' adoption of technologies which can increase agricultural productivity and reduce environmental degradation and the deterioration of soil quality (Rosegrant et al., 2002; Nkonya et al., 2004). Measures that can be taken to increase adoption of technologies include: (i) lowering loan interest rates (ii) lowering the price of other inputs and raising agricultural product prices; (iii) improving smallholder farmers' access to finance for agricultural development; (iv) adopting a "package" approach to provision of agricultural development technologies; and (v) development and rehabilitation of infrastructure for agricultural inputs and product markets (Nkonya et al., 2004; Rosegrant et al., 2002). A major problem in sub-Saharan Africa is that year after year extension workers who are hardly afforded in-service training, and are loosely linked to research, continue to disseminate the same messages repeatedly to the same audience (Mkandawire, 1993). A situation has consequently arisen where the disseminated messages to the majority of the extension audience, have become technically redundant and obsolete (Mkandawire, 1993). An additional problem is that most extension services tend to focus on the well-resourced, wealthier farmers and perceive farmers as simply agents of change (Mkandawire, 1993). The major option for increased adoption of technology is to overcome the income/ capital constraint through increased credit provision (Mkandawire, 1993). However, one of the most discernible features around credit in most sub-Saharan African countries is the lack of an educational package linked to credit for small rural producers (Chidozonga, 1993).The cost of technology is a major constraint to technology adoption (Bisanda & Mwangi, 1996).

Other Adoption Factor

It has also been found that income from off-farm sources is important in the financing of purchased farm inputs (e.g. seeds, fertilizers, herbicides, labour) (Mwania et al., 1989). In addition, cash proceeds from crop sales, and income obtained from the sale of livestock and livestock products, www.ccsenet.org/jsd Journal of Sustainable Development Vol. 5, No. 8; 2012 74 also provide cash for the purchase of inputs in crop farming (Mwania et al., 1989). Higher levels of income from each of the above sources will lead to higher rates of adoption of yield-raising technology. Labour bottlenecks, resulting from higher labour requirements that new technologies often introduce, and seasonal peaks that may overlap with other agricultural activities, are important constraints to technology adoption (Meinzen-Dick et al., 2002). Studies in some areas have shown that smallholder farmers do not adopt all components of "packaged" technologies (Nguluu et al., 1996). When exposed to innovations, smallholder farmers only take those components that they perceive as useful and economically within their reach (Nguluu et al., 1996). Those that require a substantial cash outlay are not taken up easily (Ockwell et al., 1991). There are also technologies that do not require high investment costs and still exhibit low adoption. Rukandema (1984) and Muhammad and Parton (1992) have described other socio-economic factors such as farmers' innovativeness, age, off-farm income, risk and uncertainty that may result in low technology uptake. Lack of awareness of improved practices is another reason, particularly in remote areas (Nguluu et al., 1996).

2.6 ADORPTION OF HERBICIDES

Most significantly, 90% of acres on large plantation farms in sub-Saharan Africa are treated with herbicides, the same percentage on all crop lands in developed countries while only 5% of small holder acres receive herbicide applications. Most farmers use hand hoes for weeding, and a small minority use herbicides in sub-Saharan Africa (Bisanda & Mwangi, 1996). It is only slowly that provision (Mkandawire, 1993). However, one of the most discernible features around credit in most sub-Saharan African countries is the lack of an educational package linked to credit for small rural producers (Chidozonga, 1993).The cost of technology is a major constraint to technology adoption (Bisanda & Mwangi, 1996).

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Most significantly, 90% of acres on large plantation farms in sub-Saharan Africa are treated with herbicides, the same percentage on all crop lands in developed countries while only 5% of small holder acres receive herbicide applications. Most farmers use hand hoes for weeding, and a small minority use herbicides in sub-Saharan Africa (Bisanda & Mwangi, 1996). It is only slowly that herbicides are being known as an economic way to control weeds in southern Africa (Rugare and Mabasa, 2013).

To date, smallholder farmers in southern Africa use herbicides only in Malawi, where it has become a common practice due to the influence of Sasakawa Global 2000 (Ito *et al.*, 2007). In other areas herbicides slowly become more known as an economic way of weed control (Rugare and Mabasa, 2013). Potential herbicides for CA available in Zimbabwe include atrazine, glyphosate, metolachlor and paraquat among others.

Past adoption studies The review of adoption studies by Feder and Zilberman (1985) indicated *inter alia*, that adoption decisions are influenced by a number of socioeconomic, demographic, ecological and institutional factors and are dependent on the technology. Studies of the key determinants of technology adoption by farmers growing upland rice and soybeans in Central-West Brazil (Strauss *et al.*, 1991) and to evaluate the role of human capital and other factors in adoption of reduced tillage technology in corn production (Rahm & Huffman, 1984) found that farmers' education and experience play a crucial role in facilitating technology adoption. Doss (2003) reported that the major reasons for not adopting farm-level technology in East Africa were: (1) farmers' lack of awareness of the improved technologies or a lack of information regarding potential benefits accruing from them; (2) the unavailability of improved technologies; and (3) unprofitable technologies, given the farmer's agro-ecological conditions and the complex set of constraints faced by farmers in allocating land and labour resources across farm and off-farm 4 activities. The mismatch between technology characteristics and farmers' technology preferences was also responsible for low level of technology adoption in Ethiopia (Wale & Yallew, 2007). Other studies have revealed that off-farm incomes and availability of information influence technology adoption decisions through affecting risk aversion levels of smallholder farmers. Risk aversion level is likely to be negatively associated with adoption as farmers are less certain about the profitability (productivity) of new technologies when they use them for the first time. Farmer's level of risk aversion which is the function of their poverty level, lack of information on the productivity of the technology, and stability of the impact of the technology are all important factors (Kaguongo et al. 1997; Feder & Slade, 1984; Feder *et al.*1985; Kristjanson, 1987). To improve availability of relevant information for increasing adoption, many development agents have devised several approaches and innovations. When the innovation system (such as extension service) is linked to farmers to promote effective communication, problem identification, problem solving and personal interactions of a formal or informal nature, higher adoption of technology is likely (Steffey, 1995). Putler and Zilberman (1988) revealed the importance of physical capital endowment in the adoption process. Physical capital commonly associated with adoption of technologies has been identified as farm size or cultivated land, livestock and farm implements owned (Feder & O'Mara, 1981; Rahm & Huffman, 1984; Shapiro, 1990; Nkonya et al., 1997). A Kenyan study, which evaluated the effect of women farmers' adoption of OFSP in raising Vitamin A intake, found that women farmers were likely to adopt the OFSP if the clones were sufficiently high in starch, low in fiber, and if they were introduced through community-level education programmes that focused on the health of young children (Hagenimana & Oyunga, 1999). A recent study in Mozambique revealed that some of the key factors affecting adoption of OFSP included availability of vines, intensity of extension service and number of times the respondent received vines (Mazuze, 2005). 5 A number of studies have also revealed that most of the factors affecting adoption do also affect the intensity of adoption (Alene et al., 2000; Kaliba et al, 2000).

2.7 CONSTRAINT OF HERBICIDES USE

Undoubtedly, the greatest obstacle between herbicide technology and African farmers is lack of awareness and training. Specifically, constraints involve an inadequate knowledge of which herbicide to use in a given weed-crop situation; deficiency of extension services; scarcity of trained weed science personnel; uncertainty as to the availability of herbicides; and lack of herbicides in farmer-friendly packages (Mavudzi *et al.* 2001). For herbicides to be successfully introduced, several major infrastructure systems must also be improved (Benson 1982). The extension system, for example, depends on the competence of its agents, the frequency of their visits and demonstrations, and the credibility of their communications. In 1980, Dr. Akobundu identified the need for subject matter specialists capable of evaluating weed problems and formulating herbicide recommendations on a per country basis. Farmers in sub-Saharan Africa are still operating without this expertise. Transportation and distribution of herbicides needs to be more reliable, as farmers must apply them on time in order for them to be useful. Farmers also need access to inexpensive credit and their products must be transported to market quickly and sold at a fair price. Efforts must be made to enlighten governments on the role of weed science in the crop production equation, so as to bring governments to bear on the need for plans of action to address the problem.

Although there are many U.S. funded agricultural development projects in Africa with several US universities as contracting institutions, hardly any of the projects have included training in weed science. The Weed Science Society of America defines herbicide resistance as "the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type" (WSSA 1998). Herbicide resistance has been documented as far back as 1970,

when a common weed called groundsel (Senecio vulgaris) biotype was identified that was resistant to triazine herbicides. More than 350 confirmed instances of weed resistance have been reported in 197 weed species globally (Heap 2011), and more than one-third of these are found in the United States. Resistance to herbicides that inhibit the acetolactate synthase (ALS) enzyme occurs in the highest incidences, followed by resistance to the triazine herbicides. Glyphosate resistance was first noted before the development of GR crops and was the result of exclusive use of glyphosate repeatedly for vegetation control in orchard settings. In the United States, glyphosate resistance was first noted in horseweed, again not due to GR crops because horseweed is a weed problem before planting numerous crops. The rapid adoption of GR crops was primarily due to the effectiveness of glyphosate on most economically important weeds and the simplicity of using glyphosate alone for weed control. The effectiveness of weed control in GR crops supported the widespread adoption of no-till systems that improved the utilization of soil and energy resources (Gianessi 2008). Functionally, weed control in GR crops (e.g alfalfa, canola, corn cotton, soybean, and sugarbeet) has minimized the need for aggressive tillage and mechanical tactics previously necessary. Given the economic, environmental, and time-management implications of tillage, and herbicide complexity in non-HR crops, GR crops utilizing glyphosate supported the wide-scale grower adoption of conservation tillage. With the evolution of HR weeds and the resultant inability to maintain weed control, however, the continued inclusion of conservation tillage systems is threatened. The evolution of glyphosate resistance has further threatened global food production and reinforced the need to adopt practices to protect the sustainability of the GR crops and glyphosate (Powels 2008). Whereas academia and farm consultants are suggesting tactics to proactively mitigate the evolution of GR weeds, in many agro ecosystems prevention is no longer an option. Given the prominence of evolved resistance to glyphosate, concerns about resistances to other herbicide sites of action have become less. These resistances to alternative herbicides, however, are still a significant component of agro ecosystems and should be monitored and understood when developing mitigation strategies to manage HR weed populations. Regardless of the strategies adopted by growers, the costs must be considered against the benefits of these strategies. Selection pressure in agriculture, regardless of the specific source of the selective differential, will inevitably result in shifts in weed communities. In HR crop production systems using conservation tillage, the weed community must first "adjust or adapt" to the tillage system given that tillage has a greater overall impact on the agro ecosystem than herbicides (Buhler Hartzler, and Forcella 1997). For HR weeds, however, the selection pressure is also attributable to the recurrent use of herbicides. The greater the frequency of specific herbicide use, the less the diversity of management tactics; the greater the efficiency of the herbicide on the target weeds, the faster the evolution of the HR biotype (Gressel and Segel 1978). Herbicide-resistant weed biotypes are an inevitable consequence of herbicide use, and in the case of glyphosate resistance, more opportunities exist for resistance than originally thought (Bradshaw et al. 1997; Gressel 1996; Owen 2008). Given the almost universal use of herbicides for weed control, and specifically the use of glyphosate almost to the exclusion of other herbicides in GR crops, it is not surprising that resistance to glyphosate has evolved in a number of weed species. Furthermore, the evolution of multiple and cross-resistances reflects the importance of herbicides as selective differentials in impacting the evolution of HR weed biotypes. Genetic variability coding for herbicide resistance must pre-exist in natural weed populations for the evolution of HR biotypes; spontaneous evolution of herbicide resistance has not been documented (Jasieniuk, Brule-Babel, and Morrison 1996). There are two primary mechanisms by which herbicide resistance can evolve.One, and perhaps the most widely documented, is target-site resistance where high rates of an herbicide have been used repeatedly. The other has been labeled "creeping resistance" and is attributable to using low herbicide rates. Creeping resistance may result from different genes conferring a low level of resistance and a fairly rapid reduction in the response of the weed population to the herbicide (Gressel 2009). Most current GR weeds have evolved a relatively low level of glyphosate resistance. There is evidence of creeping resistance in two Conyza species (Dinelli et al 2006, 2008). There is also documentation, however, that increasing the rate of glyphosate may expedite the evolution of GR weeds where the resistance is controlled by a single parti

2.8 ENVIRONMENTAL IMPACT OF HERBICIDE RESISTANCE CROPS

2.8.1 Loss of Habitat

The increased use of glyphosate-resistant crops has led to declines in pollinator habitat. Historically, for butterflies in the U.S., their key source of food, milkweed, was found in several key states where the butterfly feeds and breeds: Iowa, Minnesota, Wisconsin, Illinois, Indiana, parts of Ohio and the eastern Dakotas. Now fields have been planted with more than 120 million acres of corn and soybeans genetically engineered to be tolerant to glyphosate, as well as other herbicides, allowing farmers to use glyphosate to kill milkweed in the field. According to researchers, the utilization of these herbicide resistance crops has all but eliminated milkweeds from these fields, thus eliminating the butterfly's source of food.

2.8.2 Glyphosate in the Environment

A 2011 study, "Occurrence and fate of the herbicide glyphosate and its degradate amino methyl phosphonic acid in the atmosphere, conducted by the U.S. Geological Survey (USGS) monitored glyphosate content in air and water samples in the states of Iowa and Mississippi across two growing seasons. The results show that glyphosate is detected 60-100% of the time in both air and rain samples. Its concentration in rainfall is found to be at higher levels than for any other previously monitored pesticide.

A second 2011 study, Fate and transport of glyphosate and amino methyl phosphonic acid in surface waters of agricultural basins, conducted by USGS monitored water concentrations of glyphosate. The study found glyphosate persists in streams throughout the growing season of herbicide resistance crops in Iowa and Mississippi, but is generally not observed during other times of the year. The degradation product of glyphosate, amino methyl phosphonic acid (AMPA), which has a longer environmental lifetime, is also frequently detected in streams and rain.

2.8.3 GENETIC RESISTANCE

Allowing herbicide resistance crops to be grown close to organic and non-herbicide resistance crops conventional produce increases the risk of genetic cross-contamination, as pollen from herbicide resistance crops has the potential to drift onto non-herbicide resistance crops and produce offspring. Because herbicide resistance crops are prohibited under organic standards organic farmers may suffer significant financial losses if certified organic crops become polluted with genetically-engineered pollen.

A recent Survey produced by Food & Water Watch, Organic Farmers Pay the Price for herbicide resistance crop contamination, found that a third of U.S. organic farmers have experienced problems in their fields due to the nearby use of herbicides resistance crops, and over half of those growers have had loads of grain rejected because of unwitting herbicide resistance crop contamination.

In May of 2013, USDA announced that unapproved herbicide resistant wheat was found growing in an Oregon wheat field. After this discovery Japan cancelled its order to buy U.S. western white wheat. Monsanto has not conducted field trials in Oregon since 2001 when it reportedly withdrew from the state.

In September of 2013, the U.S. Department of Agriculture (USDA) refused to take action or investigate after it was confirmed that herbicide resistant alfalfa contaminated non-herbicide resistant alfalfa in Washington State. USDA claimed the contamination is a "commercial issue" and should be addressed by the marketplace and not the government.

2.9Human Health Risks

The increased use of glyphosate on glyphosate resistant crops could lead to increases in human health problems. Glyphosate-formulated herbicides have been linked to numerous health problems including cancer, particularly non-Hodgkin's lymphoma in three separate peer-reviewed studies (1, 2, 3), ADHD, rhinitis, and hormone disruption. Short term health effects include lung congestion and increased breathing rates. Chronic exposures at levels above Maximum Contaminant Levels (MCL) are likely to produce kidney damage and reproductive effects.

2.9.1. 2,4-D Tolerant Crops

Recently, USDA released for public input its Draft Environmental Impact Statement(DEIS), which calls for the deregulation of herbicide resistant corn and soybeans engineered to be tolerant to the herbicide 2,4-D. Much like glyphosate, these new varieties of herbicide resistant corn and soybeans are set to usher in dramatic increases in 2,4-D. Dow Agro Sciences produces these new herbicide resistance crops under the brand name "Enlist" which will be stacked with glyphosate resistance.

Increased use of 2, 4-D could have dramatic impacts on human and environmental health. Scientists around the world have reported increased cancer risks in association with its use, especially for non-Hodgkins Lymphoma (NHL). It is also neurotoxic, genotoxic, and an endocrine disruptor.

2, 4-D has a high potential to leach from soils and can be a potential ground water contaminate. Environmental monitoring detected the herbicide in streams, groundwater and even drinking water. Studies document 2, 4-D's negative impacts on a wide range of animals. In birds, 2, 4-D exposure reduced hatching success and caused birth defects. Toxic to fish, 2, 4-D can bio-accumulate inside the fish. 2, 4-D also is toxic to honey ally dominant nuclear gene (Zelaya,Owen, and VanGessel 2004).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the methods and procedures used to achieve the stated objectives. It gives information on the study sites, data collection and data analysis tools that were used in the study.

This study will be centred on small scale farmers in central province of Zambia, specifically the rural farming areas of Keembe Chibombo. The main focus of the study will be centred on shedding light on the adoption of herbicides. A technology that has proven to reduce crop yield losses attributed to ineffective weed control methods.

This study was designed with respect to the arrangement of conditions for data collection and analysis in a way determined by the relevance of such data the objectives of research project. The research problem was a structured on where the information required was known i.e. the negative effects of not weeding or poor weeding on crop yields among small scale farmers, the labour reduction achieved due to herbicide usage etc. Both qualitative and quantitative methods of research will be used.

Primary data will be the main source of data used for this study, and will be collected from the respondents through structured interview schedule. Information to be collected includes the socio-economic characteristics of the respondents, the appropriate extension services offered, and the factors influencing the appropriate adoption level. The study will further determine the relationship between the socio- economic characteristics of the respondents and their level of adoption of the technologies. The dependent variable will be the adoption level of appropriate herbicides technologies, which was measured by the extent of use of these technologies, while the independent variables will be the identified factors affecting level of adoption.

3.2 SOURCES OF DATA

The major source of data will be primary while secondary data will be employed to maintain direction as well as establish the background to the research problem. Primary data will be collected through the administration of questionnaire and unstructured personal interviews. Secondary data will obtained from books, journals, scientific publications, extension workers records, MAL.

3.3 TYPES OF DATA REQUIRED

From the objectives stated and based on qualitative and quantitative data, the study focused on small scale farmers. The following information will be required:

(a) Social demographics of farmers
(b) Economic demographics of farmers
(c) Agricultural production
(d) Institutions

I. A questionnaire will be administered to farmers while personal interviews will be conducted with extension workers and farmers.

3.4 DATA COLLECTION METHODS

3.4.1 Sampling procedure

The target population of the research comprised of the small scale farmers in Keembe Settlement scheme camp Chibombo. The area was purposefully selected for the following reasons:

I. Keembe chibombo is in Region II agro ecological region which is characterised by moderate rainfall of between 800-1000millitres of annual rainfall.
II. The area has a relative high number of sunshine hours
III. It has a longer growing season of between 100 and 140 days and relatively fertile soils. Such a combination of factors makes the region ideal for the application and use of herbicides. The area has high potential for high crop yield like maize, cotton, soya beans, and sunflower.

3.5 SAMPLING DESIGN

The sampling design that was employed in the study was cluster sampling, from extension workers farmer's records of villages in the chosen camp. Cluster sampling will be employed i.e. villages will be clusters in the agricultural camp. Small scale farmers will then be randomly selected from the clusters or villages.

Nine villages were selected in the camp. These include Muntemba, Kabimba, Chimpukutu, Chilwana, Mulukishi, Saamu, Nkwanga and kanyanja villages. Ten villagers were randomly selected from each cluster or village. Respondents were selected systematically from the compiled list of farmers in the camp with the help of extension workers in the study area. Thus the sample size came to 90 out of a population of slightly above 1000 small scale farmers in the camp.

3.6 DATA ANALYSIS TECHNIQUES

In this study quantitative methods of data analysis was used. That was descriptive analysis. Descriptive research is used to describe characteristics of a population or phenomenon being studied. It does answer questions about how/why/when the characteristics occurred. Hence, descriptive research cannot describe what caused what caused a situation. Though, descriptive research cannot be the basis of a causal relationship, where only one variable affects another.

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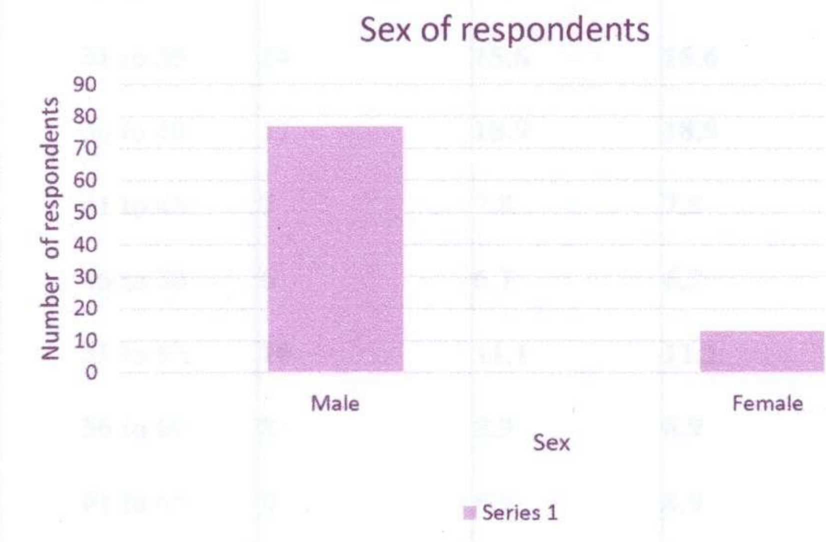
CHAPTER FOUR

STUDY FINDINGS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents and discusses the study findings. It begins with a presentation and discussion of the Demographics characteristics of the respondents. It goes on to present the outputs of the findings as generated by SPPS.

Figure 3: Distribution of Farmers by Sex



Source: Own Survey Data (2016)

The majority of the farmers were males (Figure 1). There are more males because only the household head in each household was the respondent implying that females were respondents only in female headed households. Therefore, there were more male headed households than female headed households. Males are more in the samples since household heads are assumed to be the main sources of income of which most males were married consequently household heads. Most female household heads were widows or singles.

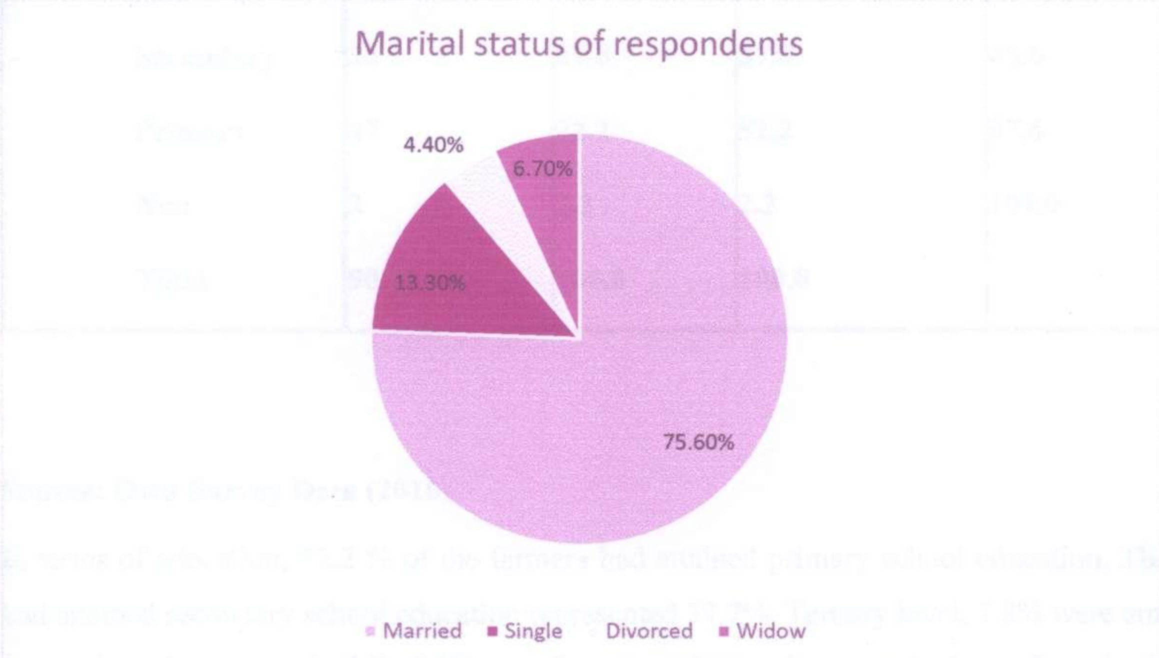
Table 1: Distribution of Farmers by Age

	Frequency	Percent	Valid Percent	Cumulative Percent
20 to 25	**8**	**8.9**	**8.9**	**8.9**
26 to 30	**12**	**13.3**	**13.3**	**22.2**
31 to 35	**14**	**15.6**	**15.6**	**37.8**
36 to 40	**17**	**18.9**	**18.9**	**56.7**
41 to 45	**7**	**7.8**	**7.8**	**64.4**
46 to 50	**6**	**6.7**	**6.7**	**71.1**
51 to 55	**10**	**11.1**	**11.1**	**82.2**
56 to 60	**8**	**8.9**	**8.9**	**91.1**
61 to 65	**8**	**8.9**	**8.9**	**100.0**
Total	**90**	**100.0**	**100.0**	

Source: Own Survey Data (2016)

The majority of the farmers (18.9%) had ages between 36 and 40 years. About 15.6% constituted those that were between 31 and 35 years while 13.3 % were between 26 and 30 years. Further, 11.1% constituted those that were between 51 and 55 while (6.7%) were between 46 and 50 years representing the smallest age group. In the sample, 56.7% of the small scale farmers were 40 years and below. This implies that majority of them are relatively young and can thus easily adopt new technologies or innovations. They would be less conservative of old traditions compared to older folks who usually are.

Figure 4: Marital status of respondents



Source: Own Survey Data (2016)

The majority (75.6%) of the respondents (household heads) were married while singles were only 13.3%. For widows 6.0% and non for widowers. Finally divorced category of household heads were 4.4%. The high levels of married couple among the farmers is likely to encourage higher levels of productivity since mostly they would be settled. They would want to better the lives of their families. Singles, widows and divorced individuals are most likely to be less involved a lot of productivity.

Table 2: Education levels

	Frequency	Percent	Valid Percent	Cumulative Percent
Tertiary	7	7.8	7.8	7.8
Secondary	34	37.8	37.8	45.6
Primary	47	52.2	52.2	97.8
Non	2	2.2	2.2	100.0
Total	90	100.0	100.0	

Source: Own Survey Data (2016)

In terms of education, 52.2 % of the farmers had attained primary school education. Those that had attained secondary school education represented 37.7%. Tertiary level, 7.8% were among the respondents interviewed while 2.2% was for respondents who never had any formal education. The implication of such relatively high education levels as the last group (Secondary level) is that they may be able to comprehend innovations, new technologies and practices easily needed in this new commercial world.

Table 3. Family size of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
1 to 5	**39**	**43.3**	**43.3**	**43.3**
6 to 10	**35**	**38.9**	**38.9**	**82.2**
11 to 15	**15**	**16.7**	**16.7**	**98.9**
16 to 20	**1**	**1.1**	**1.1**	**100.0**
Total	**90**	**100.0**	**100.0**	

Source: Own Survey Data (2016)

The majority of families have family sizes of 1 to 5 (43.3%). That's is mother father and children. Next were those who had family ranges of 6 to 10 (38.9%). Those that had family sizes of 11 to 15 represented 16.7%. The smallest category had those that had family sizes of 16 to 20 (1.1%).

Table 4. Non-farm income sources of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Charcoal burning	24	26.7	26.7	26.7
Trader	30	33.3	33.3	60.0
Fisherman	6	6.7	6.7	66.7
Teacher	2	2.2	2.2	68.9
Brick maker	3	3.3	3.3	72.2
Part time work	12	13.3	13.3	85.6
shop keeper	9	10.0	10.0	95.6
Driver	3	3.3	3.3	98.9
Builder	1	1.1	1.1	100.0
Total	90	100.0	100.0	

Source: Own Survey Data (2016)

The main source of income apart from agriculture among respondents was trading in various items (33.3%). Charcoal burning was the second most important non-farm income source (26.7%). Other no main non-farm income sources included part time work (13.3%), shop keeping (10.0%), fishing at (6.7%). The least was building as a non-farm income source at (1.1%). The area appears to have a lot of entrepreneurs who are engaged in trading of various goods and services thus increasing their income base. This allows farmers cope with farming risks. It also entails that with good income base farmers can easily adopt innovations. There are also a lot of charcoal burners in the area which in the long run would affect the agricultural sector negatively i.e. rainfall pattern, soil erosion and other natural cycles.

Table 5. Three main crops grown

	Frequency	Percent	Valid Percent	Cumulative Percent
Maize, cotton, soya beans	**9**	**10.0**	**10.0**	**10.0**
Cotton, tomato, maize	**2**	**2.2**	**2.2**	**12.2**
Beans, sunflower, maize	**12**	**13.3**	**13.3**	**25.6**
Soya beans, maize, rape	**8**	**8.9**	**8.9**	**34.4**
Sunflower, cotton, maize	**4**	**4.4**	**4.4**	**38.9**
Groundnuts, cotton, maize	**19**	**21.1**	**21.1**	**60.0**
Sweet potato, maize, cotton	**12**	**13.3**	**13.3**	**73.3**
Cabbage, tomato, maize	**3**	**3.3**	**3.3**	**76.7**
Rape, maize, cotton	**3**	**3.3**	**3.3**	**80.0**
Tomato, maize, soya	**15**	**16.7**	**16.7**	**96.7**
Groundnuts, soya, Maize	**3**	**3.3**	**3.3**	**100.0**
Total	**90**	**100.0**	**100.0**	

Source: Own Survey Data (2016)

The most common combination of crops grown in the area is maize, cotton and groundnuts (21.1%). This was followed by combination of tomato, maize and soya beans at 16.7%, sweet potato, maize, cotton at 13.3%, beans, sunflower, maize at 13.3% combinations. Maize was found in all the combinations of the most grown crops among the small scale farmers. Consequently is becomes the most important agricultural activity. Tomato in one of the main combinations indicated that is some good level of gardening in the area. Maize is the main crop grown in the area as can be seen from the combinations of the most grown crops. This implies that it is the staple food.

Table 6. Estimated annual income

	Frequency	Percent	Valid Percent	Cumulative Percent
5000 or less	49	54.4	54.4	54.4
6000 to 10000	19	21.1	21.1	75.6
11000 to 15000	8	8.9	8.9	84.4
16000 to 20000	4	4.4	4.4	88.9
21000 to 25000	1	1.1	1.1	90.0
26000 to 30000	4	4.4	4.4	94.4
31000 or more	5	5.6	5.6	100.0
Total	90	100.0	100.0	

Source: Own Survey Data (2016)

More than half of the farmers (54.4%) earn an estimated less than k5000 annually from crop and livestock sales. The next grouping consisted of those who earned between k6000 and k10000 at (21.1%) annually. The smallest group had those who earned between k21000 and k25000 per year. Those that earned more than k31000 yearly were 5 out of the sample of 90 (5.6%). Information obtained indicates that most farmers have generally low income annually from animal and crop sales consequently would affect adoption of technologies negatively.

Table 7. Number of years in agricultural activities

	Frequency	Percent	Valid Percent	Cumulative Percent
1 to 5	**13**	**14.4**	**14.4**	**14.4**
6 to 10	**22**	**24.4**	**24.4**	**38.9**
11 to 15	**14**	**15.6**	**15.6**	**54.4**
16 to 20	**13**	**14.4**	**14.4**	**68.9**
21 to 25	**9**	**10.0**	**10.0**	**78.9**
26 to 30	**19**	**21.1**	**21.1**	**100.0**
Total	**90**	**100.0**	**100.0**	

Source: Own Survey Data (2016)

Farmers who had farming experience of 6 to 10 years made a largest group (24.4%). This category was followed by those who had farming experience of 26 to 30 years (21.1%). The next categories were for those who had farming experience of 1 to 5 and 16 to 20 at (14.4%). The least was for those that had a farming experience of 21 to 25 years (10.0%). More than 60% of the farmers had 11 or more years in farming which is a long period of time this would have a positive effect on innovation adoption.

Table 8. Size of field in hectares

	Frequency	Percent	Valid Percent	Cumulative Percent
1 to 2	**65**	**72.2**	**72.2**	**72.2**
3 to 4	**21**	**23.3**	**23.3**	**95.6**
5	**4**	**4.4**	**4.4**	**100.0**
Total	**90**	**100.0**	**100.0**	

Survey Source: Own Data (2016

The majority (72.2%) of the farmers cultivated between 1-2 hectares of land, 23.3% cultivated between 3-4 hectares while 4.4% of the farmers cultivated about 5 hectares. This would imply that adoption of the technology was not based on field size increase.

Table 9: When respondent started using herbicides

	Frequency	Percent	Valid Percent	Cumulative Percent
After 2010	**42**	**46.7**	**46.7**	**46.7**
2005 to 2009	**14**	**15.6**	**15.6**	**62.2**
2000 to 2004	**3**	**3.3**	**3.3**	**65.6**
1995 to 1999	**1**	**1.1**	**1.1**	**66.7**
Non adopter	**30**	**33.3**	**33.3**	**100.0**
Total	**90**	**100.0**	**100.0**	

Source: Own Survey Data (2016)

The adoption rate of herbicides among small scale farmers in Keembe is high according to the indicated figures. Between 1995 and 1999 1.1% adopted herbicides. Next between 2000 and 2004 3.3% adopted herbicides representing an in adoption rate by 3 times higher than the previous time interval. Later between 2005 and 2009 15.6% adopted herbicides representing a 4.73 times higher than the previous time interval. Finally in the last time period after 2010 was 46.7% which was 2.99 times higher than the preceding time interval. The table further shows how high the adoption levels are in the area i.e. for every 57 farmers who adopt herbicides, three do not adopt as predicted by the logistic model. This means that there are higher chances of adopting the innovation than rejecting the innovation in the area chosen.

Table 10: Adopters of herbicides in comparison with Family size

	Family size				Total
	1 to 5	6 to 10	11 to 15	16 to 20	
Non adopter	17	8	5	0	30
Adopter	22	27	10	1	60
Total	39	35	15	1	90

Source: Own Survey Data (2016)

From the cross tabulation between family size and adopters, it has indicated that those with smaller families adopted more than those with generally large families. This could be because those with larger families had more family labour than those with smaller families consequently lower adoption resulted among large families. This appears to show that family size affects adoption of herbicides.

Table 11: Adopters of herbicides in comparison with Number of years in agricultural activities

	Number of years in agricultural activities						**Total**
	1 to 5	**6 to 10**	**11 to 15**	**16 to 20**	**21 to 25**	**26 to 30**	
Non adopter	**7**	**6**	**6**	**3**	**0**	**8**	**30**
Adopter	**6**	**16**	**8**	**10**	**9**	**11**	**60**
Total	**13**	**22**	**14**	**13**	**9**	**19**	**90**

Source: Own Survey Data (2016)

The cross tabulation indicates that the majority of the farmers who adopted weed killers had between 6 to 10 years in agricultural experience. Those that had between 26 and 30 years of experience in farming formed the second largest group. The smallest group was for those that had between 21 to 25 years in farming. Generally it appears experience positively affects adoption of herbicides.

Table 12: Adopters of herbicides in comparison with Size of field in hectares

	Size of field in hectares			Total
	1 to 2	3 to 4	5	
Non adopter	27	3	0	30
Adopter	38	18	4	60
Total	65	21	4	90

Source: Own Survey Data (2016)

Majority of the farmers who have adopted herbicides are those that own fields of sizes between 1 and two hectares. The next group was for those that owned field sizes of between 3 and 4 hectares. With the least for those that owned about 5 hectares.

Table 13: Adopters of herbicides in comparison with Education level

	Education level				Total
	Tertiary	Secondary	Primary	Non	
Non adopter	1	8	20	1	30
Adopter	6	26	27	1	60
Total	7	34	47	2	90

Source: Own Survey Data (2016)

The majority (27) of the adopters had attained primary education. For those that attained secondary education 26 had attained adopted, tertiary had 6 while only one adopter had not acquired any form of education.

Table 14: Adopters of herbicides in comparison with Training in herbicide use

	Training in herbicide use		**Total**
	No	**Yes**	
Non adopter	1	2	3
Adopter	15	45	60
Total	16	47	63

Source: Own Survey Data (2016)

Most of the adopters as can be seen have undergone training in herbicides use compared to those who did not. Training helps adopters have proper skills in use of innovations. Weed killers especially require good training. Training increases technical know-how of the farmer consequently encouraging adoption of the innovation.

Table 15: Adopters of herbicides in comparison with Ownership of a sprayer

	Ownership of a sprayer		**Total**
	No	**Yes**	
Non adopter	11	19	30
Adopter	12	48	60
Total	23	67	90

Source: Own Survey Data (2016)

The majority of the people who use herbicides own sprayers. This is because sprayers are used as implements for spraying the chemicals. It greatly reduces drudgery for the farmers who mostly do hoe weeding. A large portion of land can be sprayed in a single day by even one person.

Table 16: Adopters of herbicides in comparison with Distance in kilometers where herbicides are sold

	Distance in kilometers where herbicides are sold			Total
	3 or less	Between 3 and 6	More than 7	
Non adopter	1	0	2	3
Adopter	41	12	7	60
Total	42	12	9	63

Source: Own Survey Data (2016)

A large portion of adopters (41) live close to the source of herbicides that is 3 kilometers or less. For those that were located between 3 and 6 kilometers 12 had adopted while those that lived more than 7 kilometers 7 had adopted. This implies that the further one is from the innovation the less likely one would adopt herbicides. Accessibility affects adoption of innovations adoption, it is actually according to theory a factor that affects adoption.

Table 17: Adopters of herbicides in comparison with Belonging to any agricultural organization

	Belonging to any agricultural organization		Total
	No	Yes	
Non adopter	1	2	3
Adopter	11	49	60
Total	12	51	63

Source: Own Survey Data (2016)

The majority (49 farmers) of the adopters belong to various kinds of agricultural organisations. On the other hand only 11 who adopted herbicides did not belong to any agricultural organization. The reason why most farmers belong to agricultural organisations is that it is where they source their inputs like seed, herbicides. In addition the organizations offer training to their clients, like how to use herbicides. Consequently, this appears to positively affect adoption of herbicides.

Table 18: Adopters of herbicides in comparison with Specific agricultural organization the respondent belongs

	Specific agricultural organization the respondent belongs					Total
	NWK	CFU	GRAFAX	Alliance ginners	Self	
Non adopter	1	0	0	1	1	3
Adopter	23	14	6	6	11	60
Total	24	14	6	7	12	63

The majority of the adopters (24) belong to NWK Cotton a company that provides credit to its members, training and procures cotton from them. Conservation Farming Unit had 14 members in the sample making it the second largest group. Grafax and Alliance ginners had 6 each in the sample. Those that did not belong to any organization and bought herbicides on their own were 11. This entails that most adopters belong to agricultural organizations. A good number of farmers 4are able to purchase weed killers without credit. NWK has more members probably because of good services and that it has been in the area for a long period of time.

4.2 Social demographics

The majority of the farmers who have adopted herbicides are close to the source of herbicides. Only few have adopted herbicides who are much further from the source of herbicides. This implies that the closer one is to the source of herbicides the more likely one would adopt the innovation and vice versa. Accessibility affects adoption of innovations and is among the factors that affect adoption.

4.3 Experience

A descriptive statistics on adoption indicated that previous experiences in agriculture increased the likelihood of herbicides adoption. Farmers who have had practiced agriculture for a considerable period of time could easily relate to herbicides as an alternative farming system much more than those who were introduced to weed killers for the first time.

4.4Equipment

The herbicides adoption descriptive analysis indicated that ownership of a sprayer increased the likelihood of adoption of herbicides. This is because these implements are used for spraying the chemicals (herbicides) on weeds among sampled farmers.

4.5 Institutional Aspects

Membership in agricultural organisations had a positively influence on adoption of herbicides. This is because farmers get various kinds of support such as seeds, pesticides, herbicides and herbicides trainings from agricultural organisations and non-governmental organizations (NGOs) that they belong to.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION

5.1 INTRODUCTION

This chapter presents the conclusion and recommendations of the study based on the findings and interpretations of the study.

This study has shown that both quantitative and qualitative factors influence the adoption of herbicides. Quantitative analysis indicated that family sizes, education levels, sex, membership in farmer organisations, and ownership of herbicide spraying equipment increased the likelihood of herbicides adoption in the positive direction. Others included training, access to credit. Distance were herbicides are sold or found, increase in family size were found to have affected adoption in the in the negative direction.

The study raises the following considerations; attaining some level in education should be further encouraged; there is need to improve access to appropriate herbicide spraying equipment and encourage farmers to join various farmer organisations. More agro chemical outlets should be established to improve accessibility of weed killers. Trainings on proper use of herbicides and potential harm of herbicides should be supported. Empowerment of local farmers in order to help them improve their income levels that would further enhance adoption of the innovation. In the promotion of chemical weed control, it is important to pay attention to both quantitative and qualitative factors. Furthermore, an analysis on adoption of herbicides for the camp (Keembe settlement scheme camp) for the past 15 years has also clearly shown rapid increase in chemical weed control adoption among small scale farmers in Zambia with total adoption standing at 66.7%. The trend appears to indicate that adoption will continue rising in the area on a fast rate as seen from previous time intervals levels of adoption.

5.2 RECOMMENDATIONS

- ✓ Research should be undertaken by other researchers to establish whether there has been significant increases in yields of various crops in the area owing to the high adoption levels of chemical weed control measures.
- ✓ Government should continue encouraging the growth of the education sector in the area by building more schools like primary and secondary schools and making it affordable for all, tertiary inclusive.
- ✓ The private sector should open more agrochemical outlets in order to shorten the distance to the technology in rural areas thus improved accessibility.

APPENDICES

HOUSEHOLD SURVEY QUESTIONNAIRE

SECTION 1. SOCIAL DEMOGRAPHICS OF HOUSEHOLDS AND ECONOMIC DEMOGRAPHICS

Household code _______

1.	State your sex	1. Male 2. Female	{ }
2.	Age of respondent	1. (20-25) 2. (26-30) 3. (31-35) 4. (36-40) 5. (41-45) 6. (46-50) 7. (51-55) 8. (56-60) 9. (61-65)	{ }
3.	Marital status	1. Married 2. Single 3. Divorced 4. Widow 5. Widower	{ }
4.	What is your highest educational level?	1. Tertiary 2. Secondary 3. Primary 4. Non	{ }
5.	What is the size of your family?	1. (1-5) 2. (6-!0) 3. (11-15) 4. (16-20)	{ }
6.	What are your non-farm income sources (household head)?	1. Charcoal 2. Trader 3. Fishing 4. Part time work 5. Builder 6. Shopkeeper 7. Teacher 8. Driver	{ }
7.	What are the **<u>THREE</u>** main crops/vegetables/fruits grown	Codes typed below table.	{ }
8.	Livestock production	Codes typed below table	{ }

9.	Main agricultural activity	1. Maize 2. Goat 3. Gardening	{ }
10.	Agricultural experience in years.	1. (1-5) 2. (6-10) 3. (11-15) 4. (16-20) 5. (21-25) 6. (26-30)	{ }
11.	The approximate size of your field in hectares.	1. (1-2) 2. (3-4) 3. 5	{ }
12.	Specify for the following crops	1. Area for maize 2. Area for cotton 3. Area for groundnuts 4. Specify for others	{ }
13.	State the kind of crop production system you are engaged in.	1. Organic farming 2. Conventional farming 3. Conservation farming	{ }
14.	Do you know what herbicides are?	1. Yes 2. No	{ }
15.	When did you know about herbicides?	1. After 2010 2. 2005-2009 3. 2000-2004 4. 1995-1999 5. Before 1995	{ }
16.	When did you begin using herbicides? If no don't proceed to the next questions.	1. After 2010 2. 2005-2009 3. 2000-2004 4. 1995-1999 5. Before 1995	{ }
17.	Have you received any training in herbicides use?	1. Yes 2. No	{ }
18.	How far are you from where herbicides are sold or found approximately?	1. 3 kilometers or less 2. Between 3 and 6 kilometers 3. Between 6 and 9 kilometers 4. More than 9 kilometers	{ }

19.	Do you own a sprayer?	1. Yes 2. No	{ }
SECTION 3: INSTITUTIONS			
20.	*Do you receive any* agricultural extension services in herbicides use?	1. Yes 2. No	{ }
21.	Do you belong to any agricultural organization?	1. Yes 2. No	{ }
22.	If yes specify	1. NWK 2. CFU 3. GRAFAX 4. Alliance ginners 5. Self	{ }
23.	Do you belong to any cooperative?	1. Yes 2. No	{ }
24.	Do you have access to credit to purchase inputs like seed, fertilizers, herbicides etc.	1. Yes 2. No	{ }
25.	If yes specify the source.	1. NWK 2. CFU 3. GRAFAX 4. Alliance ginners 5. Self	{ }

SECTION 2: AGRICULTURAL PRODUCTION

6. Crop production and marketing

What are the **THREE** main crops/vegetables/fruits you have planted during the 2015/16 farming season? *(See codes below)*	What do you expect to be the total harvest of ___________?		From the expected harvest, what quantity do you expect to sell?		At what price do you expect to sell your surplus production?	
	Quantity	**Unit**	**Quantity**	**Unit**	**Price (ZMW)**	**Unit**
F01	**F02**	**F03**	**F04**	**F05**	**F06**	**F07**

Codes for vegetable grown by individual farmers	**1. Cotton, maize, groundnuts.** **2. Maize, tomato, cotton.** **3. Beans, cabbage, maize,** **4. Sweet potato, maize, cotton.** **5. Soyabeans, maize, cotton.** **6. Beans, sunflower, maize.** **7. Tomato, cabbage, maize.** **8. Sunflower, maize, groundnuts** **9. Maize, sweet potato, soya beans** **10. Cotton, maize, beans**			**Codes from incomes earned from crop sales in ranges.**		**1. k5000 or less** **2. k6000 - k10000** **3. k11000- k15000** **4. k16000- k20000** **5. k21000- k25000** **6. k26000- k30000** **7. More than k31000.**

7. Livestock production and marketing

Livestock owned	Did the HH own ______ between 1st October 2015 and 29th July 2016? *1 = Yes*	How many ______ were owned by the	Did the HH sell any of the ______ owned	The last time the HH sold ___ for cash, how	The last time the HH sold _____ for cash, how much did the HH receive in TOTAL in ZMW?

		2 = No → go to next livestock type	HH as at 1st October 2015?	between 1st October and 29th July 2016? *1 = Yes* *2 = No → go to next livestock type*	many were sold?	
	G01	**G02**	**G03**	**G04**	**G05**	**G06**
Cattle	**1**					
Goats	**2**					
Pigs	**3**					
Sheep	**4**					
Village Chickens	**5**		**N/A**			
Codes for livestock kept by a specific farmer.		**1. Cattle, goat, chicken.** **2. Chicken, goats.** **3. Chicken, cattle** **4. Chicken**		**Codes for income earned from livestock sales in ranges.**		**1. K5000 or less** **2. K6000-k1000** **3. K11000-1500** **4. K16000-k200** **5. K21000-K25** **6. K26000-K30** **7. More K31000.**

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