A retrospective analysis and priority setting exercise of investments in agricultural research in Zambia

By

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Submitted in partial fulfilment of the requirements for the degree of

MSc. Agric. (Agricultural Economics)

in the

Department of Agricultural Economics, Extension and Rural Development,

Faculty of Natural and Agricultural Sciences

UNIVERSITY OF PRETORIA

PRETORIA

February 2010

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DECLARATION

I Choolwe Haankuku declare that the thesis, which I hereby submit for the degree of MSc. (Agric) Economics at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature: **-------------------------**

Date: **-------------------------**

DEDICATION

To Uncle Jasper, my sister Chabota and the rest of my family, you are simply the best!

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ACKNOWLEDGEMENTS

I wish to express my heartfelt appreciation to Prof. Johann Kirsten, my supervisor, for the tireless counsel and suggestions rendered in producing this thesis. I also sincerely thank all members of staff of the Department of Agriculture Economics, Extension and Rural Development at the University of Pretoria for their efforts in my academic endeavours.

I am also thankful to Dr Stanley Wood and Dr Liang You of the International Food Policy Research Institute (IFPRI) and Mr Frikkie Liebenberg of the Agriculture Research Council (ARC) for their academic advice and financial support. Likewise, I am grateful to Dr Mwala of the University of Zambia for facilitating the data collection process, and to the respondents (researchers and directors) of various research institutions for making most of the data used in this study available.

I further thank my family for inspiring me and, last but not least, I wish to thank my friends Mariam Mapila, Goodness Aye and Leah Ndanga for their support.

I remain indebted to this list of individuals for their support.

ABSTRACT

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Supervisor: Professor Johann Kirsten

In 2003 national heads of African states, including Zambia, met in Maputo and pledged to increase financial resources to the agriculture sector, up to 10 % of their national budgets, in order to meet growth targets. Given the need to increase investments in agriculture, it follows that impact assessment studies have become handy as funding agencies demand better accountability and empirical justification for further investment. However, experts have reasoned that the quantity of resources is as important as the quality of spending in that, if resources are allocated efficiently, more could be achieved with the same level of resources. The lack of an effective strategy and basis upon which investments in agriculture crop research ought to be prioritised in order to improve agricultural productivity is the main concern in Zambia.

This study sought to illustrate the use of the Dynamic Research Evaluation for Management (DREAM) model to assess the economic returns of investing in agriculture technologies and to set priorities for crop-based research activities in Zambia. The study hypothesised that the financial outlay allocated to agricultural crop research is not efficiently allocated so as to achieve the nation’s agricultural production potential, and that agricultural crop research investment influences the distribution of welfare effects on producers and consumers. The DREAM model is conceptually based on the economic surplus theory and is designed for research priority setting and *ex ante* evaluations. It computes the net present value (NPV) of benefits for both producers and consumers as a result of investing in agriculture technology.

The findings from this study reveal that investment in agriculture crop research in Zambia is worthwhile as positive net present values were obtained for all crops under consideration in this study. Maize research gives the highest return to both large-scale and smallholder producers. Maize also yielded the highest returns for consumers in Zambia. In order of priority, maize is followed by soya bean, groundnuts, cotton, millet, sunflower and sorghum. In spite of this, the order of priority in terms of financial expenditure on crop research is maize, cotton, sorghum, soya bean, groundnuts, sunflower and millet. Therefore, the allocation of financial resources towards crop research is not efficient for all crops except maize since some crops such as sorghum receiving high financial expenditure in research did not necessarily generate high returns. This is because the Government still conducts the bulk of research in Zambia, and as such, other social objectives such as equity and food security considerations play a major role in determining investment patterns.

The study further establishes that the choice of crop research expenditure influences the distribution of welfare benefits on different producer groups; and that smallholder farmers in Central, Eastern and Southern province are among the group that received the highest proportion of benefits even for crops such as maize for which financial resources were efficiently allocated. Therefore, the efficiency objective may not necessarily leave smallholder farmers worse off as long as they have access to complementary infrastructure and institutions for agriculture production and marketing. As such the study recommends that the Government, private sector and other development partners must focus on raising agriculture productivity by expanding investments in crop science-based technologies; and also recommends re-allocation of financial resources between crops in favour of crops with high returns because this benefits both large scale and smallholder farmers. This must be accompanied by further investment in complementary infrastructure and good governance.

Key words: Priority setting, Crop research, Agriculture R&D Investment

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LIST OF ACRONYMS

AgGDP	Agriculture Gross Domestic Product
CAAPD	Comprehensive African Agriculture Development Programme
CDT	Cotton Development Trust
CSO	Central Statistics Office
DREAM	Dynamic Research Evaluation for Management
FAO	Food and Agriculture Organisation
FNDP	Fifth National Development Plan
FSP	Fertilizer Support Program
FTE	Full Time Equivalent
GART	Golden Valley Agriculture Research Trust
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
IFPRI	International Food Policy Research Institute
IRR	Internal Rate of Return
MACO	Ministry of Agriculture and Cooperatives
MDG	Millennium Development Goals
MRI	Maize Research Institute
NAP	National Agricultural Policy
NEPAD	New Partnership for Africa's Development
NPV	Net Present Value
PRSP	Poverty Reduction Strategy Paper
SCRB	Soils and Crop Research Board
ZARI	Zambia Agricultural Research Institute
ZMK	Zambian Kwacha

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Agriculture has been key for the development of most African countries and it regained its importance during the 1990s when nations all over the world focused on the relentless problems of hunger and poverty in these countries and, also, most recently, as a result of the food price crisis. The importance of agriculture in Africa was emphasised in the World Food Security Rome Declaration (FAO, 1996) and again in the United Nations Millennium Development Project (UN, 2001).

A number of African heads of state committed to increase financial resources to the agriculture sector, up to 10% of their national budgets, at the July 2003 African Union summit in Maputo (NEPAD, 2002:9). Furthermore, for the first time in 25 years, the World Development Report (2008) emphasised the importance of agriculture development, pointing out that agriculture must be considered as a prime option in order for Africa to overcome poverty and food insecurity as well as achieve economic growth (World Bank, 2008:3).

In light of such global consensus, Zambia, which was in the past better known as a copper producing country, has principally transformed to an agriculturally dependent economy. Also, particularly as a result of the continued decline in world copper prices, the agricultural sector became vital for the diversification of the economy and poverty reduction (PRSP, 2002). The agriculture sector in Zambia contributes 18% to the country's GDP. The sector also accounts for 67% of total employment and 25% of total exports (PRSP, 2006). More importantly, agriculture production influences the performance of secondary industries whose production structures are dependent on inputs from the agriculture sector. Therefore, agriculture growth remains critical in the development of Zambia's economy (Govereh, Shawa, Malawo & Jayne, 2006:5).

Zambia's agricultural production consists mainly of crop production, which accounts for more than 60% of the total agricultural output (Kimhi & Chiwele, 2000). The agriculture sector consists of a large number of subsistence rural farmers (800 000 households) that exist parallel to nearly 700 developed commercial farmers (Siegel and Alwang, 2005). Despite the relative importance of agriculture in Zambia, its performance in terms of food production is not satisfactory as estimates show that volatile harvests are experienced in at least one out of every three annual growing seasons, hence food security problems have periodically continued to haunt the country (Bonaglia, 2008; Dorosh *et al.*, 2007).

The low level of crop production is attributed to the reduction in investment and resource allocation from the state budget and to donor contributions to the agriculture sector that have hindered programmes to increase crop research and dissemination, and hence the failure to strategically position the sector according to its comparative advantage (PRSP, 2002:57; Govereh *et al.*, 2006). While government budget allocation to the agriculture sector since 1999 has fluctuated between four and six percent of the total national budget, actual disbursement is usually less than 50% of what was budgeted (MACO, 2009; Govereh *et al.*, 2006; PRSP, 2002:57) .

In addition, even though Zambia's current national agricultural policy is centred around liberalisation and the elimination of subsidies, the Government keeps reverting to policies targeted at maize output prices and the input market (in particular subsidising fertiliser) while neglecting other rewarding programmes that facilitate the development of infrastructure, agriculture research and other support services (PRSP, 2002:55). For a long time, the bulk of the financial resources allocated to the agriculture sector (40%) went to the Fertilizer Support Program (FSP) and only about four percent to agriculture research and extension (Jayne, Govereh, Chilonda, Manson, Chapoto & Haantuba, 2007). Such ambiguity in agriculture policies by the government and the lack of consistency between documented policies and actual implementation creates uncertainties and discourages partnering agencies (DFID, 2002; Govereh *et al.*, 2006).

Under the New Partnership for Africa's Development (NEPAD)'s Comprehensive African Agriculture Development Programme (CAAPD), the agriculture growth rate was targeted at six percent per year and, in order to realise this optimistic target, African heads of state pledged to increase budget allocations for agriculture to at least 10% of total government spending, as was mentioned above. Zambia, like many Southern African countries, endorsed this commitment and acknowledged that agriculture-led development is essential for the growth of the economy. This was also acknowledged in the country's Fifth National Development Plan (FNDP) which was submitted to the World Bank (PRSP, 2006). However, only a few nations in Southern Africa have made ground towards achieving this target, while the majority have made much slower progress than expected. In 2005, only Malawi (11%) had achieved the 10% budget allocation to agriculture target while the rest, including Zambia, averaged between four and six percent (AU, 2005). This is less than the 10% commitment made under the NEPAD declaration and much less than the 15% expenditure by Asian countries at the onset of the green revolution (Haggblade, 2007).

Nevertheless, Roseboom, Beintema and Mitra (2003:17) argue that increasing resources for agricultural technology is an indispensable but far from sufficient condition for Africa to resolve its low productivity problems. The quantity of resources is as important as the quality of spending in ensuring that resources are used efficiently. The way that spending is disbursed could translate into achieving more with the same amount of resources. Thurlow, Benin, Diao, Kalinda and Kalinda (2008) concluded that if resources were efficiently spent in Zambia, the country would need to allocate only eight percent of total government spending to the agriculture sector in order to achieve the CAADP six percent crop growth rate target. Otherwise, it would need to allocate 18% to achieve the same growth target.

Many African countries lack of an effective strategy and basis on which to set investments in agriculture for improving productivity. Govereh *et al*. (2006:9) agree with these findings and point out that policy-makers in Zambia are also faced with the challenge of improving the efficiency of public expenditure on agriculture. Although increased investments are necessary, national policy objectives will not be achieved by merely expanding agriculture budgets but also by the efficient use of resources.

1.2 PROBLEM STATEMENT

Zambia's agricultural sector is currently guided by the National Agricultural Policy: 2004-2015. With regard to soils and crop research, the republic of Zambia seeks to "generate and adapt technologies to increase production and to improve the management of agricultural research through appropriate planning, priority setting and budgeting" (MACO, 2004). In the past, the Ministry of Agriculture and Cooperatives relied on incremental budgeting, where the current year's budget was based on the previous year's figure and only adjusted for inflation. Since 2004, activity-based budgeting has been implemented in which a budget is drawn up on the basis of the research activities that need to be implemented (MACO, 2008). However, with regard to priority setting in agriculture research, the formal tool that is used is scoring, in which researchers are required to rank crop research problems on an arbitrary scale. This has the disadvantage of being subjective and it creates a situation in which most research activities being undertaken are as a result of individual researcher interpretation of the problem at hand. Such an approach may not be efficient or reflect the broader policy objectives of the country's agricultural research priorities.

Despite widespread acknowledgement that investing in agricultural research in Zambia is crucial for agriculture-led economic development (PRSP, 2002; Govereh *et al.*, 2006), little has been said about how investments in agricultural research should be prioritised in order to increase agricultural productivity and to maximise the returns from such activities when the available resources are scarce. Furthermore, there has been little analysis of past performance and congruence between priorities and expenditure in the agriculture sector. As such, there is little consensus on what the strategy for stimulating agriculture research expenditure should look like (Govereh, Malawo, Lungu, Jayne, Chinyama & Chilonda, 2009).

1.3 RESEARCH OBJECTIVES

In collaboration with the private sector and donors, the Zambian Government has an essential role to play in formulating and executing a successful strategy that will enhance economic growth through investment in the agriculture sector. In order to enhance the operation of agricultural research in Zambia, this thesis attempts to ascertain whether the financial allocation to agriculture crop research is efficient and to identify the priority crops for agriculture research investment.

The specific objectives of the study are as follows:

- To evaluate Zambia's crop production potential and productivity;
- To determine the nature and scope of crop research in Zambia;
- To identify priority crops for research investment in agriculture; and
- To determine the economic returns of crop research expenditure to producers and consumers.

1.4 HYPOTHESIS

Zambia's agriculture performance in terms of crop production has not been impressive. Between the years of 1990 and 2005, output per unit area and per household regressed by 0.06% and 0.42% per annum, respectively (Govereh *et al*., 2008). It has been argued that "Zambia's low crop productivity is partly attributed to misplaced spending priorities" (Govereh *et al*., 2009). As a result, this study tests the following hypotheses:

- That the financial outlay to agricultural crop research is not efficiently allocated towards achieving the nation's agricultural production potential.

- That agricultural crop research expenditure subsequently influences the distribution of welfare impacts on producers and consumers.

By testing these hypotheses, the study will simultaneously provide an economic approach for setting research priorities for developing countries in Africa. Its relevance is on two levels. Firstly, for agricultural researchers, policy-makers and aid officials: the results of this study will provide a basis on which necessary strategies can be devised for efficient agricultural research through adequate prioritisation of agriculture investments and policies. Secondly, for the academics and students: it will provide insights into Zambia's agricultural research system and thus offer a basis for future study.

1.5 RESEARCH METHODOLOGY

This study used both secondary and primary data, which consisted of market and technology-related variables. The procedure to achieve the study's objectives was as follows: Firstly, secondary data was accessed via requests made to authorities from the Ministry of Agriculture and Cooperatives (MACO) and from the Central Statistic Office (CSO) for market related variables. The data obtained included price and production data for maize, groundnuts, millet, sorghum, soya bean, sunflower and cotton for a three-year period (2004-2006), and the averages were used in order to even out extreme seasonal values. The production data that was obtained was disaggregated by farmer type (large and smallholder farmers) for each of the nine provinces of Zambia. Other secondary data obtained from various sources included the elasticity of supply and demand for the crops under consideration.

Secondly, a survey was conducted to obtain primary data, and a structured questionnaire was administered to all of the seven identified crop research institutions. The identified crop research institutions include: the Zambia Agriculture Research Institution (ZARI), the Zambia Seed Company (ZamSeed), the Seed Company (SeedCo), the Maize Research Institute (MRI), the Golden Valley Research Trust (GART), the Cotton Development Trust (CDT) and the University of Zambia (UNZA). The purpose of the questionnaire was twofold: to obtain data pertaining to the nature and extent of crop research in Zambia, and also to elicit expert opinion on technology related data for the empirical model. The data obtained for each of the crops considered in this study included research costs, adoption levels and lags, and the expected change in crop yield and production costs attributed to research technologies.

Finally, the data was analysed using the Dynamic Research Evaluation for Management (DREAM) model, which is a computer-based programme developed by the International Food Policy Research Institute (IFPRI) for evaluation and research priority setting for a range of technology, adoption and market conditions. The model was used to quantify the net present value (NPV) of crop research for each crop between 2005 and 2020, after which the benefits were ranked so as to execute the priority setting exercise. The aggregate benefits were then disintegrated to capture distributional benefits by farmer type and agro-ecological zones.

1.6 ORGANISATION OF THE THESIS

This dissertation is comprised of six chapters. After this introductory chapter, the second chapter discusses the potential of the agriculture sector in Zambia in terms of its structure, bio-physical characteristics, and productivity trends. Chapter three discusses Zambia's agriculture expenditure, provides a background of the research system used and reports the findings from the survey on the extent of crop research in Zambia. Chapter four consists of the literature review, and highlights the methodologies used and major findings on studies in Africa. The fifth chapter begins by giving a detailed account of the model used for data analysis in this study. It specifies the model variables and the empirical analysis applied and finally presents the findings on priority setting from the model. The thesis ends with conclusions and recommendations in chapter six.

CHAPTER 2

AGRICULTURAL POTENTIAL IN ZAMBIA

2.1 INTRODUCTION

This chapter seeks to investigate the natural resource base of Zambia, particularly in terms of its resources in relation to crop productivity, in order to gain insight into the agricultural potential of Zambia, its performance and the constraints that hinder the realisation of its potential. This will be achieved by an in-depth re-examination of past studies and literature on related aspects under consideration.

2.2 DEMOGRAPHIC AND ECONOMIC SITUATION

According to World Development Indicators (WDI), the population of Zambia was estimated to be 11.9 million and it had a growth rate of 2.4% per annum in 2008. Zambia is a low income country, overwhelmed by 78 and 53% of rural and urban poverty, respectively (CIA, 2008). It is faced with decreasing social indicators, particularly its life expectancy, which at birth is only 42 years, and a maternal mortality as high as 830 in 100 000 pregnancies (WDI, 2008). Recent figures show that Zambia is 35% urbanised (WDI, 2008). This figure has not changed much since the 1980s when the copper industry attracted rural people to the urban areas (World Bank, 2002).

The Government of Zambia has embarked on programmes that will aid economic diversification and thus reduce the economy’s reliance on the copper industry. This initiative sought to take advantage of the country's rich resource base by promoting tourism, agriculture, gemstone mining, and hydro-power (Elliott & Perrault, 2001). In recent years, the economy of Zambia has experienced modest growth, with real Gross Domestic Product (GDP) growth of 5-6% per year between 2005 and 2007. Agriculture GDP has stagnated at around 20% in the last decade while the sector recorded a growth rate of 3.5% between 2000 and 2006 (WDI, 2008). This is, however, still less than the six percent target under CAADP.

2.3 STRUCTURE OF THE AGRICULTURE SECTOR

The agriculture sector in Zambia is characterised by the co-existence of small-scale and large-scale farmers. According to Siegel and Alwang (2005), this dualism can be distinguished on many fronts, including:

- Technology use and mechanisation
- Cultivation practices and market orientation
- Crops produced
- Factors affecting location such as agro-ecological conditions and proximity to transport and markets
- Distribution of land and other household assets (e.g. human capital and financial assets)

The sector is overwhelmed by a majority of smallholder farmers that make up 85% of the country's agriculture producers, and only 15% are commercial farmers (MACO, 2004). Table 2.1 below illustrates the classification of agriculture producers in Zambia on the basis of farm size, technology, cultivation practice, market orientation, location and constraints.

Smallholder farmers use simple mechanisation (hand hoe and oxen), often employing traditional farming methods such as *chitemene*[1] and *fundikila*[2], primarily to grow rain-fed maize, roots and tubers, pulses and groundnuts, mainly for home consumption. They are dependent on household family labour, seldom use improved inputs like inorganic fertiliser and, as such, their productivity is very low (Siegel & Alwang, 2005). Under the prevailing farming conditions, smallholder farmers cultivate only a few hectares of land, primarily for

[1] The chitemene is a slash-and-burn system of cultivation.
[2] The process involves the formation of mounds of grass covered by earth on a previously fallowed site.

Table 2.1: Classification of farmers in Zambia

	Approx. # of Producers	*Approx. Farm Size*	*Technology, Cultivation Practice*	*Market Orientation*	*Location*	*Major Constraints*
Small-Scale Producers	800 000 hhs	< 5 ha (with majority cultivating 2 or less ha of rain-fed land)	Hand hoe, minimal inputs, household labour	Staple foods, primarily home consumption	Entire country	Remoteness, seasonal labour constraints, lack of input and output markets
Emergent Farmers	50 000 hhs	5-20 ha	Oxen, hybrid seed and fertiliser, few with irrigation, mostly household labour	Staple foods and cash crops, primarily market orientated	Mostly line-of-rail (Central, Lusaka, Southern provinces), some Eastern, Western provinces	Seasonal labour constraints, lack of credit, weak market information
Large-Scale Commercial Farms	700 farms	50-150 ha	Tractors, hybrid seed, fertiliser, some irrigation, modern mech., hired labour	Maize and cash crops	Mostly Central, Lusaka, Southern provinces	High cost of credit, indebtedness
Large Corporate Operations	10 farms	1000+ ha	High mechanisation, irrigation, modern mech., hired labour	Maize, cash crops, vertical integration	Mostly Central, Lusaka, Southern provinces	Uncertain policy environment

Source: Siegel and Alwang, 2005

subsistence use. However, excess produce, if any, is mostly sold to neighbours or at local markets. Large-scale farmers, on the other hand, are highly mechanised and cultivate extensive hectares using modern inputs and hired labour. They have access to irrigation facilities and grow maize, soya bean and other cash crops. They trade in international input and output marketing chains and are mostly located around urban centres with access to good physical infrastructure.

2.4 MAJOR CROPS

According to Thurlow *et al.* (2008), when using the 2004 GDP figures, maize is the major cereal crop contributor towards the Agriculture Gross Domestic Product (AgGDP) and it accounts for 23 % (Table 2.2). Other important crops in this regard include root crops (mainly cassava), which account for nine percent. Groundnuts, pulses and oil crops, fruits and vegetables, cotton and sugar also contribute significantly.

Table 2.2: Composition of Zambia's agricultural GDP (2004 figures)

Description	Initial Value of GDP (ZMK Billion) 2004	Percentage Share of Total (%)	
		Total GDP 2004	Agric GDP 2004
Total GDP	23 699	100	
Agriculture	4859	20.5	100
Cereals	**1307**	**5.5**	**26.9**
Maize	1143	4.8	23.5
Sorghum & millet	53	0.2	1.1
Other cereals	111	0.5	2.3
Root crops	444	1.9	9.1
Other crops	**895**	**3.8**	**18.4**
Pulses & oil crops	100	0.4	2.1
Groundnuts	344	1.5	7.1
Vegetables	283	1.2	5.8
Fruits	168	0.7	3.4
High value crops	**818**	**3.5**	**16.8**
Cotton	312	1.3	6.4
Sugar	337	1.4	6.9
Tobacco	109	0.5	2.2
Other export crops	61	0.3	1.3
Livestock	740	3.1	15.2
Forestry	374	1.6	7.7
Fishery	282	1.2	5.8

Source: Thurlow *et al.,* 2008

The proportion of land under crop cultivation varies significantly for different crops. Maize dominates land acreage as it accounts for 54% of total cultivated land, although a few studies indicate that its importance has reduced as patterns of production have shifted to drought-tolerant crops such as millet, sorghum and cassava (Jayne *et al.*, 2007). Cassava and other cereals collectively account for less than 30% of the area under cultivation (see Figure 2.1 below).

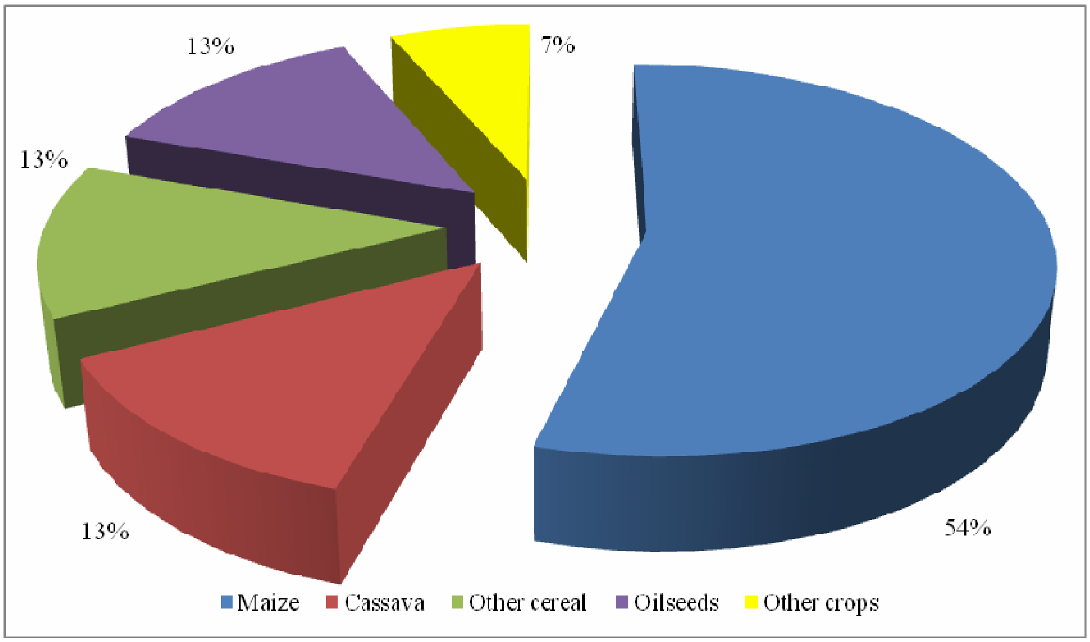

Figure 2.1: Proportion of area cultivated by crop

Source: MACO data, 2006

The scope of this study is limited to field crops. Seven crops are considered and the selection of these crops is based on their importance in terms of their contribution to the agriculture GDP and their dominance among producers, as well as the availability of data for the kind of analysis required for this study. The crops are maize, millet, sorghum, cotton, groundnuts, soya bean and sunflower.

2.5 ZAMBIA'S PHYSICAL RESOURCE BASE

The bio-physical characteristics and climatic conditions of a location assumes an important role in the productivity of the land, as it defines its capacity to support the growth of important plants and animals as well as the risk of exposure to harmful pests and diseases (Wood *et al.*, 1999). Therefore, soil fertility, acceptable temperature and the availability of water (rainfall and ground water) serve as the principal factors in determining the carrying capacity for agricultural production in a given location. These variables (soil types, temperatures and volume of rainfall) have been used to classify the agro-ecological zones of Zambia (Figure 2.2).

2.6 BIO-PHYSICAL CHARACTERISTICS

Zambia's landmass of 752 620 square kilometres is categorised into four agro-ecological zones, namely region I, IIa, IIb and III, as illustrated in Figure 2.2 below. The climate in Zambia is subtropical, with temperatures in winter and summer averaging between 15 and 30 degrees Celsius, respectively. While the annual rainfall pattern is similar over the whole country between November and March, the volume varies considerably according to agro-ecological zones (Bwalya & Naidoo, 2007). There is only one growing season as most agriculture in the country is rain-fed. The country's vegetation is typically comprised of savanna woodlands in regions of high rainfall and tropical grassland in low rainfall regions (Storrs, 1995).

Agro-ecological zone I

Region I constitutes 12 % of Zambia's total land area covering the southern, south western and eastern parts of the country. It embraces river valleys and is thus flat and steep, as well as hot and humid. This region consists of loamy to clay soils in the valley and coarse to fine loamy soils on the escarpment, while on the western side the soils are shallow. The region receives less than 800mm of annual rainfall and has a wet season of 120 to 130 days on average (MACO, 2004). The rainfall in this region is not reliable, resulting in occasional droughts, and may affect the possibility of irrigation as a result of the marked lowering of the water table, while the production of livestock is limited by the existence of tse-tse flies and trypanosomiasis (Bwalya & Naidoo, 2007; Aregheore, 2006).

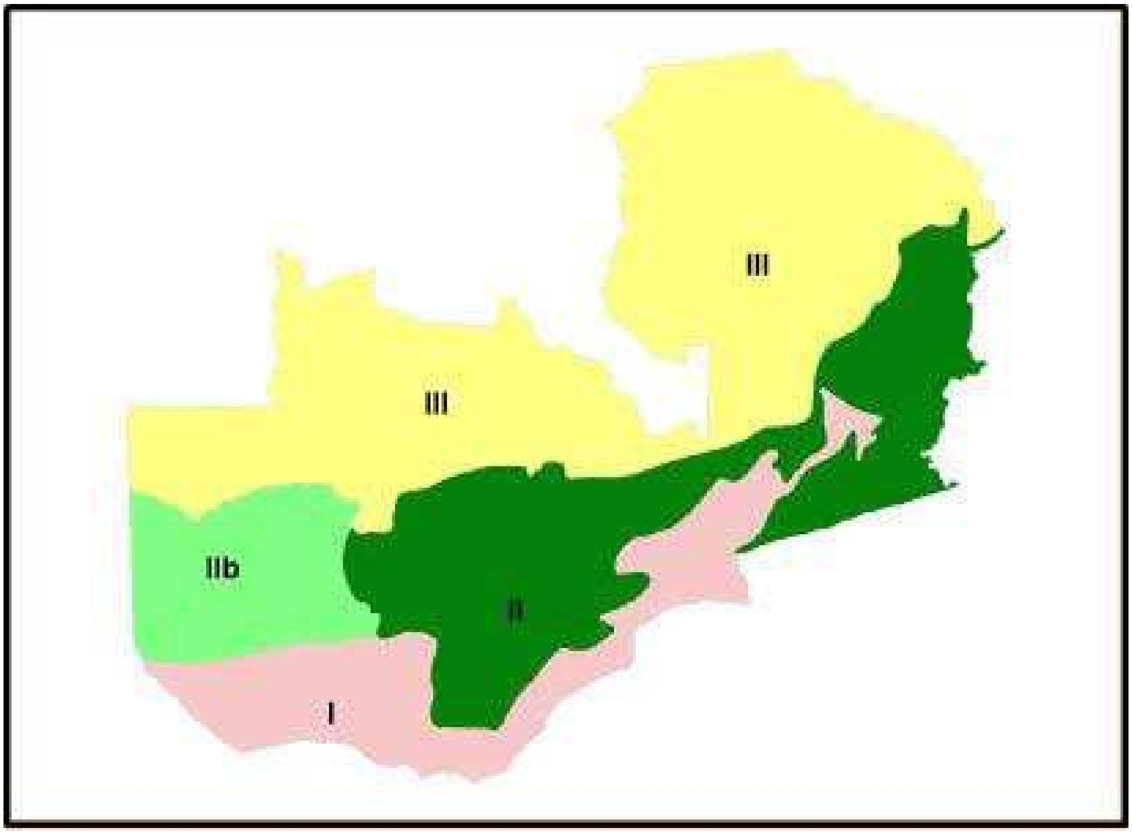

Figure 2.2: Zambia's agro-ecological regions

Source: CEEPA, 2006

Agro-ecological zone II

Region II is a plateau which covers 42 % of the country and it is sub-divided into region IIa and IIb. Region IIa covers the central, southern and eastern part of Zambia and has an annual rainfall of between 800mm to 1000mm. This region experiences a wet season of 160 to 180 days on average, has a more reliable rainfall pattern and a fairly high ground water table as opposed to region I's (MACO, 2004). It consists of fertile sandy, loamy soils that are suitable for crop production, while livestock production thrives owing to the absence of tse-tse flies.

This region has good potential for irrigation, particularly in the lower Kafue basin and in the several dambos of the central province (Bwalya & Naidoo, 2007).

Apart from having favourable agro-ecological conditions, region IIa has complementary location factors such as the presence of major urban centres and markets, as well as the existence of transport infrastructure such as the major rail line and major road arteries of the country (Bwalya & Naidoo, 2007). Region IIb is comprised mainly of the western plateau which makes up the Kalahari sand plateau and Zambezi flood plains. It also receives annual rainfall ranging from 800 to 1000 mm and has coarse, infertile sands (MACO, 2004).

Agro-ecological zone III

Region III covers the north and north western plateau areas that have a wet season of approximately 180 to 190 days on average, and it receives high annual rainfall between 1000mm and 1500mm. It constitutes 46 % of the country's land area with highly leached acidic soils (MACO, 2004). The rainfall in this region is fairly reliable and there is minimal variability[3]. The dry season is relatively short and the ground holds enough moisture for crop production. Furthermore, surface water for irrigation is easily available as there are many perennial streams (Bwalya & Naidoo, 2007).

The discussion above on the distribution of agro-ecological zones shows that opportunities and constraints in agriculture production vary by location. While agro-ecological region I has 17.3 million hectares of land with 20 % agricultural potential, region II has 27.4 million hectares with 87 % agriculture potential, and region III has 30.6 million hectares with 70 % agriculture potential (MACO, 2009). The three most limiting factors influencing agriculture production in a country where the majority of farmers are subsistence oriented are low soil fertility, availability of water and the incidence of pests and diseases (Omamo, Diao, Wood, Chamberlin, You, Benin, Sichra & Tatwangire, 2006). The diversity in the characterisation of farmers and the dissimilarity in agro-ecological zones justify the need to set priorities disaggregated by farmer type and agro-ecological zones.

[3] The beginning of the wet season and its duration from year to year is consistent.

2.7 RESOURCE UTILISATION

2.7.1 Land use

Zambia is estimated to have 48 million hectares of land that is well suited to agricultural production. Out of the 48 million hectares, only nine million hectares are under arable agriculture use and about 10 million hectares under livestock production (MACO, 2009). More than half of potential agricultural land in Zambia remains unexploited. This is illustrated in Figure 2.3 below.

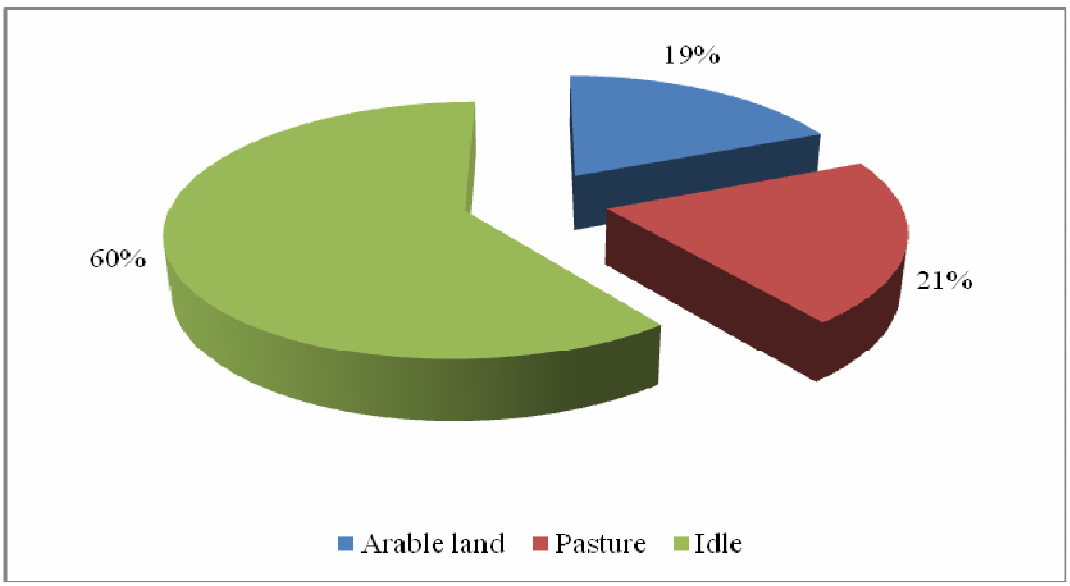

Figure 2.3: Land use in Zambia

Source: MACO, 2009

Zambia's land tenure system is dualistic: it uses the customary and statutory tenure systems. State land can be accessed through the Ministry of Lands and be leased for a renewable period of 99 years. In Zambia commercial farmers use the state land while most smallholder farmers use traditional land accessed via the customary land tenure system, in which traditional rulers allocate land (Martin, 2003). Land in Zambia is relatively still abundant especially in the northern part of the country where each rural household could have at least four ha of land[4] (FAO, 2004). However, the demand for land has recently increased and hence the call for the conversion of customary land into state land to meet land requirements in future.

2.7.2 Water use

Zambia is endowed with abundant water resources that can support agriculture production. According to the World Resources Institute (WRI) (2006), Zambia is estimated to have 105 km^3 of total renewable water resources, of which water withdrawal for agriculture is 1.32 km^3, which represents only one percent of total renewable water resources. In terms of land area, Mbumwae and Riddell (in Bonaglia, 2008) estimate the irrigation potential for Zambia to be 523 000 hectares, of which only 47 000 hectares (nine percent) is under irrigation, mainly by commercial farmers cultivating sugar, wheat and plantation crops. The bulk of agricultural production is still rain-fed and it remains to be seen whether the government will increase the land under irrigation to the optimistic target of 200 000 hectares by the year 2010.

2.8 CROP SUITABILITY

Crop suitability for each agro-ecological zone was determined on a scale of 1 to 3 (where 1 is most suitable and 3 is least suitable), as shown in Table 2.3, by matching crop requirements to the climatic and soil conditions of the country. This is important as it serves to determine the production potential of specific crops. The suitability classes indicate how crop production is affected by the various climatic and land conditions in each agro-ecological region. The climatic variables used for this rating include volume of rainfall, length of the growing season and average temperatures, while the land attributes are soil texture, soil pH and soil organic matter. Since the majority of the country's producers are small-scale, have low input use and rely on rain-fed production, it is justifiable to use rain and soil variables to indicate the agriculture potential. It can be seen from Table 2.3 that agro-ecological zone IIa and III are the most suitable for the production of most crops.

[4]Twenty percent of Zambia's land makes up the Northern Province, encompassing 14 percent of the country's population (FAO, 2004).

Table 2.3: Crop production suitability rating

Crop	Agro-Ecological Regions and Suitability Ratings			
	I	IIa	IIb	III
Groundnut	3	1	3	1
Soya bean	3	1	3	1
Beans	3	1	3	1
Millet	2	1	3	1
Sunflower	3	2	3	2
Maize	3	1	3	2
Cotton	3	1	3	2
Tobacco	3	1	3	1
Wheat	3	1	3	2

Where 1 is most suitable and 3 is least suitable

Source: MACO, 2009

2.9 CROP PRODUCTIVITY

Even though most of the country is suitable for crop production, the trend in output per hectare for most crops is characterised by visible turbulence, as depicted in Figure 2.4 below, which is evidence of instability in the sector. The crop yield trend for most crops reveals that the lowest production occurred during the early 1990s, which coincided with the period when government undertook structural reforms associated with reduced investment inflows to public sectors, including the agriculture sector, and consequently to research and extension. According to Govereh *et al.* (2008), the seemingly positive growth in output was mostly attributed to the increase in area under cultivation and labour and very little to technical change. Such low and fluctuating crop productivity has detrimental implications for achieving the desired and targeted six percent growth rate in agriculture, and hence the need to invest and seek the efficient use of resources for crop technology development.

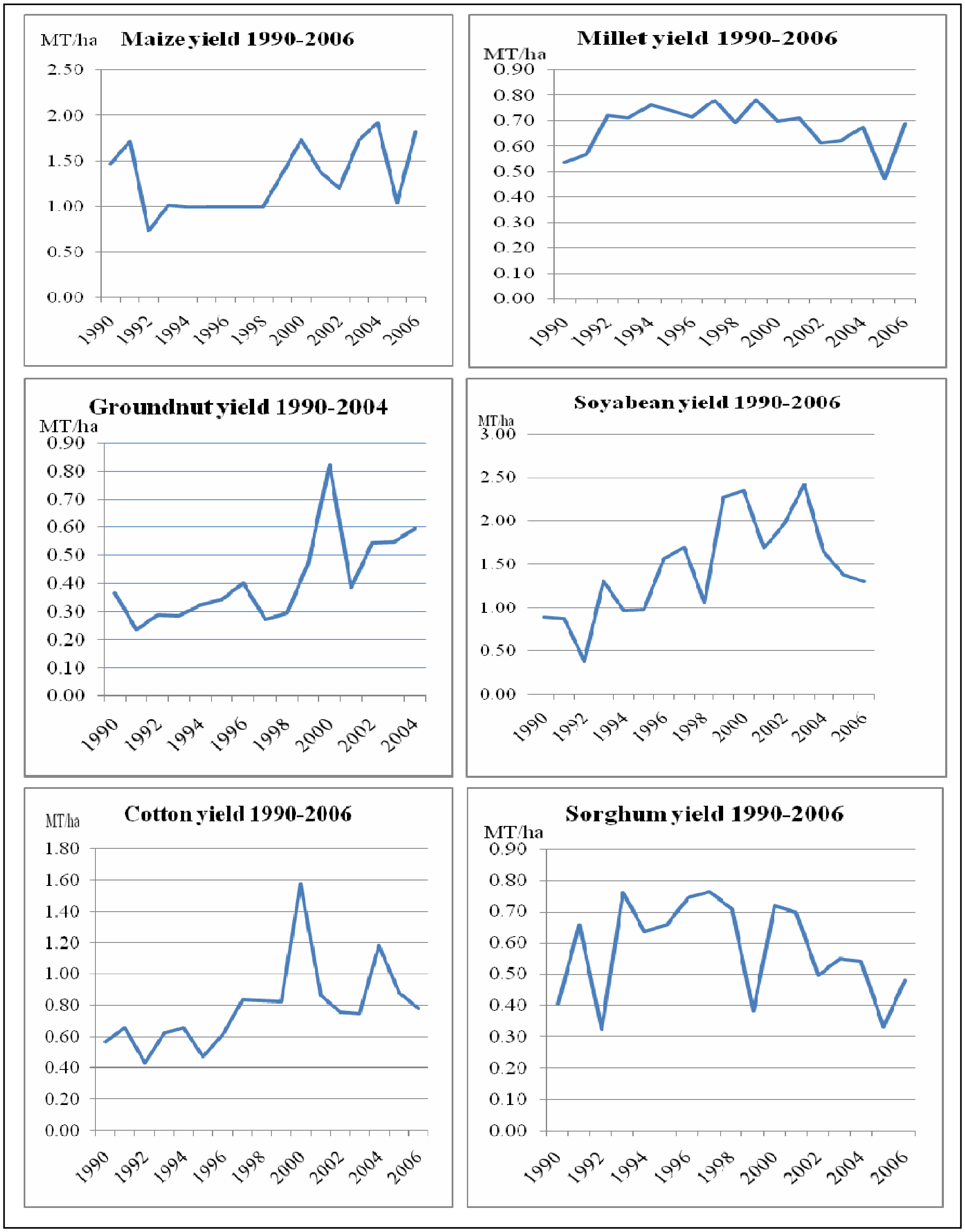

Figure 2.4: Crop productivity trends of selected crops

Source: CSO unpublished data (2008)

2.10 MAJOR CONSTRAINTS TO AGRICULTURE PRODUCTION

Some of the constraints faced by agricultural producers have been highlighted in Table 2.1 above. Low agriculture productivity under conditions of abundant land and suitable climatic conditions is due to low use of inorganic fertiliser and improved seeds, low mechanisation and the lack of access to complementary assets as well as the lack of support services such as extension services. It is estimated that there is only one extension worker for every 1000 farmers (IICD, 2009). Even though the development of extension officers has received little attention, it is important to realise that extension officers play a vital role in completing the research process, by ensuring that new technologies reach the desired end users on time and in the correct target environment. Failure to take this holistic approach when conducting research may nullify the essence of the research, as technologies may end up with the wrong users or in the wrong target environment and, worse still, developed technologies may not be disseminated at all, thereby wasting resources.

In addition to low technology development and dissemination, the government also lacks incentives to promote the utilisation of idle land. Also, there are increased inconsistencies between documented policies and actual implementation, which has held back private sector participation and weakened public-private sector partnerships (DFID, 2002; Govereh *et al.*, 2006). Further, the prevalence of HIV/AIDS has generated health related problems that have adversely affected household labour in terms of availability and household production decisions (Siegel & Alwang, 2005).

Zambia's poor infrastructure does not support the notion of economic viability and as the country is landlocked, it suffers inherently from high transaction costs as well as high input costs (e.g. fertiliser), which mostly affects the smallholder farmers that are remotely located and far from major infrastructure and markets. The poor road conditions, the long distance to the markets, the very thin input and output markets as well as the eroding credit facilities with unattractive interest rates are all impediments to agricultural development (DFID, 2002).

Crop productivity has also been limited by the high dependence on rain-fed agriculture despite the fact that some regions of the country are susceptible to occasional droughts. Also, unsustainable farming practices such as slash-and-burn, and the increased use of wood as a source of energy will soon lead to soil degradation (DFID, 2002). The need to raise Zambia's crop productivity through continued investment in science-based agriculture innovations and technology, remains fundamental to addressing low crop yields. There is need for a crop-based research system to explore varietal breeding, agronomic practices, soil conservation and plant protection, which must be complemented by a vibrant extension service system. Equally important is the need to invest in physical infrastructure such as irrigation facilities and the management of water bodies, major and feeder roads, as well as in strengthening the capacity of institutions.

2.11 SUMMARY

Zambia is endowed with abundant land and water resources as well as suitable climatic conditions that are conducive for agriculture production. Therefore, the country has a medium to high agriculture potential. However, Zambia falls short of its potential, in that its agriculture sector has underperformed when measured against variables such as the targeted growth rate, the land under cultivation, the area under irrigation and crop productivity. The constraints faced by the sector are mainly structural and human related problems that can be addressed by an appropriate institutional and policy framework that prioritises investments in agriculture research and complementary infrastructure and institutions. The next chapter in this thesis therefore investigates expenditure trends in Zambia's agriculture sector and explores the nature and scope of crop research performed in Zambia.

CHAPTER 3

ZAMBIA'S AGRICULTURE EXPENDITURE AND RESEARCH SYSTEM

3.1 INTRODUCTION

The purpose of this chapter is to investigate the trends in public agriculture expenditure in Zambia and to explore its current crop research system in order to determine the nature and scope of crop research being conducted in Zambia. This chapter consists of two major parts: The first part discusses Zambia's expenditure trends in the agricultural sector and reviews the potential key investment areas in the sector that were identified in the nation's development plan. It is worth noting that in this study the term expenditure was used to imply both short-term (current expenditure) and long-term expenditure (investment).

The second part of this chapter begins by discussing the evolution of Zambia's crop research system. This is followed by a brief discussion of the data-gathering process, which involved administering a structured questionnaire to researchers to obtain primary data pertaining to the number of researched crops, the nature of research programmes, the number of researchers, research expenditure and the sources of research funds from all the identified crop research institutions. The findings from the survey are then presented and discussed.

3.2 OVERVIEW OF INVESTMENTS IN ZAMBIA'S AGRICULTURE SECTOR

Zambia's agriculture sector has experienced fluctuations in investment that can be explained by changes in economic and policy reforms, spanning from when the country gained its independence up until the present. In the 1970s, the government enjoyed relatively high copper revenues, and thus made considerable fiscal spending across all public sectors. When copper revenue decreased, owing to low demand and consequently low prices, the Government of Zambia resorted to foreign borrowing while maintaining relatively high fiscal spending, thereby accumulating foreign debt (Hill & McPherson, 2004). In 1993, the Government of Zambia, under new leadership, went through a process of structural reform which included policies of deregulation and liberalisation, and several other structural adjustment programmes were adopted. This restructuring came with a restricted budgetary process, and as a result, most government ministries such as Tourism and Agriculture experienced a reduction in investments in order to reduce the severe budget deficit (World Bank, 2001).

The share of total budget resources allocated by the government to agriculture in the 1980s (Figure 3.1 below) was higher than the budget resource allocations from the 1990s until the present. Before 1993, the Zambian Government was actively involved in all facets of agriculture, including production, marketing, pricing, research and the provision of subsidies and credit. At the time, policies focused on more than merely the production and marketing of maize as a staple cereal to ensure that the country was self-sufficient; the government also conducted research and encouraged the adoption of hybrid maize through subsidised input distribution (Howard & Mungoman, 1996).

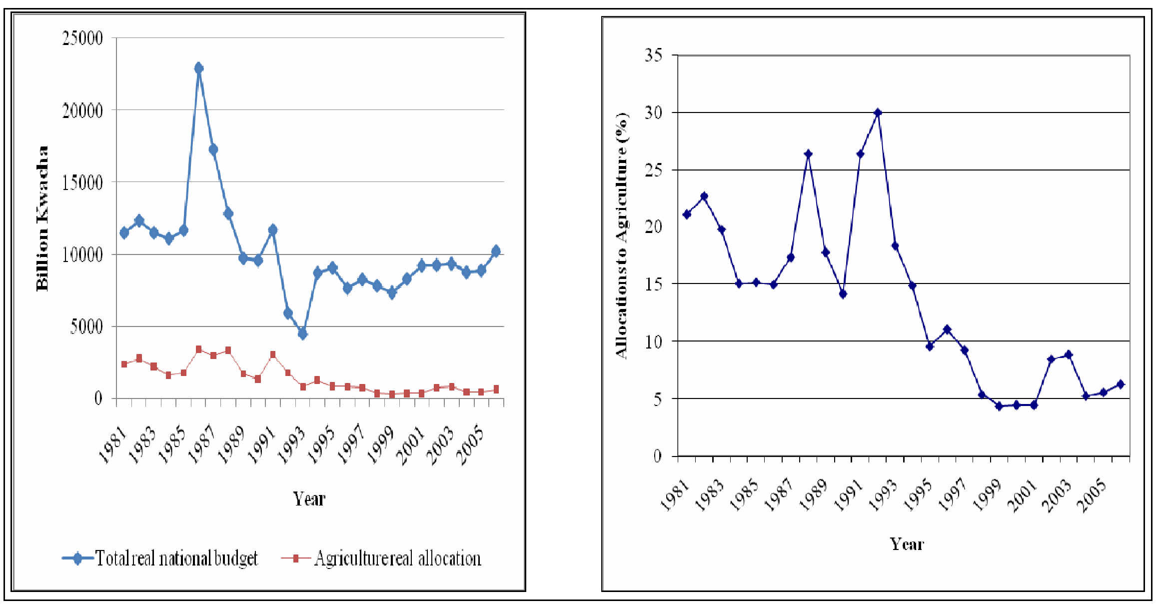

Figure 3.1: Total national and agricultural budget-real values (left) and share of national budget allocated to agriculture-% (right part); 1981-2006

Source: Govereh *et al*., 2006

The period in which the state was considerably involved in the agriculture sector coincides with the period when the share of national budget allocated to agriculture was above 14%. It was highest in 1992, reaching a peak of slightly less than 30%. However, it is worth noting that these figures exceed the 15% that Asian countries devoted to agriculture during the green revolution, even though Zambia did not realise such agricultural revolution. Therefore, it is not only the quantity of expenditure that matters, but its quality as well. Significant reductions in the share of resource allocations are observed after 1993, and compared to allocations made before structural reforms, the real size of the budget for agriculture reduced by almost 50%. In 2000, the allocation of public budget to agriculture shrunk to a low of four percent; however, it gained a little momentum during 2003, when it averaged five to six percent after the Maputo declaration regarding meeting targets of the millennium development goals (Govereh *et al.*, 2006).

3.3 THE COMPOSITION OF ZAMBIA'S AGRICULTURE BUDGET

The six major items identified by Govereh *et al.* (2006) that comprised the agriculture sector public expenditure budget between 2001 and 2006 were: personnel emoluments (salaries, wages and pensions for all personnel including researchers); recurrent departmental charges (operational expenses); poverty reduction programmes (out-grower schemes, fertiliser support programmes, agriculture research and extension, livestock production); capital expenditure (purchase of movable and fixed assets); agricultural development programmes (donor funded programmes); agricultural infrastructure spending allocated through other ministries, and other public payments (subscriptions to international organisations, grants to research trusts). Table 3.1 below shows the real budget allocations of these items.

The poverty reduction programmes have the largest share of expenditure (about 48%) and are of great importance to this study as they include, among other items, expenditure in agriculture research. Table 3.2 shows a further breakdown of resources within the poverty reduction programme item.

Table 3.1: Government budget allocations in Zambia's agriculture sector 2001-2006 (2006 billion ZMK values)

Budget Items	2001	2002	2003	2004	2005	2006
Personnel emoluments	33	52	39	89	80	84
Recurrent departmental charges	42	36	37	23	47	39
Grants and other payments	5	4	15	11	4	3
Poverty reduction programmes/HIPC	**142**	**140**	**513**	**178**	**236**	**270**
Capital expenditure	84	32	1	0	0	1
Agriculture show	0	0	0	0	1	2
Donor funded programmes	47	66	90	78	53	211
Agric infrastructure and social relief services	72	38	31	43	66	32
Allocation to provinces and districts	0	0	11	8	8	7
Total allocation to sector	**426**	**367**	**737**	**430**	**494**	**650**
National budget	**11 000**	**10 188**	**10 246**	**10 437**	**9388**	**10 237**
% of agric spending in national budget	**3.9**	**3.6**	**7.2**	**4.1**	**5.3**	**6.3**

Source: Govereh *et al.*, 2006

Table 3.2: Budget allocations within the Poverty Reduction Programme 2001-2006 (real 2006 billion ZMK values)

Poverty Reduction Programmes	2001	2002	2003	2004	2005	2006
Out-grower schemes	0	22	10	2	1	2
Land and farm block development	12	3	22	18	7	6
Farm institutes and training centre rehab	0	9	4	1	3	2
Livestock restocking and disease control	14	21	10	2	3	3
Fertilizer Support Programme	**69**	**53**	**73**	**88**	**149**	**199**
Food Reserve Agency	**0**	**0**	**364**	**59**	**63**	**50**
Fisheries development	0	4	5	1	1	1
Rural investment fund	44	11	3	2	2	1
Agriculture research	**0**	**4**	**1**	**2**	**2**	**1**
Community extension	0	0	0	1	2	1
Seed multiplication	0	4	2	0	0	0
Other poverty reduction programmes	0	8	12	2	4	4
Total[5]	**139**	**138**	**505**	**178**	**237**	**270**

Source: Govereh *et al.*, 2006

[5] The total in Table 3.2 must equal the **Poverty reduction programmes/HIPC** item in Table 3.1. The slight discrepancy in 2001, 2002 & 2003 is perhaps due to erroneous accounting since these tables were adopted from original source in this way.

It can be observed from Table 3.2 above that a greater proportion of funds (about 80%) under the poverty reduction programme were spent on only two programmes, namely the Fertilizer Support Programme (FSP) and the Food Reserve Agency (FRA), while other programmes like agriculture research received less than one percent (0.69%) of the total allocated funds, thereby effectively stagnating public agriculture research.

After a series of reforms and acknowledging the importance of agriculture, the Government's strategy to improve growth in the agricultural sector and reduce poverty among rural households is currently guided by the Fifth National Development Plan (FNDP) and the National Agricultural Policy (NAP) for the period between 2004 and 2015. In this policy document, the agricultural sector is targeted to grow at six percent per annum as opposed to the current 4.5%. Therefore, government re-identified key areas of investment in agriculture in order to realise the desired growth rate. Table 3.3 below shows the identified activities as well as the total financial resources required to carry out such activities over the period of 2006-2010.

According to the information presented in Table 3.3 below, the agriculture service and technology development, the field where research and development is placed, accounts for 11.9% of total agriculture expense, which is far more than the 0.69% computed from Table 3.2 above. On the other hand, allocations to the Fertilizer Support Programme, which have always been government's priority in terms of resource allocation, declined from about 80% to slightly more than 18% in the 2006 to 2010 budget plan.

However, it is still of great concern that the Government of Zambia allocates a significant proportion of expenditure to recurrent subsidies to individual farmers through FSP, even when studies have shown low returns on such investment (Lopez, 2007). Furthermore, private goods subsidies promote rent-seeking among recipients and also tend to reduce private input sales (Haggblade, 2007). In addition, other studies (e.g. Alston *et al*., 2005) have also shown that the highest returns on any form of agriculture expenditure are generated from investing in agriculture research and extension. Returns on agricultural research studies indicate an average of 78% in Asia, 54% in Latin America and 50% in Africa, with Africa having the highest volatility in terms of outcome, owing to the diversity of farming systems and the reliance on rain-fed crop production. This therefore necessitates the need to carefully plan and prioritise investment in crop research for African countries.

Table 3.3: Zambia's FNDP agricultural expenses (2006-2010)

Activity	Total Cost (ZMK Billion)	GRZ Contribution (ZMK Billion)	Donor's Contribution ZMK Billion	Share of Core Expenses (%)	Share of GRZ (%)	Share of Donor (%)
Irrigation Development and Support	465	227	239	10.5	8.3	14.2
Agricultural Infrastructure and Land Development	444	210	234	10.0	7.6	13.9
Livestock Development Programme	722	493	229	16.3	17.9	13.6
Agricultural Services and Technology Development	**530**	**326**	**204**	**11.9**	**11.9**	**12.1**
Fisheries Development	227	179	48	5.1	6.5	2.8
Policy Coordination and Management	137	74	64	3.1	2.7	3.8
Agricultural Marketing, Trade and Agribusiness Development	214	118	96	4.8	4.3	5.7
Cooperatives Development	41	26	15	0.9	0.9	0.9
Human Resource Development	80	60	20	1.8	2.2	1.2
Fertilizer Support Programme	**498**	**498**	**0**	**11.2**	**18.1**	**0**
Strategic Food Reserves	**130**	130	0	2.9	4.7	0
Salaries - Extension Officers	412	412	0	9.3	15.0	0
Others (Ongoing Projects)	537	0	537	12.1	0.0	31.9
Total Core Expense	**4436**	**2751**	**1685**	**100**	**100**	**100**

Source: PRSP, 2006

3.4 EVOLUTION OF ZAMBIA'S CROP RESEARCH SYSTEM

Zambia's agricultural research activities date as far back as 1922 when the first experimental cotton and tobacco gardens were created by European farmers. As in most African countries, Zambia began nationalising its agricultural research system in the late 1970s (Roseboom &

Pardey, 1995). Before then, nearly 80% of the Full Time Equivalent (FTE) researchers that worked on agricultural related aspects in tertiary education institutions and the government were expatriates. This proportion decreased to 12% in the 1990s and two percent by the year 2000 (Beintema, Eduardo, Elliott & Mwala, 2004).

During the 1970s, commodity research teams under the then Ministry of Agriculture and Water Development designed research programmes without farmer and other stakeholder consultation. After research trials which were conducted under highly managed conditions in research stations that differed from typical conditions in farmers' fields were successful, they were passed on to the farmers via extension officers. This approach did not address farmers' problems and as such, in 1978, the government in collaboration with the Centre for the Improvement of Maize and Wheat (CIMMYT), implemented an interdisciplinary farming system research and extension approach, whose emphasis was also based on on-farm research. Therefore this necessitated the establishment of provincial research stations during the 1980s (Bezuneh, Ames & Mabbs-Zeno, 1995).

In the 1990s, further restructuring in the research environment occurred with the advent of globalisation and free market forces, and research had to respond to such reform in order to meet new farmer demands. Also, the pressure to privatise research increased as there was an emergence of new research partners and commercial enterprises had entered into technology development for profit. Meanwhile, as the research system grew not only in structure but also in complexity, financial resources became more scarce and competitive. Initially, the conventional method of funding involved releasing lump sums to research institutions, and there generally was little or no contemplation on the efficiency or planning of the research (Elliott & Perrault, 2006). In light of such changes in the research environment, there was need to improve the effectiveness and efficiency of research and to focus on the most important research activities. Thus the Soil and Crop Research Branch (SCRB) of the Ministry of Agriculture, Food and Fisheries (MAFF) at the time carried out priority setting activities in 1993 and again in 1997 (MAFF, 2009).

Priority setting by the SCRB will be discussed further in subsequent chapters. For now, the discussion turns its attention to the current crop research system in Zambia, particularly in terms of the existing research institutions, personnel, research focus and research expenditure.

3.5 RESEARCH INSTITUTIONS

The National Agriculture Research System (NARS) constitutes 17 institutions that conduct research into livestock, food technology, forestry, fisheries, soils and crops. Only seven out of these 17 institutions perform crop research, therefore a census was conducted on the seven crop research institutions. A self-administered semi-structured questionnaire (one questionnaire for each research institution) was used to collect data. The director of research was responsible for answering the questionnaire, however due to the nature of the data required, human resources, finance and crop scientists within the institution had to be consulted. The data was collected over a period of 8 weeks and each institution was visited several times. The purpose of the survey was twofold: Firstly, it aimed to determine the extent of crop research in Zambia and secondly, to elicit expert opinion on technology related data for the empirical model. The primary data was analysed using Microsoft Excel in order to obtain descriptive statistics and the findings were presented using bar charts, tables and pie charts.

At this point, it is worth noting that a similar survey was conducted in Zambia about a decade ago[6] (in the year 2000). However, due to possible differences in definition of terms, the current findings where applicable, are discussed in comparison with earlier findings in terms of general trends and observations.

The seven research institutions that conduct agricultural crop research can be grouped into four categories (Table 3.4 below), namely:

- Government
- Research trusts

[6] See Beintema *et al.*, 2004

- The private sector
- Higher learning institutions

The Zambia Agriculture Research Institute (ZARI) is the major government research institution under the Ministry of Agriculture and Cooperatives (MACO). This main crop and soil public research agency was referred to as the Soil and Crop Research Branch (SCRB) in previous studies. ZARI has four technical divisions, namely:

- Crop improvement and agronomy
- Soils and water management
- Plant protection and quarantine
- Farming systems and social sciences

Table 3.4: List of agricultural crop research institutions in Zambia

Type of Institution	Name of Institution/Organisation /Station	Location
Government	Misamfu Research Station	Kasama, Northern Province
	Mansa Research Station	Luapula Province
	Mutanda Research Station	Solwezi, North Western Province
	Mufulira Research Station	Copperbelt Province
	Msekera Research Station	Chipata, Eastern Province
	Mt. Makulu Research Station	Chilanga, Lusaka Province
	Simulumbe Research Station	Mongu, Western Province
	National Irrigation Research Station	Southern Province
	Kabwe Research Station	Central Province
Research trusts	Golden Valley Research Trust (GART)	Chisamba, Lusaka Province
	Cotton Development Trust (CDT)	Mazabuka, Southern province
Private sector	Zambia Seed Company (ZamSeed)	Lusaka Province
	Maize Research Institute (MRI)	Lusaka Province
	Seed Company (SeedCo)	Lusaka Province
Higher education institutions	School of Agricultural Sciences, University of Zambia	Lusaka Province

Source: own compilation

ZARI is mandated to generate and adapt soil and crop technologies to increase the sustainability of agricultural production and serve the needs of farmers. It has nine agriculture research stations located throughout the country's provincial towns, while its headquarters are in Lusaka.

Research trusts were created in the 1990s as part of the reform process in which the Government of Zambia sought to increase private sector participation in agriculture research. The trusts are a partnership between the public and private sector and they commercially manage public assets and provide research and extension services. Research trusts obtain their funds partly from government allocations but also generate internal funds through commercialisation of technologies and from contract research and collaborative research with the private sector and donors (Bonaglia, 2008). Trusts are meant to increase flexibility in the financing and management of physical and human assets, thus ensuring better efficiency. With such regard, two crop research trusts were established, namely:

- *The Golden Valley Research Trust (GART)* - was established in 1997 to carry out research into livestock, tillage systems, water conservation, variety testing and soil fertility as well as dissemination of research results.
- *The Cotton Development Trust (CDT)* - was established in 1999 and focuses on developing and disseminating technologies for cotton growers.

Lately, the private sector also plays a significant role in performing crop research, and the three dominant organisations are: the Maize Research Institute (MRI), Seed Company (SeedCo) and Zambia Seed Company (ZamSeed). Their primary role is to develop improved seed technologies for various crops.

The University of Zambia (UNZA) is the biggest tertiary institution performing agriculture related research. The major unit with the university is the school of Agricultural Sciences.

The numbers of crop research institutions identified above are still the same institutions that existed in previous studies about a decade ago. This is not surprising as new research entities or arrangements do not always occur often in many countries, and when they do, this can be seen as a measurement of instability. Therefore, since no new research institutions were established in Zambia in the past decade indicates stability in agriculture research management.

3.6 RESEARCH PERSONNEL

Research personnel[7] were measured in Full Time Equivalent[8] (FTE). Figure 3.2 below depicts that the total number of crop researchers in Zambia grew from 115 to 161 FTEs between 2004 and 2008, thereby representing a 40% increase in the number of researchers. This increase is mainly attributed to the government research institutions that recruited 39 researchers between 2005 and 2008 after undergoing an employment freeze that ended in 2004.

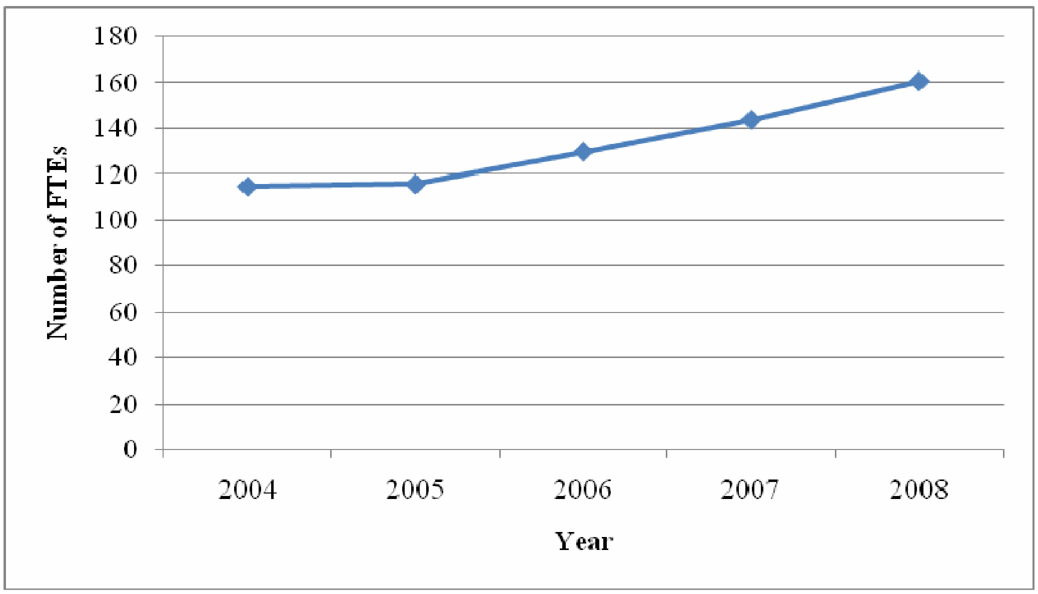

Figure 3.2: Trend in the number of crop research personnel (2004-2008)

Source: own compilation

[7] Research personnel refers to research scientists who hold a minimum of a B.Sc. degree or its equivalent via university training.

[8] A Full Time Equivalent (FTE) researcher is an individual who holds a full-time position as a researcher during the whole year.

The government has been the largest employer of FTE researchers, employing a total of 130 researchers in 2008 (Table 3.5) which accounted for nearly 80% of the country's crop researchers while research trusts accounted for 11%. The University of Zambia and the private sector stagnated at low levels with each accounting for only 4% of the country's total crop research staff.

Table 3.5: Crop research personnel 2004-2008

Research institution	**FTEs 2004-2008**				
	2004	**2005**	**2006**	**2007**	**2008**
ZARI	90	91	102	113	130
MRI	2	2	2	2	2
Seedco	1	1	1	2	2
Zamseed	3	3	3	3	3
GART	10	10	13	15	15
CDT	3	3	3	2	2
UNZA	6	6	6	7	7
Total	**115**	**116**	**130**	**144**	**161**

Source: own compilation

3.7 RESEARCH FOCUS

The data gathered from the survey pertaining to research focus is discussed at two levels: crop coverage and research programme by each research institution. Apart from highlighting the numbers of crops and research programmes covered in each institution, research focus is also discussed in terms of the proportion of time devoted to each crop and each research programme, as well as the distribution of research personnel across the various crops and research programmes.

3.7.1 Crop coverage

The government reported the highest number of research crops, with more than seven crops in which research is performed. These included but are not limited to maize, millet, groundnut, soya bean, sunflower, sorghum and cassava. The government research institutions have made remarkable progress in the last five years in terms of the development of a wide range of improved varieties and clones of traditional staple food crops such as maize, sorghum, pearl millet, cassava, sweet potatoes, cowpea and groundnuts (PASS, 2007). This is followed by the University of Zambia and Zamseed which both reported performing research on six crops namely maize, mixed beans, cassava, sunflower, sorghum, groundnut and wheat. At the bottom of the list is the Cotton Development Trust which performs research only on cotton.

It can be noted from Figure 3.3 below that six out of the seven research institutions reported performing research on maize and, based on the responses on time allocated to different research crops; it was found that a higher proportion of time is devoted to maize research in all the six research institutions. As an example, ZamSeed performs research in six crops and maize accounts for 70% of the total research time while the other five crops receive the remaining 30% time share. Similarly, MRI seed, GART, SeedCo and the government all devote a greater proportion of research time towards maize research. This agrees with earlier studies that also found maize to be the major focus of crop research in Zambia (Beintema *et al*., 2004).

Surprisingly, none of the research institutions reported conducting research into the sugar crop yet sugar is one of Zambia's major crops (Table 2.2 in chapter 2). However, this could partly be due to the fact that 87% of production at Zambia's major sugar estate and company is owned by Illovo which is based in South Africa (Illovo, 2009), therefore most sugar research is conducted by this parent institute. Even though maize is still the main research crop, other popular crops for which research activities were reported included soya bean, sorghum, millet, sunflower, cotton, groundnuts, wheat, mixed beans and cassava. The less popular crops were cowpeas, sun hemp and guar.

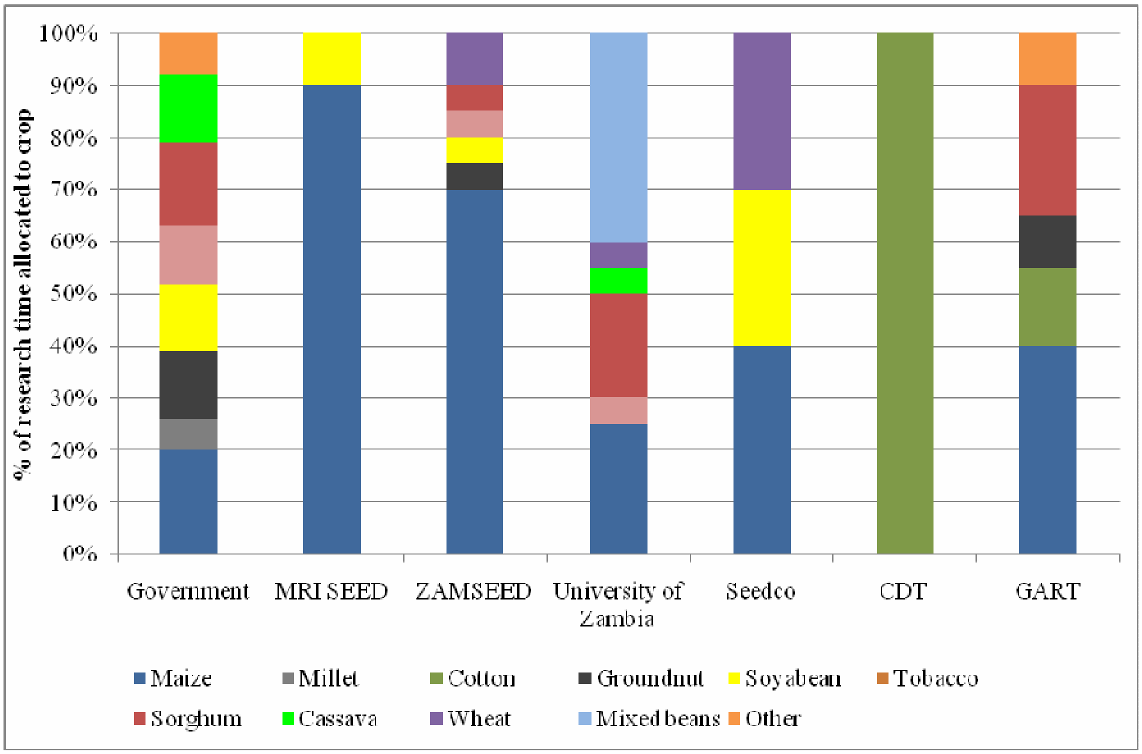

Figure 3.3: Research focus by crop

Source: own compilation

In terms of number of personnel in relation to crop focus, a total of 95 crop scientists were working on specific crops in 2008. It was found that maize had the highest number of research personnel (30 researchers), which accounted for 32% (Figure 3.4 below) of the total research staff working on various crops in 2008. This was followed by sorghum and cotton, at 15% and 12% respectively. At the bottom of the list was groundnuts and sunflower research which both accounted for only 5% of total research personnel.

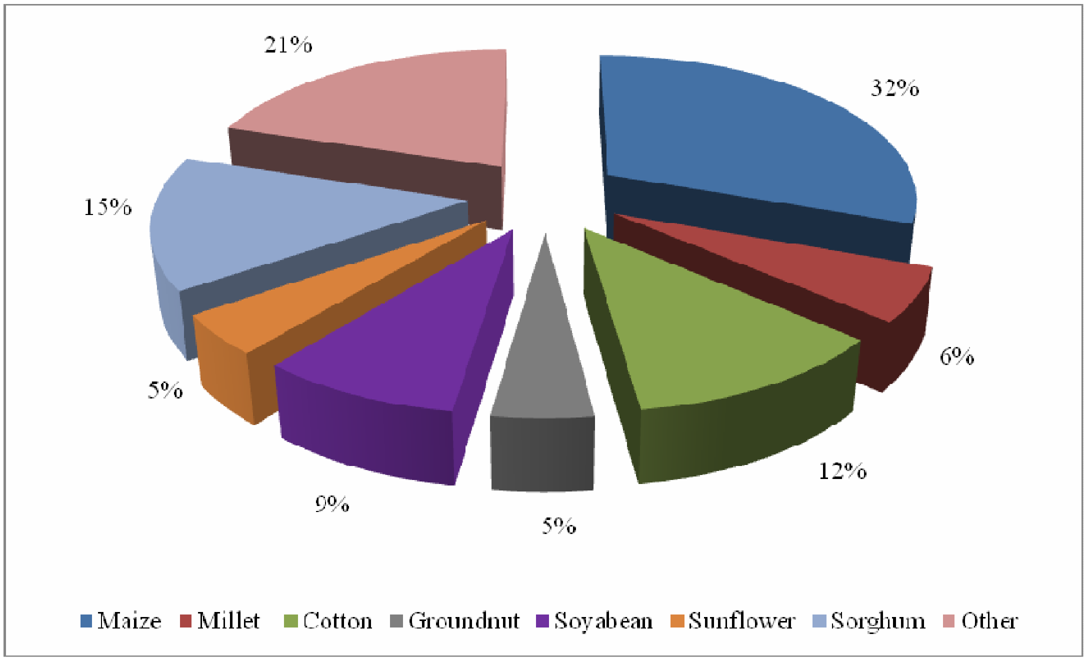

Figure 3.4: Proportion of researchers by crop

Source: own compilation

It is not surprising that maize is the most researched crop as the majority of Zambian people depend on it for their food security and also because the crop occupies the largest percentage (54%) of the total crop area under cultivation (MACO, 2009). Therefore, this justifies the need for an extensive maize-based research system especially in the face of climate change for a greater understanding of the dynamics of the maize-based farming system in order to ensure food security and the sustainability of livelihoods and natural resources.

3.7.2 Research programmes

With regard to research programmes, six disciplines were identified as important for the research crop value chain. These include genomics and plant breeding, plant protection, agronomy, soil research, post-harvest (pertaining to on-farm storage and processing) and market research. Based on the averaged responses of all the crop research institutions regarding time allocated to the various research programmes, plant breeding constituted the bulk of crop research programme being conducted in Zambia as it accounts for 50% of all research time allocated to crop research activities. Even though plant breeding was the most important activity, researchers pointed out that there was a problem of slow technology development due to the continued use of conventional methods of technology as opposed to advanced methods of biotechnology. Plant protection and agronomy were the next important research activities at 15% and 14%, respectively (Figure 3.5 below). The least researched discipline is post-harvest research, at only five percent of total time devoted to crop research programmes.

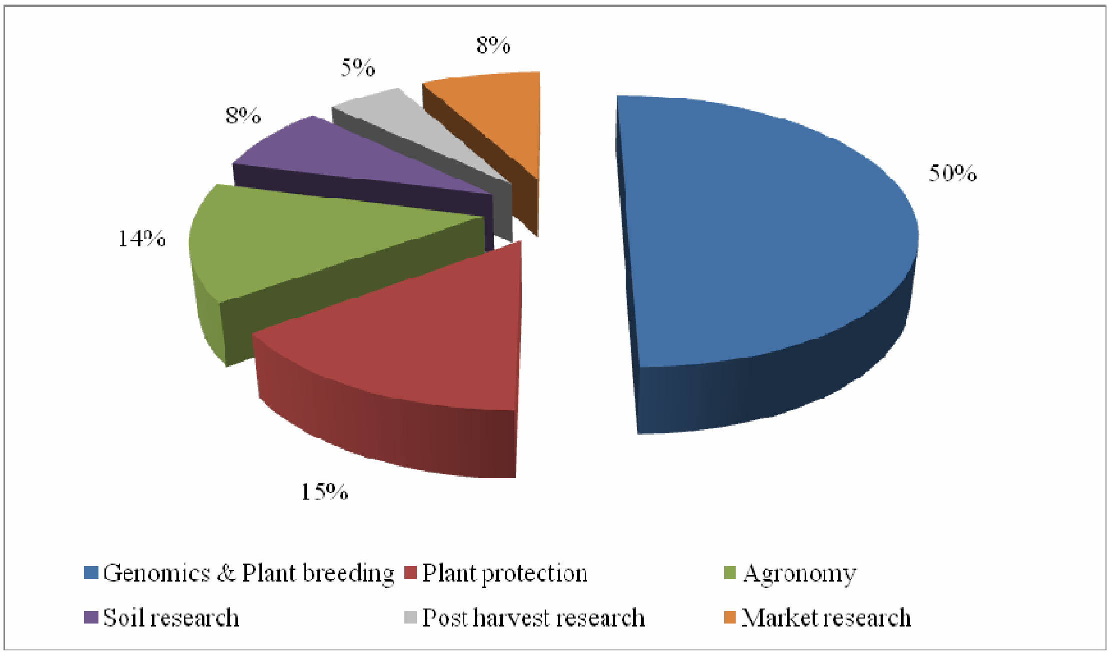

Figure 3.5: Research focus by research programme area (% of time allocated to research activity)

Source: own compilation

In terms of individual institutions, all the seven institutions reported plant breeding as the major research activity, except for GART whose major focus was agronomy (Figure 3.6 below). About 43% (three out of the seven) of these institutions perform research in all the six research disciplines (genomics and plant breeding, plant protection, agronomy, soil research, post-harvest research and market research); these are the government, the University of Zambia and the Maize Research Institute (MRI). This is followed by ZamSeed that performs research in five research disciplines. Seedco, GART and CDT had the least number of research disciplines, each concentrating on only three research disciplines.

Even though post-harvest and market research seem to receive little attention, these activities are also equally important because, as productivity increases, there will be a need to develop better ways of storage to minimise post-harvest losses and also to explore and develop new marketing channels, especially those that would link smallholder farmers to market.

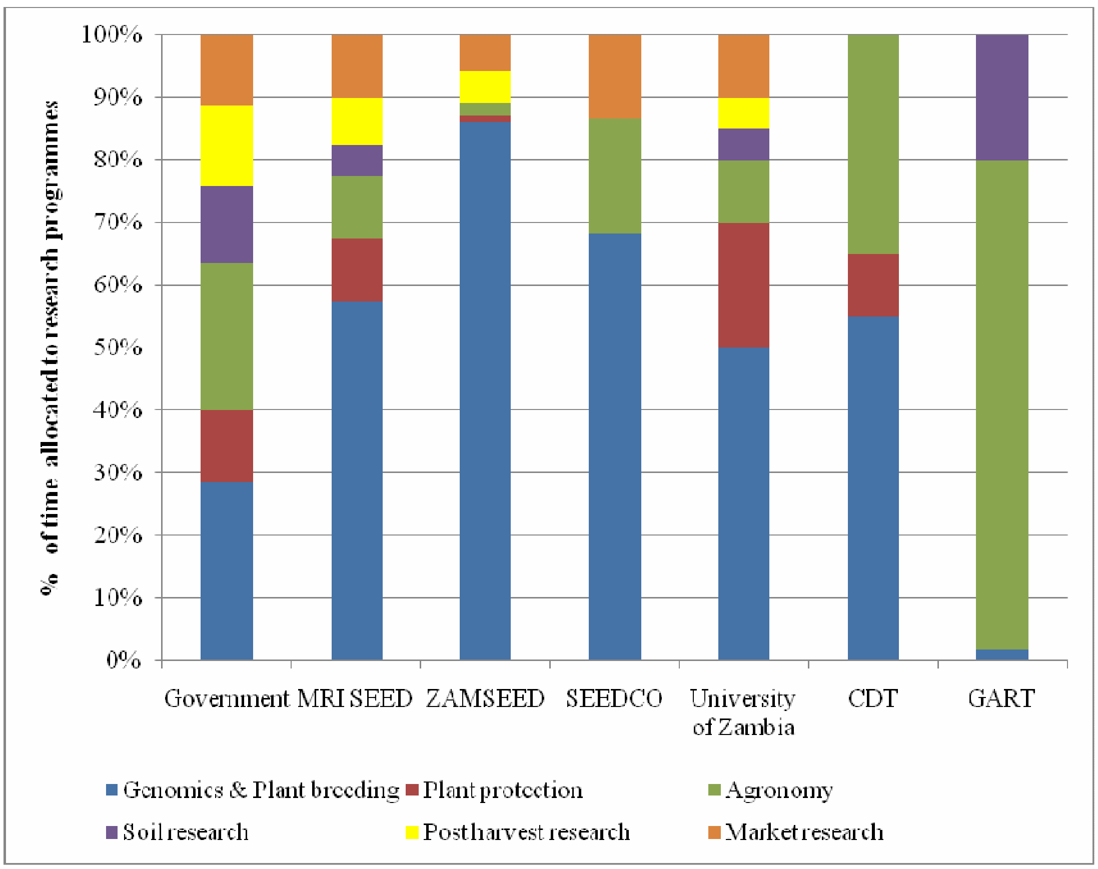

Figure 3.6: Research focus of each institution by research programme area

Source: own compilation

It can further be observed from figure 3.7 below that the largest number of researchers in 2008 (40 researchers) was in the field of agronomy, accounting for 24% of total research staff. This was followed by soil research and plant protection each at 36 and 33 researchers accounting for 22% and 20%, respectively.

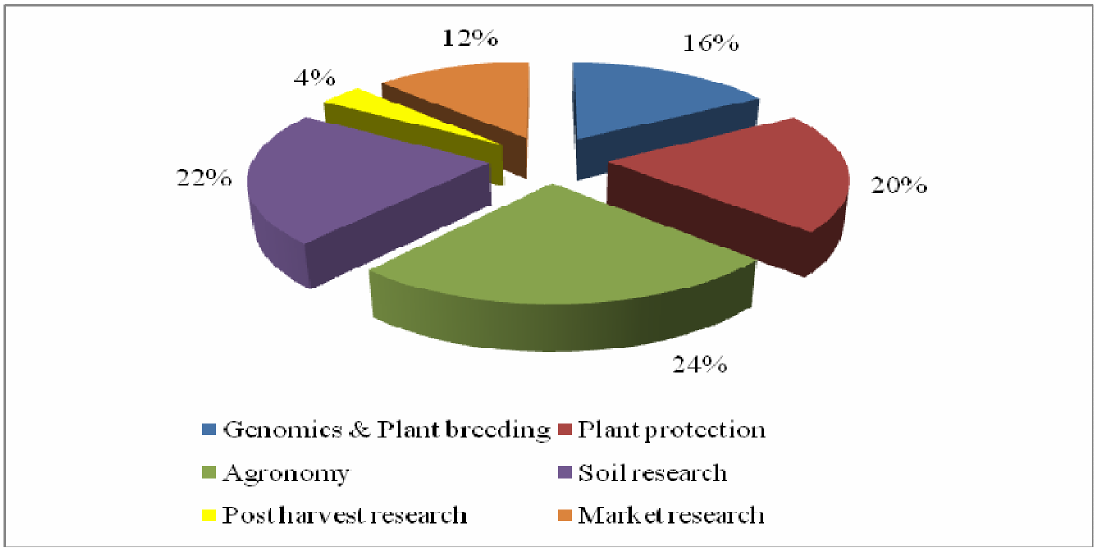

Figure 3.7: Distribution of researchers by research discipline

Source: own compilation

Despite the fact that plant breeding was reported to be the major activity in crop research, it accounts for only 16% of the research staff. This is aligned with earlier findings that human capital for plant breeding is low in relation to the large number of crops in which breeding has to be done for different farming systems in each target environment (PASS, 2007:11). Therefore, it is necessary that as the number of crop scientists increase in Zambia, these must be trained in specific fields such as plant breeding in order to meet the demands of the country. Similarly, the findings also show a small number of staff in post-harvest research as only four percent of the research staff conducted post-harvest research.

3.8 RESEARCH EXPENDITURE

In this study, total research expenditure was defined to constitute staff remuneration, operating expenses and capital expenditure. It can be observed from Table 3.6 below that total expenditure on crop research in Zambia increased consistently from ZMK 16 billion in 2004 to ZMK29 billion in 2008, indicating a 77% increase over the five-year period. It was also observed that the shares of expenditure on staff remunerations and operating expenses constituted the bulk of total research expenditure in all the institutions, accounting for more than 70% of total expenditure.

Table 3.6: Research expenditure 2004-2008 (ZMK' million)

Research Institution	Research expenditure 2004-2008 (ZMK 'million)				
	2004	2005	2006	2007	2008
ZARI	4624	4670	6067	11090	11695
Private[9]	4410	5570	6070	9330	10050
Trusts	7503	7225	6557	7560	7370
UNZA[10]	136	146	126	285	252
Total	**16673**	**17611**	**18820**	**28266**	**29366**

1US$=ZMK4500[11]

Source: own compilation (survey data)

It can further be noted from figure 3.8 below that, generally, the total amount of money spent on crop research increased in all the research institutions between 2004 and 2008. The increase in the overall total crop research expenditure is largely attributed to the government whose research expenditure increased by 80% in 2007 as a result of the advent of the country's Fifth National Development Plan (FNDP), which advocates for increased financial resources to the agriculture sector and particularly to agriculture research and technology development (MACO, 2008). Also, the increase in government expenditure was due to the fact that government recruited more research personnel over the same period. Furthermore, it was also observed that expenditure by the private sector increased consistently; reaching a height of ZMK10 billion in 2008. In 2008, the private sector accounted for 34% of total expenditure in agriculture crop research in Zambia. This agrees with earlier findings that the private sector in Zambia plays a significant role in agriculture research (Beintema *et al.*, 2004). Similarly, expenditure by research trusts was steadily maintained over the five year period while expenditure at the higher learning institution fluctuated at much lower levels with improved expenditure in 2007 and 2008.

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[9] Only two out of the three private institutions that were contacted provided this study with research cost data, implying that private cost expenditure must be larger than the values provided in the table.
[10] The value for 2004 is a proxy figure based on the 2005 and 2006 average.
[11] For annual exchange rates, see Table A3.6 in Appendix 3.

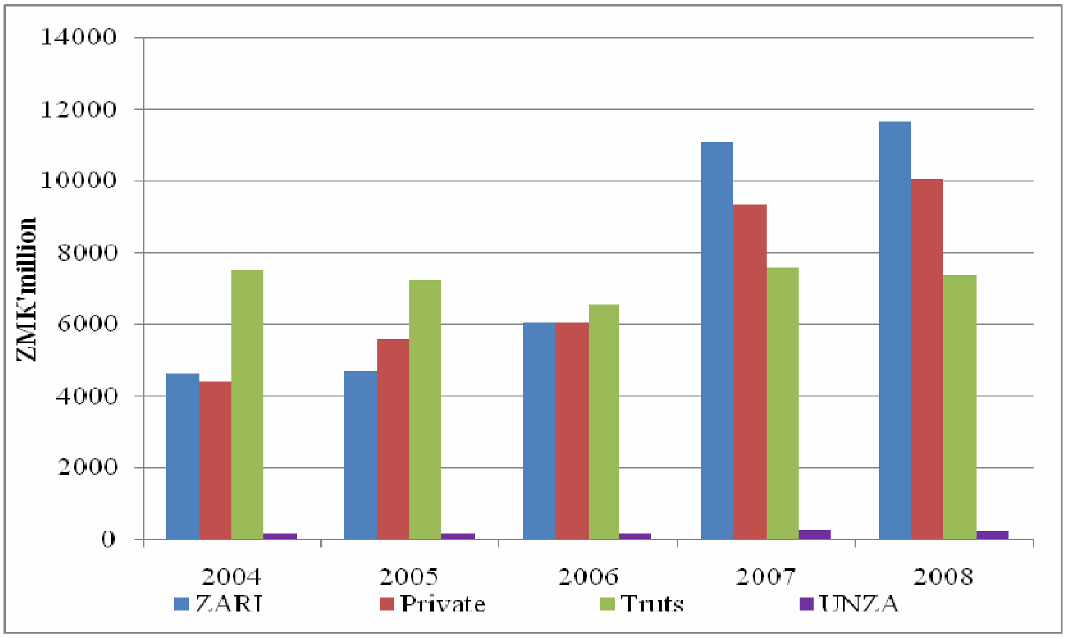

Figure 3.8: Research expenditure by type of institution (2004-2008)

Source: own compilation

In terms of expenditure on each crop, maize was by far the most funded research crop and it had a steady upward trend between 2004 and 2008 as illustrated in Figure 3.9 below.

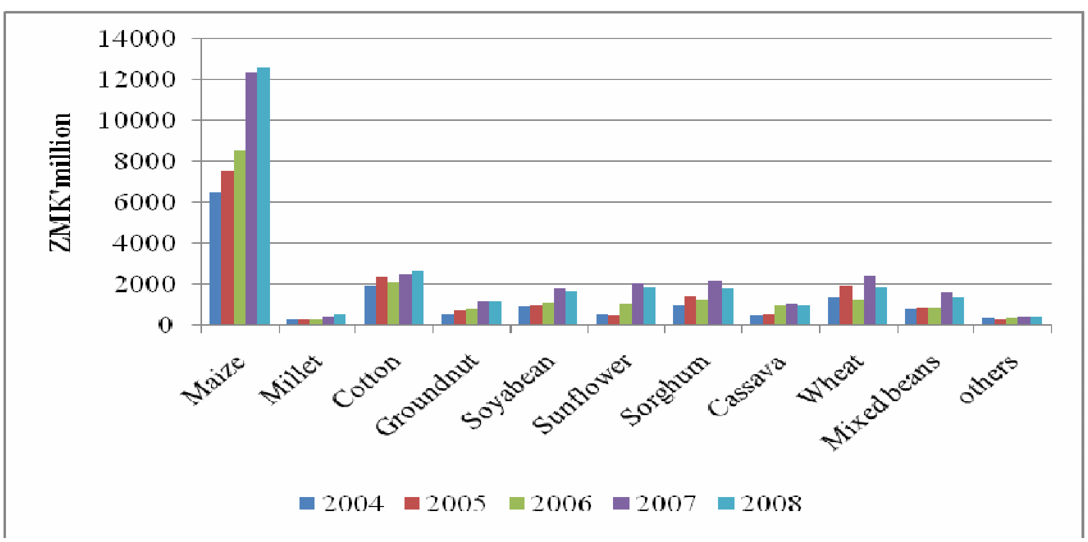

Figure 3.9: Crop research expenditure trend (2004-2008) (US$)

Source: own compilation

The financial allocation to maize research amounted to a total of more than ZMK12 billion in 2008 alone, which is ten times more than what other crops received in that year. Funding for cotton, soya bean, sorghum and wheat was also observed to have an upward trend between 2004 and 2008. On the other hand, expenditure on millet, mixed beans and cassava fluctuated at lower levels during the same period.

3.9 SOURCE OF RESEARCH FUNDS

The government funds 72% of the research budget in government research institutions, as illustrated in Figure 3.10 below. Based on responses regarding sources of research funds, it emerges that international donors and the private sector also fund government research institutions, and account for 20% and 8%, respectively. The government research institutions did not allocate any funds generated directly from the sale of research products and services since most of the research performed is public as opposed to being commercial. On the contrary, all the private research institutions reportedly funded 100% of their own research, implying that they re-invested profits earned from their sales of research products.

The University of Zambia receives 60% of its research funds from international donors, mainly through regional crop research donor projects. The private sector and government also fund research in the university, accounting for 26% and 11%, respectively, while their own funds accounts for only 8% of the total research funds. As the bulk of financial resources for research at the University of Zambia were from donors, donor fatigue explains why the University of Zambia had the lowest observable financial resource expenditure when compared to other institutions (section 3.8 above). The Cotton Development Trust (CDT) received 36% of the total research funds from the government, 31% from the private sector and 11% each from international donors and their own funds.

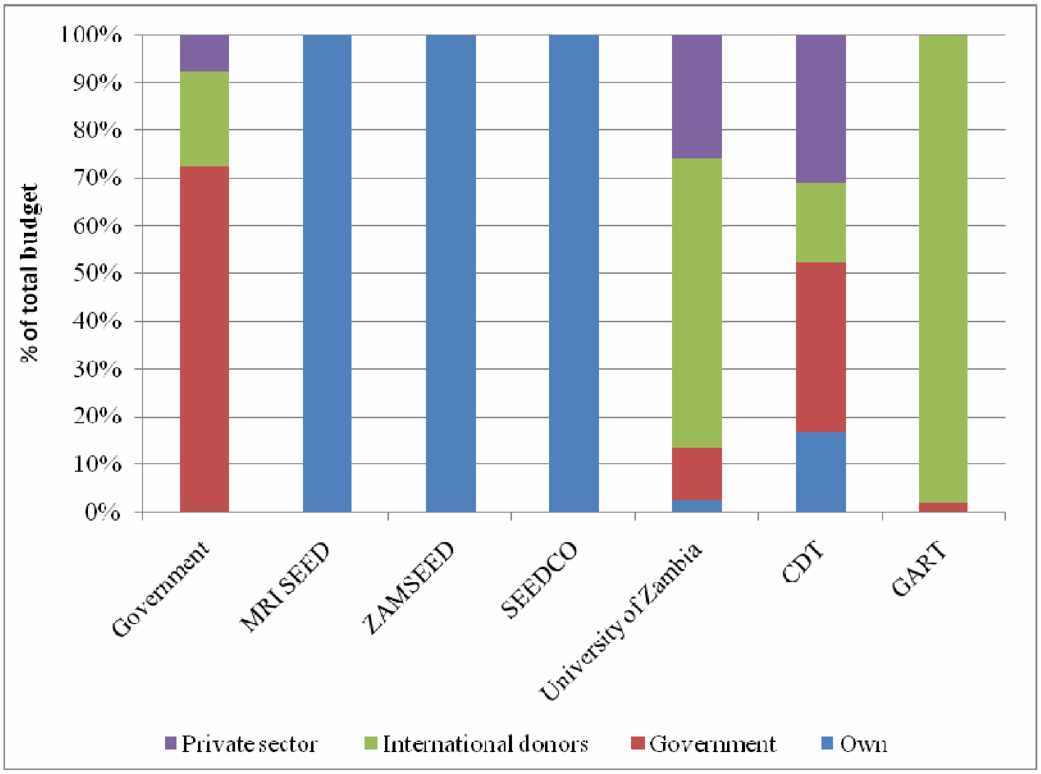

Figure 3.10: Source of research funds

Source: own compilation

It is worth noting that international donors and the private sector fund more research in higher learning institutions and research trusts than in government institutions. This is aligned with earlier findings that donor support towards the SCRB has declined since the 1990s. This is partly as a result of donor's dissatisfaction regarding the financial management of funds by the Ministry of Agriculture, and its subsequent disbursement of fewer resources. Consequently, donors diverted resources to specific projects in non-public research institutions because of the perception that accountability is easier and that these institutions are more efficient (Elliot & Perrault, 2006). The preference for higher learning institutions may also be that these institutions have relatively more qualified personnel than other institutions. In 2000, all of the research personnel at the higher learning institution held qualifications beyond a Bachelor of Science degree (Beintema *et al*., 2004). This is in contrast to government institutions, at which the majority of research personnel have a Bachelor of Science degree as their highest level of qualification.

3.10 SUMMARY

The agricultural sector in Zambia has experienced fluctuations in investment that are explained by changes in economic and policy reforms. While budget allocations to the agriculture sector declined during the structural adjustment programmes reform period (early 1990s), the Government of Zambia is advancing not only in terms of increasing total budget allocations but also in redefining key areas of investments and in redirecting financial resource allocation to important areas like agriculture research and development. However, there is still concern that a considerable amount of resources are spent on private input subsidies even when such programmes have proved to be less effective in improving crop productivity.

Seven institutions classified as government, private sector, trusts and higher learning institutions conduct crop research in Zambia. As is the case in many countries, there have been no new established crop research institutions in Zambia as the identified institutions are still the same institutions that existed about a decade ago. This indicates stability in research management and more interestingly, the number of researchers, in terms of FTEs increased between 2004 and 2008 and so did expenditure on crop research. The major sources of these funds were attributed to the government funding public institutions, and international donors funding research trusts and higher learning institutions, while the private sector entirely funded its own research. These institutions vary in terms of crop focus, ranging from one research crop to as many as seven crops. Similarly, while some institutions are specialised in a few research programme areas such as plant breeding, plant protection and agronomy, others perform research in several disciplines. Maize is still the major research crop for Zambia and plant breeding is the major research activity.

Having established that a vibrant crop research system exists in Zambia, chapter five seeks to further ascertain whether financial resources for crop research are efficiently allocated, and to conduct priority setting for an effective crop research system. Prior to this, a literature review of past studies on agriculture research in Africa is presented in chapter four.

CHAPTER 4

PRIORITY SETTING IN AGRICULTURAL RESEARCH: A LITERATURE REVIEW

4.1 INTRODUCTION

The purpose of this chapter is to review some of the existing methodologies that have been applied when conducting priority setting studies in agriculture research. In addition, the chapter also highlights some of the findings from past studies on African agriculture research in order to gain a foothold of priority setting in agriculture research and as such, develop a framework for conducting this study. The chapter begins by highlighting a few definitions of the concepts under discussion, after which various methods for priority setting are examined. This is followed by an in-depth evaluation of past studies pertaining to priority setting of agriculture research and finally, their relevance for this study is outlined.

4.2 DEFINITIONS

Priority setting in agricultural research, as defined by Mills (1998), is the process of making choices amongst a set of potential research activities and may involve orienting research to mass welfare objectives (Eicher, 1990). It extends beyond generating a hierarchical list of research items to be implemented and it influences and encompasses planning, budgeting and resource allocation in the face of competing policy objectives (e.g. efficiency vs. equity, rural producer welfare vs. urban consumer welfare, export growth vs. food security); multiple levels of implementation (multi-national, national, institutional, programmes and projects), and scarce research resources (Mills, 1998; Smith, 2001). Evaluation studies that are conducted before a project or programme is initiated (*ex ante*) are useful tools in addressing resource allocation and priority setting issues. Also, *ex post* evaluations (i.e. performed after) once research benefits have been accrued are not only useful for determining the impact of the intervention but also for informing feedback loops that are essential for the planning, selection and management of programmes to be implemented in the future (Maredia, Byerlee & Anderson, 2002).

4.3 PRIORITY SETTING METHODS

Priority setting methods range from qualitative to quantitative techniques and from informal to formal. Whereas qualitative procedures address questions associated with why and how, quantitative methods answer questions pertaining to how many (Purdon, Lessof, Woodfield, & Bryson, 2001). Formal procedures that combine both qualitative and quantitative techniques provide an opportunity to improve quality, accountability and transparency of complex decisions through a more consolidated research focus and broadened participation in the formulation of research agendas (CGIAR, 2005; Smith, 2001). Some of the formal procedures that are commonly used for priority setting in agricultural research are discussed below.

4.3.1 Scoring

Scoring methods involve the listing of several identified objectives on one hand and research programmes on the other, after which a criterion associated with performance measures that relate to efficiency is used to assess the alternative research programmes. A ten-point scale could be created against which each research programme is scored. The higher the score, the greater the contribution of the research programme to the objectives, and it is thus given priority. Scoring methods have the advantage of reconciling several objectives using little information than is needed with mathematical programming techniques. However, the scoring method tends to be very subjective (Alston *et al.*, 1998).

4.3.2 Precedence

The precedence method takes into account the previous year's funding, adjusted for inflation, as the basis for allocating funds for each research programme in subsequent years. The advantage of this approach is that it provides continuity in the funding of research programmes. However, it has the disadvantage of continuing to fund research that has reached the limit of its productivity as a result of dependence on past funding practices. The precedence method also does not provide a basis for making future benefit comparisons since decisions are based on past funding as opposed to potential performance. As a result, new areas of research are not easily introduced and it may lead to a situation in which research resources are not optimally allocated (Alston *et al.*, 1998).

4.3.3 Congruence analysis

The allocation of research funds across research programmes is in proportion to the commodity's contribution to the value of agriculture. The overall agriculture research budget is divided in the same proportion as the contribution of each commodity sub-sector to agricultural GDP (Smith, 2001:422). The commodity with the highest value of output receives more research funds. This method is one of the simplest methods in allocating resources and it is useful in comparing resource allocations across each individual unit of research. The problem with this approach is that it ignores some important factors that come into play when ranking research programmes such as adoption rates, probability of success and productivity gains induced by research (Alston *et al.*, 1998).

4.3.4 Stakeholder perception and peer review

Peer review involves individuals successively and anonymously comparing one proposal to alternative proposals, and it requires them to state their preferences. The proposal that has elicited the most preferences is more favourable. Peer review is related to stakeholder perception, where research programmes receive funds based on information sought from expert opinions. These techniques remove bias that could occur from senior influential individuals, but have the disadvantage of being subjective (Smith, 2001:423; Alston *et al*., 1998).

4.3.5 Econometric approach

This approach is concerned with the explicit specification of a function that relates inputs to outputs. The primal, dual or supply equation is used to estimate output, costs or profit measures that can be connected to past investment in research. While the primal approach may involve estimating a production function in which the dependant variable output is a function of conventional inputs (land, labour, seed, fertiliser), non-conventional inputs (infrastructure, education and other institutions) and the stock of technical knowledge (such as investment in research and extension), all included as an independent variable, the dual approaches incorporate the research expenditure variable in either the cost or profit function. The purpose is to eventually estimate the change in productivity due to research by measuring the parameters that represent the shift in supply induced by the research (Alston *et al.*, 1998). Rather than providing a basis for resource allocation, this method is most useful in qualifying which research programmes to embark upon or eliminate.

However, estimating the supply shift induced by research using the econometric approach has three major limitations. Firstly, there is a long lag between investment in research and its effect on production; secondly, there is the problem of simultaneity, which arises when unspecified independent variables (such as weather) that go into the error term are actually related to some of the explanatory variables in the model. Lastly, there is a high possibility of multi co-linearity, which makes it difficult to isolate the effects of any particular variable on output without the influence of other variables coming into play. Solutions to these problems are being sought but most of the introduced techniques to counter the problems come with their own limitations. The prohibiting constraint to the use of the econometric approach in most developing countries is the lack of data for most of the model variables. The available data is often inconsistent and incomplete, not sufficiently long enough for the required time series, and not disaggregated enough for the required level of econometric analysis (Maredia *et al.*, 2002).

4.3.6 Economic surplus approach

The economic surplus approach constitutes the most popular method used by economists to calculate and compare the benefits and costs of agriculture research. This kind of benefit cost analysis could inform decision-makers on whether to implement new research programmes or continue with existing programmes, and to make choices from alternatives as well as formulate a basis for resource allocation and priority setting (Purdon *et al.*, 2001). The change in consumer and producer surplus - a result of the outward shift in the supply function owing to technological change - is estimated. The research costs are incorporated in order to compute the internal rate of return (IRR) or the net present value (NPV) (Maredia *et al*., 2002).

Even though the economic surplus approach poses a popular tool, its use in agriculture is often limited by the fact that agriculture by nature operates in an environment where unplanned natural events could influence outcomes. As such, it is difficult to conduct evidence-based impact studies in which only research is attributable to the observed benefits. Also, wider social effects are often left out as they are difficult to quantify (Anandajajayasekeram *et al*., 2007; Purdon *et al.*, 2001).

Following the discussion above on some of the techniques commonly used to conduct priority setting, the discussion henceforth turns its attention to reviewing priority setting studies that have been conducted in Zambia and elsewhere in Africa.

4.4 STUDIES OF IMPACT ASSESSMENT AND PRIORITY SETTING ON AFRICAN AGRICULTURE

Although several studies involving impact assessment and priority setting of agricultural research have been completed globally, the number of studies carried out in Africa are comparatively few (Ehui & Tsigas, 2006). The following are some of the studies that have been done in Zambia and in other African countries.

4.4.1 Studies on Zambia

Studies on priority setting using the scoring method were conducted in 1993, 1997 and in 2001 by the Soil and Crop Research Board of the Ministry of Agriculture Food and Fisheries. The relative importance of commodities for the study in 1993 was based on policy objectives at regional level, which used no criteria to emphasise the productivity factor for those commodities for each specific country. Therefore, the major purpose of research which is to increase productivity was given less importance than it deserved (MAFF, 2009). Also, the research programme activities (commodity and non-commodity) were scored using criteria that assessed the knowledge base, duration of research, cost of research and probability of adoption. These criteria were criticised on the basis of not being weighted and for overlooking criteria such as the severity of the research problem, equity and the distribution of research benefits (MAFF, 2009).

In 1997, priorities for research were examined again, but the scoring of commodity priorities by region was based on congruence analysis (relative importance based on the economic value of production). This re-examination was done in part because the 1993 priority exercise included commodities for which research activities were marginal in terms of addressing production constraints. However, the obtained results were again inadequate to select a realistic number of priority activities because the criteria resulted in ordinal scores on a high-medium-low scale (MAFF, 2009).

As a result of the changes in the economic environment, the government decided that three basic economic goals must be considered when determining investments in different sectors: efficiency in obtaining results, equitable distribution of benefits, and the security of the population. With this in mind, research priorities were again re-evaluated in 2001 to include criteria that related to efficiency, equity and feasibility. Efficiency was given the highest weight, namely 50%, while public benefit and feasibility each had 25%. After scoring within commodity or crop categories, maize ranked first among food staples, groundnuts among food legumes, cotton in cash crops, sugar cane in plantation crops, cabbage in vegetables and citrus in fruits (MAFF, 2009).

4.4.2 Studies in Southern Africa

Muchopa *et al*. (2004:8) employed the Domestic Resource Cost (DRC) ratio analysis and multivariate models in a study of four SADC countries (Malawi, Mozambique, Tanzania and Zambia). This was an attempt to provide a logical basis for formulating agricultural policy strategies that would pave the way to agricultural investment. The authors identified regional trade and crop diversification as important areas for policy intervention. Maize, cassava and rice, in order of priority, were the staple commodities that were identified when all four countries were aggregated. The major industrial priority commodity found to be common to all countries was cotton.

However, unlike the other countries that used DRC analysis, Zambia mainly depended on qualitative estimates by stakeholders to come up with priority commodities. As such, a more comprehensive quantitative assessment should be carried out to confirm the study findings (Muchopa *et al*., 2004:12).

Mutangadura (1997) used the economic surplus approach, employing the Net Present Value (NPV) to estimate research programme economic surplus gains for the projected fifteen years in Zimbabwe, and mathematical programming to determine the optimal allocation of research resources among the various commodities under alternative weights on objectives. The expected NPVs showed that agricultural research priorities differ between smallholder farmers and large-scale commercial farmers, with maize, cotton, groundnuts, sunflower, goats, pulses and millet being of high priority for smallholder farmers, while maize, beef, cotton, coffee, wheat, dairy, stone fruit, soya beans and roses were top priority for large-scale commercial farmers. Research discipline priorities for smallholder farmers included agronomy, plant breeding and chemistry and soils, while for large-scale commercial farmers the priorities are plant breeding, agronomy, and plant protection. The optimal allocation of research resources, given the efficiency and equity objectives, revealed that the trade-off costs were relatively small with respect to putting an extra weight on the equity objective under total budget constraint. Therefore, resources could be allocated to smallholder farming research without great loss in efficiency.

4.4.3 Studies in West Africa

Manyong, Ikpi, Olayemi, Yusuf, Omonona, Okoruwa, and Idachaba (2005) performed an *ex ante* evaluation to measure the economic returns for commodity oriented research using the partial equilibrium Dynamic Research Evaluation for Management (DREAM) model to establish priority areas for government, donors and private sector intervention in Nigeria. The study used both primary and secondary data. The variables collected from secondary sources include commodity output, agriculture commodity consumption, agriculture commodity prices, elasticity of supply and demand, inflation rates, and exchange rates. Primary data was collected with a questionnaire to draw respondents' perceptions on trends in agriculture investments and amounts spent on each research option. The study was completed for 26 commodities and cassava was ranked as the first priority commodity as it had the highest gross returns (US$570 million) per year for a 17-year period (1999-2015). Other commodities, in order of importance, included yam, maize, millet, groundnut, rice, sorghum, poultry, leafy vegetables, and cowpea. However, due to the lack of data, the study did not include the cost to investment in the model; it thus concentrated of the benefits side of the cost benefit analysis.

Alene, Manyong, Tollens and Abele (2006) pointed out that, while the many priority setting studies emphasise the efficiency objective, most stakeholders would appreciate the inclusion of poverty alleviation as the key objective of investment in agriculture research. The authors addressed the question of whether research priorities should be set according to efficiency or equity criteria. The DREAM model was used to estimate economic surplus and its effect on poverty reduction as a result of investment in agriculture research in Nigeria.

The study set commodity priorities on the basis of efficiency and equity and examined the magnitude of trade-offs between efficiency and equity. The authors found that yam, cassava and maize, listed in order of importance, should be prioritised as such, based on the efficiency criteria. However, maize was found to take first place under the equity criteria, reducing poverty by five percent (Alene *et al*., 2006). This is because maize is widely grown by poor households in Nigeria. The study did, however, assert that the trade-offs between efficiency and equity were insignificant since the poor households depended on the production of food staples for both household income and consumption.

4.4.4 Studies in East and Central Africa

Omamo *et al*. (2007) conducted a study on East and Central Africa, covering eleven countries[12], to identify strategic priorities for agricultural development in the region. The analytical approach used combines three methodologies, namely: the Geographic Information System (GIS) to match spatial agricultural similarities and differences in the region; secondly, the multi-market model to analyse the linkages between agriculture and non-agriculture sub-sectors, and lastly, the DREAM model to quantify the economic returns to agriculture research. The variables used for the model in the study were agriculture commodity supply, commodity demand, agriculture commodity prices, elasticity of demand and supply and demand growth variables (income elasticity and GPD per capita growth rate).

From a regional point of view, milk is the most important commodity for agriculture growth as a result of increased investments in the sector. Other highly ranked commodities include oilseeds, cassava, fruits and vegetables (Omamo *et al*., 2007).

4.5 RELEVANCE OF REVIEWED STUDIES

The studies reviewed above have not only varied in methodologies used but also in the breadth and scope of analysis employed. However, the discussion above revealed that the methodologies for priority setting are not without limitations, and in order to address a wider scope of concerns for African agricultural research, where data is limiting, it is necessary to employ mixed method approaches that integrate both qualitative and quantitative techniques.

Even though numerous quantitative studies on agricultural research priority setting were observed to have been conducted in several countries in the African region, these were not specifically on Zambia, which often relied on stakeholder perceptions. This therefore

[12] Uganda, Tanzania, Sudan, Rwanda, Madagascar, Kenya, Ethiopia, Eritrea, Democratic Republic of Congo and Burundi.

necessitates the need to adopt and apply more comprehensive methodologies such as the economic surplus approach for the Zambian situation, as is the case in other African countries. Despite the limitations of the economic surplus approach presented in the literature above, this study employed the economic surplus method for three reasons. Firstly, this approach was most suitable for addressing the core problem of this study, which is resource allocation and priority setting, as it translates effects of agriculture knowledge, technology, production and marketing into measurable benefits that can be compared to research costs. Secondly, even though several studies on priority setting in Zambia have been completed, most of them have used the scoring method and none have attempted to apply the economic surplus approach. Lastly, the available country data allows for the application of the economic surplus approach in Zambia.

In addition, the studies reviewed above also revealed the need to conduct research studies for each African country, which quantifies the effect of trade-off between the efficiency and equity objectives when dealing with resource allocation and priority setting for agricultural commodity research. This would be of paramount importance for many African countries where the bulk of the population lives in poverty and where scarce financial resources ought to be used efficiently. Such a study would aid policy-makers, often caught between the two competing objectives of equity and efficiency, to formulate evidence-based policy decisions.

4.6 SUMMARY

Priority setting can be conducted using qualitative and quantitative methods. Despite the fact that several studies in Africa have combined and applied the economic surplus approach with other methodologies to evaluate agricultural research and to perform priority setting, Zambia has often relied on qualitative stakeholder perceptions to establish priority commodities for research. It is for this reason that this study will employ the economic surplus approach to establish priority crops for research in Zambia. The studies reviewed above were useful in providing a methodological framework on which this Zambian study was based.

CHAPTER 5

IMPACT AND PRIORITY SETTING OF CROP RESEARCH IN ZAMBIA: METHODOLOGY, FINDINGS AND DISCUSSION

5.1 INTRODUCTION

The methodology employed for this study is the economic surplus approach, which was implemented using a computer-based programme known as the Dynamic Research Evaluation for Management (DREAM) model. This chapter therefore gives a detailed account of the application of the DREAM model in assessing economic returns and priority setting of agriculture crop research. The chapter begins by briefly describing the conceptual basis of the model, the data variables and data sources as well as the empirical analysis applied. Finally, the findings are presented and discussed in relation to their influence in policy decisions.

5.2 CONCEPTUAL BASIS OF DREAM MODEL

The Dynamic Research Evaluation for Management (DREAM) model is conceptually based on the theory of economic surplus. The use of the concept of economic surplus to analyse the welfare effects of agriculture was earlier demonstrated in a research study on hybrid corn by Griliches (1958). Later, Norton, Ganoza and Pomareda (1987) applied the concept to an *ex ante* situation, and, more recently, the concept was applied to agriculture research in a priority setting procedure (Alston *et al*., 1998; Wood *et al*., 2001). According to Harberger (1971), consumer benefits can be measured as the area under the Marshallian demand curve while producer benefits can be estimated by the area above the supply curve. The net welfare effects are the benefits less the costs.

The strength of the DREAM approach lies in its ability to incorporate the conceptual issues underlying the implementation of a research priority setting exercise. These include the way research in agriculture affects agriculture knowledge, production and markets, and the way these effects are translated into measures of costs and benefits of research by means of a user-friendly computer-based programme that is menu-driven; while its complex computations are embedded in the programme to allow the user to focus on data-gathering and policy interpretation. It is also based on the economic surplus approach which underlies the economic rationale for the provision of public goods, including agricultural research. However, the concept is not without limitations and, according to critics, the nature and measure of the magnitude of the research-induced supply shift is dependent on the assumptions made in the model. Nonetheless, the poor quality of data (especially for developing countries) rather than the economic logic of the model is the more binding constraint (Alston *et al*., 1998).

5.3 DREAM MODEL

The Dynamic Research Evaluation for Management (DREAM) model was developed by the International Food Policy Research Institute (IFPRI) and the presentation of the model outlined below draws extensively from work done by Alston *et al*. (1998) and Wood *et al*. (2001).

The basic model for evaluating research benefits is depicted in Figure 5.1. S_0 is the supply function prior to any technical change induced by research, while D_0 is the demand function. P_0 and Q_0 represent the initial price and quantity, respectively. It is assumed that investing in crop research generates cost-saving and yield-increasing technologies. This effect is modelled as a parallel shift in the supply curve from S_0 to S_1, to the right, as a result of increased production, as illustrated in Figure 5.1. As a result of this research-induced supply shift, it follows that the market prices of commodities will fall from P_0 to P_1 (Wood *et al*., 2001). Therefore, consumers can consume more (from Q_0 to Q_1) of the commodity at this lower price (P_1) and are better off. Producers are also better off because they produce more. Equilibrium is defined through market clearing conditions at the new levels of production (S_1), consumption (Q_1) and price (P_1). The consumer surplus from the supply shift in Figure 5.1 is represented by the area P_0abP_1 while the producer surplus is represented by the area P_1bcI_0.

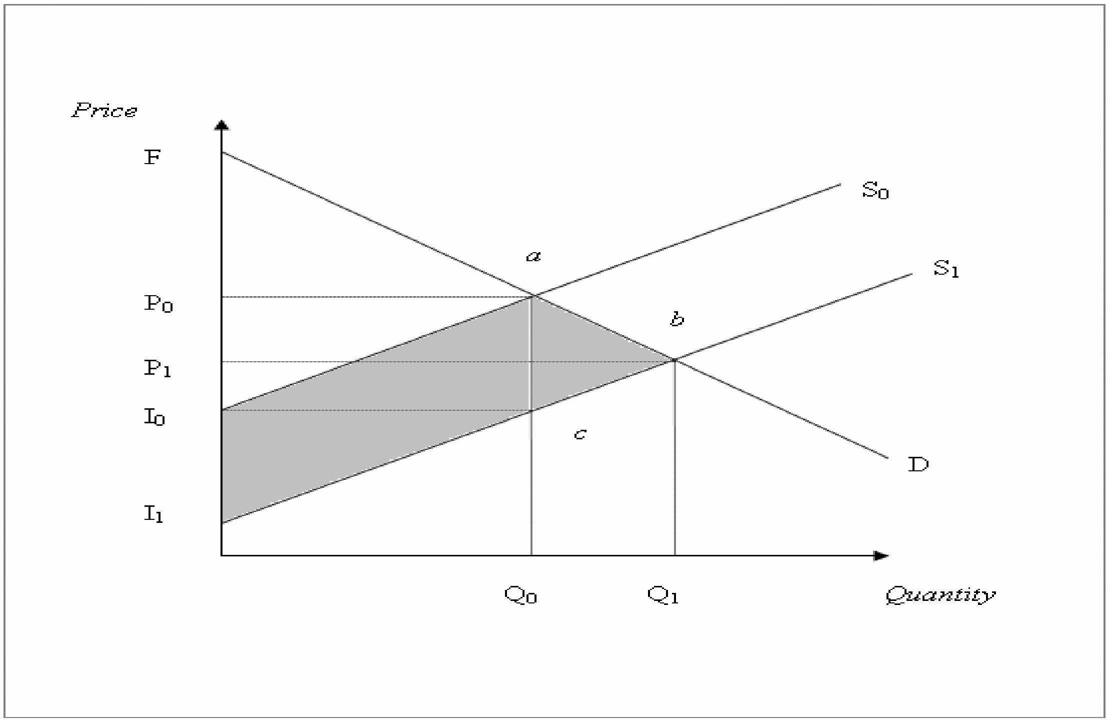

Figure 5.1: Producer and consumer surplus measures

Source: Alston *et al*., 1998

The initial linear supply and demand equations are given as:

Supply:

$$Q_{j,t} = \alpha_{jt} + e_j pp_{jt} \tag{5.1}$$

Demand:

$$C_{j,t} = \beta_{jt} + \eta_j pc_{jt} \tag{5.2}$$

Where:

$Q_{j,t}$	Quantity supplied of commodity j in year t
e_i	Elasticity of supply of commodity j
$pp_{j,t}$	Producer price of commodity j in year t
$\alpha_{j,t}$	Intercept for supply curve
$C_{j,t}$	Quantity consumed of commodity j in year t
η_j	Elasticity of demand of commodity j

$pc_{j,t}$ Consumer price of commodity j in year t

$\beta_{j,t}$ Intercept for demand curve

The change in producer and consumer surplus for a research-induced supply shift of a particular commodity in a multiple horizontal market in year *t*, can be estimated by the following formulae (Alston *et al*., 1998:389):

$$\Delta PS_{jt} = (K_{jt} + pp_{jt}^{R} - pp_{jt})(Q_{jt} + 0.5[Q_{jt}^{R} - Q_{j,t}]) \quad (5.3)$$

$$\Delta CS_{jt} = (pc_{jt} - pc_{jt}^{R})(C_{jt} + 0.5[C_{jt}^{R} - C_{jt}]) \quad (5.4)$$

Where:

PP_t	Producer price prior to research-induced supply shift
PP^{R}_{jt}	Producer price after research-induced supply shift
Q_{jt}	Pre-research producer quantity in year *t*
Q_{jt}^{R}	Post-research producer quantity in year *t*
pc_{jt}	Commodity price prior to research-induced supply shift
pc_{jt}^{R}	Commodity price after research-induced supply shift
C_{jt}	Pre-research consumer quantity in year *t*
C_{jt}^{R}	Post-research consumer quantity in year *t*
K_{jt}	Supply curve shift downwards in period *t*, due to research

The magnitude of the shift in the supply curve induced by research (K-factor in equation (5.3) above) is very important in determining the total research benefits. This crucial variable K is a function of the expected change in yield, assuming research is successful; the proportionate change in variable costs to achieve the expected yield change; the probability of research success (that research will achieve the expected yield change), the adoption rate and the depreciation of the technology. The equation for determining K is as follows (Alston *et al.*, 1998: 380):

$$K_{jt} = \left[\frac{E(Y)}{e_j} \quad \frac{E(C)}{E(Y)} \right] pA_t (1 \quad \delta_t) \qquad (5.5)$$

Where:

E(Y_j)	Expected change in yield after new technology adoption
e_j	Commodity supply elasticity
E(C_j)	proportionate change in variable costs per hectare to achieve the expected yield change
p_j	Probability of research success
A_t	Adoption rate
δ_t	Depreciation factor

Equation (5.1) and (5.2) represent the scenario without research. To model the 'with research' case, a coefficient K_{jt} is computed to measure the supply shift attributed to research. The research-induced supply shift is added to the intercept of the initial supply function to represent the case 'with research'. The supply equation is then denoted with a superscript R, as shown below, to distinguish it from the preceding 'without research' equations (5.1) and (5.2) through the supply intercept, quantities and prices denoted with a superscript R.

$$Q^R_{jt} = \alpha^R_{jt} + e_{jt}\, pp^R_{jt} \qquad (5.6)$$

$$C^R_{jt} = \beta_{jt} + \eta_j\, pc^R_{jt} \qquad (5.7)$$

The initial supply and demand equations constituted of the country's production and consumption quantities (Q_0) for the year 2005, for which individual demand and supply curves were estimated for each commodity. The expected future growth of the underlying supply curves were endogenously projected by the model after adjusting for any exogenous growth in supply and taking into account the adoption levels as well as adoption lags such that the shift in supply was attributed to research-induced productivity. This resulted in a new equilibrium price (P_1) and quantity (Q_1) at which the producer and consumer surplus measures were computed and discounted to the base year, and the cost of research was subtracted to determine the net present value benefits (equation (5.8) below). The period of analysis for this *ex ante* study was between 2005 and 2020, of which the year 2005 was used as the base year. The analysis was for a multiple horizontal market economy with no spill-over effects from research to neighbouring countries in the region. This assumption makes sense as Zambia's research system is small and any spill-over effects that may exist are negligible. However, the study acknowledged that Zambia may have benefited from research spill-over effects from other countries via the role of input companies, non-profit organisations (NGOs) and training of researchers.

$$NPV = \sum_{t=0}^{\infty} \frac{B_t - C_t}{(1+r)^t} \qquad (5.8)$$

Where NPV is the net present value, B_t is the annual research benefit, C_t is the research cost and r is the discount rate.

5.4 DESCRIPTION OF MODEL VARIABLES AND DATA

The variables included in the model are categorised into two groups, namely market and technology related variables. While market related data was obtained from secondary sources, technology related data was elicited from researchers. The following section describes the type of data collected, the theoretical basis and their empirical usage in the model.

5.4.1 Market related data

Quantity supplied and consumed - Quantity supplied consists of a 3-year average (2004-2006) of total annual production disaggregated by province and farmer type (small and large farmers) for maize, groundnuts, millet, sorghum, soya bean, sunflower and cotton. The quantity consumed consists of what is locally produced plus imports, less exports, and is adjusted for changes in available stock. However, for the purposes of this study, it was assumed that production was equal to consumption; this was also necessary for the market clearing condition of the model.

Price - The prevailing market prices for the year 2005 were obtained from the marketing department of the Ministry of Agriculture and from the Central Statistics Office. All price data is in Zambian kwacha.

Elasticity of supply and demand - It is well known from economic theory that own price elasticity of supply is positive and that of the demand function is negative. While estimates of price elasticity of demand from several studies have shown the demand elasticity to vary between -0.3 for basic commodities to -2 for non-basic commodities (Mills, 1996; Jayne *et al*., 1993), the elasticity of supply ranges from 0 to 1.2 for agricultural commodities (Mwanaumo, 1994)[13]. Chisi (2000), in a Zambian study on sorghum, used 0.4 as the elasticity of supply for sorghum. Since Zambia has only a few studies for which the elasticity of supply and demand have been estimated, this study used the average elasticity of demand and supply for Sub-Saharan Africa (SSA) for each crop (except maize and sorghum), as illustrated in Table 5.1 below.

[13] Katepa (1984), Nakaponda (1992) and Harber (1992) (in Mwanaumo *et al.*, 1997), estimated the supply elasticity of maize in Zambia to be 0.21, 0.51 and 0.8, respectively.

Table 5.1: Elasticity of supply and demand for agricultural crops in SSA

Crop	Region/ Country	Elasticity of Supply	Elasticity of Demand	Source
Groundnut	SSA	0.30	-0.41	Davis *et al.* (1987)
Maize*	Zambia	0.45	-0.57	Mwanaumo *et al.*(1997:518); Dorosh *et al*. (2007:12).
Sorghum	Zambia	0.40	-0.25	Chisi (2000:169)
Millet	SSA	0.10	-0.3	Davis *et al.* (1987)
Cotton	SSA	0.67	-0.75	Davis *et al.* (1987)
Soya bean (pulse)	SSA	0.40	-0.55	Davis *et al.* (1987)
Sunflower (oilseed)	SSA	0.40	-0.55	Davis *et al.* (1987)

*Average from several sources.

5.4.2 Technology related variables

Technology related variables are required to estimate the magnitude, timing and nature of the research-induced supply shift. Measuring the research-induced supply shift is the most important parameter in measuring benefits and for an *ex ante* assessment of programme alternatives; it involved eliciting values from scientists and economists on the potential impact of successful research on yields and production costs. The results from previous experimental trials plus observations by researchers over time of when farmers have used the technology, were used to assess changes in yield and cost. The yield and cost effects were then combined with estimated probabilities of research success and information on the likely speed and extent of adoption to determine the research-induced supply shift (Alston *et al*., 1998:304).

Exogenous growth in demand and supply - It is well known that demand and supply could exogenously grow over the period under consideration regardless of whether research is undertaken or not. Exogenous demand shift is a function of projections in population and income growth rates multiplied by income elasticity, while the exogenous growth in supply was attributed to the expansion in area under cultivation and yield growth not attributable to research (Alston *et al.*, 1998).

Adoption - The extent and rate of adoption and adoption lag of a new technology is mainly influenced by agro-ecological factors (temperature, rainfall and soil fertility), social economic factors (infrastructure, farmer education, quality and quantity of extension) and cultural factors (religion) (Mutangadura, 1997). The adoption rate of new production technology in this study is disaggregated by farmer type (small and large-scale) and its profile was assumed to be trapezoidal characterised by a linear growth and decline phase (Alston *et al.*, 1998). The adoption rate was defined in terms of the increase in the percentage of land devoted to the commodity as the farmer adopts the technology for a particular crop. The extent and rate of adoption and the adoption lag, as well as the annual depreciation rate of the technology, were all elicited from researchers. Based on responses provided by the researchers, an average period of five years for smallholder farmers and three years for large-scale farmers was used as the adoption lag.

Expected change in yield - The growth in productivity is a function of technical progress and efficiency improvements; therefore the uncertainty associated with achieving benefits from investing in research requires estimation of the probability of research success and the expected yield increase or a reduction in production cost as a result of using the new technology. Table 5.2 shows the percentage change in crop yield in Zambia associated with crop research at the level of funding in the base year for the next 5-10 years. The low level of expected increase in crop yield given by researchers indicated discontentment with the existing level of research funding, and researchers anticipated that yields would rise with more research funds. A couple of studies have attempted to establish a link between the increase in agricultural research and productivity. Battese and Coelli (1995) demonstrated that agricultural research plays an important role in explaining productivity growth using the inefficiency model and found that, investing in agricultural research and development accounted for 1.8% per annum of output growth in a sample of 19 SSA countries. Similarly, Thirtle et al. (1995), using deterministic and stochastic frontier models in a sample of 22 countries in SSA found that research and development expenditures accounted for 1.5 to 2.1% of output growth per annum, which was lower than that of other developing countries. In this study, the link between agriculture research and productivity is established through the K-value discussed above (see also Table 5.5 below).

Table 5.2: Averaged responses for the expected change in crop productivity due to research (%)

Crop	Change in Yield %	
	Smallholder Farmer	Large-Scale Farmer
Groundnut	13	15
Maize	20	22
Sorghum	16	16
Millet	20	15
Cotton	30	35
Soya bean	8	23
Sunflower	9	12

Source: Own survey data (expert opinion)

Research costs - Research costs used for this study were obtained during the survey in which the respondents were asked to provide the total annual expenditure on research for each crop. The total annual figures from the various institutions are presented in Table 5.3 below.

Table 5.3: Crop research expenditure trend 2004-2008 (ZMK' million)

Year	Research expenditure by crop -2004-2008 (ZMK' million)						
	Maize	Millet	Cotton	Groundnut	Soya bean	Sunflower	Sorghum
2004	6496	296	1920	576	932	576	960
2005	7525	300	2385	735	1050	520	1430
2006	8572	339	2088	776	1168	1108	1268
2007	12400	430	2520	1200	1814	2064	2160
2008	12640	550	2701	1205	1700	1902	1812

Source: survey data

1US$=ZMK4500

Discount rate - Economic *ex ante* evaluations of the effects of research always take into account the future streams of costs and benefits, and hence the need to discount the flow of benefits (and costs) to the base year. According to Alston *et al.* (1998), many studies have used a discount rate of five percent for social projects, which corresponds to a risk-free long-term rate of return. The real discount rate to compare costs and benefits of research over time is the real interest rate, which is computed as the nominal interest rate less the inflation rate. According to the CIA (2008), Zambia's interest rate in the base year (2005) was 18.8%, while the inflation rate for the same year was estimated to be 10.6%. Therefore, a discount rate of 8.2% (18.8 - 10.6) was used for this study.

The step-by-step procedure for analysing the data using the DREAM programme was as follows:

- The scenario page was selected to enter the commodity name associated with the scenario, in this case maize, sorghum, millet, groundnut, sunflower, soya bean and cotton. Still under the scenario page, the regions of production were also defined, firstly in terms of all of the nine provinces of Zambia, after which the provinces were assigned to agro-ecological zones. The discount rate, simulation period (15 years) and base year (2005) were also entered.
- Market data - production data for the base year disaggregated by farmer type (smallholder and large-scale) for each province was entered. Aggregate consumption data for each commodity, price data for each commodity at the provincial level, and the elasticity of demand and supply as well as data pertaining to exogenous growth variables were all entered in respective slots. See Table 5.4 below for the baseline market data for maize. Similar data for the other crops is shown in appendix A2.
- Technology - the probability of research success and the anticipated change in yield and cost of production due to research for each commodity were entered. The data was based on expert opinion elicited from researchers. This data is required for the computation of the research-induced supply shift (K-value). Table 5.5 below illustrates a manual computation of the K-value.
- Adoption - the adoption path (linear) was selected, after which data pertaining to the time expected to elapse from release of a new technology until maximum adoption and

the maximum adoption level for each crop and for each farmer group was entered (Table A3.3 to A3.6 in appendix 3).

- The cost of the research (obtained from research institutions) was entered in the cost data page for each crop (Table 5.3).
- To analyse each scenario (commodity), the model was run for a simulation period of 15 years. This was repeated for each commodity, after which scenarios were ranked based on the net present values obtained.

Table 5.4: Baseline market data: maize

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income	GDP per Capita (%)
AEZ1	Central Small	74 567.7	742	0.45	-0.57	0.6	3.1
	Central Large	129 662.1	742	0.45	-0.57	0.6	3.1
AEZ2	Copperbelt Small	52 373.0	847	0.45	-0.57	0.6	3.1
	Copperbelt Large	66 364.3	847	0.45	-0.57	0.6	3.1
AEZ2	Eastern Small	165 186.5	1034	0.45	-0.57	0.6	3.1
	Eastern Large	4128.1	1034	0.45	-0.57	0.6	3.1
AEZ3	Luapula Small	30 252.5	636	0.45	-0.57	0.6	3.1
	Luapula Large	1630.5	636	0.45	-0.57	0.6	3.1
AEZ2	Lusaka Small	11 170.3	1163	0.45	-0.57	0.6	3.1
	Lusaka Large	21 890.8	1163	0.45	-0.57	0.6	3.1
AEZ3	Northern Small	116 206.7	742	0.45	-0.57	0.6	3.1
	Northern Large	1810.5	742	0.45	-0.57	0.6	3.1
AEZ3	North western Small	40 674.3	561	0.45	-0.57	0.6	3.1
	North Western Large	139.8	561	0.45	-0.57	0.6	3.1
AEZ1a	Southern Small	91 910.2	1034	0.45	-0.57	0.6	3.1
	Southern Large	28 607.4	1034	0.45	-0.57	0.6	3.1
AEZ1b	Western Small	29 041.3	1426	0.45	-0.57	0.6	3.1
	Western Large	570.7	1426	0.45	-0.57	0.6	3.1
	Zam Consumption	866 186.6					
	Discount Rate	8%					

Source: Source: multiple secondary sources (MACO unpublished; Mwanaumo, 1997; CIA, 2008)

Table 5.5: Computation of the K-value for a smallholder farmer in central province of Zambia

	Expected Yield Change(E(Y))	Expected Cost Change (E(C))	Elasticity (e_j)	E(Y)/e_j	1+E(Y)	E(C)/(1+E(Y))	P	(1-δt)	At	E(Y)/e-E(C)E(Y)	PA(1-δt)	K
Maize	0.20	0.23	0.45	0.45	1.20	0.19	0.60	0.95	0.10	0.26	0.06	0.015
Sorghum	0.16	0.23	0.40	0.39	1.16	0.19	0.60	0.95	0.05	0.19	0.03	0.005
Sunflower	0.09	0.15	0.40	0.23	1.09	0.14	0.60	0.95	0.10	0.09	0.06	0.005
G/nuts	0.13	0.20	0.30	0.43	1.13	0.18	0.60	0.95	0.05	0.25	0.03	0.007
Millet	0.20	0.15	0.10	2.00	1.20	0.13	0.60	0.95	0.05	1.88	0.03	0.053
Soya bean	0.08	0.18	0.40	0.21	1.08	0.16	0.60	0.95	0.05	0.05	0.03	0.001
Cotton	0.31	0.25	0.67	0.46	1.31	0.19	0.60	0.95	0.10	0.27	0.06	0.015

Notes:

K_t was computed using equation below:

$$K_t = \left[\frac{E(Y)}{e_t} - \frac{E(C)}{E(Y)}\right] pA_t(1-\delta_t)$$

5.5 LIMITATIONS OF THE STUDY

The major source of bias that could have influenced the findings of this research is the quality of the data that was used for the model. For example, data on elasticity of supply did not permit the distinction between smallholder farmers and large-scale farmers. Other sources of data quality compromise may have arisen during the survey due in part to recall error, as respondents were required to provide data for previous years. This recall error is the inability of respondents to remember information from previous years. Such errors were resolved by ensuring that the respondent consulted with other people or documents. It was observed that some respondents felt that financial data was too confidential and, as such, vital information could have been held back. In the case of secondary data, the quality of the data was cross-examined by checking several sources to ensure that the values for a given variable were consistent.

The sections that follow below present the findings from the partial equilibrium Dynamic Research Evaluation for Management (DREAM) model that was used to evaluate *ex ante* the economic returns for crop research. The crop priorities from aggregated present value benefits are discussed. In order to capture the distribution of benefits across farmer type and agricultural region, crop priorities are also ranked for different farmer types and agro-ecological zones.

5.6 AGGREGATE RESEARCH BENEFITS

Maize was found to have the highest net present value benefit for the discounted aggregate present value benefits for the period between 2005 and 2020, and was therefore ranked first. This was followed by soya bean, groundnuts, cotton, millet, sunflower and lastly, sorghum (Table 5.6 below).

Table 5.6: Capital budgeting results for crop research investment

Crop	Total NPV (ZMK' Million)	IRR (%)	Benefit/Cost	Ranking
Maize	114 360	52.4	14.25	1
Soya bean	13 161	22.3	25.64	2
Groundnut	7186	15.1	86.14	3
Cotton	5219	11.9	21.68	4
Millet	1284	21.5	42.80	5
Sunflower	1140	13.0	21.92	6
Sorghum	930	10.3	6.59	7

1US$=ZMK4500

Source: own compilation based on DREAM results

In terms of the quality of investment, the computed internal rates of return were found to be greater than the cost of capital, while the benefit-cost ratios were greater than one for all crops. This therefore indicated that investing in crop research was a worthwhile investment at a discount rate of 8%. This is aligned with earlier findings that investing in crop research (and other public goods) was worthwhile and would be more advantageous when compared to investing in private input subsidies. While a study in India found lower returns for private input subsidies (0.5%) than returns for investments in agricultural research (6.9%) (Lopez, 2006), Jayne *et al.* (2007:11) pointed out that fertiliser subsidies had not achieved any appreciable growth in crop output in Zambia. Despite such arguments, the Fertilizer Support Programme has remained important in Zambia and thus still receives the bulk of the agricultural budget resources (18%). While this has serious policy implications for the Zambian Government, particularly to scale down the programme by shifting resources from fertiliser subsidies to crop research and infrastructure development (Haggblade, 2007), there is also need to redesign and improve the operational efficiency of the Fertilizer Support Programme by addressing problems related to rent-seeking behaviour, processes of delivery and definition of targeted clientele (such as viable but vulnerable) in order that the programme remains effective even with fewer resources. In addition, there is need to sensitise farmers to the need for collective action for the survival of the fertiliser programme.

When actual investment in crop research was compared to returns on investment for each crop for the period under consideration (Table 5.7 below), it was observed that maize had the highest returns and also had the highest financial expenditure, implying that resources to this crop were efficiently allocated. It is not surprising that maize is the crop that ranked first in terms of the net present value benefits. This was because all of the investment, marketing and export policies in the country have always favoured the production of this crop and, as such, maize technologies are developed by both the public and the private sector. It is also worth noting from the findings in chapter three that all of the identified crop research institutions except the Cotton Development Trust performed research in maize, and have released more than 16 improved maize varieties since 1992 (ZARI, 2009). The survey also revealed that improved maize varieties were the most widely adopted, with adoption levels higher than 60% for both smallholder and large-scale farmers, hence the crop is extensively produced. Maize is also widely consumed as it is the country's staple food crop. The production of soya bean, on the other hand, was mainly promoted by the private sector for large-scale farmer adoption and hence the crop ranked second. The Cooperative League of the United States (CLUSA) previously facilitated the production of soya beans by smallholder farmers through the out-grower schemes but small-scale production declined during 2004 soon after the project funding was concluded (Parker, n.d).

Table 5.7: Resource expenditure versus returns on investment

Crop	**Crop Rank by**	
	Financial resource Allocation	**Returns on Investment (Based on DREAM NPV results)**
Maize	1	1
Soya bean	4	2
Cotton	2	4
Sorghum	3	7
Groundnut	5	3
Sunflower	6	6
Millet	7	5

Source: own compilation based on DREAM results

However, for the rest of the crops in Table 5.7 above, financial allocations did not necessarily match returns on investment. While sorghum ranked third in terms of the total financial resource allocation, it had the least return on investment. Such an outcome was observed because of public crop research conducted by the government, whose social objective (such as equity, food security, drought-tolerant crops) was also important.

In earlier priority setting studies by the Soil and Crop Research Board, even though the efficiency objective had a weight of 50% and that of public benefit objective had a weight of 25% (ZARI, 2009); crops with low returns still received higher funding. This is because the promotion of sorghum, millet and cassava research was the government's strategy for ensuring food security by encouraging the growth of drought-tolerant crops in the face of climate changes. In the past decade, Zambia experienced several droughts: in 1992, 1994, 1998, 2001 and 2002 (CEEPA, 2006; Govereh, 2007). As such, the diversification from staple crops to crops that were drought-tolerant, such as sorghum and millet, was recommended as an adaptation to the recurring climate changes for the vulnerable subsistence small-scale farmers in the country (CEEPA, 2006).

The need for the government to protect the vulnerable in society by promoting less efficient programmes is a familiar practice in many countries, but the extent to which efficiency is given up in order to achieve social objectives is most crucial and the lack of strategy on how this trade-off ought to be done is perhaps the reason for slow economic growth in most poor countries today like Zambia.

In this regard, the private sector could play a vital role in ensuring efficiency in crop research by performing research in profitable crops, thereby allowing the government to conduct research on crops for the poor and based on social objectives. However, in 1993 and 1997, in the era of structural reform, the Zambian Government optimistically assumed that the private sector would take up research responsibility for commercial crops with potential for high profit and, as a result, dropped some crops (oilseeds, tea, coffee and flowers) from regional public research programme priority lists. However, this did not occur as planned since, until recently, the private sector had been reluctant to invest in crop research. The reason for this was because the government had overlooked the need for creating an enabling environment to complement such reform. In response, the Plant Breeders Rights Act was drafted and completed in 1999 but it has not been implemented at the time of this study, as government is still making further consultation (ZARI, 2009).

5.7 CROP PRIORITIES BASED ON AGRO-ECOLOGICAL ZONE

When crop priorities were disaggregated according to agro-ecological zones (Figure 5.2 below), it was found that maize, soya bean, cotton and sunflower yielded the highest benefits for agro-ecological zone IIa. It is worth noting for agro-ecological zone IIa that crop production is driven by more than favourable climatic conditions. This region also contains the country's major road and rail line infrastructure as well as most of the urban centres of the country. As a result, not only are most commercial farmers located in agro-ecological zone IIa, so are major millers, ginneries and oilseed companies and, as such, commercial crops such as soya bean, maize, cotton and sunflower are popular in this region. The availability of transport infrastructure in the region not only reduces transaction costs for producers but also ensures that markets are readily available and accessible from the densely populated urban centres.

Agro-ecological zone III had the biggest comparative advantage for groundnut, millet and sorghum. Conversely, agro-ecological zone IIb had very little potential for crop production and the model suggested that sorghum would have the biggest comparative advantage for the region. The study results also revealed negative benefits for soya bean in agro-ecological zone III. Such analysis was relevant and informed a useful guide for a more rewarding agriculture research portfolio, and served as a basis for agriculture diversification for the various agro-ecological zones of the country. However, cultural factors also have an important role to play, as in the case of sorghum and millet. It was observed that, even though these crops are meant to be drought-tolerant crops, they were grown more widely in the region that receives the highest rainfall in the country (agro-ecological zone III) and were less acceptable in the Southern part of the country that receives the lowest rainfall.

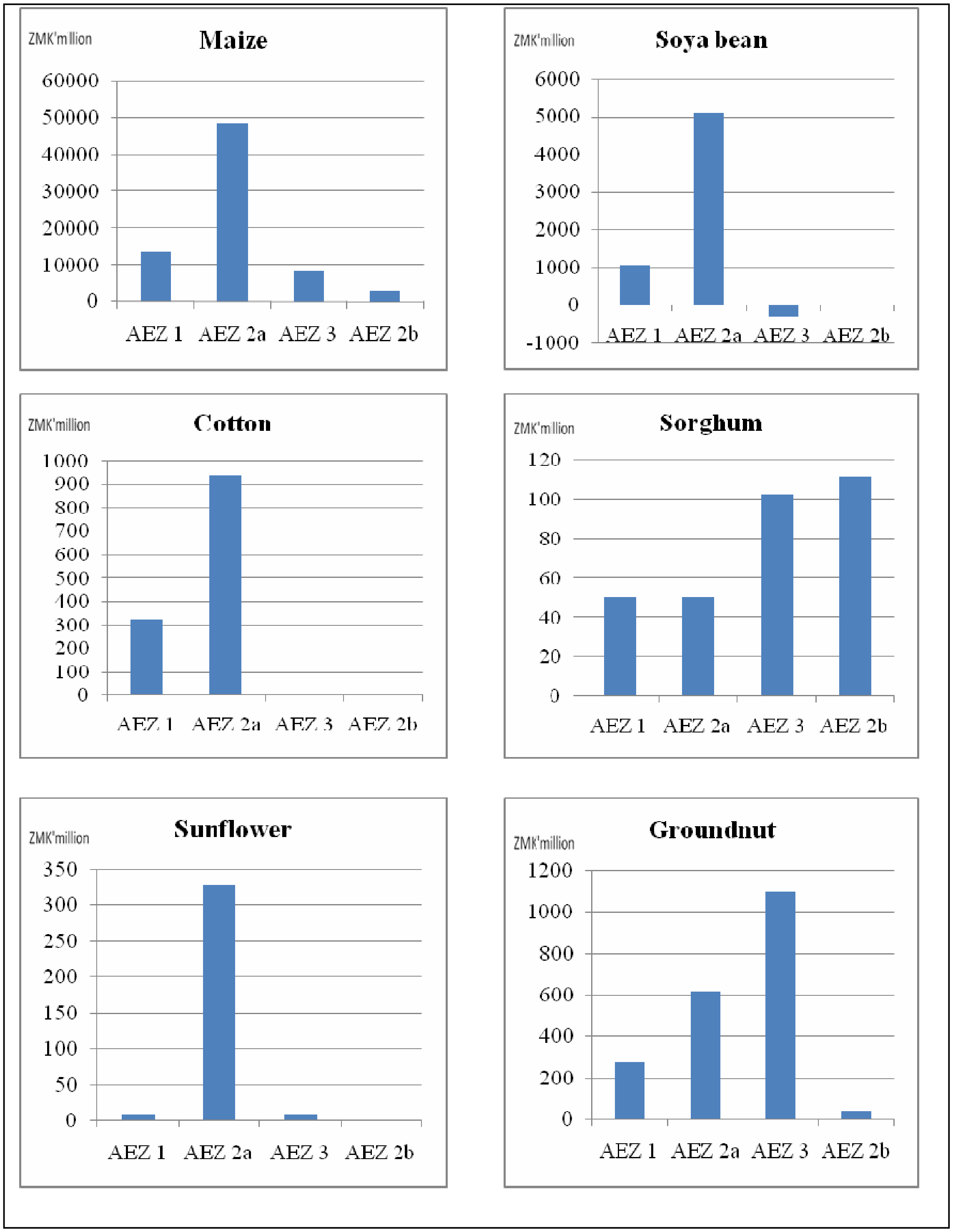

Figure 5.2: NPV benefits by agro-ecological zone

Source: own compilation based on DREAM results

5.8 CROP PRIORITIES BY FARMER TYPE

Since the data was also disaggregated by farmer type, net present values were computed for large-scale and smallholder farmers. The model revealed that the top three crops for large-scale farmers were maize, soya bean and sunflower (Table 5.8). This makes sense because, apart from the need to export these commercial crops (e.g. maize), grain milling, seed oil extraction and livestock feed processing constitute the major crop processing industries in Zambia. As such, large-scale farmers grow these crops as their market is readily available.

Table 5.8: Net present values for large and smallholder farmers

Crop	Large farmer Surplus NPV (ZMK' Million)	Smallholder farmer Surplus NPV (ZMK' Million)
Maize	30930	46093
Soya bean	7523	141
Groundnut	299	2688
Cotton	219	2656
Millet	281	569
Sunflower	351	185
Sorghum	280	592

Source: own compilation based on DREAM results

Crop priorities for smallholder farmers included maize, groundnuts and cotton in agro-ecological zone I and II, while maize, groundnuts and small grains (sorghum and millet) were the priority crops for smallholder farmers in region III. It is worth noting that groundnut crops are widely grown by smallholder farmers across the country, not only because this crop is a good source of protein in the Zambian people's diets, but also because groundnuts are often grown in rotation with maize. This is advantageous to smallholder farmers who use inorganic fertilisers in limited amounts because groundnut crops are essential for fixing nitrogen in the soil. The production of cotton on the other hand is influenced by the presence of private companies that promote cotton production by smallholder farmers as a cash crop via out-grower schemes. Cotton (and soya bean) production by smallholder farmers is only viable with the support of proper institutional arrangements that ensure the provision of inputs, extension services and a market for the crop. The success of cotton research is therefore heavily influenced by such complementary institutions that facilitate adoption of the technology by farmers. Consequently, it is difficult to isolate the contribution of research from complementary institutions and or policies that enhance adoption.

Sorghum is mostly grown by smallholder farmers, especially those in the Northern part of the country where the crop is culturally more accepted. Recently, there has been a shift from land under cultivation with maize to sorghum, cassava and millet in the Northern region. This trend in which smallholder farmers returned to the production of traditional crops is driven not only by changes in the climate but also by a change in policies after the reform period, which resulted in reduced public expenditure on smallholder farmer maize production and marketing (Jayne *et al.*, 2007).

5.9 DISTRIBUTIONAL BENEFITS

Even though the setting of priorities in this study was based on the efficiency objective only, it was necessary to examine how these benefits are distributed among the farmer types under the efficiency objective. Therefore, the benefit values computed by the model for each farmer group were expressed as a percentage of the total aggregate net present value benefits (Table 5.9 below).

In the case of maize, 20% of the total net present value benefits were accrued to large-scale farmers in the Central Province. This was followed by smallholder farmers of the Eastern and Southern Province at 16% and 13%, respectively. While all the benefits of soya bean were accrued by large-scale farmers, most of the benefits for groundnuts and cotton were accumulated by smallholder farmers.

However, it is worth noting that smallholder farmers located in the Southern, Central and Eastern region of Zambia accrued much higher net present value benefits than smallholder farmers in other regions. This is because these farmers are not only based in the agro-ecological zone with favourable agriculture production but they also have access to better communication and transport infrastructure. This therefore necessitates not only the need for increased infrastructure in rural areas but also the need to increase extension services through increasing the number of extension workers in the long-term. Meanwhile, intensifying the use of other information media, where it is available, can be used to reach farmers in order to allow for the few available extension officers to visit farmers in remote areas more regularly.

Table 5.9: Distributional benefits for farmer types at provincial level

Farmer type	Crops						
	Groundnut	Maize	Millet	Sorghum	Soya Bean	Sunflower	Cotton
Central Small	6 %	10 %	3 %	9 %	-1 %	4 %	19 %
Central Large	0 %	20 %	29 %	0 %	38 %	10 %	1 %
Copperbelt Small	4 %	5 %	0 %	11 %	0 %	1 %	0 %
Copperbelt Large	0 %	9 %	0 %	0 %	35 %	0 %	0 %
Eastern Small	25 %	16 %	2 %	4 %	-4 %	33 %	58 %
Eastern Large	0 %	1 %	0 %	0 %	0 %	32 %	0 %
Luapula Small	14 %	1 %	4 %	3 %	0 %	0 %	0 %
Luapula Large	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Lusaka Small	1 %	3 %	0 %	0 %	0 %	0 %	1 %
Lusaka Large	0 %	5 %	0 %	2 %	16 %	8 %	0 %
Northern Small	30 %	7 %	48 %	5 %	-1 %	6 %	0 %
Northern Large	0 %	0 %	0 %	0 %	0 %	1 %	0 %
North Western Small	6 %	2 %	1 %	22 %	0 %	0 %	0 %
North Western Large	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Southern Small	19 %	13 %	4 %	10 %	0 %	3 %	19 %
Southern Large	2 %	4 %	1 %	3 %	16 %	1 %	2 %
Western Small	2 %	3 %	7 %	31 %	0 %	0 %	0 %
Western Large	0 %	0 %	0 %	1 %	0 %	0 %	0 %
Total	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**

Source: own compilation based on DREAM results

The model also showed that consumers benefited from investing in crop research. As a result of the research-induced supply shift, production increased and the equilibrium price decreased, hence the quantity consumed increased and consequently increased consumers' welfare. Table 5.10 below shows the net present values for the change in consumer surplus for each commodity.

Table 5.10: Net present values for consumer surplus (ZMK'Million)

Crop	Consumer Surplus NPV (ZMK' Million)
Maize	37 337
Soya bean	5450
Groundnut	3293
Cotton	2340
Millet	433
Sunflower	594
Sorghum	51

Source: own compilation based on DREAM results

According to the results obtained from the model, when consumption 'without' the research-induced supply shift was compared to consumption 'with' the research-induced supply shift, it was revealed that consumption of groundnuts, millet and sorghum 'with' the research-induced supply shift increased by 10%, 11% and 3%, respectively. The consumption of sunflower, maize and cotton also increased, by 62%, 55% and 26% respectively; while consumption of soya bean almost doubled. The model therefore illustrated that soya bean, sunflower, maize and cotton are more responsive to a price change. This is not surprising because these crops are important primary inputs for Zambia's agricultural industries and are thus more affected by market price changes as opposed to crops produced for subsistence consumption, which would not be influenced much by market prices.

5.10 SUMMARY

This chapter provided a detailed description of the methodological process applied and the results obtained in this study. It explained the application of the DREAM model in quantifying the economic surplus changes from agricultural research for producers and consumers, using market and technology related data. It also explained variables used in the model and their data sources, which included both secondary and primary data. Net present value benefits were computed using the DREAM model and it was found that the crops for research under the efficiency objective, in order of priority, were maize, soya bean, groundnuts, cotton, millet, sunflower and sorghum. Only the financial resources spent on maize matched returns on investment - this was not the case for the rest of the crops. As such, the allocation of financial resources towards crop research has not been efficient for all crops except maize under consideration in this study. Therefore, this will demand a re-orientation of expenditure in crop research to match priority crops revealed in this study. This could only be achieved if private sector participation in crop research increases as the government often has other social objectives to consider. However, investing in crop research was worthwhile as all crops had positive net present values and producers and consumers benefited through increased welfare. More importantly, the distribution of the accrued welfare impact varied among producer groups with large scale farmers taking the lead in some crops and small scale in others.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter presents the conclusions of the study and the follow-on recommendations. A brief summary of the study is outlined, after which the conclusions are discussed. Then, specific recommendations for policy-makers as well as cross-cutting recommendations for researchers in public and private institutions are outlined. The suggestions for future studies are also discussed.

6.2 SUMMARY OF THE STUDY

Zambia is endowed with abundant land and water resources as well as favourable climatic conditions that support agricultural production. However, while there is high production potential, crop productivity remains low and one of the impediments, among other constraints, is the challenge of improving the efficiency of expenditure in agriculture research in order to increase crop productivity and to strategically position the sector according to its comparative advantages. The study was based on the hypothesis that financial outlay to agriculture crop research has not been efficiently allocated towards achieving the nation's crop production potential.

Since crop research plays a significant role for attaining the desired increase in crop productivity, a survey on all crop research institutions was conducted to determine the nature and extent of crop research in Zambia. It was found that seven institutions categorised as government, private sector, research trusts and higher learning institutions, conduct crop research in Zambia. These institutions varied in terms of the number of crops and research programmes under consideration.

Literature revealed that methodologies for priority setting range from qualitative approaches to quantitative techniques. The application of these methodologies to studies involving priority setting in agriculture varied extensively in scope and depth. Even though many quantitative studies on priority setting in agriculture have been completed in Africa, studies done in Zambia were mostly based on stakeholder perceptions through the scoring method. Therefore, this study sought the efficient allocation of resources through priority setting using the DREAM model, which is based on the theory of consumer and producer surplus. Net present values were used to quantify the benefits of crop research for producers and consumers as well as to set priorities. In order of priority, the crops were found to be: maize, soya bean, groundnuts, cotton, millet, sunflower and sorghum.

6.3 CONCLUSIONS

Positive net present values were obtained and the internal rates of return were greater than the cost of capital for all crops under consideration in this study for the simulated period (2005-2020). Therefore, investing in agriculture crop research in Zambia is worthwhile. This coincides well with the fact that crop production potential in Zambia is high yet most of it still remains untapped. In addition, the low levels of crop yields with the existing level of research funding all signal the need for public and private sectors as well as international organisations to increase investments in Zambia's crop research. The results obtained from this study could serve as a basis for a strategic guide regarding future investments into crop research, and subsequently assist with the establishment of a crop-based research system that is efficient and more rewarding. Based on the study findings, further investments should be made on maize research as it yields the highest returns and benefits both large scale and smallholder farmers. Also, maize is the country's staple crop and further investments in maize research would provide a greater understanding of the dynamics of the maize based farming system in the advent of climate change for increased food security and farmer incomes. Other crops for research investment are soya bean, cotton, groundnuts and sunflower.

The allocation of financial resources towards crop research was not efficient for all crops as some of the crops receiving high investment did not necessarily have higher net present value benefits. For instance, while sorghum ranks third in terms of the total financial resource allocation, it had the least returns on investment. This therefore demands re-allocations of financial resources between crops in favour of crops with high returns. However, such adjustment may not be easily attained because the government still conducts the bulk of research in Zambia, and it caters for other social objectives such as equity and drought tolerance, and hence the need to diversify its expenditure to less efficient crops such as sorghum and millet. Nonetheless, the extent to which social objectives supersede efficiency must be addressed strategically without compromising economic development. Also, importantly, increasing and using research funds efficiently would broaden the spectrum of research crops under consideration without necessarily shifting resources from staple priority crops such as maize, thus including other crops such as millet, sorghum, rice, wheat and potatoes. These and other crops could contribute to the country's food security, directly or indirectly through increased farmer incomes.

It was also deduced that crop research investment influences the distribution of welfare benefits on different producer groups. The study further established that smallholder farmers in some regions were among the group that received the highest proportion of benefits, even for crops (maize) whose financial resources were efficiently allocated towards research. Therefore, the efficiency objective may not necessarily leave smallholder farmers worse off as long as they have access to complementary infrastructure and institutions for agriculture production. This distributive aspect derived from the choice of crop research investment can serve as a very crucial policy instrument for policy makers in targeting specific producer and consumer groups in order to enhance overall national development objectives.

Agricultural crop research in Zambia has grown in terms of research personnel and expenditure and also, no new research institutions were identified save those that existed in the year 2000. The need to establish new research entities can be viewed as a measurement of instability, therefore since no new institutions were established in Zambia in the past decade signifies stability in agricultural research management. The major research crop was still maize and plant breeding was the major research activity. While the increase in the number of research personnel is attributed to the government, increase in expenditure was as a result of the increased consistency in expenditure by both the government and the private sector.

However, despite these positive trends, the quality of expenditure in Zambia's agriculture research system must still be improved.

6.4 RECOMMENDATIONS

6.4.1 Recommendations for government and policy-makers

The state plays an important role in facilitating the success of research and technology development and dissemination through good public governance, and provides a stable macro-economic environment. In this regard, the following aspects must be given greater attention.

- Given that the intellectual property rights policy for plant breeders still needs enforcement, the Government of Zambia must act promptly to implement this act. This will create an enabling environment for private sector participation in agriculture crop research and will coerce the private sector and international partners to make further investments in crop research. Increased participation by the private sector and international organisations in crop research will allow these institutions to invest in crops with high returns while the government could focus on crops with social benefits.

- The distributional benefits showed that smallholder farmers in Luapula, particularly in the Northern and Western provinces, which have relatively worse infrastructure, benefited less than their counterparts in other provinces. Increased productivity growth from released technologies without complementary infrastructure and institutional arrangements may prove to be counterproductive. As such, there is need for major investment in transport infrastructure, research stations, storage facilities, telecommunications and market facilities. Apart from the physical hardware, there is also a need to strengthen the institutional set-up of, for example, intellectual property rights, contract enforcement, credit facilities, market information (demand, supply, prices, grades and standards) and increased transparency.

- There is a need for the government to continue to secure financial resources to increase investment in public agriculture research with high returns, as opposed to overspending on recurrent subsidies (Fertilizer Support Programme) that render only quick short-term benefits. If soil fertility is the problem, it would be more beneficial in the long-term to invest in soil fertility technologies and environmentally compatible farming systems, such as conservation farming, that foster sustainable development.

- The government must increase the capacity for the development of human capital in terms of both scientists and extension officers by increasing the number of tertiary institutions offering agricultural science education, and providing financial support. There is a need to increase the number of agriculture researchers and extension officers in the country and for the existing ones to pursue further training and higher degrees beyond a Bachelor of Science degree.

- As opposed to setting research priorities based on researchers' scoring that may be biased, there is a need for economic-based evidence to justify research agendas. This study recommends maize, cotton and groundnuts as crops for smallholder farmers; and maize, soya bean and sunflower as crops for large scale farmers. But more than just economic justification, setting the research agenda must take into account all stakeholders' perceptions, including those of farmers, extension workers, researchers, research managers and policy-makers. This will ensure that developed technologies will be more demand-driven. The government must provide a platform for such synergy among the various stakeholders.

- There is a need to clearly communicate the government's policy objectives with regards to crop research, in terms of what role the government should play and what the private sector and higher education institutions are expected to cover. This will create an opportunity to address multiple but competing objectives such as equity and efficiency. Also, a common vision will be created that will ensure that setting research agendas, and consequently resource allocation, is not based on individual interpretation of the research problem.

6.4.2 Recommendations for research institutions

The recommendations presented below are cross-cutting for researchers in public and private institutions and for various research disciplines.

- The survey results showed that the average maximum adoption for most crop technologies was 50% and below. In this regard, researchers must encourage a two-way flow of information between researchers and other stakeholders as this would help improve adoption levels or explain low adoption levels. Therefore, farmers would not only be on the receiving end but would provide researchers with vital feedback essential for formulating future research agendas, improving technologies in progress and avoiding the repetition of mistakes. This would help researchers to pay attention to 'what works'. Further, researchers must find creative ways of presenting their findings in a manner that suits the different end users.

- Survey findings show that some research institutions were only conducting a single research activity such as plant breeding. In this regard, there is a need for researchers to collaborate and consult with other researchers in order to ensure synergy across research disciplines and institutions (private and public). This will ensure that research is multi-disciplinary as opposed to being discipline specific, and will prevent a research system in which only one aspect such as plant breeding is covered while other complementary activities such as plant protection, agronomy and post-harvest are left out. Neglecting a holistic research approach could result in a new crop variety being produced, which would not have the necessary agronomic or plant protection recommendations for its success. Therefore, the entire research chain must be covered so that a complete package of technologies is released.

- Researchers still employ conventional methods for crop breeding while the use of quicker, advanced technologies, such as biotechnology, remains unexploited. There is a need to explore the potential benefits of this branch of science in order to reduce the research development time lag and to increase crop productivity in Zambia.

6.4.3 Suggestions for future research

This study is only indicative of what the strategic decision on priority setting should look like. There is still a need to build up studies that incorporate multiple sources of evidence using more robust methodologies. Some of the key suggestions for future research are:

- Current agriculture research is happening in a dynamic and complex world where resources are scarce; the gap between the rich and poor is wider and economies are more globalised and liberalised; consumer tastes and preferences are changing; the physical environment is degrading and farming systems are vulnerable to and affected by climate changes. Therefore, priority setting and allocating resources among different research activities across competing policy objectives requires strategic intervention, with an increased capacity to take this dynamism into account as much as possible.

- Priority setting based on any single objective (efficiency, equity, food security, environmental protection) will always fall short; therefore, multiple objectives must be incorporated. Priority setting must be done on a regular basis as the environment is not static, which implies that what matters keeps changing. It must be an ongoing process of planning and evaluation and must be implemented timeously so that it provides feedback for further planning. In addition, future studies could also compare the efficiency of the various research institutions and or specific research programmes so that the quality of expenditure is improved at the micro level (individual institution).

- In terms of methodologies for the priority setting process, multiple methodologies that combine both quantitative measurement and qualitative assessment must be applied in order to capture the reality on the ground. Also, the regions of analysis and producers as well as consumers must be disaggregated in order to develop specific policies that target the different groups.

Getting the right crop research priorities is the springboard for achieving agricultural competitiveness as it strategically positions agriculture production according to its comparative advantages. It is therefore essential that research managers and policy-makers incorporate the findings and recommendations from this study by expanding expenditure on crop research as this increases the welfare of the Zambian farmers. There is also need for re-allocation of financial resources between crops, that is, from low returns crops to crops with high returns in order to improve efficiency for a better and more effective Zambian agriculture sector.

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8. APPENDICES

Appendix 1: Questionnaire

Scientist Questionnaire for Crop Research

SECTION A: BACKGROUND INFORMATION

Name of Institution: ____

Type of Institution: (e.g. NGO, higher education) ________________________________

Respondent

Name: _________________________ **Position: ______________________**

Date: __________________________ **Specialisation: ____________________**

SECTION B: RESEARCH FOCUS

1. In which of the following crops does the institution conduct research? Indicate research focus in terms of percentage of time devoted to each research crop.

Crop	Yes	Research Focus (%)
Maize		
Millet		
Cotton		
Groundnut		
Soya bean		
Tobacco		
Sunflower		
Sorghum		
Cassava		
Any other		

2. In which component of the Crop Value Chain for each of the selected crops above do you carry out research?

Crop	Components of the Crop Value Chain						
	Genomics & plant breeding	**Plant protection**	**Agronomy**	**Soil research**	**Post-harvest research**	**Market research**	**Other (specify)**

3. For each component selected above, indicate the percentage of time for each research program for each crop?

Crop	Components of the Crop Value Chain						
	Genomics & plant breeding	**Plant protection**	**Agronomy**	**Soil research**	**Post-harvest research**	**Market research**	**Other (specify)**

SECTION C: RESEARCH COSTS

4. What has been the total cost of each research programme in the past five years (staff remuneration, operating expenses and capital expenditure)?

Components of the Crop Value Chain	Cost of Research Programme				
	2004	**2005**	**2006**	**2007**	**2008**
Genomics & plant breeding					
Plant protection					
Agronomy					
Soil research					
Post-harvest research					
Market research					
Other (specify)					

5. Estimate the total cost of research by crop in the past five years?

Crop	**Cost of Research**				
	2004	**2005**	**2006**	**2007**	**2008**

6. Estimate in terms of percentage the source for the research funds?

Components of the Crop Value Chain	Percentage of Funds (%)				
	Own	**Government**	**International donors**	**Private sector**	**Other (specify)**
Genomics & plant breeding					
Plant protection					
Agronomy					
Soil research					
Post-harvest research					
Market research					
Other (specify)					

SECTION D: RESEARCH PERSONNEL

Notes:

- **For the purpose of this survey, research scientists include individuals who hold a minimum of a BSc. degree or its equivalent via university training.**

- **A Full Time Equivalent (FTE) researcher refers to a person who holds a full-time position as a researcher during the whole year.**

Question 7 and 8 to be answered by full time equivalents while question 9 and 10 by non-full time equivalents (i.e. part-time research position)

7. How many scientists (full time equivalents (FTEs)) have conducted research in each component of the Crop Value Chain in the past five years?

Components of the Crop Value Chain	**No. of FTE Scientists**				
	2004	**2005**	**2006**	**2007**	**2008**
Genomics & plant breeding					
Plant protection					
Agronomy					
Soil research					
Post-harvest research					
Market research					
Other (specify)					

8. How many scientists (full time equivalents) have conducted research on each crop selected in question 1 above for the past five years?

Crop	**No. of FTE Scientists**				
	2004	**2005**	**2006**	**2007**	**2008**

9. If there are scientists that are not full time equivalents (FTEs) that conduct research, give the number of these scientists and the approximate percentage of time spent on research in each component of the Crop Value Chain in the past five years?

Research Component	Number & Percentage Time of Non-FTEs									
	2004		2005		2006		2007		2008	
	No.	%	No.	%	No.	%	No.	%	No.	%
Genomics & plant breeding										
Plant protection										
Agronomy										
Soil research										
Post-harvest research										
Market research										
Other (specify)										

10. If there are scientists that are not full time equivalents (FTEs) that conduct research, give the number of these scientists and the approximate percentage of time spent on research for each crop in the past five years?

Crop	Number & Percentage Time of Non-FTEs									
	2004		2005		2006		2007		2008	
	No.	%	No.	%	No.	%	No.	%	No.	%

SECTION E: EXPECTED RESEARCH OUTCOME

11. What are the expected research outcomes from each component of the Crop Value Chain?

Components of the Crop Value Chain	Research Programme Outcome			
	1	2	3	4
Genomics & plant breeding				
Plant protection				
Agronomy				
Soil research				
Post-harvest research				
Market research				
Other (specify)				

12. What would be the most likely expected yield increase per hectare for smallholder farmers be in 5-10 years with no research funding, with the current research funding for the next 5 years, with 50 % more funding, and with 100 % more funding?

Crop	Expected Yield Increase (%)			
	No funds	Current funds	50% more funds	100% more funds

13. What would be the most likely expected yield increase per hectare for large farmers be in 5-10 years with no research funding, with the current research funding for the next 5 years, with 50 % more funding, and with 100 % more funding?

Crop	Expected Yield Increase (%)			
	No funds	Current funds	50% more funds	100% more funds

14. What is the expected percentage contribution of each component of the Crop Value Chain to the yield change indicated above with the current level of funds? **(Must add to 100 % for each crop)**

Crop	Components of the Crop Value Chain						
	Genomics	**Plant breeding**	**Plant protection**	**Agronomy**	**Chemistry & soils**	**Market research**	**Other (specify)**

15. What is (would be) the expected percent change in total variable costs per hectare if smallholder farmers adopted the research technology? **(Indicate if change is positive/negative prior to digit)**

Research Component / Crop	Expected Change in Variable Cost (%)				
Maize					
Millet					
Cotton					
Groundnut					
Soya bean					
Tobacco					
Sunflower					
Sorghum					
Cassava					
Other					

16. What is (would be) the percent change in total variable costs per hectare if large farmers adopted the research technology? **(Indicate if change is positive/negative prior to digit)**

Research Component / Crop	Expected Change in Variable Cost (%)				
Maize					
Millet					
Cotton					
Groundnut					
Soya bean					
Tobacco					
Sunflower					
Sorghum					
Cassava					
Other					

17. What is the probability (percent chance) that investing in crop research will lead to new technology that will result in increased yield or decreased variable costs for smallholder and large-scale farmers?

Crop	Probability (%)	
	Smallholder Farmers	Large-Scale Farmers

SECTION F: ADOPTION

18. What is the maximum expected level of adoption and what is the adoption lag? When will the key research results (transferable technologies) be available? What will the rate of technology depreciation be and after how many years will technology begin to depreciate? (In relation to smallholder farmers)

Crop	Max. Adoption (%)	Adoption Lag (Years)	R&D Time Lag (Years)	Rate of adoption	Rate of Annual Depreciation	Onset of Depreciation (Years)

19. What is the maximum expected level of adoption and what is the adoption lag? When will the key research results (transferable technologies) be available? What will the rate of technology depreciation be and after how many years will technology begin to depreciate? (In relation to large-scale farmers)

Crop	Max. Adoption (%)	Adoption Lag (Years)	R&D Time Lag (Years)	Rate of Adoption	Rate of Annual Depreciation	Onset of Depreciation (Years)

20. Do you expect an increase (or decrease) in area devoted to the commodity over the next 5 to 10 years? If so, what percent per year?

Crop	Expected Increase in Area
Maize	
Millet	
Cotton	
Groundnut	
Soya bean	
Tobacco	
Sunflower	
Sorghum	
Cassava	
Any other	

-------Thank you-----

Appendix 2: Baseline Market Data

Table A2.1: Baseline market data: Sorghum

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	2207.1	2445	0.4	-0.25	0.6	3.1
	Central Large	32.8	2445	0.4	-0.25	0.6	3.1
AEZ2	Copperbelt Small	2689.8	2445	0.4	-0.25	0.6	3.1
	Copperbelt Large	0.0	2445	0.4	-0.25	0.6	3.1
AEZ2	Eastern Small	879.3	2445	0.4	-0.25	0.6	3.1
	Eastern Large	0.4	2445	0.4	-0.25	0.6	3.1
AEZ3	Luapula Small	542.7	2895	0.4	-0.25	0.6	3.1
	Luapula Large	0.0	2895	0.4	-0.25	0.6	3.1
AEZ2	Lusaka Small	44.6	2895	0.4	-0.25	0.6	3.1
	Lusaka Large	94.7	2895	0.4	-0.25	0.6	3.1
AEZ3	Northern Small	856.1	2895	0.4	-0.25	0.6	3.1
	Northern Large	0.0	2895	0.4	-0.25	0.6	3.1
AEZ3	North western Small	4013.4	2895	0.4	-0.25	0.6	3.1
	North Western Large	0.0	2895	0.4	-0.25	0.6	3.1
AEZ1a	Southern Small	1841.4	2895	0.4	-0.25	0.6	3.1
	Southern Large	152.7	2895	0.4	-0.25	0.6	3.1
AEZ1b	Western Small	5330.6	2961	0.4	-0.25	0.6	3.1
	Western Large	28.2	2961	0.4	-0.25	0.6	3.1
	Zam Consumption	18713.8	2767				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Chisi,2000; CIA,2008)

Table A2.2: Baseline market data: Millet

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	770.5	1720	0.1	-0.3	0.6	3.1
	Central Large	0.0	1720	0.1	-0.3	0.6	3.1
AEZ2	Copperbelt Small	74.8	1720	0.1	-0.3	0.6	3.1
	Copperbelt Large	0.0	1720	0.1	-0.3	0.6	3.1
AEZ2	Eastern Small	607.1	1720	0.1	-0.3	0.6	3.1
	Eastern Large	0.0	1720	0.1	-0.3	0.6	3.1
AEZ3	Luapula Small	1929.2	1734	0.1	-0.3	0.6	3.1
	Luapula Large	0.0	1734	0.1	-0.3	0.6	3.1
AEZ2	Lusaka Small	0.0	1734	0.1	-0.3	0.6	3.1
	Lusaka Large	0.0	1734	0.1	-0.3	0.6	3.1
AEZ3	Northern Small	22766.6	1734	0.1	-0.3	0.6	3.1
	Northern Large	4.2	1734	0.1	-0.3	0.6	3.1
AEZ3	North western Small	222.2		0.1	-0.3	0.6	3.1
	North Western Large	0.0	1734	0.1	-0.3	0.6	3.1
AEZ1a	Southern Small	1463.8	1734	0.1	-0.3	0.6	3.1
	Southern Large	0.0	1734	0.1	-0.3	0.6	3.1
AEZ1b	Western Small	1749.2	1739	0.1	-0.3	0.6	3.1
	Western Large	0.0	1739	0.1	-0.3	0.6	3.1
	Zam Consumption	29587.5	1731				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Davis *et al.*, 2008; CIA, 2008)

Table A2.3: Baseline market data: Groundnut

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	3995.6	4133	0.3	-0.41	0.6	3.1
	Central Large	98.9	4133	0.3	-0.41	0.6	3.1
AEZ2	Copperbelt Small	3118.3	4133	0.3	-0.41	0.6	3.1
	Copperbelt Large	37.1	4133	0.3	-0.41	0.6	3.1
AEZ2	Eastern Small	21440.9	4133	0.3	-0.41	0.6	3.1
	Eastern Large	16.5	4133	0.3	-0.41	0.6	3.1
AEZ3	Luapula Small	10260.1	4438	0.3	-0.41	0.6	3.1
	Luapula Large	39.2	4438	0.3	-0.41	0.6	3.1
AEZ2	Lusaka Small	313.8	4438	0.3	-0.41	0.6	3.1
	Lusaka Large	25.1	4438	0.3	-0.41	0.6	3.1
AEZ3	Northern Small	22729.3	4438	0.3	-0.41	0.6	3.1
	Northern Large	16.6	4438	0.3	-0.41	0.6	3.1
AEZ3	North western Small	5422.5	3923	0.3	-0.41	0.6	3.1
	North Western Large	0.0	3923	0.3	-0.41	0.6	3.1
AEZ1a	Southern Small	5242.2	4438	0.3	-0.41	0.6	3.1
	Southern Large	40.1	4438	0.3	-0.41	0.6	3.1
AEZ1b	Western Small	1410.9	4438	0.3	-0.41	0.6	3.1
	Western Large	10.5	4438	0.3	-0.41	0.6	3.1
	Zam Consumption	72796.2	4164				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Davis *et al*., 2008; CIA, 2008)

Table A2.4: Baseline market data: Soya bean

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	3931.1	2128	0.4	-0.55	0.6	3.1
	Central Large	21228.1	2128	0.4	-0.55	0.6	3.1
AEZ2	Copperbelt Small	724.3	2128	0.4	-0.55	0.6	3.1
	Copperbelt Large	30125.7	2128	0.4	-0.55	0.6	3.1
AEZ2	Eastern Small	9658.5	2128	0.4	-0.55	0.6	3.1
	Eastern Large	193.5	2128	0.4	-0.55	0.6	3.1
AEZ3	Luapula Small	120.3	2005	0.4	-0.55	0.6	3.1
	Luapula Large	1.2	2005	0.4	-0.55	0.6	3.1
AEZ2	Lusaka Small	412.1	2005	0.4	-0.55	0.6	3.1
	Lusaka Large	9909.9	2005	0.4	-0.55	0.6	3.1
AEZ3	Northern Small	3297.7	2005	0.4	-0.55	0.6	3.1
	Northern Large	168.1	2005	0.4	-0.55	0.6	3.1
AEZ3	North western Small	203.0	2005	0.4	-0.55	0.6	3.1
	North Western Large	100.0	2005	0.4	-0.55	0.6	3.1
AEZ1a	Southern Small	79.2	2005	0.4	-0.55	0.6	3.1
	Southern Large	9506.3	2005	0.4	-0.55	0.6	3.1
AEZ1b	Western Small	0.6	2299	0.4	-0.55	0.6	3.1
	Western Large	0.6	2299	0.4	-0.55	0.6	3.1
	Zam Consumption	89660.4	2144				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Davis *et al*., 2008; CIA, 2008)

Table A2.5: Baseline market data: Cotton

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	28679.8	1200	0.67	-0.75	0.6	3.1
	Central Large	552.9	1200	0.67	-0.75	0.6	3.1
AEZ2	Copperbelt Small	65.0	1200	0.67	-0.75	0.6	3.1
	Copperbelt Large	8.4	1200	0.67	-0.75	0.6	3.1
AEZ2	Eastern Small	80864.7	1200	0.67	-0.75	0.6	3.1
	Eastern Large	177.7	1200	0.67	-0.75	0.6	3.1
AEZ3	Luapula Small	0.0	1200	0.67	-0.75	0.6	3.1
	Luapula Large	0.0	1200	0.67	-0.75	0.6	3.1
AEZ2	Lusaka Small	1531.1	1200	0.67	-0.75	0.6	3.1
	Lusaka Large	62.4	1200	0.67	-0.75	0.6	3.1
AEZ3	Northern Small	23.7	1200	0.67	-0.75	0.6	3.1
	Northern Large	0.0	1200	0.67	-0.75	0.6	3.1
AEZ3	North western Small	0.0	1200	0.67	-0.75	0.6	3.1
	North Western Large	0.0	1200	0.67	-0.75	0.6	3.1
AEZ1a	Southern Small	41970.0	1200	0.67	-0.75	0.6	3.1
	Southern Large	717.3	1200	0.67	-0.75	0.6	3.1
AEZ1b	Western Small	533.6	1200	0.67	-0.75	0.6	3.1
	Western Large	26.5	1200	0.67	-0.75	0.6	3.1
	Zam Consumption	155213.0	1200				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Davis *et al*., 2008; CIA, 2008)

Table A2.6: Baseline market data: Sunflower

Agro-Ecological Zone	Region/Farmer	Production (Tons)	Price ZMK '000/Ton	Elasticity		Demand Growth Variables	
				Supply	Demand	Income elasticity	GDP per Capita (%)
AEZ1	Central Small	726.9	1128	0.4	-0.55	0.6	3.1
	Central Large	230.2	1128	0.4	-0.55	0.6	3.1
AEZ2	Copperbelt Small	95.5	1128	0.4	-0.55	0.6	3.1
	Copperbelt Large	9.1	1128	0.4	-0.55	0.6	3.1
AEZ2	Eastern Small	5446.0	1128	0.4	-0.55	0.6	3.1
	Eastern Large	1190.4	1128	0.4	-0.55	0.6	3.1
AEZ3	Luapula Small	36.7	1128	0.4	-0.55	0.6	3.1
	Luapula Large	0.7	1128	0.4	-0.55	0.6	3.1
AEZ2	Lusaka Small	11.7	1000	0.4	-0.55	0.6	3.1
	Lusaka Large	301.5	1000	0.4	-0.55	0.6	3.1
AEZ3	Northern Small	1137.9	1200	0.4	-0.55	0.6	3.1
	Northern Large	16.0	1200	0.4	-0.55	0.6	3.1
AEZ3	North western Small	91.8	1200	0.4	-0.55	0.6	3.1
	North Western Large	0.0	1200	0.4	-0.55	0.6	3.1
AEZ1a	Southern Small	635.8	1200	0.4	-0.55	0.6	3.1
	Southern Large	52.2	1200	0.4	-0.55	0.6	3.1
AEZ1b	Western Small	2.8	1290	0.4	-0.55	0.6	3.1
	Western Large	2.1	1290	0.4	-0.55	0.6	3.1
	Zam Consumption	9987.2	1206				
	Discount Rate	8%					

Source: multiple secondary sources (MACO unpublished; Davis *et al*., 2008; CIA, 2008)

Appendix 3: Baseline Technology Data (Primary Data)

Table A3.1: **Expected yield increase % (expert opinion) smallholder farmers**

Research Institution / Crop	Expected Yield Increase % (Expert Opinion)							Average (%)
	1	2	3	4	5	6	7	
Maize	3	25	3	60	20	10		20
Sorghum	2	25	30	5	30	5		16
Sunflower	2	20	5			5		9
Groundnut	1	15	30	5	30	5		13
Millet		20						20
Soya bean		20	3	2		2		8
Cotton					30	3	60	31

Table A3.2: **Expected yield increase % (expert opinion) large-scale farmers**

Research Institution / Crop	Expected Yield Increase % (Expert Opinion)							Average (%)
	1	2	3	4	5	6	7	
Maize	3	30	10	50	30	10		22
Sorghum	2	20			35	5		16
Sunflower	2	30				5		12
Groundnut	1	20			35	5		15
Millet		15						15
Soya bean		20	10	50		10		23
Cotton					40	5	60	35

Table A3.3: **Maximum expected level of adoption % (expert opinion) smallholder farmers**

Research Institution / Crop	Maximum Expected Level of Adoption % (Expert Opinion)							
	1	2	3	4	5	6	7	Average (%)
Maize	50	50	60	30	60		50	50
Millet	50							50
Cotton					40	60	5	35
Groundnut	60		40		30		50	45
Soya bean	60	20	30	20			15	29
Sunflower	60		50				15	42
Sorghum	50		50		40		35	44

Table A3.4: **Maximum expected level of adoption % (expert opinion) large-scale farmers**

Research Institution / Crop	Maximum Expected Level of Adoption % (Expert Opinion)							
	1	2	3	4	5	6	7	Average (%)
Maize	70	80	80	80	60		70	73
Millet	60							60
Cotton					20	90	20	43
Groundnut	65		30		10		40	36
Soya bean	75	80	80	90				81
Sunflower	75		50					63
Sorghum	70		50		30		35	46

Table A3.5: Expected adoption lag no. of years (expert opinion) smallholder farmers

Research Institution / Crop	Expected Adoption Lag No. of Years (Expert Opinion)							
	1	2	3	4	5	6	7	Average
Maize	12	4	3	5	4		4	5
Millet	10							10
Cotton					5	5	4	5
Groundnut	10		4		5		4	6
Soya bean	8	5	3	5				5
Sunflower	7		2					5
Sorghum	7		2		5		4	5

Table A3.6: Expected adoption lag no. of years (expert opinion) large-scale farmers

Research Institution / Crop	Expected Adoption Lag No. of Years (Expert Opinion)							
	1	2	3	4	5	6	7	Average
Maize	10	3	3	2	3		2	4
Millet	8							8
Cotton					5	3	2	3
Groundnut	8		4		5		2	5
Soya bean	6	3	3	2			2	3
Sunflower	5		3				2	3
Sorghum	5		3		5		3	4

Table A3.6: Annual exchange rate

Yearly exchange rate (2004-2008)				
2004	2005	2006	2007	2008
4800	4500	3600	4000	3700

Source: CIA, 2008; BOZ, 2005