IMPACT OF RAINFALL VARIABILITY AND AGRICULTURAL FACTORS ON MAIZE YIELD IN LUSAKA PROVINCE, 1976 TO 2002

By

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DECLARATION

I, Kamuna Ackim Banda, declare that this dissertation represents my own work. It has not previously been submitted for a degree or any award at the University of Zambia or any other institution. All published work or materials from other sources incorporated in this report have been specifically acknowledged and adequate reference thereby given.

Signed..

Date....2ND JUNE, 2006.

THE UNIVERSITY OF ZAMBIA

APPROVAL

THIS DISSERTATION BY *MR. KAMUNA ACKIM BANDA* ENTITLED: *"IMPACT OF RAINFALL VARIABILITY AND AGRICULTURAL FACTORS ON MAIZE YIELD IN LUSAKA PROVINCE, 1976 - 2002"* IS APPROVED AS FULFILLING THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN GEOGRAPHY OF THE UNIVERSITY OF ZAMBIA.

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ABSTRACT

There are many non climatic factors influencing the agricultural potential of an area, but of the climatic factors, the most important are the distribution in time and the amount of rainfall. The purpose of this study is to probe rainfall variability based on the persistence model which follows a theoretical distribution, and the theory of runs which requires that time series of rainfall data be considered as a success or failure about a selected truncation level. The overall objective of the study was to investigate the rainfall patterns, the agricultural factors, some drought run parameters and the frequency of their occurrence during the period 1976-2002 in relation to maize yields. The methodology included the use of probability sampling techniques, time series analysis, magnitude frequency analysis and the principal axis factor analysis in which 15 variables were correlated yielding six factors which were then orthogonally rotated and their factor matrices interpreted in terms of content of the variables that loaded most highly.

The major findings were that there exists high rainfall variation within Lusaka Province whilst coefficients of variation show that Lusaka Province displays no evident trend. It has been established that it were wet spells in drought years that increased maize yields. Lusaka is prone to one-year droughts with the most severe droughts not being the most intense droughts. It has been discovered that before 1988 few factors influenced high maize yields whilst after 1989 the factors at interplay doubled causing Lusaka Province to plummet in rank in level of production. The conclusion was that there was an increase in the length of the growing season without a corresponding increase in maize yield due to the strong influence of the Southern Oscillation Index and Sea Surface Temperatures on rainfall variability. For purposes of implementing study results, recommendations were made. These included the need for an effective early warning unit, adapting farming to wet spells, improved input provision and marketing, and need for further research on individual agricultural factors. Application of study results should help farmers and agricultural officers in adopting the right kind of farming methods adapted to the changing environment and agricultural practices in the country.

This dissertation is dedicated to all my family members.

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DEFINITIONS OF THE TERMS

Drought year: when the rainfall recorded during the rain year is less than the normal rainfall

Farmer: any person who cultivates maize and any other crop(s) on a farm in peri-urban and urban areas.

Flood year: when the rainfall recorded during the rain year is greater than the normal rainfall.

Growing season: period starting 1st November of that named year to 31st March of the following year.

Inputs: refer to the seed amount and fertilizer supplied in a year.

Large scale farmer: a farmer who cultivates the land of greater than or equal to 20 hectares.

Marketing: here is assumed to be the amount of maize sales in a year

Medium scale farmer: a farmer who cultivates the land of between 5.0 and 19.99 hectares.

Non-rain day: when rainfall recorded on any day is less than one millimetre.

Normal rainfall: refers to the 30 years rainfall average for the three districts in Lusaka Province. These are equal to 816.1mm, 907.7mm and 759.9mm respectively for, Lusaka city, Chongwe, and Kafue districts.

Maize production: the total number of 90kg bags produced in a given area.

Rain day: when rainfall on any day is equal to or greater than one millimetre.

Rainfall intensity: the rate at which rain falls during the hot-wet season.

Rainfall reliability: when rainfall always come at a time it is expected and is of a constant duration, and in the amount almost equivalent to the truncation level.

Rainfall variability: the year to year change of rainfall amounts from the truncation level in terms of both the commencement and the termination of the hot-wet season.

Small scale farmer: a farmer who cultivates land of up to 4.99 hectares.

Yield: the total number of bags harvested per unit area.

ACRONYMS

ANOVA	Analysis of Variance
CSO	Central Statistical Office
ENSO	El Nino Southern Oscillation
IUCN	World Conservation Union
QBO	Quasi-Biennial Oscillation
SO	Southern Oscillation
SOI	Southern Oscillation Index
SST	Sea Surface Temperatures
WMO	World Meteorological Organisation

CHAPTER ONE: INTRODUCTION

1.1 Introduction

There are many non climatic factors influencing the agricultural potential of an area, but of the climatic factors in Zambia, the most important is rainfall in terms of its distribution in time and amount. Thus apart from small areas of irrigated land, almost all agricultural activity is confined to the rainy season. Agriculturally, various factors of the rainfall season are of interest.

Hutchinson (1974) says for most farmers, time is punctuated by the crop cycle and the rain that accompany the shifting zenith of the sun. In some years and in some places, in ways we do not fully understand, the rains lag behind this seasonal shift or seemingly fail all together. In such years the crop cycle is broken and drought ensues. People and nations suffer set backs to their hopes for improved life and livelihood and even, more rarely, death and desolation by famine.

This research sought among other things to:

(a) Identify the full range of possible human adjustment to the hazard and

(b) Study how farmers perceive and estimate the occurrence of drought.

The research further probed the levels of rainfall variability, and the duration, magnitude, intensity and the frequency of drought occurrences between 1950 and 2002 as a way of knowing with accuracy the fundamental properties of drought which would allow for proper planning of drought impact mitigation in Lusaka Province.

In Zambia, the international donor community has provided food and non- food aid towards food relief. For the 1992 and 1995 droughts this was valued at over US $ 70 million (Sichingabula, 1994) and US $40 million (Banda et al., 1997), respectively, which is indicative of the extent to which drought impacts the household food security.

Although a calendar month is normally used as the minimum sampling interval for climate studies, daily amounts can be of interest in terms of "event size" frequency analysis of wet and dry spells. These have been incorporated in this research as well.

There is need for evolving a standard definition of drought. With the problem of quantifying drought still remaining unsolved, it is important that any set of indices selected for characterising drought, besides being a rational combination of climatological parameters, should also be realistically related to the magnitude of the impact on various aspects of the economy (Gupta and Kapoor, 1999). It is in this line that this research also focuses on maize yields during drought years, it being the staple food crop grown in Lusaka Province, in order to evaluate the effects of drought on the agriculture sector of Zambia in general and the Lusaka Province in particular.

1.2 Theoretical background

1.2.1 Dry spell during the wet season

It is important in all types of agriculture to be aware of the possibility of long dry spells during the rainy season. Some of the dry spells can be very significant if their duration is more than 10 days. The distribution of dry spells of dry days (< 0.01 inches) follows a theoretical distribution.

Thus, if q is the probability of a particular day being dry, the probability of a run of dry days is (1-q) q, that is, a wet day, followed by a dry day, if it is assumed that there is no persistence, that is, any day is not affected by the previous day. The probability of a run exactly one day is (1-q) q (1-q), that is, wet, dry, and wet and a run of x days is $(1-q)^2 q^x$ (Hutchinson 1974). However, this random model does not fit the data at all well, so it must be assumed that persistence occurs.

In the persistence model provided by Hutchinson (1974), the probability of a dry day occurring depends on whether the previous day was dry (q_o) or wet (q_1). Thus the probability of a run at least 1, 2, 3------- x days is

$$q_1,\ q_1 q_o,\ q_1 q_o^2 \text{------}\ q_1 q_o^{x-1}$$

And of a run of exactly 1, 2, 3------ x days is

$$q_1 (1-q_o),\ q_1 q_o (1-q_o) \text{---------}\ q_1 q_o (1-q_o)^{x-1}.$$

Statistical analysis of drought requires that time series of rainfall data be considered as a success and failure process in which success is the positive and failure a negative about a selected threshold value. This is the application of the statistical theory of runs (Yevjevich, 1967) which simplifies the analysis of time series of stochastic or deterministic variables such as meteorological and hydrological events which encompass droughts.

In the theory of extreme values, droughts are defined as the smallest annual values with every year producing one lowest value or a drought. But for droughts defined as the basis of water supply and demand, the lowest values are not necessarily deficit amounts because of the possibility that the threshold value for a particular drought may be smaller than the lowest value of the given event.

Yevjevich (1967) has shown that for independent discrete time series of run length (n), one can obtain probabilities of values x greater than X_0 as p and smaller values as q = 1-p. The distribution of run length of size n, n = 1, 2---- is given for an infinite population as $f(n) = qp^{n-1}$

Where f (n) is the probability of a run length of size n. Yevjevich (1967) further observed that the values of p and q may be estimated by the frequencies $Pc = N_1 / N$ and $qc = N_2 / N$, with N_1 as the number of values x above x_o---- and $N_2 = N - N_1$, the number of x values below x_o. The probabilities of run lengths have been shown to be independent of the underlying distributions (Yevjevich, 1967).

1.3 Statement of the problem

The extent of drought occurrence in Lusaka Province is not well known because no study of the physical parameters of drought has been done. Furthermore, Lusaka Province is losing its prestige as the largest maize producer in Zambia by plummeting from the first position to the second during the 1976-1988 and 1989-2002, respectively, as shown by Tables 1 and 2.

Table 1. Maize Production (90kgs bags) for four selected provinces from 1976-1988.

Year	Eastern	*Lusaka	Southern	Northern
1976	120,000	160000	200,000	147,462
1977	221,822	332,267	163,060	612,175
1978	63,694	306,290	234,111	263,979
1979	116,910	250,150	215,250	360,230
1980	379,920	307,492	265,740	384,298
1981	376,508	528,500	338,433	510,500
1982	99,310	802,110	414,600	248,540
1983	289,310	803,129	414,821	549,540
1984	326,995	790,892	514,441	578,594
1985	481,663	791,894	476,924	579,516
1986	537,102	706,140	471,310	515,740
1987	478,186	1,001,199	417,304	417,639
1988	811,470	1,033,678	1,035,934	714,830
Total	4,302,890	7,813,741	5,161,928	5,883,043
Rank	04	01	03	02

*Lusaka Province comprises three districts namely Lusaka, Kafue and Chongwe minus Luangwa district of Lusaka Province.

Source: Ministry of Agriculture and co-operatives (2004).

Table 2: Maize Production (90kgs bags) for four selected provinces from 1989-2002.

Year	Eastern	*Lusaka	Southern	Northern
1989	540,326	509,326	456,082	150,776
1990	283,367	269,855	287,456	103,261
1991	316,108	373,075	185,707	85,602
1992	82,317	212,266	25,215	71,984
1993	339,391	482,254	462,637	120,274
1994	213,845	250,879	193,605	180,862
1995	197,936	191,506	84,455	117,828
1996	375,942	424,385	286,532	113,010
1997	248,093	197,778	251,936	97,251
1998	194,292	167,078	149,386	44,225
1999	284,356	133,774	200,574	62,388
2000	279,964	13,748	251,946	38,523
2001	196,317	220,399	211,281	43,496
2002	202,385	179,010	63,093	38,022
Total	4,337,968	4,233,169	3,648,735	1,432,191
Rank	01	02	03	04

*Lusaka Province comprises three districts namely Lusaka, Kafue and Chongwe minus Luangwa district of Lusaka Province.

Source: Ministry of Agriculture and co-operatives (2004).

Furthermore Table 3 shows that there were fewer droughts (four drought years in 12 years) in Zambia between 1976 and 1988 and it is in this period that the Lusaka Province was ranking first among the only four provinces chosen which are the chief maize producing belts in Zambia as shown in Table 2. But between 1989 and 2002 there was an increase in drought frequency (nine droughts in 13 years).

Table 3: National-wide drought occurrences 1976-2002

Period	Drought years	Frequency over total time
1976-1988	1979,1981,1983,1987	4 droughts in 12 years
1989-2002	1990,1991,1992,1994,1995, 1996,1997,1998,1999	9 droughts in 13 years

Source: Meteorological Department (2004).

It is in this period that the Lusaka Province plummeted in the ranking from first to second position as shown in Table 2. The extent to which agricultural factors are responsible for this decline needed enquiry. The decline in rank is an indicator that there were factors which were causing farmers in Lusaka Province not to produce more than they did before 1989. These factors once identified could be used to design mitigation strategies so that farmers can sustain their production levels.

Lusaka has a population of 1,391,329 (14.1 %) out of Zambia's total population of 9,885,591 (CSO, 2003). This poses a large threat if drought is not thoroughly investigated in that a great population could be affected by drought.

1.4 Objectives of the study

The overall objective of this study was to investigate the drought run parameters and the frequency of their occurrence during the meteorological period 1950 to 2002, and the agricultural factors from the period 1976 to 2002 in relation to maize yields.

Arising from the overall objective are the following six specific objectives:

1. To determine the extreme drought duration for the period 1950 to 2002.

2. To determine the drought intensity for the period 1950 to 2002.

3. To assess rainfall variation and severity of drought in Lusaka Province in the period 1950 to 2002.

4. To show the spatial distribution of severest n-year droughts.

5. To assess impacts and implications of intra-seasonal wet spells on maize yields between 1976 and 2002.

6. To establish the extent to which agricultural factors have affected maize yields between the period 1976 and 2002.

1.5 Research hypotheses

The following six hypotheses were tested in order to attain the above objectives:

1. Intra-seasonal wet spells had significantly increased than intra-seasonal dry spells between the period 1950 and 2002.

2. Droughts had significantly increased than floods during the period 1950 and 2002 in Lusaka Province.

3. Rain-fed agriculture in Lusaka Province is not adapted to the wet spells of drought years.

4. Maize yields in drought years between 1976 and 2002 were increasing with rainfall.

5. There was significant rainfall variation in Lusaka Province.

6. There was a significant correlation between maize yield, inputs and marketing when drought is kept constant.

1.6 Rationale

There is no previous study that has been done to assess the effects of intra seasonal wet spells on crop yields. Nasitwitwi (1998) assessed the effects of dry spells on crop yields. More studies are required on basic drought and impact assessment research (Sichingabula, 1997) because this area of study has almost been neglected in Zambia. Most studies on drought concerning food production in Zambia have been concentrated in the Southern Province (Chifuwe, 1994; Liandu, 1985; Michelo, 1985; Mweebo, 1989; Sichingabula,1994) and at national level (Sichingabula, 1998), but none has been specifically conducted in Lusaka Province.

1.7 Significance of the study

Results will be useful to farmers and agricultural planners to use the right kind of methods in farming as a way of adapting to the changing agricultural environment especially with regard to increased drought occurrences in Lusaka Province.

1.8 Organisation of the report

This dissertation is composed of seven chapters. Chapter One provides the theoretical background to this study and outlines the statement of the problem, objectives and research hypotheses. It also justifies why the study was undertaken. Chapter Two reviews existing literature on the subject in Africa as a whole, East Africa and Zambia. Chapter Three describes the study area in terms of location, size, population density, the physical characteristics, the socio-economic conditions and lastly explains why the area was chosen for investigation.

Chapter Four describes the methods used for the collection and analysis of data, and the study limitations. Chapter Five presents the findings of the study which are discussed in Chapter Six. Chapter Seven summarises and concludes the study with some recommendations made for purposes of implementing study results.

CHAPTER TWO: LITERATURE REVIEW

2.1 Rainfall variability in Africa

A lot of work has been done on rainfall variability in Africa, for example Ogallo (1979) and, Nicholson and Entekhabi (1987) and many others. Most of these studies have used data collected during the instrumental era and therefore do not represent a period long enough to describe climate change satisfactorily. However, their results are good indicators of general trends of climate change on the continent.

Speculations on climate change in Africa have been made by many people. For example, Lamb (1974) suggested that the general circulation of the atmosphere is changing through an equatorial shift of principal climate belt. However, some previous studies on an annual rainfall series for certain African regions have revealed no established trends (Landsberg, 1975). In some cases positive or negative trends have been observed in certain parts of the records. These results although for a short period, show that most of the annual series had generally an oscillatory characteristic without significant trends. The positive or negative trends observed through smoothing the graphs were found to be significantly giving an impression that rainfall in Africa is oscillatory in time.

The series for the sub-Saharan region are very similar all having above normal rainfall in 1930-1940 and 1950-1960; and below normal rainfall in 1910-1920, 1940-1950 and 1968-1984. The negative trend observed after 1968 depicts the severe drought conditions which prevailed in the Sahel in those years. Oscillatory behaviour is also clearly observed in the Northern, Southern Kalahari and East African series. The prominent cycles observed by different authors in the annual rainfall series for different areas in Africa were; 2-2.5, 3.3-4.4, 5-6.5 and 10-12 years (Nicholson and Entekhabi, 1987).

The relationship between SST's in the southern Atlantic and African rainfall has been studied by Lough (1986) for the Sahelian area and Hirst and Hastenrath (1983) for the South Western African region. However, Nicholson and Entekhabi (1987) looked into rainfall variability in equatorial and southern Africa in relation to SST's along the south west coast of Africa, and Nyenzi (1991) looked into the relationship between East African rainfall variability and SST's over both the Indian and the Atlantic oceans.

These studies, although of limited geographic extent, showed evidence that variability of SST's in the upwelling regions is most pronounced on time scales 2-2.5, 3.3-3.8, and five to six years. They also showed the existence of strong relationships with rainfall throughout equatorial and Southern Africa.

Relationships between the southern oscillation index (SOI) and rainfall in Africa have been investigated by Nicholson and Entekhabi (1986). The results suggested a strong influence of the SOI on rainfall variability in Southern Africa and parts of the Equatorial belt. There exists minimal influence in Northern Africa. Coherence with the SOI was particularly strong in the QBO range of 2-2.5 years especially in the tropic and Southern Africa. The co-spectra of the SOI with rainfall series indicated a positive relationship in most cases. Low index values, generally associated with ENSO events, corresponded to drier condition. An exception was over the equatorial sector, that is, 15° South to five degrees North, which was coherent with SOI in the QBO range where the relationship was inverse with wetter conditions corresponding to SO low index values.

The climate change indicators reviewed above for both East Africa and Africa do not seem to suggest direct negative or positive trends. This may be due to the short period of the records available. However, there are evidences of oscillatory behaviour with dominant cycles in the time scale of 2 - 2.5, 3.3 - 4.4, and 5 - 6.5 years.

2.1.2 East African rainfall variability

Most studies on East African rainfall variability have shown that rainfall fluctuations within East Africa are homogeneous (Nyenzi, 1991). Most series show average precipitation during the 1950's and well above average during the 1960's. The series which show a definite trend over the period of record is that of Northern Kenya. The

Lodwar series with an upward trend might have been affected by changes in the observation site or other local factors (Nyenzi, 1991). Results obtained in other studies in East Africa and other tropical areas associated 2 - 2.5 year's peak with the QBO and the five to six years peak with the SO phenomenon. The 3 - 3.5 year's peak has not been associated with any physical phenomena although it has also been observed in other studies of tropical rainfall over the Pacific Ocean (Nyenzi, 1991). These results suggest that East African rainfall is either indirectly or directly modulated by sea surface temperatures (SST's) over the Atlantic and Indian oceans. The clearest linkages of SST's with rainfall variability for East Africa are in the ranges of five to six years.

2.1.3 Rainfall variability in Zambia

Hutchinson (1974) says although mean values of rainfall are indicative of the general rainfall regime, variation from the mean have just as important an effect on man's response to climate; for example, the dry 1972 / 73 season reducing the maize crop by up to 50 % in some areas.

Hutchinson (1974) further says for annual rainfall, since the normal distribution is so well known instead of presenting a table of probabilities, a distribution map of standard deviation, taken for 116 long term stations in Zambia is given.

Throughout Zambia, the value of the standard deviation is about one quarter that of the annual rainfall. This is relatively a high figure, indicating that there is the probability that rainfall will be less half normal one year out of forty. For some areas 1972 / 73 was that year.

2.2 Types of drought

According to Gupta and Kapoor (1999) droughts may be broadly classified into three

types; meteorological, hydrological, and agricultural.

Meteorological drought is a situation whereby there is a significant decrease from climatologically expected and seasonally normal precipitation over a wide area. This drought is marked with depletion of surface water and consequent drying of the reservoirs, lakes, streams and rivers, cessation of spring flows and fall in ground water levels or it may necessitate curtailment of power generation and affect industry as well as agriculture.

Hydrological drought is the situation whereby the volume of rainfall that falls during a given season is unable to produce good stream of flow yield for power generation. Agricultural drought is a situation whereby soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and cause extreme crop stress and wilting.

2.3 Drought occurrence and the implications of drought occurrence in Zambia.

According to Sichingabula's (1998) study, drought in Zambia occurs every year as there is always a part of the country experiencing below normal rainfall. Probability of drought occurrence is lowest in the wettest northeastern area (34 %) and highest in the driest southwestern area (66 %). For most of the country this was found to be 50 %. The droughts of 1924,1933,1946,1949 and 1965 impacted more than 80 % of the 46 districts. The 1949 event was the most wide spread and impacted the greatest area (92 %). The 1987 and 1992 drought each impacted 90 % and 88 % of the country's area, respectively.

Thus, based on the historical records (1921-1996) droughts covering more than three quarters of the country could be expected at least once in a decade. Whenever centers of drought were located in high rainfall areas, drought generally impacted more than 80 % of the country's area causing severe suffering among the local people.

Tiffen and Mulele (1994) state that rainfall in Zambia is unimodal due to the southern movement of the Inter-Tropical Convergence Zone (ITCZ) and this caused the southern half of Zambia to be the worst affected by the 1992 drought. Tiffen and Mulele (1994) further state that the main areas affected by the 1991-92 drought were the low and medium rainfall zones, which include some of the more highly populated rural areas of Zambia, and the provinces normally producing a surplus of maize for sale to urban areas.

Implications of drought in Zambia include people migrating to wetter areas, planting drought resistant crops and early maturing grain varieties, death of livestock due to thirst and hunger, poor nutrition among the people and less income due to less crop yields (Muzumara, 1990; Banda, 2001; Mwenda, 2002).

2.4 The impacts of meteorological drought in Zambia.

Although drought is mostly associated with negative impacts and effects, it is, however important to note that it also brings positive effects in some areas. This is particularly true in the study by Chifuwe (1994) in Monze where drought had positive effects which included the construction of feeder roads, dams and wells, grain storage bins and employment provision through the food for work programme. Liandu (1985) found that in Masuku, Choma district, drought caused high numbers of cattle deaths which led to malnourishment due to low milk intake and poor diet by the local people.

Michelo's (1985) study demonstrates that drought in Zambia continues to create household food insecurity as revealed in Monze where crop yield fell during the drought years of 1982, 1983 and 1984, respectively, as follows: maize by 52 %, 40 % and 29 %, sunflower by 57 %, 37 % and 40 %, groundnuts by 50 %, 29 %, and 26 %. In this same study it was found that due to drought cattle sales generally increased by 125 % among peasant farmers who were the most affected by drought than emergent and commercial farmers.

Studies have predicted that drought can lead to accelerated desertification in some areas. Sichingabula (1994) doing a regional study of drought impact in the entire Southern Province of Zambia discovered that persistent occurrence of droughts up to 10 year duration could witness a northward movement or advancement of the Kalahari desert in

Southern Zambia, migration of sand dunes presently fixed by vegetation and increased human suffering.

According to Chipeta (1998), Zambia has experienced several droughts with those occurring between 1921 and 1930 being more severe. He further states that 1930-1950 was alternated by rapidly wet years, but on the whole, the rainfall season was relatively good. In southern Africa, moderate droughts were reported between 1930 and 1931, 1932 and 1933 and, 1946 and 1947.

Chipeta (1998) further contends that the 1967-1968 heralded the beginning of a period of successive dry years across Africa. From 1981-1992 wet years were rare and drought was normal for most of the years. In 1981-1982 drought intensified. In 1991-1992 Zambia experienced what is described as one of the worst droughts during the century. According to Chipeta (1998) the causes of drought from a meteorological point of view are the weakness in rainfall producing mechanism and the El Nino effect which is the warming of the SST's in the Pacific Ocean at certain years causing wet and dry conditions on some parts of the globe. It should however be noted that not all El Nino are associated with droughts in Zambia. The 1997-1998 El nino had two effects on the weather of Zambia, that is, excessive rain in the northern half and normal to below normal in the southern half.

CHAPTER THREE: DESCRIPTION OF THE STUDY AREA

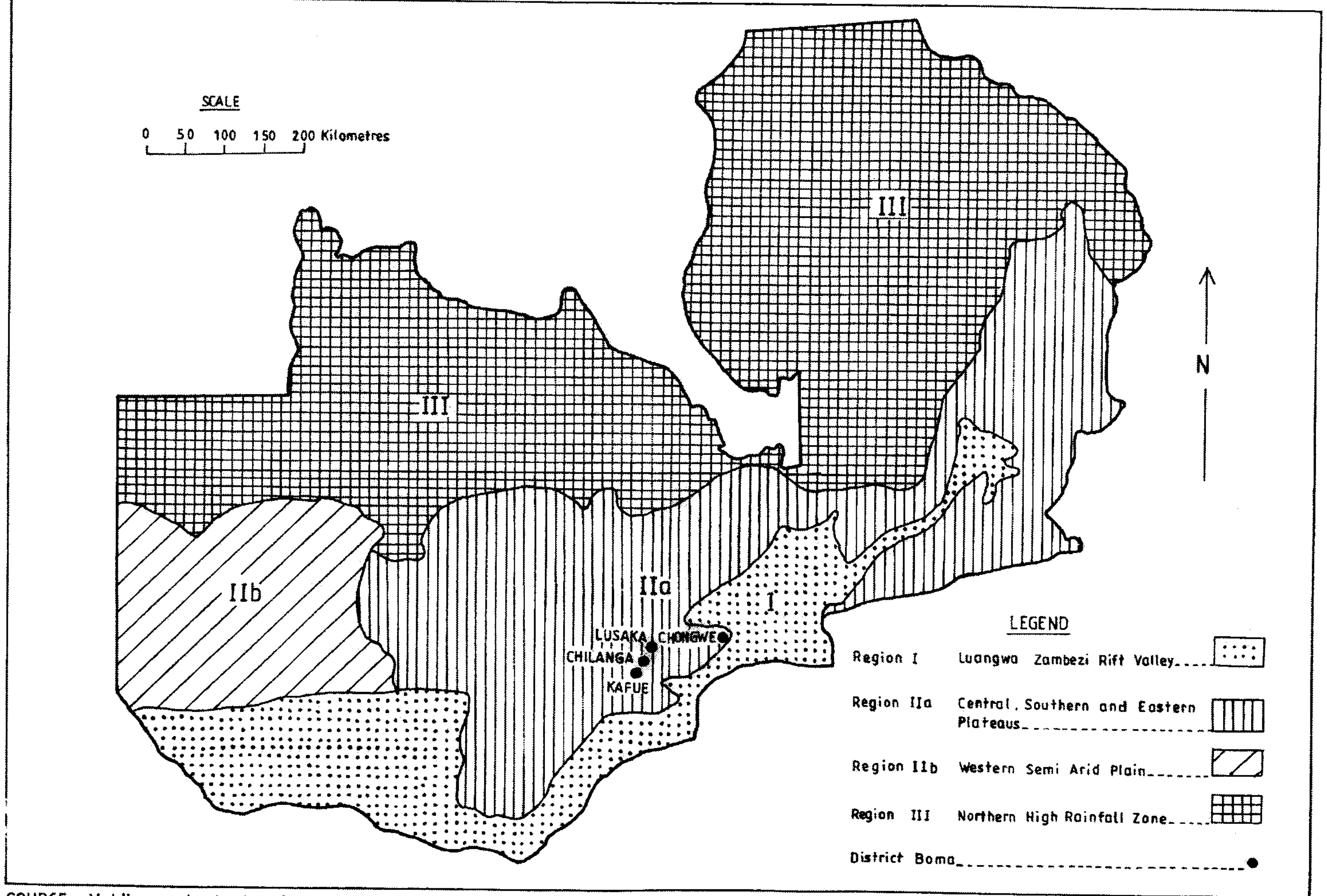
3.1 Introduction

Lusaka Province has four districts, namely, Lusaka, Chongwe, Kafue and Luangwa. The Province extends from 27 ° 45¹ East to 30 ° 26 ¹ East and 14 ° 40 ¹South to 16 ° South. It has an area of 21,896 sq. km and a population of 1,391,329 people (CSO, 2003) giving a population density of 64 people per square kilometre. Lusaka Province is inhabited by people of different tribes but the Soli are indigenous to Lusaka and Chongwe districts and parts of Kafue.

3.2 Physical setting/physical characteristics

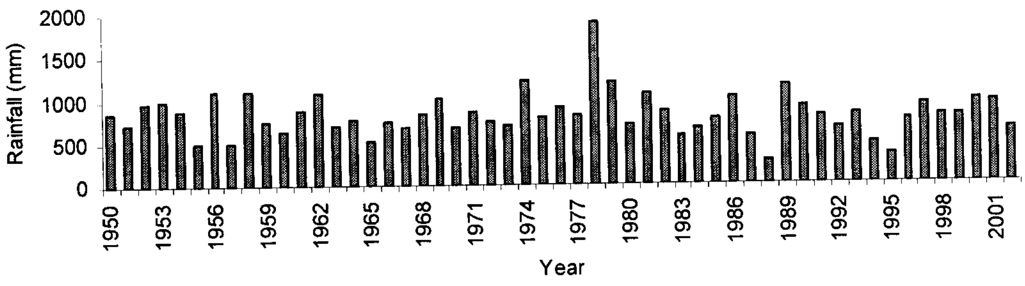
Lusaka Province is drained by three major rivers, namely, Kafue, Chongwe and Lunsemfwa. It is dominated mainly by the sand veldt soils. It lies in the middle veld of Zambia which has an altitude of between 900metres and 1200metres above sea level. Three districts out of the four lie in the agro-ecological zone IIa, which comprise the central, southern and eastern plateaus and which receive annual rainfall of between 800mm and 1000mm. Luangwa district lies in agro-ecological region one which comprise the Luangwa and Zambezi rift valleys and which receives annual rainfall of less than 800mm. This is shown in Figure 1.Furthermore, three districts out of the four have meteorological stations which have up to date statistics of climatic parameters of periods greater than 30 years. These are Lusaka, Kafue and Chongwe. Lusaka has 52 years, Kafue 45 years and Chongwe 35 years. The long term rainfall means are 816.1mm, 759mm and 907.7mm for Lusaka, Kafue and Chongwe Districts, respectively. Luangwa District has no meteorological station. Lusaka Province as a whole has 52 years on record and a long term mean of 863.1mm. Figures 2 to 5 below show the annual rainfall distributions for each of the three districts as well as for Lusaka Province. Note that the calculation of rainfall amounts for Lusaka Province is explained in chapter four. It should be noted that although Luangwa District is part of Lusaka Province, it is not part of the study area. The reason for its exclusion is explained in chapter four.

Figure 1. THE AGRO-ECOLOGICAL REGIONS OF ZAMBIA



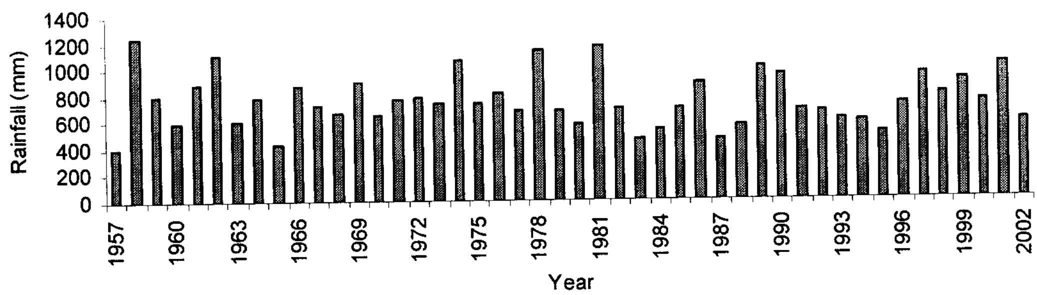
SOURCE : Veldkamp et al., (1987)

Figure 2. Annual rainfall distribution in Lusaka Province (1950-2002)



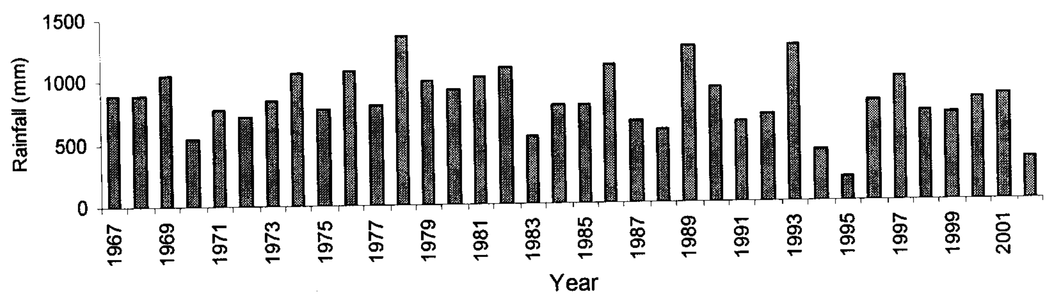
Source: Department of Meteorology (2005).

Figure 3. Annual rainfall distribution in Kafue District (1957-2002)



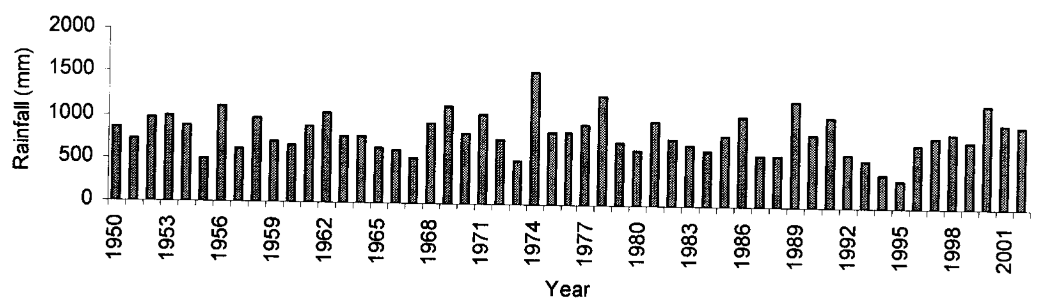
Source: Department of Meteorology (2005).

Figure 4. Annual rainfall distribution in Chongwe District (1967-2002)



Source: Department of Meteorology (2005).

Figure 5. Annual rainfall distribution in Lusaka District (1950-2002)



Source: Department of Meteorology (2005).

3.3 Socio-economic conditions

Most people in Chongwe district are engaged in agriculture especially dairying, poultry, cultivation of maize and market gardening whilst those in Kafue district are employed in local manufacturing industries and also engage in fishing on the Kafue river. The people of Lusaka district are mostly employed in the informal sector such as small scale quarrying and trading in assorted merchandise. It is only a small percentage of people in Lusaka district that are employed in the formal sector.

3.4 Reasons for the choice of the study area

The study area was chosen because of the following reasons:

(1) Some relief agencies especially the Catholic Relief Services have during drought periods concentrated on impact reduction by offering relief maize to the drought victims as shown in Table 4.

Table 4: Value of relief food supplied to the victims in Lusaka Province in drought years by the Catholic Relief Service.

Drought period	Amount of maize (90kg bags) supplied	Amount of rice (50kg bags) supplied	Kwacha equivalent
1990 – 1992	38,056	11,250	390,280,000
1994 – 1999	69,315	28,629	1,141,680,000
TOTAL	107,271	39,879	1,531,960,000

Source: Catholic Relief Services (2001).

Although this is good, it may not be sustainable since it is only dealing with the effects or symptoms and not addressing the root cause. The whole region (Lusaka Province) has therefore been chosen for investigation in order to increase the level of awareness and preparedness in handling of future droughts on a sustainable basis.

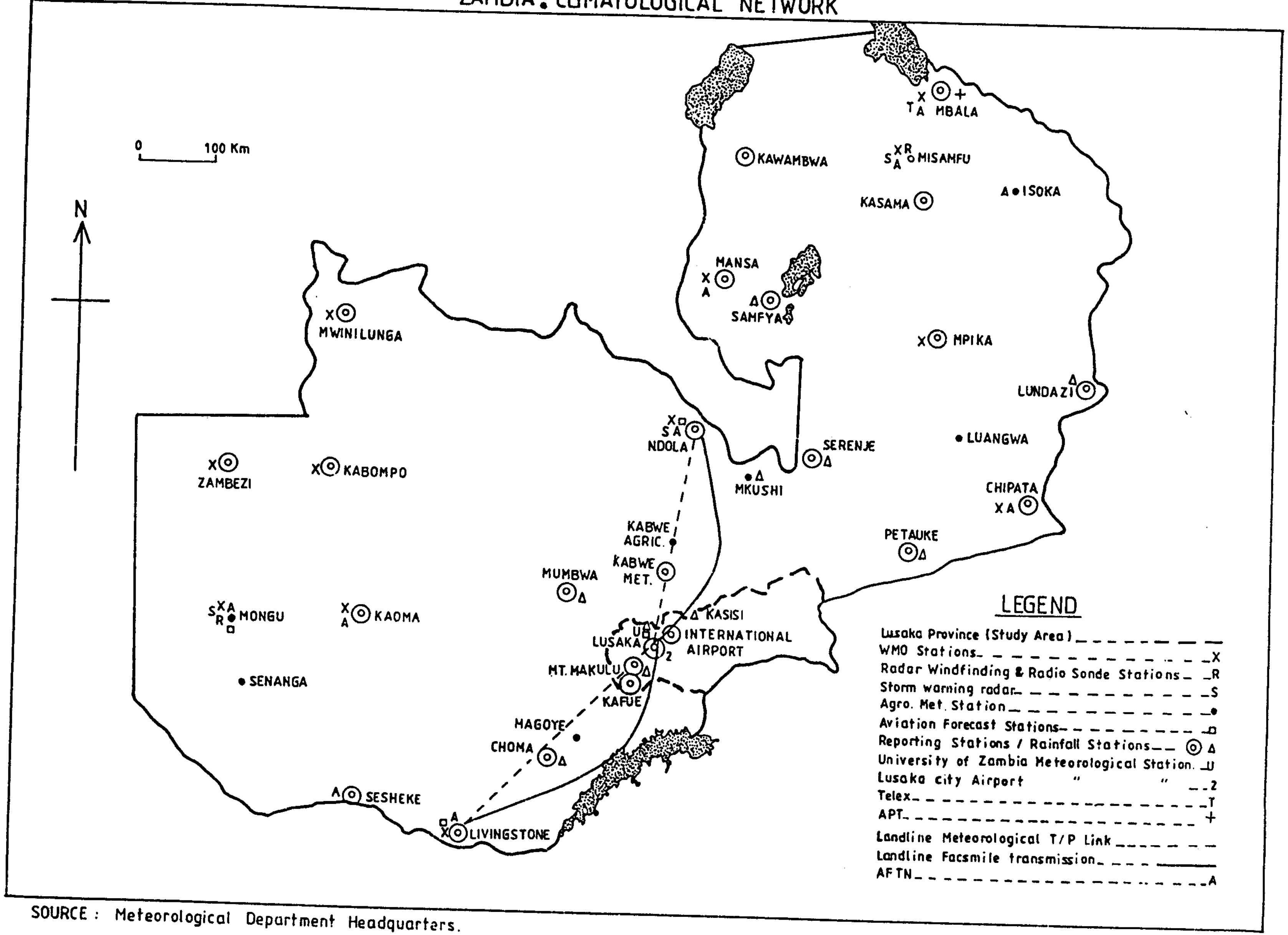
(2) It is one of the regions which has a large number of rainfall gauging stations in Zambia (six in total), a requirement for accurate assessment of rainfall variability as shown by Figures 6 and 7.

Further more there are accurate and constant climatic parameter recordings at these stations because of their location in the central part of Zambia, due to the vital and quality needs of rainfall data for agricultural research at research stations, aviation purposes at the airports, and hydrological assessments for industrial and domestic water provision.

(3) Most studies done have partially covered Lusaka Province. None of the studies has focused on investigating variations within the three districts of Lusaka Province in terms of rainfall and crop yield.

FIGURE 6

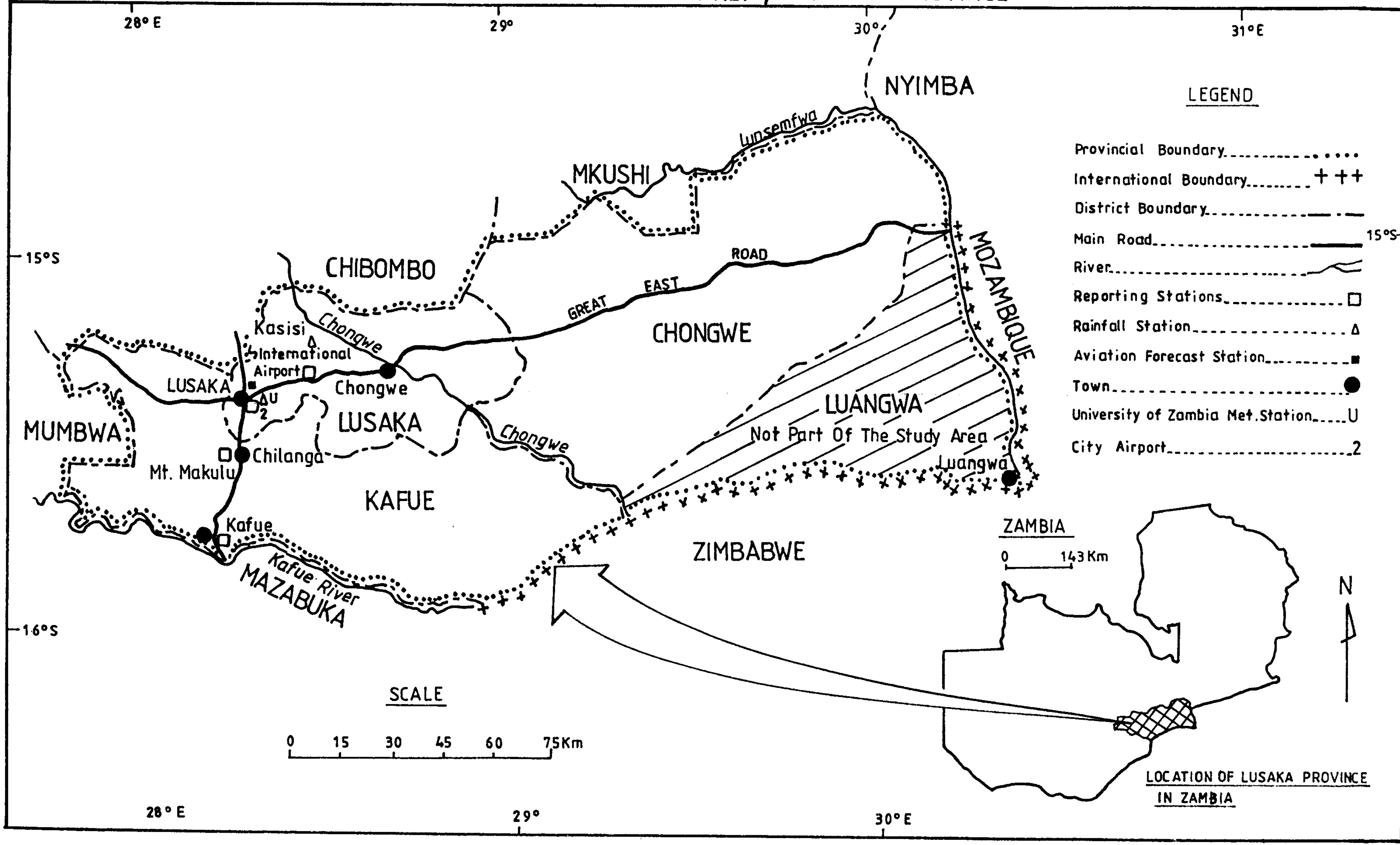
ZAMBIA: CLIMATOLOGICAL NETWORK



SOURCE: Meteorological Department Headquarters.

Figure 7

LOCATION OF STUDY AREA, LUSAKA PROVINCE



CHAPTER FOUR: METHODOLOGY AND ANALYSIS

4.1 Types and sources of data

In order to achieve the objectives and test the hypotheses of this study, the following sampling techniques and data types from different sources were used:

4.1.1 Primary data

An interview schedule was administered to farmers. The schedule sought among other information the seed type used, problems faced by the farmers, crops grown, cultivation practices, farmers' perception of drought, impact of dry and wet spells on maize growth and the farmers' drought coping strategies (see Appendix 1).

4.1.2 Secondary data

Precipitation (rainfall) data were obtained from the Meteorological Department Headquarters in Long acres, Lusaka. Note that the rainfall amount for Lusaka Province was computed by adding annual rainfall values of the three meteorological stations, namely, Chongwe, Lusaka and Kafue in the respective years and then obtaining the annual mean. No one station is called Lusaka Province.

Crop yields statistics were obtained from the Early Warning Unit of the Ministry of Agriculture and Co-operatives, at Mulungushi House in Lusaka.

The sampling frame (list of farmers in the three districts of Lusaka Province) was obtained from the Central Statistical Office Headquarters. Data on marketing and input provision was obtained from the Zambia National Farmers Union Head Office., Lusaka. Literature review was done at the University of Zambia main library, the British Council and American libraries and on the internet.

4.2 Sampling techniques

A total of 42 farmers were interviewed out of 372 farmers in the three districts, using an interview schedule. A combination of the stratified random sampling and the lottery method of the simple random sampling technique were used. In choosing the sample size, the main determining factors were time and financial resources which allowed only a sample of 11.3 % of the population to be interviewed. This sample size was however large enough to reduce the sampling error and it ensured a proportional representation of the three different categories of farmers in the three strata (districts), namely, Lusaka, Chongwe and Kafue. The criteria for farmer (sample) selection included type of seed used, accessibility to irrigation, marketing strategies used, inputs used among other reasons. The breakdown of the farmers was as follows:

•Small scale farmers selected were 22 out of 198
•Medium scale farmers selected were 16 out of 144
•Large scale farmers selected were four out of 30

The farmers were drawn from each of the three districts (stratum) in which meteorological stations had up-to-date data on precipitation. The sample size was drawn using the following procedure described in Appendix 2.

Each cell in Table 5 below is multiplied by F = 1 / 9 or 0.11 to obtain the proportional number of farmers required as shown in the corresponding cells in Table 6.

Table 5: Sampling frame for agricultural surveys/farmers based on the 2000 Zambian census frame for Lusaka Province.

District	Number of farmers			TOTAL
	Small scale farmers	Medium scale farmers	Large scale farmers	
Chongwe	99	72	14	185
Kafue	96	63	11	170
Lusaka Urban	03	09	05	17
TOTAL	198	144	30	372

Source: Central Statistical Office (2004)

Table 6 below shows determined sample numbers of farmers in each category after multiplying district population by 0.11, the conversion coefficient.

Table 6: Selected stratified random sample of farmers for Lusaka Province based on the 2000 census frame for Zambia.

Number	District	Number of farmers			TOTAL
		Small scale farmers	Medium scale farmers	Large scale farmers	
01	Chongwe	11	08	02	21
02	Kafue	11	07	01	19
03	Lusaka Urban	00	01	01	02
	TOTAL	22	16	04	42

Secondly, after stratification (Table 6), the lottery method of the simple random sampling was employed to draw farmers in each district by writing the farm plot numbers on pieces of paper and putting them in a box, mixing them thoroughly, and drew the required number of farmers without replacement. The list was compiled and the selected individual farmers were approached for interviews.

To achieve the seventh objective and to ascertain the major elements responsible for the change in maize production levels between the periods 1976-1988 and1989-2002, the units of measure used are listed in Appendix 3.

4.3 Limitations and assumptions for the data use and analysis

4.3.1 Missing rainfall data

The rainfall records obtained from the Meteorological Department Headquarters had gaps in the data set which created "climatic noise". Chongwe (Lusaka International Airport) had one year (1993) missing whilst Lusaka City had had five years (1968-1972) missing. To overcome this problem the missing values were estimated by calculations using the formula provided by Viessman et.al, (1989) listed in Appendix 4.1.

4.3.2 Crop yield data

The records obtained from the Ministry of Agriculture and Co-operatives early warning unit at Mulungushi House started from 1976. As such analysis concerning crop yields of maize, cotton and sorghum cover the period 1976-2002.

Furthermore, the data has an error estimate of 13 % which is too large too yield excellent results. The data set also lacked data on household yields since the Ministry of Agriculture and Co-operatives uses crop forecast at district, provincial and national level. The data set also does not include amounts that are retained by the farmers for their use such that consumption data was absent. However to overcome this limitation an assumption was made that consumption was equal to maize production minus maize sales. Thus, when production and sales figures were available consumption was obtained as a residual.

4.3.3 Region homogeneity

Agro-ecological region IIa uses temperature and rainfall for its definition (Dent and Young, 1981). It has almost the same:

(a) length of growing season and this depends on the difference between the 70% dependable rainfall and evapotranspiration.

(b) Number of dry 10 day periods (dekads)

(c) occurrence of frosts

(d) sunshine hours and

(e) mean monthly temperature.

The assumption made is that all factors including rainfall are constant throughout these districts of Lusaka Province because they all lie in agro-ecological region IIa hence being similar in the climate characteristics described above (see Figure 1).

4.3.4 Rainfall data

A number of techniques have been developed to assess the homogeneity of precipitation data (Alexandersson, 1986). They rely on the basic assumption that precipitation at one location maintains a constant ratio to a composite index of precipitation at a network of nearby stations (Cf. Bradley, 1976, p.29). Thus, the problem of precipitation networks not being sufficiently dense in Lusaka Province to allow one to assess the reliability of the particular record by comparison with adjacent station records was taken care of.
Furthermore, to solve homogeneity of precipitation problems, the alternative taken was to study precipitation trends at only a few "bench mark" climatological stations (Karl and Quayle, 1988), which were selected as being relatively free of biases that produce

inhomogeneities in their records. For this project, three of the six stations are in Lusaka Province (see Figure 7).

Since at the present time, very few comprehensive large scale assessment of precipitation data homogeneity have been carried out, the general approach used was to average a large number of what climatologists consider to be the best quality station records for a given region (in this case Lusaka Province) and assume that data inhomogeneity problems at individual stations are randomly distributed in time, such that the net effects of the biases are largely cancelled out.

According to Thorn (1966) the gamma distribution fits rainfall data for most time intervals. Rainfall amounts are in theory zero bounded continuous variables with positive skewness, that is, the long tail to the higher values. The amount of skewness decreases as the time interval increases, so that annual rainfall approaches a normal distribution for all practical purposes. Since the duration of this study was 52 years, it was assumed that the skewness had been eliminated and therefore that the data set for this project had approached a normal distribution to allow for the use of robust statistical techniques.

4.4 Analysis

The analysis of data involved the use of several statistical techniques to test the research hypotheses and to achieve the study objectives.

4.4.1 Determination of drought parameters

Three drought run parameters were determined using the analytical definitions provided by Sichingabula (1998), namely,

(1) Drought severity determined as the cumulative percentage departure of the n-year drought from normal rainfall.

(2) Drought intensity determined as the ratio between cumulative departures from the normal rainfall of n-year drought to n-year drought, and

(3) The run length determined as the time between successive failures from the normal rainfall, indicating duration or n-year.

Drought frequency was determined as the number of drought occurrences in a 52-year period (1950-2002) expressed as a percentage of time.

The probability of drought (P) and the recurrence interval (T) were calculated using the formulae given in Appendix 4.2.

The mean durations of wet and dry spells were calculated using the formulae given below:

$$\text{The mean duration of wet spells} = \frac{\text{Total number of rain days}}{\text{Total number of wet spell intervals}}$$

$$\text{The mean duration of dry spells} = \frac{\text{Total number of non-rain days}}{\text{Total number of dry spell intervals}}$$

4.4.2 Rainfall analysis

Analysis of rainfall data was based on the years on record for precipitation amounts presented in Table 7:

Table 7. Rainfall records of selected stations in Lusaka Province.

Rainfall station	Years on record	Long term mean (mm)	District name
Lusaka international airport/Chongwe	1967-2002 (35 years)	907.7	Chongwe
Kafue	1957-2002 (45 years)	759.9	Kafue
Mount Makulu (under Kafue)	1961-2002 (41 years)	840.4	Chilanga/Kafue
Lusaka city airport/Lusaka urban.	1950-2002 (52years)	816.1	Lusaka

Source: Meteorological Department (2004).

Rainfall variability and drought analysis used long term means (30-year rainfall) for the three stations, namely, Lusaka, Chongwe and Kafue which have more than 30 years on record and also because their years on record are greater than five years which were used to calculate the five- year moving mean for the data since the maximum period is only 52 years. Chilanga was not analysed because it is not a district. Luangwa was not analysed because it has no meteorological station and it is in agro ecological region one which is different from the other three districts of Lusaka Province.

Graphs of actual rainfall amounts were plotted together with the moving means to establish the levels of rainfall variations within Lusaka Province as well as by calculating and plotting the coefficient of variations.

Maize yields statistics including that of sorghum at both the Central Statistical office and the Ministry of Agriculture and Cooperatives Early Warning unit only exists from 1976. This is the reason why objective five and hypothesis four have 1976 to 2002 as their period of analysis.

The following rainfall statistical values were determined:

(i) Mean = $\Sigma x / n$; (ii) Standard deviation, $S = \sqrt{\frac{\Sigma x^2 - (\Sigma x)^2 / n}{n - 1}}$;

(iii) Coefficient of variation, $Cv = S / x * 100\ \%$; (iv) coefficient of skewness = a / s^3; and (v) moving averages.

ANOVA was used to test the fifth hypothesis in order to determine whether rainfall varied significantly in the three districts of Lusaka Province. The student't' test was employed to test the first and second hypotheses. Simple bar graphs were used to show the rainfall trend from 1950-2002. Graphs of actual rainfall amounts were plotted together with the moving means to establish the levels of rainfall variations in Lusaka as well as by calculating and plotting the coefficient of variation.

Trend graphs were employed to ascertain whether maize yields in drought years were significant. The partial and multiple correlation techniques were used to test the sixth hypothesis, that is, to ascertain whether there was a significant correlation between maize yield, inputs and marketing when drought was controlled for.

Lastly, both the principal component analysis and the factor analysis techniques were used to achieve the sixth objective, that is, to establish the extent to which agricultural variables have affected maize yields. A principal axis factor analysis was conducted on the correlations of 15 variables. Six factors were extracted with Eigen values equal to or greater than 1.00. These six factors were then orthogonally rotated using the method of Varimax with Kaiser normalisation and the loadings of the six factors are shown in the rotated factor matrix. The meanings of these factors were then interpreted in terms of content of the variables that loaded most highly on them.

4.4.3 Socio-economic analysis

Methods of percentage, mean, mode and range were used to analyse the data that was collected from the interview schedule.

CHAPTER FIVE: FINDINGS

5.1 Introduction

This chapter presents results of the study obtained based on the analysis conducted on the data collected as described in Chapter Four.

5.2 Drought duration, intensity and severity

Drought run parameters revealed that the most intense n-year event in terms of magnitude was the 2-year (1987-1988) drought with -51.35 % departure from the normal rainfall followed by the 1-year drought of 1957 with -41.8 % with the least intense being the 1-year (1977) drought with -6.9 % as shown in Table 8.

Table 8. Ranking of intense droughts in Lusaka Province 1950-2002

Rank	Magnitude of n-yr drought (years)	Period	Magnitude of severity (%)	Drought intensity (%)
1	2	1987- 88	- 102.7	-51.35
2	1	1957	- 41.8	-41.8
3	1	1955	-41.6	-41.6
4	1	2002	-27.7	-27.7
5	6	1991-96	-161.1	-26.85
6	2	1959-60	-41.5	-20.75
7	1	1980	-18.6	-18.6
8	6	1963-68	-110.7	-18.45
9	4	1982-85	-72.0	-18.0
10	4	1970-73	-58.1	-14.53
11	1	1975	-9.1	-9.1
12	2	1950-51	-18.16	-9.08
13	2	1998-99	-18.0	-9.0
14	1	1977	-6.9	-6.9

On severity, the severest n-yr drought in terms of magnitude were the droughts of 1991-1996, 1963-1968 and 1987-1988 with -161.1 %, -110.7 %, -102.7 % departures from the normal rainfall, respectively. The least severe was the 1-year (1977) drought with only -6.9 % strength as shown in Table 9.

Table 9.Ranking of severe droughts in Lusaka Province 1950-2002

Rank	Magnitude of n-yr drought (years)	Period	Magnitude of severity (%)
1	6	1991-96	-161.1
2	6	1963-68	-110.7
3	2	1987-88	-102.7
4	4	1982-85	-72.0
5	4	1970-73	-58.1
6	1	1957	-41.8
7	1	1955	-41.6
8	2	1959-60	-41.5
9	1	2002	-27.7
10	1	1980	-18.6
11	1	1975	-9.1
12	2	1998-99	-18.0
13	2	1950-51	-18.16
14	1	1977	-6.9

Table 10 shows that Kafue had been more prone to 1-year droughts followed by Lusaka and Chongwe. Lusaka experienced more 2-year droughts than Kafue and Chongwe which had the same frequency (30%). Only Chongwe had experienced a 3-year drought. All the three districts experienced similar frequency in terms of 4-year droughts. Kafue did not experience any 5-year drought whilst Chongwe did not experience any 6-year drought during the period 1950-2002.

Table 10. The frequency of n-year droughts by district in Lusaka Province (1950-2002)

n-year drought	Lusaka District	Kafue district	Chongwe district	Total frequency
1	5	10	3	18
2	4	3	3	10
3	0	0	1	1
4	1	1	1	3
5	1	0	1	2
6	1	1	0	2

These results have been mapped as shown in Figure 8 in order to achieve the fourth objective. Figure 8 shows that 1-year, 2- year and 4-year droughts were widespread and affected all the three districts of Lusaka Province whilst the 3-year and 6-year drought affected only Chongwe district and Lusaka and Kafue districts respectively and were not widespread.

The student 'Z' test for the frequency of droughts being more significant than flood of 0.05 level of significance yielded tcalc 6.48 which is greater than tcrit at 95 % accuracy. We therefore reject Ho and accept H_1. This proves the second research hypothesis correct that droughts had significantly increased than floods in Lusaka Province during the period 1950-2002. The standard deviation in the rainfall data was 228.68 mm.

The student 'Z' test for the frequency of intra-seasonal wet spells being more significant than intra-seasonal dry spells during the meteorological period 1950-2002 at 0.05 level of significance yielded tcalc 3.77 which is greater than tcrit . Therefore Ho was rejected and H1 accepted. Intra-seasonal wet spells had significantly increased than intra-seasonal dry spells between 1950-2002.The first research hypotheses has been proven correct.

Figure 8 THE DISTRIBUTION OF N-YEAR DROUGHTS IN LUSAKA PROVINCE (1950- 2002).

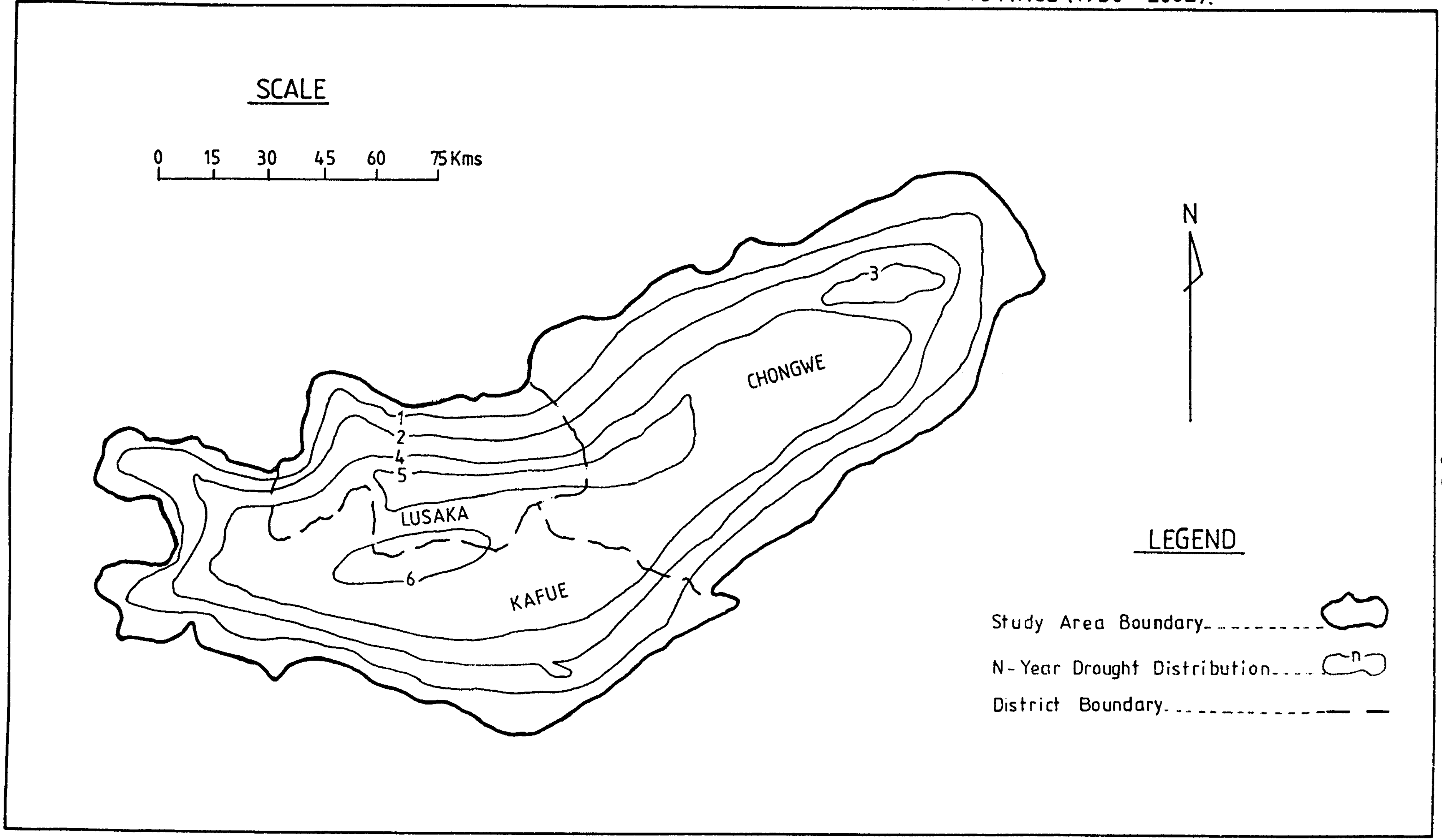


Figure 9 for the magnitude frequency analysis revealed that the relationship between recurrence interval and rainfall amount is non-linear and that low rainfall amounts have longer return periods than high rainfall events which are more frequent. This shows that drought magnitude decreases with increasing recurrence interval.

5.3 Rainfall variation and drought occurrence

One (1)-year droughts occurred 11.3 % of the time, 2-year droughts in 7.5 % of the time whilst 4-year and 6-year droughts each occurred 3.8 % of the time with no records of a 3-year and a 5-year drought having been experienced (Table 11).

Table 11. Percentage occurrence of n-year droughts in Lusaka Province (1950-2002)

n-year drought	Frequency (n)	Frequency (%)
1	6	11.5
2	4	7.5
4	2	3.8
6	2	3.8

To determine the rainfall variation in the three districts of Lusaka, the use of ANOVA revealed that **F** calc 3.96 is greater than **F** crit, 0.05, df 2,129=3.06. Therefore, Ho is rejected and H_1 is accepted implying that there was a significant rainfall variation in the three districts of Lusaka Province.

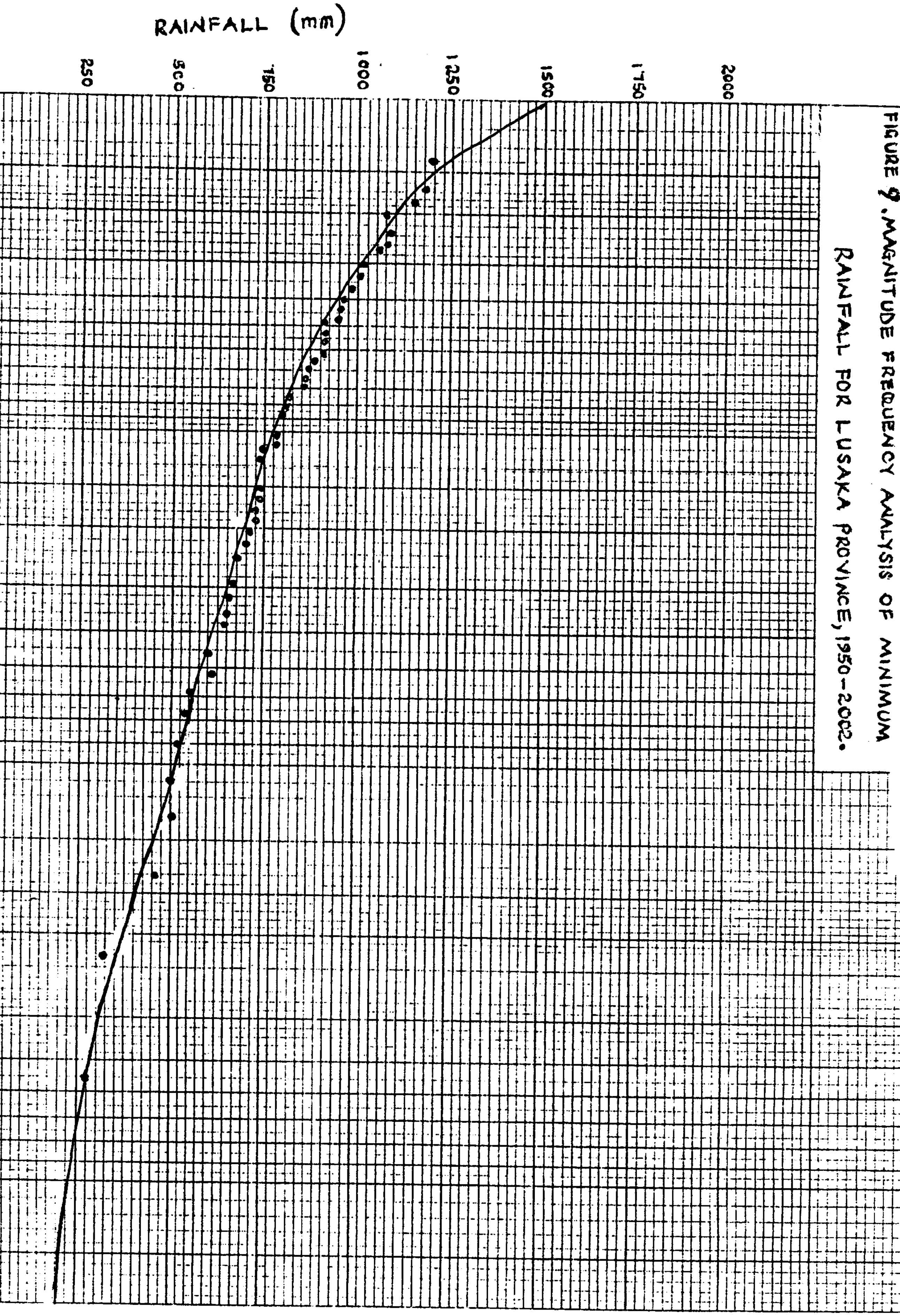


FIGURE 9. MAGNITUDE FREQUENCY ANALYSIS OF MINIMUM RAINFALL FOR LUSAKA PROVINCE, 1950–2002.

Analysis of rainfall in the three districts using the coefficients of variation showed that Lusaka district (Figure 10) and Kafue district (Figure 11) have many positive trends with Chongwe district (Figure 12) having a moderate upward trend and Lusaka Province as a whole (Figure 13) showing no evident trend.

Figure 10. Rainfall coefficients of variation for Lusaka District (1950-2002)

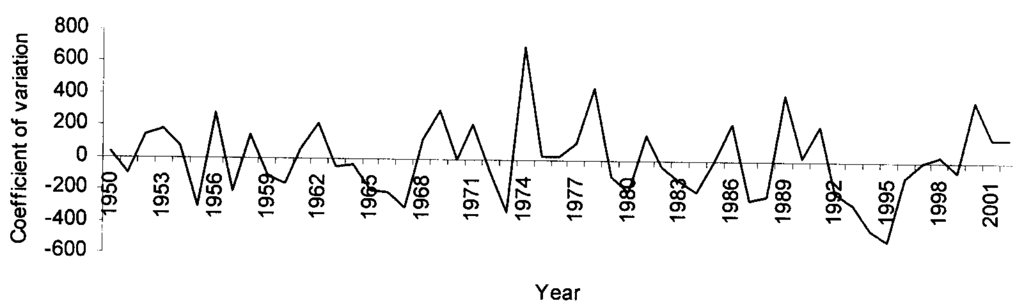


Figure 11. Rainfall coefficients of variation for Kafue District (1957-2002)

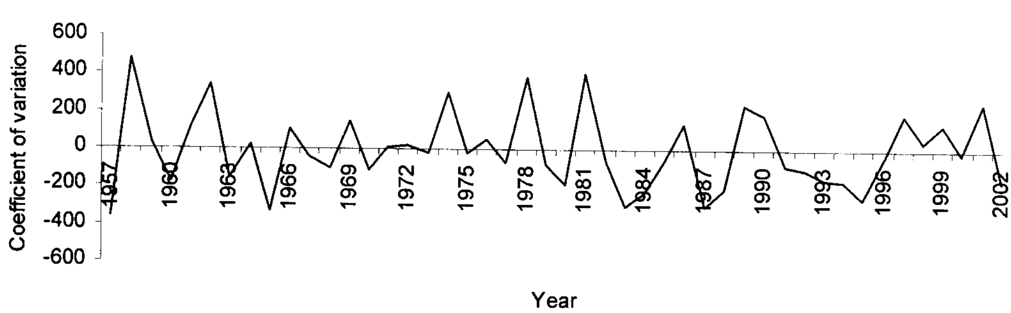


Figure 12. Rainfall coefficients of variation for Chongwe District (1967-2002)

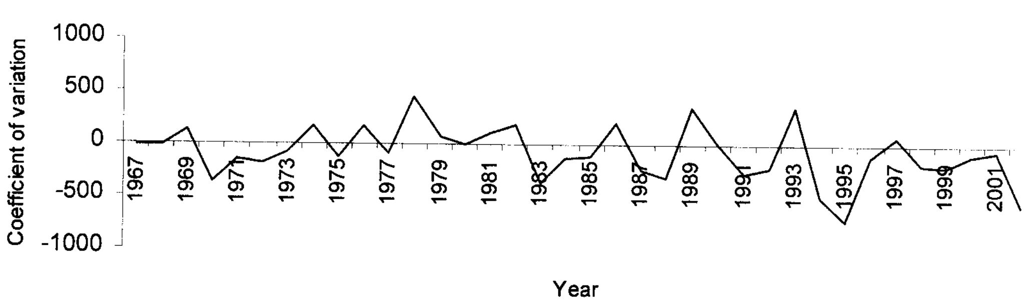
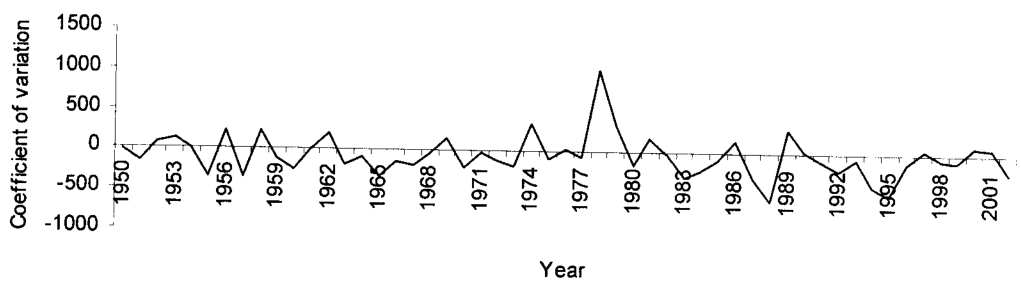


Figure 13. Rainfall coefficients of variation for Lusaka Province (1950-2002)



The overall drought frequency for Lusaka Province was calculated to be 64.2 %. Further analysis for the three districts of Lusaka Province revealed drought frequencies of 52.8 %, 56.5 % and 63.9 % for Lusaka, Kafue and Chongwe districts, respectively, as shown by Table 12.

Table 12. Percentage of drought frequency in Lusaka province

Area	Period	Drought year	Total years on record	percentage frequency of drought occurrence
Kafue district	1957-2002	26	46	56.5
Lusaka district	1950-2002	28	53	52.8
Chongwe district	1967-202	23	36	63.9
Lusaka Province	1950-2002	34	53	64.2

5.4 Relationship between rainfall and crop yields

Trend analysis for maize, cotton and sorghum yields between 1976 and 2002 show that yields were generally increasing with increased rainfall (flood years) and also decreasing in years of reduced rainfall (drought years) as shown in Figures 14 to 16 below:

Figure 14. Trends in rainfall and maize yield in Lusaka Province (1976-2002)

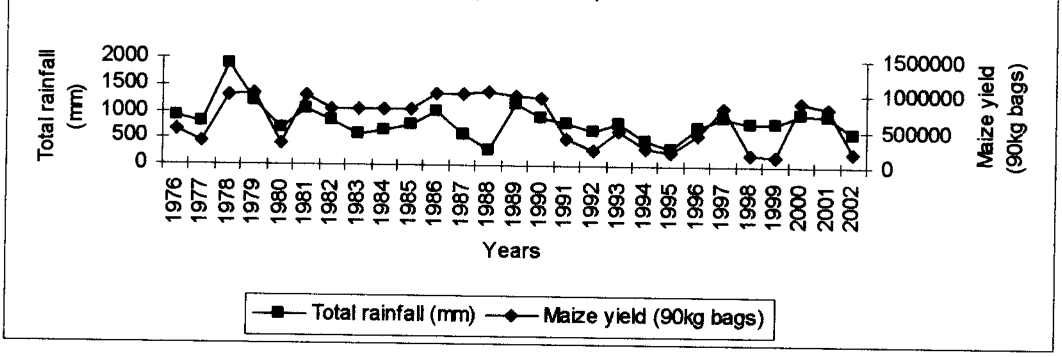


Figure 15. Trend in rainfall and sorghum yields in Lusaka Province (1976-2002)

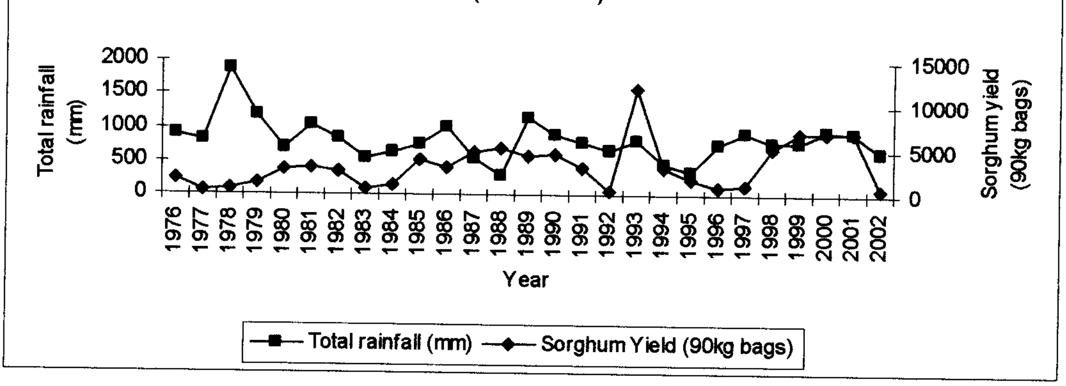
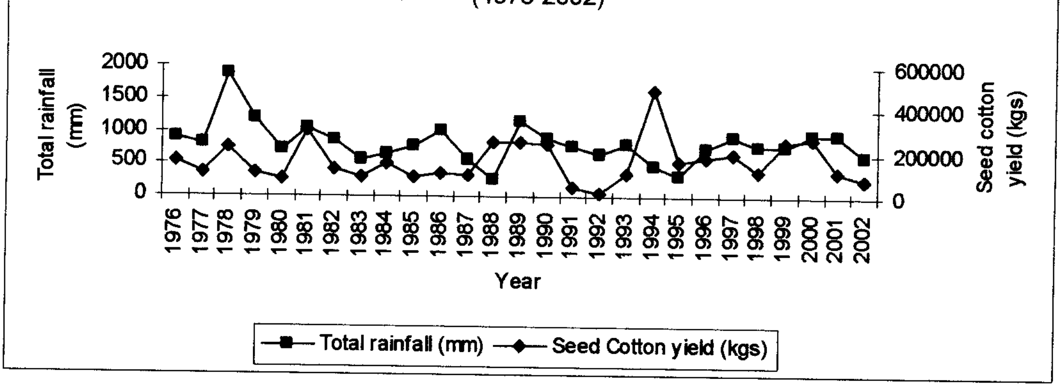


Figure 16. Trend in rainfall and seed cotton yield in Lusaka Province (1976-2002)



It was difficult to distinguish crop production of small scale farmers to that of medium scale farmers and large scale farmers in relation to how they were affected by drought due to absence of data at the Ministry of Agriculture and Co-operatives for the individual category of farmers. The crop yield data available at the Ministry of Agriculture and Co-operatives are only combined aggregates. Despite this limitation, the interview schedule however revealed that the small scale farmers stated that their yields were very low in drought times due to not having access to irrigation. The medium scale farmers and large scale farmers responded that crop yields were the same or even more in some drought years because they utilised irrigation to offset rainfall deficiency. Based on this finding, it can be stated that small scale farmers were impacted more negatively by drought than either medium scale farmers or large scale farmers.

Analysis of trends in historical rainfall using the 5-year moving averages for all the three districts, namely, Lusaka (Figure 17), Chongwe (Figure 18), Kafue (Figure 19) and Lusaka Province as a whole (Figure 20) showed some similarity in certain periods. For example, most series showed average precipitation between 1962-1967, 1989-1993, and well above average between 1968-1970 and 1993-2000 with below normal rainfall mainly being experienced between 1955 and 1995. This finding of below normal rainfall between the years 1955 and 1995, shown in the trend analysis of rainfall in Figures 17-20, corresponds with the drought durations in Chapter 5.2 where the n-year droughts occurred in 1963-1968, 1987-1988 and 1991-1996.

Figure 17. Trends in historical rainfall for Lusaka District (1950-2002)

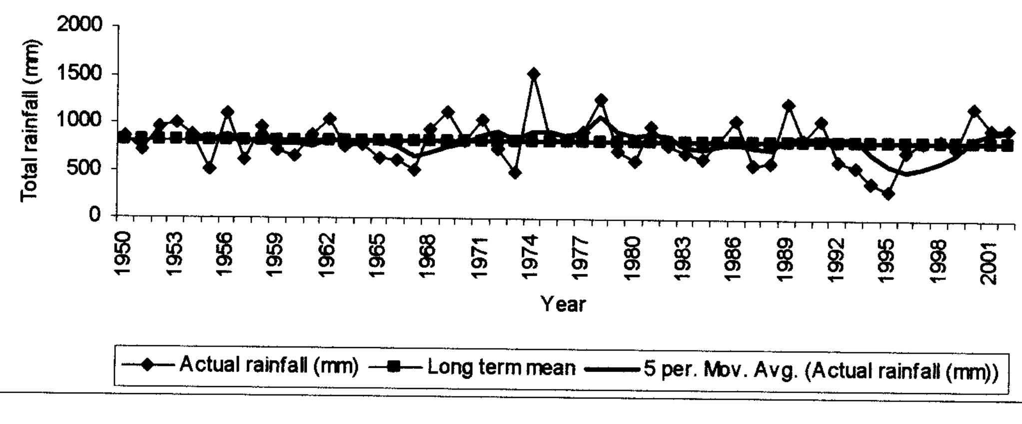


Figure 18.Trends in historical rainfall for Chongwe District (1967-2002)

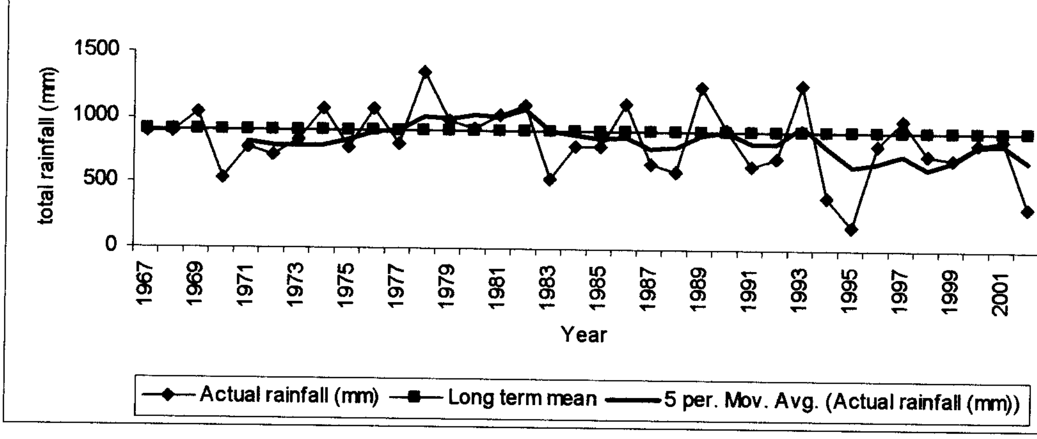


Figure 19. trend in historical rainfall for Kafue District (1957-2002)

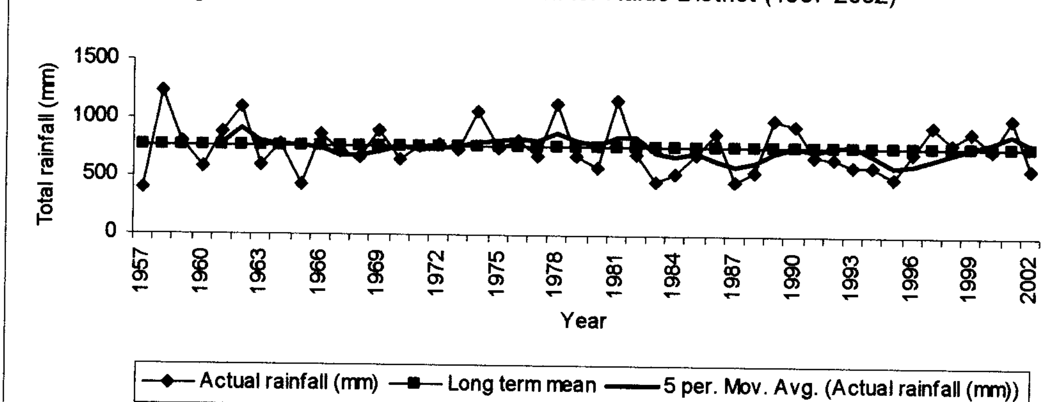
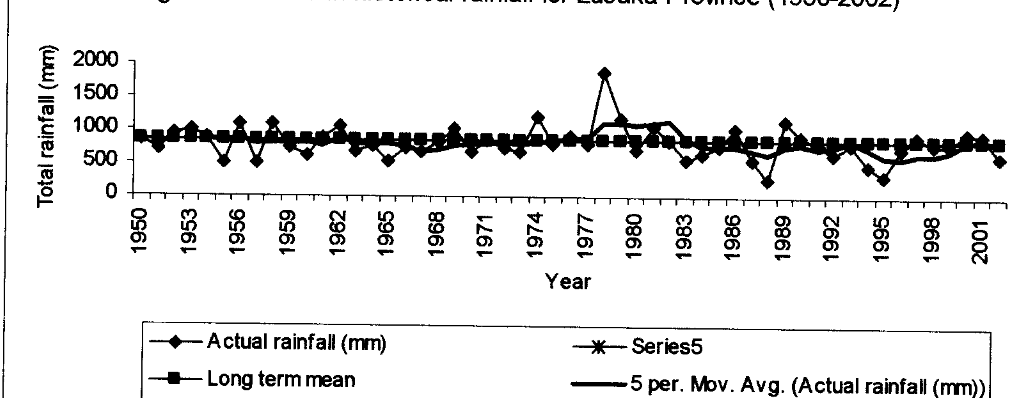


Figure 20. Trend in historical rainfall for Lusaka Province (1950-2002)



5.5 Effect of agricultural factors on maize yields

The Principal Component Analysis and factor analysis involved, firstly, the determination of simple correlation of variables. Table 13 shows the simple correlation matrix between the climatic and non-climatic variables. Clearly some pairs of variables are highly correlated, with that between seed and area, fertiliser and area, and that between fertiliser and seed having the highest direct and perfect co-efficient of 1.000. Any co-efficient with a value greater than |0.400| is significant at 95 % significance level.

The Principal Component Analysis and factor analysis then involved the determination of two sets of analyses, one for the period 1976-1988 and the other for 1989-2002.
Six components in each case provided explanation of over 86 % of the variation in the original data, and, although the explanation may be improved by including more components, this analysis, only included those components having Eigen values greater than 1.0. This is because factors having Eigen values less than one consist of uninterpretable error variation. The Appendices 5.1 and 5.2 show the weights, which can be between +1.0 and -1.0, ascribed to each element. By convention weights greater than |0.7| are considered important, although all variables were included in calculating the component scores.

In Appendix 5.1, component one, was heavily weighted towards non-climatic variables, namely, maize (0.799), sales (0.714), area (0.857), fertiliser (0.857) and seed supplied (0.857). Component two was weighted in favour of climatic variables, namely, rain days (0.791) and non-rain days (-0.788). Components three to six were not weighted out towards any variable. The loadings in factors three to six were harder to interpret for set one. These factors were safely ignored because they did not contribute heavily to the total communality.

Table 13. Simple correlations between agricultural variables.

factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
maize yields	1														
maize sales	**.960**	**1**													
area	**.512**	**.415**	1												
seed supplied	**.512**	**.415**	**1.00**	1											
fertiliser supplied	**.511**	**.415**	**1.00**	**1.00**	1										
pressure	-.290	-.198	-.372	-.372	-.372	1									
temperature	-.093	-.118	.134	.134	.134	.348	1								
rainfall	-225	-.267	-.279	-.279	-.279	.010	-.077	1							
evaporation	.094	.113	.171	.171	.171	-.128	-.193	**-.470**	1						
sunshine hours	.153	.117	-.059	-.059	-.059	.004	-.071	**-.440**	.251	1					
rain days	-.081	-.058	-.091	-.091	-.090	.004	-.024	-.020	.200	-.271	1				
wind speed	-.299	-.190	-.189	-.189	-.188	-.067	.041	-.156	.314	.033	.269	1			
non-rain days	016	-.010	.037	.037	.036	.012	.015	.061	-.194	.250	**-.989**	-.272	1		
wet spells	**-.405**	-.355	-.165	-.165	-.165	.257	.034	.071	.177	-.262	.338	.179	-.281	1	
dry spells	-.371	-.357	-.206	-.206	-.206	.280	.043	.036	.083	-.128	.245	.146	-.173	**.906**	1

The Appendix 5.2 data had higher loadings present in all the six components as compared to Appendix 5.1which only loaded highly in two components. In appendix 5.2, component one was heavily weighted towards input variables of area, seed supplied and fertiliser supplied with all of them having 0.968 loadings. Component two loaded highly towards rainy and non-rain days with loadings of 0.960 and -0.972, respectively. Component three loaded heavily towards rain episodes with dry spells having 0.929 and

wet spells having 0.928 loadings. Component four emphasised marketing with maize yields loading 0.836 and sales of maize loading 0.840. Component five emphasised evaporation and the factors affecting evaporation. Evaporation itself loaded 0.719, rainfall -0.814 and sunshine =0.712. Component six only emphasised heat with temperature loading 0.878.
In terms of communality of the variables, these are shown in Appendix 5.3 and Appendix 5.4. The Appendix 5.3 shows the fraction of the total communality for each variable shared with others. It is evident that 53.3 % (8/15) of the variables shared over 90 % of the variability. Area, fertiliser supplied and seed supplied each shared the highest variability of 98.45 % with other variables. These were followed by non-rainy days (94.7 %), maize (93.3 %) and dry spells (90.95 %). Wind speed had the least communality with the other variables with only 64.4 % shared variability.

Results in Appendix 5.4 are quite similar to those in Table 13. In Appendix 5.1, 53.3 % (8/15) of the variables shared over 91 % of the variability Area, seed supplied and fertiliser each shared the highest variability of 98.6 % with other variables. This was followed by rain days (95.7 %), non-rain days (95.6 %), wet spells (95.1 %), and wind speed had the least communality with other variables with only 65 % shared variability.

5.6 Effect of agricultural factors on maize yields when rain is controlled for

To test the sixth hypothesis, partial correlation coefficients of four variables, namely, maize yield, maize sales, seed supplied and fertilizer supplied were determined and results presented in Appendix 6.

The maximum probabilities obtained were seed=1.5 %, P (maize) =0.6 %, P (fertilizer) =1.5 % and P (sales) =0 %. Probability =. gives a perfect correlation of 1.000 and no level of significance is given for this value as it never varies since the variable is correlated with itself.

that when maize yield, inputs (seeds and fertilizer) and sales (marketing) are correlated when rainfall in drought years between 1976 and 2002 is held constant, Ho is rejected and H_1 is accepted at 5% error. Therefore there was a significant correlation between maize, inputs and sales when rainfall in drought years is controlled for. The sixth hypothesis is therefore proven correct.

5.7 Socio –economic data

The sample interviewed comprised 33.3 % female farmers and 66.7 % male farmers whose age range was from 27 years to 73 years with the mean age being 55.4 years. Only 7.1 % of the respondents did not have title deeds to their land (farms/fields) whilst 92.9 % of them possessed title deeds. The farmers had stayed in their respective farming areas for a mean period of 19.9 years over a range of 10-32 years. On average, the farmers had been cultivating maize for a mean period of 16.5 years over a range of eight to 30 years. In terms of crops the farmers grew, the mode revealed that farmers cultivated three crops although the range was from one to five crops. The crops grown are classified as grains, tubers, fruits, vegetables, beverage crops and legumes as shown in Appendix 7. On the seeds used, 57 % of the farmers used both local and hybrid seed varieties. Most farmers (61.9 %) used seeds which were drought tolerant and 64.3 % of the farmers did not use seeds adapted to wet spells. The mean hectarage cultivated by the farmers was 4.33 hectares whilst the range was from 0.01-25 hectares.

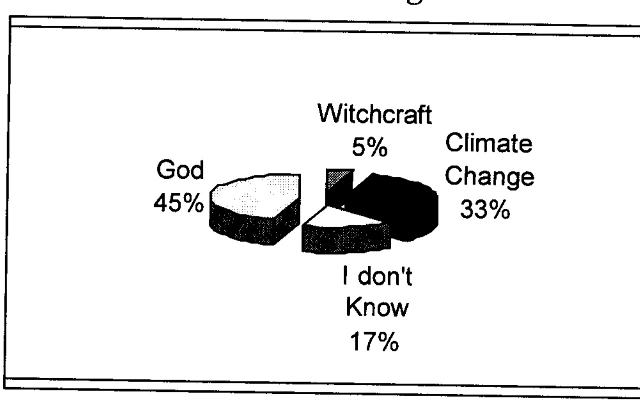
On whether the farmers had ever used irrigation, 78.6 % said yes and 21.4 % said no. Most farmers (69 %) also managed to plant maize at the right time whilst 31 % failed to plant maize at the correct time. Comparing maize yields in drought and flood years, 54.8 % of the farmers stated that the yields were the same, 2.3 % said the yields actually increased whilst 42.9 % of the farmers said yields declined.

The farmers described the rainfall in the past eight years as normal (52.4 %), erratic (42.8 %) and as plenty (4.8 %). The farmers also stated that when rains were late, 73.8 %

of them experienced crop failure, and 83.3 % of them said they experienced bad yield when the rain was not adequate for crop growth. All the farmers described their places as good for farming in terms of soils and other conditions. Most farmers (64.3 %) had experienced drought and despite this condition, 59.5 % of the farmers did not change the crops to grow, 57.1 % of them did not change farming techniques and 64.3 % of them did not change places where to cultivate. In both cases, when there were prolonged wet and dry spells, the farmers said the maize yields were bad to levels of 57.1 % and 66.7 %, respectively.

During drought times most farmers (83.3 %) struggled to survive by rationing foodstuffs whilst 14.3 % said they survived by God's grace. Asked as to what the farmers thought caused droughts, 5 % attributed it to witchcraft, 33 % to climate change, 45 % to God and 17 % had no idea as to what the cause was (Figure 21).

Figure 21. Causes of drought.



Source: Field data

Asked on whether the farmers kept records of their annual maize harvests, the majority (69%) of them did not. Asked on whether the farmers sold all their maize, 76.2 % said they did not. They did retain an average of 15 by 50kg bags with a range of six -32 (50kg) bags which they used for hiring labour (11.9 %), feeding their livestock (31 %) and for home consumption (57.1 %). On what the farmers thought were the positive effects of drought, they stated among other answers, that it had taught them the importance of food preservation and rationing, it had made them alert not to take weather for granted, it had helped their communities build infrastructure through the food for work programme, and drought gave them an opportunity to receive food aid. The negative effects of drought that were cited included loss of income, hunger, drying up of streams, water rationing and electricity load shedding. On the education levels of the respondents, 4.8 % had primary education, 45.2 % had secondary whilst the majority (50 %) of them had tertiary education. This implied that 100 % of them had been to school indicating that the farmers were reasonably literate.

CHAPTER SIX: DISCUSSION

6.1 Drought occurrence

Lusaka Province can be considered to be a drought prone area because drought years occurred most of the time 64.2 % and flood years occurred 35.8 % of the time. At district level, Chongwe was the most prone to drought (63.9 %) followed by Kafue (56.5 %) and Lusaka (52.8 %). An earlier study by Sichingabula (1998) revealed that the probability of drought occurrence for Lusaka Province was 58 %. This study has however showed that the probability of drought occurrence was 64.2%. In this regard, this study has demonstrated that the drought situation in Lusaka Province has worsened since there are less flood occurrences than droughts. The finding that Lusaka was a drought prone area was further confirmed by the revelation that droughts had been more significant than floods. Lusaka Province was most prone to 1-year droughts (11.3 %). This had further been confirmed by the finding which showed that 1-year droughts in all districts summed up to 18, 2-year droughts to 10 with the least being the 3-year drought which occurred once. It should be noted that drought frequency for Lusaka Province had been done without the study of factors responsible for the commencement and termination of droughts because it was beyond the scope of this project. More prognostication of atmospheric processes need to be made before head way can be made in this direction. According to Gupta and Kapoor's (1999) definition of a severe drought, Lusaka had only suffered five severe droughts which occurred in 1963-1968, 1970-1973, 1982-1985, 1987-1988 and 1991-1996.The remaining droughts ranking from six to 14 were not severe (Table 9). A comparison of drought severity to drought intensity revealed that the most severe droughts were not necessarily the most intense droughts except for only the 1-year (1977) drought which was both the least severe and least intense drought with -6.9 % magnitude in both parameters. The magnitude frequency analysis of minimum rainfall (Figure 9) also reinforced the second hypothesis where H_1 had been accepted by it being non-linear showing the presence of significant drought prevalence in Lusaka Province. This non-linear distribution which exists between rainfall and recurrence interval makes planning for droughts and floods in Lusaka Province highly difficult because of the stochastic nature of the rainfall amounts received.

6.2 Rainfall variation and crop yields

The trend analysis of maize yield and rainfall (Figure 14) show that between 1976 and 1986, maize increased and dropped when rainfall also increased and dropped. It was only between 1987 and 1989 that the trend was defied because rainfall declined whilst maize yield increased. The probable reason why maize yield increased when rainfall decreased between 1987 and 1989 was that the distribution of wet spells was even despite the total rainfall sum being less. The timing of wet spells is very helpful in agriculture since it boosts soil moisture needed for plant growth. From 1990 to 2002 we observed maize yields increasing and decreasing with the same pattern occurring in rainfall amounts. It is therefore valid to argue that it is not totals of rainfall received in drought years that affect yield, but rather how the rainfall is distributed in terms of the frequency of wet spells which is of value to the farmers. This was also demonstrated by the high factor loading in Principal component analysis of wet spells in both sets one and two where the loading were 0.566 and 0.929 in factors two and three, respectively.

This study revealed that sorghum yields reduced in all the years which had rainfall amounts above 1000mm. This is probably because Sorghum is a drought resistant crop needing less rainfall and therefore high rainfall quantities have a negative effect on its yield (Nasitwitwi, 1998). Sorghum was used as a control experiment to show yield between a drought tolerant crop and that which is not, such as maize.

This study also revealed that seed cotton yield displayed a cyclic pattern with time. This implied that, on average, cotton yield increased with increased rainfall once after a consecutive period of two years of low or decreased rainfall (Figure 16) except in the years 1984-88 and 1994 where the trends defied each other by seed cotton yield being opposite to rainfall amounts received. The cyclic pattern of seed cotton is similar to that of sorghum. This too can be attributed to Nasitwitwi (1998) who stated that cotton is also a drought tolerant crop, hence its behaviour and that of sorghums are similar.

Given these findings, it is valid to argue that intra-seasonal wet spells had significantly increased more than intra seasonal dry spells during the period 1950-2002. This was beneficial to farmers and it could safeguard the income levels of the farmers if only the farmers adopted using long wet spell tolerant seed varieties in their agriculture. It was saddening to note that 64.3 % of farmers responded that they did not use wet spells tolerant seed varieties. Thus, more enlightenment is needed on their part so that they know that the plummeting situation in Lusaka's rank as a chief maize producer could be reversed if only they would adapt their rain-fed agriculture to wet spells. With the increased prevalence of drought occurrence in Lusaka Province (64.2 %), adapting agriculture to wet spells is the key to having household and provincial food security.

6.3 Rainfall variability

This study has demonstrated that rainfall fluctuations in Lusaka Province are homogeneous. This implies that rainfall distribution in all the three districts and Lusaka Province as a whole occur in a similar pattern or fashion. Years of higher rainfall (floods), average rainfall and low rainfall (droughts) occur in the same periods or years thereby yielding a uniform trend in terms of the spatial distribution of rainfall. It is however important to note that below normal rainfall between 1955 and 1985 could be associated with the occurrence of El Nino during these periods (Nicholson and Entekhabi, 1986; Chipeta, 1998).The high rainfall variation existence within Lusaka Province as discovered by the acceptance of H_1 is in conformity with the results obtained by Nicholson and Entekhabi (1986) who investigated the relationship between the Southern Oscillation Index [SOI] and rainfall in Africa. Their results suggested a strong influence of SOI on rainfall variability in Southern Africa where coherence with the SOI was particularly strong in the Quasi Biennial Oscillation [QBO] range of 2-2.5 years especially in the tropics and Southern Africa, where Zambia lies. The possible mechanisms postulated to be coupling African rainfall and SOI include equatorial and sub-tropical zone flow, modulation of Hadley circulation intensity, planetary waves in mid-latitude, and Sea Surface Temperatures [SST`s]. It is also felt that the mechanisms are probably area specific.

6.4 Causes of Lusaka Province plummeting in rank in level of maize production

The results from Principal component analysis and factor analysis show that during the first period 1976-1988, maize yields were high (0.799) and the sales were also high (0.714). This was because only few factors (four in total), namely, area cultivated, seed supplied, fertilizer supplied and rain days were at play as shown in components one and two (Appendix 5.1).The hectarage of maize and the provision of inputs (fertilizer and seeds) each had a high loading of 0.857 as shown by the factor loadings in component one. Rain days were significant (0.791) as shown in component two, thereby encouraging high yields of maize to be produced since inputs were available. This was the reason why Lusaka Province ranked first in Zambia in terms of maize production during the period 1976-1988.These factors are evident by their higher loadings in components one and two.

Conversely, in the period 1989-2002, we see more factors (10 in total) affecting maize yields and these loaded highly in all the six components. It is worthy noting that in the period 1976-1988 (Appendix 5.1), five factors loaded heavily in component one whilst for Appendix 5.2 (1989-2002) only three factors loaded highly in component one. Maize yield and marketing/sales load had significantly reduced from almost 0.8 in Appendix 5.1 to less than 0.4 in Appendix 5.2. This reduction could explain why Lusaka Province plummeted in rank to second position in terms of maize yields during this period. Component two in both Appendices 5.1 and 5.2 all had two factors, namely, rain days and non-rainy days loading highly. These are uniform in each case. It is interesting to note that component three in Appendix 5.2 loaded heavily in dry and wet spells whilst rainfall received in drought years in this period had a strong negative load (-0.814) in component five. These loadings further provide strong evidence as to what the role wet spells and rainfall play in affecting maize yields. Earlier, simple correlation in Table 13 revealed that maize yields declined with increased rainfall hence the negative loading (-0.23). But wet spells had a higher positive loading of 0.928 and this supports Table 13 were wet spells correlate significantly with maize yields (|.405|). Therefore, the principal component analysis, factor analysis and simple correlation revealed that it is not the totals of rainfall received in drought years that affect maize yield, but rather it is how the rainfall is distributed in terms of the frequency of wet spells which is of value to the farmers. This fact has also been cemented by the findings of partial correlation co-efficients which have revealed that maize yields are still significant even when rainfall in drought years is held constant. This is also shown in the correlation matrix (Table 13) where wet spells correlated significantly with maize yields at 5% error to a level of |0.405|.

Had rainfall been important, both the partial and simple correlation co-efficients for maize yield and wet spells would not have been significant at 95 % level of accuracy. But since it is the wet spells not the rainfall amount that are important, maize yields had still remained significant thereby accepting the H_1 for the sixth hypothesis. Other important heavy loadings in Appendix 5.2 were sunshine (0.712) and evaporation (0.719) in component five and temperature (0.878) in component six. The involvement of temperature as an important variable could be attributed to increased global warming and the El Nino occurrence which accelerated in the advent of the 1990's (Sichingabula 1998; Chipeta, 1998). Increased temperature could also be caused by increased daily sunshine hours. High sunshine hours could lead to increased temperatures which in turn cause the high evaporation rate loadings, Appendix 5.2. The above interpretation has demonstrated that before 1989, three factors, namely, rain days, inputs and marketing/sales made maize yields high. But after 1989, government policy of a liberalized free market economy made marketing difficult and poor for the farmers and this led them not to produce much maize as they did before 1989. Coupled with poor government policy on agriculture were also climatic factors such as increased temperature and evaporation and sunshine factors which were at interplay. A combination of these complex interactions between these factors led to the decline in maize yields in Lusaka Province between the periods 1989-2002 hence affecting the province's rank in terms of maize production.

It is important to emphasise that the acceptance of H_1 for the first hypothesis is important because it demonstrates that despite the increased prevalence of drought occurrence in Lusaka Province of 64.2 % (Table 12), adapting agriculture to wet spells still remains key to having food security especially that it has now become evident from the above discussion that a combination of climatic and non-climatic factors had also affected maize yields. This discussion has shown that it is difficult to isolate rainfall or any other single element as the major cause of reduced maize yields but it is a combination of all these factors, collectively called agricultural factors, which had negatively impacted Lusaka Provinces' rank in terms of maize production during the period 1989-2002. Rainfall alone cannot be isolated as the main cause of maize yields decline in Lusaka Province as a whole. There was no evident trend of rainfall variability although there existed high rainfall variation within Lusaka Province shown by the acceptance of H_1 for the fifth hypothesis.

6.5 Farmers' drought coping strategies

Most farmers (54.8 %) said that maize yields were the same in both drought and flood years. This was mostly due to the wet spells distribution and because most of the farmers used irrigation to replenish soil moisture thereby guaranteeing good yields. These farmers (69 %) also managed to plant their maize at the right time in November-December. Those farmers (42.9 %) who said that the yields were low in drought years were mostly those who planted late and had no access to irrigation. Analysis of the results also showed that since 61.9 % of the farmers used maize seeds adapted to long dry spells, their maize yields became low because of the well distributed wet spells. Had they used seeds adapted to wet spells, higher yields could have been harvested.

Further analysis of the results showed that despite 64.3 % of the farmers experiencing droughts, 57.1 % of them did not change their farming strategies, 59.5 % of them did not change the crops they planted and 64.3 % of them did not change the place where to cultivate. Most of them said this is due to the unpredictability nature of drought occurrence. This therefore shows that there is need for an effective early warning system of drought occurrence in order to increase the levels of adaptability and preparedness for the farmers as opposed to the present lack of information dissemination about drought occurrences to the farmers. Early warning would help farmers devise techniques of soil moisture conservation, appropriate seed types to be used and possible relocation within their farm land to areas that could be suitable for crop growth.

6.6 Implications of drought occurrence in Lusaka Province on agriculture

The implications of drought occurrence in Lusaka Province on agriculture were that it had led to farmers adopting the planting of drought resistant hybrid maize seeds. Drought occurrence had led to reduced crop production due to the drying up of streams used for irrigation, and it led to the eventual loss of income by the farmers who depended on rain-fed agriculture. Drought had also made farmers alert and more aware of its consequences thus making the farmers take interest in knowing weather patterns presented by the Department of Meteorology. Drought had also led to infrastructure development, such as crop storage sheds, through the food for work programme. Other than these, there seemed to be few implications of drought occurrence in Lusaka Province since farmers did not change their cultivation techniques, they did not relocate to new places for planting, and they did not change the crops they grew no matter how severe and intense the droughts were.

CHAPTER SEVEN: SUMMARY, CONCLUSION AND RECOMMENDATIONS.

7.1 Summary

It has been established that Lusaka Province had experienced increased rainfall variation with droughts occurring more than floods. It has also been revealed that the non-linear distribution which exists between rainfall and recurrence interval makes planning for droughts and floods in Lusaka Province highly difficult because of the stochastic nature of the rainfall amounts received. The research also revealed that maize yields reduced with increased rainfall amounts in drought years while it has been found that it was the wet spells in drought years that caused increased maize yields. This has also been confirmed by the partial correlation co-efficient analysis. It has also been discovered that high rainfall variation occurs within Lusaka Province but that the analysis of the co-efficients of rainfall variation showed that Lusaka Province displays no evident trend. The results have also shown that Lusaka Province was more prone to one-year droughts with the most severe droughts not being the most intense droughts. Principal components and factor analyses showed that Lusaka Province ranked highest in terms of maize production between 1976-1988 due to better marketing of maize, increased hectarage cultivated, adequate inputs provision and due to the significant number of rain days. After 1988 more factors loading highly in all the components negatively affected the maize production. There was also a drop in maize marketing. This worsening scenario relegated Lusaka Province to second position in terms of maize production during the period 1989-2002. The significant high temperatures have been attributed to increased global warming. This study also discovered that it is difficult to single out one variable as the main cause of reduced maize yields due to high factor loadings in all the six components during the 1989-2002 period. Lastly, it has been discovered that the drought run parameters do not seem to suggest direct negative or positive trends on maize yields. This may be due to the short period of records available for both maize yields and rainfall.

7.2 Conclusion

From the above findings, the study had concluded that rainfall variability had negatively impacted the other agricultural factors influencing maize yields in Lusaka Province. Due to high rainfall variability, drought occurrence increased in Lusaka Province. Since little or no measures to combat drought had been instituted, drought led to the other agricultural factors being increased in magnitude. Such factors included among others increased temperatures, high evaporation levels, increased wet and dry spell occurrences, and increased sunshine hours all of which have an effect on maize growth. Thus, the increase in magnitude of these agricultural variables after 1989 suggests the lengthening of the growing season to that which is longer than that required by maize. This had negatively affected maize yields in that maize yields in Lusaka Province declined. This conclusion is similar to that of Sichingabula (1998) who stated that the implications of rainfall variability and drought occurrence on Zambia include the lengthening of the growing season for crops without necessarily causing an increase in crop yields. The increases in rainfall variability and in the length of the growing season in Lusaka Province can be attributed, to some extent, to climate change in that the SOI and SST's have a strong influence on rainfall variability in Southern Africa where Zambia lies (Nicholson and Entekhabi, 1986).

7.3 Recommendations

For the purposes of utilising some of the study results, the following recommendations were made:

1. The Ministry of Agriculture and Co-operatives through its agriculture extension services wing should embark on a sensitization campaign to farmers about the positive effects of having more wet spells than dry spells on agriculture in an environment where drought frequency has significantly increased than floods. This will ensure less crop failure in that farmers will be aware that the increased intra-seasonal wet spells frequency can still support crop growth to maturity despite .

increased drought occurrence if only they embrace wet spell farming strategies.

2. Seed companies should embark on research into wet spell tolerant seed varieties as opposed to now when focus is on the seed varieties which can withstand long periods of dry spells (drought tolerant seed varieties).

3. Farmers and residents of Lusaka Province should adapt their agriculture to wet spells as a way of defeating the increased drought occurrence in the region and also as a way of reducing dependence on donor relief foods which are not sustainable and do not flow constantly.

4. The Meteorological Department of Zambia should be given more support for data collection to avoid gaps in rainfall measurements available.

5. The Meteorological Department of Zambia should also improve its capacity in data collection on SST`s, QBO, SOI and El Nino occurrence and how they impact on the Zambian climate in general and Lusaka Province in particular.

6. The early warning unit in the Ministry of Agriculture and Co-operatives should improve data storage on crop yields. There is need to get up-to-date data which should include crop production by the different categories of farmers, and the maize bags retained by the farmers for their own use and not only record that which the farmers sale. This will improve their data quality. This calls for the government to firstly, make available trained and motivated personnel who will effectively gather such data and secondly, purchase better equipment for data storage and processing.

7. Further research is required on the collective effects of the agricultural factors' characteristics in order to ascertain the extent to which the variables interact to cause reduced maize yields in Lusaka province.

8. Government should step up efforts of timely input provisions and marketing to the farmers. These are the major discouraging factors causing the farmers not to produce high quantities of maize.

9. The government should look at possibilities of subsidising irrigation equipment for those farmers who reside near rivers or streams and sinking boreholes for the farmers who have no easy access to streams or rivers so that the farmers' efforts are not devastated by poor rains in drought years.

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APPENDICES

APPENDIX 1. INTERVIEW SCHEDULE ON IMPACT ASSESSMENT OF RAINFALL VARIABILITY ON AGRICULTURAL FACTORS INFLUENCING MAIZE YIELDS IN LUSAKA PROVINCE, 1950 TO 2002.

INTRODUCTION

This interview on drought seeks to gather information which could be used to find ways of reducing drought impact on maize yields. It is also part of the GEO 6000 course at the University of Zambia. Therefore, the information got from this interview will be used to improve maize farming methods and also for academic purposes and that your information will be treated with a high degree of confidentiality. You are therefore, encouraged to answer the questions honestly.

A. PERSONAL INFORMATION.

Age.. Sex..

District.................................... Level of education............................

Farm No/ Village name...

B. FARMING INFORMATION.

(1) For how long have you been living in this farming area? ....

(2) What is your farming hectarage?...

(3) Do you have title deeds to the land you cultivate on? No.......... Yes..........................

(4) Which farmer category do you belong to?..

Small scale .... Medium scale..................... Large scale...................

(5) Name the crop(s) you grow during the rainy season.

No	Crop name	Hectarage	Seed	used
			local	hybrid

(6) Name the crops you grow during the dry season if any

....

(7) For how long have you been growing maize?..

(8) How have your maize yields been during drought years when compared to flood years?

High.................. Same.............................. Low.........................

(9) What problems do you face with maize farming?

No market.............................. High labour requirements............................

Crop diseases.......................... Crop failure due to drought........................

Lack of technical advice and inputs...

(10) In what way would you as a maize farmer want government to help in drought mitigation?

Warn farmers of drought occurrence in advance..

Supply drought tolerant seeds before the start of the rain ....

Introduce radio programmes on agricultural drought....................................

Other (state)...

(11) Is this a good place to be a farmer?...

(12) How would you describe the rain in the past eight years?...

(13) a. What happens to your farming if the rains are late?...

b. What happens if the rains do not come in the right amount needed for your crop?..

(14) a. Do you often experience drought, that is, do the rains fail often?...........................

b. How often?..

(15) a. If there is the drought what is the reason for it?..

b. If the rains fail, what do you do to survive?..

(16) If there is no much rain, does it make any difference on how you cultivate, that is, do you change your technique of farming)?..

(17) If there is not much rain, does it make any difference on what you cultivate, that is, do you plant different crops?.. ....

(18) If there is not much rain, does it make any difference where you cultivate?.............

(19) In this area what is the best time for planting the maize?..

(20) Do you usually manage to plant at the best time?..

If no, what are the problems of planting at the best time?...

(21) Have you ever used irrigation (any form of water control for cultivation)?...............

If yes, what type? (Describe)..

(22) What do you think of using irrigation?..

(23) What do you think are the negative effects of drought?...

(24) What do you think are the positive effects of drought?...

(25) How is crop growth (especially maize) when the rain is falling continuously, that is, long wet spells of more than 5 days?..

(26) Do you use any maize seed varieties which have the potential to withstand long periods of continuous rainfall?..

(27) How is crop growth (especially maize) if it does not rain for a long period of time, that is, long dry spell of more than 5days?...

(28) Do you use any maize seed varieties which have the potential to withstand long dry periods?...

(29)After harvesting maize, do you sell everything? Yes............. No..................

(30) If no, approximately how many 50kg bags of maize do you retain?..........................

(31)Do you keep records of your annual maize harvests? Yes................ No...........

(32) How do you use the maize retained?

Payment for labour.................... home consumption.......................

Feeding livestock...................... Other (state)..............................

THANKYOU

APPENDIX 2.0 Calculation of the proportion of the sample to the population

F = n / N = 42 / 372 = 1 / 9 or 0.11

Where: F = Proportion between the sample and the population

n = the size of the sample required

N= the size of the population

APPENDIX 3.0 Units of measure for agricultural factors influencing maize yields

1. Maize yield (90kg bags)
2. Maize sales (90kg bags)
3. Area of maize cultivated (ha)
4. Fertiliser supplied (50kg bags)
5. Seed supplied (10kg bags)
6. Mean annual pressure (mb)
7. Mean annual temperature (^{o}C)
8. Mean evaporation (cm)
9. Mean annual sunshine (hours per day)
10. Mean annual wind speed (knots)
11. Annual number of rain days
12. Annual number of non-rain days
13. Total annual number of dry spells in days
14. Total annual number of wet spells in days
15. Total annual rainfall (mm)

APPENDIX 4.0 Formulae for calculating different rainfall parameters

4.1 Missing rainfall values

$$P_x = \frac{1}{3}\left[\left(\frac{N_x}{N_a}\right) P_a + \left(\frac{N_x}{N_b}\right) P_b + \left(\frac{N_x}{N_c}\right) P_c \ldots\ldots\right]$$

Where:

P_x = the missing precipitation/ period.

X = station with missing data.

N= mean rainfall for stations a, b, c,....

P = precipitation of station a, b, c,....

4.2 Probability of drought (P) and the recurrence interval (T)

$P = m / n + 1,$ $T = n + 1 / m$

Where n: number of years on record

m: rank of annual rainfall

APPENDIX 5.0 Factor loadings and communality of agricultural variables

5.1. Factor loadings for the agricultural variables (1976-1988).

FACTOR	1	2	3	4	5	6
EIGEN VALUES	4.49	2.61	1.85	1.64	1.25	1.14
CUMULATIVE %	29.9	47.3	59.7	70.6	78.9	86.5
MAIZE YIELDS	.799	.010	-.163	-.253	.286	.351
MAIZE SALES	.714	.029	-.225	-.264	.331	.374
AREA	**.857**	.305	.324	.183	-.104	-.083
FERTILISER	**.857**	.306	.324	.183	-.104	-.084
SEED SUPPLIED	**.857**	.305	.324	.183	-.104	-.083
PRESSURE	-.464	-.103	.108	.322	.646	.126
TEMPERATURE	-.009	.030	.386	.378	.591	-.460
EVAPORATION	.157	.502	-.548	.293	-.210	.045
RAINFALL	-.360	-.287	.525	-.465	-.223	.058
SUNSHINEHOURS	.162	-.251	-.669	.399	.087	.037
WINDSPEED	-.290	.382	-.383	.099	-.179	-.475
RAINDAYS	-.263	**.791**	-.074	-.449	.211	-.090
NON-RAIN DAYS	.189	**-.788**	.094	.466	-.245	.117
DRY SPELLS	-.525	.455	.220	.399	-.071	.462
WET SPELLS	-.525	.566	.260	.330	-.113	.402

Extraction Method: Principal Component Analysis. a 6 components extracted.

Rotation method: Varimax with Kaiser Normalization. a Rotation converged in 6 iterations.

5.2. Factor loadings for the agricultural variables (1989-2002).

FACTOR	1	2	3	4	5	6
EIGEN VALUES	4.50	2.71	1.92	1.72	1 .38	1.19
CUMULATIVE %	30.0	47.5	60.3	71.0	79.9	87.6
MAIZE YIELDS	.355	.037	-.267	**.836**	.153	-.111
MAIZE SALES	.256	.082	-.239	**.840**	.188	-.096
AREA	**.968**	-.032	-.064	.191	.067	.067
FERTILSER	**.968**	-.032	-.064	.191	.067	.007
SEED SUPPLIED	**.968**	-.032	-.064	.191	.067	.007
PRESSURE	-.426	-.055	.307	.083	.013	.699
TEMPERATURE	.211	.025	-.063	-.176	-.036	**.878**
EVAPO RATION	.172	.207	.189	-.068	**.719**	-.281
RAINFALL	-.220	-.047	.012	-.133	**-.814**	-.162
SUNSHINE HOURS	-.193	-.341	-.176	.117	**.712**	.003
WINDSPEED	-.092	.378	-.056	-.567	.404	-.071
RAINDAYS	-.060	**.960**	.165	-.020	-.012	-.013
NON-RAIN DAYS	.091	**-.972**	-.103	-.019	-.016	-.002
DRY SPELLS	-.113	.087	**.929**	-.144	.016	.064
WET SPELLS	-.050	.206	**.928**	-.199	-.025	.027

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a Rotation converged in 6 iterations.

5.3 Communality of the agricultural variables (1976-1988)

Variable	Initial	Extraction
MAIZE YIELDS	1.000	.933
MAIZE SALES	1.000	.880
AREA	1.000	.984
FERTILISER	1.000	.984
SEED SUPPLIED	1.000	.984
PRESSURE	1.000	.775
TEMPERATURE	1.000	.853
EVAPORATION	1.000	.709
RAINFALL	1.000	.757
SUNSHINEHOURS	1.000	.705
WINDSPEED	1.000	.644
RAINDAYS	1.000	.954
NON-RAIN DAYS	1.000	.957
DRY SPELLS	1.000	.909
WET SPELLS	1.000	.947

Extraction Method: Principal Component Analysis.

5.4. Communality of the agricultural variables (1989-2002)

Variable	Initial	Extraction
MAIZE YIELDS	1.000	.943
MAIZE SALES	1.000	.882
AREA	1.000	.986
FERTILISER	1.000	.986
SEED SUPPLIED	1.000	.986
PRESSURE	1.000	.778
TEMPERATURE	1.000	.855
EVAPORATION	1.000	.719
RAINFALL	1.000	.767
SUNSHINE HOURS	1.000	.708
WINDSPEED	1.000	.650
RAINDAYS	1.000	.957
NON-RAIN DAYS	1.000	.956
DRY SPELLS	1.000	.912
WET SPELLS	1.000	.951

Extraction Method: Principal Component Analysis.

APPENDIX 6.0 Partial correlation co-efficients of maize yield, maize sales, seed supplied and fertilizer supplied when rainfall is controlled for.

	MAIZE SALES	MAIZE YIELD	SEED SUPPLIED	FERTILISER SUPPLIED
MAIZE SALES	1.0000 (n= 0) P=.	.9734 (n= 14) P= .000	.5410 (n= 14) P= .015	.5410 (n= 14) P= .015
MAIZE YEILD	.9734 (n= 14) P= .000	1.0000 (n= 0) P=.	6160 (n= 14) P= .006	.6160 (n= 14) P= .006
SEED SUPPLIED	.5410 (n= 14) P= .015	.6160 (n= 14) P= .006	1.0000 (n= 0) P=.	1.0000 (n= 14) P= .000
FERTILSER SUPPLIED	.5410 (n= 14) P= .015	.6160 (n= 14) P= .006	1.0000 (n= 14) P= .000	1.0000 (n= 0) P=.

(Coefficient / (D.F.) / 2-tailed Significance)

". "Is printed if a coefficient cannot be computed

APPENDIX 7.0 Crops grown by the interviewed farmers.

Crop(s)	Number of crop(s) grown	Frequency of the farmers
Grains	1	10
Grains and vegetables	2	4
Grains, tubers, fruits	3	2
Grains, tubers, fruits vegetables and legumes	5	2
Grains, tubers, legumes, vegetables	4	2
Grains, fruits, vegetables	6	7
Grains, fruits, coffee	3	3
Grains, fruits, legumes	3	2
vegetables, Grains, fruits, legumes	4	2
vegetables, Grains, legumes	3	2
Grains, beverages, tubers	3	3
Grains, tubers, legumes	3	3
Total		42

Source: Field data