

ASSESSMENT AND CHARACTERIZATION OF DROUGHT  
OCCURRENCE IN THE LAKE VICTORIA BASIN OF KENYA:  
A CASE STUDY OF WEST KENYA.

By

ISAIAH ANG'IRO NYANDEGA

THIS THESIS HAS BEEN ACCEPTED FOR  
THE DEGREE OF M.A.(1990)  
AND A COPY MAY BE PLACED IN THE  
UNIVERSITY LIBRARY.

A THESIS SUBMITTED IN PART FULFILLMENT FOR THE DEGREE OF MASTER  
OF ARTS IN GEOGRAPHY (CLIMATOLOGY), IN THE DEPARTMENT OF  
GEOGRAPHY, UNIVERSITY OF NAIROBI. 3-4-1990

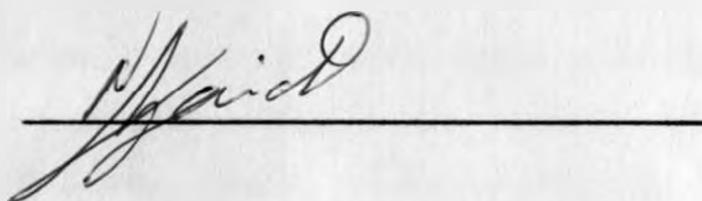
University of NAIROBI Library



0479936 7

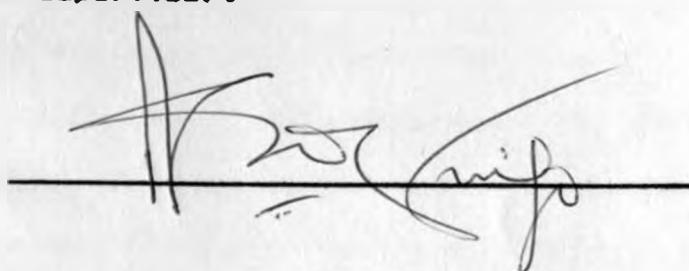
## **DECLARATION**

This Thesis is my original work and has not been presented for a degree in any other University.



**ISAIAH ANG'IRO NYANDEGA**

This Thesis has been submitted for examination with my approval as the University Supervisor.



**PROF. R.S. ODINGO**  
**(DEPARTMENT OF GEOGRAPHY)**  
**UNIVERSITY OF NAIROBI.**

## **DEDICATION**

To my parents, the late Nehemiah Nyandega and Mama  
Agness Awino Nyandega.....

## **ABSTRACT**

The droughts of early 1970s and early 1980s were some of the worst on record in the history of Sub-Saharan Africa. Drought, which in this study refers to an extended period of exceptional low rainfall, has been associated with negative effects in Africa with the droughts of early 1970s and early 1980s being some of the worst especially in the Sahel region. The effects of these droughts of the 1970s and the 1980s led to increased attention on the climatic anomalies in Africa especially drought in the Sahel. The increased attention had hitherto largely ignored the high rainfall areas of Africa in terms of drought occurrence and yet these areas are the granaries of the Continent's populace.

This study was aimed at finding out whether the high potential lands of Kenya are prone to drought occurrence (especially meteorological drought). The study also was aimed at finding out, if the above was true, whether there are unique characteristics of drought occurrence in the high potential lands of Kenya that can be used as a basis for better informed resource planning. Lake Victoria Basin which has the largest share of the high potential lands in Kenya was selected as the main area to be covered by the study. The Nyanza and Western Provinces (WEST KENYA) were used as representatives of the Lake Victoria Basin of Kenya and this was because nearly all the agro-climatic zones of the Basin are found there.

v

Daily rainfall totals data from twelve Rainfall Recording Stations as were available at the Meteorological Headquarters, Nairobi, were used for the study. In addition, data on the daily river flows for Nzoia, Yala, Nyando, Sondu-Miriu, and Gucha-Migori were also used as supporting information as were the agricultural reports for West Kenya. The daily rainfall data used were for the period 1971-80 and were those of the months of January to July.

The main statistical analysis technique used in the study was the Time-Series Analysis which allows a temporal presentation of the data. This technique therefore suited the need in the study to identify periods of abnormal low rainfall that could be described as meteorological drought conditions. Of the various Time-Series Analysis techniques, the study used the Series Plot, the Weighted (Binomial weights) Running Mean, the Autocorrelation Test, and the Correlogram Test. The study first subjected the data distributions to basic statistical analysis using the Mean, Median, Mode, Kurtosis, Skewness, Frequency Tabulation, and the Analysis of Variance Test (ANOVA) so as to reveal the central or general tendencies in the data. In the study, the hypothesis investigated was that, the droughts of the early 1970s and the early 1980s never occurred in West Kenya and the food shortage experienced during the periods could not have been as a result of rainfall failure. Statistical significance tests were in all cases done at alpha 0.05 level.

It was found that the droughts of early 1970s and early 1980s could be traced in the daily rainfall series for the months of January to July between 1971 and 1985 as was characterised by depressed rainfall distributions ( $<5\text{mm}$  per day) or breaks in the rainfall series ( $<0.25\text{mm}$  per day). The depressions ( $<5\text{mm}$  per day) or breaks ( $<0.25\text{mm}$  per day) were not well defined in the rainfall series distributions and this indicated more of erratic or delayed or early ending distribution of rains than well defined meteorological drought situations. The "drought conditions" traced in the rainfall distributions between 1971 and 1985 occurred in mid 1970s and in the 1970s-1980s transition period especially 1979-1981 period. Food shortages, therefore, which were experienced outside the periods above could not have been due to nature anomalies (rainfall failure) only.

On the basis of the findings, it was realised that a detailed characterization of drought occurrence in the Lake Victoria Basin of Kenya was still limited unless the daily water balance conditions in the Basin were availed. Nevertheless, it was concluded that agronomic practices in West Kenya should have in-built "drought shock-absorbers" like food buffer stocks, growing of time tested drought resistant crops, and other forms of production and drought management strategies. This was because the possibility of rains not meeting the crop requirements was found

to be very real in West Kenya. The study faced the problem of poor data entry and erroneous recording and it is therefore recommended that data recording, entry and Meteorological Stations (or recording stations) should be managed by trained and interested personnel.

## LIST OF CONTENTS

TITLE	PAGE
TOPIC	1
DECLARATION	11
DEDICATION	iii
ABSTRACT	iv
LIST OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDICES	xii
ACKNOWLEDGEMENTS	xv
CHAPTER ONE	1
1.0. INTRODUCTION	1
1.1. General Remarks	1
1.2. Statement of the problem	2
1.3. Aims of the study	8
1.4. Justification of the study	10
1.5. The study Area	14
CHAPTER TWO	27
2.0. LITERATURE REVIEW	27
2.1. Purpose of the Review	27
2.2. The Review	28
CHAPTER THREE	48
3.0.0.0. RESEARCH METHODOLOGY	48
3.1.0.0. Data Source	48

3.2.0.0. Data Collection . . . . .	49
3.3.0.0. Data Analysis Techniques . . . . .	51
3.3.1.0. Introduction . . . . .	51
3.3.2.0. Analysis of Variance Test . . . . .	59
3.3.3.0. Time-Series Technique . . . . .	63
3.3.4.0. Plotting the Time-Series . . . . .	65
3.3.5.0. Smoothing the Series using the 5-day Moving Average . . . . .	66
3.3.5.1. Disadvantages of Moving Average Method . . . . .	67
3.3.6.0. Autocorrelation Function.rk . . . . .	68
3.3.7.0. Testing the significance of Autocorrelation functions . . . . .	70
3.3.8.0. Correlogram . . . . .	72
3.3.9.0. Why the Time-Series Analysis of the Data . . . . .	72
CHAPTER FOUR . . . . .	76
4.0.0. RESULTS AND DISCUSSIONS . . . . .	76
4.1.0. Basic Statistics Results . . . . .	76
4.1.1. January Results for 1971-85 period . . . . .	76
4.1.2. February Results for 1971-85 period . . . . .	78
4.1.3. March Results for 1971-85 period . . . . .	81
4.1.4. April Results for 1971-85 period . . . . .	83
4.1.5. May Results for 1971-85 period . . . . .	85
4.1.6. June Results for 1971-85 period . . . . .	87
4.1.7. July Results for 1971-85 period . . . . .	89

<b>4.2.0. Analysis of Variance Test Results for the months of January-July during 1971-85 period . . . . .</b>	<b>91</b>
<b>4.3.0. The Time-Series Results, 1971-85 period —</b>	<b>92</b>
<b>4.3.1. Five-day weighted running means Results 1971-85 period . . . . .</b>	<b>92</b>
<b>4.3.2. January Results, 1971-85 . . . . .</b>	<b>93</b>
<b>4.3.3. February Results, 1971-85 . . . . .</b>	<b>96</b>
<b>4.3.4. March Results, 1971-85 . . . . .</b>	<b>98</b>
<b>4.3.5. April Results, 1971-85 . . . . .</b>	<b>102</b>
<b>4.3.6. May Results, 1971-85 . . . . .</b>	<b>106</b>
<b>4.3.7. June Results, 1971-85 . . . . .</b>	<b>110</b>
<b>4.3.8. July Results, 1971-85 . . . . .</b>	<b>113</b>
<b>4.4.0. The Autocorrelation Significance Test Results(1971-85), January-July . . . . .</b>	<b>117</b>
<b>4.4.1. January Results, 1971-85 . . . . .</b>	<b>118</b>
<b>4.4.2. February Results, 1971-85 . . . . .</b>	<b>126</b>
<b>4.4.3. March Results, 1971-85 . . . . .</b>	<b>132</b>
<b>4.4.4. April Results, 1971-85 . . . . .</b>	<b>137</b>
<b>4.4.5. May Results, 1971-85 . . . . .</b>	<b>143</b>
<b>4.4.6. June Results, 1971-85 . . . . .</b>	<b>149</b>
<b>4.4.7. July Results, 1971-85 . . . . .</b>	<b>153</b>
<b>4.5.0. The Shape of the Correlogram: January to July Results(1971-85) . . . . .</b>	<b>158</b>
<b>4.6.0. Daily River Flows . . . . .</b>	<b>164</b>
<b>4.7.0. Agricultural Reports . . . . .</b>	<b>165</b>

<b>CHAPTER FIVE</b>	<b>192</b>
<b>5.0. SUMMARY, CONCLUSIONS, RECOMMENDATIONS</b>	
<b>AND LIMITATIONS</b>	<b>192</b>
<b>5.1. Summary</b>	<b>192</b>
<b>5.2. Conclusions</b>	<b>199</b>
<b>5.3. Recommendations</b>	<b>202</b>
<b>5.4. Limitations</b>	<b>205</b>
<b>REFERENCES AND APPENDICES</b>	<b>206</b>

#### **LIST OF TABLES**

<b>Table:</b>	<b>Page</b>
<b>3.1. Rainfall Stations arranged according to altitude in West Kenya</b>	<b>51</b>
<b>3.2. Stations used in the Study</b>	<b>56</b>
<b>3.3. Analysis of variance steps</b>	<b>60</b>
<b>4.4. Basic Statistics for Usigu Health Centre in January(rainfall data)</b>	<b>166</b>
<b>4.5. Basic Statistics for Bungoma Agriculture Office in February (rainfall data)</b>	<b>167</b>
<b>4.6. Basic Statistics for Malava in April(rainfall data)</b>	<b>168</b>
<b>4.7. Basic Statistics for North Mount Elgon Station in March (rainfall data)</b>	<b>169</b>
<b>4.8. Frequency tabulation for January (Muhuru rainfall data)</b>	<b>170</b>

<b>4.9. Estimated Autocorrelations for lags 1-24 (Muhuru rainfall data) .</b>	<b>171</b>
<b>4.10. West Kenya (study area) weather conditions and agricultural performance reports(1956-86)—</b>	<b>172</b>
<b>LIST OF FIGURES</b>	
<b>FIGURE:</b>	<b>Page</b>
<b>1.1. A Map of West Kenya showing Rainfall recording Stations .</b>	<b>22</b>
<b>1.2. Agro-Ecological Zones of West Kenya .</b>	<b>23</b>
<b>1.3. A Map of West Kenya showing 60% reliability of Rainfall in the First Rains .</b>	<b>26</b>
<b>4.4. Time sequence plot of June rainfall for Kisumu Station(1983-85) .</b>	<b>176</b>
<b>4.5. Time sequence plot of July rainfall for Kosele Station(1983) .</b>	<b>177</b>
<b>4.6. Time sequence plot of April rainfall for Kisii Station(1983-85) .</b>	<b>178</b>
<b>4.7. Time Series and Moving Average for January rainfall(1971-85),Kisumu Station .</b>	<b>179</b>
<b>4.8. Time Series and Moving Average for April rainfall(1971-85), Kisumu Station .</b>	<b>180</b>
<b>4.9. Time Series and Moving Average for July rainfall(1971-85), Kisumu Station .</b>	<b>181</b>
<b>4.10.Time Series and Moving Average for March rainfall(1971-85), Bungoma Station .</b>	<b>182</b>

<b>4.11. Time Series and Moving Average for July</b>	
rainfall(1971-85), Kosele Station .	183
<b>4.12. Time Series and Moving Average for June</b>	
rainfall(1971-85), Kisii Station .	184
<b>4.13. Time Series and Moving Average for</b>	
July rainfall(1971-85), North Elgon Station .	185
<b>4.14. Kisumu: Estimated Autocorrelations, January</b>	
(1971-85) .	186
<b>4.15. Usigu: Estimated Autocorrelations, April(1971-85)</b>	187
<b>4.16. Bungoma: Estimated Autocorrelations, May(1971-85)</b>	188
<b>4.17. Nyamira: Estimated Autocorrelations, April(1971-85)</b>	189
<b>4.18. Malava: Estimated Autocorrelations, April(1971-85)</b>	190
<b>4.19. Kucha-Migori river flows in 1971-72.</b>	191

#### LIST OF APPENDICES

<b>APPENDIX:</b>	<b>Page</b>
I. BASIC STATISTICS FOR KISUMU(1971-85)IN JANUARY.—	221
II. BASIC STATISTICS, KISUMU IN FEBRUARY .	222
III. BASIC STATISTICS, KISUMU IN MARCH .	223
IV. BASIC STATISTICS, KISUMU IN APRIL .	224
V. BASIC STATISTICS, KISUMU IN MAY .	225
VI. BASIC STATISTICS, KISUMU IN JUNE .	226
VII. BASIC STATISTICS, KISUMU IN JULY .	227
VIII. FREQUENCY TABULATION(KISUMU) MAY .	228
<b>IX. ESTIMATED AUTOCORRELATIONS:KISUMU IN JANUARY</b>	
(1971-85)—	229

X. ESTIMATED AUTOCORRELATIONS: KISUMU IN APRIL(1971-85) ——————	230
XI. ESTIMATED AUTOCORRELATIONS: KISUMU, JUNE(1971-85)—	231
XII. TIME SEQUENCE PLOT: MAY RAINFALL FOR KISII STATION(1983-85).—————	232
XIII. TIME SERIES AND MOVING AVERAGE FOR MAY RAINFALL(1971- 85):KISUMU STATION ——————	233
XIV. TIME SERIES AND MOVING AVERAGE FOR MARCH RAINFALL(1971- 85):KISUMU STATION ——————	234
XV. TIME SERIES AND MOVING AVERAGE FOR MAY RAINFALL (1971-85):KISII STATION ——————	235
XVI. TIME SERIES AND MOVING AVERAGE FOR JANUARY RAINFALL(1971-85):MUHURU STATION ——————	236
XVII. TIME SERIES AND MOVING AVERAGE FOR APRIL RAINFALL(1971-85):MUHURU STATION. ——————	237
XVIII. TIME SERIES AND MOVING AVERAGE FOR MAY RAINFALL (1971- 85):MUHURU STATION. ——————	238
XIX. TIME SERIES AND MOVING AVERAGE FOR JULY RAINFALL (1971-85):MUHURU STATION. ——————	239
XX. TIME SERIES AND MOVING AVERAGE FOR JULY RAINFALL (1971-85):KISII STATION .—————	240
XXI. TIME SERIES AND MOVING AVERAGE FOR MARCH RAINFALL(1971- 85):KOSELE STATION. ——————	241
XXII. TIME SERIES AND MOVING AVERAGE FOR FEBRUARY RAINFALL(1971-85):MUHURU STATION. ——————	242

XXIII. TIME SERIES AND MOVING AVERAGE FOR MAY RAINFALL (1971-85): ELGON STATION	243
XXIV. USIGU: ESTIMATED AUTOCORRELATIONS(MAY)-1971-85	244
XXV. MUHURU: ESTIMATED AUTOCORRELATIONS(JANUARY).. 1971-85.	245
XXVI. MUHURU: ESTIMATED AUTOCORRELATIONS(MAY).. 1971-85.	246
XXVII. MUHURU: ESTIMATED AUTOCORRELATIONS(JUNE).. 1971-85.	247
XXVIII. KISII: ESTIMATED AUTOCORRELATIONS(FEBRUARY).. 1971-85.	248
XXIX. KISII: ESTIMATED AUTOCORRELATIONS(APRIL).. 1971-85.	249
XXX. KISII: ESTIMATED AUTOCORRELATIONS(JUNE).. 1971-85	250
XXXI. KISUMU: ESTIMATED AUTOCORRELATIONS(MAY).. 1971-85.	251
XXXII. KISUMU: ESTIMATED AUTOCORRELATIONS(FEBRUARY)- 1971-85.	252
XXXIII. ELGON: ESTIMATED AUTOCORRELATIONS(MAY).. 1971-85	253

## ACKNOWLEDGEMENTS

I did receive great assistance and /or help from various people and institutions during my study and I would like to say to them all, many thanks. I am especially very grateful to Professor R.S. Odingo, my supervisor, of Department of Geography, University of Nairobi, for ensuring the work was completed successfully in time. His scholarly guidance was inspirational and his ability to detect mistakes did help to minimise mistakes in the work. My gratitude goes to the Department of Geography academic staff members for making me feel at home when seeking advice and guidance. To Mr Njuguna of the Meteorological Department, Dagoretti Corner, Nairobi, I say thanks a lot for availing the needed Hydrometeorological data. In data analyses, I received able assistance from Mr Silvester Obuon of the Government Treasury, Ministry of Planning and National Development, to him, my appreciation. For the immense cartographic work involved in the study, my gratitude to Mr Okach and Mr Okumu of the Department of Geography, University of Nairobi. The involving work of typing this Thesis was done by Miss Judy-Lynn Rabar assisted by Miss Christine Akoth and to them many thanks.

To do research in Kenya there is need for research permit and in this I received appropriate assistance from the Office of the President. This study was ably financed by the University of Nairobi through the Department of Geography, my great thanks to the

Institution for the assistance. The Meteorological Department Headquarters, Ministries of Agriculture and livestock development, University of Nairobi Libraries, Ministry of Water Development and FAO Library at Matungulu House, all assisted in getting the needed data or the necessary information, to them great thanks. For the moral assistance I received from my colleagues, Mwaura, Musingi, Magiya, Muiruri, and Kamunto during my study and research work, I say "may GOD be with them". To my mother, Mama Agness Nyandega ,to my sister Jane Amollo "Zilly" and to my friend Hilda Akinyi, I pass my joyful "thank you" for the homely assistance and guidance. Finally, I would like to say that I am responsible for any mistake in this thesis due to either data analyses inadequacy or typographic errors.

## **CHAPTER ONE**

---

1.0

### **T N T R O D U C T I O N**

---

#### **1.1 General Remarks**

---

In the early 1970s and early 1980s, the sub-Saharan Africa experienced some of its worst drought periods on record and the effects were most felt in the marginal lands (see Odingo, 1985). Since the effects of meteorological droughts have been most "demonstrated" in the marginal lands, where famines and deaths have been common, people have tended to associate drought in Africa with the Sahel region which extends from West Coast of Africa to the East Coast of Africa. Kenya is part of the Sahel complex with isolated "rainfall isles" like the Kenya highlands and the Lake Victoria Basin. The rainfall isles are usually the main food producing areas and droughts assume national importance when they strike in these "high rainfall potential isles". It would be good, therefore, to look into the meteorological conditions of the "high potential isles", within the Sahel region that usually ease off pressure on the marginal lands in times of needs, during the so called drought periods. This is to enable one judge whether the high potential lands of a region are prone to drought occurrence or not and to find out the nature of drought occurrence, if possible, in those areas.

Most studies on drought in Africa have been done in the marginal lands (Odingo, 1985) but little on drought in the "high potential areas". Various definitions of drought exist and "people have tended to use the terms drought, desertification and famine synonymously" (Gregory, 1988). Whatever definition of drought given, water deficiency is central and in terms of moisture availability, rainfall has been the most useful parameter. In meteorological circles, drought is seen as a period of prolonged rainfall deficiency that is significantly below the normal tendency. It was the aim of this study to investigate using the daily rainfall data, whether the drought periods of early 1970s and first half of 1980s affected the high potential lands in Kenya. In this study the Lake Victoria Basin of Kenya, which is a high potential region and hence agriculturally productive part of Kenya, was chosen and the study was concentrated in West Kenya (Nyanza and Western) which has all the agro-climatic zones of the Basin.

#### **1.2 Statement of the Problem**

Kenya is to a greater extent an agricultural country with over eighty percent of the land area being semi-arid or arid. The remaining portion of the land area of the country is either medium rainfall region or high rainfall area. As a result the potential of any land area in Kenya is mostly judged by its ability to sustain cultivated agriculture and therefore the major agricultural areas in the country are found in the high rainfall areas mainly and to a smaller extent in the medium rainfall areas. Since

agriculture is a major economic sector of the economy of Kenya, one would logically expect major population concentrations to be in the main agricultural regions as is the case in the country. It is due to this dependence of the economy on agriculture that rainfall becomes a major actor in the economic planning of Kenya. Any rainfall anomaly in the rainfall distribution and amount in the high potential lands and to a smaller extent in the medium potential lands of the country is bound to have a telling implication on the country's economy. One such rainfall anomaly that has become a major problem in major agricultural lands in Africa and majorly in the Sahel regions as is Kenya is drought.

Drought is a meteorological phenomenon which is very difficult to define and predict and this has resulted in lack of appropriate drought management strategies thus leading to disastrous effects like famine and desertification. What exactly constitutes a drought condition is a matter of disciplinary dispute but the occurrence of drought has been part of human history from time memorial as long as some kind of agriculture, horticulture or civilization existed. Due to lack of universally accepted definition of drought, it has been very difficult to give its causes especially as concerns the immediate and ultimate cause. Also lack of definition plus the creeping nature of drought has made it difficult to determine the start and end of drought period. Since it is difficult to come by a universal definition and prediction of drought, it would be better to deal with drought occurrence which

has been recorded in human history and even layman can claim to recognise. This study was carried out to establish the rainfall status of the high potential lands of Kenya during the so called drought periods. The question that concerned the study was that "are the high potential lands of Kenya ,which are the main agricultural areas, prone to drought occurrence?"

Drought occurrence is a natural feature of the General Circulation System of the Earth and can therefore occur anywhere on the Earth surface depending on the definition with only duration and severity varying from one climatic zone to the next. In Africa, major droughts have been most severe in the Sahel complex ,which Kenya is part of, usually resulting in famines and desertification. As a result, most studies on drought in Africa have been done in the Sahel zones, sometimes called the semi-arid or marginal lands. The possibility of drought occurrence in the high potential lands of Africa has been, to a greater extent ignored especially when dealing with severe drought and yet they are the major agricultural lands. Droughts in Africa usually assume national importance when the high potential lands can no longer produce enough food to supply those in the marginal lands as well as those in the agricultural lands. In Kenya, the high and medium potential lands are also the major population centres and is therefore very vulnerable to climatic anomalies mostly rainfall. This study recognised the risk involved in neglecting the possibility of drought occurrence in the high potential lands of Kenya and

therefore did set out to minimize this bias in drought study in Kenya.

The high potential lands of Kenya, in terms of agricultural production and rainfall amount and distribution, are restricted to the Kenya highlands, the Lake Victoria Basin, and to a limited extent the South Western part of the coastal region. The largest share of the high potential lands in Kenya is in the Lake Victoria Basin which is also the major grain growing region of the country. Lake Victoria and associated land features have a moderating role on the climate of Kenya due to the meso-scale circulations generated. This study was based in the Lake Victoria Basin of Kenya focusing mainly on West Kenya (Nyanza and Western Provinces combined) which has all the agro-climatic zones of the Basin.

Major droughts rarely cover small areas and in the early 1970s especially between 1972 and 1974, there was a near worldwide drought and the most demonstrated effects were in the Sahel regions of Africa. Again in the first half of the 1980s, a major drought occurred in the Sahel regions of Africa especially in Eastern Africa leading to massive food importation to meet the needs of the "hungry people of Africa". The question that concerned this study was that "did the great Sahelo-Ethiopian droughts of the early 1970s and the early 1980s affect the daily rainfall distributions over the high potential lands of Kenya to warrant food shortages that were recorded during those periods or was nature not guilty?"

Kenya is in Eastern Africa which is part of the Sahel complex and one would expect the droughts of early 1970s and early 1980s to have been experienced in Kenya. It is therefore fair enough to investigate the rainfall status over the major rainfall areas in Kenya and to try identifying the salient features of drought periods that can be used in designing appropriate drought management strategies in an attempt to minimize the effects of drought. This study made an attempt to identify the major rainfall characteristic during the drought periods over the high potential lands in Kenya, in this case the Lake Victoria Basin. The study used the daily rainfall data between 1971 and 1985, during which some of the most disastrous droughts occurred, as the basis of analysis.

In the agricultural calendar of Kenya, the first crops grown during the long rains are the most important and their failure may as well spell famine and are largely dependant on the rainfall performance. The long rains generally occur between March and May although in the Lake Victoria Basin no well defined boundary exists between the long rains and the short rains. Some of the driest periods in the Lake Basin are found between January and February and between June and July. The study was based on the rainfall data for the months of January to July when some of the wettest and driest periods respectively are expected in the Lake Basin.

Even though there is no universally accepted definition of drought, the question of water availability is central to all definitions currently available. In the Tropical world the main source of water is rainfall and as a result studies on drought are usually based on rainfall distribution and amount. In many cases, studies on rainfall distribution in Africa and in Kenya particularly, have been based on the mean annual or monthly rainfall values and not the actual totals. Even the few studies that have used the actual totals have mostly been dealing with monthly or annual values with few exceptions. Also the rainfall studies in the high potential lands of Kenya have not been, in many cases, directly concerned with drought occurrence. This study used the daily rainfall totals to investigate whether the high potential lands of Kenya are prone to drought occurrence and if so whether there are unique characteristics of drought occurrence in those areas one can use in designing drought management strategies to be used in mitigating the effects of drought. The data analysis was based on the five day interval taking into account the moisture retention capacities of major soils in the Lake Victoria Basin. Lake Victoria Basin of Kenya is a large region of about 46,000 square kilometres and without covering the whole region the study focused on West Kenya which has all the agro-climatic zones of the Basin.

It was the purpose of this study to draw the attention of the scientists and planners to the fact that, drought is a normal part

of the General Circulation System and its occurrence should be expected anywhere on the surface of the earth. Drought management strategies should therefore be part of the overall planning in the high potential lands in Kenya as they are in the marginal lands. It is also important to take note of the fact that, even if there is no universally accepted definition of drought, specific definitions are possible depending on the interest of the scientist and on the climatic zone and it was the hope of this study to help in the search for specific definition of drought in the various high potential regions of Kenya. This study did not attempt to give causes of drought in Kenya and did not specifically attempt to deal with drought forecasting although references were made towards this field of study.

### 1.3 Aims of the Study

The main objective of the study was to find out whether the drought periods of 1972-74/76, 1980-1981 and 1984-1985 affected the daily rainfall distribution in West Kenya. If this was so, then it would show that meteorological droughts are also a factor in the high potential lands. Secondly, if there were signs of drought occurrence, attempt was made to check whether there were some major characteristics one could use to describe drought periods in West Kenya.

Drought is a normal feature of the atmospheric General Circulation system and to this the possibility of its occurrence in any region on the earth surface is not unique. There is a general assumption that drought occurrence is a confine of the arid and semi-arid lands and this is a dangerous trend since the other regions are also subject to the General Circulation system. The difference may be in the definition, the intensity, and the frequency of drought occurrence. Drought as a factor in resources planning and management is only important where there is some kind of human activity or where the activities in an area affects human activities. Since Lake Victoria Basin of Kenya is one of the most agriculturally productive and one of the most populous regions in the country, it is wise to check its meteorological condition during the so called drought period in order to know its vulnerability to drought occurrence. It is also important to have proper drought management strategies and, in this, drought occurrence characteristics are important since the causes of drought are not easy to pinpoint as is the universal definition of drought.

The hypothesis used in the study was that no year showed any sign of exceptionally low rainfall during the months of March-May (period of long rains peaks), and therefore periods of food shortage did not correspond with periods of low rainfall (exceptional). That is, the droughts of early 1970s and early 1980s never occurred in West Kenya and the food shortage experienced

during the periods could not have been as a result of rainfall failure. Exceptional rainfall in the study was considered as failure of rains during the months of April and May when the long rains were expected to peak. Also, high rainfall during the months of January-February were considered unseasonal likewise to rainfall peaking in July.

The significance of statistical results were tested at alpha 0.05 (95 percent confidence level).

#### 1.4 Justification of the Study

This study was a deviation from the common practice in Africa and elsewhere, with a few exceptions, as concerns drought studies. Most of the literature on drought has been concerned with the marginal lands or the arid and semi-arid lands (see Literature Review). This concern with drought in the marginal lands is due to the fact that drought is most common in these areas and particularly in the most marginal lands. These aside, "national droughts" often result when drought affects the high potential lands especially the food producing areas in a given country. The Lake Victoria Basin of Kenya falls within the high potential lands in Kenya and is rightly regarded as the "grain granary" of the country. Unfortunately the Lake Victoria Basin is not immune from the effects of the General Circulation system and this study was designed to determine the rainfall condition of the Basin during

the drought periods in Eastern Africa taking into account the role of Lake Victoria in the climate of the region. This would help in determining indirectly the effects of drought on agricultural production since most of the so called drought periods in Eastern Africa have been accompanied with food shortages and sometimes famines; that is, it would help in establishing whether nature has been responsible for most of the famine periods recorded in Eastern Africa or whether to look for other explanations.

Most of the work on drought in Eastern Africa, Kenya included, has tended to concentrate on the Human aspects and therefore ended up discussing mainly famine and desertification rather than the equally interesting meteorological drought (see literature review). The study concentrated on the physical aspects of drought in order to help bridge the gap and show that meteorological drought can be a factor in the climatic scene of high potential lands. This is important because people have tended to neglect the possibility of drought occurring in the high potential lands despite the fact that in the event of even a slight meteorological anomaly, the high potential lands are the most vulnerable in terms of human settlement, ecological balance, and food production. The study of physical drought was also intended to help in solving the confusion always met when dealing with drought, famine and desertification. Famine can simply be seen as shortage (severe) of food supply and desertification simply as the encroachment of desert conditions or decline of vegetation cover. Drought can be a cause of both famine

and desertification but not always and that depends on human activities and responsibilities. Meteorological drought is an inherent part of the climatic scene of Africa (Ojany and Ogendo, 1973; Zewde, 1976) and there is therefore need to check whether periods of drought always result in famine especially in the high potential lands which are usually the food granaries in the given countries.

The period 1971-1985 was chosen because two of the most felt droughts not only in the sub-Saharan Africa but also globally, occurred during the period. The 1972 ( $\pm 4$ ) was an almost world wide drought that brought to the world's attention the vulnerability of the Sahel region to climatic anomalies. The 1984 ( $\pm 2$ ) drought magnified the effects of drought as was shown by the Ethiopian and Sudanese hunger plights which herald in the food-aid and famine fund raising era as if drought was a new phenomenon.

Whatever definition of drought given, water deficiency is an ever present element and in this, rainfall is the most important element in Tropical Africa. Most of the agronomic or agricultural practices in Africa, Kenya included, are largely based on rainfall amount and distributions throughout the year. This study therefore used rainfall totals (daily) which affect the soil moisture availability and therefore water available for plant growth, evapotranspiration, runoff, deep percolation, underground storage

and river flows. Stream flows were also used as supporting information on rainfall distribution during the period of study.

The analysis of rainfall was on a daily basis and this deviated from the common practice of analysing drought occurrence annually or monthly. It was the view of the study that drought can even occur on a weekly or less basis. The analysis of rainfall totals on daily basis was done for every month so as to help check whether there had been a change in the daily distribution of rainfall during 1971-85 period. This is important because it is not uncommon to "hear" people complaining of declining rainfall (the author's experience, Dissertation, 1987). Analyses of monthly means and annual means have not shown any major change in the rainfall trends in Eastern Africa but the answer may be in the day to day rainfall total distribution rather than the mean values.

Finally, the study concentrated on rainfall totals (daily) during the period of January to July because of the fact that the driest and wettest months are within this duration. Also crops of most importance in terms of food supply are planted during this time and any failure in rainfall is bound to affect food supply, especially during the April-May peaks, when most crops are in their development stages.

### 1.5 The Study Area.

Lake Victoria Basin of Kenya is an extensive geographical region extending from the Mau ranges to the border with Uganda and from the border with Tanzania to the Uasin Gishu District. The study focused on an area within the Lake Victoria Basin of Kenya, West Kenya, comprising of two administrative provinces; Nyanza and Western.

West Kenya is within latitudes 1°15' North and 1°30' South and longitudes 34° East and 35°30' East. This means the study area is located within the Equatorial zone and within Eastern Africa region, and thus the synoptic features affecting these regions affect West Kenya. The situation of the study area within the Lake Victoria Basin exposes it to the influence of macro-scale circulations generated due to the presence of the Lake Victoria and associated land features. West Kenya is bordered by Uganda to the West, Rift Valley Province on the Kenya side and Tanzania to the South-West-South.

West Kenya has a land surface generally sloping towards the Lake with occasional projections like the Bunyore Hills, Seme Hills, Seme Tors, Nyando escarpment, Homa Hills, Wire Hills, Great Ranges and others. On the sides bordering the Rift Valley, there are embankments "guarding" the flanks like Mount Elgon to the north west, Nandi Hills, Mau escarpments and the Gusii Highlands.

The near bowl-like shape of the Basin with the large expanse of water in the middle, the projecting physical features within and on the flanks are major actors in the rainfall distribution and amount in West Kenya as well as temperature moderation and evaporation rates in addition to the effects of General Circulation. West Kenya land surface is dominated by the waters of Lake Victoria and associated rivers with river Nzoia, river Yala, river Nyando, river Miriu-Sondi and Gucha-Migori being the major ones. River regimes (seasonal flow) are closely linked with rainfall amount and distribution in the Lake Victoria Basin (Lamb, 1986) and if there is drought in the basin, flows are likely to be affected.

Soils of the study area (West Kenya) are mostly those that have been derived from the Nyanzian and Kavirondian rock systems. Soils of any geographical region are effected by several factors usually acting in unison. Those factors may be given as climate, the parent material, vegetation cover, nature of the earth surface, living organisms in the earth and human activities. In the tropics (Lake Victoria Basin has a modified equatorial climate) the major climatic elements that affect soil formations and types are rainfall and temperature (distribution and amount) as they affect soils depth (weathering), maturity, drainage, distribution, and mineral composition. The parent material is mostly important when considering the soil chemical composition, soil colour, and distribution. Vegetation cover affect the chemical and biological

composition and age of the soil in terms of erosion. The nature of the land surface affect the soil drainage, distribution ,maturity. The living organisms and human activities are mostly important when considering soil as a living body and in terms of soil conservation . In the Lake Victoria Basin, the major actors in the soil types and distributions are parent rocks, mostly the Nyanzian and Kavirondian system which are the oldest rock systems in Kenya and in some areas there are volcanic intrusions and Sedimentary systems. Rainfall and temperature amount and distribution are also important factors in soil types and distribution in the basin as is the nature of the earth surface.

In West Kenya, Ferrrasols dominate the high grounds with high moisture carrying capacities and are deeply weathered. Vertisols dominate the plains with high moisture retention capacities; a factor that leads to water logging during the rains and this causes difficulty in working the soils . There are other soil types, in pockets of areas, like nitosols, histosols and gleysols amongst other numerous ones. Soil types affect the soil water balance in terms of albedo, moisture retention capacity and moisture carrying capacity. This therefore affects the potential of the soils which in turn may determine the type of land use and vegetation cover to be found in an area.

The vegetation cover of West Kenya has largely been humanised and what now remains is mostly derived vegetation cover. There are

now Derived Savannah as can be seen mostly in South Nyanza and pockets of modified equatorial forest as the Kakamega forest. Along the lake, there are lacustrine grass cover/vegetation but all in all, there is little left of the natural vegetation of the Lake Basin. The vegetation cover of a given geographical region may act as a climatic indicator especially the shallow rooted plants like grass. The vegetation cover also plays a role in soil formation, water balance, energy balance, wind flow structure and ecological balance in a given geographical unit ,and therefore a very integral part of a region's climate.

In Kenya, the most important element of climate is rainfall and the main rain-generating systems are associated with the passage of the Intertropical convergence zone (ITCZ). Other factors affecting the climatology of rainfall in Kenya are topography (altitude mostly), inland lakes, Indian Ocean, the Trade Winds (South East and North East), Egyptian air mass and the Congo(Zaire) air mass. These factors therefore define rainfall regions of Kenya, rainfall seasons, rainfall distribution and amount in the country, and finally rainfall reliability. The factors affecting rainfall distribution in Kenya must not be looked at in isolation from the General Circulation system of the earth; that is specific factors affecting the climate of a given region must be understood from a broader context of the General Circulation System. The climate of the Lake Victoria Basin must

therefore be seen in the context of the climate of Eastern Africa, climate of the tropical world and the climate of the world.

The main factors affecting the rainfall climatology of the Lake Victoria Basin are the synoptic scale seasonal flow which is predominantly easterly throughout the year, and the meso-scale circulations created by the Lake in the presence of the highlands in the Eastern, Southern and Northern neighbourhood (Mungai, 1984). Other factors that need to be considered are the Congo (Zaire) air mass, distance from the Lake (Lake littoral receive little as compared to other places). In general, the Lake Victoria basin receives more than 50mm per month (the barrier between a dry month and a wet month) throughout the year, with a maximum during April and May. This effect of rainfall throughout the year is attributed to the interaction between the strong Lake-breeze and the larger-scale flow. Zonally, rainfall amount and reliability varies with the Lake littoral receiving less, about 700mm annually (and less reliable), and other areas receiving up to over 2000mm per annum like Kakamega area and Kisii Highlands. These variations in rainfall amount and reliability leads to the agro-climatic zonation of West Kenya from I-IV (Schmidt and Jaetzold, 1982). The potential for rain fed agriculture varies from very high in Zone I to medium in Zone IV (see figure 2). The proportion of medium potential land is very small and confined to the Lake littoral. The daily distribution of rainfall also range much with short torrential

rains in the Lake littoral to long steady rains in the highlands and other areas away from the Lake littoral.

Other climatic factors are very conservative in West Kenya with little variation from year to year. Temperature averages 21° Centigrade but may reach 25° Centigrade in the littoral. Kisi highlands are cooler due to altitude factor. Evaporation varies from 1650mm in the Kisi highlands to over 2000mm per year in the littoral. Relative humidity is high throughout the year.

Generally, the climate of the Lake Victoria Basin, in this case West Kenya, is that of warm and moderately wet nature conforming to the tropical or equatorial conditions though modified by meso-scale circulations generated by local factors. Although there are no well defined rainfall seasons in the Lake Victoria Basin the period of the long rains and short rains can be identified as is the generally dry seasons. The existence of wet seasons and dry seasons, relatively, points to the possibility of having periods of rainfall not favourable to crop growth. On this basis the study was done to check whether the unfavourable rainfall condition can occur when the favourable situation is expected or to check what may be described as unfavourable condition in West Kenya so that proper agricultural or agronomic planning can be done taking into account the possibility of unfavourable rainfall condition occurring.

Most people in West Kenya are involved in rural-based activities mostly small scale agriculture. The large scale

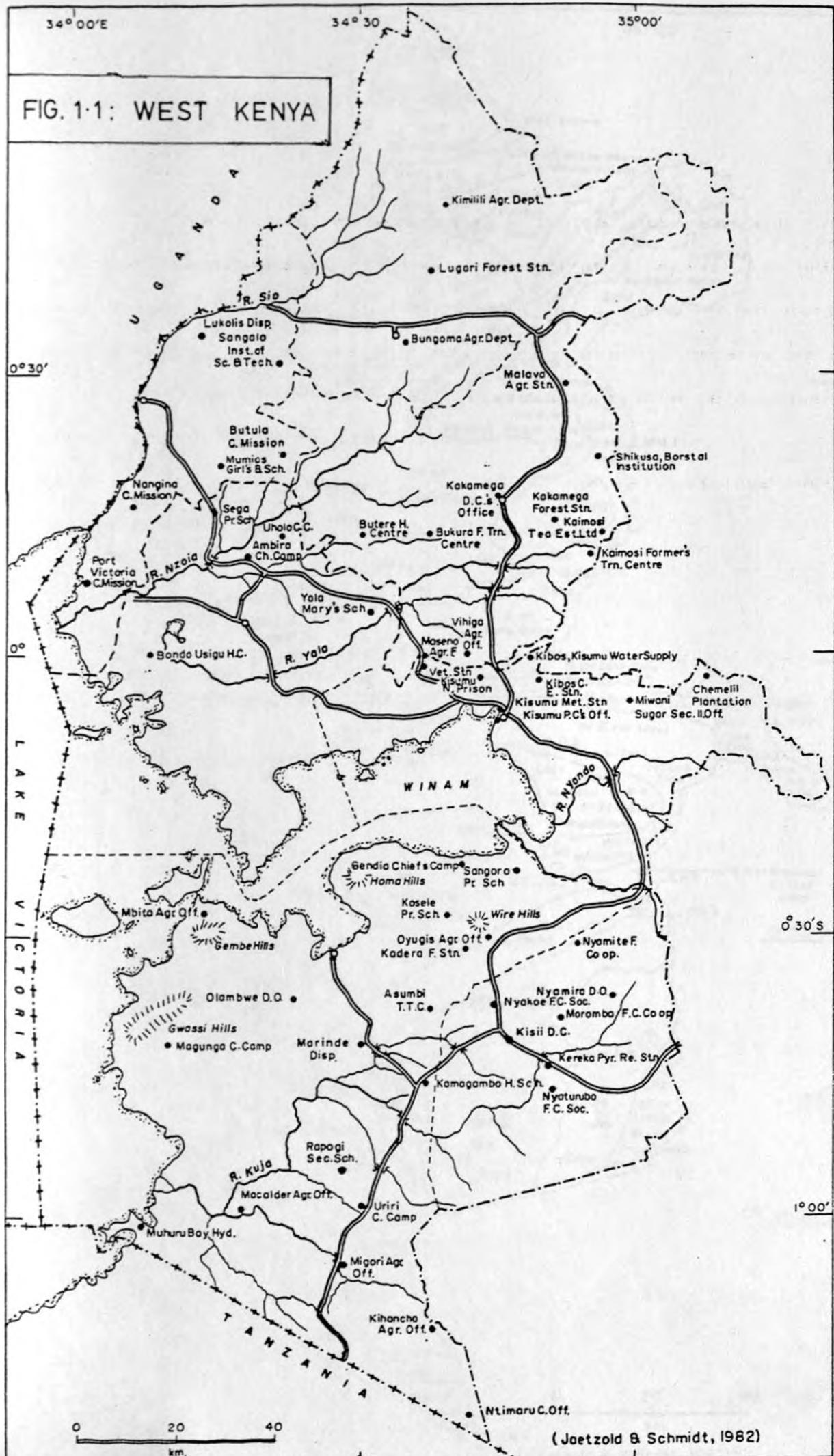
agricultural activities are mostly the preserve of big companies like the Mehta and Madhuani groups in the Nyanza Sugar Belt. Crops grown in the region are mostly food crops for consumption and sales like Maize, Sorghum, Bananas, Finger millet amongst others. Major cash crops are Sugar, Tea, Pyrethrum, Coffee and Sisal to a small extent. Those in the Lake littoral are in some cases involved in the fishing industry. Mining activities used to be part of West Kenya economy but of late they have received little attention and whoever is involved does little in terms of output.

Most agricultural activities are rain-dependent and any anomaly in the rainfall distribution, directly or indirectly affects farming activities, especially floods and droughts respectively.

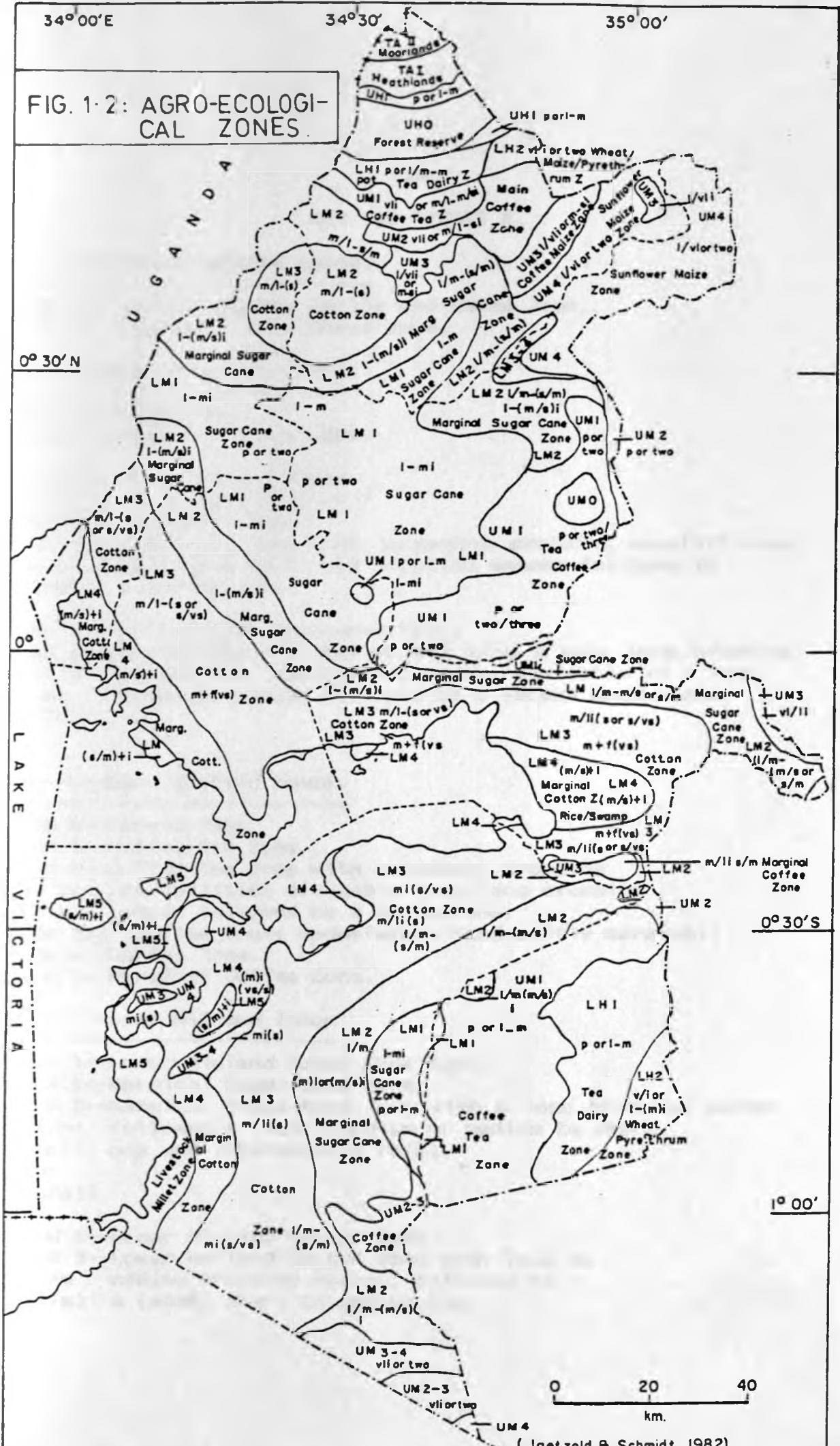
The population of West Kenya is quite large reaching over 4 million people (1979 census, see District Development Plans for Nyanza and Western province). Regions with the most concentration of people are Kakamega and Kisii Districts and the least settled is South Nyanza. As has been said above, the population is largely rural based with little urbanization although urban centres growth has been increasing; Kisumu, Kakamega, Kisii, Homa Bay, Webuye, Siaya and Busia are some of the major urban centres. notable characteristic of these urban centres is their close relationship with the rural areas.

In conclusion, West Kenya is within a high rainfall zone in Kenya with little part of it in the semi-arid (relatively wet) zone. A large section of the study area is in the high potential zone and all the agro-climatic zones of the Lake Victoria Basin of Kenya can be found in West Kenya. It would therefore be necessary to check the daily rainfall conditions over the region during the drought periods of 1972-74/76, 1980-81 and 1984-1985, and this was the main purpose of the study.

FIG. 1·1: WEST KENYA



## FIG. 1-2: AGRO-ECOLOGICAL ZONES.



## KEY TO FIGURE 2.

TA-----Tropical-Alpine Zones.

- 
- 1.TA I--Tropical Alpine Cattle and Sheep Zone.
  - 2.TA II-Tropical Alpine Sheep Zone.

UH-----Upper Highland Zones.

- 
- 1.UH 0--Forest Zone.
  - 2.UH 1--Sheep and Dairy Zone.

LH-----Lower Highland Zones.

- 
- 1.LH 1---Tea-Dairy Zone.
  - 2.LH 1---Tea-Dairy Zone with permanent cropping possibilities.  
o or dividable in a long cropping season followed by  
i-m a medium one.
  - 3.LH 2---Maize/Wheat-Pyrethrum Zone.
  - 4.LH 2---Maize/Wheat-Pyrethrum Zone with a very long cropping  
v1 i season and intermediate rains, dividable in a long  
or cropping season followed by a (weak) medium one.  
1-(m)i

UM-----Upper Midland Zones.

- 
- 1.UM 0--Forest Zone.
  - 2.UM 1--Coffee-Tea Zone.
  - 3.UM 1--Coffee-Tea Zone with permanent cropping  
o or possibilities dividable in a long cropping  
i-m season followed by a medium one.
  - 4.UM 2-3--Coffee Zone( undifferentiated,partly marginal)
  - 5.UM 2--Coffee Zone.
  - 6.UM 3--Marginal Coffee Zone.

LM-----Lower Midland Zones

- 
- 1.LM 1--Lower Midland Sugar Cane Zone.
  - 2.LM 2--Marginal Sugar Cane Zone.
  - 3.LM 2--Marginal Sugar Cane Zone with a long cropping season  
1/m- followed a (weak) medium or medium to short  
(m)i one and intermediate rains.  
or  
(m/s)i
  - 4.LM 3--Lower Midland Cotton Zone.
  - 5.LM 3--Lower Midland Cotton Zone with long to  
1/m medium cropping season, followed by  
(s/m) a (weak) short to medium one.

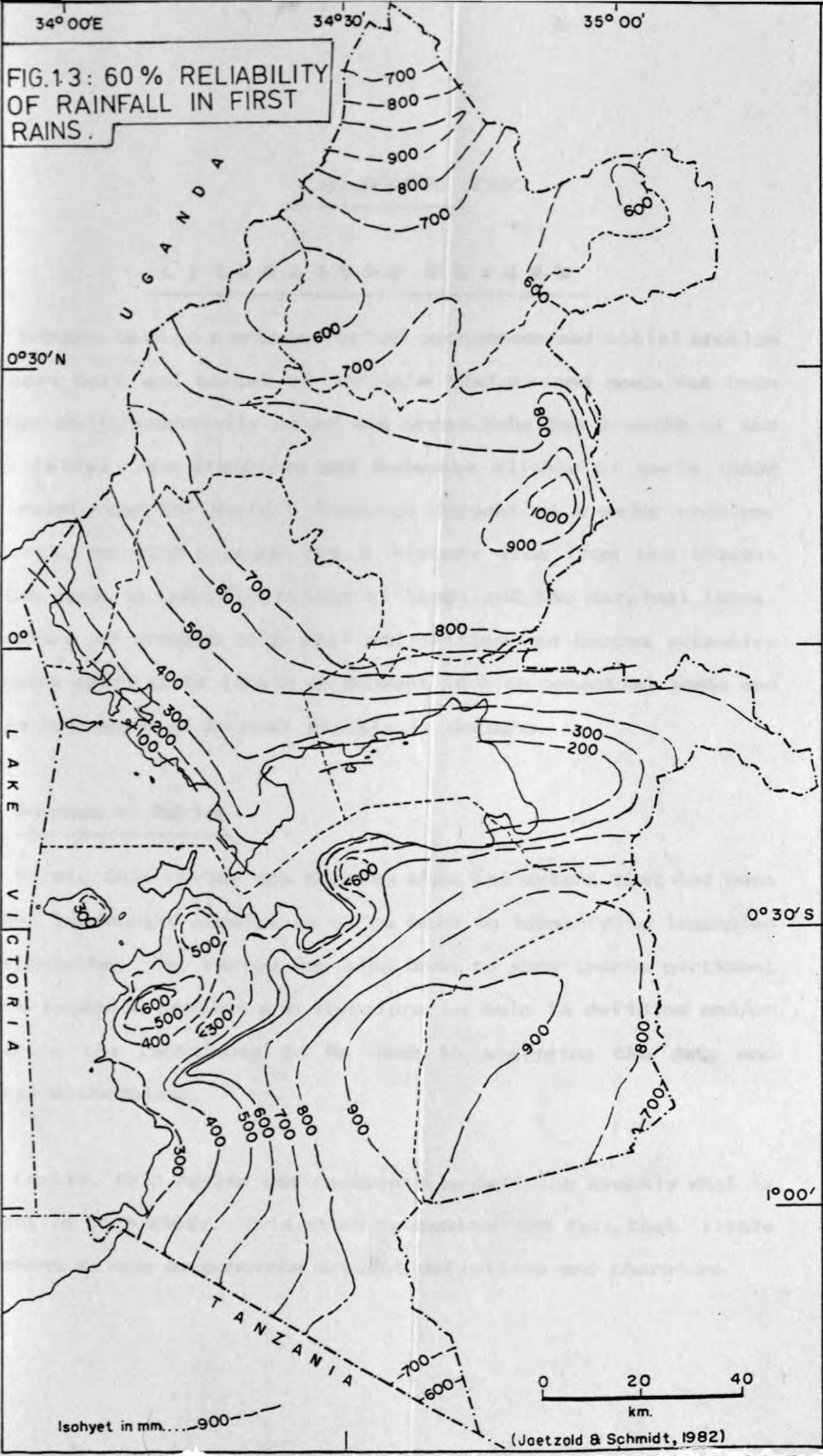
- 6.LM 3----Lower Midland Cotton Zone with a medium  
m/1is to long cropping season, intermediate rains  
and a (weak) short one.
- 7.LM 3---Lower Midland Cotton Zone with a medium cropping  
mi season, intermediate rains and a (weak) short to  
(s/vs) very short one.
- 8.LM 4---Marginal Cotton Zone.
- 9.LM 5---Lower Midland Livestock-Millet Zone.

34° 00'E

34°30'

35° 00'

FIG.13: 60 % RELIABILITY  
OF RAINFALL IN FIRST  
RAINS.



## **CHAPTER TWO**

---

2.0.

### **LITERATURE REVIEW**

---

Drought both as a meteorological phenomenon and social problem has been part and parcel of Africa's history and much has been written on it especially after the great Sahelian Drought of the early 1970s. The Ethiopian and Sudanese plights of early 1980s have reinforced the World's focus on drought as a major problem. In Kenya, no ethnic group has a history free from the drought problem both in the high potential lands and the marginal lands. Literature on drought both oral and written has become extensive but there seems to be little on drought in high potential lands and little agreement as to what exactly is drought.

#### **2.1 Purposes of Review**

---

First, this review was done to show the extent that had been reached in drought studies so as to help in identifying loopholes and strengths. The review was also done to show trends pertinent to the research problem and therefore to help in defining and/or designing the techniques to be used in analysing the data and general methodology.

Lastly, this review was necessary in defining exactly what is drought in this study. This study recognised the fact that "little agreement exists as concerns drought definition and therefore

whatever definition given in any study is only relevant to that study."

## 2.2 The Review

Drought as a natural disaster has drawn the attention of various scientists, the media and the public at large especially as concerns its occurrence and social-cum-economic effects. This has led to great confusion as to what really constitute a drought situation. There is no universally accepted definition of drought or a drought situation and whatever definition that may be offered is bound to be relative and specific to the job at hand. Attempts have been made to define drought universally but has met with little success.

Hounan (1972) and McCutchan (1978) recognised the difficulty faced in defining drought. Hounan (1972) suggested that "the best solution may be specific definition or approaches to meet different requirements". He went further to give the various definitions that might suit meteorologists, agriculturists, hydrologists and economists. McCutchan (1978) said that "it is generally impossible even to say that drought has started until a significant period of below-normal rainfall has already occurred". He made an observation that "drought is capable of many interpretations, and a variety of different aspects must be considered if any serious attempt is to be made to see how its effects can be mitigated."

Felch (1978) gave a meteorological definition of drought as "a regional manifestation of a generally fluctuating climate associated with aberration (abnormality) of the atmospheric circulation". The phrase "generally fluctuating" is important because a fluctuating climate does not mean drought occurrence unless the condition is abnormal in the sense of the average condition in an area and therefore need to investigate how the element used in the study behaves internally. This would help in defining the boundary between the normal and abnormal condition in a particular area. Felch made a distinction between drought and aridity noting that "aridity is low average rainfall or available water, and it is a permanent feature of the region in question. Drought on the other hand is a temporary feature of the climate". This view was very relevant to this study and an attempt was made to check the rainfall tendency (daily) and to identify any abnormal feature using the  $< 0.25\text{mm}$  and rainfall  $< 5\text{mm}$  rainfall per day limits respectively.

Sandford (1978) defined drought in economic terms as "a rainfall-induced shortage of some economic good brought about by inadequate or badly-timed rainfall". The "badly-timed" phrase is important for a shift in rainfall regime without change in the total amount at the end may well trigger off a drought.

Odingo (1978 and 1985) observed that drought "is a phenomenon deeply related to agricultural practices and environmental set-

ups." He described a drought situation as "a period significantly long, when the water shortage due to the failure of rains or other human causes is such that normal agricultural activities for example pastoralism are equally brought to a halt through lack of grazing".

Gregory (1986) gave a complete summary of the possible definitions of drought, whatever approach is taken. He warned against the use of the terms drought, desertification and famine synonymously. In conclusion, Gregory said that "generally, droughts are normally seen as being restricted to land areas where some form of agriculture, horticulture, or silviculture is possible". To him, even humid areas can experience droughts and therefore any definition of drought should be relative, not absolute. The observation that "even humid areas" can experience drought is very important for most studies on drought have tended to neglect the high rainfall lands especially in regions with over 1000mm rainfall per year and yet in these areas such rainfall alteration can lead to crop failure or seriously depressed crop yields.

Many other definitions have been given and even attempts made to give quantitative definitions but they all end up being meteorological, social, economic or agricultural. In this study, drought in the Lake Basin was seen in terms of failure of the April-May rains. The definition was then polished quantitatively

in terms of daily rainfall of less than 0.25mm distribution in a day or less than 5mm per day.

Since it is almost impossible to come by a universal definition of drought, the question that is now faced is whether there are common characteristics that can be used to identify a drought situation. In this case also, various characteristics have been given depending on whether one is a hydrologist, a climatologist and or meteorologist, agriculturist, social scientist or an economist. Felch (1978), Odingo (1978), Rijks (1978) among others have given various characteristics of drought. Felch's important observation to this study was that it is almost impossible to get very severe droughts in a very small area. Therefore, near global droughts of the 1970s and the 1980-81 and 1984-5 droughts that devastated most of Africa must have covered large areas of Kenya and it is important to check whether they extended to the high potential lands especially the Lake Basin where the Lake is normally expected to play a major moderating effect. In Odingo's observations as concerns drought characteristics, three were most important in the study; that is, the following conditions according to Odingo (1978) could be declared "drought situations" depending on the observer and on the type of agriculture or other mode of land use with which it is to be associated:

- (i) a shift in the occurrence (or onset) of seasonal

rains especially for the months critical for crop performance; in the study, the months of April and May when most crops in the basin are in their "development stage" are considered (see Nyandega, 1987).

- (ii) the complete failure of seasonal rains followed by the rain proper the following year; this can happen even in the high rainforest zones (Oguntoyinbo et al 1977, UNDP, 1976).
- (iii) too much rain at the wrong time; this could also be called unseasonality of rainfall.

In this study, the conditions above were checked against daily rainfall during the noted periods of drought in Kenya so as to identify which one is characteristic of drought period in the Lake Basin.

Examining the various definitions and characteristics of drought, one quickly realises that the list can be endless and therefore in this study, the meteorological definition was taken and the characteristics to be looked for were also to be meteorological. With this approach a drought situation was taken as a period of exceptionally below-normal rainfall. Below-normal rainfall in this study for example included the occurrence of long rains well after the first five months of the year when they were normally expected; that is, normal rains in the Basin in terms of

long rains are those occurring from February/March and peaking in April-May then fading off from late or mid June. January and February (especially early February) are usually dry relatively as is late June and July. Any exception to the trends above as concerns long rains is abnormal but to be exceptionally abnormal there must either be failure of rains totally to peak in April-May or occurrence of dry spells, on a continuous basis for more than half of April-May period.

If the definition and characteristics of droughts can be seen from a relative point of view, then one need to provide an answer to the question "what causes drought or a drought situation?". On causes of drought in the world and Africa in particular, one has to be careful about the question of the ultimate cause, and immediate cause. Climatologists and Meteorologists relate drought occurrences to forces that produce rainfall and any failure in terms of development of the forces is most likely to result in drought.

Writing on rainfall in Africa, Griffiths(1972) gave the following factors as resulting in relatively low (or even failure of) rainfall in East Africa as compared to other areas in the same latitudinal position as :

- (i) Divergent character of both the North-East and South-West monsoons;

- (ii) The shallow depth of the South-West monsoons;
- (iii) The strong meridional flow in all but the transition seasons;
- (iv) Lastly, the stable stratification aloft (intrusion of the inversion layer) together with a marked decline in the moisture content. Other factors noted are topography and the nature of the land surface.

Wood and Lovett (1974) dealing with recent droughts in Africa, associated drought occurrence in Ethiopia with the solar cycles (sun-spot activities) especially the 11 year solar cycle. Hussein (1978) discussing the drought situation in Ethiopia, put the blame on the social and political system that had existed prior to the 1974 revolution and not meteorological phenomena. In fact, Hussein's work more or less considers drought and famine as synonymous and he stated that "famine is a social phenomenon and it results for the most part from the socio-economic system and the manner in which production and distribution are carried out in a society".

Lamb (1977) disputed the findings of Wood and Lovett (1974) linking drought in Ethiopia with the 11 year sunspot cycle. He blamed the wind and pressure distributions within and from without Africa. Schove (1977) linked the Sahelo-Ethiopian droughts with the Southern Oscillation (this is a pressure see-saw between the

Eastern Atlantic and the Indian Ocean) and the El Niño (a warm upwelling along the coast of Peru in South America; the ENSO (El Niño plus Southern Oscillation) factor.

Felch (1978) explained meteorological anomalies in terms of the physical forces and restraints which determine large scale atmospheric circulation patterns, coupled with regional and local factors which superimpose local climate peculiarities on the large-scale climatic background. He considered the prolongation of drought period a result of the absence of large scale vertical activities/motions.

Odingo (1978) took an environmental approach to the causes of drought question giving possible causes as :

- (a) Increase of population pressure on the marginal lands.
- (b) Urbanization and its effects on vegetation cover in terms fuel supply.
- (c) Increase in stock numbers in the pastoral-lands.

Gregory (1986) gave a complete summary of possible causes of meteorological drought as:

- (i) Air subsidence and anticyclonic development over and/or in a region;
- (ii) Changes in location, intensity and frequency of atmospheric circulation systems affecting a

place:

- (iii) Ocean surface temperatures and related oceanic circulation especially location of warmer and colder surface waters or temperature changes of ocean masses over a larger area;
- (iv) The possible role of Southern Oscillation and El Nino (warm upwelling along the Western Coast of South American continent); The ENSO as a Teleconnection factor. Teleconnection is delayed impact of atmospheric circulation changes far from the drought area concerned with long chain of intermediate effects;
- (v) Southern Hemisphere temperate and sub-tropical circulations and northern hemisphere droughts;
- (vi) Changes in Arctic conditions and the Sub-Saharan droughts;
- (vii) Changes in upper atmospheric circulation, including jet stream location;
- (viii) Local modification of surface conditions;
- (ix) Changes in atmospheric gaseous and aerosol composition especially the carbon dioxide and ozone questions, introduction of volcanic dusts or by-products of combustion;
- (x) Desertification
- (xi) Variation in sun's energy output.

It is not necessary for all the facts above to be in operation at a go. Noting the various possible causes of drought, one quickly records the many differences in depiction of drought. This study was not concerned with the causes of drought but with whether drought has occurred in the Lake Basin (West Kenya) or not and with whether there are notable characteristics in terms of daily rainfall distribution, of drought occurrence in the basin.

Meteorological drought is usually of importance to the people when its occurrence affects human activities especially socio-cultural and socio-economic set-ups. Drought has had a history of adverse effects especially in Africa and Asia Minor. Most people do associate drought with famine, deaths, malnutrition, mass population displacement (see Hussein et al., 1976, Odingo 1985, etc). The socio-ecological implications of drought are usually used to determine the severity of a drought period.

Many people, even laymen, can claim to know the effects of drought. Most work on drought in Africa has concentrated on the social effects and economic effects [Odingo (1985)]. Writing on the cost of famine to the nation, Mbithi and Wisner (1972) divided the effects of drought into direct costs which the government incurs in alleviating the burden of drought over the affected population, primarily through famine relief and production losses (economic cost), and social costs like nutritional problems and nutritionally related diseases, family and community disruption,

misery and loss of human dignity. Others have also noted these effects plus political implications and economic effects (Hussein et al 1976, UNDP 1976, Odingo, 1985, etc). This study did not deal with the effects of drought but indirectly touched on famine to check whether meteorological droughts usually lead to famine or not.

The study dealt mainly with occurrence of drought especially in the high potential lands in Kenya. Neil (1981) reporting to the parliament on famine and floods in Kenya in 1981 noted that "the long rains failed in 1981 almost throughout the country and yet the short rains were exceptionally heavy causing floods throughout the country". Lamb (1966) writing on the climate in the 1960s referred to the work of Morth (1955) and other geological evidences to point out that even the Lake Basin showed signs of drought occurrence. Morth (1987) explained the principle features of Lake Victoria's level fluctuations in terms of rainfall anomalies; reference to drought and floods.

Holt and Seaman (1976) looking at the scope of the 1974-1976 drought in Ethiopia said that within Ethiopia, drought was a localised disaster, even though it struck a significant proportion of the territory. This is important because people do ignore the fact that drought can be a local or regional affair, and that patterns can be noted in drought occurrences in a given area.

UNDP (1978) warned against ignoring the possibility of drought occurring in the regions with 1,500mm of rain a year or above. Zewde (1976), Ojany and Ogendo (1973) all noted that drought has been a feature of the African climate from time immemorial. To Zewde (1976), drought is not always the cause of famine, for famine has always been inherent in the Ethiopian socio-economic set-up in the manifest contradiction between means of production and distribution of wealth. That locusts, cattle plagues and drought merely transformed an endemic situation into an epidemic. This is an important view for this study recognised the fact that many other factors may lead to famine and that famine is not drought and vice versa.

Baker (1977) studying the background to drought occurrence in East Africa said that "over large areas of East Africa, drought is probable although not precisely predictable". To him, the impact of drought will vary under different climatological conditions and in accordance with the characteristics of other elements in the environment, more particularly soils and vegetation. He particularly emphasised the importance of soil moisture, evapotranspiration (potential and actual), moisture balance and other soil factors. This suggests that even the high potential lands may be subject to drought occurrence though the overall impact may not be the same as in the marginal lands. It was in this connection that Oguntoyinbo et al (1977) gave the example of drought occurring in Southern Nigeria in the rainforest zone to

sound a warning to those ignoring drought as a factor in high rainfall areas. Wood (1977) noted that droughts are a recurrent phenomena in Africa. This statement was important to this study for there was need to check whether the drought periods investigated had the same characteristics in terms of daily rainfall distribution or not.

Felch (1978) asserted that "most of the world's agricultural areas are subject to drought, but the duration and intensity vary greatly from one climatic zone to the next". Wetheral et.al (1978) warned against the tendency in some quarters to under-estimate the importance of drought and rainfall unreliability in areas outside the low rainfall extremities of the semi-arid zones. They said that drought may not be so spectacular in the higher rainfall areas, but it still can be of greater overall significance since it is in such areas that major population concentrations are to be found. This is the case with West Kenya especially the high rainfall areas. Holt (1982) gave the example of drought occurrence in the high rainfall zone(s) of Zaire, in the "heart" of Zaire (Congo) Basin, in 1978 due to localized effects.

In his work on rainfall occurrence in the Lake Victoria Basin of Kenya, Mungai (1984) noted that dry spells are a common feature of the rainfall regimes in the Lake Victoria Basin of Kenya and that there is need to check how long a spell becomes regarded an abnormal situation. Ojany and Ogendo (1973) took note of the

history of famine in the Lake Basin which have been linked to drought occurrences, and said that drought and floods as two extremes of weather have been present in the history of Kenya from time immemorial. Odingo (1985) singled out the periods 1972-76, 1980-81 and 1984-1985 as some of the worst drought periods in Eastern Africa. One can generally say that , the high potential lands have had their share of droughts in Eastern Africa, and that drought occurrence have been experienced in the high potential lands like Kenya Highlands, Lake Victoria Basin and others. So it is important to investigate whether the 1972-76, 1980-81 and 1984-85 droughts affected West Kenya in terms of the definition given and whether, if there were drought periods, famine occurred, and lastly whether the drought periods had common characteristics to be used in drought recognition and management.

Quantitative analyses of drought situations have been attempted but still the problem of universally accepted definitions surfaces. Another problem is that no one has actually managed to point precisely when the drought begins until after it has long progressed. The work of Conrad and Pollak (1962) brought out this problem clearly as it was concerned with the quantitative analysis meteorological phenomena . Morth (1967; early version 1955) related the fluctuations of Lake Victoria levels with rainfall in the basin catchment and pointed out that a fall in lake level is a reflection of periods of dry spells or even drought situations.

Winstanley (1973) analysing rainfall trends in Africa, the Middle East and India, said that "in the marginal lands, it is not unusual for the monsoon rains to fail each year but it is almost unusual for them to fail so widely in several consecutive years". Writing on drought and irrigation in East Africa, Hall (1978) considered the facet of drought which causes rainfall shortages or delays the arrival of winter rains to be the climatic problem. According to him, the problem is not the scarcity of rainfall in absolute terms but that of irregular distribution over the year, especially during the rainy seasons. This may be the case in West Kenya since this is a region of relatively high to moderate rainfall with the exception of some places in the Lake littoral which may be said to be semi-arid but relatively wetter than other semi-arid regions in Kenya. Felch (1978) used the Palmer's index as a drought indicator but still warned against its general use in various climatic zones.

Masaya (1978) using spectral analysis technique in comparing rainfall variations in Kenya and Zimbabwe noted that drought and floods are usually followed by heavy rains which cause human suffering. In spectral analysis, the peaks in the spectrum suggest the existence of a cycle and any rainfall value below the secondary mean is defined as drought. Mungai (1984) using the 5.0mm per day as the limit between a dry day and a wet day, found the occurrence of dry spells in the Lake basin a common feature.

Kiangi (1978) investigating the nature of the physical and windflows in the atmosphere over Eastern Africa during 1967 (good year) and 1972 (drought year) in response to near global drought of 1972, found no change in the physical structure of the atmosphere. On the other hand, the windflows were shown to be different during April and July of 1967 and 1972 respectively. There was also upper level convergence in 1972, a feature often associated with suppressed weather activities, and hence less rainfall or drought.

Schneider (1978) gave the following problems faced in forecasting future droughts:

- (i) no physical theory explaining the connection between drought and other physical meteorological factors is generally accepted;
- (ii) Droughts are not even geographically comparable, nor do they last for the same length of time, nor do they exhibit the same severity.

These observations by Schneider (1978) were well considered in the study especially the second one (ii). Since it is not very possible to point out clearly the start and end of drought, an overview of the distribution of one central element in drought occurrence, namely, rainfall, was considered crucial in this study.

Rainfall analyses have been done in Africa, Eastern Africa included, and the world over thoroughly, but usually using the annual values or monthly averages with little use of the actual daily rainfall. Henderson (1949) working on some aspects of climate in Uganda with special reference to rainfall said that in Lake Victoria zone, rainfall is well distributed throughout the year and peaks in March-April-May and October-November. That dry seasons (relatively) occur between December and March and June-July. Griffiths (1958) gave various tests one could use in testing for normality in rainfall data like the Cornu's criterion which uses the relationship between the mean deviation and the standard deviation. The same researcher in 1972 used 50mm per month isohyet line to differentiate between a wet month and a dry month. Jaetzold and Schmidt (1982) on rainfall distribution in West Kenya said that rainfall is more or less continuous with little distinction between the first and second rains. The more or less continuous rainfall makes it difficult to decide when the "so called" second rains start and stop. Mungai (1984) gave three rainfall regimes in the Lake Victoria basin:

- (i) Eldoret regime.
- (ii) Kibos regime.
- (iii) Transitional regime.

These regimes were used in the study when choosing representative stations.

Sansom (1952) noted the increasing rainfall trend between 1920 and 1949 but with a belt that existed where rainfall was decreasing from Kenya Coast across Lake Victoria. He recommended the use of 5-year moving average in working out the annual rainfall trend. In the study, the 5-day moving average was used as a low filter pass to remove oscillations less than five days. Jagannathan and Parthasarathy (1973) on trends and periodicities of rainfall over India noted that persistence, the alternative to randomness has the property of low frequency variation, which introduces positive serial correlation at small lags. They recommended the use of autocorrelation functions in studying the structure of a time series like rainfall. To smoothen any series, the use of Binomial Coefficients to weight the series as provided by WMO (1966) was recommended. This study used the Binomial Coefficients to weight the 5-day running means.

Rodhe and Virji (1976) pointed out the lack of any definite long term trends of annual rainfall in East Africa except at some stations in northern Kenya where the trend towards increased precipitation in recent years was indicated. Subjecting their data to spectral analysis, they found peaks at frequencies corresponding to the following time periods; 2-2.5, about 3.5 and 5-5.5 years. Ogallo (1978, 1980) also found no definite trend in annual rainfall distribution over Africa and East Africa respectively. From these works, it seems as if no major trend have been found in the annual rainfall distribution over Africa and East Africa to indicate any

major "down turn" in rainfall amount. Most of the work quoted above use the annual amounts or monthly means and totals but the picture probably may be hidden in the daily distribution of rainfall and that is the approach adopted in the present study.

On the general trends of statistical analysis in climatology, the work of Conrad and Pollak(1962), and Stringer(1972) are very comprehensive. On time series analysis and the relevant significance tests, the following work were important in this study: Blackman and Tukey (1958), Quenouille (1968), Kendall (1976), F.A.O(1973)and Saikkonen (1985) .

Generally, literature on drought has become extensive since the 1972 Sahelian drought and is bound to increase with current food supply situation in Africa. Literature on drought has, generally, concentrated more on the effects of drought than on drought per se thus the current confusion as concerns drought and famine. The available literature is also not very clear about drought definition and the causes of drought . The study used a meteorological definition of drought but attempted not to give causes of drought in West Kenya. Literature on rainfall trends in Africa has tended to rely on mean data than the actual totals and this might have resulted in not getting hidden characteristics of rainfall distributions. This study therefore relied mostly on rainfall data as recorded by the various stations in West Kenya so to establish the actual rainfall situation during the 1971-1985

period. As concerns the drought study regions, the literature is more on the marginal lands but to a greater extent ignoring the high potential lands in the world over. In Kenya there is general lack of literature on drought in the high potential areas and the study was done in an attempt to correct this anomaly. The study recognised drought as a normal part of the world climate and can therefore occur anywhere on the earth surface. If the basic characteristics of drought occurrence in any region can be established, it would then be easy to design appropriate drought management strategies in a given geographical unit. Since the high potential lands of Kenya are the main food producing areas and population centres, it is very essential to establish their meteorological conditions (mainly rainfall amount and distribution) because any small rainfall anomaly may result in a national disaster.

Kenya has been the only African country to have the meteorological service which has been able to predict the onset of droughts. This has been done by the Meteorological Department of the Ministry of Agriculture. Droughts are usually accompanied by low pressure areas (low pressure systems) and dry air masses (anticyclones). Thus according to Kinyua and others (1980), a good indicator of the likely onset of drought is the presence of low pressure areas off the coast of East Africa. Thus an increase in pressure over these off-shore areas will indicate a general absence of low pressure areas and thus indicate the likelihood of drought. According to Kinyua and others (1980), the following factors are important in determining the onset of drought:

- a) The position of the low pressure area associated with the off-shore anticyclonic areas. If such an anticyclone moves far enough

## **CHAPTER THREE**

---

### **3.0.0.0**

### **RESEARCH METHODOLOGY**

---

#### **3.1.0.0 Data Source**

---

This study was based on the daily rainfall data, mainly, and a little on river flows and agricultural performance reports. The rainfall data used were those of the months of January, February, March, April, May, June and July. River flow information and agricultural reports were also for the same months.

Rainfall data were retrieved from the computer stores at Dagoretti Corner, Meteorological Department Headquarters, Nairobi. This work was only possible after the rainfall stations had been identified and mapped to show the spatial representation of the various agro-climatic zones (see figure 1.1). The rainfall stations were mostly concentrated in the Western Province, and Kisii and South Nyanza Districts. Few stations from Kisumu and Siaya Districts were used (Table 3.2) due to either lack of data consistency or lack of stations but all the agro-climatic zones in these areas were well represented by stations in Busia, Bungoma and South Nyanza Districts.

Data on river flow were retrieved from the Ministry of Water Development computer stores, Nairobi, on a daily basis for each

month from January to July for 1977-1985 period. The data were recorded on computer sheets for each month with corresponding years.

Data on agricultural performance came from district agricultural reports as given by agricultural stations in West Kenya (see Table 4.4). Reports of particular interest were those for the period 1971-1985 with reference to the long rains, and agricultural production.

Stations (Rainfall, Hydrological and Agricultural) from which the data came were confined to West Kenya and represented nearly all the agro-climatic zones of the Lake Victoria Basin. The Stations were also those with the most representative and the most consistent data for the period 1971-1985. Altitude was also used as a factor in choosing the representative stations.

Generally, data used in the study came mainly from secondary sources and there was no attempt made to collect primary data in the study. This resulted in some difficulty in cross-checking some data that appeared to be uneven, as was shown by Kisii data for all the months in 1971.

### 3.2.0.0 Data Collection

To get the necessary data for the study, all the Rainfall Recording Stations in West Kenya were first marked out from the

list of stations provided by the Meteorological Department. Stations with the longest records and those that have been closed were at first all marked out giving the altitudes, locations (latitudes and longitudes) and periods of record (see Table 3.1).

The stations were then cross-checked with the three rainfall regimes of the Lake Basin; Eldoret, Kibos and Transition regimes (Mungai, 1984). The representative stations were then chosen on the basis of data consistency, length of record, altitude, agro-climatic zone and climatic regime. Forty-five stations were selected or chosen on the basis of the above factors.

The forty-five stations were again weighed on the basis of the factors already mentioned above and spatial representation, and on this basis twelve stations were chosen (see Table 3.2). After selecting the stations, rainfall data were collected on a daily basis from January to July for each station. For each month, data were arranged under the corresponding years for 1971-1985, and these were then entered into computer diskettes (information stores) using a Statgraphic package (this package is for statistical and graphic work). In the diskettes, each month for a given station was taken as a file and each year taken as a variable for the study was to deal with the yearly rainfall set ups as displayed on a daily basis. The same method was followed

when collecting river flow data for Rivers Nzoia, Yala, Nyando, Miriu and Gucha-Migori.

Data on agricultural performance were tabulated for the whole of West Kenya (see Table 4.4) and then compared with the stations rainfall record especially in the analyses of the results.

### **3.3.0.0 Data Analysis Techniques**

#### **3.3.1.0 Introduction**

The collected data were subjected to various statistical analysis techniques to show rainfall distribution over the years (1971-1985). This was in search of years that could have been exceptional in terms of rainfall distribution and variation. First, the basic statistics of the mean, standard deviation, Skewness and Kurtosis were used to show the central tendency. The

---

**Table 3.1:Rainfall Stations Arranged according to Altitude in WEST KENYA (source: Meteorological Department books).**

---

A	1650m and Above	Alt. m
Number	Name	Alt. m
88.34.001	North Mount Elgon Forest station	2190
90.34.032	Moromba Farmers Co-op society	1890

90.34.065	Nyamira District office	1830
91.34.019	Ntimaru Chief's office	1800
89.34.072	Kaimosi Tea Estate Ltd	1740
90.34.001	Kisii District Commissioner office	1740
90.34.046	Nyabomite Farmers Co-op	1710
89.34.078	Kaimosi Farmers Training Centre	1680
90.34.031	Nyatirubo F.C. Society	1680
89.34.028	Kakamega Forest Station	1650
89.34.060	Kimilili Agric. Dept.	1650

B 1650 - 1500

89.34.016	Lugari Forest Station	1590
89.34.061	Malava Agric. Station	1560
89.34.103	Vihiga Agric. office	1560

89.34.001	Kakamega DC's office	1530
90.34.048	Rapogi Sec. School	1530
90.34.069	Kibos Kisumu Water Supply	1530
90.34.005	Kamagambo School	1500
90.34.058	Nyakoe F.C. Society	1500
     C      1499.7-1350.		
90.34.047	Uriri Chief's camp	1470
89.34.002	Bukura Farmers T. Centre	1440
89.34.031	Yala St. Mary's School	1440
90.34.011	Maseno Vet. Station	1440
90.34.023	Oyugis Agric. office	1440
89.34.082	Bungoma Agric. Dept.	1410.6
90.34.023	Oyugis Agric. office	1440

90.34.041	Marinde Dispensary	1350
90.34.045	Kosale Pr. School	1350
90.34.047	Uriri Chief's camp	1470
90.34.062	Kodera Forest Station	1350
90.34.066	Magunga Chief's camp	1350
91.34.010	Nigori Agric. office	1350
91.34.015	Kihancha Agric. office	1410
Below 1350		
89.33.028	Port Victoria Catholic Mission	1230
89.34.013	Mumias Girls' Boarding School	1318.8
89.34.030	Nangina Catholic Mission	1200
89.34.037	Lukolis Disp., Kakamega	1200

89.34.039	Bungoma. Butula Catholic Mission	1275
89.34.058	Sega Pr. School	1200
89.34.059	Uholo Chief's camp	1200
90.34.004	Kisumu PCB office	1127.7
90.34.007	Miwani Sugar Sec. II office	1302
90.34.018	Gendia Chief's camp	1200
90.34.021	Bondo Usigu Health Centre	1215
90.34.025	Kisumu Met. station	1130.7
90.34.060	Kisumu New Prison	1200
90.34.063	Lambwe Divisional office	1200
90.34.067	Sangoro Primary School, Nyakwere	1140
90.34.81	Kibos Cotton Exp. station	1154.1
90.35.046	Chemelil Plantations	1209.6
91.34.009	Muhuru Bay Hydromet station	1200

**Table 3.2: STATIONS USED IN THE STUDY**

Number	Name	Lat.	Long.	Alt(= m)
1. 88.34001	Mount Elgon Forest	1 08N	34 45E	2230
2. 90.34065	Nyamira DO's office	0 35S	34 55E	1860
3. 90.34001	Kisii DC's office	0 41S	34 47E	1770
4. 89.34.060	Kimilili Agric office	0 47N	34 40E	1680
5. 89.34061	Malava Agric office	0 28N	34 50E	1590
6. 89.34082	Bungoma Agric office	0 34N	34 33E	1430
7. 90.34.062	Kodera Forest	0 31S	34 39E	1370
8. 90.34.045	Kosele Primary	0 26S	34 42E	1370
9. 89.33.026	Port Victoria	0 07N	33 59E	1250
10. 90.34.021	USIGU HEALTH CENTRE	0 05S	34 08E	1230
11. 91.34.009	Muhuru Bay Hydromet	1 00S	34 07E	1220
12. 90.34.025	Kisumu Met office	0 06S	34 45E	1150

mean daily value was used to check whether the < 0.25mm/day (this is an extreme value), < 5mm/day and > 5mm/day were a common feature or not. The < 0.25mm/day was being used to define the meteorological dry day by the Meteorological Department although this figure is no longer used as it was realised the amount was too low for Kenya (it was the exceptional low amount that the study was interested and thus the use of this figure) and the 5mm/day limit was used by Mungai (1984) as the barrier between a dry spell and wet spell for agricultural purposes. In using the standard deviation, the tendency towards exceptional distribution was checked at 95% confidence limit; that is two standard deviation and any that fall outside  $\pm$  2 standard deviation was considered exceptional. Positive skewness was taken to show tendency towards positive distribution and therefore exceptional distributions were to be negative and vice versa. Kurtosis showed the general distribution and zero or near zero or negative Kurtosis values showed tendency towards platykurtic (flat) distribution and therefore low rainfall. Positive kurtosis showed tendency to have exceptional rainfall in the torrential nature or high falls (indicated by leptokurtic distribution). The basic statistics did not give the actual distribution but just the central tendency and were therefore reinforced by the use of frequency distribution tables.

The frequency distribution used 21 classes to get the best distribution showing the < 0.25mm/day , < 5mm/day and > 5mm/day.

To test statistically the central tendency shown by the Mean, Standard deviation and Frequency Tabulation statistics, the Analysis of Variance Technique was done to test the hypothesis (null) that there were no differences in the mean daily rainfall distribution for each month over the years (1971-1985). The test was carried out at 95% confidence limit or alpha 0.05. This was to give indications on whether there had been significant variation and differences over the years in the daily rainfall distribution or not.

To give the actual picture and structure of the daily rainfall distribution of each month during the period 1971-1985, a higher statistical technique was found to be necessary and in the study, the Time Series Technique was the most appropriate in terms of structure of the distribution and the process behind the distribution of rainfall. The daily rainfall values,  $y_i$ , were plotted against time (days),  $t_i$ . This gave the actual distributions and the graphs were drawn using the statgraphic package. Numerous variations shown in the series necessitated a further study of the components of the series that might have been present; trend, cycles, periodicity and random (irregularities). A five point moving weighted average was used as a low filter pass to smoothen off high frequency oscillations of less than five days. This was then checked to see whether there were periods of exceptionally low or high rainfall in keeping with the main aim of the study. The distributions shown were then examined for

persistence (a common feature in climatic events) or randomness using a time-domain technique, namely, autocorrelation function, rk. The autocorrelation function results were then tested for significance, using the formula originally given by Anderson (1941) but later modified by FAO (1973), against the first Markov Chain Model. The process behind the distribution were then checked or investigated by plotting the autocorrelation coefficients against time lag, k.

### 3.3.2.0 Analysis of Variance Test

---

The mean of a data distribution reflects the nature of the various elements of the data. It is therefore important when dealing with several variables in the data to investigate whether there is any difference of means between variables (in the study, daily rainfall of the various years, 1971-1985). One of the best tests of the difference of the means in the data is the analysis of variance test. In using the analysis of variance test, the following assumptions were made:

- (i) Data was assumed to be normally distributed; greater than 30 in numbers (daily).
- (ii) The samples (yearly data) were independent; on a yearly basis yes but on a daily basis no.
- (iii) Equal population standard deviation; might have not been so due to differences in the number of days of the various months.

The hypothesis tested in the analysis was that the yearly daily rainfall means were equal ( $H_0$ ) during the 1971-1985 period.

In the study, the one-way classification technique was used. The yearly rainfall values are usually not affected by one another (Stinger, 1972). The daily rainfall observations were obtained for 15 (or less 4 years) years, where the number of observations ranged from 28 days to 31 days. The analysis of variance test was aimed at giving the daily rainfall variation for each year (within variance) about the mean and between the yearly variation (between variance) about the overall mean. Data for analysis were represented as below:

Table 3.3: Analysis of Variance Table

Years!	Rainfall value (daily)					Mean
1971 :	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x
	1.1	1.2			1.31	
1972 :	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x
	2.1	2.2			1.31	
.	.	.	.	.	.	-
1985 :	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x . . . . .	x
	15.1	15.2			15.31	

First, the mean for individual years for each month (e.g. January) from 1971-1985 were worked out as:

$$\bar{y} = \frac{\sum_{i=1}^{31} x_i}{n} \quad (1.3)$$

where  $\Sigma xy$  is the total daily rainfall for each month in a particular year between 1971-1985.

n - the number of days in the particular month.

The mean for the whole period was then worked out. This came from the basic statistics and frequency tabulation results as already mentioned in the preceding sections. The mean for the month in the period 1971-1985 was then represented by  $\bar{x}$ .

Generally, in the analysis, the daily rainfall values for the individual years were represented by  $x_1, x_2, \dots$ , the sample means by  $\bar{x}_1, \bar{x}_2, \dots, \bar{x}_K$  and the overall mean for each month in the period 1971-1985 by  $\bar{x}$ .

The "within variance" was estimated by using the formula

$$\frac{\sum_{i=1}^K \sum_{j=1}^n (x_{ij} - \bar{x}_{ij})^2}{N - K} = S_{w_i}^2 \quad (2.3)$$

where N is the total number of days for the particular month in question during 1971-1985.

K - the number of days in the particular month.

The 'between variance' was estimated by using the formula:

$$\Sigma(\bar{x} - \bar{\bar{x}})^2$$

$$\frac{\Sigma(\bar{x} - \bar{\bar{x}})^2}{K-1} = S_{b2}$$

$$(3.3)$$

where  $\bar{x}$  is the mean daily rainfall for individual

years;

$\bar{\bar{x}}$  - overall mean daily rainfall for the period

1971-1985.

The above formulae are inbuilt in the statgraphic package and only the data addresses were given to the get  $S_y^2$  and  $S_b^2$  respectively. To test the significance of the results, the F-distribution at alpha 0.05 were used;  $F = S_b^2/S_y^2$  where  $S_b^2$  is the best estimate of between variance and  $S_y^2$  is the best estimate of the within variance.

If F was found to be significantly great, there was then significant difference between the means of various years and therefore the null hypothesis was rejected otherwise  $H_0$  was

accepted or the judgement was reserved until further analysis was applied.

The analysis of variance test together with the basic statistics results gave the general tendency of the daily rainfall distribution for the various months between 1971-1985 in West Kenya. These central tendency measures and tests did not give the internal structure and processes involved in the rainfall distributions over the period of study. Need for an investigation on the structure and processes of distribution of daily rainfall was therefore apparent.

### 3.3.3.0 Time-Series Technique

This was the main statistical technique used in the study and the question of whether there occurred a period of exceptionally low rainfall or not was largely based on the results of this analysis technique.

A Time-Series consists of observations taken at a specified time, usually at equal intervals or simply observations arranged sequentially with respect to time. Mathematically, a Time-Series can be defined by values  $y_1, y_2, y_3, \dots, y_n$  of a variable  $y$  (daily rainfall in the study). Variable  $y_i$  in the study was a function of time ( $t$ ), days, symbolized by  $y_i = F(t)$ . (4.3)

Time-Series has several components and these components suit best the study of natural fluctuations like daily rainfall time-series. The components are:

- Trend; long term movement
- Cycles; fluctuations about the trend of greater or less regularity.
- Seasonal fluctuations which repeat themselves within fixed periods of time less than one year (in the study less than one month)
- Random, residual or irregular fluctuations.

A Time-Series is therefore represented as a sum of (additive model) or product of (multiplicative model) the above four components, namely,  $Y = T + C + S + I$  or  $Y = TCSI$  where

T - trend

C - cycles

S - seasonal effects

I - irregular or random effects.

To study the "properties" of a Series, there is usually the need to decompose the Series into its various components using either the Time domain Autocorrelation function,  $r_k$ , (serial correlation) or Frequency Domain (Spectral analysis). This study used the Time-domain method to study the properties of the daily Time Series for stations in West Kenya. Each month was studied

separately and Series plot for each year worked out (see figures 4.4-4.6).

Many natural processes have been observed to belong to periodic, Moving Average (MA), Autoregressive (AR) or Auto-regressive-Moving Average (ARMA) processes. Using the moving average (weighted) and autocorrelation analysis method, the Series were examined to check for any trend, cyclic, seasonal or irregular fluctuations in the Series which may be used to characterise drought periods and the model they would fit.

#### 3.3.4.0 Plotting the Time-Series

For each month, the daily rainfall values represented by  $y_i$  for all the years from 1971 to 1985 were plotted against time (days), depending on the number of days in the month.

No attempt was made to average the days of the month for there was need to show what actually happened. A statistical package, statgraphic, was used to carry out the task. The graphs for all the years, depending on the month, were fixed in one graphic frame with the same vertical and horizontal scales respectively. This was to provide a visual impression of the differences and to give the actual fluctuations (see figs 4.4-4.6). Also, this was to give years of exceptionally low daily rainfall distribution relative to other years.

So many irregular distributions may hide the trend, or cycle or seasonal distribution and in the study, the original scenes showed web-like distributions and were therefore not easy to observe and describe. As a result, the need to smoothen the series became a necessity. In smoothing the series, one can either use the least square method or the moving average method. This study used the moving average technique to smoothen the series that resulted from the plots.

### 3.3.5.0 Smoothing the Series Using the 5-day Moving Average

---

The Moving Average (MA) process can be mathematically expressed as:

$$x_t = \epsilon_t + a_1 \epsilon_{t-1} + a_2 \epsilon_{t-2} + \dots + a_n \epsilon_{t-n} \quad (5.3)$$

where

- $x_t$  is the Time Series
- $a_1, a_2, \dots, a_n$  are some constants
- $\epsilon_t$  is the random shock at time t (see Kendall, 1973, 1978).

The moving average used in this study was a low filter pass removing fluctuations of high frequency less than five days. The five day interval is important for agricultural purposes in terms of soil moisture retention capacity of most soils in West Kenya. The moving average used in this was a 5-day one expressed as :

$$\frac{y_1 + y_2 + y_3 + y_4 + y_5}{5} \quad \dots \quad (6.3)$$

5

$$\frac{y_2 + y_3 + y_4 + y_5 + y_6}{5} \quad \dots \quad (7.3)$$

5

until all the values of the data range were covered. The smoothing moved from one year to the other and therefore even in the overall smoothed series the x-axis provided the scale to identify distribution for particular years (see figs 7-13 ).

### 3.3.5.1 Disadvantages of Moving Average Method

- (i) The choices of the length of moving average is arbitrary; in the study, the soil moisture retention capacity influenced the 5-day point.
- (ii) Moving averages made from purely random Time-series can generate irregular apparent periodicities by the process of Slutsky-Yule effect.
- (iii) Moving averages give little weight to the middle values and the first and last values are usually lost.

To correct some of the above disadvantages or defects of moving average, weighted moving averages were preferred in the study. In this study the Binomial Coefficients were used as given by WMO, 1966 (.0.22,.2,.12,.05,.02). The Time Series was then

examined for persistence or randomness as a way of checking the property of the distribution shown. The Time-domain method (Autocorrelation function,  $r_k$ ) was used to carry out this task. One should note that the time-domain and frequency domain methods are complementary but not the same (see, Erat, 1973, Ogollo, 1977)

### 3.3.6.0 Autocorrelation Function, $r_k$

A time-Series is considered randomly distributed when each event is statistically independent of all preceding and succeeding events. Many hydrometeorological processes are due to persistence in the data (a common feature in meteorological daily rainfall data where occurrence of an event today is likely to affect the occurrence of the same event the following day). Dependent events are usually analysed using Autocorrelation (serial correlation) function,  $r_k$ , technique.

The Autocorrelation function,  $r_k$ , is the ratio of the auto-covariance,  $C_k$ , to the variance  $C_0$ , that is  $r_k = C_k / C_0$ . The following steps were followed when working out the autocorrelation functions for the various months during the period of records:-

(i) The data sequence (daily rainfall records) were denoted by  $\{y_i\} = i = 1, 2, 3, 4, \dots, N$ . (8.3)

(ii) The arithmetic mean of daily rainfall data were then

$$\text{worked out: } \bar{y} = \frac{\sum y_i}{N} \quad (9.3)$$

where  $N$  is the number of days of record and  $y$  the mean.

(iii) The Autocovariance (or simply the covariance),  $C_k$ , was worked out as :-

$$C_k = \sum_{i=1}^{N-k} (y_i - \bar{y})(y_{i+k} - \bar{y}) / N \quad (10.3)$$

(iv) The variance was then worked out :-

$$C_0 = \sum_{i=1}^N (y_i - \bar{y})^2 / N \quad (11.3)$$

(v) Finally,  $r_k = C_k / C_0$  (12.3)

In the statgraphic package, the general formula for the Autocorrelation function,  $r_k$ , is inbuilt and is given as :-

$$r_k = \left[ \frac{1}{N-k} \sum_{i=1}^{N-k} y_i y_{i+k} - \frac{1}{(N-k)^2} (\sum_{i=1}^{N-k} y_i)^2 \right] \frac{(\sum_{i=1}^{N-k} y_{i+k})^2}{\sum_{i=1}^{N-k} y_{i+k}^2} * \quad (13.3)$$

$$\left\{ \left[ \frac{1}{N-k} \sum_{i=1}^{N-k} y_i^2 - \frac{1}{(N-k)^2} (\sum_{i=1}^{N-k} y_i)^2 \right]^{1/2} \right\}$$

$$\left[ \frac{1}{N-k} \sum_{i=1}^{N-k} y_{i+k}^2 - \frac{1}{(N-k)^2} (\sum_{i=1}^{N-k} y_{i+k})^2 \right]$$

where  $r_k$  is the auto-correlation function of order k (time-lag) and  $y_i$  = the rainfall values. Note that \* in the formula is multiply.

### 3.3.7.0 Testing The Significance of Autocorrelation functions

If the sequence of the daily rainfall data were random, the calculated value of all  $r_k$  should differ from zero only by sampling variation, so that when  $r_k$  were plotted against k (lag time), the points should not show large divergence from the horizontal axis. The autocorrelation functions were tested for significant divergence from zero to check against persistence.

In theory, it is expected that the Autocorrelations Coefficients of all lags (other than zero) have large-sample error,  $\pm 1/\sqrt{N}$ . An approximate test of significance that was used in the study to check for persistence was obtained by comparing autocorrelation functions  $r_k$  (coefficients) with the range  $\pm 2/\sqrt{N}$ ; values lying outside this range suggested presence of persistence in the data sequence. This was done until the point where the lag time showed no persistence or complete persistence so as to be used in defining normal number of wet or dry days.

Usually, the first order autocorrelation function,  $r_1$ , is used in testing for persistence or randomness and in the study the test was carried out at a 0.05. A simplified form of  $r_1$  that can be used is :

$$r_1 = \frac{1/N-1 \sum_{i=1}^{N-k} (y_i - \bar{y})(y_{i+k} - \bar{y})}{\frac{1}{N} \sum_{i=1}^N (y_i - \bar{y})^2} \quad (14.3)$$

where  $r_1$  is distributed normally about the mean  $-1/(N-1)$  with variance  $(N-2)^2 / (N-1)^3$ .

The test used in the study was given by Anderson (1941) and modified by FAO (1973) where if  $r_1$  lies outside the range :

$$(-1/N-1 + 1.96(N-2)/(N-1)^{3/2}, \quad (15.3)$$

$$-1/N-1 - 1.96(N-2)/(N-1)^{3/2})$$

then there was evidence that  $r_1$  was significantly different from zero and therefore not random and vice versa. If  $r_1$  was found to be significantly different from zero, indicating persistence, it was checked if it approximated to an exponential relation:  $r_k = r_1^k$  :  $r_k \geq r_1^k$  indicating a Markov linear type of persistence while  $r_k < r_1^k$  showed that persistence was not linear.

To reinforce the Significance Test results, the autocorrelation functions  $r_k$  were plotted against  $k$  (lag-time) to "throw some light on" the internal structure of the observed series. The plot is called the correlogram. In the study, the work was done by computer using the statgraphic package and the results were in block forms rather than the traditional line graph.

### 3.3.8.0 Correlogram

A plot of  $r_k$  against  $k$  is called the correlogram. The shape given by plots revealed, in the study, the nature of the process in the Time Series for each month. For a periodic process, the correlogram was periodic; for moving average process, the correlogram vanished; for auto-regressive process, the correlogram was exponential (fitting the first order Markov process,  $r_k = r_1$  and the correlogram decaying); see figures 14-18.

The correlograms and the autocorrelation function tests were used together to describe the structure of the Series studied.

### 3.3.9.0 Why Time Series Analysis of The Data

The characteristic feature of Time-Series, as compared to other statistical subjects, is that the observations occur in temporal order. This is important in that, among other things, it deals with the relationship of values from one term to the next, in serial correlation along the series. This suited the study most for there was need to check whether there were differences between the Series over the period of study, 1971-1985. When there are several Series to consider as a multivariable complex as was in the study, there will arise a dimension of complexity beyond that of multivariate analysis. In multivariate analysis, the concern is with relationships or interrelationships among variables regardless of the order in which the individuals which bear them are

presented. With a multivariate Time Series as was the case in the study, there is need to consider, in addition, the correlations and cross-correlation among the Series when one or more lead or lag behind the others.

In the study, the Time Series Analysis Technique was used based on the following functions of the technique:

(a) at the most superficial level, a particular Series is considered and a simple system constructed to describe its behaviour in a concise way. This was the main reason for using the Time-Series in studying the daily rainfall distribution in West Kenya so as to identify the periods of exceptional rainfall. There was need to describe the behaviour of daily rainfall from 1971 to 1985, the period which experienced some of the worst droughts in recent climatic history of Africa;

(b) explaining the Series behaviour in terms of other variables and to relate the observations to some structural rules of behaviour. In the study, the autocorrelation function was used to analyse the structure of the Series and then to relate the processes to the periodic, moving average, autoregressive and first order Markov chain models.

The Time-Series analysis usually present some problems that were also faced in the study like:

- (i) when to make observation and in Time-Series analysis there are rarely rules of general and universal application; a great deal depends on the purpose of the study. In the study, so long as there was daily rainfall record, no attempt was made to check whether the recording took place in the morning, afternoon or at night;
- (ii) the study assumed that the yearly records were independent but in Time Series analysis, there is the problem of aggregation. So long as the Series is cumulative as was the case when using running-means, the variables become dependent on one another;
- (iii) there is also the problem of continuity and discontinuity. The rainfall data record might have been discreet but cumulatively continuous. So the problem must be stated clearly. In the study, the rainfall data were taken as discreet variables between the years but continuous within the years.
- (iv) there is the calender problem especially the February end problem and also that months do not have uniform number of days and weeks. In the study, no attempt was made to adjust the records since the study was to show the actual situation and not what was supposed to be there.

(v) the problem of defining the length of the Series is also notable. In the study, if one was considering the years that elapsed between the 1971 and 1985, one would come out with fifteen years as length of the various series. This study used the data entry per day to give the length of the various Series and in this case the length of the Series were according to the number of days in a particular month, January - July, for the period 1971-1985.

Even if there are disadvantages in Time-Series analysis technique, it still provide the most suitable option in terms of statistical techniques in studying the structure, and process of a Series like rainfall and river flow over a given period. Also since drought has been noted as a recurring meteorological phenomenon, a temporal analysis of data is the best way of investigating drought occurrence and characteristics in a given geographical unit as was the case in the study.

N/B. In cases where rainfall data were missing for particular stations, data from adjacent stations were used to fill in the gap or data from a station within the same agro-climatic zone were used in data analyses in this study.

## CHAPTER FOUR

### 4.0.0 RESULTS AND DISCUSSIONS

---

In this section of the thesis, a detailed examination was made of the results obtained followed by a discussion of their significance if any.

#### 4.1.0 Basic Statistics Results

---

The basic statistics used in the study were the Mean, Standard deviation, Kurtosis, Skewness and Variance. These basic statistics revealed the central tendencies and therefore the general behaviour of the rainfall data on a daily basis.

##### 4.1.1 January Results for 1971-85 Period

---

Starting with the Lake littoral ( $\leq 1250\text{mm}$ ), represented by Kisumu Meteorological Station, Muhuru Bay Hydrometeorological Station, Usigu Health Centre and Port Victoria, the mean daily rainfall was found as a rule to be low. Muhuru Bay, Usigu Centre and Port Victoria showed mean daily rainfalls of each less than 0.25 mm per day in 1974, 1975, 1976, 1980 and 1982, an indication that the years were the worst in terms of dry spell occurrence.

Generally, the Stations mentioned in the Lake littoral showed a general tendency of mean daily rainfall less than 5mm per day with the worst centre being Muhuru Bay and the relatively better

centre being Kisumu. The Kurtosis and Skewness values were always positive indicating that extreme cases were those of high rainfall distributions and the normal was low rainfall distributions. Also, even if the Kurtosis and Skewness values were positive, they tended to be near or less than one thus showing platykurtic tendencies in the rainfall distributions. These were indications of low rainfall distribution.

The Standard deviation and Variance values were always greater than the Means and this showed greater coefficient of variations, and this could possibly be attributed to occasional occurrence of heavy downpours(Tables 4.4., 4.8., and appendix I). The Stations of the Lake littoral represented solely the Kibos regime of Mungai(1984).

Moving to the Lake Basin low midlands (above altitude 1,250 metres), January was still dry but relatively better than the Lake littoral. The difference with the Lake littoral during January was only noticeable in terms of total amount but the less than 5mm per day rains still dominated. The low midlands zone was represented by Koole Primary School, Kodera Forest Station, and Bungoma Agricultural Department Office. Around Bungoma, the 1975 and 1979 mean daily rainfalls were exceptionally high. The Standard deviations and Variances still showed great coefficient of variations and the Kurtosis and Skewness values showed the extreme values to be those of high rainfall distributions; the

distributions were generally low and positively skewed. The occurrence of mean daily rainfalls of 0.25mm was rare with only Kosele and Bungoma showing that trace in 1975 and 1974 respectively.

In the upper midlands zone (1500m and above) represented by Malava Agricultural Office, Kisii District Office, Nyamira District Office and by the highland station, Mount Elgon Forest Station, the occurrence of mean daily rainfalls of each less than 0.25 mm per day was none existent although the less than 5mm per day was still the normal feature. Variation was still great according to the Standard deviation and Variance results. The extreme features were most likely to be high rainfall distributions as was shown by positive Kurtosis and Skewness values.

Generally, January was as a rule a dry month during the period of study and one could conclude from the central tendency statistics that it was the normal feature in the Lake Basin rainfall regime. Extreme variations were possibly due to occasional occurrence of heavy downpours but the distribution seemed to be platykurtic ultimately indicating generally low rainfall.

#### **4.1.2 February Results for 1971-85 Period**

---

In the Lake littoral, the February rains were lower than the January rains as was indicated by the high number of years showing

mean rainfall records each of less than 0.25mm per day. Uaigu showed 1972, 1975, 1977, 1980, 1983 and 1984; Muhuru Bay, 1971, 1980, and Port Victoria, 1971 and 1982; as the worst years and the less than 5mm per day was shown by all stations throughout the period of record. Kisumu was better off because 1978 and 1979 had more than 5mm per day mean rainfall and no year showed mean rainfall less than 0.25mm. The rainfall distribution in February was still relatively platykurtic but the Kurtosis and skewness values were mostly positive indicating the occurrence of extreme cases in terms of heavy rainfalls. This showed that the distribution was mainly low with occurrence of high rainfall distributions being abnormal but not an impossibility.

The standard deviation and the variance values were greater than the mean in most cases indicating great coefficients of variation in the daily rainfall distributions; this was mostly due to the high possibility of getting zero and heavy downpour respectively in a day during the month.

In the low midlands zone(above 1250m), the mean daily rainfall of less than 0.25mm per day was rare/nonexistent but the less than 5mm per day being normal. 1978 showed heavy rainfalls in Kosele region as was 1974, 1975, 1981 and 1983. In the Kodera Forest region, 1976 and 1979 showed exceptional high daily rainfall mean. The Bungoma region showed exceptional mean daily rainfall in 1972, 1973, 1978, 1979(Table 4.5). These years were exceptional in that

they had mean daily rainfalls greater than 5mm per year. This showed that, although the lower midlands zone is within the Kibos rainfall regime zone of Mungai(1984), it was better off than the Lake littoral and the possibility of planting low water requirement crops as from February was greater than in the Lake littoral.

In the upper midlands zone (1500m and above) which is mainly in the transitional zone with only Mount Elgon station and Kimilili showing Eldoret regime type of rainfall distribution, (Mungai,1984) , the February rainfall were relatively better off than in the first two zones. Only 1971 showed mean rainfalls of less than 0.25mm per day and in the case of Kisii the data was suspect for all the 1971 data were found to be low throughout the months of record. The February rains were still relatively low as was shown by the domination of rainfall of less than 5mm per day. The coefficients of variations were still great and the distribution was still relatively platykurtic.

Generally February in the Lake Basin (1971-85) was dry and this seemed to be the normal but in the low midlands, the mean, the Kurtosis and Skewness values indicated improved rainfall amounts although the coefficients of variation was still great.

#### 4.1.3 March Results for 1971-85 Period

---

The Lake littoral zone showed improved rainfall distribution in March but the general tendency was that of low rainfall distributions. The mean daily rainfall was still generally less than 5mm per day. The less than 0.25mm per day mean rainfall was only shown by Muhuru Bay in 1971 and Usigu Health Centre in 1974, 1983, 1984 and 1985 showing Usigu as the worst off area. Kisumu and Port Victoria area were better off with 1975, 1978, 1979, 1980, 1981 and 1985 showing mean daily rainfalls generally above 5mm per day.

The Kurtosis and Skewness values were generally positive but in the Muhuru Bay area and Usigu area, 1971 showed zero or near zero values showing extremely low rainfall distribution tendencies. This could have been due to the occurrence of very heavy downpours during that year or that the rains were extremely low.

In the low midlands zone, the March rainfall showed marked improvement with mean daily rainfalls of less than 0.25mm per day being very rare. Only Kosele area showed a mean daily rainfall distribution of less than 0.25mm per day in 1971 and generally, Kosele, apart from altitude, seems to fit in the Lake littoral zone. Daily mean rainfall coefficient of variation was still great as the Standard deviation and the Variance tended to be greater than the mean. The Kurtosis and Skewness values were mostly

positive with only Kosele in 1975 showing negative Kurtosis value. This showed that 1975 was wetter relatively and the low rainfalls seemed to have been the extreme or that there were heavy downpours in that year. The less than 5mm per year rainfall still dominated as was the case in the Lake littoral but the balance was better here.

In the upper midlands zone, March rainfall was relatively better than was in the other two zones with only the Mount Elgon area which was more of Eldoret regime than the transitional regime showing relatively low rainfall (Table 4.7). Malava area showed exceptional low distribution (mean) in 1973, and 1982, Mount Elgon in 1980 and Kisii in 1984. Variation in mean daily rainfall was still great and the less than 5mm per day still dominated but the balance was better relatively than in the low midlands zone. The Kurtosis and Skewness values were exceptional in Kisii in 1984 where they tended towards zero showing a rather platykurtic distribution thus indicating a generally low rainfall than in other years during 1971-85 period. The Mount Elgon area also showed this tendency in 1980. Nyamira area showed the wettest tendency in the whole midlands zone followed by Kimilili, Malava, Kisii and lastly Mount Elgon. March daily rainfall (mean) was relatively better off than in January and February and the improved mean daily rainfall gave a tendency towards a general increase in rainfall. It therefore seemed to be that rainfall as would be expected starts peaking in March in the Lake Basin but this was not universal even

within the zones mentioned above. Daily rainfall variations seemed to be still considerable and the occurrence of heavy downpours as indicated by the dominance of positive Kurtosis and Skewness values was still the normal feature.

#### 4.1.4 April Results for 1971 -85 Period

April rainfall for the period under consideration was relatively good in the Lake littoral with no year showing mean daily rainfall below 0.25mm per day. In the Muhuru Bay area, only 1972, 1975, 1976, 1980 and 1981 showed mean daily rainfalls less than 5mm per day; Usigu data showed a generally low rainfalls with the less than 5mm mean daily rainfalls dominating; Port Victoria showed low rainfalls (mean) in 1978, 1978-79 and 1981 and; Kisumu area showed low rainfalls in 1981, 1982 and 1984. The Variances and Standard deviations were still great and this showed that daily variations tended to be high. Kurtosis and Skewness values were generally positive and the distribution were leptokurtic, that is, the distribution was generally peaked showing that rainfall was relatively high.

The low midlands April rainfalls were generally as expected with no year showing mean daily rainfall less than 0.25mm per day and the equal or greater than 5mm per day mean daily rainfall dominating. Only 1972 and 1982 tended to have shown mean daily rainfalls less than 5mm per day. Variations on a daily basis tended to have been great as was shown by large values of Standard

deviation and Variance than the mean. Kurtosis and Skewness values were positive and generally above zero showing general tendency towards heavy downpours at the same time extreme values were mostly to be those of high rainfall distributions.

The upper midlands April rains were good with no period showing mean daily rainfall less than 0.25mm per day except 1978 in Kisii. This could have been due to data error as was in 1971 when mean daily rainfall was less than 5mm per day. In the Malava area only 1973, 1978 and 1979 showed mean daily rainfalls less than 5mm per day(Table 4.6). Kimilili showed a tendency towards mean daily rainfalls less than 5mm per day in 1973, 1974 and 1979. Nyamira area showed the tendency of less than 5mm per day only in 1984; Elgon area seemed to have been different from the rest of the upper midlands zone with many years showing mean daily rainfalls less than 5mm per year. Generally in the upper midlands zone, mean daily rainfall was above 5mm per day. The coefficients of variation on a daily basis tended to have been considerable with the Standard deviations and Variance values being generally greater than the mean values. The Kurtosis and Skewness values were generally positive showing tendency towards peaked rainfall distributions and the extreme values most likely to be in the form of heavy downpours.

In the Lake Victoria Basin during the period 1971-1985, April rainfall was generally as expected but particular years showed low

rainfall distributions but not very exceptional. It therefore seems that April is generally a good month in terms of daily rainfall distribution and if crops are to be planted, their development stages (this is the period when water is most needed in crop development) should fall in this month.

#### 4.1.5 May Results for 1971 - 85 period

---

The Lake littoral showed good rainfall in May but not as was in April. The less than 0.25mm mean daily rainfall was still rare but the less than 5mm per day tended to have increased in number as compared to the April rains. Usigu area (see figure one) showed 1984 as having mean daily rainfall of less than 0.25mm per day but the 1971 period in the same month seemed to have been better off with the low rainfall distributions being the extremes as was shown by the negative or near zero Kurtosis and Skewness values respectively. Variations of daily rainfall was still notable as shown by larger Standard deviation values and Variance values than mean values. In the littoral therefore, the crops grown should by mid May be in their late season stage (maturity stage). That is, fast maturing crops are suitable and should be hardy drought resistant crops.

The low midlands showed May to be good in terms of daily rainfall with the greater or equal to 5mm per day mean daily rainfall still dominating. Only Bungoma area showed mean daily

rainfalls less than 0.25mm, in 1971. Kosele area showed 1973, 1979, 1981, 1983, 1984 as having mean daily rainfalls less than 5mm per day. Kodera Forest area showed mean daily rainfall distribution less than 5mm only in 1984. Bungoma area showed mean daily rainfalls of each less than 5mm per day in 1976, 1977 and 1985. The area also showed platykurtic distribution in 1971 showing general tendency of low rainfall distributions. Mean daily rainfall distribution coefficients of variation was high with the values of Standard deviations and Variances being generally greater than the Mean values.

The upper midlands zone showed May rainfall to be generally as good as the April rainfall. The mean daily rainfall of less than 0.25mm per day was very rare with only Mount Elgon forest area showing the tendency in 1983. Daily coefficients of variation tended to be high and the Kurtosis and Skewness values indicated leptokurtic distributions. The extreme values were mostly in the form of heavy rains. Malava area showed tendency of extreme values to be low rains in 1982, 1983 and 1984 and rainfalls less than 5mm per day in 1971, 1972 and 1981. Kimilili area showed 1981 as the year of a relatively low rainfall with mean daily rainfall being less than 5mm per day. Kisii area showed 1971, 1974, 1978, 1981, and 1984 as having relatively low rainfall distributions with mean daily rainfall being less than 5mm but greater than 0.25mm. Nyamira showed this tendency in 1974, 1978, 1979, 1981, 1983, 1984 and 1985. Mount Elgon area seemed to have been drier than other upper

midlands areas with more years showing mean daily rainfalls of each less than 5mm per day.

Generally May rainfall was as expected in the Lake Victoria Basin during the 1971-85 period and meaningful crop growing practice must integrate this rainfall distribution tendency into its structure.

#### **4.1.6 June Results for 1971 -85 period**

June rainfall in the Lake littoral showed the expected decline from the April-May peaks with Muhuru Bay showing 1971 and 1981 with mean daily rainfall less than 0.25mm per day; Usigu showed the tendency in 1972, 1982, 1983 and 1984; Port Victoria showed the tendency in 1971; with Kisumu showing none of this tendency. The less than 5mm per day mean daily rainfall in June dominated in the Lake littoral. To this, therefore, the crops grown should be in their late season and/or harvest stage (see Nyandega, 1987). Kurtosis values and Skewness values showed tendency to be positive and therefore extremes were mostly to be in the form of heavy downpours. The Standard deviation and Variance values were generally greater than the mean showing high coefficients of variation on a mean daily basis.

The low midlands showed decline in June rainfall but not as was in the Lake littoral. The less than 0.25mm per day rainfall was rare but the less than 5mm per day dominated. Kosele area showed

generally high mean daily rainfalls in 1974, 1982 and 1983 as was Koderia Forest area in 1973, 1977 and 1982. Bungoma area showed this high mean ( $> 5\text{mm per day}$ ) daily rainfall distribution in 1976. Daily mean coefficients of variation was still high and the extreme values were most likely to be the heavy downpours as shown by positive values of Kurtosis and Skewness.

The upper midlands zone showed relatively good rains in June but not as was in April-May period. Malava area still showed the greater or equal to 5mm per day mean daily rainfall dominating, and other areas like Kisii, Nyamira and Kimilili showing a near balance between  $\leq 5\text{mm rainfall per day}$ . The distribution was still leptokurtic showing that extremes were most likely to be in the form of heavy downpours. Daily mean coefficients of variation was still high as the Standard deviations and Variances were greater than the Means. June rainfall showed the expected decline but this depended on the zone as Malava area still showed heavy rainfall but the Lake littoral had already reached dry time. In the Lake littoral, to reduce the risk of crop failure, crops should be in the harvest stage; in the low midland zone, the end of the late season stage and; in the upper midlands, the crops should be in the early late season stage.

#### 4.1.7 July Results for 1971 -85 period

July was dry in the Lake littoral as was January / February time with mean daily rainfalls generally less than 5mm per day and means of less than 0.25mm per day not uncommon. Muhuru Bay showed 1972, 1977, 1978, 1979 and 1980 as having less than 0.25mm per day mean daily rainfalls. Daily coefficients of variation was still high with the extremes most likely to be in the form of heavy downpours.

The low midlands showed a dry July but not as in the Lake littoral with the less than 0.25mm per day mean rainfalls being rare features. Generally the mean daily rainfalls were less than 5mm per day and to this, the crops in the zone should be in their harvest stage when minimal or no water supply is required. Daily coefficients of variation was generally high with the extreme values most likely to be in the form of heavy downpours as was indicated by positive Kurtosis and Skewness values. Kosele area (see figure one) showed relatively good mean daily rainfall in 1976, 1977 and 1978; Kodera Forest showed good mean daily rainfall in 1975 and; Bungoma area showed the relatively good mean daily rainfall in 1974 and 1983.

The upper midlands showed relatively better rainfall distributions in July than was in the low midland zone but the expected decline in rainfall amounts in July was noticeable. The

Elgon area still showed a relatively steady rainfall probably indicating the influence of the Zaire(Congo) air mass. Malava area still showed the greater or equal to 5mm per day mean daily rainfalls dominating with only 1971, 1973, 1975, 1982 and 1984 showing mean daily rainfall of less than 5mm per day. Kimilili area showed the less than 5mm per day mean rainfall dominating with only 1972, 1974, 1975 and 1979 being the exceptions. In the Kisii area the less than 5mm per day rainfall dominated with 1974, 1975, 1976, 1983, 1984 and 1985 as the exceptions. As to the general tendency, only 1971, 1974, 1975, 1976, 1978, 1981 showed mean daily rainfall of greater or equal to 5mm in the Kisii area.

July rainfall was generally low in the Lake Basin during 1971-1985 period and this seems to be the general tendency. Variations in rainfall amounts and distributions from one station to another and from one zone to another were shown to be the norm. July rainfall tended to approach the January/February levels in most places but the transitional zone mostly found in the upper midlands showed better rainfall (relatively) in July. Crops grown in the Lake Basin at least should be in their late season stage of growth but mostly in the harvest stage.

Generally, the basic statistics indicated variations in mean rainfall distribution within and between different zones in the basin. The statistics also indicated that the dry spells of less than 0.25mm and 5mm per day rainfall, respectively, tended not to

be the extremes. Instead, the extremes were mostly indicated to be in the form of heavy downpours. Also, because there could only be either a dry day or a wet day, the less than zero extremes were not to be expected (see Tables 4-8 for example). Since the basic statistics showed a tendency towards differences in rainfall distributions, especially the mean daily rainfall, it was now important to see how significantly different or not different the mean daily rainfalls were from one another in the various zones and even within each zone of the study area. This would indicate significance of the differences to help in identifying rainfall distributions that were not normal in the daily rainfall regimes of the months of January-July (1971-85).

#### **4.2.0      Analysis of variance Test Results for the months of January - July during 1971 - 85 period**

The tests were carried out to check the null hypotheses that the mean daily rainfall were equal to one another for all the months during 1971-85 period; that is, there were no significant differences of the means for all the various months from January to July during 1971-85 period. The tests were carried out at alpha 0.05. The results showed significant differences for all the months from January to July in mean rainfall distributions (1971-85 period). The null hypothesis was therefore rejected and to this, it was accepted that there were significant differences in the mean rainfall distributions for all the months during 1971-85 period. After establishing that there were differences in the mean

distribution, it was therefore fair to start investigating the actual distribution of daily rainfall to see if the basic statistics results, the frequency results and the analysis of variance test results indicated the trend in the actual structure. It was also important to check the internal structure of the indicated tendencies and the processes behind them.

#### 4.3.0 The Time Series Results, 1971-85 Period

The raw Series showed high frequency of variations and a mixture of many years data showed no smooth trend or feature thus presenting a not easy to describe features(see figures 4.4-4.6 and appendix XII). To solve this problem of very many variations not easy to describe, the data were combined sequentially but still with distinctive years. The Series were then smoothed using five-day weighted running means to remove the high frequency oscillations of less than five days. The weights used were binomial coefficients extracted from normal variate tables (WMO, 1966).

#### 4.3.1 Five-day Weighted running means Results, 1971-85 Period

These were to give years for each month that showed a low distribution exceptional from the general set up or distribution. The years were not only to be exceptionally low but even indications of decline were to be noted and the exceptionally high distributions to be equally taken into account.

#### 4.3.2 January Results, 1971-85

In the Lake littoral represented by Kisumu Meteorological Station (= 1150m), Muhuru Bay Hydrometeorological Station (= 1220m), Usigu Health Centre (= 1230m) and Port Victoria (= 1250m), the weighted Series showed January as a dry month(appendix XVI) throughout the period (1971-85). This case as was supported by the basic statistics results already discussed. The Kisumu area showed a generally low rainfall with occasional peaks over 5mm per day indicating heavy downpours(fig.4.7). 1974 showed marked low distributions as were most of 1976, 1979, 1980 and 1983-84 periods. Days of less than 5mm per day were more than those of over 5mm per day but a prolonged period showing a whole month without a wet day was rare or non-existent during the period of study. Muhuru Bay area showed marked low rainfall distributions in January during the period of study in 1974, part of 1975, 1978, 1980-82 and 1984-85. There were more days with less than 5mm per day and the chances of getting a dry day was high. Usigu area showed marked lows in January throughout the period with 1974 and the 1980-84 period being exceptional.

The January rains were generally below 5mm per day with few peaks indicating heavy downpours, occasionally. Around Port Victoria Station, rainfall less than 5mm per day in January throughout the 1971-85 period dominated with 1974-76 time showing marked low as was 1979, and 1981-84 time. Days with over 5mm

rainfall were few but not absent, a factor showing the occurrence of heavy downpours occasionally.

The Lake Basin low midlands represented by Kosele Primary (= 1370m), Kodera Forest (= 1370m) and Bungoma Agricultural Office (=1430m) showed January as a dry month as was the case in the Lake littoral although difference in rainfall amounts could be noted. Kosele area showed a low rainfall distribution with many days having less than 5m per day record. 1971 had a low break but not complete. 1974-76 showed a near complete break and a restrained distribution was exhibited between 1983-84 but not a complete break. Kodera Forest area displayed a relatively low rainfall distribution in January with many dry days of less than 5mm per day rainfalls. 1976-77 showed marked low indicating an exceptional case, although dry days of less than 5mm were a common feature. Bungoma area indicated January rainfalls as erratic in distribution with major lows shown in 1972, 1974-75, 1980-81, 1984-85. Rainfalls of over 5mm per day were rare but not absent and occasional storms were a feature indicated by peaked distribution.

The upper midlands represented by Malava Agricultural Office (= 1590m), Kimilili Agricultural Office (= 1680m), Kisii District Office (= 1770m), Nyamira District Office (= 1860m) and Mount Elgon Forest Station (= 2230m) still showed restrained and/or low January rainfall. Malava area showed January as generally dry with many breaks indicating dry prolonged times as was in 1980, 1982-84 but these were not unique in January. In the Kimilili area, the month

was relatively dry with dry spells being a common feature (<5mm per day). Part of 1972, in 1974-76 period and in 1979, general lows were indicated but not exceptional as the less than 5mm per day rainfalls dominated (see basic statistics results eg Tables4-8). 1980, 1981-82 and 1985 also showed breaks in the rainfall Series indicating extended low periods in terms of rainfall distribution in the month. Kisii area indicated 1971, 1974, part of 1977, 1981 and 1984 as periods of low rainfalls as compared to the general Series. These were not "clear cut" exceptional periods from the others for there were many dry days with occasional wet days of sometimes above 10mm per day. Nyamira area showed erratic January rainfall distribution dominated by the less than 5mm per day but the less than 0.25mm per day rainfall not a common feature. Only 1980s showed signs of a general low rainfall distribution as indicated by breaks in the Series. Mount Elgon January rainfall Series showed 1972, 1974-75, 1976, 1981, 1983 and 1985 as years of exceptional low rainfalls as indicated by breaks in the Series. Also, 1977, 1978 and 1979 showed exceptional high rainfalls. Low rainfalls of less than 5mm per day tended to dominate in January in the Elgon area. The 10mm per day rainfalls and above looked unseasonal in January in the Series.

Generally, in the Lake Basin, the January rainfall was low and this seemed to be the case in the rainfall climatology of the basin, and the breaks shown in the Series did not seem to be unique, that is, occasional dry spells were a normal feature of the

daily rainfall distribution in the Basin.

#### 4.3.3 February Results, 1971-85

The February daily rainfall Series in the Lake littoral showed a very dry month relatively with many dry spells and breaks indicating extended dry periods. Around Kisumu area, there were many dry days in February with occasional wet spells accompanied by heavy downpours as indicated by leptokurtic distributions. 1973, part of 1976, 1983-84 showed marked breaks in the Kisumu February rainfall Series, implying extended dry or low rainfall period with the daily rainfall generally below 5mm per day. The Muhuru Bay area showed marked breaks in the February rainfall Series in 1972, 1975, 1977, part of 1978 and 1980-85 (appendix XXII) and generally there were more dry days (less than 5mm per day rainfall) than wet days. Usigu rainfall Series had marked lows throughout February, generally below 5mm rainfall per day with only 1981 showing exceptional peaking (unseasonal). Port Victoria area had marked breaks or tendency towards marked breaks in 1971, 1973, 1975, 1976, 1979, 1980, 1981-82 and 1984-85 indicating prolonged periods of rainfalls less than 5mm per day. Occasional storms were shown by peaked distribution reaching over 10mm per day.

The low midlands still had a relatively dry February as was shown by lows and/or breaks in the rainfall Series. Kosele had a major break or low in 1980, and 1983-85 showed erratic distribution

with a decline or low tendency. The Kodera area Series in February was marked with many dry days (less than 5mm rainfall per day) but offered no major break. 1972-73 period showed a tendency towards low rainfall distribution of less than 5mm per day. Bungoma area also showed a dry February with many breaks showing low rainfall than in January. Part of 1971, 1972, 1974-75, 1977, 1980, 1981 and part of 1984 showed marked breaks in the Series indicating prolonged dry periods of less than 5mm per day rainfall.

In the upper midlands, February was still relatively dry but the rains seemed to have started picking up. Malava area February Series showed lows or breaks in 1972, 1976-78 and 1981, that indicated extended dry periods or days. Generally February rainfalls in the Malava area between 1976 and 1981 showed more erratic behaviour than other periods but no well defined breaks could be said to have occurred. February was still relatively dry in the Kimilili area with more dry spells (< 5mm per day) and breaks indicating prolonged dry days. Part of 1972, 1974, 1975-76 and 1981, exhibited marked breaks indicating prolonged low rainfall distribution of less than 5mm per day but the breaks seemed to be part of February rainfall Series. Kisii area Series showed marked breaks in the Series in 1971 and also between 1973 and 1975. Generally, apart from 1971 (the data was suspect), there were no well defined major breaks as there was a tendency towards a balance between dry days and wet days. Nyamira Series results indicated that rainfall below 5mm per day were common but complete gaps to

indicate prolonged dry days were rare. 1972, 1975, 1983 and 1984 showed traces of marked breaks but really no complete gap appeared to indicate a break (prolonged dry days) in the series. The Elgon area rainfall less than 5mm but occasional leptokurtic peaking indicated heavy downpours as a feature. 1974-77 showed an exceptional break indicating prolonged dry days (less than 5mm rainfall per day). The eighties also showed erratic distribution with occasional breaks especially 1980-81 but 1978-79 indicated exceptional heavy rainfall generally over 5mm per day (rainfall unseasonality).

Generally, February rainfall was low in the Lake littoral and low midlands but started peaking in the upper midlands. The breaks were more notable in the littoral and the low midlands than in the upper midlands. Even in the littoral and the low midlands, the breaks were rarely complete indicating more of erratic behaviour in rainfall than exceptionally prolonged periods as dry days were a common feature of the rainfall climatology of West Kenya in February (see the basic statistics results tables, and frequency tables in the appendix).

#### 4.3.4 March Results, 1971-85

March seemed a moderate month in the Lake littoral relative to the months of January and February. There were signs of rains increasing, in amount and frequency, late in the month. In the Kisumu area, dry days and wet days were common but 1973, part of

1976, 1983-84 showed marked breaks or low rainfall distribution generally below 5mm per day (appendix XIV). The breaks were not complete, an indication of either late or more erratic rainfall distribution. Muhuru Bay gave a relatively moderate March with many wet days than in February and January respectively. 1975-76, 1979-80 and 1984 tended to have had big gaps in the Muhuru area but were not complete. The breaks indicated either more erratic rainfall distribution or delayed rainfall in March. Usigu area gave an indication of occasional heavy downpours as shown by leptokurtic distribution but the dry days continued to dominate. Relatively, March rains were good as compared to the February and January rains respectively. 1974 and 1984 showed marked breaks but these seemed not to have been uncommon. Indications were that rainfall started "picking up" in late March in the Usigu area. Around Port Victoria Station, March rainfall Series showed an increase in the number of rainy days (equal to or above 5mm per day rainfall) as compared to January and February rainfall respectively. 1971, 1973, 1976, 1980 and 1984 exhibited marked breaks in the Series indicating prolonged dry days of generally less than 5mm per day rainfall.

The low midlands March rainfall Series indicated a good, relatively, rainfall distribution, a sign that the long rains were picking up. Kosele March rainfall fluctuated much but peaks over 5mm per day or even over 10mm were becoming a feature. Dry days were also common thus indicating a moderate month in terms of rainfall distribution. 1972-73, 1974, 1975-76, showed exceptional

peaking indicating heavy rains and were therefore unseasonal. Part of 1977 and 1980-81 showed breaks indicating prolonged dry days but the breaks were not complete and were therefore signs of delayed rains and or erratic distribution than prolonged dry spells. Kodera area Series indicated March rains of steady distribution but generally less than 5mm per day with occasional peaking. Complete breaks in the Series were rare and only 1973-75 seemed to have had a decline in rainfall amount as compared to the general distribution of the Series (appendix XX). Bungoma area gave a Series with fluctuating distribution between dry spells and wet spells (fig 4.10). 1973, 1976, 1980-81 showed not complete breaks in the Series but was generally above 0.25mm (a meteorological wet day) and the breaks were not well defined, an indication of erratic low rainfall. 1984-85 Series had a break with low peaks, an indication that dry spells could easily occur and were a more common feature. Occasional downpours of over 5mm per day were also notable and therefore a reflection of the moderate "face" of the March rainfall in the Bungoma area.

March rainfalls in the upper midlands showed decline in the early stages especially the first two weeks relative to the late surge of rainfall in February. In the Malava area, March rainfalls indicated peaking as from mid-month with heavy downpours interspersing dry days. 1972-73, 1974, 1980, 1982-84 showed breaks that were exceptional in March and these indicated prolonged low rainfall times, although the breaks were not complete. Kimili

rainfall Series were marked with leptokurtic distributions indicating heavy downpours interceded by dry spells. 1973, 1975, 1982 and 1985 showed breaks in the Series but the breaks were not complete. This indicated more of erratic rainfall distribution and/or delayed rainfall in March. The March rainfalls generally were above 0.25mm per day used in defining meteorological dry day and wet day respectively, but there was a tendency towards a balance between above and below 5mm per day rainfall. The below 5mm per day rainfalls were prominent in the early stages of the month. Kisii area had good March rainfalls during 1971-85 but the dry days were still a feature in the series. 1971, 1973, part of 1980 and part of 1984 showed tendency towards rainfall less than 5mm per day but the breaks were not complete indicating more of erratic rainfall distribution. Nyamira area had steady March rainfalls but showed decline between 1972 and 1975. The breaks shown during that period were not well defined but the 1980s showed average low rainfall distribution. March rainfalls in the Elgon area seemed to have been lower than around other stations in the upper midlands. There were breaks in the Series in late 1972, in 1976, 1979-80 and 1983-84 which were clearly abnormal from the general Series. The gaps or breaks in the Series indicated prolonged dry days that could have led to a drought situation but the gaps were not complete and one could not assign them to drought situations with confidence. Only 1979-80 gap was complete and this clearly was a meteorological drought set-up.

In the Lake Basin, during the 1971-85 period, March rainfalls were relatively better than in January and February respectively but there were differences between the zones and even within the zones. The occurrence of breaks in the Series indicating prolonged dry days were accompanied by leptokurtic distributions indicating heavy downpours.

#### 4.3.5 April Results, 1971-85

---

The April rainfall Time-Series portrayed the April rainfalls as relatively high within the Lake Basin. Rainfall of over 5mm per day were as frequent as were the dry days and sometimes dominating in the Series. In the Lake littoral, April Series showed a better rainfall distribution relative to January, February and March. In the Kisumu area, average, there were more days of equal or over 5mm per day rainfall than the dry days and especially less than 0.25mm per day. 1972 showed a hesitant break indicating delayed rains and 1974 rains seemed to have ended early, and the same trend of delayed or rainfall ending early were portrayed in 1979-80 and 1981-82 (fig 4.8). The breaks were not complete and this indicated that the rainfall tended to be erratic in distribution during those periods. Generally, in the Kisumu area, the April rainfall during 1971-85 period was relatively good although the years from 1979 to 1985 showed a generally low rainfall but averagely, the 5mm per day possibility was still high. Muhuru Bay area Series portrayed relatively good rains in April with not well marked breaks in the Series in 1972-73, 1974, 1975, 1977, 1979, 1980-81 (appendix XVII)

indicating more of erratic behaviour of rainfall Series than unique prolonged periods. The periods noted above although not unique in the Muhuru Bay, tended to have had a low rainfall distribution, relatively, in April. Usigu area Series in April indicated a relatively wet month but few days received rainfall above 5mm, although downpours were greater in amount on numerous occasions relative to other months. 1980, 1982 and 1984 tended to have had exceptional breaks in the Series but the breaks in the Series were rarely complete indicating more of erratic distribution than uniquely prolonged dry days that could be described as drought situations. Usigu April's rainfall Series indicated a lower rainfall distribution than in the Kisumu area and slightly near that of Muhuru, if not worse. Port Victoria area April's rainfall Series had numerous peaks but there were periods where even if rainfall was above 5mm per day, signs of decline were notable with occasional breaks showing less than 5mm per day rainfall. Between 1978-79, the Series tended to have been generally below 5mm per day as was in 1981-82 period although heavy downpours of over 10mm per day were not impossible. The periods noted mostly had erratic rainfall distribution and delayed peaking of rainfall in April.

The low midlands April's rainfalls were relatively better than those of the Lake littoral although the Kosele's were more towards the Lake littoral' situation. Kosele area rainfall Series gave relatively high rains with many days having more or equal to 5mm per day but dry days were still a feature and no major breaks could

be identified in the Series. Partly 1975-77 period showed breaks indicating tendency to high frequency of dry days and erratic rainfall distribution or not well peaked April rainfall. Generally April rainfall was good but dry days still appeared and had high (relatively) possibility of occurrence. Also, the Series showed a tendency towards low distribution in the late 1970s and early 1980s; a tendency towards platykurtic rainfall distribution. Kodera Forest Series showed steady rainfall distribution in April with restricted dry spells although their occurrence possibility was high as shown by the fluctuating series. No year showed major breaks in the Series although the fluctuations indicated a possibility of prolonged dry days. Bungoma area had a Series generally above 5mm per day. 1972 indicated a major break in the Series and this could have been a bad year agriculturally for Bungoma area. There were small breaks in 1974, 1977, 1981 indicating not well developed rains in April which could have affected yields of food crops grown especially maize, reaching their development stages during this month. In the Bungoma area, the 1980s generally had a relatively low rainfall distribution although there were daily rainfall distribution mostly above 5mm per day. This could have been important in terms of crop productions for the established agronomic practices were to be adjusted to the new condition: was that time there before failure?

The upper midlands had heavy rainfall in April with dry days being less frequent. Malava area had heavy rains with no major

break throughout the 1971-85 period. 1980, 1981 and 1985 showed gaps in the series but these were not complete indicating hesitant rains. Generally, in the Malava area, the 1979-81 period April rains were more erratic relatively but could not be said to constitute drought situations or prolonged dry days, although the possibility was there. Kimilili area had a generally wet rainfall Series, generally above 5mm per day. The Series was well distributed with no unique break but dry spells were a feature. April was generally wet in Kimilili area and the distribution was leptokurtic indicating a frequency of heavy downpours averaging over 10mm per day. Kisii area was also wet in April as the Series was generally above 5mm mark but dry days were a common feature. Only 1971 and 1978 showed breaks with the 1971 one being more of data recording error than a meteorological factor. 1978 in the Kisii area had a generally low rainfall and the distribution was more erratic; that could have led to agricultural drought depending on the crops grown. Nyamira area Series showed a generally high rainfall throughout the period (1971-85) with no major break. Only 1978 showed a not complete break that could have been a delayed rainfall time or that the rains did not develop to the general level. The 1980s indicated averagely low rainfall but the 5mm average still dominated. April was a wet month in the Nyamira area and this seems to be the general situation. Mount Elgon area Series indicated high rainfalls in April as days with 10mm rainfall or more tended to dominate. 1972, 1974, 1976, 1978, 1980, 1982 and

1983 indicated decline in rainfall amounts or mostly delayed peaking in the April period. Low peaks interspersed dry periods during these years more or so indicating erratic distributions than complete failures with only 1974 showing a defined break to indicate low rainfall distribution or prolonged dry days.

In the Lake Basin, West Kenya, during the 1971-85 period, the April rainfall was generally high with few dry days. Indications were that although the April rains were high, possibility of prolonged dry days were there as noted by gaps in the Series especially in the Lake littoral and low midlands.

#### 4.3.6 May Results, 1971-85

May rainfall Series in West Kenya indicated variations in rainfall amounts and distributions from one zone to the other but was still good as the Series were generally above 5mm per day. In the Lake littoral, May Series showed early peaking but decline towards the end during 1971-85 period; seemingly the general feature of the May rainfall in the Lake littoral. In the Kisumu area, May rainfall was generally high, equal to or above 5mm per day (appendix XIII). The Series indicated lows as shown by breaks in 1974, 1976 and 1981-84. The breaks were not complete for peaks of over 5mm per day were in between, indicating delayed, or early ending or erratic rainfall distribution than a well defined prolonged period of dry days, a drought situation (meteorological).

Muhuru Bay had a steady Series of May rainfall with peaks occasionally reaching over 10mm per day (appendix XVIII). No well defined gap appeared in the Series but restricted breaks occurred in 1974, 1978, 1980-81 and 1984 indicating not well developed May rains, especially early ending and erratic distribution. Depending on the crops grown, an agricultural drought situation (when the water supply is unable to meet the requirements of the crops) could occur. Usigu May rainfalls were relatively lower than those of other stations already mentioned in the Lake littoral with 1979, 1981 and 1984 showing breaks in the Series that could be disastrous in terms of agricultural production depending on the crops grown. In meteorological sense, the breaks were not unique as dry spells were a common feature in the Series. Port Victoria May rainfall was generally good, and was more towards the Kisumu level than to those of Muhuru and Usigu areas. The Series showed daily rainfall generally above 5mm per day but 1971, 1973, 1976, 1980 and 1984 indicated prolonged periods of days having less than 5mm per day rainfall. These were indications of early endings of May rainfalls and could affect crops if they were still in their development stage; a stage when water (soil moisture) is most needed.

The low midlands had tendencies in the Series of rainfall peaking more in May than in April although the Kosele area was more towards the Lake littoral levels. The Kosele area had a relatively high rainfall Series in May but 1972-73, 1979 and 1983-84 periods' rainfall were relatively low with the distribution being more

erratic. Also, the Series in those years indicated early ending of the May rainfalls. Dry spells were a common feature in the Series and therefore possibility of extended dry period was real. May rainfalls in the Kidera area were relatively high and steady although dry spells were common. No unique break in the Series was noted but the possibility of break occurring was indicated by the fact that the dry spells were common in the "face" of the Series. May rainfall in the Bungoma area was steady but occasional breaks could be identified as was in 1973, 1978, 1979 and part of 1981. These breaks were not complete indicating more of erratic and early ending distributions than unique phases of the Series. Generally in Bungoma area, 1973-74 and 1978-81 Series showed decline in rainfalls but not a well defined one that could be used to say that there were drought situations during those particular periods. Only that, the decline tendency could disrupt the established agronomic practices. Generally in the low midlands, May rainfall was high but indications were that a decline towards the end was a real possibility and crops should be past their development stages by then.

The upper midlands indicated peaked rainfall distribution in May and was generally heavy, above 5mm per day. Malava area had heavy rainfall in May but this fluctuated although generally above 5mm per day. 1980, 1982-83 showed breaks in the Series which seemed exceptional and could have been drought situations. Generally in the Malava Series, 1979-85 period showed rainfall

distribution affected by breaks that seemed abnormal from the overall Series. That period in terms of rainfall climatology, was relatively fragile. Kimilili was also wet in May as the Series indicated a generally above 5mm per day rainfall. 1981-82 showed a gap in the series that indicated more of erratic distribution than a unique break in the Series. Dry spells were also not unique and the near breaks shown in 1981-82 looked like a normal phase of the Series although generally low. May rains were steady with occasional exceptional peaking in the Kisii area (appendix XV). Only 1971 indicated exceptional low but this seemed to have been due to recording error in data entry as has been noted in the preceding paragraphs. 1978 showed a near drought situation and was exceptional in the Series for rainfall was generally below 5mm per day. Generally 1975-76 and 1977-78 Series though above 5mm per day in most cases tended to have been low and erratic. 1981 also showed generally low rainfall as was 1984 but the years noted were not unique in the Series as dry spells were part of the distribution. All in all, May rainfall in the Kisii area was high and the situation could be described as wet although occasional extended lows were possible. Nyamira May rainfall Series had no major break but mid 1970s and late first half of 1980s showed decline tendencies which were more of erratic and early ending distributions than unique features. Elgon May rainfalls were peaking(appendix XXIII), an indication that the rains started rise more in April and was peaking in May. The May Series showed not complete breaks in 1979, 1980 and 1983-84 that pointed to erratic

distributions than unique features in the Series. Only 1983-84 showed a real break of less than 5mm per day rainfall; an indication that an agricultural drought situation could have occurred but not a real meteorological drought situation.

Generally in the Lake Basin (West Kenya), May rainfall seemed to have been high and steady during 1971-85 period although possibility of extended dry periods for at least two weeks was there, more so towards the Lake littoral.

#### **4.3.7 June Results, 1971-85**

In the Lake littoral, June rainfall Series (1971-85) started fading off towards the January - February levels, indicating a more peaked distribution in April-May period and decline as from June. Kisumu area had exceptional rainfall peaks in 1972, 1977-78, and 1980 which were unseasonal in the Series. 1976, 1979, 1981 and 1984 series showed general low rainfall distributions below 5mm per day especially 1979 and 1981 and 1984 indicating rainfall distribution generally below 5mm per day and even below 0.25mm per day. Indeed, the June rainfall series showed generally low rainfalls but there seemed to have been as many lows below 5mm as were peaks with a tendency of rains from 1977 to 1985 to have major peaks between exceptional lows. Muhuru Series had "a fading" June rainfall in the first half of 1980s. Occurrence of a dry day was most probable in the Series and major gaps appeared in the Series in 1983, 1980-

81 and 1984-85 indicating prolonged dry periods with erratic rainfall distributions. June was generally dry in the Usigu area, with dry days dominating; the Series was dominantly below 5mm per day and the less than 0.25mm days were many. 1982-84 indicated marked breaks in the Series but this was not uncommon as dry spells dominated the Series. Port Victoria series showed a fluctuating series, generally, with more dry days but 1971, 1973-74, 1976-77, 1980-81 and 1984-85 showed more explicitly prolonged dry days of less than 5mm per day. Occasional peaks indicated the fact that it was not easy to get a month throughout 1971-85 period without a wet day ( $> 5\text{mm}$  per day).

The low midlands June Series indicated declining rainfalls but were relatively better than the lake littoral with Kosele being closer. Kosele Series showed a patchy distribution with many dry spells. 1973 showed a break that indicated short June rains and 1975-76 showed a pronounced erratic June rainfall. There was exceptional peaking in 1977, unseasonal, but 1980-81 was drier and could have been drought situation. There was another unseasonal peaking in 1982-83 period. Generally, June was dry in the Kosele area with occasional peaking being a feature and this seemed to be the general rainfall set up in the month. Kodera Series in June indicated erratic distribution but better was off than the Kosele situation. Rainfall was distributed throughout the month but with irregular pattern indicating high risk of dry spells. The rainfall Series was generally below 5mm per day but rarely falling below

0.25mm per day mark. June Series showed low peaks generally but no major break in the Series indicating more of rainfall not developing fully than prolonged periods of dry days. Bungoma area June's Series showed a relatively good peaking but the fluctuations were notable. Rainfall Series fluctuated with no major break but part of 1975, 1977, 1978, 1979 or generally between 1978-81, indicated low rainfalls of erratic distribution or not well developed rains.

June rains were still good and steady in the upper midlands but relatively lower than in the April-May period except around Mount Elgon Forest Station where the June rains were still at near par with the May rainfall. Infact, the Elgon rainfall regime indicated peaking from mid-April to June. In the Malava area, 1982-83 showed exceptional breaks but not complete in the Series indicating low and erratic distribution than well defined prolonged dry period during the well distributed rainfall month in the area. Generally, 1979-85 period in the Malava area showed rainfall distribution affected by breaks that seemed abnormal from the overall Series; the period was generally low and erratic in rainfall distribution. Kimili Series gave no major break in the Series and the rainfall was balanced between less and above 5mm per day respectively. 1974 and 1980-81 indicated tendencies towards less than 5mm per day rainfall. These tendencies could have been dangerous if the crops were still in their development stages or in their early late season stages. Kisii Series (fig. 4.12) indicted low distribution

in 1971 (generally less than 5mm per day) as was in 1979, 1981 and 1983. 1972-73 showed exceptional high peaking and therefore unseasonal rainfall that could have been dangerous if the crops were in their harvest stages; crop damage in the farms due to excess water leading to rotting. June rainfall Series was fluctuating but still good in the Nyamira area than around Kisii station area. 1973 showed a break in the Series as was 1976 and 1980-84 but the breaks were not complete indicating erratic distributions and not well developed distributions seemed to be normal throughout with few gaps that were not really exceptional as was in 1981.

June rainfalls in the Lake Basin during 1971-85 period showed marked variations between the three altitudinal zones; Lake littoral, low midlands and upper midlands. The variations were present even within the zones but generally June rainfall had indicated decline from the April-May peaking with the Elgon Station area being slightly exceptional. Generally, in the Lake littoral, crops grown should be in their harvest stages, in the low midlands, late season stage and in the upper midlands, early late season stage.

#### **4.3.8 July Results, 1971-85**

July was generally dry in the Basin and in some places very dry. In the Lake littoral, July was very dry and nearly drier than

February with rainfall generally below 5mm per day and the distribution being pronouncedly erratic. In the Kisumu area, rainfall peaks above 5mm per day and lows were common but 1973 showed a prolonged period of below 5mm per day (fig.4.9). The prolonged dry days also appeared in 1975 and in the 1977-78 period. Rainfall unseasonality appeared in 1981-82 period with rainfall above 5mm per day seemingly common. Only 1973 showed a well defined low but the other years mentioned were having incomplete breaks, indications of erratic distribution. Muhuru area had a generally dry month of July in 1971-85 (appendix XIX) period with few days receiving rainfalls each equal to or above 5mm per day. A near complete gap appeared in the Series between 1976 and 1981 with few days receiving rainfall equal to 5mm per day. Between the period noted, there was a notable decline in the July rains but the situation was seemingly the norm in the area. July in the Usigu area was very dry (1971-85) with dry spells dominating the Series. 1972, 1975-76 showed marked breaks in the Series but these were not uncommon for the domination of dry spells indicated high possibility of prolonged dry period in July. Port Victoria area was relatively better off in terms of July rains than the Muhuru and Usigu areas respectively but closer to the Kisumu area's level. July in the Port Victoria area was generally having more days with less than 5mm per day but days with even over 20mm per day were possible. 1971-73, part of 1974, 1977-78, 1981, 1983 showed in the Series, generally prolonged period of less than 5mm per day.

rainfall but the breaks were not complete indicating erratic distributions than a real drought situations.

In the low midlands, July was relatively dry with the less than 5mm per day rainfall Series dominating. Kosele area was dry in July with 1974 showing a major break in the Series but 1976-78 showed exceptional peaking above 10mm interceded with dry spells (fig.4.11); rainfall unseasonality. 1979-80 indicated patchy rainfall distributions with 1983 showing marked breaks in the Series as was in 1974; prolonged dry periods. 1972-76 period was relatively drier than other years in the 1971-85 period but the situation was more of a patchy distribution than a real drought situation. Bungoma area indicated a steady rainfall Series in July but 1973, 1979-81 showed signs of breaks although the breaks were not well defined; erratic distributions.

July rainfalls in the upper midlands was relatively better than in the zones already mentioned although relative to the preceding months, it was dry. Malava area rainfall Series in July indicated irregular rainfall distributions in 1972, 1974, 1981-82 but no major break. Kimilili area Series had lows in 1977, 1980, 1983-84 but the lows were not complete, indications of irregular rainfall distributions than a unique situations. Kisii area had low rainfall Series in 1971, 1978 and 1981 (appendix XX) with indications that the rainfalls were more erratic and in some cases failed to develop to the general level(1978) but the 1971 rainfall

data was not to be trusted as already mentioned in the preceding paragraphs. Nyamira July rainfall Series was steady and relatively good with only 1973 and 1982 showing lows but not complete ones. In the Elgon area, the July rains were steady and in some cases high indicating more of an Eldoret regime than the transition regime of Mungai(1984). 1984 tended to have had a unique gap in the Series and this indicated a near drought situation. The rainfall distribution in July was relatively steady as compared to other stations in the upper midlands already mentioned.

Generally the July rainfall was relatively low with the less than 5mm per day rainfall being dominant. This indicated that, crops grown even in the upper midlands should be in the stage of growth where water requirements were minimal; harvest stage or if anything, irrigation water is to be made available to the crops.

The weighted Series showed rainfall distributions between January and July having peaks in April-May period during 1971-85 and this seemingly is the situation in West Kenya. The Series also indicated the possibility of prolonged dry periods, relatively, in all the months as were indicated by breaks (gaps) in the rainfall Series of various months during the 1971-85 period. Also, the breaks were not very complete with less than 0.25mm per day breaks being very rare; an indication of less possibility of meteorological drought although the tendencies were there. The less than 5mm per day Series breaks were more common and possible in all

the months but these varied in length with the zones; the Lake littoral being more susceptible and the upper midlands least vulnerable. That is, the possibility of agricultural drought was real and could occur even in a matter of days, depending on soil moisture balance , in all the agro-climatic zones of West Kenya but the Lake littoral seemed more vulnerable. The vulnerability of the various zones to agricultural drought could further be better assessed by considering the types of crops grown, their lengths of growth, and their water requirements as to the water balance of the various soils of the basin.

#### 4.4.0      The Autocorrelation Significance Test Results, (1971-85);January - July.

This test was used to check whether the Series distributions shown and described above were due to chance ,random distribution (white noise), or there were persistence tendencies(red noise)in the distributions. The first autocorrelation function test was used based on Anderson's modified formula (FAO, 1973):

$$(-1/N-1 + 1.96(N-2)/(N-1))^{3/2}, \quad -1/N-1 - 1.96(N-2)/(N-1)^{3/2}$$

If the first autocorrelation coefficient was within the range above, the distribution was random and the reverse meant persistence. If there was persistence at first lag, it meant that a rainfall event could be repeated the following day. Indication of persistence at first lag was then checked against first order Markov Chain model; an event occurring two days in a row;  $r_k < r_1^k$  meant non linear distribution and  $r_k > r_1^k$  meant that the

distribution fitted the first order linear Markov distribution model, where  $r_k$  was the autocorrelation coefficient ,k lag time and  $r_k^k$  was  $r_k$  raised to lag k. The distribution was then checked for persistence or random distribution at lag 5 ( $r_5$ ), lag 10 ( $r_{10}$ ), and lag 15 ( $r_{15}$ ) which were more meaningful in terms of soil moisture retention capacity in West Kenya, using estimate,  $\pm 2/\sqrt{N}$ , where N was the number of days in the period.

#### 4.4.1 January Results, 1971-85

In the Lake littoral, at lag one, the coefficients were generally outside the range with few exceptions in January indicating persistence in the distribution. That is, if there was a dry day, it was most likely to be followed by dry day, and the same was true for a wet day. In the Kisumu area, the January autocorrelation coefficient at lag one was .15078 and the Anderson's range was 0.08864 and - 0.09295. This meant that at lag 1,  $r_k$  was significantly different from zero and this showed persistence (Red noise) in the Series distribution and the break in the distribution Series was most likely to continue for at least two days. At lag 5, using the  $\pm 2/\sqrt{N}$  estimate equals to  $\pm .09275$ ,  $r_k$  was -.01705 and therefore within the range indicating random distribution. Since  $r_k$  was negative, the distribution at lag 5 was most likely to decline, that is, rainfall distribution within five days was most likely to show decline from the first values. Therefore at lag 5, a break in the Series was not predictable as

it was equally likely to get a dry break as it was to get wet period. At lag 10, using  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ),  $r_k$  was  $-.03399$  indicating random distribution as was the case at lag 5 and the same was true at lag 15 where  $r_k$  was negative and within the confidence limits  $\pm 2/\sqrt{N}$ . In January of the Kisumu area, indications were that persistence was most likely at lag less than 5 and thereafter random distribution was dominant. At lag 5,  $r_k$  was less than  $r_1^k$  and this indicated non-linear persistence at lag 1 and the same was true at lag 10.

Muhuru Bay area January autocorrelation coefficient at lag 1 was equal 0.09898 and the Anderson's range was .09167 and  $-.09628$ . This showed that  $r_1$  was significantly different from zero and thus, persistence in the series at lag 1. At lag 5 with the confidence limits  $\pm 2/\sqrt{N}$  of  $\pm .09800$ ,  $r_k$  was negative ( $-.01207$ ) and within the limits indicating random tendency in the series at lag 1. Testing for the Markov chain model at lag 5,  $r_k$  was less than  $r_1^k$  indicating the persistence at lag 1 to be non-linear. At lag 10, using the  $\pm 2/\sqrt{N}$  ( $\pm .09800$ ) limits,  $r_k$  was negative and within the limits ( $-.07008$ ) indicating random and declining tendency in the series distribution as was in lag 5. The same was true at lag 15 and this generally pointed to a tendency to have persistence at high frequencies, less than 5 days, but random distribution at low frequencies, more than 5 days. At lag 10, the distribution showed  $r_k < r_1^k$  indicating non-linear persistence at lag 1 and therefore not fitting the first order Markov chain model.

The Usigu area January rainfall Series with lag 1 autocorrelation coefficient of .38985 at Anderson's range of .09503 and -.10000, showed that there was persistance at lag 1 for  $r_k$  was significantly different from zero. At lag 5,  $r_k$  was outside the limits  $\pm 2/\sqrt{N}$  and this indicated persistance in the series distribution. Testing against the first order Markov chain at lag 5, there was indication of the distribution persistance being of linear Markov type; that is, there was greater possibility of a rainfall event of the same order occurring two times in a row. At lag 10, there were still indications of persistance for  $r_k$  (.32448) was outside the limits  $\pm 2/\sqrt{N}$  ( $\pm .09963$ ) and this still showed a linear Markov persistance. At lag 15,  $r_k$  (.08175) was not significantly different from zero for it was within the limits  $\pm 2/\sqrt{N}$  ( $\pm .09963$ ) and this indicated random distribution. Persistance seemed to have been common in the January rainfall Series with frequencies equal to or less than ten days showing persistance.

Port Victoria area showed random distribution (white noise) for  $r_1$  was within  $-1/N-1 + 1.96(N-2)/(N-1)^{3/2}$ ,  $-1/N-1 - 1.96(N-2)/(N-1)^{3/2}$  range. At lag 5, there was indication of persistance for  $r_k(r_5)$  was outside the limits  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ). At lag 10,  $r_k$  was within the limits  $\pm 2/\sqrt{N}$  and was negative indicating decline and random distribution. At lag 15,  $r_k$  was still within the limits and negative. Generally, the Series distribution gave a mixture of random and persistance showing that the rainfall tendency was more

unpredictable at high frequencies less than 5 days but a bit predictable as one nears 5 day.

Generally in the Lake littoral, the distribution showed persistence at high frequencies (less than 5 days) but random distribution at low frequencies. One has to note the possibility of both random and persistence events in the rainfall distribution of the Lake littoral in January on a daily basis.

In the low midlands, the January daily rainfall Series showed a general randomness at lag 1 with few exceptions. Kosele area daily rainfall autocorrelation coefficient at lag 1 ( $r_1$ ) was .02703 and was within the Anderson's range (.09166, -.09628) and therefore not significantly different from zero. This showed that the distribution at lag 1 was random (white noise). That is, if there was no rain today, it was equally likely to have rain or no rain the following day. Using the  $\pm 2/\sqrt{N}$  estimate ( $\pm .09600$ ), there was still random tendency at  $r_5$  (.02175). At lag 10 ( $r_{10}$ ), using the  $\pm 2/\sqrt{N}$  estimate, the distribution was still having random tendency as was at lag 15 ( $r_{15}$ ) showing that the January daily rainfall distribution was mostly random and at lag 1 and alpha 0.05, randomness was the feature. In the Kodera area  $r_1$  was significantly different from zero for it was falling outside the Anderson's range (.09166, -.09628) as  $r_1 = .28629$ . This showed that if there was a dry day, the following day was most likely to be dry and the same was true with wet days. At lag 5 ( $r_5$ ) using  $\pm 2/\sqrt{N}$  estimate

( $\pm .09600$ ), there was random tendency in the rainfall distribution as  $r_5 = .05993$ . The same was true at lag 10 and lag 15. This indicated persistence tendency in daily rainfall distribution in January around Kodera area at high frequencies (days less than five) but random tendency at low frequencies (equal or greater than five days). The persistence at lag 1, was checked against the Markov linear model at lag 5 and lag 10. At lag 5,  $r_k > r_1^k$  and this indicated linear Markov persistence and the same was true at lag 10. Around Bungoma area, at lag 1, the January rainfall series was random as  $r_k$  was within the Anderson's range (.08864, -.09295) and therefore not significantly different from zero. At lag 5, using the  $\pm 2/\sqrt{N}$  estimate ( $\pm .09275$ ), there was tendency towards random falling distribution as  $r_5$  (-.03907) was within the limits and negative. The same was true at lag 10 (-.00741). At lag 15, although still within the  $\pm 2/\sqrt{N}$  limits, there was a random tendency but with a rising distribution.

It seemed as if the January daily rainfall distribution showed more of random distribution than persistence in the low midlands although inspection of the autocorrelation coefficients showed that a mixture of random (white noise) and persistence was possible in the low midlands.

In the upper midlands, the January rainfalls Series were showing more of persistence (Red noise) than random (White noise) distribution with the exception of the Elgon area Series. Malava

area Series had an autocorrelation coefficient at lag 1 ( $r_1$ ) equal .43818 and this was outside Anderson's range of .08864 and -.09295. As a result  $r_1$  was significantly different from zero and showed persistence in the Series and the same was true at lag 10 and lag 15 respectively. Generally, the January Series in the Malava area showed persistence tendency at lag 1; there was 95 percent confidence that persistence was a feature of the Series. The kind of persistence present in the Series was investigated by checking whether the distribution of the Series fitted the first order Markov chain model. At lag 5,  $r_k > r_1^k$  where k was 5 indicating linear persistence and the same was true at lag 10. In the Kimilili area, the January Series autocorrelation coefficient at lag 1 ( $r_1$ ) was .16445 and therefore outside the Anderson's range of .08864 and -.09295. This showed significant difference from zero and to this, at lag one, there was persistence in the Series. Using the  $\pm 2/\sqrt{N}$  estimate ( $\pm .09275$ ), at lag 5 ( $r_5$ ), the autocorrelation coefficient of -.04632 was within the limits and this indicated random tendency in the Series distribution, that is after a span of five days there was random tendency in the Series, and the next five days distribution were most likely to be low. The same situation was at lag 10 and lag 15 and this indicated persistence tendency in the January rainfall Series at high frequencies (less than 5 days) but random tendency at low frequencies (greater or equal to 5 days) with falling distribution. Since at lag one,  $r_k$  was significantly different from zero and therefore showing persistence in the distribution, a test was done

to check the kind of persistence at lag 5 and 10 respectively. At lag 5 and lag 10,  $r_k < r_1^k$  showing a non-linear persistence and therefore not fitting the first order Markov chain model. That is, even though there was persistence at lag 1, it was unlikely to have the same amount of rainfall two days in a row, as opposed to linear persistence where the likelihood of two days in a row rainfall of the same amount was highly possible. Kisii area rainfall Series at lag 1 ( $r_1$ ) had autocorrelation coefficient of .38808 and therefore outside the Anderson's range of .08864 and -.09295. At lag 1,  $r_1$  was significantly different from zero and this showed persistence in the rainfall series. Using the  $\pm 2/\sqrt{N}$  estimate ( $\pm .09275$ ) to check the possible nature of the Series distribution at lag 5, 10 and 15 respectively, it was found that at :

- lag 5,  $r_k$  was within the limits and negative indicating (.04844) random (white noise) distribution in the Series;
- lag 10,  $r_k$  was within the limits and negative indicating random distribution of a declining nature in the Series; and
- lag 15,  $r_k$  (-.03660) was within the limit and negative indicating random tendency in the Series distribution with falling levels.

Since at lag 1 in the Kisii area Series, the autocorrelation series showed persistence, a test was done to check the kind of persistence when k was 5 (lag 5) and 10 (lag 10) respectively. At lag 5 ( $r_5$ ),  $r_k > r_1^k$  and this showed linear persistence, fitting first order Markov chain model but at lag 10,  $r_k < r_1^k$  showing non-linear persistence in the Series distribution. Generally, the

Kisii Series tended to have had persistence at high frequencies (less than 5 days) but random tendencies at low frequencies. Nyamira area Series at lag 1 ( $r_1$ ) had autocorrelation coefficient equals to .26797 falling outside the Anderson's range (.09166 and -.09628) thus showing persistence in the series. At lag 5,  $r_k$  was .08445 within the limits  $\pm 2/\sqrt{N}$  ( $\pm .09600$ ) and therefore indicating random tendency in the Series distribution. This showed that the January rainfall Series in the Nyamira area had a mixture of persistence and random tendencies. Since  $r_1$  at 95 confidence limit showed persistence, it was checked against the linear Markov model using the  $r_k > r_1^*$  or  $r_k < r_1^*$  at lag 5 and 10 respectively. The result was that at both lags,  $r_k > r_1^*$  and this indicated linear persistence thus fitting the Markov model. Elgon area station was unique in that at lag 1,  $r_k$  (.07304) was not significantly different from zero and this showed random distribution (white noise). This was because  $r_1$  was within the Anderson's range (.08864, -.09295). At lag 5, using the  $\pm 2/\sqrt{N}$  estimate ( $\pm .09275$ ),  $r_k$  was within the limits and this indicated random tendency in the Series distribution. At lag 10 and 15 respectively,  $r_k$  was negative and within the limits ( $\pm 2/\sqrt{N}$ ) and this indicated random falling tendency in the Series distribution. In general, the January rainfall Series in the Elgon area had a random tendency.

In conclusion, January daily rainfall Series in West Kenya tended to have had a mixture of persistence and random distribution. Persistence was a feature at high frequencies (less

than 5 days) and random at low frequencies ( $> 5$  days), but this was not well defined indicating more of a mixture in the rainfall distribution structures. Persistence at lag 1 was common but not exclusive as the case of Kosele, Port Victoria and Elgon demonstrated.

#### 4.4.2 February Results, 1971 - 1985

In the Lake littoral, the February rainfall Series at lag 1 ( $r_1$ ) tended to have been random; that is, there were equal chances of getting a wet day or dry day. In the Kisumu area  $r_1$  was .04839 and was within the Anderson's range (.09158, -.09617). This showed at alpha 0.05 that  $r_1$  was not significantly different from zero and the Series distribution was random (white noise). At lag 5 ( $r_5$ ), the autocorrelation coefficient was -.02045 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits. This indicated a random falling tendency in the Series distribution. At lag 10,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits but was positive and therefore showing a random positive tendency in the Series distribution. The same was true at lag 15. The Kisumu rainfall Series distribution tended to have been random. In the Muhuru area rainfall Series, the autocorrelation at lag 1 ( $r_1$ ) was .03145 and within the Anderson's range (.09337, -.09814). This meant that at lag 1,  $r_1$  was not significantly different from zero and therefore at lag 1 the Series was random; white noise in the Series. At lag 5 ( $r_5$ ),  $r_k$  was .00474 and this was within the limits,  $\pm 2/\sqrt{N}$ , and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  was negative and within  $\pm 2/\sqrt{N}$  limits

indicating random falling tendency in the Series distribution. At lag 15,  $r_k$  was within  $\pm 2/\sqrt{N}$  limits but positive and therefore showing random positive series distribution. In the Usigu area,  $r_k$  at lag 1 was -.00276 and within the Anderson's limits (.09468, -.09962). This was unique in that at lag 1 to get random and falling Series distribution is rare. The  $r_1$  was not significantly different from zero and was negative, indicating a falling or low Series distribution. At lag 5,  $r_k$  was within the  $\pm 2/\sqrt{N}$  ( $\pm .09926$ ) limits indicating random tendency in the Series distribution and since  $r_5$  was negative, the random tendency was also showing declining distribution tendency. The same was true at lag 10 and lag 15. This indicated that the Usigu area rainfall Series was generally random and falling or low in distribution. The Port Victoria rainfall series autocorrelation coefficient at lag 1 ( $r_1$ ) was negative (-.00521) and within the Anderson's range (.09156, -.09617). This showed that at lag 1,  $r_k$  was not significantly different from zero and to this the Series distribution was random and declining or low. At lag 5 ( $r_5$ ),  $r_k$  was -.02735 and within the limits,  $\pm 2/\sqrt{N}$ , ( $\pm .09589$ ) showing random falling tendency in the Series distribution. The same was true at lag 10 but at lag 15, although random tendency was still present, the distribution no longer had a falling tendency. The Port Victoria February rainfall Series showed a general random distribution.

In the low midlands, the Series distribution showed persistence tendency in general although deviations from this were to be expected. In the Kosele area, the autocorrelation coefficient at

lag 1 ( $r_1$ ) was .14778 and this was outside the Anderson's range (.09156, -.09617). This showed significant difference from zero at a 0.05 and to this, there was persistence in the Series distribution at lag 1. At lag 5,  $r_k$  was .01311 and this was within the limits  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ). This indicated random tendency in the Series distribution. The same was true of the series at lag 15. Generally, the February Series in the Kosele area showed persistent at high frequencies (< 5 days). The Kodera area February rainfall Series autocorrelation coefficient at lag 1 was .20929 and fell outside the Anderson's range (.09156, -.09617). At lag 1 therefore,  $r_k$  was significantly different from zero at alpha 0.05 and this showed persistence in the Series. At lag 5,  $r_k$  was -.01553, falling within the limits  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ). This indicated random falling tendency in the Series. At lag 10 and 15, respectively, coefficients ( $r_{10} = .08413$ ,  $r_{15} = .04501$ ) were within the  $\pm 2/\sqrt{N}$  limits but were not negative indicating random positive distribution in the Series. Since lag 1 had shown persistence in the Series, a check was done to see whether it fitted the Markov linear model or not at lag 5 and 10 respectively. At lag 5,  $r_k > r_1^*$  indicating linear Markov persistence but at lag 15,  $r_k < r_1^*$  indicating non-linear persistence. Bungoma area rainfall Series had autocorrelation coefficient at lag 1 of .07377 and this was within the Anderson's range. To this, at lag 1,  $r_k$  was not significantly different from zero at alpha 0.05 and the Series distribution was therefore random. At lag 5,  $r_k$  was .06160 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits indicating random tendency in

the Series distribution. The same was true at lag 10 (.06459) but at lag 15, the distribution had a random tendency.

In the upper midlands, the rainfall Series distributions were generally persistent in nature during the month of February. In the Malava area, at lag 1,  $r_k$  was .36743 and fell outside the Anderson's range (.09156, -.09617) thus showing significant difference from zero. At lag 1 therefore, there was persistence in the Series distribution. At lag 5,  $r_k$  was .17895 and this was outside the limits  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) indicating persistence tendency in the February rainfall Series in the Malava area. Since there was persistence in the Series at lag 1, a test was done to check the types of persistence in the Series. At lag 5,  $r_k > r_1^k$  showing linear persistence (Markov chain model) and the same was true at lag 10. Generally, the persistence in the February rainfall Series in the Malava area was of the linear Markov type. In the Kimilili area,  $r_k$  at lag 1 was .28427 and outside the Anderson's range (.09156, -.09617). This showed that  $r_k$  at lag one was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  was .09154 and within the limits,  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ), indicating random tendency in the Series distribution. At lag 10,  $r_k$  was .12720 and this was outside the limits,  $\pm 2/\sqrt{N}$ , indicating persistence in the Series. At lag 15,  $r_k$  was .03816 and within the  $\pm 2/\sqrt{N}$  limits. This indicated random tendency in the Series distribution. Generally, in the Kimilili area, there tended to have been persistence tendency at less than 5 days , random

tendency at 5 or more days, persistence tendency towards ten days and random tendency towards a month duration. Checking the kind of persistence shown at lag 1, the lag 5 and 10 bases were used respectively. At lag 5,  $r_k > r_1^k$  showing linear Markov Persistence and the same was true at lag 10. Kisii area autocorrelation coefficient ( $r_k$ ) at lag 1 was .24373 and this was outside the Anderson's range (.09156, -.09617). This showed that  $r_1$  was significantly different from zero and the series distribution showed persistence. At lag 5,  $r_k$  was .02866 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits, indicating random tendency in the Series distribution. At lag 10,  $r_k$  was .00742 and within the  $\pm 2/\sqrt{N}$  limits as was at lag 15, indicating random tendencies in the Series at lag 10 and 15 respectively. This indicated persistence in the Series distribution at high frequencies. At lag 5,  $r_k > r_1^k$  indicating linear Markov Persistence and the same was true at lag 10. In the Nyamira area, the February rainfall Series autocorrelation coefficient ( $r_k$ ) at lag 1 was .27433 and outside the Anderson's range (.09156, -.09617). This showed that at alpha 0.05,  $r_1$  was significantly different from zero and the Series distribution was therefore persistent in nature. At lag 5,  $r_k$  was .05868 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits, indicating random tendency in the Series outside the  $\pm 2/\sqrt{N}$  limits indicating persistence tendency in the Series distribution. A general picture of the Series showed persistence tendency at high frequencies (< 5 days), random tendency at low frequencies although persistence after five day consecutive period was to be expected. Testing to check the kind

of persistence at lag 1 using the lag 5 and lag 10 bases, it was found that at lag 5,  $r_k > r_1^k$  and the same at lag 10. This indicated linear Markov Persistence in the Series distribution. Finally, in the Elgon area, the autocorrelation coefficient at lag 1 of the February Series was .07733 and within the Anderson's range (.09156, -.09617). this showed that at lag 1,  $r_k$  was not significantly different from zero and the Series distribution was therefore random (white noise). At lag 5,  $r_k$  was .04313 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits, indicating random tendency and the same was true at lag 10 and 15 respectively. February Series distribution in the Elgon area was generally random although persistence at certain lags could be noticed, for example at lag 2, lag 4 and lag 11 which were just one lag from the lags used in the analysis.

In West Kenya generally, the February rainfall Series showed persistence at high frequencies (< 5 days) but random tendency at low frequencies (> 5 days). This is important in terms of rainfall events behaviours and in this study the occurrence of dry or wet days. If persistence is a factor in the daily rainfall climatology of an area, the possibility of dry day or wet day extending to a spell is high and this may eventually developed into a defined period of a given rainfall event.

#### 4.4.3 March Results, 1971 - 1985

March rainfall Series distribution showed persistence tendency throughout West Kenya at lag 1 with only the Port Victoria area in the Lake littoral showing random distribution. The lake littoral like the rest of West Kenya showed persistence in the Series distribution especially at high frequencies (< 5 days). In the Kisumu area, the autocorrelation coefficient ( $r_k$ ) at lag 1 was .17789 and this was outside the Anderson's range (.08864, -.09295) thus showing persistence in the Series distribution. At lag 5 ( $r_5$ ),  $r_k$  was .07995 and there within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits. This indicated random tendency in the Series distribution. The same was true at lag 10 and 15 respectively although at lag 15 there was random falling tendency in the Series distribution. The kind of persistence indicated at lag 1 was investigated using the lag 5 and 10 respectively as bases. At lag 5,  $r_k > r_j^k$  showing linear Markov Persistence and the same was true at lag 15. Muhuru Bay area autocorrelation coefficient at lag 1 was .09898 and this was outside the range (.09167, -.09628). This showed that at alpha .05, lag 1 autocorrelation coefficient was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  was .04623 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09600$ ) limits, indicating random tendency in the Series distribution. The same was true at lag 10 and 15 respectively although at lag 15, the random tendency showed rainfall decline in the Series distribution. To check the kind of persistence at lag 1, it was checked whether

$r_k$  (where k was 5 and 10) was greater or lesser than  $r_1^k$ . At lag 5,  $r_k > r_1^k$  indicating linear Markov Persistence and this was also true at lag 10. Generally, Muhuru Bay March Series showed persistence tendency at high frequencies (< 5 days) and random tendency at low frequencies. In the Usigu area, the autocorrelation coefficient at lag 1 was significantly different from zero at alpha 0.05. At lag one ( $r_1$ ), therefore, persistence was a feature in the series distribution. At lag 5,  $r_k$  was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits indicating persistence tendency in the Series distribution. This tendency continued up to lag 10 and 15 respectively. The kind of persistence shown at lag 1 was of the linear Markov type using lag 5 and 10 respectively as bases; for  $r_k$  was greater than  $r_1^k$  ( $r_k > r_1^k$ ). Persistence was a major feature of the March Series distribution in the Usigu area. The Port Victoria area March Series autocorrelation coefficient at lag 1 ( $r_1$ ) was .06864 and this was within the Anderson's range (.08864, -.09295). At lag 1 therefore,  $r_k$  was not significantly different from zero showing randomness in the Series distribution. At lag 5,  $r_k$  (-.01353) was within  $\pm 2/\sqrt{N}$  limits and was negative, indicating random falling tendency in the Series distribution. The same situation was true at lag 10 but at lag 15, although the random tendency was positive. Port Victoria Series indicated generally a random tendency in the distribution of daily rainfall.

In the low midlands, persistence was a major feature in the March daily rainfall Series. In the Kosele area at lag 1, the

autocorrelation coefficient ( $r_k$ ) was .23792 and this was outside the Anderson's range of .08864 and -.09295. At lag 1 therefore,  $r_k$  was significantly different from zero showing persistence in the Series distribution. At lag 5,  $r_k$  (.03056) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits, thus indicating random tendency in the Series distribution. The same was true at lag 10 and 15 respectively although at lag 15,  $r_k$  was negative. The persistence shown at lag 1 was of linear Markov type using  $k = 5$  and 10 respectively ( $r_k > r_1^k$ ). The Kodera area March rainfall Series autocorrelation coefficient at lag 1 was .17384 and this was outside the Anderson's range (.08864, -.09295). At lag 1,  $r_k$  was therefore significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.08870) was slightly within the  $\pm 2/\sqrt{N}$  ( $\pm .09285$ ) limits and this indicated random tendency in the Series distribution. At lag 10 and 15,  $r_k$  was still within the  $\pm 2/\sqrt{N}$  limits thus showing random tendency in the Series distribution. There was a general tendency towards persistence at high frequencies (< 5 days) and randomness at low frequencies (> 5 days). The persistence shown at lag 1 was linear Markov for  $r_k > r_1^k$  where  $k$  was 5 and 10 respectively. The Bungoma area March Series showed persistence at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The Autocorrelation Coefficient ( $r_k$ ) at lag 1 ( $r_1$ ) was .13583 and this was outside the Anderson's range (.08864, -.09295). This showed that  $r_1$  was significantly different from zero and there was persistence in the Series distribution. At lag 5 (.06980),  $r_k$  was within the limits

$\pm 2/\sqrt{N}$  ( $\pm .09275$ ) and this indicated random tendency in the Series distribution. At lag 10 and 15 respectively there was random falling tendency as the  $r_k$  were within the  $\pm 2/\sqrt{N}$  limits and were negative. Persistence shown at lag 1 was linear Markov type when  $k$  was 5 but non-linear when  $k$  was 10 and this indicated mixed or more than one process in the Series.

The upper midlands March rainfall Series showed general persistence at high frequencies ( $< 5$  days) but a mixture of persistence and random distribution at low frequencies ( $> 5$  days). Malava area autocorrelation coefficient ( $r_k$ ) at lag 1 ( $r_1$ ) was .34939 and this was outside the Anderson's range (.08864, -.09295). At lag 1, therefore,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  was .20897 and this was outside the  $\pm 2/\sqrt{N}$  limits thus indicating persistence tendency in the Series distribution. There was still persistence tendency at lag 10 but at lag 15,  $r_k$  within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this indicated random tendency as from mid month in the Malava area. The persistence shown at lag one was linear Markov as at lag 5 and 10 respectively,  $r_k > r_1^k$  (where  $k = 5$  and 10). The Kimilili Series at lag one showed persistence. This was so because,  $r_1$  equals to .18113 was outside the Anderson's range (.08864, -.099295) and therefore significantly different from zero. At lag 5,  $r_k$  was .133100 and this was outside the  $\pm 2/\sqrt{N}$  ( $\pm .092275$ ) limits thus indicating persistence tendency in the Series distribution. At lag 10,  $r_k$  was .033678 and within the  $\pm$

$2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution. At lag 15,  $r_k$  was  $- .00761$  and within the  $\pm 2/\sqrt{N}$  limits, indicating random falling tendency in the Series distribution. The persistence shown at lag one was linear Markov type when  $k$  was 5 and 10 respectively ( $r_k > r_1^k$ ). Kisii area rainfall Series showed persistence in distribution at lag one ( $r_1 = .25905$ ). Lag one autocorrelation coefficient was outside the Anderson's range (.08864, -.09295) and therefore significantly different from zero at alpha 0.05. At lag 5  $r_k$  was .0877705 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits. This indicated random tendency in the Series distribution. The same was true at lag 10 and 15 respectively although  $r_{10}$  was negative (-.00958). Generally, March Series showed persistence at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag one was linear when  $K$  was 5 but non-linear when  $K$  was 10. This indicated a mixed process behind the Series distribution. Nyamira area March rainfall Series autocorrelation coefficient at lag one ( $r_1$ ) was .28169 and outside the Anderson's range (.08864, -.09295). This showed that, at lag one,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.07083) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  (.18671) was outside the  $\pm 2/\sqrt{N}$  limits thus indicating persistence tendency in the Series distribution. At lag 15,  $r_k$  (.04193) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution.

In summary, the March rainfall Series in the Nyamira area showed persistence tendency at high frequencies and a mixture of random and persistent distributions at low frequencies ( $> 5$  days). Elgon area March rainfall Series showed persistence tendency at lags  $> 5$  days but random tendency at lags  $> 10$  days. At lag one,  $r_1$  was .29817 and outside Anderson's range (.08864, - .09295). This showed that  $r_1$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.10492) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this indicated persistence tendency in the Series distribution. At lag 10,  $r_k$  (.04129) was within the  $\pm 2/\sqrt{N}$  limits thus indicating random tendency in the Series distribution as was the case at lag 15. In both the Nyamira area and Elgon area, when  $K$  was 5,  $r_k > r_1^k$  thus indicating linear Markov Persistence at lag one. The same was true in the Elgon area at lag 10 but non-linear in the Nyamira area.

#### 4.4.4 April Results, 1971 - 85

The April rainfall Series showed a mixture of persistence and random distribution in West Kenya. The Lake littoral and the upper midlands showed more persistence in the Series than the low midlands which had more of random distribution in the Series. This difference seemed to have been due to the fact that the littoral was generally low in rainfall and the possibility of dry spells occurring was high. In the upper midlands, the April Series was high in rainfall amount and the possibility of wet spells occurring

was high unlike the low midlands where there was some balance between the wet and dry spells occurrences.

In the Lake littoral, the April rainfall Series at lag one showed general persistence with the exception of the Port Victoria area. The Kisumu area April rainfall Series autocorrelation coefficient (appendix X) at lag one was .11847 and this was outside the Anderson's range of .09006, - .09452. At lag 1, therefore,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  was .02436 and within the  $\pm 2/\sqrt{N}$  limits thus indicating random tendency in the Series. The same was true at lag 15 and this generally indicated that, the April rainfall Series had a persistence tendency at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag 1 was linear Markov type when K was 5 but Non-linear at K equals to 10. In the Muhuru Bay area, the April rainfall autocorrelation coefficient (Table 4.9) at lag one ( $r_1$ ) was .17148 and outside the Anderson's range (.09006, - .09452). To this,  $r_k$  was significantly different from zero and this showed persistence in the Series at lag one. At lag 5,  $r_k$  was .02541 and this was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits, indicating random tendency in the Series distribution. The same was true at lag 10 and 15 although at lag 15, there was random falling tendency in the Series distribution.

Generally, there was persistence tendency at high frequencies ( $< 5$  days) and random tendency at low frequencies ( $> 5$  days) in the April rainfall Series of the Muhuru Bay area. Persistence at lag one was linear Markov type when  $K$  was 5 and 10 respectively because the result of model fitting was  $r_k > r_1^k$ . In the Usigu area, the April rainfall Series autocorrelation coefficient at lag one was .23653 and this was within the Anderson's range (.009317, -.09791). There was, then, significant difference between  $r_1$  and zero and this showed persistence in the Series distribution. At lag 5,  $r_k$  (.09054) was within the  $\pm 2/\sqrt{N}$  limits thus indicating persistence tendency in the Series distribution. At lag 15,  $r_k$  (.06634) was within the  $\pm 2/\sqrt{N}$  limits and therefore showed random tendency in the series distribution. The Usigu area Series, in general, showed a mixture of persistence and random distribution tendencies in the April rainfall Series. The persistence shown at lag one ( $r_1$ ) was Linear Markov type when  $K$  was 5 and 10 respectively. Port Victoria area autocorrelation coefficient at lag one was .03575 and this was within the Anderson's range (.09008, -.09452). This showed that  $r_k$  was not significantly different from zero and there was random in the Series distribution. At lag 5,  $r_k$  (-.05859) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits and this indicated random tendency in the Series. This tendency was shown again at lag 10 and 15 although at lag 10, the tendency in the Series distribution was random and falling. Port Victoria April rainfall Series was generally showing random tendency.

In the low midlands, the April rainfall Series showed a mixture of persistence and random distribution with those areas nearing the Lake littoral showing persistence and those towards the upper midlands indicating random distribution. The Kosele area April rainfall autocorrelation coefficient at lag one was .14778. This was outside the Anderson's range, thus,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.01311) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09589$ ) limits and this indicated random tendency in the Series distribution. At lag 10 and 15 respectively,  $r_k$  was negative and within the  $\pm 2/\sqrt{N}$  limits and this indicated random falling tendency in the Series distribution. The persistence shown at lag one was linear Markov when K was 5 and non-linear when K was 10 thus indicating a mixture of persistence types in the Series. The Kodera area autocorrelation coefficient at lag one in April was .06011 and this was within the Anderson's range (.09006, - .09452). At lag one, therefore,  $r_k$  was not significantly different from zero and there was randomness in the Series distribution. At lag 5,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this was true at lag 10 and 15 respectively, thus indicating random tendency. The Bungoma area April rainfall autocorrelation coefficient at lag 1 ( $r_1$ ) was .03021 and this was within the Anderson's range of .09006, and this was within the Anderson's range of .09006, and - .09452. This showed that  $r_k$  was not significantly different from zero at lag one and there was random distribution in the Series. At lag 5,  $r_k$  (- .02394) was within the limits,  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ), and this

indicated random tendency in the Series distribution and the same tendency was shown at lag 10 and 15 respectively.

In the upper midlands, the April rainfall Series at lag one showed general persistence in distributions, an indication to the general steady rainfall distributions. In the Malava area, the April rainfall autocorrelation coefficient at lag one was .26025 and this was outside the Anderson's range of .09006 and -.09452. This showed that,  $r_k$  at lag one was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  was .10688 and outside the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits thus indicating persistence tendency in the Series distribution. The same was true at lag 10 but at lag 15,  $r_k$  (.06186) was within the  $\pm 2/\sqrt{N}$  limits and this showed random tendency as from mid April in the Series. The persistence shown at lag one in the Series was linear Markov when K was 5 and 10 respectively. The Kimilili April rainfall Series autocorrelation coefficient at lag one ( $r_1$ ) was .17379. This was outside the Anderson's range of .09006, and -.09452 thus showing that  $r_k$  lag one was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (-.01955) was negative and within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits. This indicated random falling tendency in the Series distribution at lag 5. The same random tendency was shown in the Series distribution at lag 10 and 15 respectively although at lag 10,  $r_k$  was positive.

Generally, there was persistence tendency at high frequencies in the Kimilili April rainfall Series. Persistence shown at lag one was non-linear when  $K$  was 10 ( $r_k > r_1^k$ ). In the Kisii area, the April rainfall autocorrelation coefficient ( $r_k$ ) at lag one was .20496 and this was within the Anderson's range of .09006, and .09452. This showed that at lag one,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.17546) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) and this indicated persistence tendency in the Series distribution. At lag 10, persistence tendency was still present but at lag 15,  $r_k$  (.00854) was within the  $\pm 2/\sqrt{N}$  limits thus indicating random tendency in the Series from mid month. There was a general persistence tendency in the April rainfall Series distribution in the Kisii area. Persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively. Nyamira April rainfall Series showed randomness in distribution at lag 1. This was so because at lag 1  $r_k$  (.00805) was not within the Anderson's range and therefore not significantly different from zero. At lag 5,  $r_k$  was .08445 and within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) and this showed random tendency in the Series distribution and this was true at lag 10 and 15 respectively. The lag 1  $r_k$  was unique for it showed a random falling rainfall distribution and this could have been due to very high daily rainfall amount followed randomly by a relatively low rainfall amount. That is, a day of rainfall could equally be followed by a wet day or dry day but whatever the result, it was bound to be relatively low than the previous day rainfall event!

The Elgon area April rainfall Series showed general persistence in distribution. At lag 1,  $r_k$  (.22548) was outside the Anderson's range of .09006 and -.09452. This showed that  $r_k$  at lag 1 was significantly different from zero and therefore, persistence was present in the Series distribution. At lag 5,  $r_k$  (.18107) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits and this indicated persistence tendency in the Series distribution. At lag 10 and 15,  $r_k$  ( $r_{10} = .02484$  and  $r_{15} = .01815$ ) was within the  $\pm 2/\sqrt{N}$  limits and this showed random tendency past five days in the Series distribution. The persistence shown at lag 1 ( $r_1$ ) was linear Markov when  $k$  was 5 and 10 respectively.

#### 4.4.5 May Results, 1971 - 85

In the Lake littoral, the May rainfall Series at lag 1 showed a general random distribution with the Usigu area Series being the exception. In the Kisumu area, the autocorrelation coefficient at lag 1 of the May Series was .03108 and this was within the Anderson's range of .08864 and -.09295. This showed that, at lag 1,  $r_k$  was not significantly different from zero and there was then random distribution in the Series. At lag 5,  $r_k$  (.12109) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this indicated persistence tendency in the Series distribution. At lag 10 and 15, respectively,  $r_k$  was negative and within the  $\pm 2/\sqrt{N}$  limits and this indicated random falling tendency. The May rainfall Series in the Kisumu area showed a general random distribution with

indications of persistence at some lags, for example at lag 5. Muhuru Bay rainfall Series in May showed random distribution at lag 1 ( $r_1$ ). This was due to the fact that, at lag 1,  $r_k$  (.06510) was within the Anderson's range of .09167 and -.09828 and this showed not significant difference from zero. At lag 5,  $r_k$  (.08016) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09600$ ) limits and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  was -.10340 and therefore outside the  $\pm 2/\sqrt{N}$  limits. This indicated a persistent falling tendency in the Series distribution. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution. The Muhuru Bay May rainfall Series was generally random but there were indications of persistence especially at low frequencies ( $> 5$  days). Usigu area showed persistence in the May rainfall Series distribution at lag 1. At lag 1 ( $r_1$ ),  $r_k$  was .24889 and this was outside the Anderson's range of .09167 and -.09828, thus showing significant difference from zero. At lag 5, the May rainfall Series showed indications of random tendency / distribution as  $r_k$  (.06660) was within  $\pm 2/\sqrt{N}$  ( $\pm .09600$ ) limits. At lag 10, there was indication of persistence tendency in the Series distribution as  $r_k$  (.19580) was outside the  $\pm 2/\sqrt{N}$  limits. At lag 15, there was indication of random distribution in the Series for  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits. The Usigu area showed an alternating tendency in the Series distribution between persistence and random distribution. The persistence shown at lag 1 was linear when  $k$  was 5 and 10 respectively for the test results was  $r_k > r_1^k$ . Port Victoria series

in May showed random distribution at lag 1. This was due to the fact that, at lag 1,  $r_k$  (.00539) was within the Anderson's range (.08864, -.09295) and therefore not significantly different from zero. At lag 5,  $r_k$  (-.05292) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this indicated random falling tendency in the Series distribution. The same tendency was shown at lag 10 and 15 but at lag 15, the tendency was positive. The May rainfall Series was generally random in distribution around Port Victoria area.

In the low midlands, the May rainfall Series showed general persistence in the distribution. In the Kosele area, at lag 1 ( $r_1$ ),  $r_k$  was .20788 and this was outside the Anderson's range of .09166 and -.09628. This showed that  $r_1$  was significantly different from zero and there was persistence in the Series distribution. The same was true at lag 10 and 15 although at the latter lag, there was random falling tendency. The persistence shown at lag 1 ( $r_1$ ) was linear Markov when  $k$  was 5 and 10 respectively as the test results showed  $r_k > r_1^k$ . The May rainfall Series distribution showed persistence as  $r_k$  at lag 1 was .11105 and outside the Anderson's range of .08864 and -.09295 in the Kodera area. The  $r_1$  was therefore significantly different from zero. At lag 5, the Kodera area May Series showed signs of random distribution. The same was true at lag 10 and 15 respectively although at the latter lag, there was random falling tendency. The persistence shown at lag 1 ( $r_1$ ) was linear Markov when  $k$  was 5 and 10 respectively as the results showed that  $r_k > r_1^k$ . The may rainfall Series distribution

showed persistence as rk at lag 1 was .11105 and outside the Anderson's range of .08864 and -.09295 in the Kodera area. At lag 5, the Kodera area May Series showed signs of random falling tendency as rk (-.04419) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09285$ ), limits. At lag 10, rk was outside the  $\pm 2/\sqrt{N}$  limits and indicated persistence tendency in the Series distribution. At lag 15, rk was within the  $\pm 2/\sqrt{N}$  limits and as rk was negative, there was random falling tendency in the Series distribution. The May rainfall Series generally showed varying forms of distribution; persistence and random tendencies at various lags. The persistence shown at lag one was non-linear when k was 5( $r_k < r_{1k}$ ) but linear when k was 10 thus indicating the importance of time in the persistence tendency in the Series. In the Bungoma area, rk was .22559 at lag one and was outside the Anderson's range of .08864 and -.09295. This showed that at lag one, rk was significantly different from zero and there was persistence in the Series distribution. At lag 5, rk was outside the  $\pm 2/\sqrt{N}$ , ( $\pm .09275$ ), limits and this indicated persistence tendency in the Series distribution. At lag 10, rk was still outside the  $\pm 2/\sqrt{N}$  limits thus indicating continued persistence tendency in the Series distribution. At lag 15, rk was within the  $\pm 2/\sqrt{N}$  limits and this showed random tendency in the Series distribution. The May rainfall Series in Bungoma area showed a general balance between persistence and random tendencies with persistence as a feature in the first half of the month. Persistence shown at lag one was linear when k was 5 and 10 respectively. Persistence tendencies in the low midlands rainfall

Series in May were probably indications of steady rain unlike in the Lake littoral where random tendencies dominated the May Series.

The upper midlands May rainfall Series showed general persistence in the rainfall distribution and this was probably an indication of steady rains. In the Malava area,  $r_k$  was .29477 at lag one and this was outside the Anderson's range. At lag one therefore,  $r_k$  was significantly different from zero and there was persistence in the Series distribution(May). At lag 5,  $r_k$ (.10245) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this showed persistence tendency in the Series distribution. At lag 10,  $r_k$  was still outside the  $\pm 2/\sqrt{N}$  limits but at lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits thus indicating random tendency. This generally indicated the dominance of persistence in the Series distribution although random tendencies were possible especially in the second half of the month. The persistence shown at lag 1 ( $r_1$ ) when k was 5 and 10 respectively in the May rainfall Series of Malava was linear Markov ( $r_k > r_1^k$ ). The Kimilili  $r_k$  (.14908) at lag 1 was significantly different from (Anderson's range: .08864, -.09295) zero and this showed persistence in the Series distribution. At lag 5,  $r_k$  (.03845) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) and this indicated random tendency in the Series distribution. At lag 10 and 15 respectively,  $r_k$  was negative and within the  $\pm 2/\sqrt{N}$  limits thus indicating random falling tendency. The May Series in the Kimilili area showed persistence in distribution at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The

persistence shown at lag 1 when  $k$  was 5 was linear Markov ( $r_k > r_1^k$ ) but non-linear ( $r_k < r_1^k$ ) when  $k$  was 10 and this indicated tendency to have "mixed process" in the Series. The Kisii area May rainfall Series showed persistence in the distribution at lag 1 as  $r_k$  (.14000) was significantly different from zero (Anderson's range was .08864 and -.09295). At lag 5,  $r_k$  (.08979) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) range and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  (.10048) was outside the  $\pm 2/\sqrt{N}$  limits and this indicated random (white noise) tendency in the distribution. At lag 15,  $r_k$  was still outside the  $\pm 2/\sqrt{N}$  and this indicated a general persistence in the Series distribution although random tendency was also possible as was at lag 5. The persistence shown at lag 1 when  $k$  was 5 and 10 respectively was linear Markov ( $r_k > r_1^k$ ). Nyamira area May Series showed persistence at lag 1 for  $r_k$  (.17432) was significantly different from zero. At lag 5,  $r_k$  (.03562) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this showed indications of random tendency in the Series distribution. The same was true at lag 10 and 15 respectively. This showed that, the May rainfall Series in the Nyamira area had persistence tendency at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag 1 was linear Markov ( $r_k > r_1^k$ ) when  $k$  was 5 and 10 respectively. There was persistence in the May rainfall Series distribution in the Elgon area for  $r_k$  (.13195) at lag 1 (Anderson's range:- .08864, -.09295) was significantly different from zero. At lag 5,  $r_k$  (-.00170) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) limits and this showed falling tendency

in the Series distribution as was the case at lag 10 and 15 respectively. The May rainfall Series in the Elgon area was generally having persistence in the Series distribution at high frequencies (< 5 days) and random tendency at low frequencies (<5 days). The persistence shown at lag 1 ( $r_1$ ) was non-linear when  $k$  was 5 and 10 respectively.

#### 4.4.6 June Results, 1971 - 1985

The June rainfall Series in West Kenya had a mixture of random and persistence tendency in distribution with the random tendency more pronounced towards the Lake littoral, and persistence tendency towards the upper midlands.

In the Lake littoral, the June rainfall Series autocorrelation coefficients at lag 1 indicated random distributions in the Series with Usigu area being the exception. In the Kisumu area, at lag 1,  $r_k$  (.15078) was within the Anderson's range (.09006, -.09452). This showed that  $r_k$  was not significantly different from zero at lag 1 and there was random distribution in the Series. At lag 5,  $r_k$  (-.05820) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random falling tendency in the Series distribution. Random tendency (positive) was also indicated at lag 10 and 15 and this generally showed a tendency to have random distribution of June rains around Kisumu. In the Muhuru Bay area, at lag 1,  $r_k$  (.01722) was not significantly different from zero (within the Anderson's range) and this showed random distribution in the Series. At lag 5,  $r_k$  (-

.04695) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) range and this indicated random falling tendency in the Series distribution. Random tendency still persisted at lag 10 and 15 respectively although at lag 15,  $r_k$  was positive. In the Usigu area, at lag 1 ( $r_1$ ),  $r_k$  (.37945) was outside the Anderson's range and was therefore significantly different from zero. This showed persistence in the Series distribution. At lag 5,  $r_k$  was outside the  $\pm 2/\sqrt{N}$  limits and this indicated persistence tendency in the Series distribution, and this continued upto lag 10. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series. June rainfall in the Usigu area was generally persistent in the Series distribution. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively ( $r_k > r_1^k$ ). The Port Victoria area June rainfall Series at lag 1 had autocorrelation coefficient of .00904 and this was within the Anderson's range of .09008, -.09452. At lag 1 therefore  $r_k$  was not significantly different from zero and this showed random distribution (White noise) in the Series. At lag 5,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution and this was also the case at lag 10 and 15 respectively.

The low midlands June rainfall Series was generally persistent in distribution although the Kosele Series was more towards the random tendency of the Lake littoral. In the Kosele area, at lag 1,  $r_k$  (.01249) was within the Anderson's range (.09008, -.09452) and to this  $r_k$  was not significantly different from zero. This

showed random distribution (White noise) in the June rainfall Series. At lag 5,  $r_k$  (.02778) was within the  $\pm 2/\sqrt{N}$  limits and this showed random tendency in the Series distribution and the same was true at lag 10 and 15 respectively. In the Kodera area, at lag 1 ( $r_1$ ),  $r_k$  (.18328) was outside the Anderson's range of .09006 and -.09452. This showed that  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 10, there was persistence tendency in the Series as  $r_k$  (.15180) was outside the  $\pm 2/\sqrt{N}$  limits and the same was true at lag 15. Generally, the June rainfall Series showed persistence tendency in distribution. The persistence shown at lag 1 was linear Markov when k was 5 and 10 respectively ( $r_k > r_1^k$ ). The Bungoma area June rainfall Series showed persistence in distribution at lag 1. This was due to the fact that at lag 1,  $r_k$  (.09491) was outside the Anderson's range (.09006 and -.09452) and therefore significantly different from zero. At lag 5,  $r_k$  (.03740) was within the  $\pm 2/\sqrt{N}$  limits showing random tendency in the Series distribution. The same was true at lag 10 and 15 respectively. The persistence shown at lag 1 was linear Markov when k was 5 ( $r_k > r_1^k$ ) and non-linear when k was 10 ( $r_k < r_1^k$ ) thus indicating mixed process in the Series distribution.

In the upper midlands, the June Series distribution at lag 1 was generally showing persistence tendency. In the Malava area, at lag 1,  $r_k$  (.23945) was significantly different from zero and this showed persistence (Red noise) in the Series distribution.

At lag 5,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  was outside the  $\pm 2/\sqrt{N}$  limits and this gave indications of persistence in the Series distribution. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series. The June Series distribution was alternating between persistency and randomness, generally. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively ( $r_k > r_1^k$ ). The Kimilili June rainfall Series distribution showed randomness and this was due to the fact that  $r_k$  (.08271) was within the Anderson's range (.09006, -.09452). At lag 5,  $r_k$  (.05788) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) thus indicating random tendency in the Series distribution. At lag 10,  $r_k$  was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits and this indicated persistence tendency in the Series distribution. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and was negative therefore indicating random falling tendency in the Series distribution. The Kimilili rainfall in June was generally random in distribution. The Kisii rainfall Series distribution at lag 1 showed persistence. At lag 1,  $r_k$  (.21711) was outside the Anderson's range of .09006 and -.09452 and therefore significantly different from zero. At lag 5,  $r_k$  (.03460) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution. At lag 10,  $r_k$  was outside the  $\pm 2/\sqrt{N}$  limits and this showed persistence tendency in the Series distribution. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution. The June Series distribution showed a mixture of persistence and random

tendency. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively ( $r_k > r_1^*$ ). Nyamira area June rainfall Series at lag 1 showed persistence in distribution. At lag 1,  $r_k$  (.18615) was significantly different from zero (Anderson's range .09006, -.09452). At lag 5,  $r_k$  (.13024) was outside the  $\pm 2/\sqrt{N}$  limits thus indicating persistence tendency in the Series distribution and the same was true at lag 10. At lag 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits and this indicated random tendency in the Series distribution. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively ( $r_k > r_1^*$ ). The Elgon June rainfall Series at lag 1 was random in distribution. At lag 1,  $r_k$  (.02386) was within the Anderson's range (.09006, -.09452) and therefore not significantly different from zero. At lag 5, 10 and 15,  $r_k$  was within the  $\pm 2/\sqrt{N}$  ( $\pm .09428$ ) limits and this indicated random tendency in the Series distribution. The June Series distribution in the Elgon area was generally random.

#### 4.4.7. July Results, 1971 - 85

The July rainfall Series in West Kenya showed a mixture of persistence and random tendency more pronounced in the near shore Stations of Muhuru and Kisumu and the upper most station of Elgon forest. Generally the persistence nature of the Series distribution reflected the dominance of dry days (< 5mm per day) in July rather than dominance of wet days as was during April-May period. Random distribution indicated more of the uniqueness of the occasional heavy storms during the relatively dry month of July

rather than oscillation between wet and dry days although the occurrence of a storm was equally likely as the occurrence of dry spell.

In the Lake littoral, the near shore Stations showed random distribution at lag 1 and the Stations towards the low midlands showed persistence in rainfall distribution. In the Kisumu area,  $r_k$  at lag 1 (.08657) was within the Anderson's range. This showed that  $r_k$  at lag 1 was not significantly different from zero and there was randomness in the Series distribution. At lag 5,  $r_k$  (-.02171) was within the  $\pm 2/\sqrt{N}$  ( $\pm .09275$ ) and this indicated random falling tendency in the Series distribution. The same was true at lag 10 and 15 respectively and this indicated a general random tendency in the Kisumu area July rainfall Series. In the Muhuru area, at lag 1, the  $r_k$  of July rainfall Series was .06229 and this was within the Anderson's range of .09167 and -.09628. So  $r_k$  at lag 1 was not significantly different from zero and the Series distribution was random. At lag 5,  $r_k$  was within the  $\pm 2/\sqrt{N}$  ( $\pm .09600$ ) limits and this indicated random tendency in the Series distribution. The same was true at lag 10 and 15 respectively although the tendencies were falling (declining) in rainfall amount per day. In the Usigu area, at lag 1,  $r_k$  (.52863) was outside the Anderson's range (.09879, -.10418) and therefore significantly different from zero. This showed that there was persistence in the Series distribution at lag 1 in the Usigu area. At lag 5,  $r_k$  (.21708) was outside the  $\pm 2/\sqrt{N}$  limits and this indicated persistence in the Series

distribution and this was true at lag 10 and 15 respectively. The July rainfall Series in the Usigu area showed general persistence tendency in distribution. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively. In the Port Victoria area, at lag 1,  $r_k$  (.16080) was outside the Anderson's range (.08864, -.09295) and this showed significant difference from zero and therefore persistence in the Series distribution. At lag 5,  $r_k$  (-.00789) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random falling tendency in the Series distribution. The random falling tendency was also shown at lag 10 and 15 respectively. The July rainfall Series generally showed persistence at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag 1 was non-linear when  $k$  was 5 and 10 respectively.

In the low midlands, the July rainfall Series distribution displayed general persistence. In the Kosele area, at lag 1,  $r_k$  (.31534) was significantly different from zero( Anderson's range; .09503, -.10000) and there was persistence in the Series distribution. At lag 5,  $r_k$  (-.01150) was within the  $\pm 2/\sqrt{N}$  limits and this showed persistence tendency in the Series distribution. The July Series distribution had a mixture of persistence and random tendency. The persistence shown at lag 1 was non-linear ( $r_k < r_1$ ) when  $k$  was 5 and linear Markov ( $r_k > r_1$ ) when  $k$  was 10. In the Kodera area, at lag 1,  $r_k$  (.19716) was significantly different from zero and this showed persistence in the Series distribution.

At lag 5 and 15,  $r_k$  was within the  $\pm 2\sqrt{N}$  limits thus showing random tendency in the Series distribution. At lag 10,  $r_k$  (.10223) was outside the  $\pm 2\sqrt{N}$  limits and this indicated persistence. Generally, the July Series distribution alternated between persistence and random tendency. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively. The Bungoma rainfall Series distribution at lag 1 was random and falling. At lag 1,  $r_k$  (-.00514) was not significantly different from zero (Anderson's range .08864, -.09295).

The upper midlands Series also showed general persistence in the Series distribution. In the Malava area, at lag 1,  $r_k$  (.27927) was significantly different from zero and this showed persistence in the Series. At lag 5,  $r_k$  (.11421) was outside the  $\pm 2\sqrt{N}$  limits and this indicated persistence in the Series distribution and this was still true at lag 10 and 15. Generally, there was persistence in the July rainfall Series in the Malava area. The persistence shown at lag 1 was linear Markov when  $k$  was 5 and 10 respectively. In the Kimilili area, at lag 1,  $r_k$  (.21447) was significantly different from zero and this showed persistence in the Series distribution. At lag 5,  $r_k$  was negative and within the  $\pm 2\sqrt{N}$  limits. This indicated random falling tendency in the Series distribution. The random tendency continued at lag 10 and 15 respectively. The July Series in the Kimilili area showed persistence at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag 1 was non-linear ( $r_k < r_1^k$ ) when  $k$  was 5 and linear Markov ( $r_k > r_1^k$ ) when

$k$  was 10. The Kisii July rainfall Series autocorrelation coefficient ( $r_k$ ) at lag 1 was .19131 and this fell outside the Anderson's range of .08864 and -.09295. At lag 1 therefore,  $r_k$  was significantly different from zero and there was persistence in the Series distribution. At lag 5,  $r_k$  (.02973) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution as was the case at lag 10 and 15 respectively. The Kisii rainfall Series showed persistence tendency at high frequencies (< 5 days) and random tendency at low frequencies (> 5 days). The persistence shown at lag 1 was linear Markov ( $r_k > r_1^k$ ) when  $k$  was 5 and non-linear ( $r_k < r_1^k$ ) when  $k$  was 10 thus indicating mixed process in the Series distribution. In the Nyamira area, at lag 1,  $r_k$  (.21352) was significantly different from zero and there was persistence in the July rainfall Series distribution. At lag 5,  $r_k$  (.00534) was within the  $\pm 2/\sqrt{N}$  limits and this indicated random tendency in the Series distribution as was the case at lag 15. At lag 10,  $r_k$  (.10481) was outside the  $\pm 2/\sqrt{N}$  limits and this indicated persistence in the Series distribution. The July rainfall Series distribution was alternating between persistence and random tendency. The persistence shown at lag 1 was linear Markov ( $r_k > r_1^k$ ) when  $k$  was 5 and 10 respectively. The Elgon area July rainfall Series distribution was random at lag 1, where  $r_k$  (.07102) was not significantly different from zero Anderson's range (.08864, -.09295). At lag 5,  $r_k$  (.10047) was outside the  $\pm 2/\sqrt{N}$  ( $\pm .09278$ ) limits and this indicated persistence in the Series distribution.

At lag 10 and 15, there was random falling tendency in the Series distribution, respectively. Random tendency dominated the Series distribution although persistence tendency was also possible.

Generally, the "face" of rainfall distributions during the months of January to July from 1971 to 1985 was dominated by persistence tendency during the very dry, relatively, and very wet months. Random tendency was mainly a feature towards the end of the month although its occurrence could not be ruled out even at lag 1.

#### 4.5.0      The Shape of the Correlogram: January to July Results (1971 - 85)

A correlogram results when  $r_k$  (autocorrelation coefficient or function) is plotted against  $k$  (lag time); see figures 4.14-4-18 and appendices XXIV-XXXIII. The shape of a correlogram in principle, reveals the nature of a process. For a periodic process, the correlogram is periodic; for a moving average process, it vanishes (decays); and for a first-order Markov process,  $r_k > r_1$ , the correlogram decays exponentially. Usually, when the number of data points is small, the correlogram fails to damp off as expected because the observed auto-correlation functions are subject to inflation due to sampling errors. The need to find the process behind the series distribution, and to reinforce

the significant test results of  $r_k$  already worked on led to the correlogram plots.

In the Kisumu area, the correlograms for all the months showed a mixture of periodic processes and auto-regressive processes in the Series but the processes were not well defined. In January, the correlogram was periodic and decayed towards the end. There was a diffused cycle in the process and most of the processes were shown in the correlogram upto lag 4 and 5. In February, the correlogram was periodic with hidden rapid swings indicating cycles. The correlogram decayed towards the end. In March, the correlogram was periodic and decayed from lag 10 but not completely. In April, the correlogram failed to dampen and showed more of periodic variations. In May, the correlogram decayed early or dampen early but towards the end showed swings and periodicity. In June, there was a general cyclic variation with rapid periodic movements mostly on the negative side. The July correlogram showed oscillatory movement with rapid periodicity mostly on the negative side. Generally, the Kisumu correlograms from January to July showed a mixture of periodic and autoregressive processes in the series distribution.

In the Muhuru Bay area, the January correlogram failed to dampen and showed more of periodic processes with hidden cycles and the same was true with February correlogram. In March, the correlogram was periodic and decayed around lag 10 to 14 but then

failed to dampen completely as late swings were noted. The April correlogram showed periodic movements with hidden cycles but started decaying as from lag 4. In May, the correlogram failed to dampen and showed periodic movements with hidden cycles, and the same was true with the June and July correlograms. The combined correlogram from January to July showed a general periodic movement with hidden cycles and decay tendency shown towards the end. This indicated a mixture, Autoregressive Moving Average (ARMA) process.

In the Usigu area, the January correlogram decayed but periodic or cyclic variations were also shown. The February correlogram decayed fast but steadied out at lag 3 forming a near straight line. March correlogram decayed with periodic movements. The April correlogram showed signs of cyclic variations and although there was decline tendency, the correlogram failed to dampen off completely. The May correlogram indicated cyclic (periodic) variations and failed to dampen off or decay. In June, the correlogram decayed with signs of cyclic variations (or periodic). July correlogram decayed but not completely and cyclic variations signs shown. Generally, the correlograms from January to July showed signs of cyclic variations (periodic) and decayed towards the end but not completely.

In the Port Victoria area, the January correlogram was periodic with hidden cyclic movements. In February, the correlogram had not well defined periodic movements with hidden

cyclic variations. The March correlogram was mostly periodic with cyclic tendency between lags 5 and 11. The April correlogram was periodic but decayed towards the end (not completely). In May, the correlogram decayed with cyclic tendency. The June correlogram dampened off or decayed with swings indicating hidden cycles or periodic movements. In July, the correlogram decayed in the initial stages but then rose towards the end with swings indicating hidden cycles or periodic movements. The combined data gave a correlogram for January - July period showing periodic variations processes with swings indicating cyclic variations.

In the Kosele area, the January correlogram was periodic with levels of variations increasing with lags and therefore failed to dampen off or decay (and signs of hidden cycle movements were given). The February correlogram decayed towards lag 15 but thereafter rose with periodic movements. The March correlogram decayed thus fitting the theoretical correlogram of dampening towards the end; first order Markov process. In April, the correlogram showed a big trough, probably part of a cycle, with periodic movements and failed to dampen off or decay. The July correlogram decayed in the initial stages but then swung up to give a cyclic (periodic) process. Generally, the correlograms showed a mixture of processes in the Series distribution from January to July.

In the Kodera area, the January correlogram was periodic and failed to decay (there were signs of hidden cyclic movements). In February, the correlogram showed "big" swings, probably cyclic movements, but decayed towards the end. In March, the correlogram was periodic but the movements were not well defined and failed to dampen off. In April, the correlogram was periodic with hidden cycles and failed to dampen off. The same was true with May and June correlograms. In July, the correlogram decayed with periodic and irregular swings. The combined data for January to July gave a correlogram which was periodic with hidden cycles and failed to dampen off properly.

In the Bungoma area, the correlogram for January, February, March, April, May, June and July respectively were periodic and generally failed to dampen off or decay except the May correlogram which decayed with periodic tendency in distribution. In the Malava area the January correlogram was periodic with hidden cycles and decayed towards the end. The February correlogram was periodic and decayed towards the end. The same was true with March, April, May, June, July correlograms respectively. Generally, the correlograms from January to July in the Malava area were periodic with hidden cycles and decayed indicating a mixture of processes in the Series distribution.

In the Kimilili area, January correlogram decayed with hints of cyclic (periodic) movements. The February, March correlograms

respectively, decayed with periodic movements. In April, the correlogram was periodic with hidden cyclic tendency and decayed towards the end. The May correlogram was periodic with big swings indicating cyclic tendency but failed to dampen off completely. The June, July correlograms respectively, were periodic and decayed towards the end. The correlograms viewed collectively, decayed towards the end with irregular periodic variations.

In the Kisii area, the correlograms for January, February, March, April, May, June and July were mostly periodic with hidden swings indicating cyclic movements. The February, March, correlograms respectively, were periodic in movements but decayed towards the end. In the Nyamira area, January correlogram was irregular in distribution and showed signs of cyclic (periodic) movements but failed to dampen off. In February, the correlogram showed signs of decay but also signs of hidden cyclic movements (periodic). The March correlogram decayed but with some peaking at the middle lags showing traces of cyclic movements (periodic). The April correlogram was largely periodic and failed to dampen off completely. The May correlogram rose with lag times showing signs of exponential movement. The June correlogram failed to dampen off and had periodic tendency. The July correlogram showed signs of decline or decays were there towards the end. The Nyamira correlogram showed mixed processes at work in the series distributions.

Lastly, in the Elgon area, the correlograms, from January to July, were mostly periodic in shapes and showed signs of decay towards the end. Hidden cyclic movements were also noted but the February correlogram was largely periodic and failed to dampen off as was expected theoretically. The correlograms showed a mixture of processes at work in the Series distribution, mostly ARMA (Autoregressive Moving Average process).

The general picture of the correlograms from January to July in West Kenya rainfall daily distributions indicated a mixture of processes and this had already been shown in the autocorrelation coefficient significant tests results.

#### 4.6.0 Daily River Flows

The daily river flow data for River Nzoia (Kakamega, IDD1A), Nyando (Ahero bridge), Miriu (Sondu Bridge) and Gucha-Migori (Muhuru Bay) indicated less daily variations; see figures 4.19-4.21. Periods of floods were indicated by standard deviations surpassing the daily mean flow and periods of low flow were indicated by the standard deviation and the mean being almost equal. There were year to year differences in daily river flows for particular months and this was also shown in the year to year rainfall for particular months in West Kenya, as was shown in the analysis of variance results.

#### **4.7.0 Agricultural Reports**

---

Agricultural reports from West Kenya between 1956 to 1986 showed that periods of low rainfall or delayed long rains had occurred and this affected agricultural productions. Floods and/or too much rain were also noted as factors in crop production but even farmers ability to prepare land in time and to get the right seeds were also noted as factors. What was important in the reports as concerns the study, was the link between low or delayed long rains not developing properly, with crop production in West Kenya (see Table 4.10). The rainfall series analysis showed that there were periods of low rainfall or erratic rainfall distribution, or long rains delaying or ending early (see time series analysis section).

Table: 4.4

## BASIC STATISTICS FOR USIGU HEALTH CENTRE IN JANUARY (RAINFALL DATA)

Variable	1972	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Sample size	31	31	31	31	31	31	31	31	31	31	31	31	31	31	-
Average	1.59677	0.574194	1.55161	0.1	6.452	1.90323	2.54839	2.65416	6.00323	0.696774	1.15484	2.92581	-	1.64194	-
Median	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-
Mode	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-
Variance	70.323	10.2206	20.0852	0.151333	1.290	112.29	73.6559	81.9799	226.202	11.757	41.3432	63.2993	-	12.3745	-
Standard Deviation	8.38588	3.19697	4.48166	0.389016	0.0360	10.5967	8.5823	9.05427	15.04	3.42885	6.42987	7.95609	-	3.51774	-
Standard error	1.50615	0.574194	0.804929	0.069869	6.452	1.90323	1.54143	1.6262	2.70126	0.615839	1.15484	1.42896	-	0.631805	-
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-
Maximum	46.7	17.8	17.8	2	0.2	59	44	48	50.4	19	35.8	29.1	-	10.9	-
Skewness	5.53692	5.56776	2.88842	4.44501	5.56776	5.56776	4.208	4.5751	2.39548	5.4172	5.56776	2.73272	-	1.86072	-
Kurtosis	30.7541	31	7.34754	20.5812	31	31	19.2053	22.5072	4.40859	29.7446	31	6.22295	-	1.89891	-

Table: 4.5

## BASIC STATISTICS FOR BUNGOMA AGRIC STATION IN FEBRUARY (RAINFALL DATA)

Variable	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Sample size	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Average	0.748276	5.35517	6.05517	0.806897	1.51379	4.34828	0.955172	6.02069	5.84483	0.610345	1.68276	1.62414	2.24138	2.51379	1.48966
Median	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mode	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variance	7.95901	166.775	180.445	11.615	11.1634	214.106	11.4654	151.772	219.933	5.61596	37.2908	17.9405	28.0389	37.6662	42.188
Standard Deviation	2.82117	12.9142	13.433	3.40807	3.34116	14.6324	3.38606	12.3196	14.8301	2.3698	6.10662	4.23562	5.29518	6.13728	6.4952
Standard error	0.523879	2.3981	2.49444	0.632863	0.620439	2.71716	0.628776	2.28769	2.75388	0.440061	1.13397	0.786532	0.98329	1.13966	1.2061
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	12.2	52.8	57.8	18.3	15.3	56.4	16.3	51	75.5	12.4	27	17.9	22.1	24.2	34.1
Skewness	3.6915	3.0182	2.81315	5.178	2.92028	3.33331	3.99535	2.4583	4.03481	4.75947	3.73206	3.07113	2.77798	2.58253	4.9038
Kurtosis	12.7713	8.7920	8.24855	27.3769	9.98291	10.2667	16.4786	6.24638	18.3545	23.825	13.2377	9.23523	7.65735	6.04519	24.859

Table : 4.6

## BASIC STATISTICS TABLE FOR MALAVA AGRIC STATION IN APRIL (RAINFALL DATA)

Variable	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Sample Size	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Average	7.27667	5.6	2.78333	10.1967	9.72	4.25667	9.62333	7.66	3.98	5.18	12.1233	10.1967	9.02333	15.24	12.6467
Medium	0	0	0	0	0	0	4.5	0	0	0	11	4.2	2.5	0	4.35
Mode	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variance	131.739	166.954	43.1442	266.095	342.439	62.8419	149.079	209.455	45.5817	45.3796	145.545	375.362	139.525	397.549	218.825
Standard Deviation	11.4778	12.9211	6.56842	16.3124	18.5051	7.92729	12.2098	14.4726	6.75142	6.73644	12.0642	19.3743	11.8121	19.9386	14.7927
Standard Error	2.09554	2.35906	1.19922	2.97823	3.37855	1.44732	2.22919	2.64232	1.23263	1.2299	2.20261	3.53724	2.15658	3.64028	2.70077
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	43.9	63	32.2	62.8	90.9	30.7	40.6	50.8	30.2	20.6	51	83	52	49.2	44
Skewness	1.78952	3.5017	3.49536	1.86945	3.2598	2.59157	1.38081	2.26206	2.24015	1.11496	1.52147	3.15474	1.77063	0.71104	0.76813
Kurtosis	2.80014	13.8843	14.1648	3.25271	12.8619	6.73959	1.07056	4.34261	6.64608	0.264647	2.91559	9.84146	4.58949	-1.35728	-0.909

Table : 4.7

**BASIC STATISTICS TABLE FOR NORTH ELGON STATION IN MARCH (RAINFALL DATA)**

Table 4.8.

## FREQUENCY TABULATION FOR JANUARY RAINFALL(MUHURU BAY, 1971-85)

Class	L.L	U.L	MDP	FRE.	REL.F	CUM.FRE	CUM.RF	KEY
1	.0	2.25	1.12	31	.071	380	.876	
2	2.25	4.50	3.37	19	.044	399	.919	L.L-LOWER LIMIT
3	4.50	6.74	5.62	7	.016	406	.935	U.P-UPPER LIMIT
4	6.74	8.99	7.87	5	.012	411	.947	MDP-MID POINT
5	8.99	11.24	10.11	4	.009	415	.956	FRE-FREQUENCY
6	11.24	13.49	12.36	3	.007	418	.963	CU. FRE=CUMULATIVE FREQUENCY
7	13.49	15.73	14.61	2	.005	420	.968	RE.F-RELATIVE FREQUENCY
8	15.73	17.98	16.86	5	.012	425	.979	
9	17.98	20.23	19.10	4	.009	429	.988	
10	20.23	22.48	21.35	2	.005	431	.993	CUM.RF-CUMULATIVE RELATIVE FREQUENCY.
11	22.48	24.72	23.60	0	.000	431	.993	
12	24.72	26.97	25.85	1	.002	432	.995	
13	26.97	29.22	28.10	1	.002	433	.998	
14	29.22	31.47	30.34	0	.000	433	.998	
15	31.47	33.71	32.59	0	.000	433	.998	
16	33.71	35.96	34.84	0	.000	433	.996	
17	35.96	38.21	37.09	0	.000	433	.998	
18	38.21	40.46	39.33	0	.000	433	.998	
19	40.46	42.70	41.58	0	.000	433	.998	
20	42.70	44.95	43.83	0	.000	433	.998	
21	44.95	47.20	46.08	1	.002	434	1.000	
>21	47.20			0	.000	434	1.000	

**Estimated Autocorrelations for April Rainfall Data during the 1971-85 period. Muhuru Bay Station.**

Lag	Estimate	Standard Error	Lag	Estimate	Stnd.E.
1	.17148	.04714	2.	.08304	.04851
3.	.01725	.04882	4.	-.02436	.04884
5.	.02541	.04886	6.	.03448	.04889
7.	-.01976	.04895	8.	-.02546	.04896
9.	.00136	.04899	10.	.07423	.04899
11.	.02291	.04924	12.	-.02693	.04927
13.	-.01580	.04930	14.	-.01934	.04931
15.	-.02434	.04933	16.	-.01470	.04935
17.	-.05408	.04936	18.	-.00486	.04949
19.	.01810	.04950	20.	.07257	.04951
21.	.06451	.04975	22.	-.02409	.04993
23.	.02289	.04996	24.	-.00424	.04998

Table 4.9.

TABLE 4.10: WEATHER CONDITIONS(RAINFALL) AND AGRICULTURAL PERFORMANCE IN WEST KENYA FROM 1956 TO 1986(Kenya government).

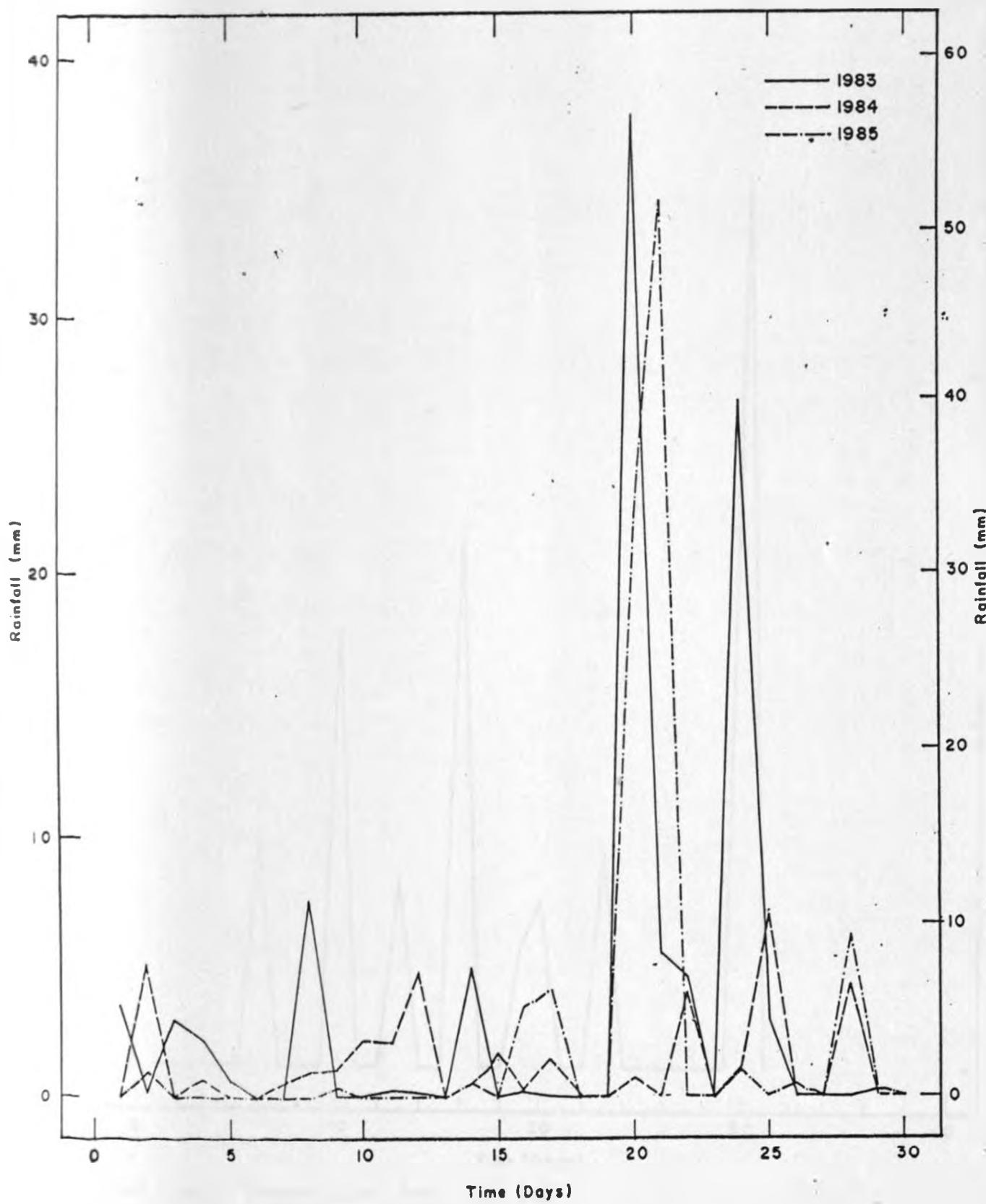
Year	Weather	Agriculture	General Remarks
1956	Upto average rainfall distribution but localised and this was unfavourable to crop production.	Arable farming not very much favoured but good for livestock.	Break in June and July rains and heavy storms thereafter affected crop production.
1957	Average long rains with dry June and July. Late short rains.	Good long rain crops but below par short rains crops.	Average crop year
1958	Late long rains preceded by long dry period. Short rains failed.	Good year in terms of crop production	Average crop Year
1959	Long rains disappointing but short rains heavier than usual	Bad year in terms of long rains crop especially in the lowlands.	Year averagely not good in crop production.
1960	Same as 1959	"	"
1961	Worst weather ever in the first and second quarter with failure of long rains. Heavier than usual short rains causing floods.	Failure of long rains crops and floods causing damage in the short rains period. Army worms causing great damage.	Bad year (drought ) livestock suffered. Bumper crops in the last quarter destroyed by heavy rains.
1962	Uniform rainfall throughout the year	Good long rains harvest	Good crop year
1963	January and February wetter than usual. Long rains delayed but very heavy.	Good crop and livestock year	Generally good year.

1964	Heavy rains during the long rains	Heavy rains affected crop yields.	Good year
1965	Poor distribution of long rains.	Crop failure and drop in yields but still the food supply was satisfied.	Poor crop year.
1966	Good long rains but rains short of the expected wet year level	Good crops apart from the effects floods in the lower lands and the effects of hailstones.	Good crop year
1967	Unusual weather conditions with long rains delayed upto end of march or mid April; a drought situation This was followed by heavy rains during the short rains.	Long rains crops not good but good short rains crops.	Moderate crop year.
1968	Long rains started early and continued heavily till June.	Satisfactory food supply.	Good year in terms of rainfall.
1969	Intermittent rains. Long rains not well defined.	Crop yields low	Not good year
1970	Well developed long rains and short rains.	Good crops	Average year crop year.
1971	Delayed long rains	Not good for long rains crops but good for short rains crops	Moderate to bad year.
1972	Long rains starting in February but intermittently; good short rains.	Satisfactory crop yields.	Moderate year

1973	Long rains not well developed	Decline in crop yields	Not a good year
1974	Rainfall intermittent in distribution	Not good yields due to unreliable rainfall.	Not a good year
1975	Uniform rainfall	Satisfactory food situation	Good year
1976	Long rains started in March but poor short rains	Good long rains crops but decline in short rains crop	Moderate year
1977	Long rains not good but well developed short rains	Average crop production	Moderate year
1978	Long rains early	Long rains crops harvest affected by heavy rains. Livestock situation good.	Good rainfall year
1979	Dry year	Crop yield declined with the exception of some upper midlands areas.	Moderate to bad year
1980	Drier than 1979	Poor crops	Bad Year.
1981	Adequate rainfall	Good crops	Moderate year
1982	Adequate rainfall	Satisfactory crop production	Good year
1983	Long rains delayed a bit	Moderate crops	Moderate year
1984	Dry year especially during the long rains	Significant crop yields decline	Very bad year
1985	Good rains favourable for crop production and livestock condition	Good year	Good year

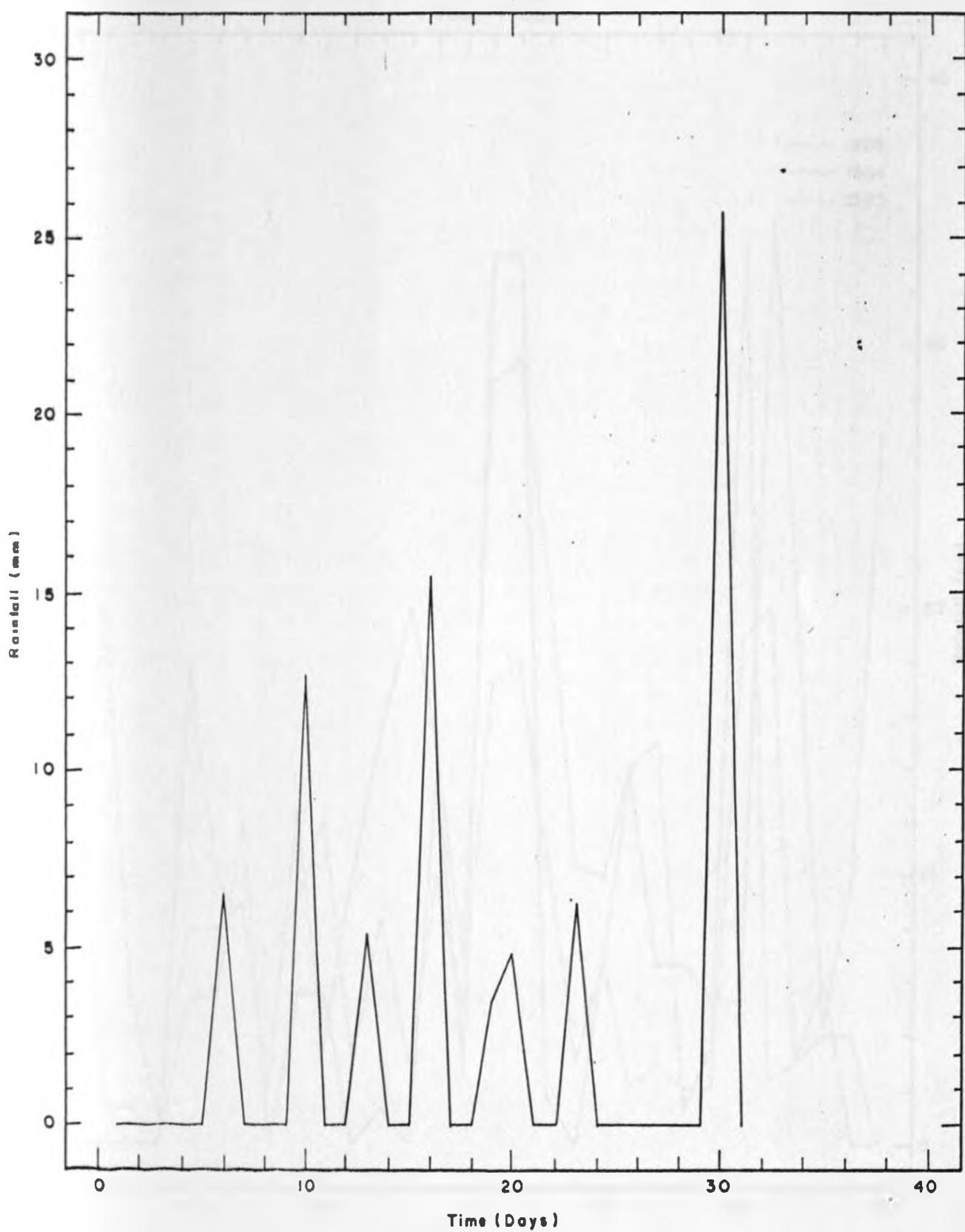
1986	Good rainfall year	Good crops	good year
Source: Kenya Government; Ministries of Agriculture and Livestock Development.			

Fig.4.4 : TIME SEQUENCE PLOT OF JUNE RAINFALL FOR  
KISUMU STATION (1983-1985)



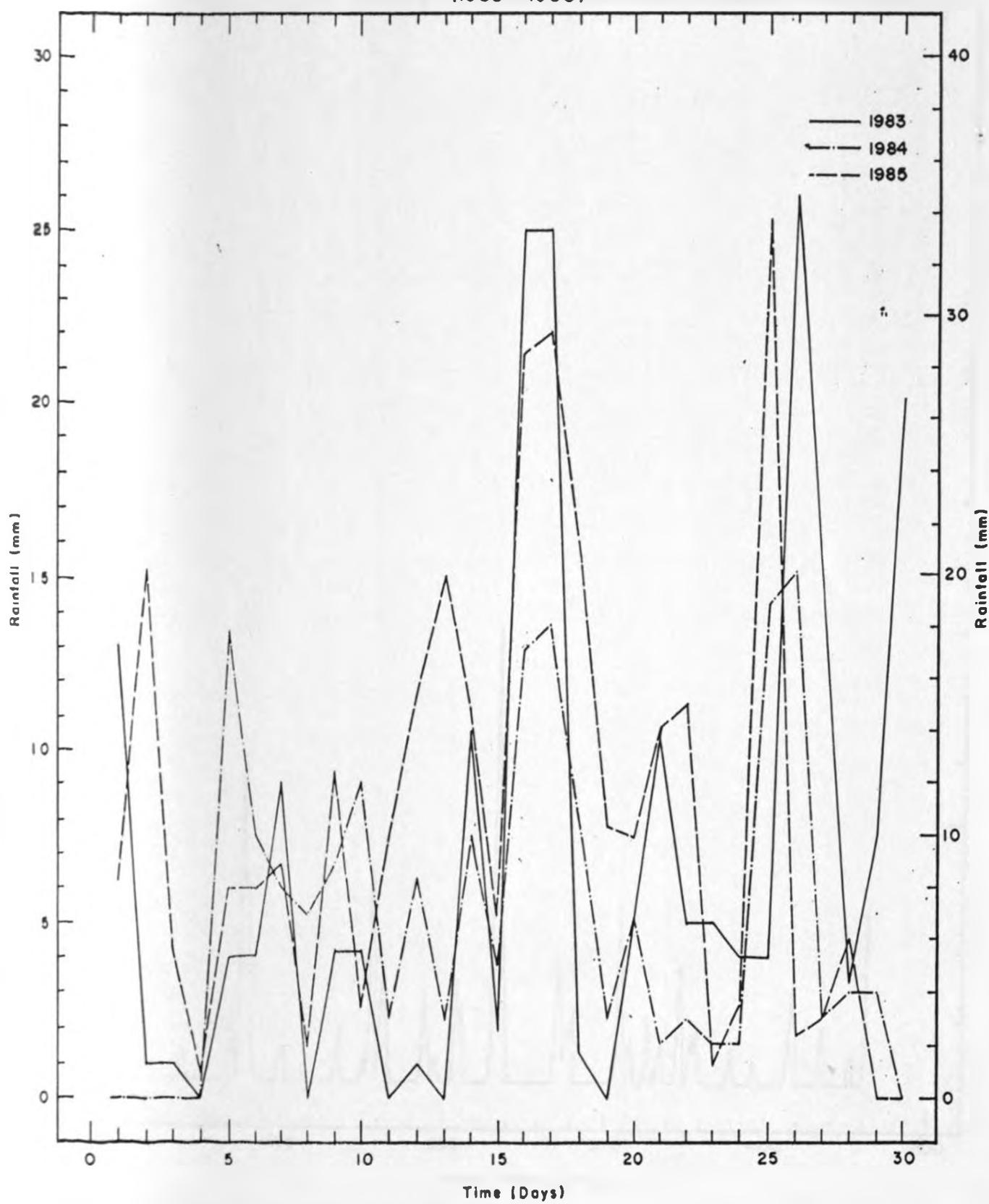
(Data Source: Meteorological Dept. 1971-85)

Fig.4.5: TIME SEQUENCE PLOT JULY RAINFALL FOR KOSELE STATION  
(1983)



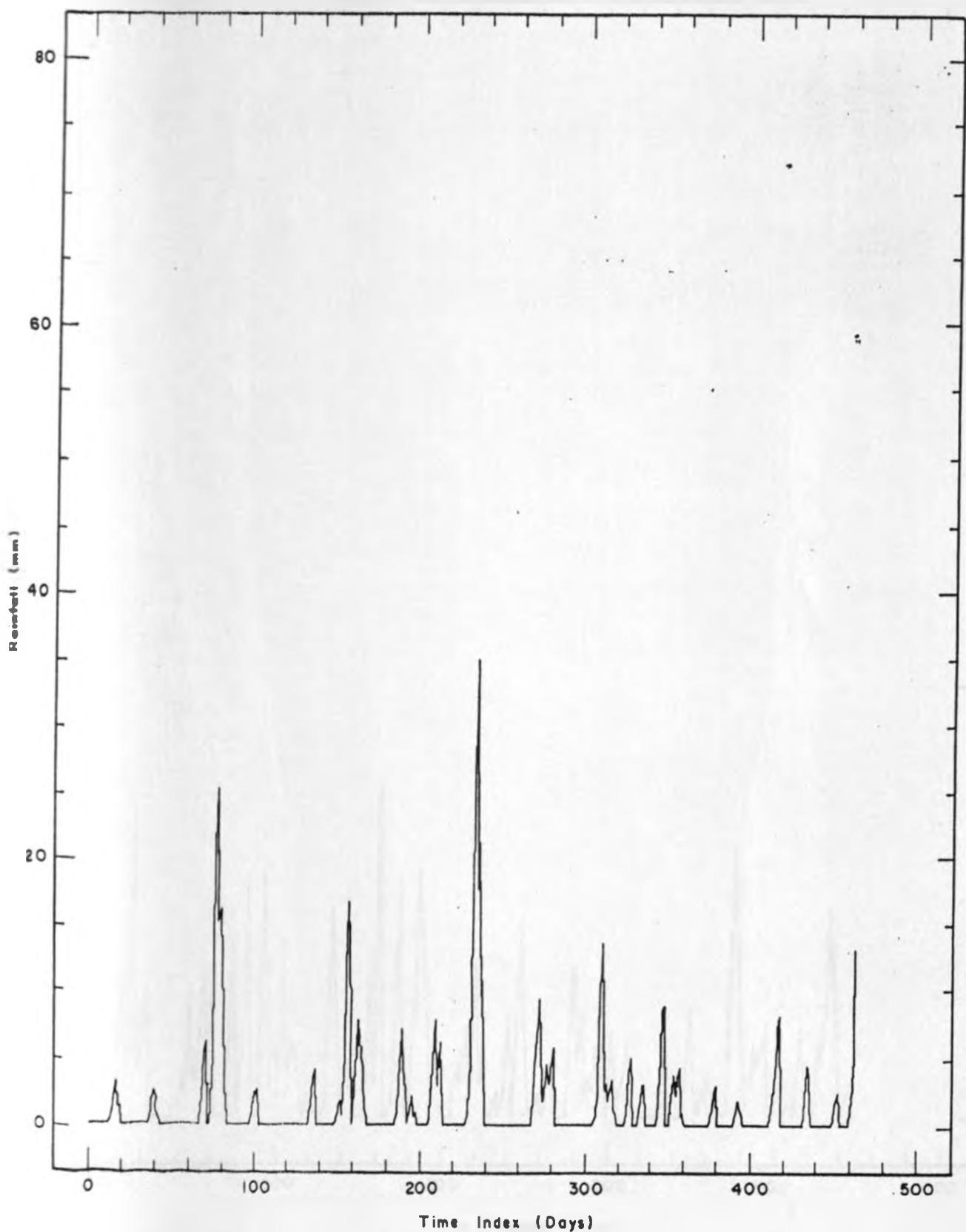
(Data Source: Meteorological Dept. 1971- 85)

Fig. 4.6 : TIME SEQUENCE PLOT APRIL RAINFALL FOR KISII STATION  
(1983-1985)



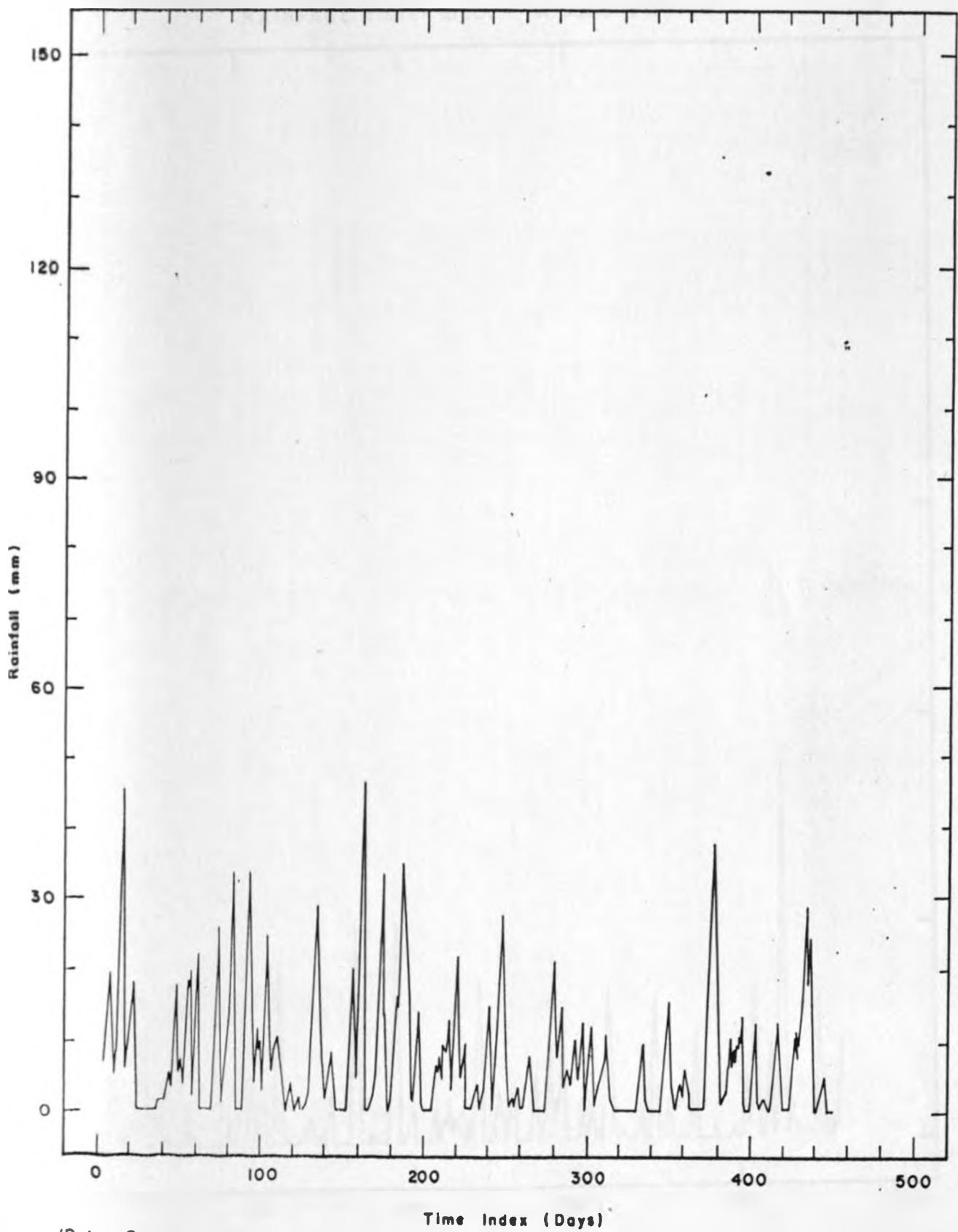
(Data Source: Meteorological Dept. 1971-85)

Fig 4.7: TIME SERIES AND MOVING AVERAGE FOR JANUARY  
RAINFALL (1971 - 1985) KISUMU STATION



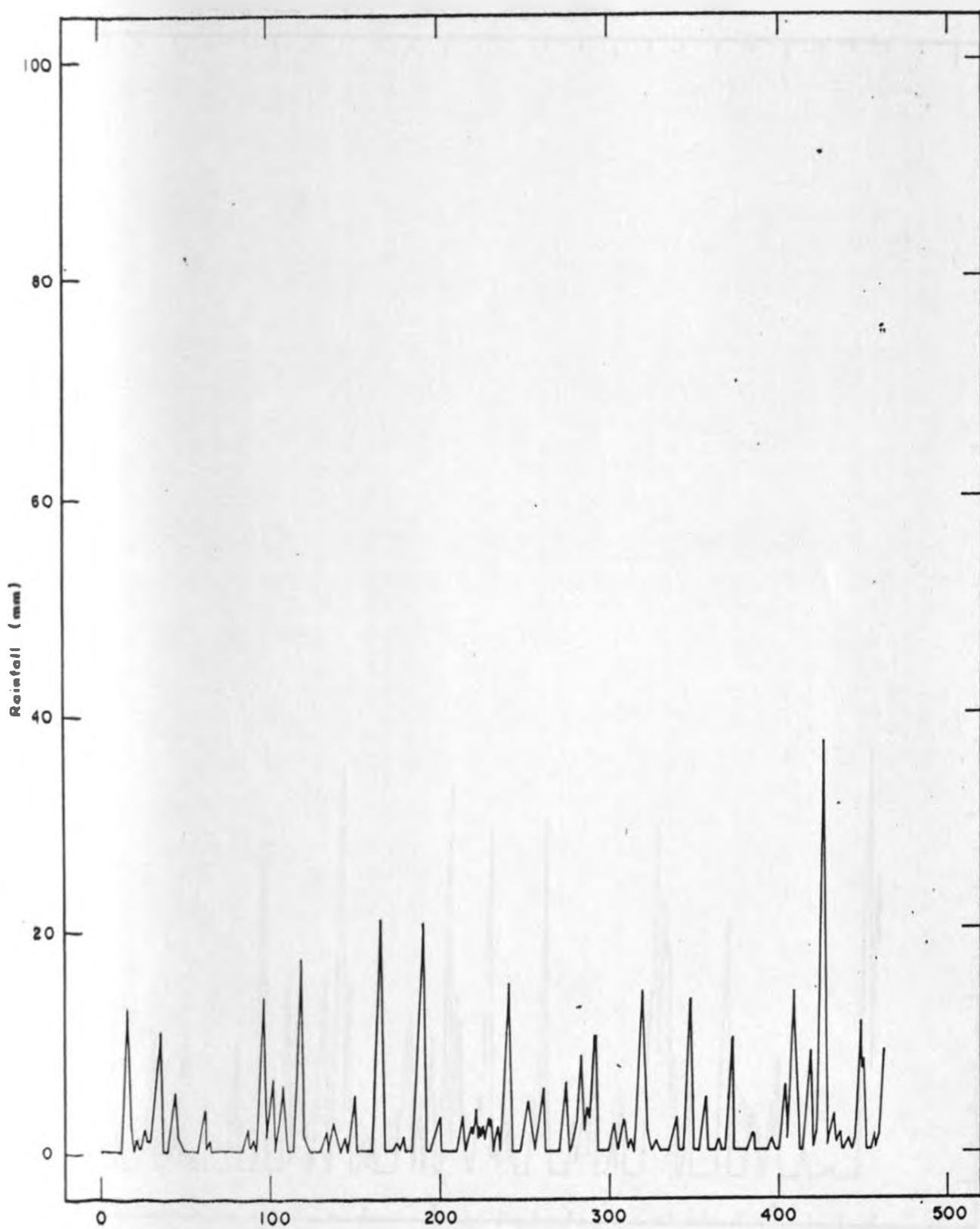
(Data Source: Meteorological Dept..1971-85)

Fig. 4.8 : TIME SERIES AND MOVING AVERAGE FOR APRIL  
RAINFALL (1971 - 1985) KISUMU STATION



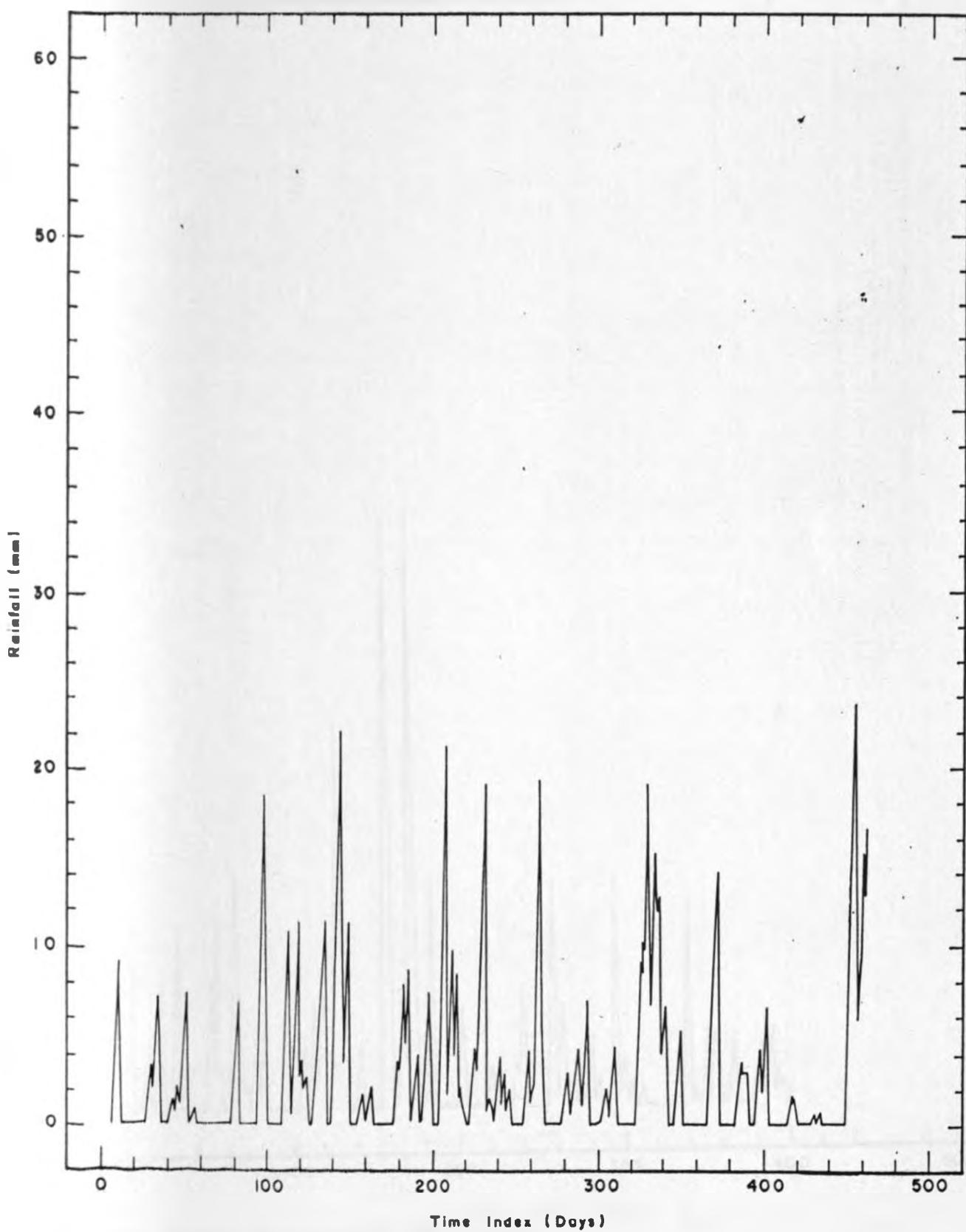
(Data Source: Meteorological Dept. 1971-85)

Fig.4.9 : TIME SERIES AND MOVING AVERAGE FOR JULY  
RAINFALL (1971- 1985) : KISUMU STATION



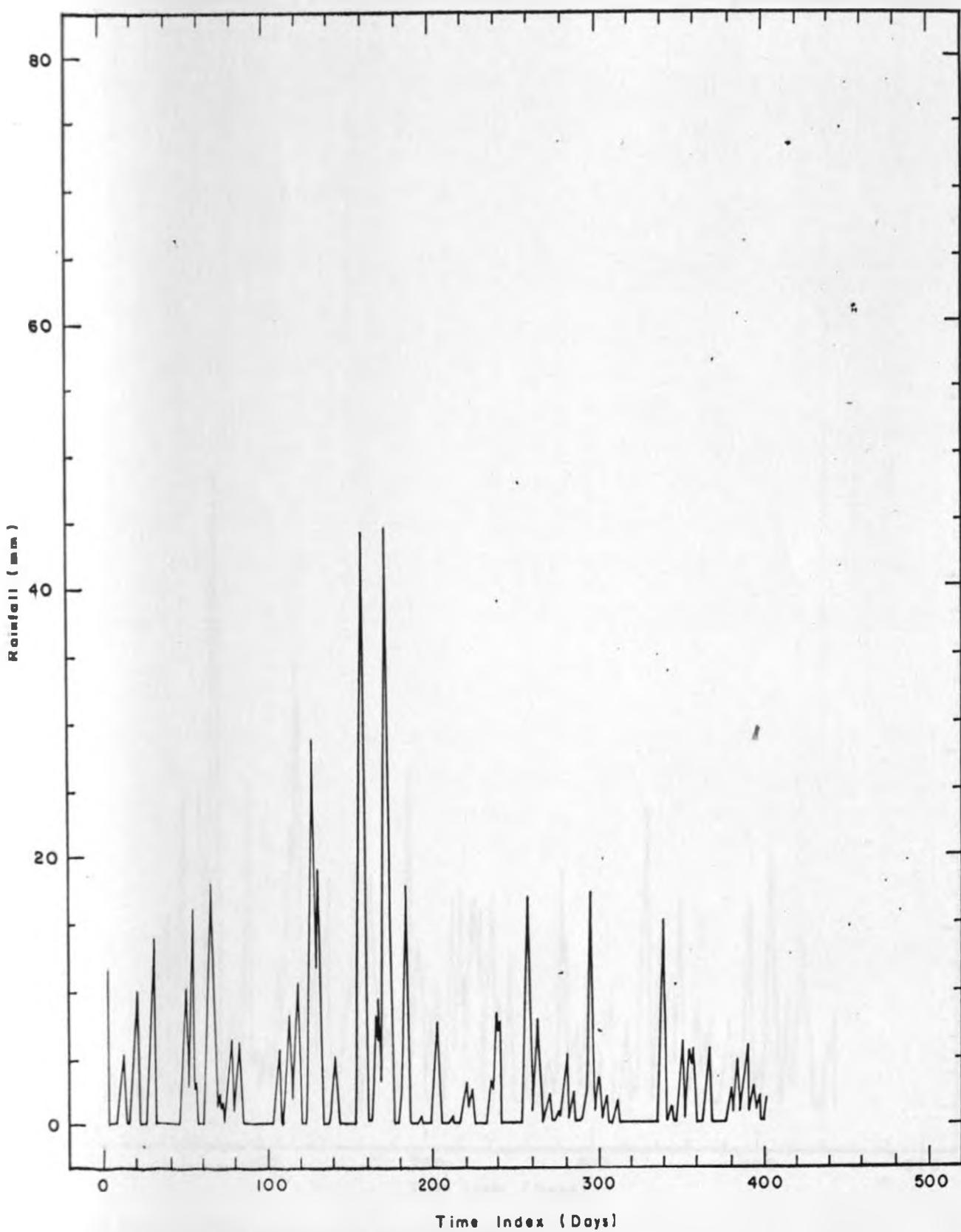
(Data Source : Meteorological Dept. 1971- 85)

Fig 4.10 : TIME SERIES AND MOVING AVERAGE FOR MARCH  
RAINFALL (1971 - 1985) BUNGOMA STATION



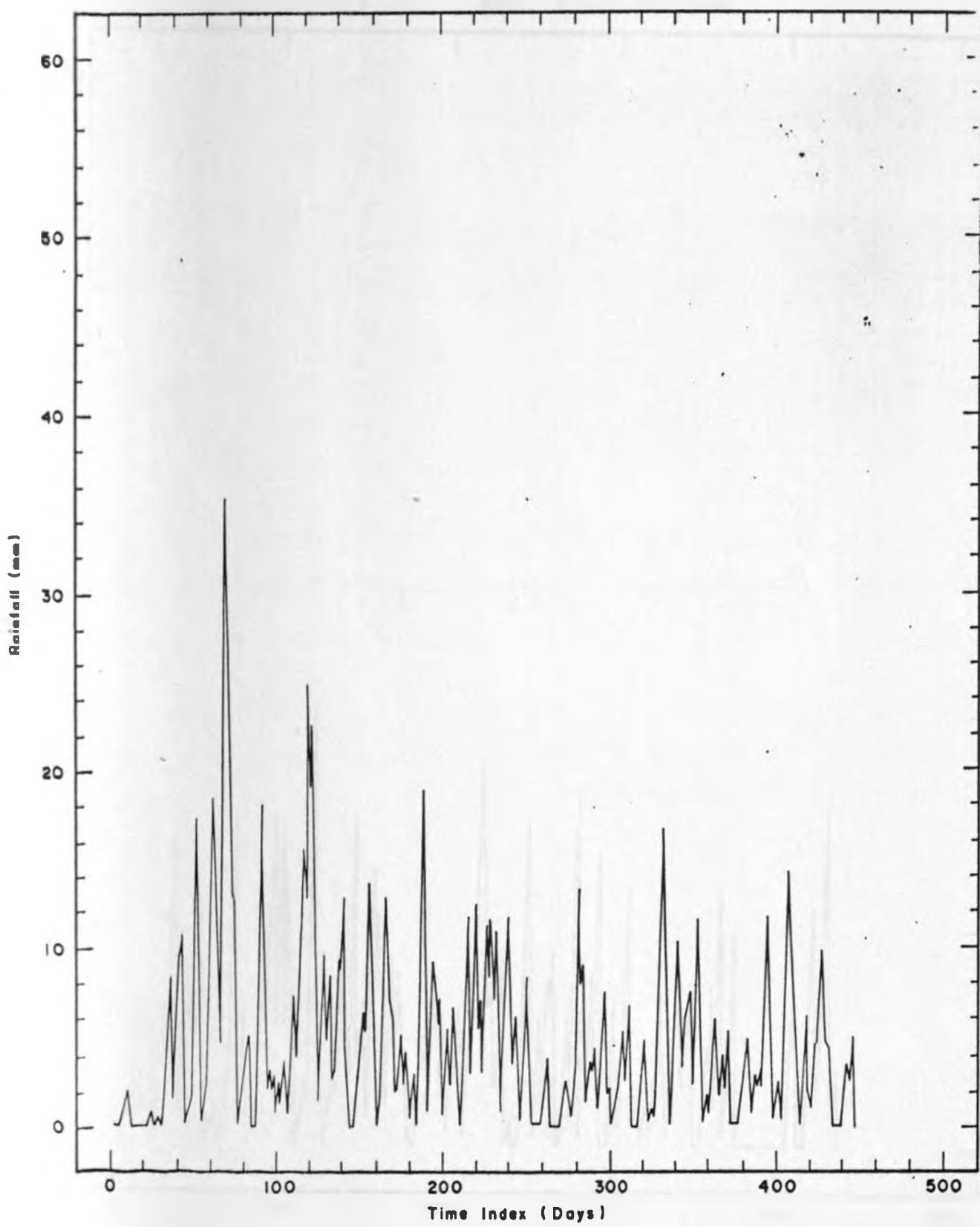
(Data Source: Meteorological Dept. 1971-85)

Fig. 4II: TIME SERIES AND MOVING AVERAGE FOR JULY  
RAINFALL (1971 - 1985) KOSELE STATION



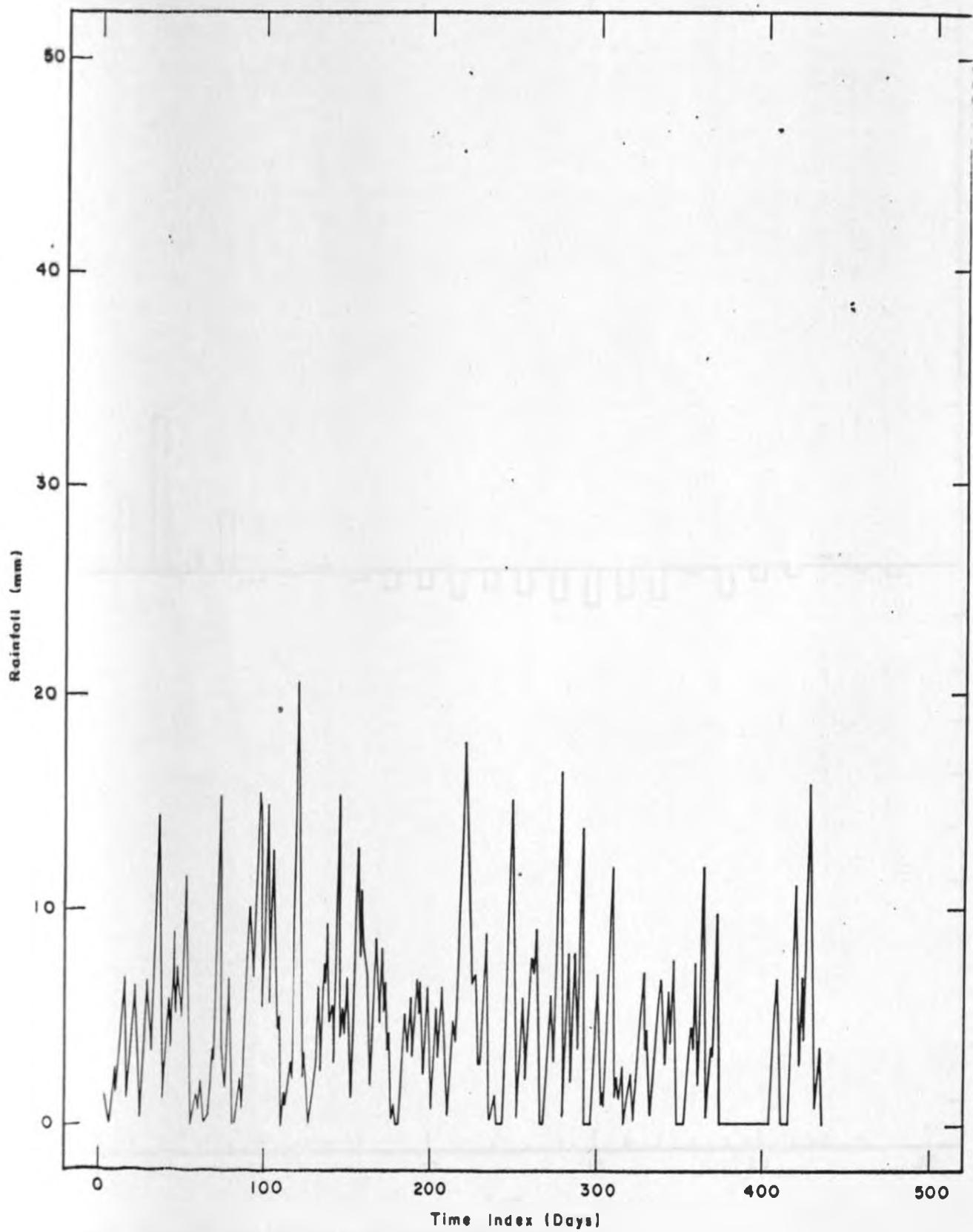
(Data Source: Meteorological Dept. 1971-85)

Fig. 4.12: TIME SERIES AND MOVING AVERAGE FOR JUNE  
RAINFALL (1971 - 1985) KISII STATION



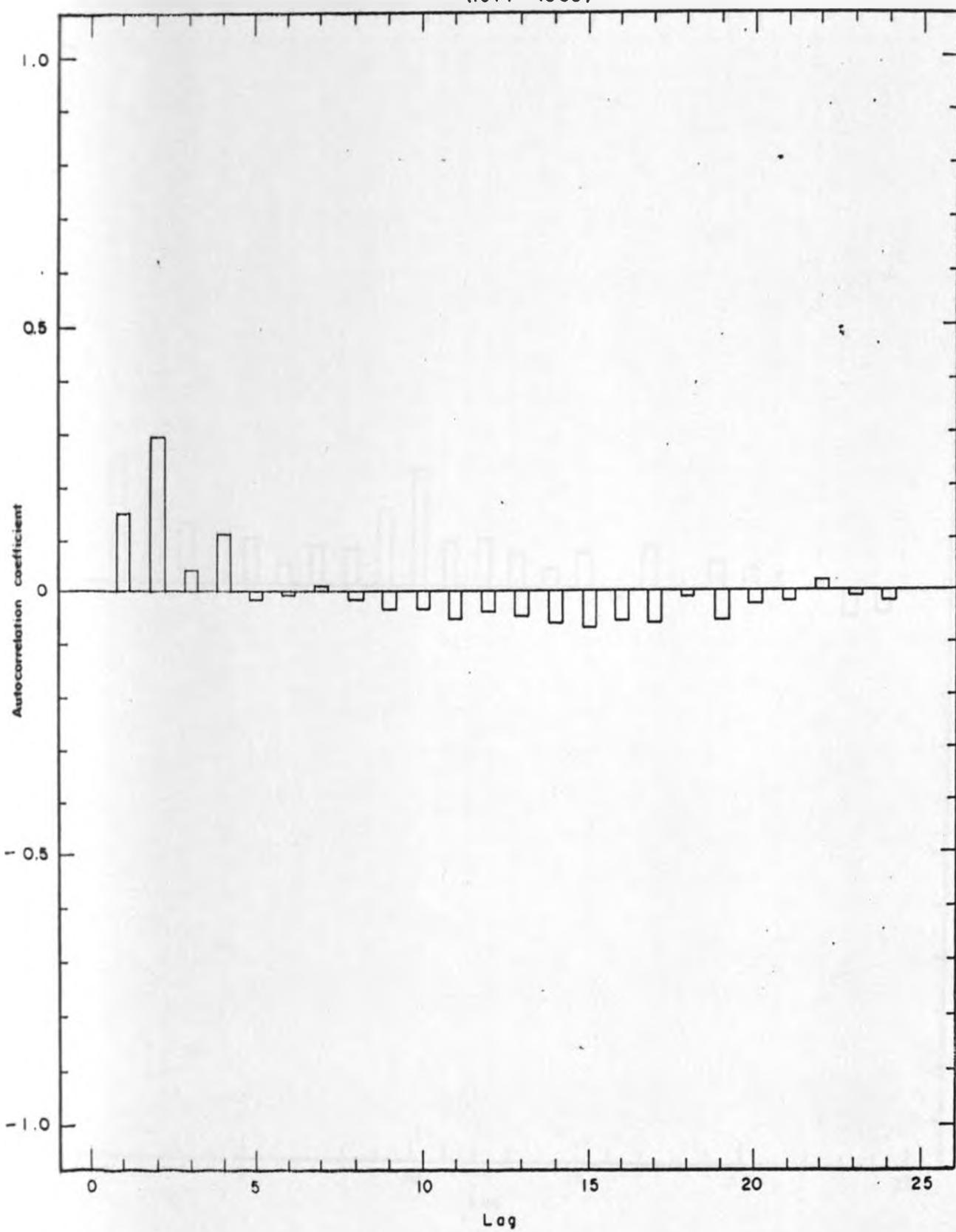
(Data Source: Meteorological Dept. 1971-85)

Fig. 4.13: TIME SERIES AND MOVING AVERAGE FOR JULY  
RAINFALL (1971 - 1985) : ELGON STATION



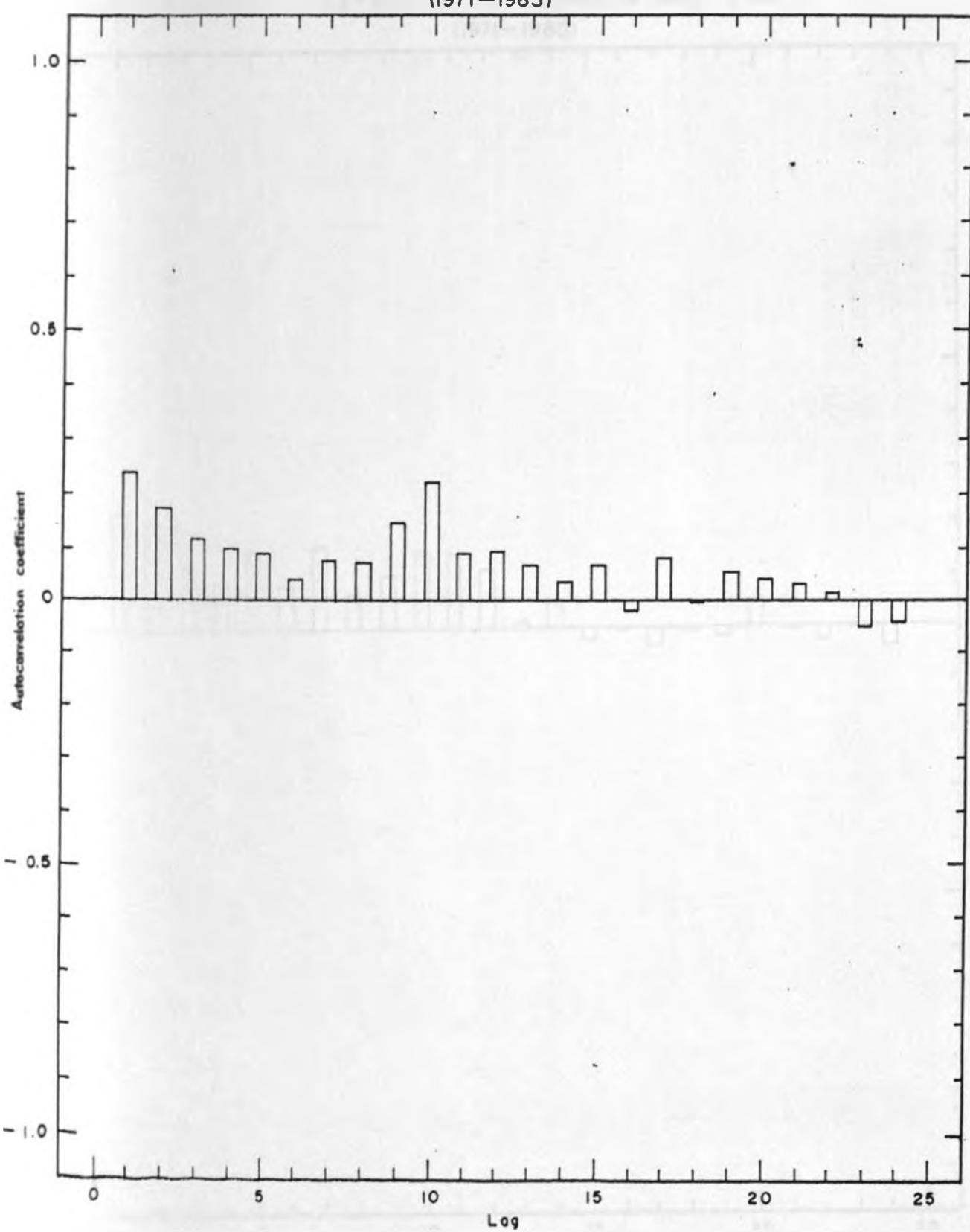
(Data Source: Meteorological Dept. 1971-85)

Fig.4.14 : KISUMU : ESTIMATED AUTOCORRELATIONS (JANUARY)  
(1971-1985)



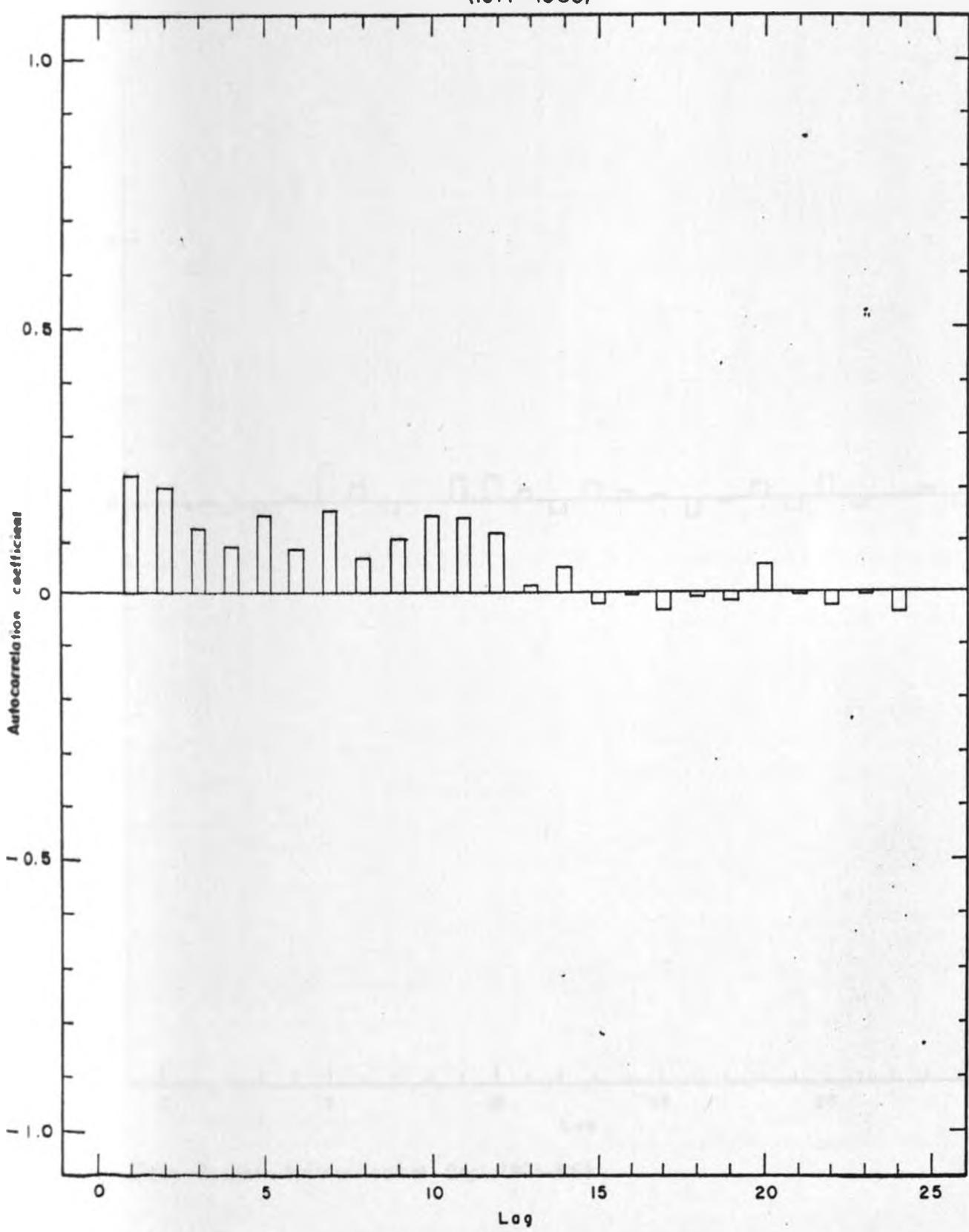
(Data Source: Meteorological Dept. 1971- 85)

**Fig 4.15 : USIGU : ESTIMATED AUTOCORRELATIONS (APRIL)  
(1971-1985)**



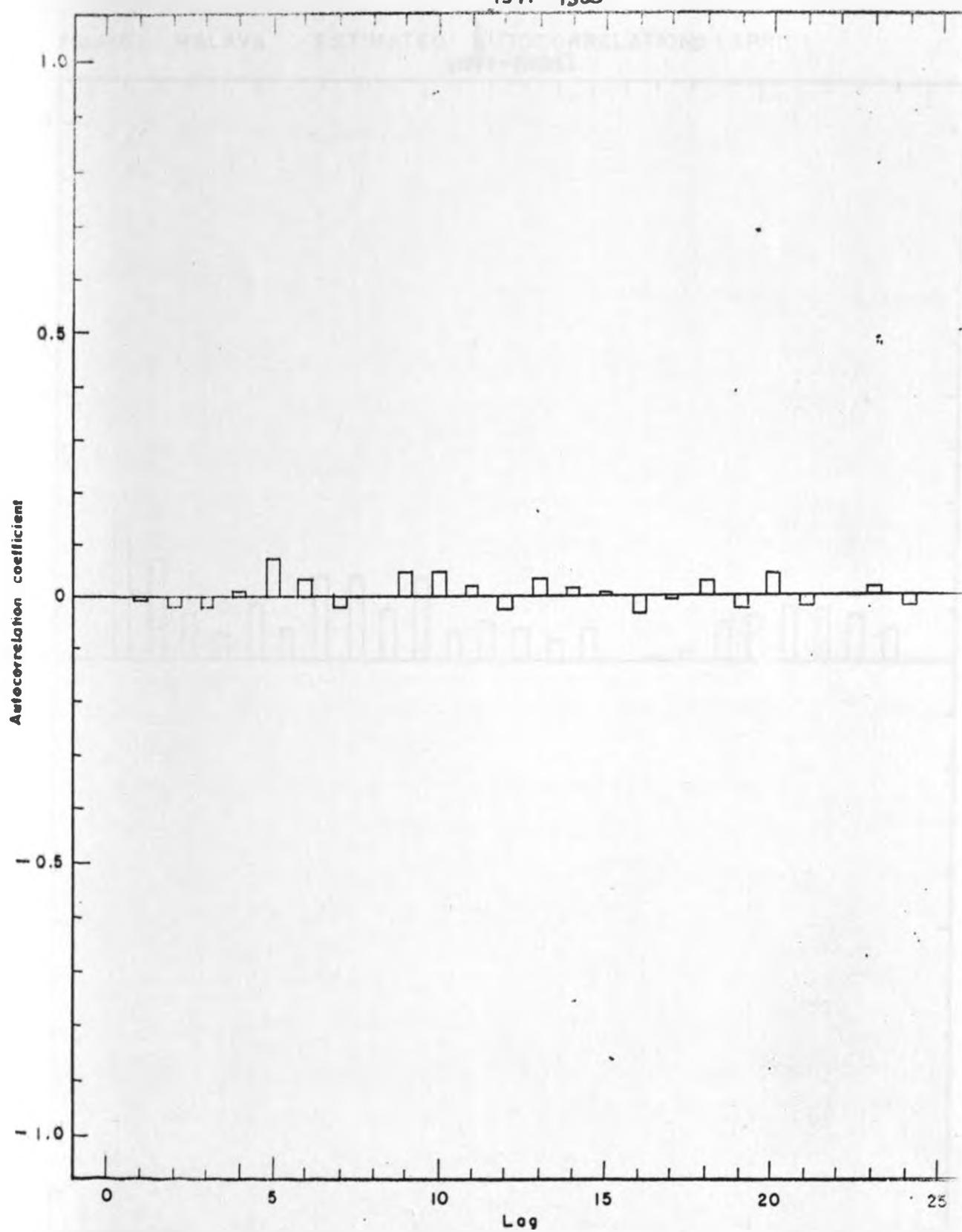
(Data Source : Meteorological Dept. 1971-1985)

Fig 4.16 : BUNGOMA : ESTIMATED AUTOCORRELATIONS (MAY)  
(1971-1985)



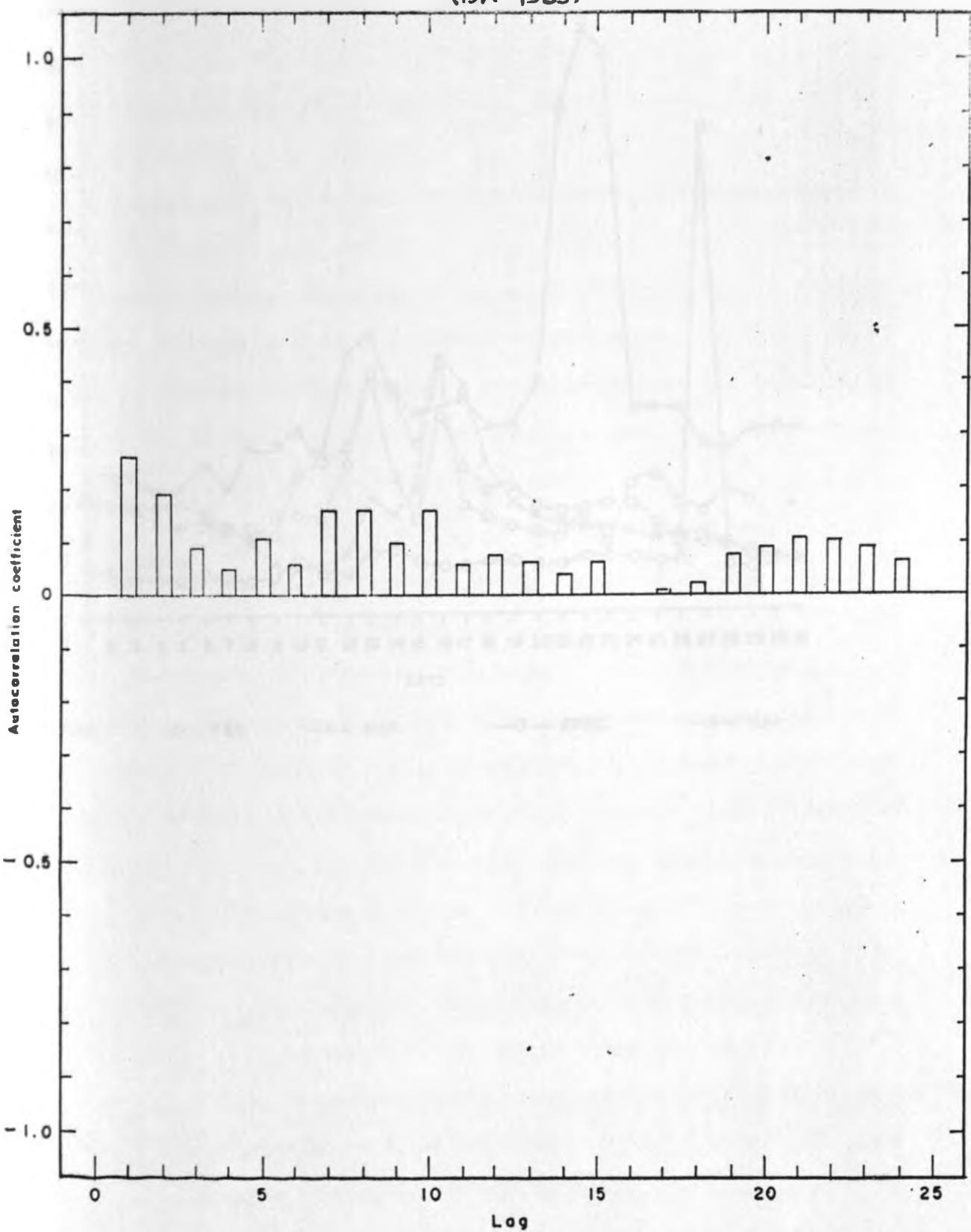
(Data Source: Meteorological Dept. 1971-85)

Fig 4.17 : NYAMIRA : ESTIMATED AUTOCORRELATIONS (APRIL)  
1971-1985



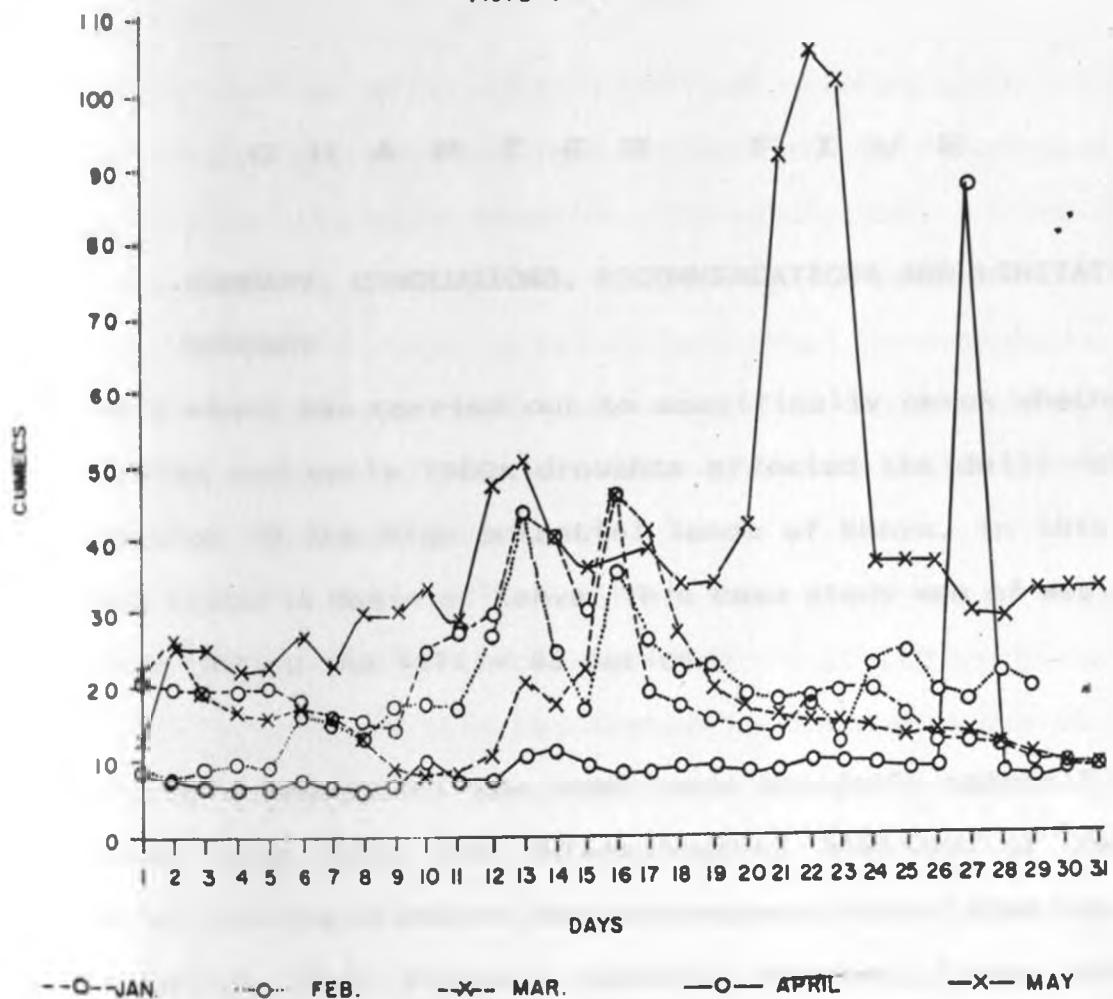
(Data Source : Meteorological Dept. 1971-85)

Fig.4.18 MALAVA : ESTIMATED AUTOCORRELATIONS (APRIL)  
(1971-1985)



(Data Source: Meteorological Dept. 1971-85)

FIGURE 4-19 MIGORI RIVER DAILY FLOW  
(1972 JAN—MAY)



## CHAPTER FIVE

### 5.0 SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

#### 5.1 SUMMARY

This study was carried out to specifically check whether the early 1970s and early 1980s droughts affected the daily rainfall distribution in the high potential lands of Kenya, in this case, the Lake Victoria Basin of Kenya. This case study was of West Kenya situation during the 1971 - 85 period.

The data needed for the study were the daily rainfall totals and these came from the Meteorological Stations or rainfall recording Stations of Muhuru Bay Hydrometeorological Station, Usigu Health Centre, Port Victoria Catholic Mission, Kisumu Hydromet Station, Kosele Primary School, Kodera Forest Station, Bungoma Agricultural Office, Kisii District Office, Nyamira District Office, Malava Agric Office, Kimilili Agric Office and North Mount Elgon Forest Station all of West Kenya. The Stations were grouped according to altitude, a factor affecting rainfall amount and distribution in the Lake Victoria Basin of Kenya. Kisumu Meteorological Station, Muhuru Hydrometeorological Station, Usigu Health Centre and Port Victoria Catholic Mission comprised, in the study, the Lake littoral; Kosele Primary School, Kodera Forest Station and Bungoma Agriculture Office made up, in the study, the low midlands and lastly; Malava Agriculture Office, Kimilili

Agriculture Office, Kisii District Office, Nyamira District Office and North Mount Elgon Forest Station represented, in the study, the upper midlands. Strictly speaking, the agro-climatic zones of West Kenya (see figure 2) were represented differently by the above stations. For references, data on river flows; Rivers Nzoia, Yala, Nyando, Miriu and Gucha-Migori, were analyzed but did not form part of the main analysis and this was true with the agricultural reports from West Kenya.

The daily rainfall data were then first subjected to basic statistical techniques and the statistics used were the Mean, the Median, the Mode, the Variance, the Standard Deviation, the Skewness, the Kurtosis, the Minimum and Maximum values and lastly the Frequency Tabulation. These were necessary as central tendency statistics required in giving indications of the general trend of the daily rainfall distributions from January to July during the 1971-85 period. The statistics showed that the daily rainfall conditions in West Kenya were low, relatively, in January, February and July but the inferences depended very much on the distance from the Lake Victoria and on altitude. March, April, May and June, averagely showed a maximum with April-May period showing relatively wetter conditions. In the Lake littoral, only April and May showed good rainfall, relatively, with the Usigu-Muhuru areas showing a near arid rainfall conditions, with the exception of April-May period and Kisumu and Port Victoria areas showing relatively better rainfall conditions. In the Lake littoral, 1972,

1975, 1976, 1979, 1980, 1981, 1982 and 1984 showed, averagely, rainfall distribution tendencies towards less than 0.25mm per day (meteorological dry day) with the first half of the 1980s showing the worst rainfall conditions, especially in the Usigu - Muhuru areas.

In the low midlands, the average daily rainfall conditions were better off than in the Lake littoral although the Kosele area conditions leaned toward the Lake littoral conditions. The rains were better off as from March up to June. In the low midlands, 1972, 1973, 1979, 1981, 1982, 1983 and 1984 showed daily rainfall totals generally below 5mm especially in the Kosele area. The first half of the 1980s was generally low in rainfall distribution.

The upper midlands' daily rainfall average conditions were relatively better than in the low midlands and no month could be said to be meteorologically dry (averagely). Generally, January, February and July showed averagely low daily rainfall conditions with March, April, May and June, averagely being wet. Places like Malava and Nyamira showed averagely good rainfall conditions from January to July throughout the 1971-85 period. 1971 in the Kisii area tended to have had a generally low daily rainfall conditions and this seemed to have been due to data recording error. 1971, 1972, 1976, 1979, 1980, 1982 and 1984 tended to have been low in rainfall distribution (< 5mm per day), but those varied from place to place especially in areas bordering the low midlands and towards

the outer fringes of West Kenya to the North West and Southern areas. Generally, the basic statistics showed that mean daily rainfalls of each less than 0.25 were restricted to the Usigu-Muhuru areas especially in the January-February and June-July periods. The occurrences of dry days < 0.25mm were common features of the daily rainfall distributions in West Kenya but the nature of their distributions varied from place to place and from day to day with the extreme rainfall conditions most likely to be in the form of heavy downpours as was shown by positive Kurtosis values and positive Skewness in distribution.

The Analysis of Variance Technique was then used and this showed significant differences in mean daily rainfall in each month during the 1971-85 period ( $\alpha = 0.05$ ). Since the Variance Analysis Technique showed significant differences in mean daily rainfall conditions in each month during 1971-85 period, there was need to study the daily rainfall sequences for each month so as to identify the mean rainfall conditions that seemed abnormal. The seemingly abnormal conditions could show whether the drought conditions of early 1970s and early 1980s affected daily rainfall conditions in West Kenya. Time-Series Technique was the most appropriate method of analysis in case of Time-dependent activities, like daily rainfall in the study. In the Time-Series technique, the 5-day weighted running mean(moving average), the Time-domain Autocorrelation Test and the correlograms were used to analyse the daily rainfall sequences for January - July during the

1971 - 85 period. In the Time-Series Technique, the daily rainfall data were plotted for each month from 1971 to 1985. This gave individual years' Series behaviour for each month from 1971 to 1985. The raw Series given gave "confused" set-up not easy to describe. To solve this problem, a 5-day weighted running mean was used to smoothen the Series for each year in sequence depending on the month during the 1971-85 period. The weights used in the running means were binomial coefficients (0.22, 0.20, 0.12, 0.05, 0.02). The years that showed breaks or lows (less than 5mm per day rainfall) were marked as abnormal if the breaks or lows were not common in the Series as a whole. The daily rainfall data for each month were then subjected to Autocorrelation function,  $r_k$ , (Time-domain) tests to check whether the distributions shown were due to chance (random distribution or white noise) or there was persistence in the series (red noise) at lag 1 so that a rainfall condition to day was most likely to appear the next day. If there was persistence in the Series, the first order Markov model test ( $r_k = r_1 k$ , where  $k$  was lag time) was used to check the kind of persistence. The correlograms were then used to check the kind of processes behind the Series distribution; periodic, moving average, Autoregressive (first order Markov process) processes.

In the Lake littoral the daily rainfall data for the months of January to July between 1971 and 1985, the Time Series results indicated generally low rains between January and February and also between June and July. The Muhuru Bay area and Usigu area rains

were the lowest and indications of prolonged dry days that could results in Meteorological droughts were notable. The general view of the 1971-85 rainfall distributions for the months of January to July indicated the 1975-77 period to be generally low in rainfalls and could have affected agricultural yields in the Lake littoral. In the low midlands, the 1979-81 generally indicated low or depressed rainfall distributions and lastly, in the upper midlands, 1983-84 was relatively low in rainfall amounts and distributions. The low rainfall periods mentioned above were not well defined and generally showed erratic, late start or early ending of the rains in the given month. This therefore showed that in West Kenya the low rainfall periods could not be marked as meteorological drought periods but could easily qualify as agricultural drought periods depending on the type of crops grown.

Generally, during the 1971-85 period there was "a low" in rainfall distributions during the transition period of 1979-81 in West Kenya and the indications were that a moderated meteorological drought condition could have occurred.

The daily rainfall data in West Kenya during the 1971-85 period indicated general persistence in the series at high frequencies (<5 days) and a mixture of random and persistence tendencies at low frequencies (>5 days). That is , the possibility of getting extended dry or wet period of less than five days in the daily rainfall Series of West Kenya was high and in the daily

rainfall data for January to July during the 1971-85 period could have had telling effects on crops performance. At low frequencies rainfall distributions in West Kenya between 1971-85 was unpredictable due the mixture of random and persistence tendencies and this was an indication of equal and /or unequal possibility of getting extended dry or wet periods in the daily rainfall climatology of West Kenya during the period of study. There was a tendency in the data to have persistence tendencies dominating the Series distributions during the very wet or very dry periods. One could therefore take note of the fact that during the wet or dry months a persistence condition was to be expected and to be wary of any deviation.

The internal structures of many daily rainfall distributions in West Kenya indicated a mixture of periodic, moving average , and autoregressive processes. No well defined process could be identified in the daily rainfall Series for the months of January-July during the period of study and this indicated further the problem of predicting daily rainfall conditions.

The daily river flows showed general persistence tendencies in the Series and showed little variations on daily basis but were indicative of rainfall conditions on annual basis. The agricultural reports for West Kenya also gave indications of rainfall performance in the region during the period of study and did indicate periods that were not favourable to agricultural

productions with the early 1980s being a bad period generally. From the Time Series Analysis results certain conclusions were reached as concerns drought occurrence in the Lake Victoria Basin as per the 1971-85 daily rainfall data.

## 5.2 Conclusions

From the time-series analyses results (moving average results, autocorrelation tests and correlograms) the following conclusions were made from the 1971-85 daily rainfall data for the months of January to July:

(i) January, February and July were the driest months in West Kenya during the period of study (1971-85) but this depended very much on distance from the Lake and altitude. In the Lake littoral, the months of January, February, March, June and July were generally low in rainfall (< 5mm per day) with the Usigu -Muhuru areas showing the lowest distributions. March, April, May and June in west Kenya were relatively good in rainfall distribution especially in the upper midlands (> 5mm per day average rainfall).

(ii) The droughts of 1972-74 and 1984-85 could not be well defined in the West Kenya rainfall series (January - July) during the period of study as breaks or low (< 5mm per rainfall) occurred in a not well defined way. The breaks were also not complete indicating more of not well developed rains which were erratic in distribution. So the major characteristics of the breaks that showed prolonged dry days were those of erratic distribution

and delayed or early ending rains within a given month for each year during the periods of study.

(iii) The breaks were more pronounced in the Lake littoral during the 1975-77 period than during the 1972-74 period. The low midlands also showed this tendency but the upper midlands daily rainfall conditions were not affected. In the upper midlands, the 1979-81 showed low rainfall conditions (< 5mm per day rainfall). The 1983-84 period tended to have had low distribution during the April- May period in West Kenya but this still varied with the distance from the Lake and altitude.

(iv) In West Kenya the mean < 5mm per day rainfall condition should be used to describe abnormal situations during the April-May rains especially in the low midlands and upper midlands. In this case, in the Lake littoral, 1972-73, 1973, 1977, 1979-80, 1982 and 1984 showed low rainfall distribution that must have affected established agronomic activities especially in the Usigu-Muhuru areas. In the low midlands, 1975-77 and 1980-81 indicated low rainfall conditions that must have affected agronomic activities. In the upper midlands, this tendency was more during the 1979-81 period. It should be noted that the periods or years given above did not show well defined dry periods but rather periods of delayed, early ending and erratic rains.

(v) The < 0.25mm mean condition was not of much meaning in West Kenya except in January, February and July months in the Usigu-Muhuru areas where those indications could be noted. As to this, meteorological drought condition was limited during the

period of study and the dry conditions shown were not unique in the general series of the January, February and July months in the Lake littoral.

(vi) Isolated prolonged dry periods could be noted from the Lake littoral to the upper midlands, relatively, and this was an indication that widespread meteorological low rainfall conditions were restricted in the Lake Victoria basin, West Kenya, during the period of study, 1971-85. Generally, indications were that meteorological drought conditions were a possibility but their occurrences were limited.

(vii) Persistence was a major feature in the rainfall series distribution in West Kenya at high frequencies (less than 5 days). Persistence in series distributions therefore indicated the possibility of having extended dry period but this was limited to the less than five days although even longer periods could be noted. Persistence was mostly a factor during the drier months or during the wetter months and random distributions were noted in the transition months especially in March and June. It should therefore be noted that a given meteorological condition, in terms of daily rainfall, could be termed abnormal if it persisted more than five days but the possibility was there due to the linear tendencies at <5 lag time.

(viii) There were a mixture of processes behind the series distributions shown and the most common processes noted were periodic, moving average and autoregressive appearing in combined forms.

(ix) Generally, the effects of the early 1970s were delayed in West Kenya until the mid 1970s and the effects were not very meaningful meteorologically but could have been meaningful agriculturally. The 1980s drought seemed to have been an extension of the mid 1970s drought with the 1979-81 period showing the worst conditions agriculturally. The periods that showed breaks in the rainfall series did not seem to be unique meteorologically as they were to be expected in conditions where the occurrences of dry spells were a greater possibility and persistence a feature of many series distributions. The breaks could have been more meaningful agriculturally for the "adaption-time" factor was a limiting feature of the series in that the breaks come in erratic forms.

In general, breaks in the daily rainfall series especially in the April-May period showed that meteorological anomalies were a possibility in the rainfall climatology of West Kenya. Since persistence was also a feature of the series distributions, the possibility of extended dry periods was real in the rainfall climatology of West Kenya, and that several processes were behind the various distributions indicated the possibility of getting several types of meteorological conditions in West Kenya, drought included.

### 5.3 Recommendations

From the experience and data analysis results, the following recommendations should be considered seriously by scholars and government planners.

(i) The results of this study should be combined with the results of a detailed daily water balance study in West Kenya so as to be able to make authoritative statements about drought periods in relation to the situation in West Kenya. That is, agricultural drought conditions should be studied more closely in West Kenya as meteorological "lows" are features of the daily rainfall climatology of the region.

(ii) Agronomic or agricultural practices in West Kenya should have inbuilt drought-shock absorbers, as possibility of extended dry period is a real feature of the series. This may have a telling effect on crop performance especially when crops are in their development stages.

(iii) The Usigu-Muhuru areas should not be involved in crop cultivation but if need be, fast maturing and drought resistance crops reaching their development stages in mid April should be grown. In the low midland areas, drought resistance crops should be grown and major crops growing should be mostly carried out in the upper midlands, but having in mind the possibility of rains delayance, or early ending of rains or just erratic rainfall distribution that may limit the full potential of the various crops grown being achieved.

(iv) Recording of daily rainfall should be monitored by trained personnel as some problems were noted as concerns data entry and data consistency. Also, stations network should be improved in West Kenya especially towards the Winam gulf (Kano plains) and towards the South East. Data gathering as concerns

other factors of climate of the Lake Basin should also be improved especially on actual evapotranspiration and vegetation cover, horizontal and vertical temperature distribution, relative humidity, wind movements and structures, and the interaction of the various climatic elements in the "Lake environment".

(v) The definition of a drought situation in West Kenya should be based on the less than 5mm rainfall per day mark and this should be used in conjunction with the soil moisture balance of the various soils in West Kenya.

(vi) If the January - February rains are exceptionally high or steady, early ending of the April- May rains should be expected to be more erratic in distribution. This should be seen in terms of moisture availability in the atmosphere of the Lake Basin (West Kenya). Also, if delay in the onset of the long rains is noted, the farmers should expect to have good rains in the May-July period and should therefore adjust their agronomic set-ups, if there is time, to that expectation.

(vii) The occurrence of extended dry periods in January, February and July should be expected in West Kenya especially in the Lake littoral and low midlands and rain-based activities should be organised with this reality in mind. Extended dry periods in April and May should be seen as abnormal, although the limited possibility is there.

#### 5.4 Limitations

This study was faced with some problems that limited the certainty of the conclusions made and the most notable were:

(i) The most serious problem faced was data availability and this was in the form of lack of consistency in data entry, biased representation of agro-ecological zones of West Kenya, data accessibility and lack of control in collecting primary data as the study was based on secondary data.

(ii) In analyses of data, there was delayance due to lack of the right computer package to handle the vast data in the manner wanted. The package was acquired from a government establishment only after valuable time loss.

(iii) Lastly, the duration covered in the study, 15 years, was not long enough to enable confident statements to be made although even five-year period is enough to give basic indications of the climatic conditions of a region. The limited period covered therefore did not allow for the drought definition to be given with certainty. Also drought definition in West Kenya as a whole was limited by the fact that various climatic conditions exist in West Kenya starting from the semi-arid Usigu-Muhuru areas to the Afro-Alpine Elgon area.

## REFERENCES AND APPENDICES

## R E F E R E N C E S

- Anderson, R.L., 1942: "Distribution of Serial Correlation Coefficient"; Ann.Math. Statist., Vol 13 No. 1.
- Anderson, T.W., 1958: The Statistical Analysis of Time-Series. John Wiley & Sons, New York.
- Baker, S.J.R., 1977: "A Background to the Study of Drought in East Africa" in Drought in East Africa (SECHERESSE EN AFRIQUE) 2; African Environment Special Report 8.
- Bhalme, H.N. and D.A. Mooley, 1983: On the performance of modified Palmer Index. Archiv.fur.meteorologie.Geophysik und Bioklimatologie Ser. B. 22:281-295.
- Barring, L., 1988: "Aspects of Daily Rainfall Climate Relevant to Soil Erosion in Kenya"; Thesis (Ph.d). Dept of Physical Geography, University of Lund; Sweden.
- Blackman R.B. and T.W. Tukey, 1958: The Measurement of Power Spectra from the point of view of Communication Engineering; Dover Publications Inc., New York.

Blalock (JR) H.M., 1960: Social Statistics; McGraw-Hill Inc..  
Singapore.

Botswana Society, 1978: Proceedings of the Symposium on Drought in  
Botswana; Gaborone.

Brillinger, D.R., 1975: Time-Series Analysis and Theory; University  
of California, Berkley.

Carter J.P.(edit),1982:"FamineinAfrica";Proceedings of the  
conference a working group on Famine in Africa. Pergamon  
Press, New York.

Carter, J.P., 1982:"Great Famines and theirRelevance" in Famine in  
Africa;Proceedings of the Working Group on Famine in Africa  
edited by Carter J.P., New York.

Chapman, T.G.(edit),1972: Australian-UNESCO Seminar onDrought ;  
Australian Government Publishing Service; Canberra,1976.

Charley, R.J., 1971. Physical Geography - A Systems Approach;  
Prentice Hall Inter. Kennedy, Inc; London PP. 260-277.

Cochrane, J., 1967: "An agro-climatology survey of a semi-arid area  
in Africa South of the Sahara" in W.M.O. Technical Note No.  
86.Geneva; pp 21 - 136.

Conrad, V. and L.W. Pollak, 1962: Methods in Climatology: Second Edition, Harvard University Press.

Dagg, M., 1965: A rational approach to the selection of crops for areas of marginal rainfall in East Africa" in E. Afr. Agric. For. J. Vol. 30., PP 296 - 300.

Dale, I.R., 1952: "Is East Africa Drying Up?" in E.Afr. Agr. J. No 1.17 PP 166 - 118.

Dimopoulos, G., 1965: A Simple Method of Describing Fluctuations in Meteorology . WMO Technical Note No 73;Brussels.

Dorenboos, J. and W.O.Pruit, 1982: "Crop Water Requirements"; Irrigation and Drainage Paper 24 (Revised Edition) by F.A.O. Rome . Part 1, PP 1 - 65.

Erat, S.J., 1973. "Time-Series Analysis of Annual Temperatures", Mon. Weather Rev., No 101, PP 501 - 504.

F.A.O., 1973."Mathematical Models in Hydrology": Irrigation and Drainage paper 19. United Nations,Rome.

Felch, R.E., 1978: "Drought; Characteristics and Assessment" in North American Droughts edited by Rosenburg. AAAS-Westview Press Inc.Colorado. PP. 25 - 46.

Flohn, H., 1964: "The Causes of Aridity of North Eastern Africa" in Wurenburger Geographicle Arbenten Vol 12 in Meteorological Department Memoirs, 1966, Nairobi.

Godske, C.L., 1968: The Future of Meteorological Data Analysis". WMO Technical Note No. 100, 1968, Geneva.

Gottman, J.M., 1981: Time-Series Analysis: A Comprehensive Introduction for Social Scientists. Cambridge University Press, Cambridge.

Gregory, S., 1963: Statistical Methods and the Geographer; Fourth Edition. Longman Inc., New York, 1982.

Gregory, S., 1986. "The Climatology of Drought". Geography Vol. 71 part 2 no. 311.

Griffiths, J.F., 1958: "An Initial Investigation of the annual rainfall in East Africa"; E.A. Meteorological Dept Memoirs VOL.3 No.5

Griffiths,J.F, 1963."Rainfall Maps of Eastern Africa and Southern Africa". E.A.Meteorological Dept. Memoirs vol.3 No. 10

Griffiths,J.F.,1972. "Climate of Africa"-World Survey of Climatology Vol. 10. Elsevier publishing co., Amsterdam.

Hare, F.K., 1977: "Climate and Desertification" in U.N. Conference on Desertification. Nairobi, Kenya. pp. 9 - 84.

Hare, F.K., 1987: "Drought and Desication: Twin Hazards of a variable climate" in Planning For Drought; Toward a Reduction of societal Vulnerability by D.A. Wilhite et al. 1987. London

Henry, A.J., 1906: "Drought Climatology of United States"; U.S. Weather Rev. Bull., WB No. 361.

Hoel, P.G., 1947: Introduction to Mathematical Statistics (Fifth Edition, 1984) .John Wiley & Sons Inc., California.

Holt, J. and J. Seaman, 1976: "The Scope of the Drought" - Drought and Famine in Ethiopia, Rehab; African Environment Special Report 2., I.A.I., London.

Huonam, C.E., 1972: "Assessment and Recognition of Drought" - Australian - UNESCO Seminar: Drought; Canberra.

Hussein, A.M.(edit), 1976: Drought and Famine in Ethiopia, Rehab - African environment Special report 2; I.A.I., London.

Jaetzold, R. and H. Schmidt, 1982: Farm Management Handbook of Kenya. Natural Conditions, Vol II, West Kenya.

Jagannathan, P. and B. Parthasarathy, 1973: "Trends and Periodicities of Rainfall over India"; Mon Weath. Rev. No. 101, PP. 371 -375.

Johnson, D.H. and H.T. Morth, 1962: "Forecasting research in East Africa"; E.A. Meteorological Dept. memoirs vol. 3 No. 9.

Kates, R.W., 1985: "Interaction of Climate and Society" in Climate Impact assessment Edited by Kates et al. SCOPE. John Wiley & Sons Ltd. pp. 4 - 40. New York.

Kendall, M., 1976: Time-Series; Second Edition (Early edition, 1973). Griffins and Co., Ltd. London.

Kiangi, P.M.R., 1978: "Physical and Windflow Characteristics of the atmosphere over Eastern Africa during 1967 (normal year) and 1972 (drought stricken year)". Dept. of Meteorology, University of Nairobi.

Laikhtman, D.L. and N.P. Rusin, 1957: On the Meteorologocal criterion of drought. Glavnaya Geofizicheskaya Observatiria. Trudy, 69-70.

Lamb, H.H., 1966: "Climates in the 1960s: World's Wind Circulation reflected in prevailing temperature, rainfall patterns and the levels of African Lakes". Geographical J. Vol. 132 No. 2. pp 183 - 212.

Lamb, H.H., 1977: "Some Comments on Drought in Recent Years in the Sahel - Ethiopian Zone of North Africa" - Drought in Africa (SECHERESSE EN AFRIQUE) 2; I.A.I; London. pp 33- 37.

Lamb, P.J., 1982: Persistence of Subsaharan drought. Nature 299:46-48.

Lee, D.M., 1979: Australian Drought Watch System. In M.T.Hinchey,ed. Botswana Drought Symposium. Botswana Society, Gaborone.

Haddox, R.A., 1980: Mesoscale Convective Complexes. Bull.Am. Meteorol. Soc. 61:1374-1387.

Manabe, S. et al, 1980: Sensitivity of a global climate model to an increase of Carbon dioxide concentration in the atmosphere. J.Geophys.Res.85,no.10,:5529-5554.

Masaya,T.R., 1978: "A Comparison of Rainfall Variations in Kenya and Zimbabwe". Proceedings of the Symposium on Drought in Botswana. Botswana Society, Gaborone. Botswana.

Mbiti, P. and B. Wisner, 1972: "Drought and Famine In Kenya" IDS Working Paper No. 46, University of Nairobi, Kenya.

McCutchan, A.I., 1972: "Drought; the general view" - Australian - UNESCO Seminar; Drought. Canberra.

Morth, H.T., 1967: "Investigation into meteorological aspects of variation in the level of Lake Victoria"; E.A. Meteorological Dept. memoirs vol. 4, No. 2.

Mungai, D.N., 1984: "Analysis of some seasonal rainfall characteristics in Lake Victoria Region of Kenya" - Unpublished M.A. Thesis, Dept. of Geography, University of Nairobi, Kenya.

Neil, T., 1961: Famine and Floods in Kenya, 1961; A report to the Legislature. Nairobi.

Nyandega, I.A., 1987: "The use of Water Balance approach in the assessment of the growing seasons for maize and sorghum in South Nyanza District". Unpublished B.A. Dissertation, University of Nairobi.

Obasi, G.O.P. and P.M.R. Kiangi, 1977: "Water Balance in Kenya"; Seminar paper (early version, 1973), Dept. of Meteorology, University of Nairobi.

Odingo, R.S., 1978: "Drought and Man in EASTERN AFRICA (Ethiopia, Kenya and Tanzania): A Study of causes, consequences and policy recommendations in Ethiopia, Kenya and Tanzania". IFIAS Project.

Odingo, R.S., 1985: "State of the art review of research on Drought in Eastern Africa (Ethiopia, Kenya and Uganda)". IDRC, NAIROBI

Ogallo, I.J.A.J., 1977: "Periodicities and Trends in the annual rainfall over Africa", Unpublished MSc. Thesis, University of Nairobi.

Ogallo, I.J.A.J., 1980: Time-Series of rainfall in East Africa ; Ph.D Thesis, Dept. of Meteorology, University of Nairobi.

Ojany, F.F. and R.B. Ogendo, 1973: Kenya: A Study in Physical and Human Geography, Nairobi. Longman.

Oguntonyinbo, J.S., 1977: "The Extent and Intensity of the 1969-73 drought in Nigeria: A provisional analysis in Drought in Africa (SECHERESSE EN AFRIQUE) 2., I.A.I. London.

Palmer, W.C., 1957: Drought - A normal part of climate . Weekly Weather and Bulletin 44. no.1a (January 10):6-8.

Palmer, W.C., 1965: "Meteorological Drought" in U.S. Weath. Bur. Res., paper No. 85, U.S. Department of Commerce; Washington.

Quenouille, M.H., 1968: "Analysis of Multiple Time-Series"; Griffins Statistical Monographs and courses. Griffins, London.

Ramdas, D.A., 1950: Quoted in Indian Journal of Met. and Geophys. Vol 1 No. 4.

Republic of Kenya 1984-88: District Development plans for Kisii, South Nyanza, Kisumu, Siaya, Kakamega, Busia, and Bungoma Districts. Ministry of Finance and Planning; Rural division. See agric. and livestock report(1956-85)

Rijks, D., 1978: "Experience of Drought in the Sahel region". Proceedings of Symposium on Drought in Botswana. Gaborone.

Rodhe, H. and H. Virji, 1976: "Trends and Periodicities in East Africa Rainfall data". Mon. Weath. Rev., 104, pp 307 -315.

Saikkonen, P., 1985: "Comparing asymptotic properties of some tests used in the specification of Time-Series models" - Statistical Studies 6; Helsinki.

Sandford, S., 1978: "Towards a definition of drought". Proceedings of the Symposium on Drought in Botswana; Gaborone.

Schove, D.J., 1977: "Africa:- Drought and the Spectrum of Time"; Drought in (SECHERESSE EN AFRIQUE) 2., I.A.I., London. pp 43 - 54.

Schneider, S.H., 1978: "Forecasting future drought; Is it possible?" in North American Droughts by Rosenburg, N.J. (Edit).

Sneyers, R., 1968: "Climatological Analysis of Local series of Observations"; WMO Technological Note No. 100, 1968, Geneva.

Spiegel, M.R., 1961: Theory and Problems of Statistics; Schaum's Outline Series; McGraw-Hill, Inc., Singapore.

Spiegel, M.R., 1975: Theory and Problems of Probability and Statistics; Schaum's Outline Series. McGraw-Hill Inc., Singapore.

Stringer, E.T., 1972: Techniques of Climatology; W.H. Freeman and Co., San Francisco.

Subrahmanyam, V.P. 1967. Incidence and Spread of Continental Drought. WMO/IHD Report No.2. WMO, Geneva.

Tannehill, I.R., 1947: Drought: Its causes and effects. Princeton Univ. Press. Princeton, New Jersey.

Thornthwaite, C.W., 1954: "An examination of the concept and measurement of potential evapotranspiration". Publ. in Climat. vol. 7.

Thornthwaite, C.W. and J.R. Mather, 1955: "The Water Balance" publ. climat. vol. VII.

UNDP, 1976: "Drought in Africa - A Report".

United Nations Organization, 1977: "Climate and Desertification"; United Nations Conference on Desertification; August 29 - Sept 9; Nairobi, Kenya.

Wetherell, H.I., 1978: "Drought in the Sahel: A Broader Interpretation with regard to West Africa and Ethiopia" in Proceedings of the Symposium on Drought in Botswana; Gaborone.

Winstanley, D., 1973: "Recent Rainfall Trend in Africa and Middle East and India". Nature 243 (5407), PP 464 - 465.

Winstanley, D., 1974: Seasonal rainfall forecasting in West Africa. Nature 248:464-465.

Wilhite, D.A., 1987: Understanding the drought phenomenon:the role of definition in planning for drought;Toward a reduction of societal vulnerability by D.A. Wilhite and W.E.Easterling (edit). London.

Whipple, W.Jr., 1966: Regional Drought Frequencies Analysis. Proc. ASCE 92, No. ir2(June 1966).

WMO, 1962: "Numerical Methods of Weather Analysis and Forecasting"; Technical Note No. 44; Geneva.

WMO, 1966: "Climatic Change"; Technical Note No. 79. Geneva.

WMO, 1967: "A Note on Climatological Normals"; Technical Note No. 84; Geneva.

Wood, C.A. and R.R. Lovett, 1974: "Rainfall, Drought and Solar Cycle"; Nature, 251 pp 594 - 596.

Wood, C.A., 1977: "A Preliminary Chronology of Ethiopian Drought". Drought in Africa (SECHERESSE EN AFRIQUE) 2; I.A.I., London.

Woodhead, T., 1968: "Studies of the Potential evaporation in Kenya". E.A. Agr.for. Research Organization. Ministry of Natural Resources, Water Dept., Physics Div., Republic of Kenya.

Woodhead, T., 1970: "Water Balance as a Guide to site potential". E.A. Agr. For. Research Org., M.O.N.R., Water Dept., Physics Div., Republic of Kenya.

Zewde, B., 1976: "An historical outline of famine in Ethiopia"; Drought and Famine in Ethiopia, Rehab. African Environment Special report 6. I.A.I., London.

## APPENDIX I

### BASIC STATISTICS FOR KISUMU (1971-85) IN JANUARY

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	31	.0403	0	0	2.036	1.427	0.256	0	8.7	3.9	14.9
Y72	31	.384	0	0	1.167	1.080	0.194	0	5.3	3.6	14.7
Y73	31	4.285	0	0	92.754	9.631	1.730	0	44	2.9	9.2
Y74	31	.368	0	0	1.496	1.223	0.220	0	5.9	3.9	15.5
Y75	31	.619	0	0	4.885	2.210	0.397	0	12	4.5	21.1
Y76	31	2.852	0	0	57.287	7.589	1.359	0	37	3.7	14.7
Y77	31	2.303	0	0	23.603	4.858	0.873	0	18	2.4	4.9
Y78	31	4.726	0	0	223.06	4.935	2.682	0	68	3.5	11.9
Y79	31	1.997	0	0	23.051	4.801	0.982	0	21	3	9
Y80	31	1.426	0	0	36.848	6.053	1.087	0	33	5.2	27.6
Y81	31	1.268	0	0	10.478	3.327	0.581	0	14	3	9.1
Y82	31	1.565	0	0	23.922	4.891	0.878	0	25	4.2	18.6
Y83	31	.497	0	0	2.616	1.618	0.291	0	8.4	4.3	20.1
Y84	31	1.442	0	0	17.273	4.156	0.746	0	21	4	17.4
Y85	31	3.123	0	0	98.705	9.935	1.784	0	50	4.1	17.3

VAR=VARIABLE

SS=SAMPLE SIZE

AVER=AVERAGE

MED=MEDIAN

MOD=MODE

VA=VARIANCE

STD=STANDARD DEVIATION

S.E=STANDARD ERROR

MI=MINIMUM

MAX=MAXIMUM

SKEW=SKEWNESS

KURT=KURTOSIS

Y=19

In all cases of appendices of Basic Statistics.

APPENDIX II

BASIC STATISTICS FOR KISUMU (1971-85) IN FEBRUARY

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	29	0.393	0	0	1.567	1.252	0.232	0	5.6	3.37	1.455
Y72	29	4.224	0.6	0	58.143	7.625	1.416	0	36	2.93	10.16
Y73	29	3.528	0	0	46.076	6.788	1.260	0	23	2.03	2.984
Y74	29	0.955	0	0	8.095	2.845	0.528	0	11	3.02	8.173
Y75	29	1.814	0	0	15.072	3.882	0.721	0	13	2	2.638
Y76	29	2.324	0	0	23.658	4.864	0.903	0	21	2.66	7.78
Y77	29	2.862	0	0	45.070	6.713	1.247	0	30	3.15	10.47
Y78	29	8.110	0	0	81.923	9.051	1.681	0	26	0.98	-0.88
Y79	29	8.068	0.6	0	252.68	15.898	2.952	0	69	2.68	7.517
Y80	29	1.586	0	0	31.030	5.570	1.034	0	27	3.98	6.014
Y81	29	1.052	0	0	13.028	3.609	0.670	0	18	4.28	19.57
Y82	29	2.379	0	0	43.632	6.605	1.227	0	30	3.38	11.70
Y83	29	1.6	0	0	14.997	3.873	0.719	0	17	3.02	9.572
Y84	29	1.745	0	0	51.219	7.157	1.329	0	38	5.15	27.12
Y85	29	2.931	0	0	34.757	5.896	1.095	0	20	2.05	3.035

APPENDIX III

BASIC STATISTICS FOR KISUMU (1971-85) IN MARCH

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	31	2.365	0	0	91.283	9.554	1.716	0	51	4.77	23.67
Y72	31	2.284	0	0	19.927	4.464	0.802	0	13	1.82	1.792
Y73	31	0.445	0	0	5.5326	2.352	0.422	0	13	5.54	30.81
Y74	31	4.816	0	0	117.68	10.847	1.948	0	51	3.12	10.68
Y75	31	9.032	3.1	0	129.35	11.373	2.043	0	36	1.15	0.207
Y76	31	1.061	0	0	32.151	5.670	1.018	0	32	5.56	30.94
Y77	31	4.490	0	0	162.48	12.747	2.289	0	67	4.40	21.09
Y78	31	7.726	5	0	115.56	10.75	1.931	0	41	1.71	2.324
Y79	31	6.994	0	0	195.56	13.984	2.512	0	57	2.34	5.157
Y80	31	5.732	0	0	139.51	11.812	2.121	0	39	1.97	2.380
Y81	31	9.871	0.5	0	390.55	19.762	3.549	0	82	2.60	6.644
Y82	31	1.958	0	0	69.415	8.332	1.496	0	46	5.34	29.07
Y83	31	1.277	0	0	18.033	4.247	0.763	0	19	3.66	12.81
Y84	31	1.1	0	0	9.725	3.118	0.560	0	14	3.38	11.19
Y85	31	7.974	0	0	364.76	19.099	3.430	0	96	3.67	15.39

APPENDIX IV

BASIC STATISTICS FOR KISUMU (1971-85) IN APRIL

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	30	11.513	3.6	0	498.61	22.127	4.040	0	116	3.91	17.68
Y72	30	7.607	0.9	0	240.72	15.515	2.833	0	61	2.58	6.220
Y73	30	7.177	0	0	238.11	15.431	2.817	0	52	2.27	3.990
Y74	30	10.19	3.6	0	192.45	13.873	2.533	0	47	1.50	1.515
Y75	30	5.483	0	0	115.38	10.742	1.961	0	52	3.20	12.35
Y76	30	11.043	1.2	0	685.29	26.178	4.779	0	129	3.80	14.50
Y77	30	9.863	2.9	0	201.31	14.189	2.590	0	43	1.38	0.472
Y78	30	7.063	0.9	0	153.71	12.398	2.264	0	45	2.11	3.665
Y79	30	5.403	0	0	146.90	12.120	2.213	0	63	3.93	17.97
Y80	30	7.45	2.8	0	108.95	10.438	1.906	0	36	1.50	1.303
Y81	30	3.173	0.3	0	29.728	5.452	0.995	0	23	2.13	4.698
Y82	30	3.757	0.1	0	51.670	7.188	1.312	0	28	2.48	6.010
Y83	30	8.453	1.5	0	188.63	13.734	2.508	0	52	1.88	2.893
Y84	30	4.773	0.9	0	59.859	7.737	1.413	0	31	2.08	4.066
Y85	30	7.363	0.8	0	160.94	12.686	2.316	0	51	2.24	4.933

APPENDIX V

BASIC STATISTICS FOR KISUMU (1971-85) IN MAY

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	31	9.323	0.1	0	235.40	15.343	2.756	0	63	1.98	4.08
Y72	31	6.245	1.4	0	87.527	9.356	1.680	0	34	1.61	1.56
Y73	31	7.535	1.5	0	255.59	15.987	2.871	0	78	3.36	12.71
Y74	31	2.284	0	0	24.363	4.936	0.887	0	18	2.55	5.50
Y75	31	5.419	1.6	0	101.32	10.066	1.808	0	48	3.12	11.09
Y76	31	2.3	0.3	0	28.315	5.321	0.956	0	28	3.98	17.87
Y77	31	9.271	0.5	0	424.39	20.601	3.700	0	89	2.76	7.64
Y78	31	6.319	0	0	184.79	13.894	2.441	0	63	2.98	9.83
Y79	31	4.594	0	0	118.23	10.873	1.953	0	51	3.22	11.27
Y80	31	3.797	0.5	0	55.612	7.457	1.339	0	29	2.41	5.05
Y81	31	5.442	0.3	0	125.48	11.202	2.012	0	43	2.56	6.11
Y82	31	2.623	0.5	0	20.255	4.501	0.808	0	17	2.25	4.56
Y83	31	3.877	0	0	73.581	8.578	1.541	0	33	2.46	5.27
Y84	31	4.019	0	0	74.583	8.636	1.551	0	36	2.70	7.14
Y85	31	7.316	2.5	0	141.10	11.879	2.133	0	52	2.40	6.14

## APPENDIX VI

## BASIC STATISTICS FOR KISUMU (1971-85) IN JUNE

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	30	1.49	0	0	7.370	2.715	0.496	0	12	2.49	6.676
Y72	30	3.517	0	0	97.022	9.850	1.798	0	49	3.80	15.81
Y73	30	1.133	0	0	7.947	2.819	0.515	0	14	3.76	15.99
Y74	30	3.48	1	0	27.065	5.202	0.960	0	18	1.68	1.930
Y75	30	1.153	0	0	6.054	2.460	0.449	0	11	2.92	9.440
Y76	30	1.35	0	0	7.554	2.748	0.502	0	9.2	2.19	3.614
Y77	30	2.987	0.6	0	28.349	5.324	0.972	0	19	2.20	4.133
Y78	30	3.083	0	0	58.799	7.668	1.400	0	37	3.52	13.92
Y79	30	1.9	0.1	0	11.037	3.322	0.607	0	13	1.93	3.275
Y80	30	2.207	0	0	48.381	6.956	1.270	0	37	4.66	23.29
Y81	30	2.603	0.3	0	46.698	6.834	1.248	0	36	4.50	22.14
Y82	30	5.677	0	0	155.63	12.475	2.278	0	42	2.25	3.72
Y83	30	3.347	0.2	0	67.597	8.222	1.501	0	38	3.49	12.33
Y84	30	1.903	0.7	0	8.051	2.837	0.518	0	11	1.70	2.130
Y85	30	3.673	0	0	120.70	10.986	20.006	0	52	3.75	14.26

APPENDIX VII

BASIC STATISTICS FOR KISUMU (1971-85) IN JULY

VAR	SS	AVER	MED	MOD	VA	STD	S.E	MI	MAX	SKEW	KURT
Y71	31	1.906	0	0	25.149	5.015	0.901	0	27	4:40	21.52
Y72	31	2.442	0.1	0	35.439	5.953	1.069	0	30	3.86	16.51
Y73	31	0.5	0	0	1.808	1.345	0.242	0	5	2.73	6.317
Y74	31	4.358	0.5	0	105.02	10.248	1.841	0	43	3.08	9.205
Y75	31	1.242	0	0	5.424	2.329	0.418	0	11	2.59	7.671
Y76	31	2.871	0	0	86.260	9.288	1.668	0	50	4.79	24.46
Y77	31	3.013	0	0	88.517	9.408	1.690	0	51	4.80	24.74
Y78	31	2.845	0	0	27.937	5.286	0.949	0	20	2.15	4.155
Y79	31	1.974	0	0	20.32	4.508	0.810	0	18	2.69	6.833
Y80	31	2.855	0	0	36.634	6.053	1.087	0	29	3.19	11.51
Y81	31	2.439	0.5	0	23.577	4.856	0.872	0	21	2.74	7.470
Y82	31	2.948	0	0	72.389	8.508	1.528	0	37	3.38	11.07
Y83	31	0.881	0	0	8.474	2.911	0.523	0	16	4.84	24.86
Y84	31	6.268	0.3	0	287.28	16.919	3.044	0	87	1.03	18.01
Y85	31	2.813	0	0	39.909	6.317	1.135	0	23	2.46	4.915

## APPENDIX VIII

FREQUENCY TABULATION FOR KISUMU(1971-85) IN MAY

## APPENDIX IX

**Estimated Autocorrelations For Kisumu (1971-85) in January**

Lag	Estimate	standard error	Lag	Estimate	standard error
1	.15078	.04637	2	.29352	.04742
3	.04310	.05117	4	.11273	.05125
5	-.01705	.05178	6	-.00628	.05180
7	.00999	.05180	8	-.01396	.05180
9	-.03292	.05181	10	-.03399	.05185
11	-.04904	.05190	12	-.03528	.05200
13	-.04484	.05205	14	-.06084	.05214
15	-.06530	.05229	16	-.05617	.05246
17	-.05746	.05259	18	-.01009	.05273
19	-.05307	.05273	20	-.02441	.05285
21	-.02059	.05287	22	.02006	.05289
23	-.00989	.05290	24	-.01959	.05291

APPENDIX X

Estimated Autocorrelations For Kisumu (1971-85) in April

Lag	Estimate	standard error	Lag	Estimate	standard error
1	.11847	.04714	2	.05649	.04780
3	-.02120	.04795	4	.00752	.04797
5	.02436	.04797	6	.01123	.04800
7	-.00331	.04800	8	-.05259	.04800
9	.00434	.04813	10	-.02416	.04813
11	.09950	.04816	12	.01699	.04861
13	.01148	.04863	14	-.04777	.04863
15	-.06405	.04874	16	-.03712	.04892
17	.01453	.04899	18	-.06015	.04900
19	-.05809	.04916	20	-.02650	.04931
21	-.04580	.04934	22	-.00837	.04944
23	.00373	.04944	24	.02788	.04944

## APPENDIX XI

### Estimated Autocorrelations For Kisumu (1971-85) in June

Lag	Estimate	standard error	Lag	Estimate	standard error
1	.06071	.04714	2	.00770	.04731
3	.04509	.04732	4	.08945	.04741
5	-.05820	.04779	6	-.07061	.04794
7	.02083	.04817	8	-.00413	.04819
9	-.07131	.04819	10	.02841	.04843
11	-.05246	.04846	12	-.01797	.04859
13	-.05457	.04861	14	-.03422	.04874
15	.00633	.04879	16	-.02401	.04880
17	.03180	.04882	18	.00990	.04887
19	-.02425	.04887	20	-.01677	.04890
21	-.02665	.04891	22	.00093	.04894
23	.00624	.04894	24	-.05400	.04895

### KEY FOR APPENDIX VIII

Lo.L-Lower Level

Up.L-Upper Level

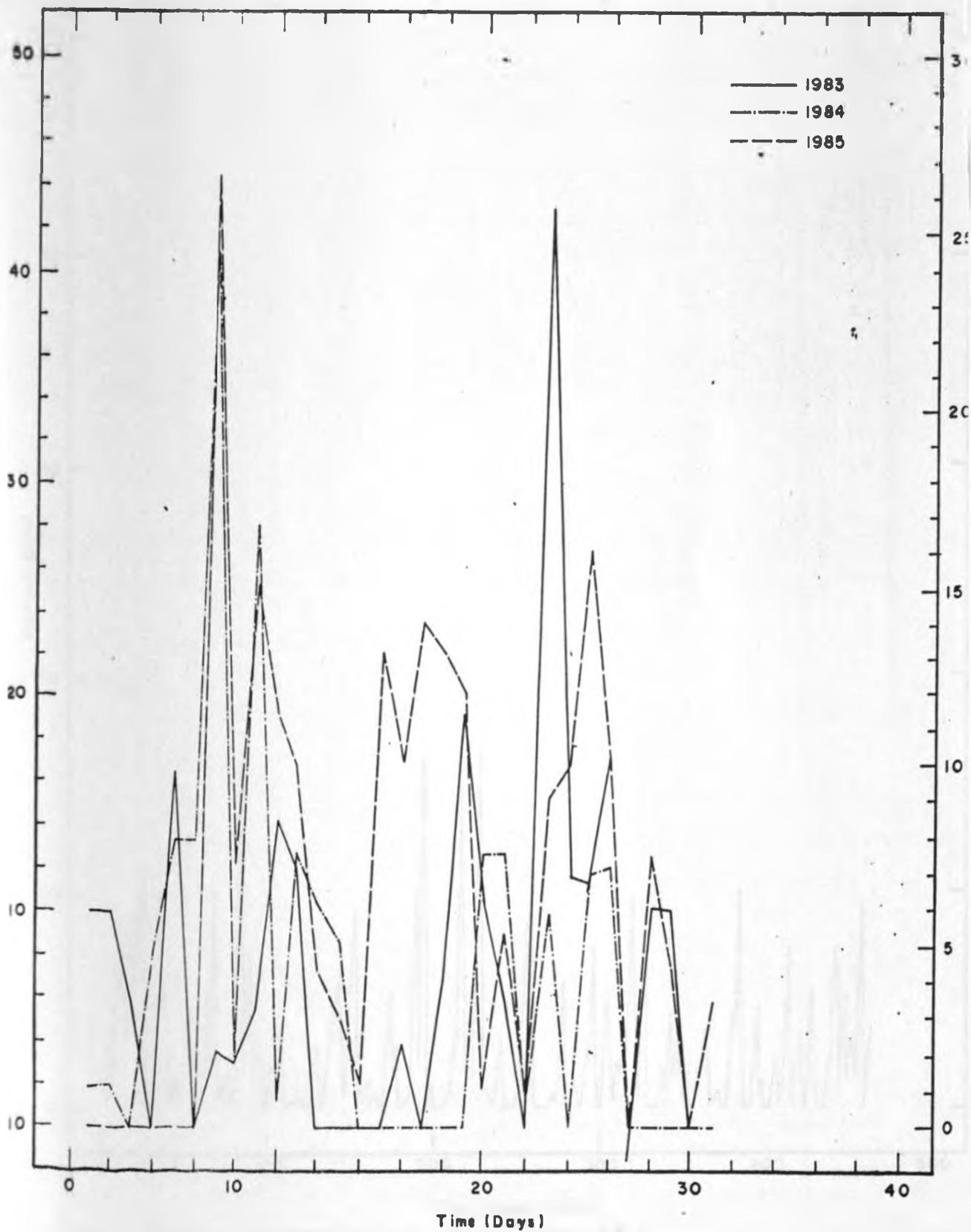
FREQ-Frequency

REL.FRE-Relative Frequency

CU.FRE-Cumulative Frequency

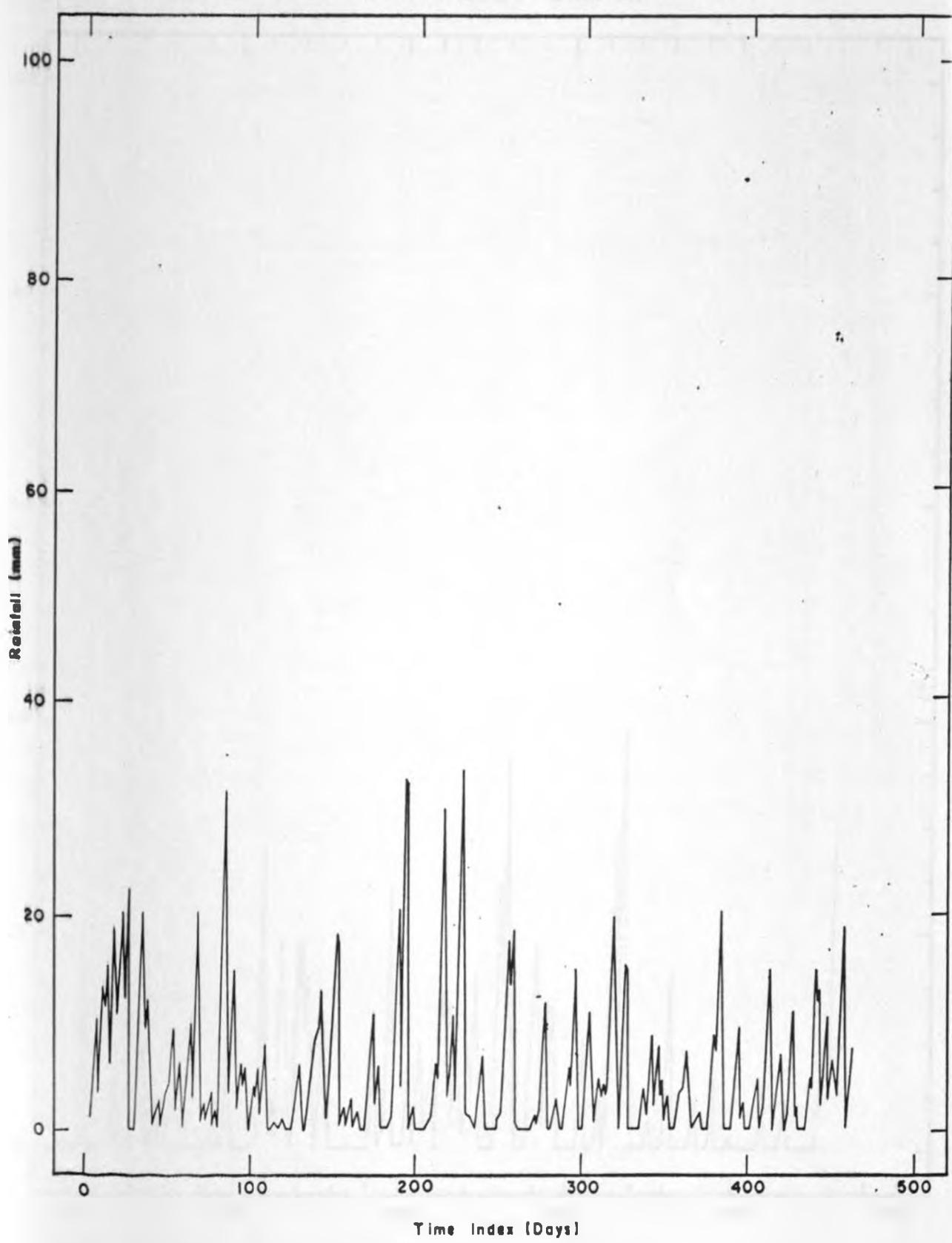
CU.FRE.FREQUENCY-Cumulative Relative Frequency

APPENDIX XII  
TIME SEQUENCE PLOT—MAY RAINFALL FOR KISII STATION



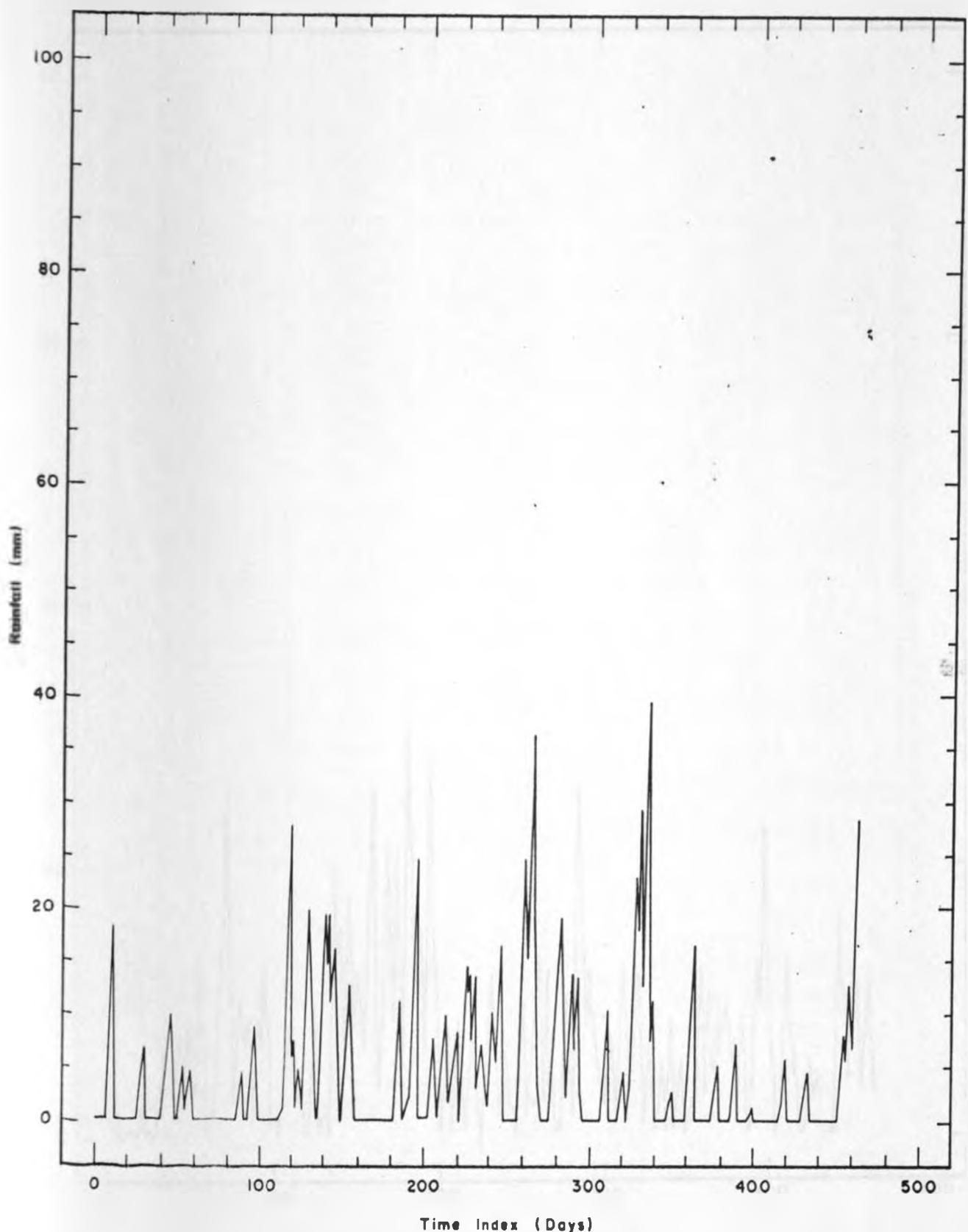
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XIII  
TIME SERIES AND MOVING AVERAGE FOR MAY  
RAINFALL (1971 - 1985) : KISUMU STATION



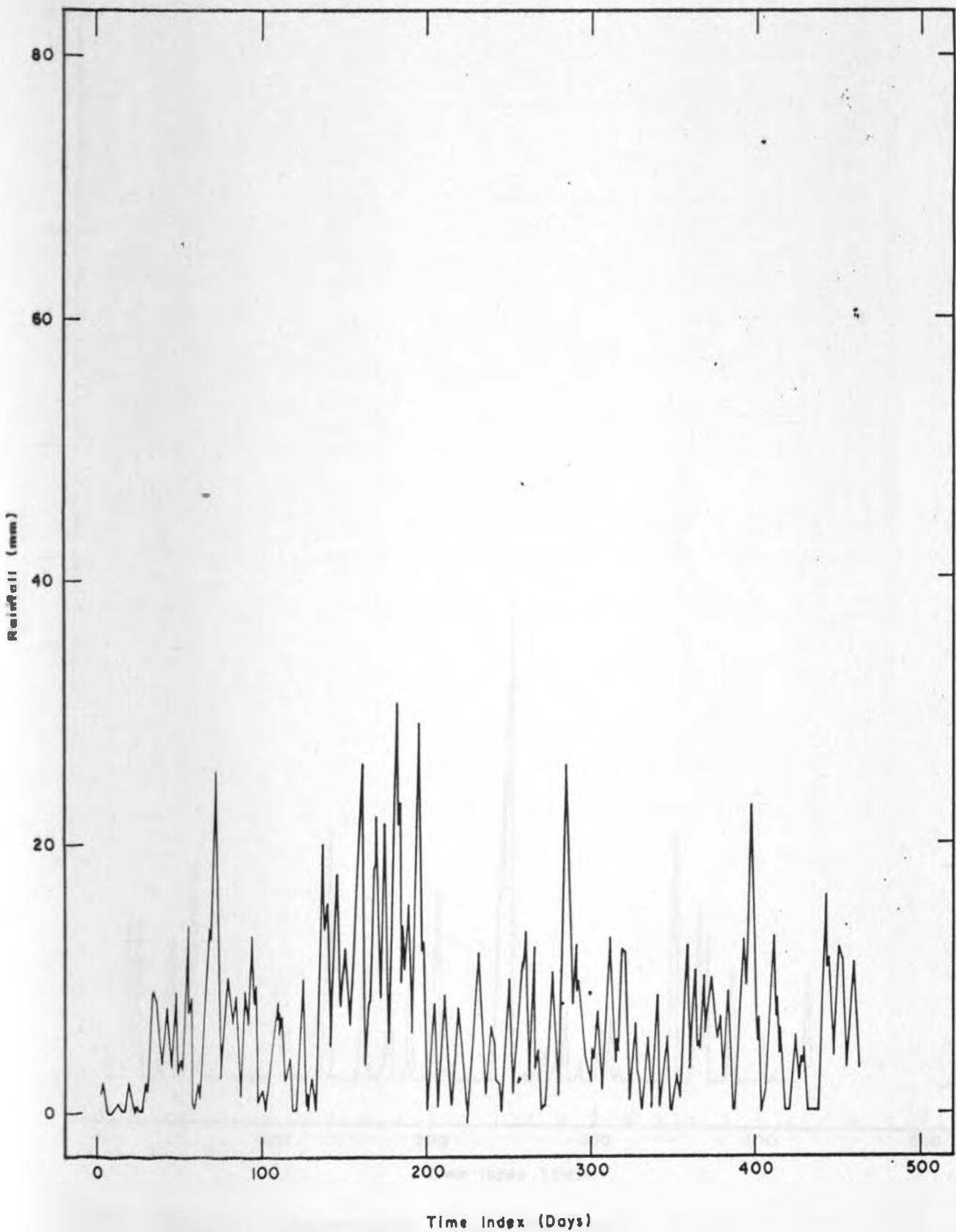
( Data Source: Meteorological Dept. 1971-85 )

APPENDIX XIV  
TIME SERIES AND MOVING AVERAGE FOR MARCH  
RAINFALL (1971 - 1985) KISUMU STATION



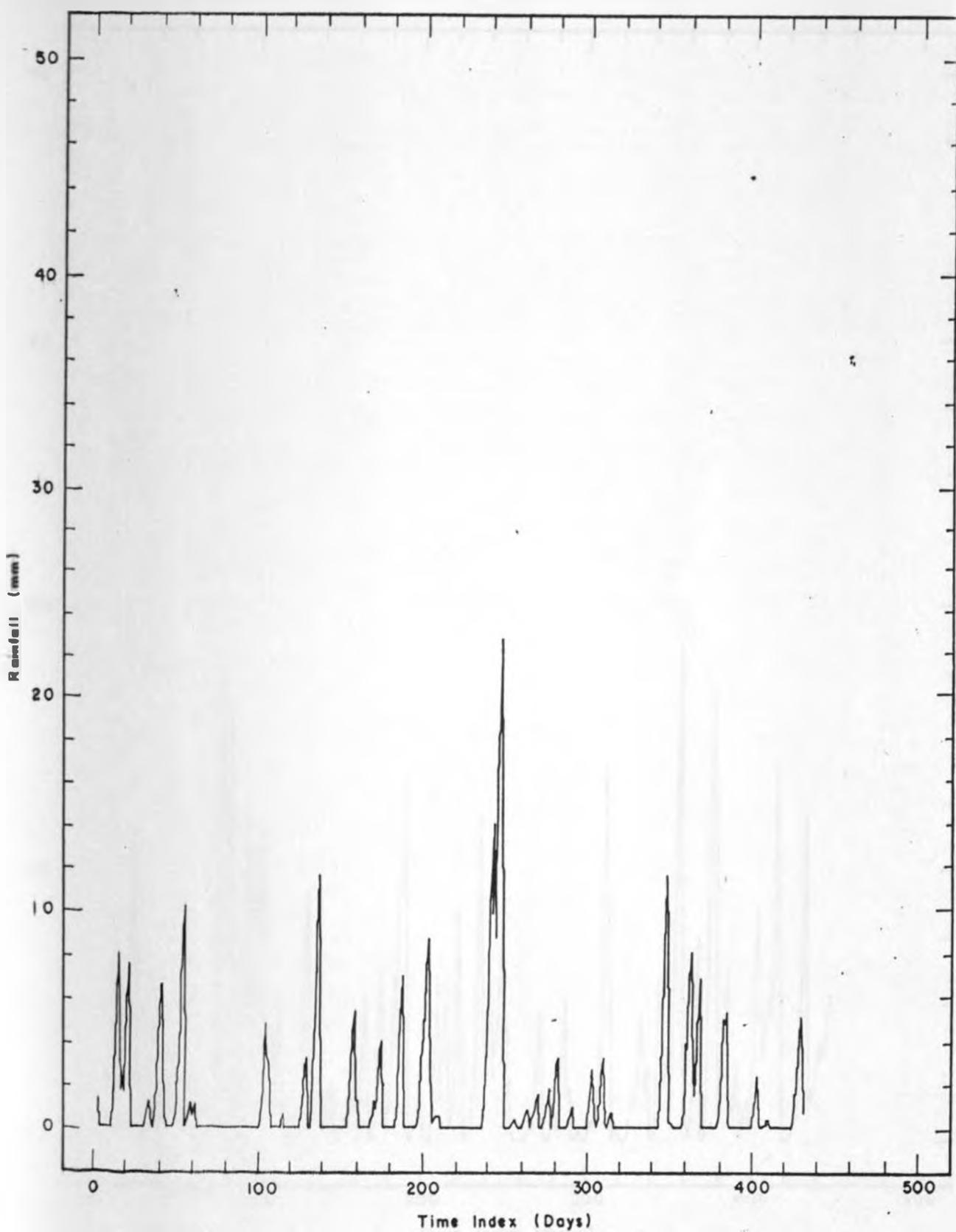
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XV  
TIME SERIES AND MOVING AVERAGE FOR MAY  
RAINFALL (1971 - 1985) : KISII STATION



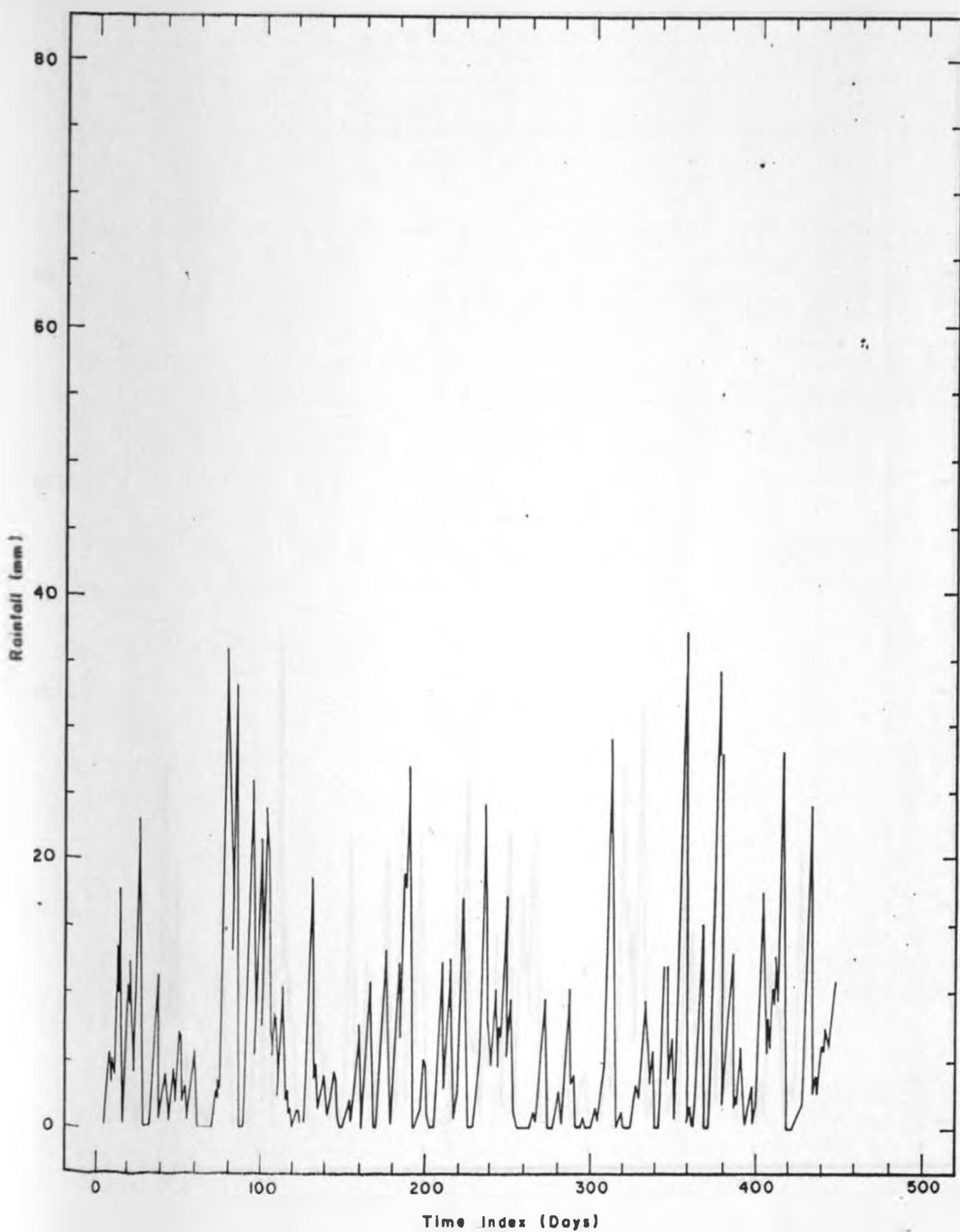
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XVI  
TIME SERIES AND MOVING AVERAGE FOR JANUARY  
RAINFALL (1971 - 1985) MUHURU STATION



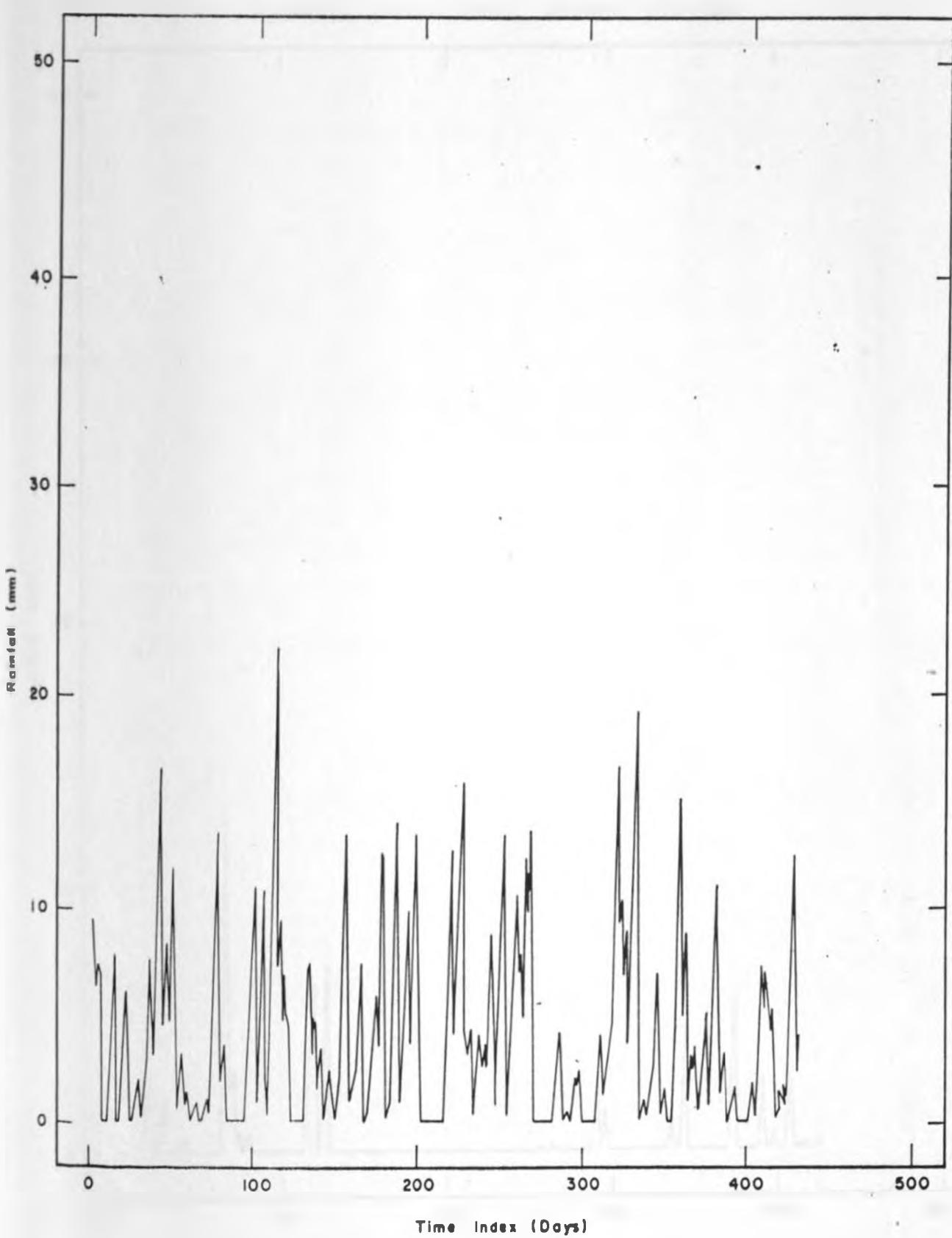
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XVII  
TIME SERIES AND MOVING AVERAGE FOR APRIL  
RAINFALL (1971-1985) MUHURU STATION



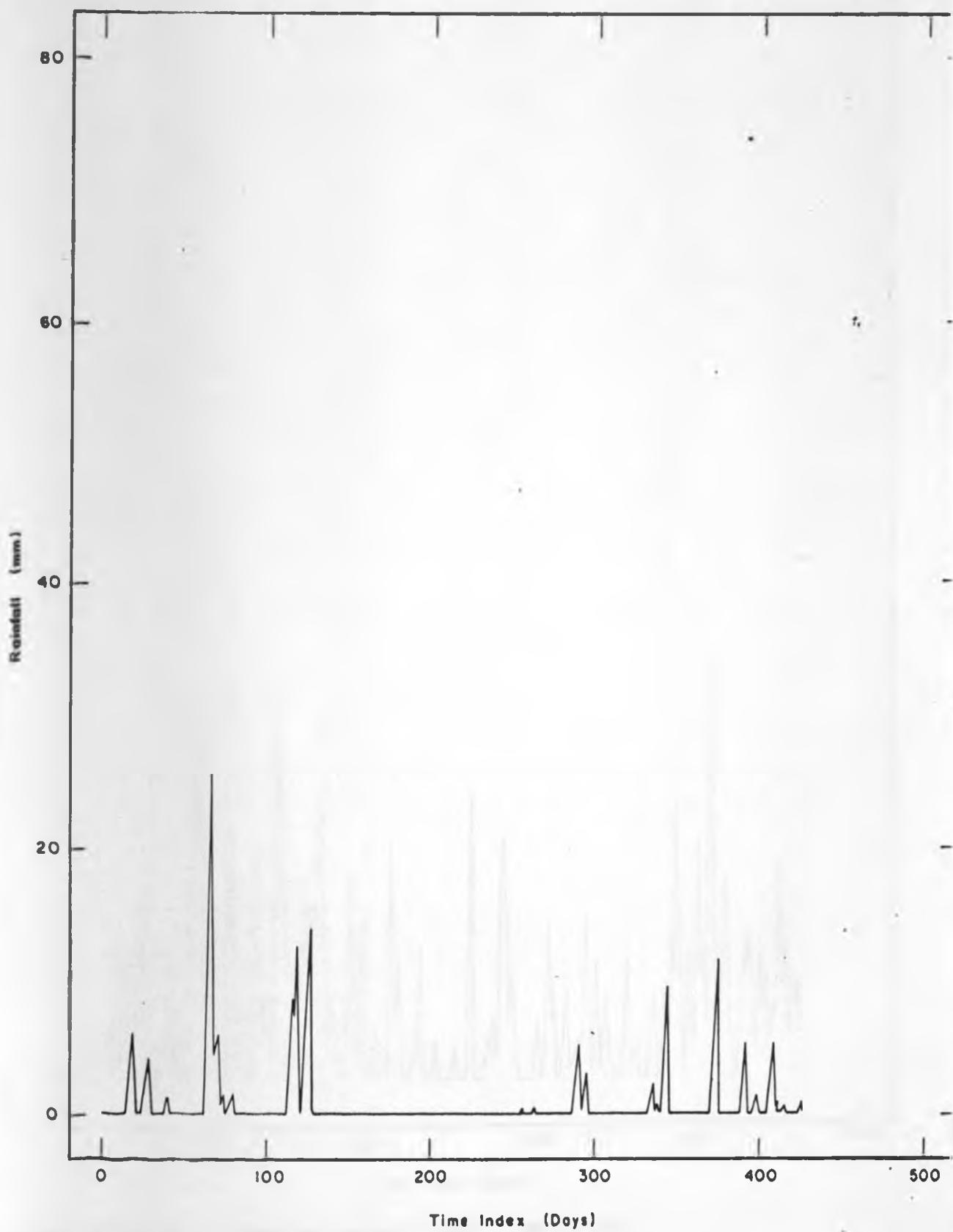
(Data Source: Meteorological Dept. 1971-85 )

APPENDIX XVIII  
TIME SERIES AND MOVING AVERAGE FOR MAY  
RAINFALL (1971-1985) : MUHURU STATION



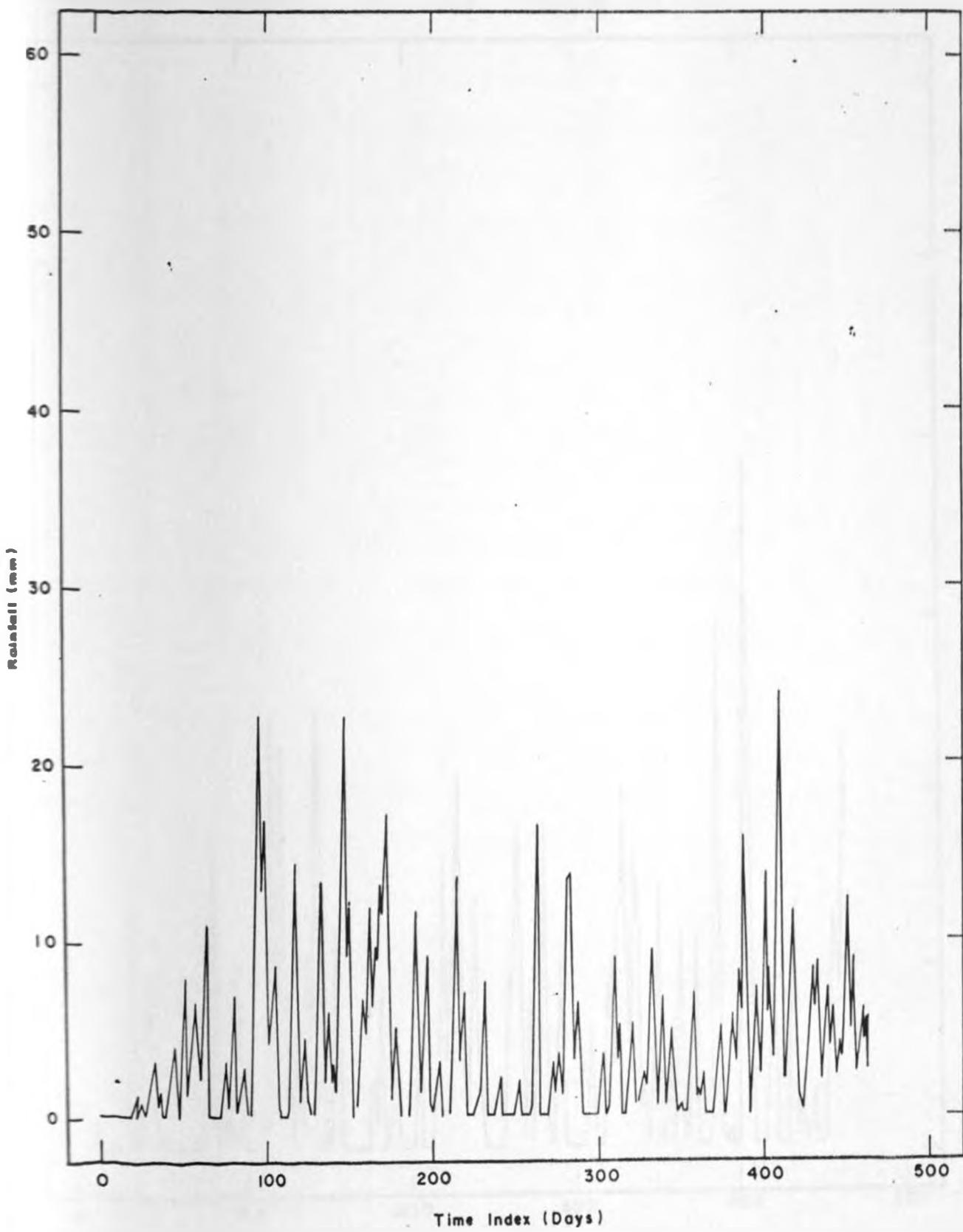
( Data Source : Meteorological Dept. 1971-85 )

APPENDIX XIX  
TIME SERIES AND MOVING AVERAGE FOR JULY  
RAINFALL (1971 - 1985) : MUHURU STATION



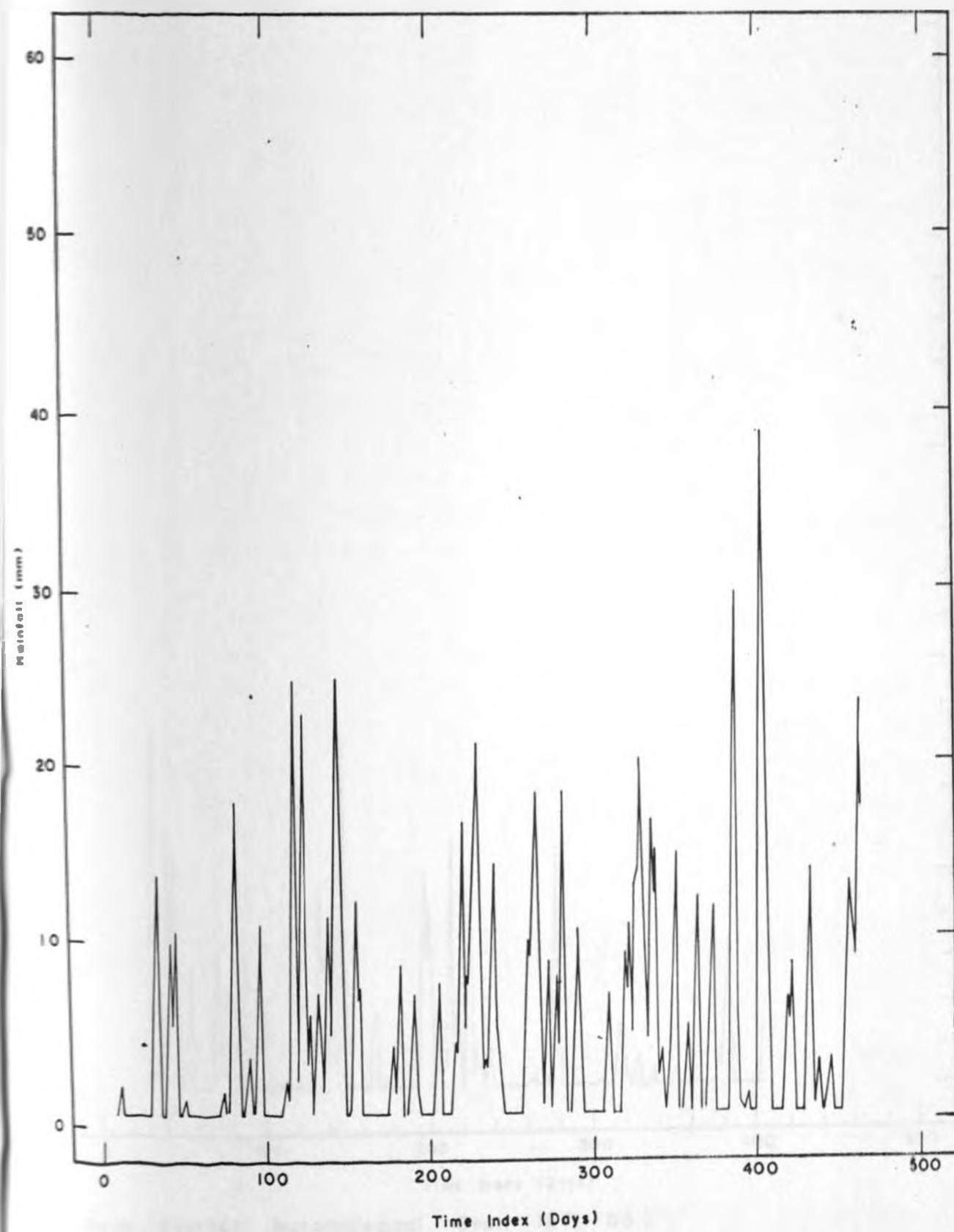
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XX  
TIME SERIES AND MOVING AVERAGE FOR JULY  
RAINFALL (1971-1985) : KISII STATION



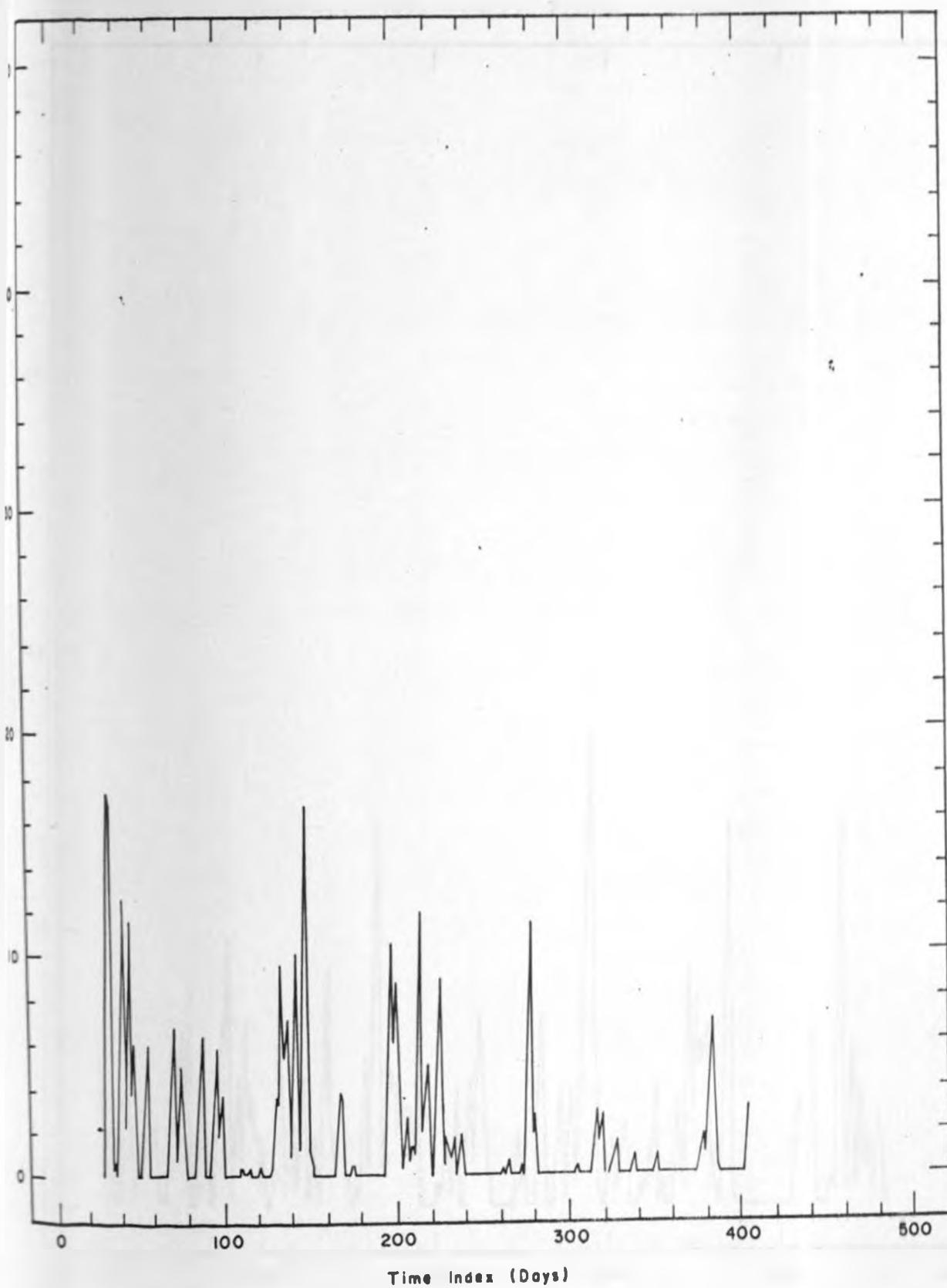
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XXI  
TIME SERIES AND MOVING AVERAGES FOR MARCH  
RAINFALL (1971 - 1985) : KOSELE STATION



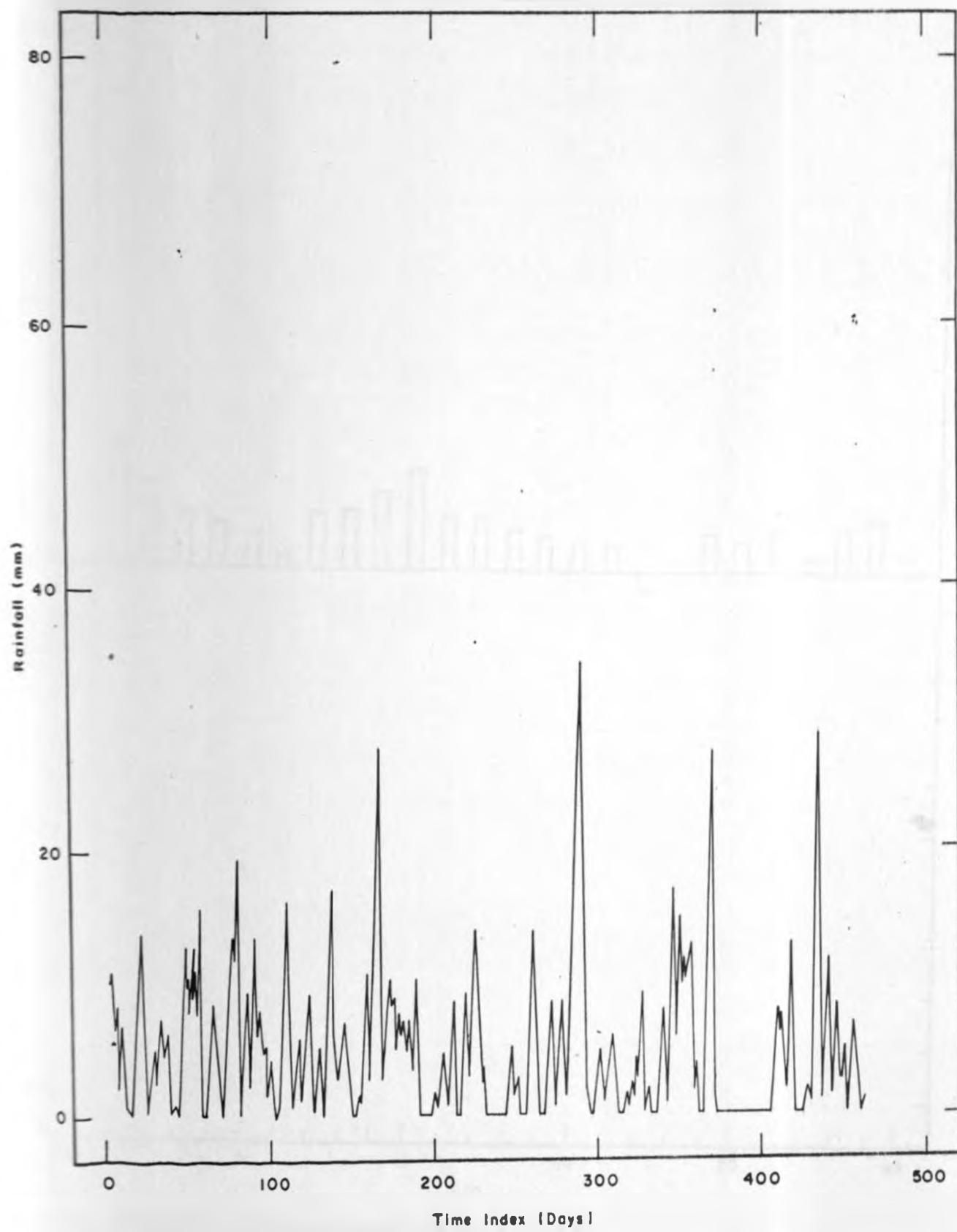
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XXII  
TIME SERIES AND MOVING AVERAGE FOR FEBRUARY  
RAINFALL (1971 - 1985) MUHURU STATION



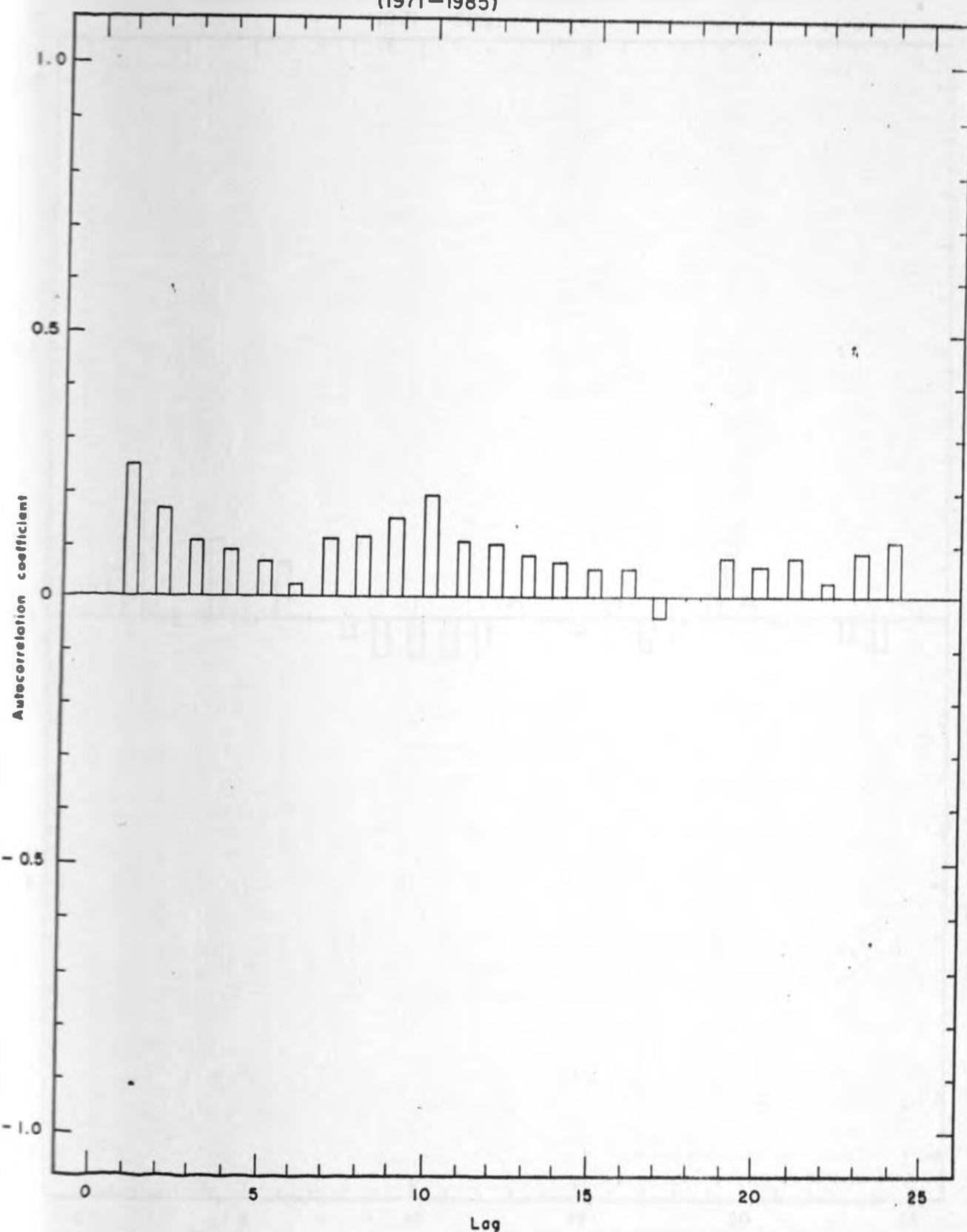
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XXIII  
TIME SERIES AND MOVING AVERAGE FOR MAY  
RAINFALL (1971 - 1985) : ELGON STATION



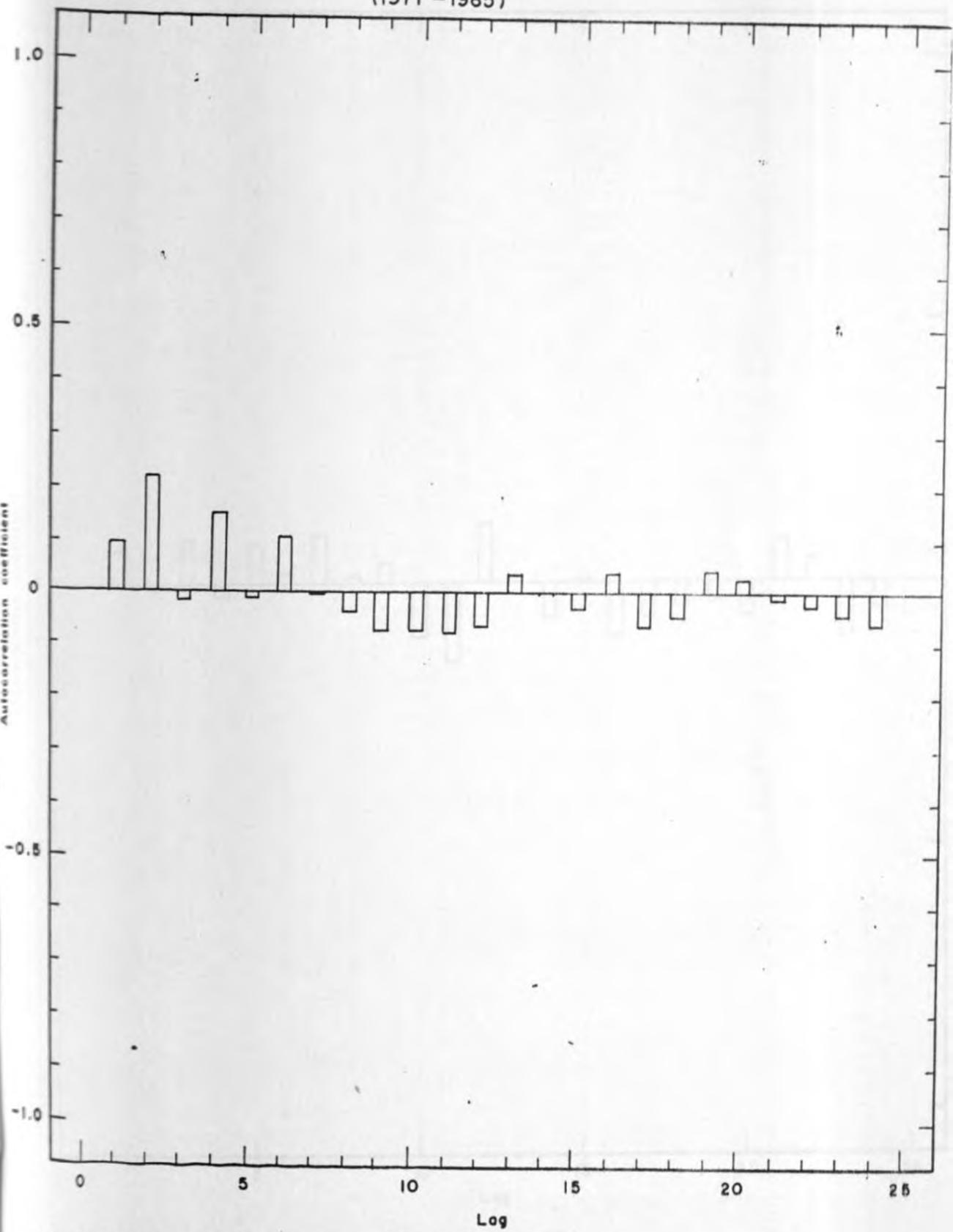
(Data Source: Meteorological Dept. 1971 - 85)

APPENDIX XXIV  
USIGU—ESTIMATED AUTOCORRELATIONS (MAY)  
(1971–1985)



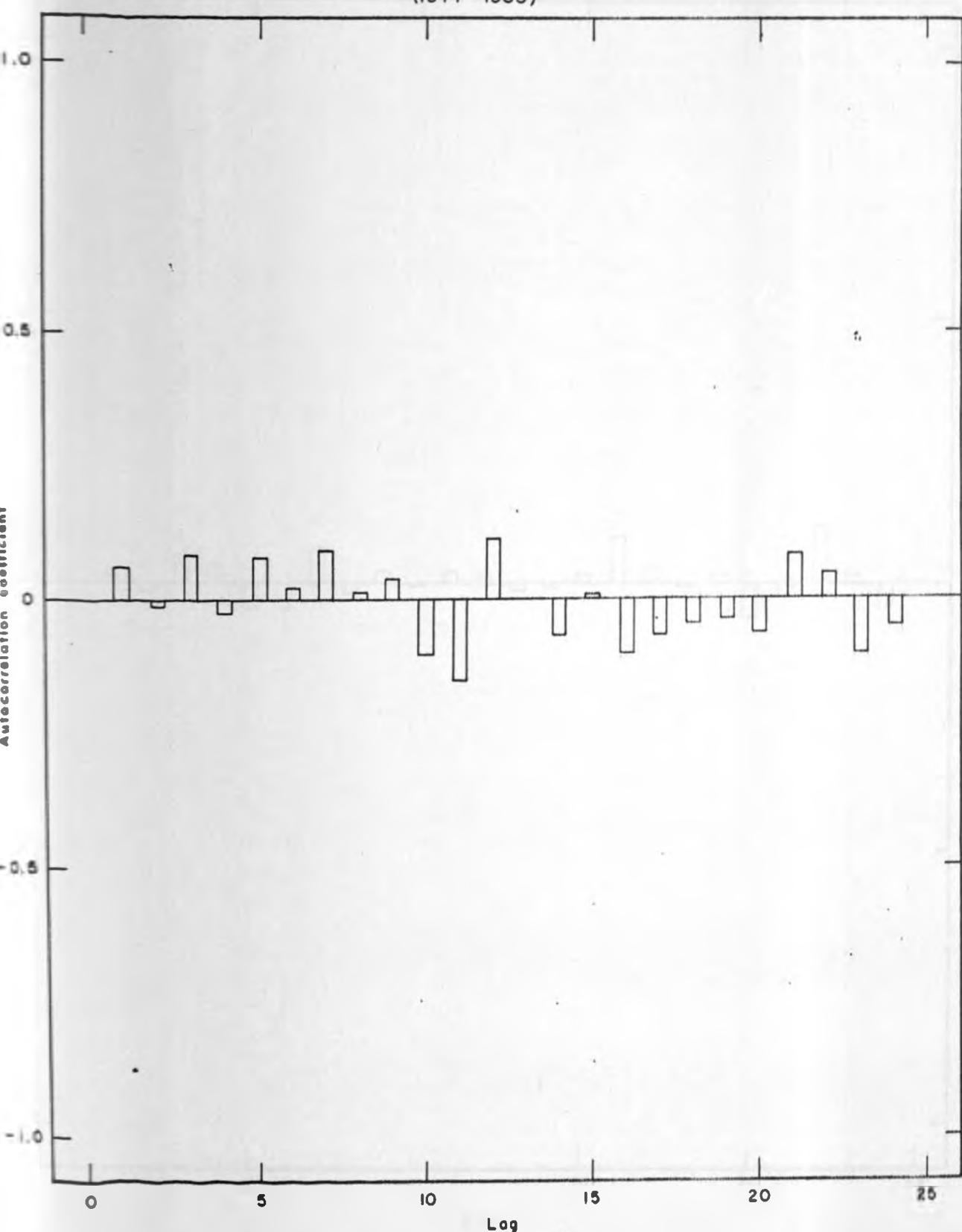
(Data Source: Meteorological Dept. 1971–85)

APPENDIX XXV  
MUHURU—ESTIMATED AUTOCORRELATION (JANUARY)  
(1971–1985)



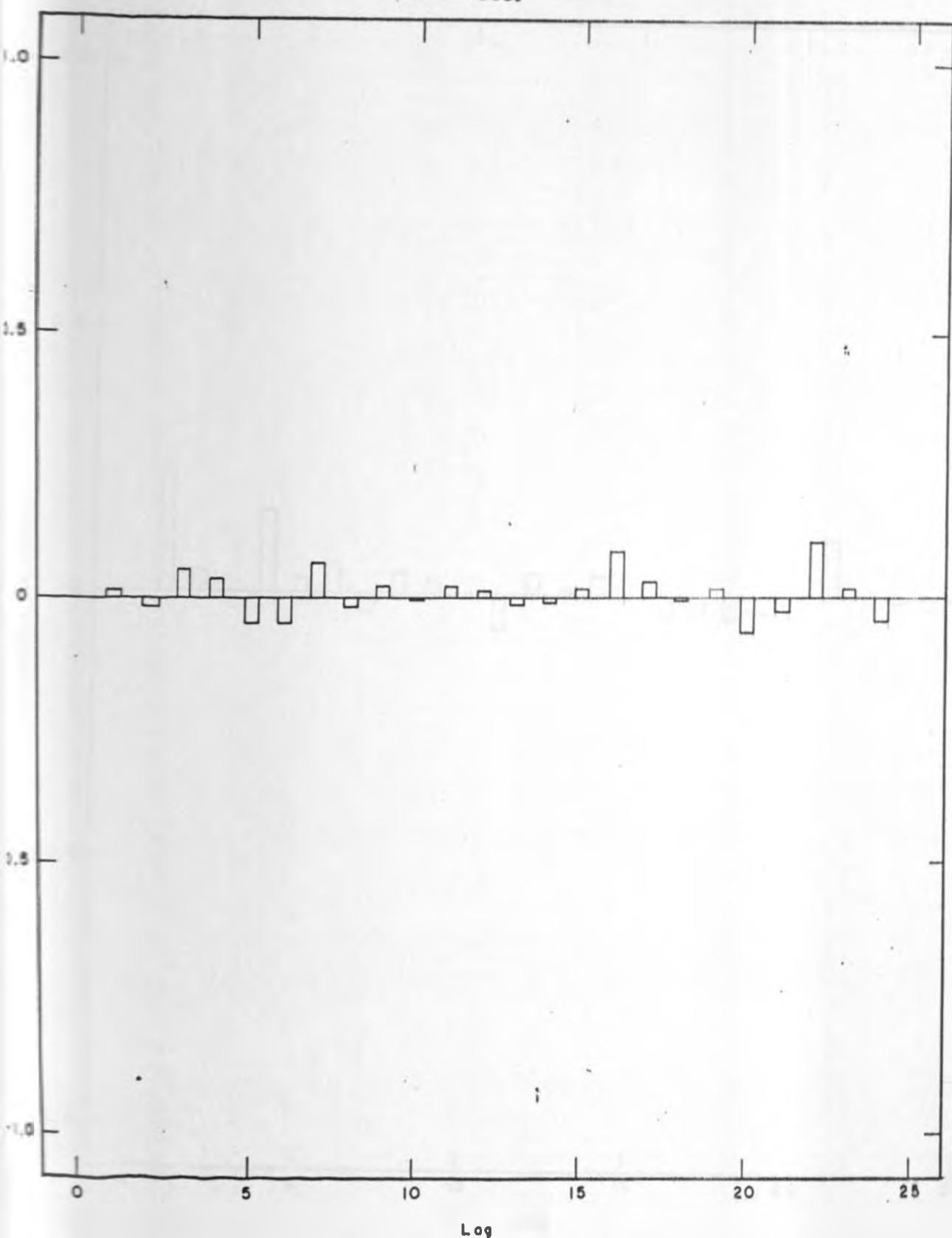
(Data Source: Meteorological Dept. 1971–85)

APPENDIX XXVI  
MUHURU — ESTIMATED AUTOCORRELATIONS (MAY)  
(1971—1985)



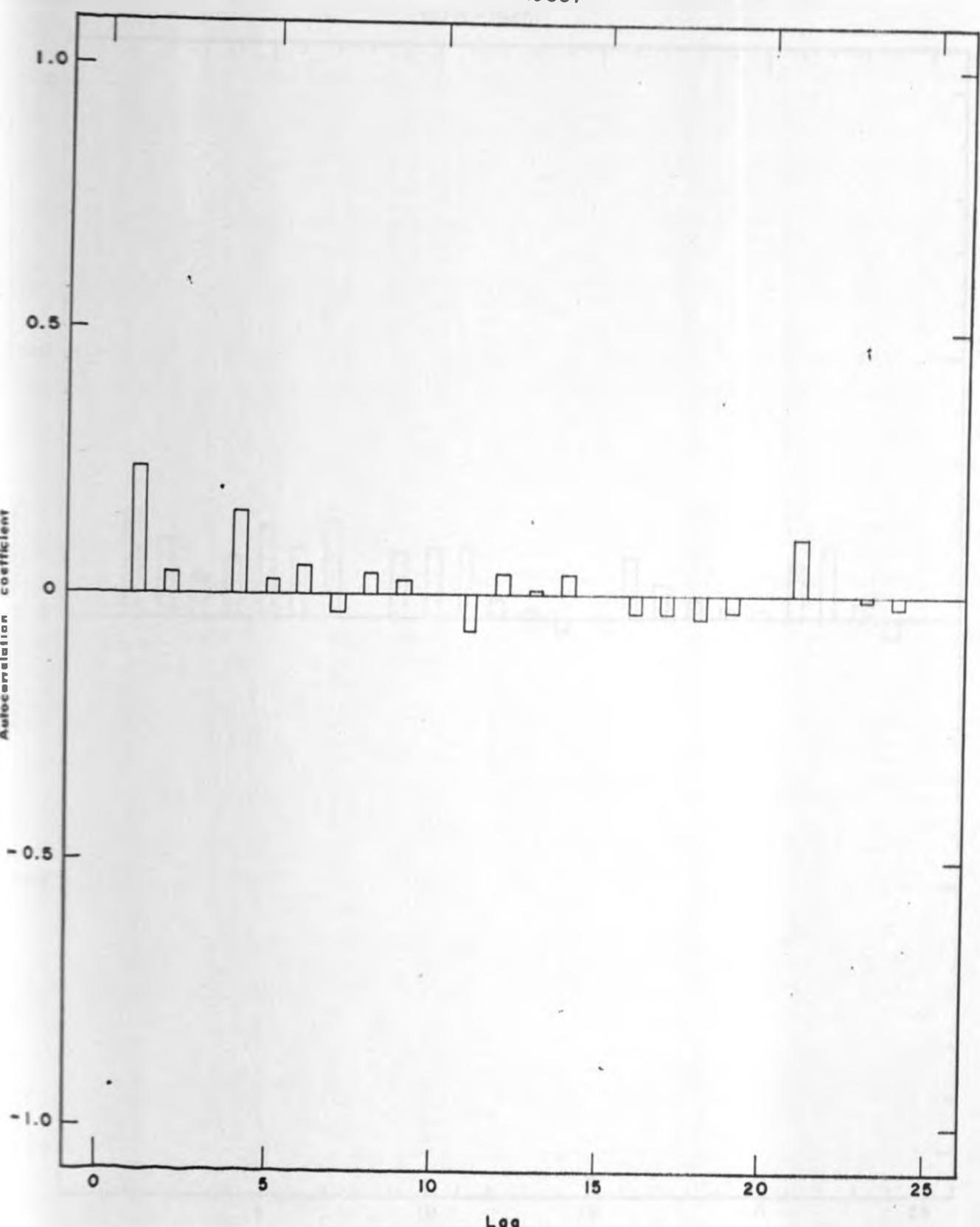
(Data Source : Meteorological Dept. 1971- 85)

APPENDIX XXVII  
MUHURU — ESTIMATED AUTOCORRELATION (JUNE)  
(1971—1985)



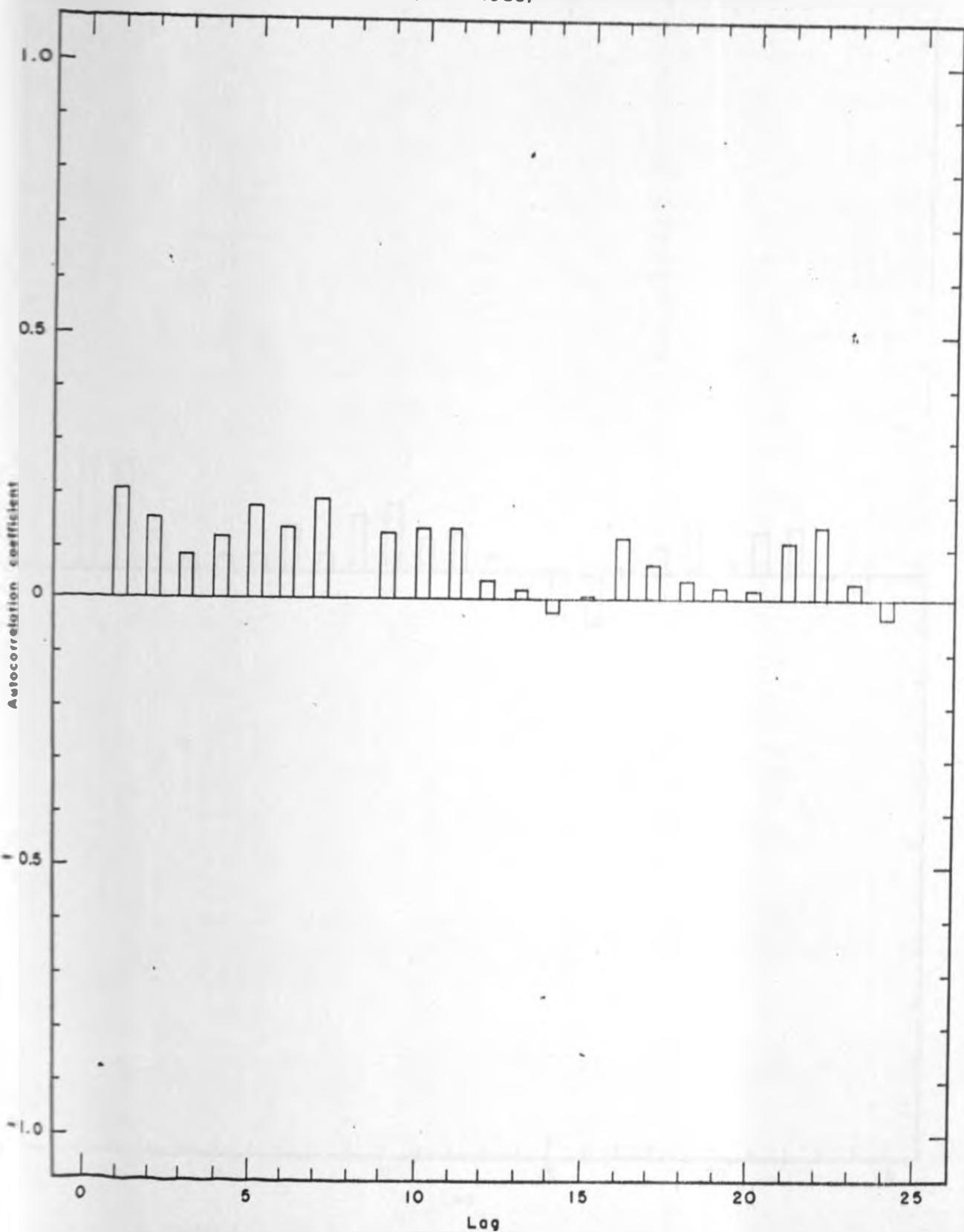
Data Source: Meteorological Dept. 1971-85)

## APPENDIX XXVIII

29 KISII — ESTIMATED AUTOCORRELATIONS (FEBRUARY)  
(1971—1985)

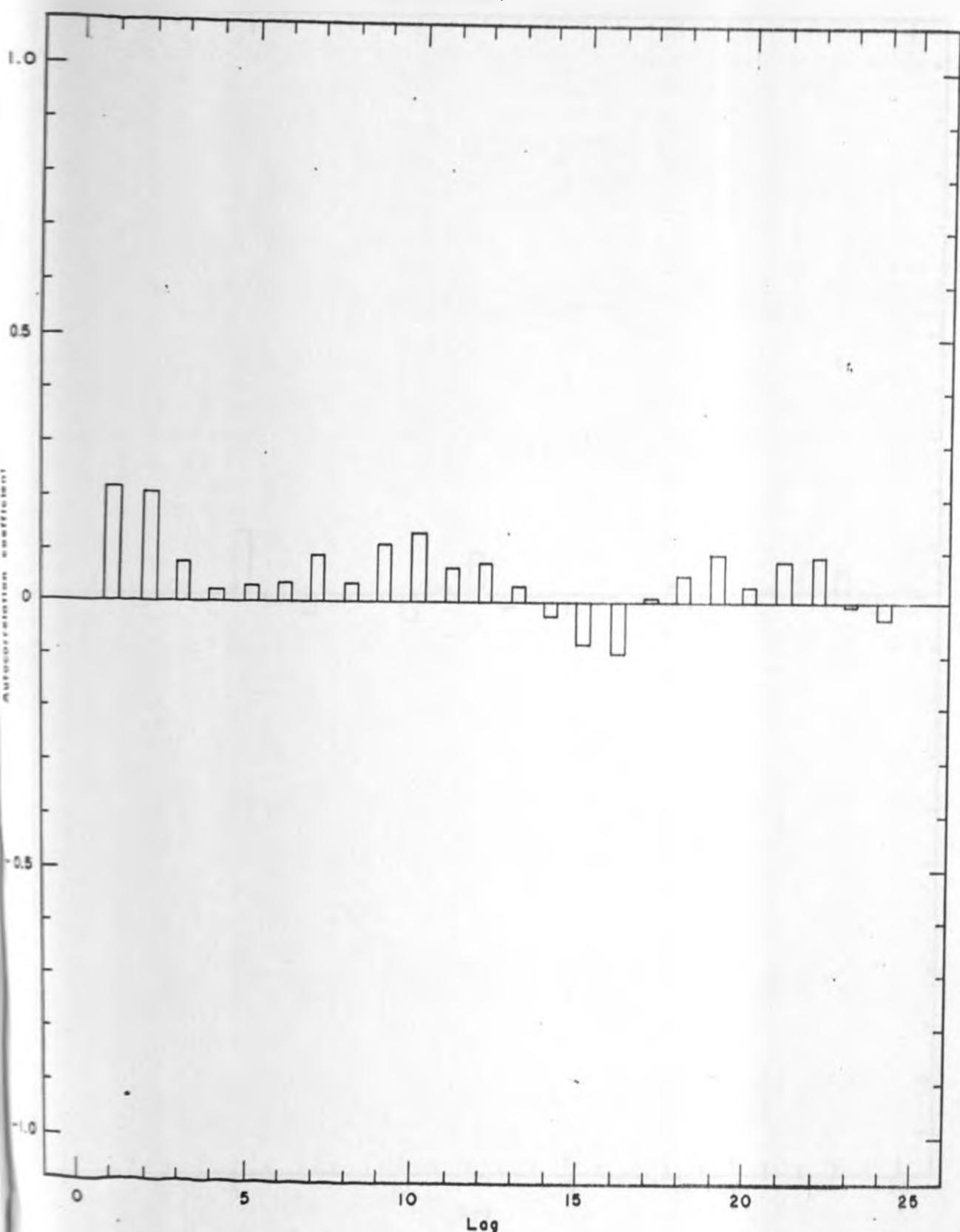
(Data Source: Meteorological Dept. 1971-85)

## APPENDIX XXIX

KISII — ESTIMATED AUTOCORRELATIONS (APRIL)  
(1971–1985)

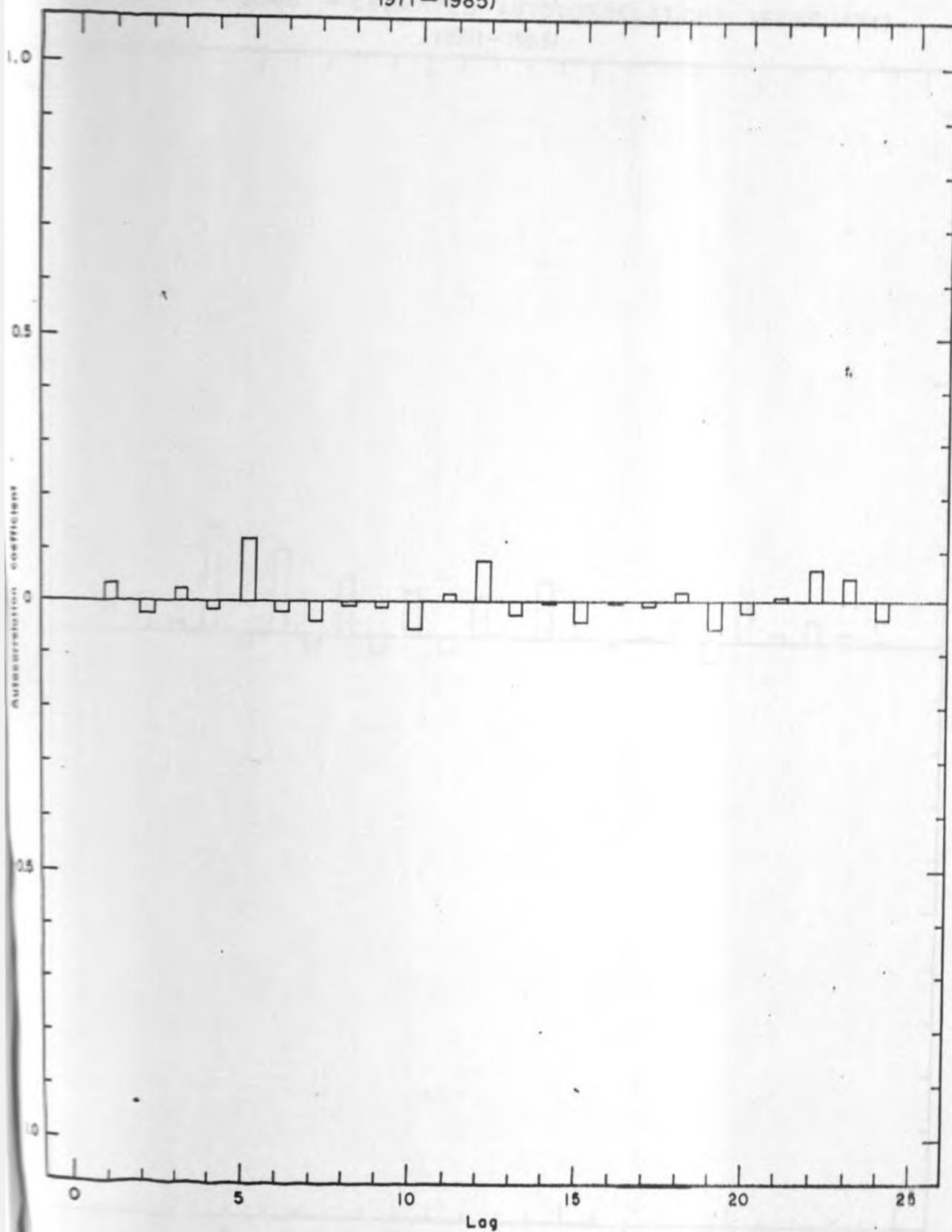
(Data Source: Meteorological Dept. 1971-85)

APPENDIX XXX  
KISII — ESTIMATED AUTOCORRELATIONS (JUNE)  
(1971—1985)



(Data Source: Meteorological Dept. 1971-85)

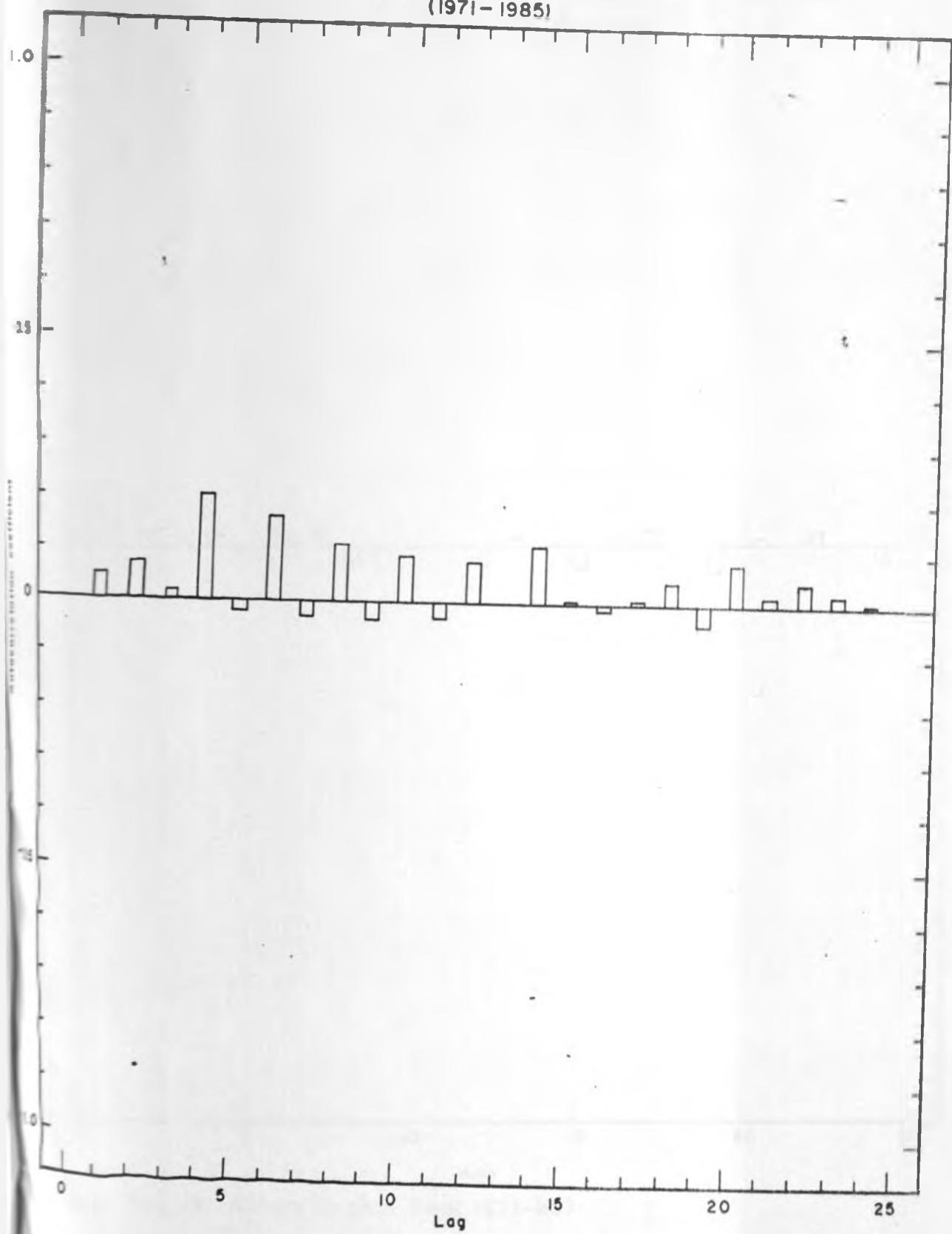
APPENDIX XXXI  
KISUMU - ESTIMATED AUTOCORRELATIONS (MAY)  
1971 - 1985)



(Data Source: Meteorological Dept. 1971-85)

APPENDIX XXXII

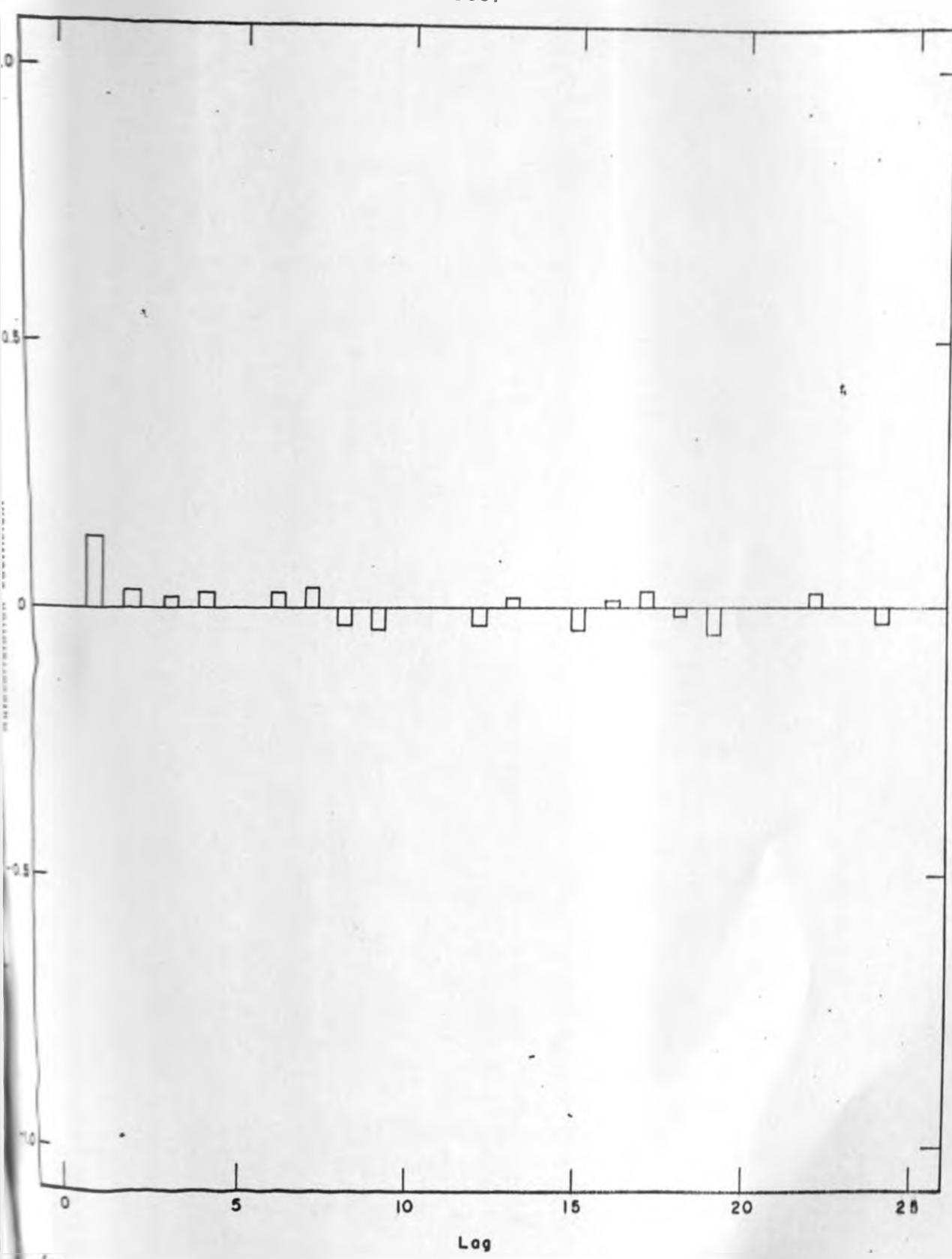
KISUMU — ESTIMATED AUTOCORRELATIONS (FEBRUARY)  
(1971–1985)



Data Source: Meteorological Dept. 1971–85)

APPENDIX XXXIII

ELGON - ESTIMATED AUTOCORRELATIONS (MAY)  
(1971 - 1985)



(Data Source: Meteorological Dept. 1971-85)