ANALYSIS OF SOME SEASONAL RAINFALL CHARACTERISTICS IN THE LAKE VICTORIA REGION OF KENYA

by

DAVID N. MUNGAI

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DECLARATION

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

Signature ....

DAVID N. MUNGAI

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

Signature ....

PROF. R.S. ODINGO

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ABSTRACT

Unlike any other part of Kenya, the Lake Victoria Drainage Basin is a complicated area both in terms of its orography and weather systems. The interplay of orography and the meso-scale lake-induced circulation systems, in the presence of the lower tropospheric flows, gives rise to seasonal rainfall regimes which have previously been variously defined. Knowledge of the seasonal rainfall regimes that occur in the area and some aspects of the characteristics of rainfall in each seasonal rainfall regime is important for water resources planning in general and for agriculture in particular. This study was an attempt to define and delimit the seasonal rainfall regimes of the Kenyan part of the Lake Victoria Drainage Basin. On the basis of the identified seasonal rainfall regimes, a few sample stations were selected and whose data were used to study the frequency of occurrence and distribution of wet and dry spells of various lengths.

The seasonal rainfall regimes were determined from a 67 x 67 inter-station correlation matrix which was based on the 10-day median rainfall of each station. The correlation matrix was subjected to Principal Components Analysis (PCA) the outcome of which was the extraction of 4 components (based on Kaiser's criterion of an eigenvalue of 1.0) which explained 89.2% of the system variance. Only the first two components showed spatial coherence and meaning; the first and second Varimax rotated principal components explained 50.8% and 33.1% of the total variance. This led to the identification and delineation of the "Kibos" and "Eldoret" seasonal rainfall regimes. At the boundaries of each regime, there were stations that had almost equal loadings on the first and second Principal Components (or seasonal rainfall regimes). These were considered transitional areas.

An examination of the annual march of the 10-day or "decade" rainfall for selected stations in each seasonal rainfall regime revealed that the "Kibos" regime is mainly bimodal, the rainy periods being March-May and October-December; for some stations, there is a third but relatively unimportant peak in August. The "Eldoret regime" has two rainfall peaks falling within a single rainy season which extends from April to September. The transitional zones around Kakamega, Nandi and Kericho have rainfall almost throughout the year.

For each seasonal rainfall regime, as well as for the transitional zones, a few stations were selected for the study of wet and dry spells. Two criteria were used to define a wet (and also dry) day i.e. 1.0mm and 5.0mm. The latter limit was chosen because of its agricultural importance given that potential evaporation in the study area is in the order of 4-6mm day^{-1}. For each station, for the common 30-year period (1941-1970), a count was made with the aid of a computer programme, of the wet and dry spells of various lengths. From these data, it was found that the frequency of both wet and dry spells fell off exponentially from the shortest duration to the longest. Wet and dry spells of short duration were more frequent in the "Kibos" regime. The data further showed that wet spells of longer durations were more frequent around Kericho and Tambach. For the 1.0mm criterion, the dry spells were longer than the wet spells except at Kakamega, Jamji Estate, Kericho and Sotik. These data help to emphasize the important differences between the main seasonal rainfall regimes. Near the lake, rainfall tends to fall in storms lasting anything from some minutes to a few days, while, particularly in the "Eldoret" regime and in the transitional areas, rainfall tends to persist for longer durations.

For some stations, the wet spells data were well described by both the Markov chain and Exponential distribution models according to the χ^2 goodness-of-fit test. Only in one case did the observed dry spells data fit the Exponential distribution model well: in all other cases, the fit of the dry spells data to the two models was poor.

From the cumulative frequencies of wet and dry spells, the percentage of times a period of a given type of weather (wet or dry) was followed by the same type of weather was evaluated. It was found that the probability of a type of weather recurring is higher the longer that type of weather has persisted.

The Principal Components Analysis (PCA) method clearly brought out the seasonal rainfall regimes existing in the study area. The delineation of the different seasonal rainfall regimes forms a basis for future planning of a more representative agro- and hydro-climatological network in the region. From the study of the wet and dry spells data, the spatial contrasts in the pattern of rainfall occurrence between the different rainfall regions were shown. This information is important in any consideration of water resources utilization in general, and in agriculture in particular.

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CHAPTER 1: INTRODUCTION

1.1 General considerations

Rainfall is one of the most important factors that influence agriculture. Rainfall has a major effect in determining the potential of an area in terms of the crops which can be grown and the timing and sequence of farming operations. From the agricultural point of view, rainfall is important as a supplier of soil moisture. The proportion of rain water that will constitute the soil moisture reserve depends largely on rainfall and soil characteristics, i.e. the total rainfall and its distribution, rainfall intensity and duration, soil depth and moisture holding characteristics, and the balance between rainfall and evapotranspiration, etc.

The agricultural rhythms occurring in different parts of Kenya are to a large extent controlled by the seasonal occurrence of rainfall. The seasonal occurrence of rainfall itself is the result of the main controls of weather and climate over Kenya, namely:

a) The general circulation: Kenya is influenced mainly by the South-East and North-East Trade winds: In the middle part of the year, an incursion of westerly winds occurs affecting mainly the western sector of the country. In much of the eastern sector of the country, the seasonal variations of rainfall are the result of the seasonal shifts of the Inter-Tropical Convergence Zone (ITCZ) which is related to the sun's apparent movements.

b) Topography and exposure: The effect of topography and exposure is mainly on the amount of rainfall received at a place: Topography, particularly over the Kenya highlands, acts to make the ITCZ rather diffuse.

c) Latitude: This determines the length of the rainy seasons and the timing of rainfall maxima and minima.

d) Inland lakes (particularly Lake Victoria): This control, together with topography, introduces modifications to the general circulation patterns. The nature of these modifications, and their effect on the pattern of rainfall occurrence in western Kenya are discussed in section 1.4.2.

An important aspect of the rainfall climatology of a place is the objective determination of the seasonal rainfall regimes. This is not a straightforward task to do as the various controls of weather and climate discussed above rarely act singly. Rather, because of the highly variable character of the atmospheric processes and the modifications that may occur from place to place, the seasonal rainfall regimes are bound to be complex. It is possible nevertheless to arrive at a generalized picture of the resultant seasonal rainfall regimes occurring in an area. As will be apparent in Chapter 2, the outcome of a seasonal rainfall regime analysis may well be a reflection of the analytical techniques used by an investigator. The results should, however, be similar no matter how many different methods have been used to determine the seasonal rainfall regimes. The main difference will occur in distinguishing the onset, duration and cessation of the seasonal rains. Although it is difficult to give precise limits of the onset, duration and cessation of the rainy seasons, a general picture should be given because it is important from the farming community's point of view.

An examination of the seasonal rainfall totals may indicate that adequate amounts of rainfall for a particular crop were received. This may, in reality not be so, for it is important to know the frequency of occurrence of rain and no-rain periods of different durations. Apart from revealing the pattern of the rainfall generating mechanisms that operate over an area, the study of wet and dry spells yields data that can be helpful in agricultural planning, especially with regard to planting, supplementary irrigation, erosion control strategies, the control of forest fires, and use of machinery on the farm.

It should be appreciated, however, that even if the seasonal rainfall regimes are objectively determined and delineated and that data are available of the wet and dry spells, soil and crop management factors should be taken into account to further define the availability of the growing season. As a first approximation, it is useful to know the seasonal rainfall regimes that occur in an area, and in addition, some rainfall characteristics in each regime.

The rainfall characteristics which are of special agricultural significance include the occurrence of wet and dry spells of various lenghts. This study set out as its major objectives (i) the determination and delineation of the seasonal rainfall regimes occurring in the Lake Victoria Drainage Basin and (ii) an examination of the occurrence and distribution of wet and dry spells in each seasonal rainfall regime within the same Basin.

1.2 Statement of the problem

The Lake Victoria Drainage Basin, because of its geographical location and tectonic history is an area of considerable diversity in terms of its orography and weather systems. The interplay of these two factors gives rise to seasonal rainfall regimes which are variously defined at the moment particularly with respect to their onset and cessation and consequently their duration; see for example Griffiths (1958, 1972); Survey of Kenya (1970) and Potts (1971). The seasonal rainfall regimes and their spatial expression have a marked influence on water supply problems in general, and on agriculture in particular. Most of the previous approaches to the definition of rainfall seasonality, and hence the growing season in this region and in Kenya in general have used the monthly rainfall data. Thus, tables and graphs of "representative stations" have been used in this "characteristic rainfall types" method to describe an areally continuous phenomenon, but in discrete classes. Little or no indication is usually given of the variability of the seasonal rainfall regimes depicted by the average data. All that one can infer from such data is that half of the time, the seasonal pattern of rainfall occurrence is realised. The approach lacks precision especially in indicating the transitions from one rainfall regime to another. Moreover, most of the rainfall studies have been done over one or all of the East African territories and thus have a low spatial resolution.

A feature of great significance to water supply in general, and to agriculture in particular is the occurrence and duration of wet and dry spells. Although the study area is commonly thought of as an area of high potential from the climatic point of view, dry spells do occur which can have serious implications on crop yields and forest fires. After the first "useful rains" when planting can be done, the occurrence of dry spells especially of long duration (for example 10 days or longer) after sowing is dangerous to germination and crop establishment. The severity of this phenomenon will be determined by the amount of antecedent soil moisture (which is a function of soil depth and soil moisture holding characteristics) evaporation rate and the rooting habit of crops.

Wet spells on the other hand have the significance that they affect not only crop growth per se, but they also affect farming operations, for example, seedbed preparation, weeding and harvesting. They also affect the incidence and virulence of plant diseases and pests. Together with the factors of soil type, slope gradient and land use etc, the frequency of wet spells affects soil erosion. The importance of the wet spells will depend on the antecedent soil moisture, the soil moisture storage capacity, the rainfall amount during the wet spells, the time when the rain falls, the balance between rainfall and evapotranspiration and the soil and crop management factors, etc.

1.3 Objective of the study

The objective of the study was two-fold:

i) To identify and delineate the seasonal rainfall regimes occurring in the study area. The method of Principal Components Analysis (P.C.A.) was used as an objective technique to achieve this goal and thereby validate the hypothesis that there exist general patterns of spatial covariation of rainfall seasonality in the study area against the null hypothesis that each rainfall station has a unique spatial distribution (see section 4.2.).

ii) To study the frequency of occurrence and the duration of wet and dry spells in each seasonal rainfall regime identified in (i). The [illegible]-square [illegible] goodness-of-fit test was used to validate the hypothesis that the observed sequences of wet and dry spells were well represented by the first order Markov chain and exponential distribution models against the null hypothesis that the data are not from the specified models (see sections 3.3.4 and 4.3.3).

It is hoped that the results will provide useful data which will be of interest to the farming community and agricultural planners, the hydrologist and meteorologist. The results may be particularly useful for the planning of additional climatological stations in the area studied.

1.4 The study area

1.4.1 Location and relief

The study area is confined to the Kenyan part of the Lake Victoria Drainage Basin (see fig. 1). It is situated in western Kenya and is bound approximately by longitudes $34^{\circ}00'$E and $35^{\circ}40'$E and latitudes $1^{\circ}30'$ [illegible] and $1^{\circ}20'$N. It has a total area of about $46,000km^2$ of which about $3,800km^2$ is water surface (mainly the Winam Gulf). In the west of the study area is Winam gulf and in the east are the western slopes of the Mau hills. In the north are Mt. Elgon and the Cherangani hills. The altitude of the area varies from slightly over [illegible] metres near the lake to well over 3,000 metres on Mt. Elgon and the Cherangani hills (see fig. 2). The greater part of the study area is below 2,[illegible] metres

Figure 1 Location of the study area

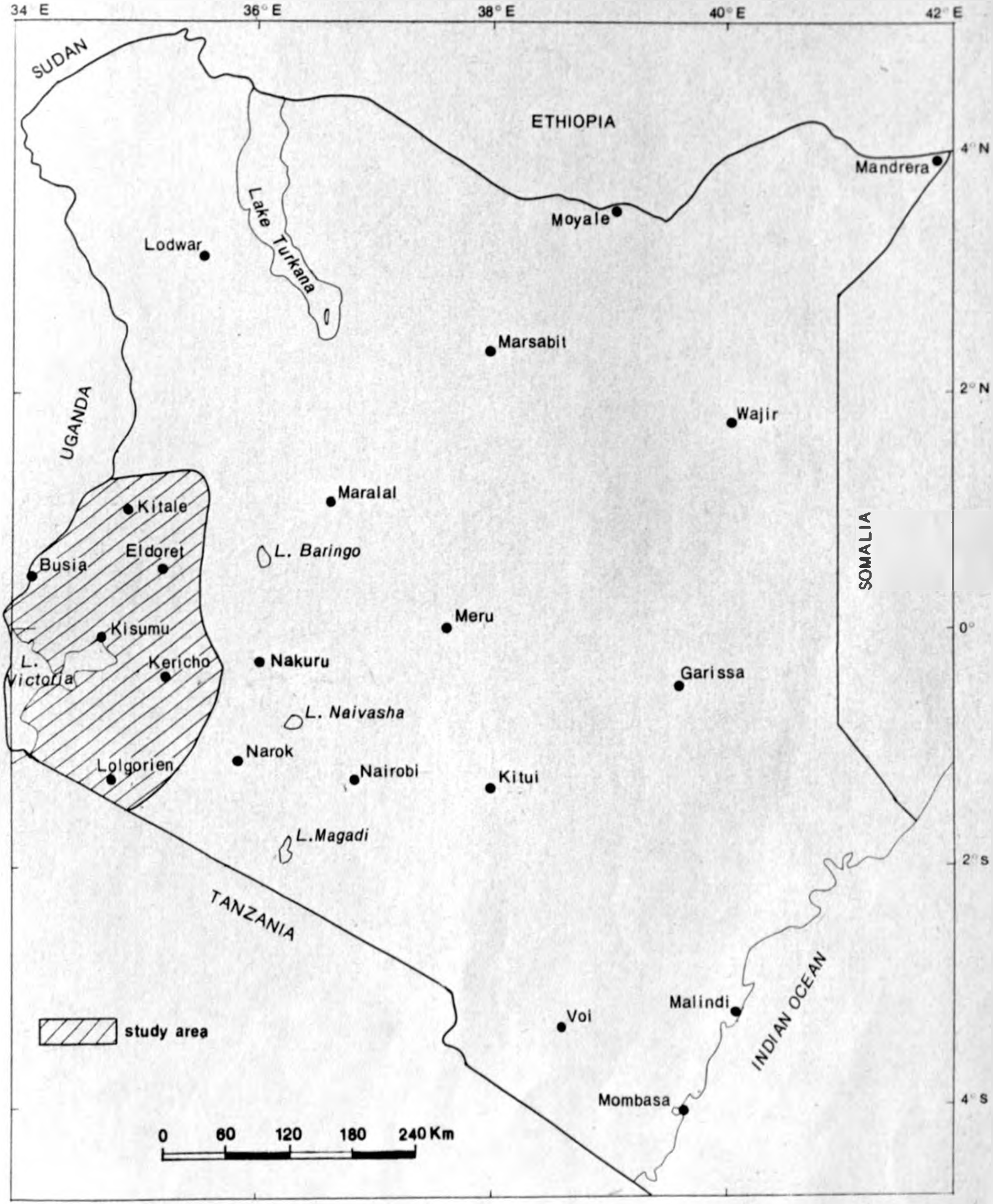
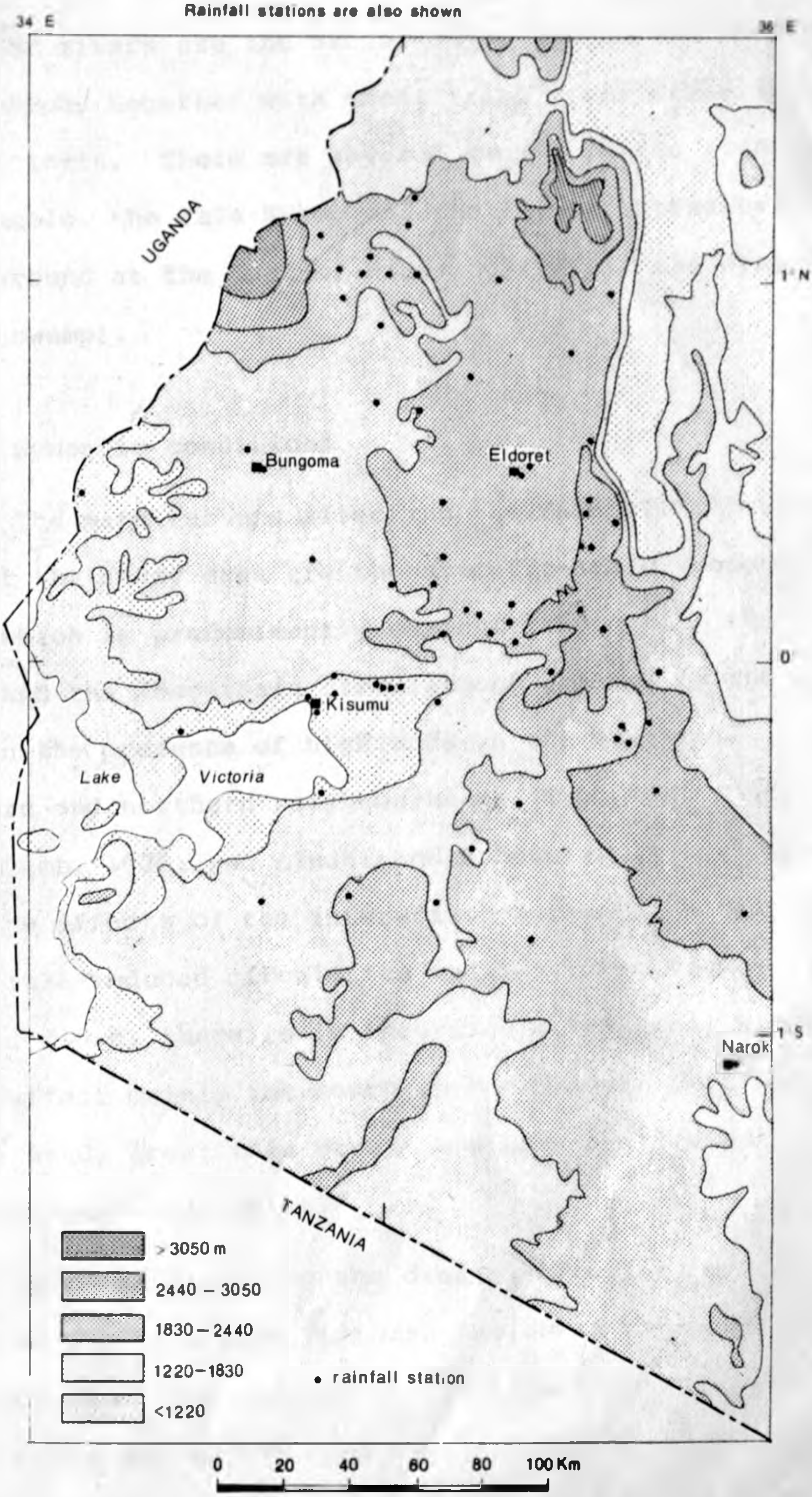


Figure 2 Relief map of the Lake Victoria Drainage Basin area
Rainfall stations are also shown



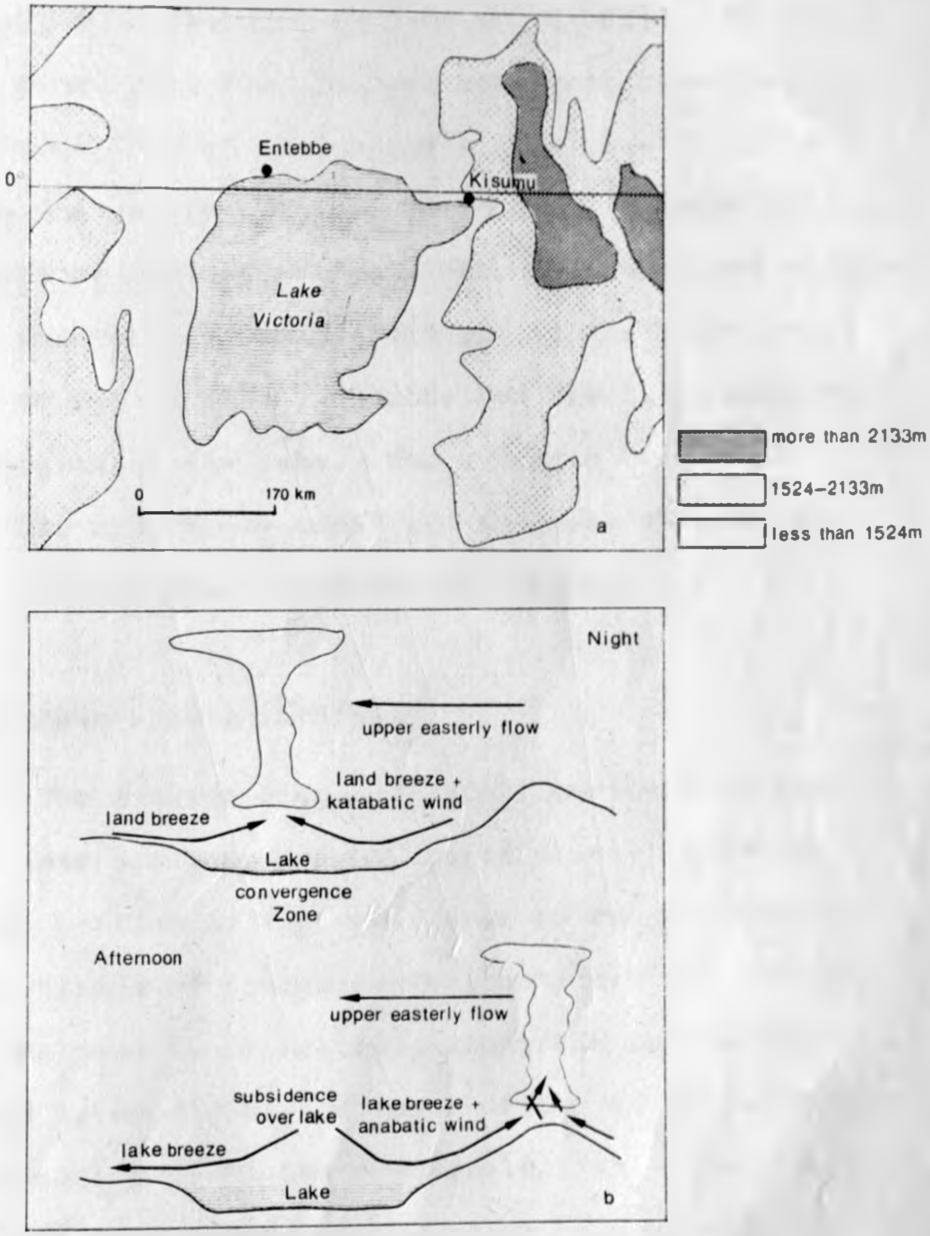
The major rivers are the Nzoia, Yala, Nyando and Sondu-Miriu which, together with their tributaries drain into Lake Victoria. There are several swamps in the area, for example, the Yala Swamp and the fairly extensive swamp ground at the head of Winam Gulf (i.e. the Nyando-Miruka swamp).

1.4.2 Synoptic conditions

The main factors affecting the rainfall climatology of the study area 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 highlands in the eastern, southern and northern neighbourhoods (Thompson, 1957; 1970, Lamb, 1970; and Asnani and Kinuthia, 1979). Apart from the effects of the interaction between the meso-scale lake-induced circulation and the lower tropospheric flows, there is an incursion of westerly winds which affect mainly the northern and eastern portions of the study area; this makes them have a different seasonal rainfall regime.

A model depicting the diurnal circulation patterns over the Lake Victoria region is shown in Fig. ③. Because of the temperature contrasts between land and lake, winds in the lake region blow off-shore during the day. On reaching the highlands, the lake-breeze is counteracted by the prevailing easterly winds

Figure 3 (a) Relief map of the Lake Victoria region (generalised)
(b) Weather over northern Lake Victoria area (after Lumb, 1970)

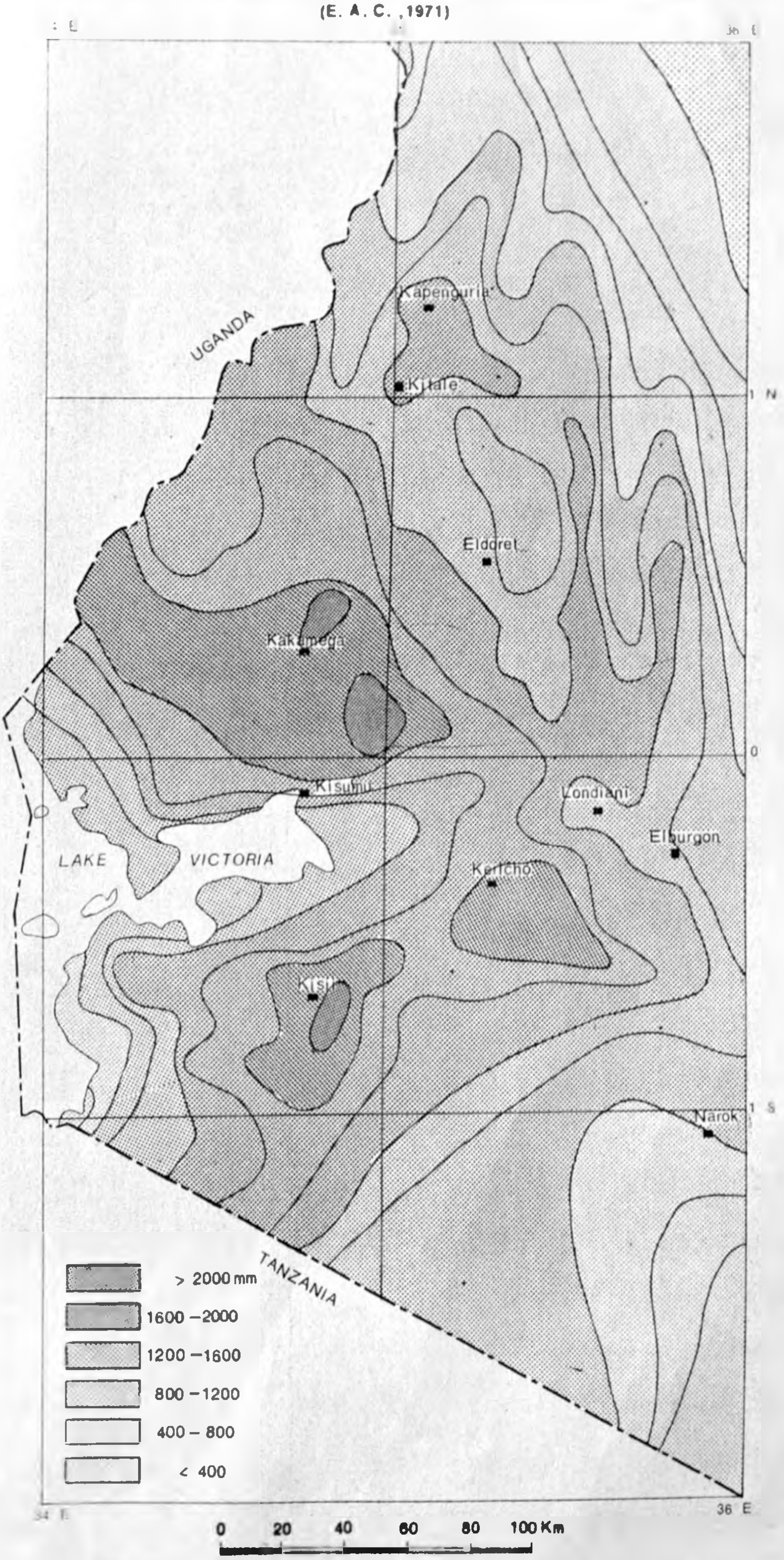


in lower troposphere, thus creating a convergence zone over the highlands. This leads to afternoon thunderstorms and appreciable amounts of rainfall. At night there develops a low pressure zone over the lake area. ~~The~~ convergence of land-breezes over Lake Victoria causes the uplift of warm, moist air. Because of the strength of the easterlies aloft, the resultant clouds drift westwards to bring rainfall in early morning hours to such areas as Entebbe and Bukoba on the western margins of the lake. The synoptic conditions therefore are rarely ideal for the lake margins in Kenya to have high rainfall year round.

1.4.3 Mean annual rainfall

The average annual rainfall varies from some 700mm near the lake shores, particularly in the south-western portion of the study area to over 2,000mm on the highlands of Kakamega, Kericho and Kisii (see fig. 4). The paucity of rainfall along the Lake Victoria margins is explicable in terms of the quite interesting interaction between the meso-scale lake circulation and the lower tropospheric circulation as was mentioned in section 1.4.2. As is evident in figure 4, the rainfall decrease is sharper towards the lake than in any other direction. The rainfall gradient is sharp again towards the Rift Valley. The monthly (seasonal) distribution of rainfall in the study area will be discussed in chapter 4.

Figure 4 Mean annual rainfall (in mm) in the Lake Victoria Drainage Basin area (E. A. C. ,1971)



1.4.4 Radiation, temperature and relative humidity

Solar radiation is important from the point of view of photosynthesis and evaporation. The seasonal variation of solar radiation in the Lake Victoria region is small as the data of table 1 indicate.

The amount of solar radiation reaching the surface of the earth is a function of the seasonal variations of the atmospheric conditions of dust and water content, cloud amount and type, the extinction coefficient of the clear sky, the earth-sun geometrical relationships and the slope/aspect of the surface. In the study area, radiation receipt is highest in the period from December to March compared to the rest of the year. In terms of spatial contrasts, the Lake Victoria lowlands, as exemplified by Kibos, Kisumu and Ahero receive higher radiation compared to such high altitude stations as Kericho, Kisii and Kitale. The lower radiation on the highlands is due to increased cloud cover.

Temperature is a significant climatic element because of its influence on evaporation and on plant growth and development. Atmospheric humidity on the other hand is significant due to its effect on evaporation and also on the incidence and virulence of plant diseases and pests. The seasonal as well as the spatial contrasts of temperature and relative humidity in the study area are shown in tables 2-5 for the months of January, April, July and November. April and November

Table 1. Daily radiation (Langleys) for some stations in the study area (the radiation data was measured with the Gunn-Bellani Radiation Intergrator).

	Ahero	Busia	Kericho	Kibos	Kisii	Kisumu	Kitale
January	626	591	551	655	514	530	559
February	632	572	551	644	525	554	527
March	633	555	538	634	523	504	490
April	575	557	443	593	501	509	492
May	594	561	440	583	454	502	480
June	565	547	458	575	501	497	467
July	525	505	414	543	477	468	439
August	539	538	418	557	489	496	451
September	594	596	454	624	570	529	501
October	600	592	439	625	541	533	495
November	585	553	431	598	489	524	438
December	616	600	498	636	532	557	564
Year	590	564	470	606	510	517	496

Source: East African Meteorological Department (1975)

Table 2. Temperature and humidity conditions during January for some stations in the Lake Victoria Drainage Basin

Station	means		Range °C	R.H. %	
	max. °C	min. °C		0900hr	1500hr
Ahero	31.3	15.3	16.0	61	36
Busia	29.4	15.5	13.9	69	47
Eldoret	25.2	8.3	16.9	63	39
Equator	19.7	7.7	12.0	71	43
Kapenguria	25.0	8.2	16.8	62	43
Kericho	24.0	8.7	15.3	60	47
Kibos	30.8	15.3	15.5	60	36
Kisii	26.9	11.7	15.2	64	49
Kisumu	30.6	17.0	13.6	60	41
Kitale	27.1	10.4	16.7	70	35
Koru	29.5	13.2	16.3	64	41
Molo	21.9	6.5	15.4	69	44

Source: East African Meteorological Department (1975)

Table 3. Temperature and humidity conditions during April for some stations in the Lake Victoria Drainage Basin

	means			R.H. %	
Station	max. °C	min. °C	Range °C	0900hr	1500hr
Ahero	29.1	16.8	12.3	74	53
Busia	28.0	16.8	11.2	80	62
Eldoret	24.7	11.2	13.5	76	49
Equator	19.2	8.8	10.4	83	55
Kapenguria	23.8	9.9	13.9	70	58
Kericho	22.3	10.1	12.2	77	73
Kibos	28.1	16.7	11.4	73	52
Kisii	25.8	13.2	12.6	77	59
Kisumu	28.8	17.9	10.9	76	53
Kitale	25.2	12.8	12.4	83	55
Koru	27.4	14.6	12.8	75	62
Molo	21.1	8.5	12.6	80	56

Source: East African Meteorological Department (1975)

Table 4. Temperature and humidity conditions during July for some stations in the Lake Victoria Drainage Basin

Station	means		Range °C	R.H. %	
	max. °C	min. °C		0900hr	1500hr
Ahero	28.9	15.7	13.2	72	44
Busia	26.8	15.7	11.1	81	56
Eldoret	21.8	9.5	12.3	86	60
Equator	15.8	7.8	8.0	84	74
Kapenguria	21.3	9.6	11.7	78	70
Kericho	20.5	9.1	11.4	81	70
Kibos	27.8	14.9	12.9	71	44
Kisii	25.0	12.0	13.0	68	53
Kisumu	27.7	16.2	11.5	74	49
Kitale	22.9	11.8	11.1	90	64
Koru	27.0	13.3	13.7	76	60
Molo	18.7	6.8	11.9	82	65

Source: East African Meteorological Department (1975)

Table 5. Temperature and humidity conditions during November for some stations in the Lake Victoria Drainage Basin

Station	means		Range °C	R.H. %	
	max. °C	min. °C		0900hr	1500hr
Ahero	30.5	15.6	14.9	65	48
Busia	27.7	16.2	11.5	75	58
Eldoret	23.6	10.1	13.5	71	51
Equator	18.6	7.9	10.7	84	56
Kapenguria	22.9	9.1	13.8	69	59
Kericho	21.9	9.5	12.4	69	67
Kibos	29.2	15.8	13.4	65	47
Kisii	25.5	12.1	13.4	68	61
Kisumu	30.2	17.3	12.9	63	45
Kitale	24.4	11.2	13.2	78	53
Koru	28.3	13.5	14.8	66	54
Molo	20.1	7.5	12.6	77	57

Source: East African Meteorological Department (1975)

are rainy months while January is a dry and hot month. July is cool and dry over most parts of Kenya.

1.4.5 Potential evaporation (Eo)

Potential evaporation (Eo) is in the order of 2,200mm yr^{-1} near the lake down to about 1,400mm yr^{-1} on the highlands (see fig. 5). Potential evaporation, like temperature, is inversely related to altitude as is indicated in fig. 6. On a daily basis, potential evaporation in the study area is about 4-6mm day^{-1} (Woodhead, 1968).

1.4.6 Agroclimatic zones

Agroclimatic zones provide a first impression of the climatic suitability of various land use alternatives with emphasis on the suitability for particular crop varieties. According to the Kenya Soil Survey agroclimatic zonation methodology, the study area falls in agroclimatic zones I-IV (Sombroek et al, 1982). The potential for rainfed agriculture varies from "very high" in zone I to "medium" in zone IV (see fig. 7 and table 6). There is probably no other region in Kenya that contains such a high proportion of high potential land from the agroclimatic point of view as the study area. The proportion of medium potential land is very small and confined to the Lake Victoria littorals.

Figure 5 Annual potential evaporation (Eo, in mm) in the Lake Victoria Drainage Basin area (after Woodhead, 1968).

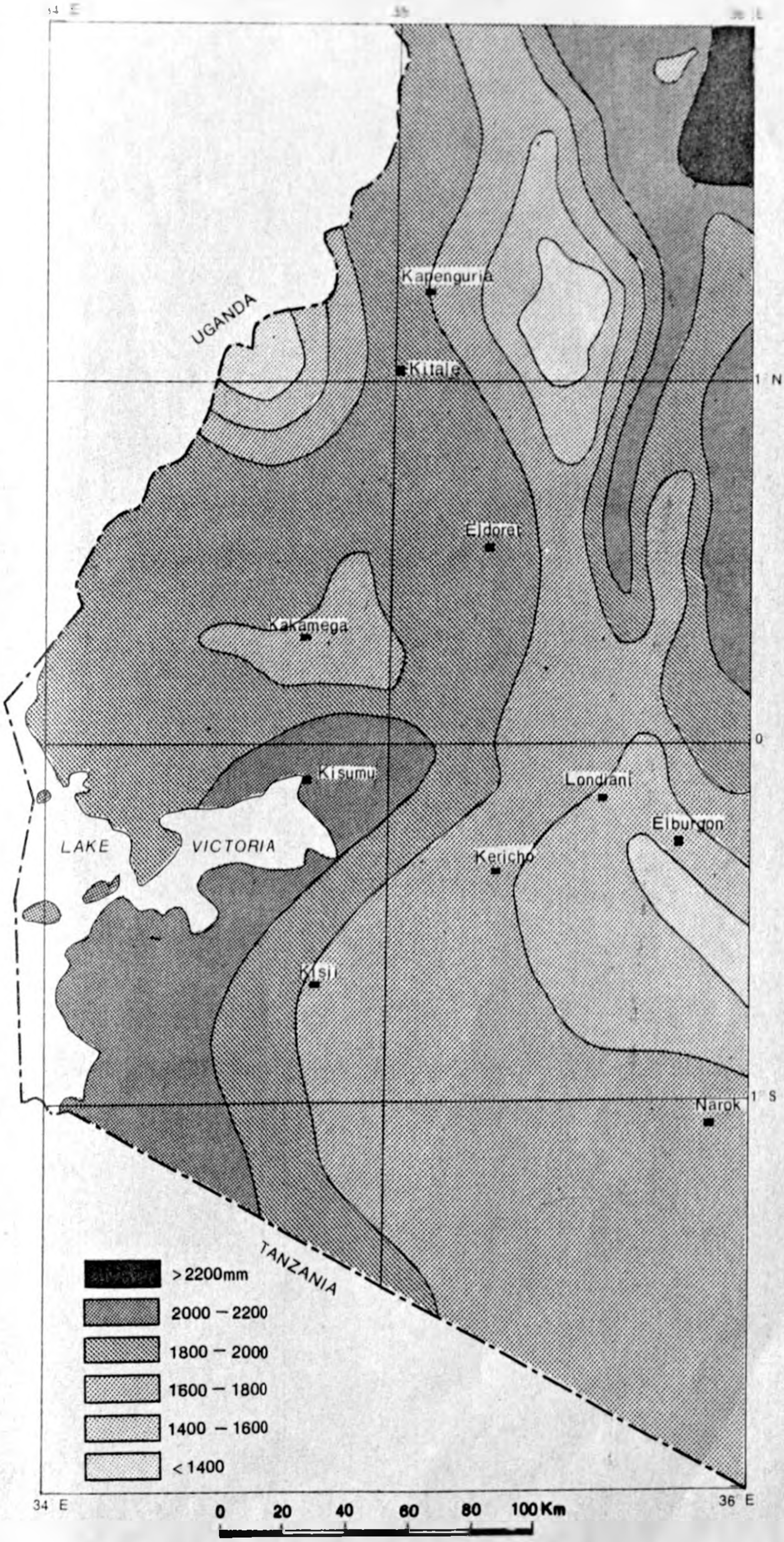


Figure 6 Average annual potential evaporation(Eo) as a function of elevation in the Lake Victoria Drainage Basin The data are from Woodhead (1968). Names of meteorological stations are given

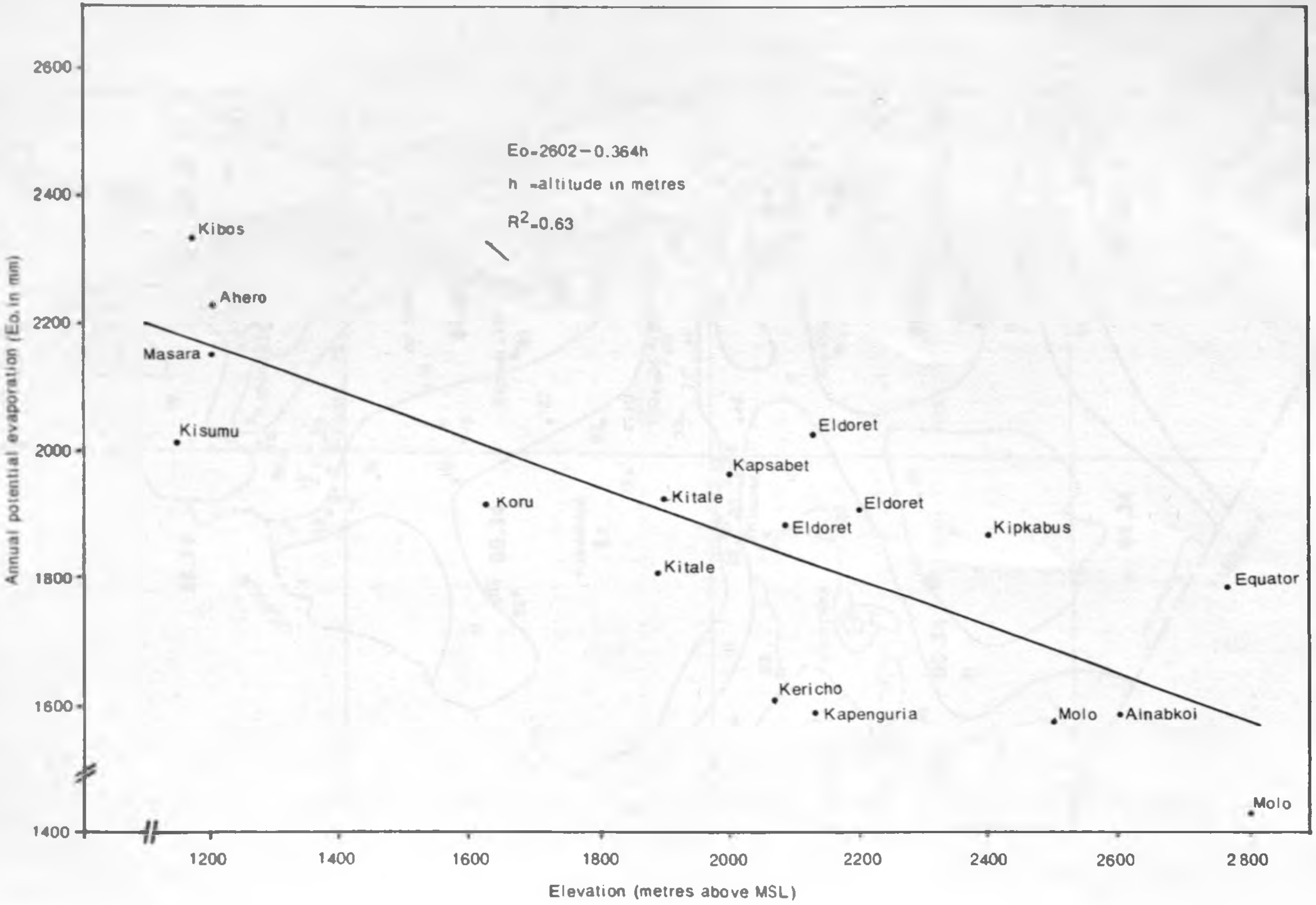


Figure 7 Agroclimatic zones (with rainfall stations used in this study)

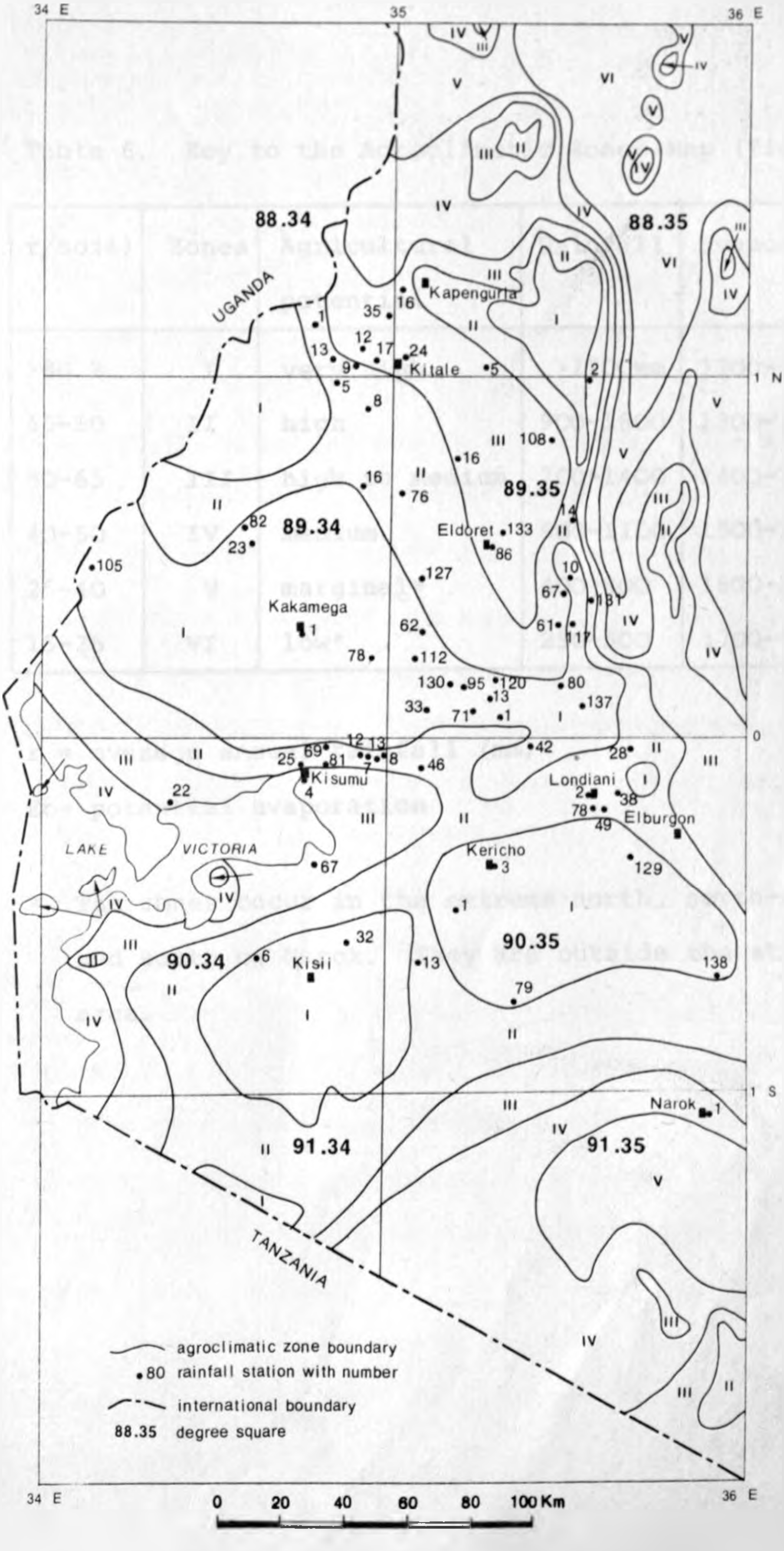


Table 6. Key to the Agroclimatic Zones Map (fig. 7)

r/Eo(%)	Zones	Agricultural potential	Rainfall	Evaporation
>80 %	I	very high	>1200mm	1200-2000mm
65-80	II	high	900-1600	1300-2100
50-65	III	high to medium	700-1400	1400-2200
40-50	IV	medium	600-1100	1500-2300
25-40	V	marginal*	400-800	1600-2400
15-25	VI	low*	250-500	1700-2500

r = average annual rainfall (mm)
Eo= potential evaporation

* The zones occur in the extreme north, north-east and south of Narok. They are outside the study area.

CHAPTER 2: LITERATURE REVIEW

The most studied climatic element in East Africa is rainfall. The various rainfall studies have focussed on the spatial characteristics of the daily rainfall (e.g. Johnson, 1962) or the mean monthly and mean annual rainfall (e.g. Tomsett, 1969; E.A.C., 1971), the variability of annual rainfall (e.g. Glover, Robinson and Henderson, 1952) or the reliability of rainfall during the rainy seasons (e.g. Kenworthy and Glover, 1958; Dowker, 1963; Manning, 1950; Glover and Robinson, 1953 and Braun, 1978a; 1978b).

Some attempts have been made to define and delimit the seasonal rainfall regimes occurring in East Africa. Examples of such studies include those of Walter (1952), Kenworthy and Glover (1958), Griffiths (1958; 1972), Tomsett (1969), Survey of Kenya (1970), Potts (1971), Atwoki (1975), Braun (1977), Nieuwolt (1978), Hills (1978) and Alusa (1978).

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Walter (1952), Tomsett (1969), Braun (1977) and Nieuwolt (1978) used either the simple method of expressing the average monthly rainfall as a percentage of the average annual rainfall or mapped the average monthly rainfall to show the monthly progression of the rain belts. Hills (1978) on the other hand calculated and mapped the 6-day median rainfall for some 236 stations in East Africa. From the derived maps, it is possible to follow the progression of the rainy seasons and also obtain a rough approximation of their onset, duration and cessation.

Kenworthy and Glover (1958) used the mean monthly rainfall to define and map the duration of the main growing seasons in Kenya. When it was not clear from the mean rainfall regime which months could be regarded as wet months, the mean monthly rainfall was compared with its standard deviation; if the standard deviation was less than 50% of the mean, that month was included as part of the rainy season. The main seasonal rainfall at the Kenya coast was indicated to extend from April to June while in western Kenya, the seasonal rains extend from April to August. For the rest of the country, the main rains extend from March to May.

In order to define and map the rainy seasons, Griffiths (1958) defined a rainy month as one in which the rainfall exceeded one twelfth of the annual amount. Using this criterion, he divided Kenya into some seven major seasonal rainfall regimes. According to this study, the Lake Victoria region is shown to have three main seasonal rainfall distribution types, namely:

a) The Arua-Kitale-Kericho type with a single rainy period extending from April to September. The zone is further subdivided on the basis of mean annual rainfall into the Kericho area with over 1500mm yr^{-1} and the rest of the zone with 1250-1500mm yr^{-1}.

b) The bimodal northern Lake Victoria regime with a mean annual rainfall of 1100-1500mm. The rainy periods extend from March to June and October to November. This regime extends around the northern shores of Lake Victoria, mainly in Kenya and Uganda.

c) The monomodal Narok regime with the rainy period extending from November to May. The mean annual rainfall in this regime is some 600-750mm.

Although this classification is close to that shown in the Kenya Atlas (Survey of Kenya, 1970), there are discrepancies relating to the onset and/or the end of the rainy seasons and their duration. This is not made any clearer by Griffiths' (1972) later study in which more details are shown than in the earlier study. In the latter study, Griffiths used 50mm per month as a criterion to distinguish wet months. A superimposition of twelve monthly maps of wet areas produced 52 separate regions covering 30 different rainfall seasons over East Africa.

Potts (1971) used harmonic analysis to assess quantitatively the annual march of rainfall in East Africa. According to this study, a good portion of the Kenyan part of the Lake Victoria Basin was classified as a transition zone. To the north and east of the transition zone are unimodal and trimodal seasonal rainfall regimes (see fig. 8 and table 7). To the south, Fig 8 Basic rainfall regimes of East Africa based on harmonic analysis data (after Potts, 1971)

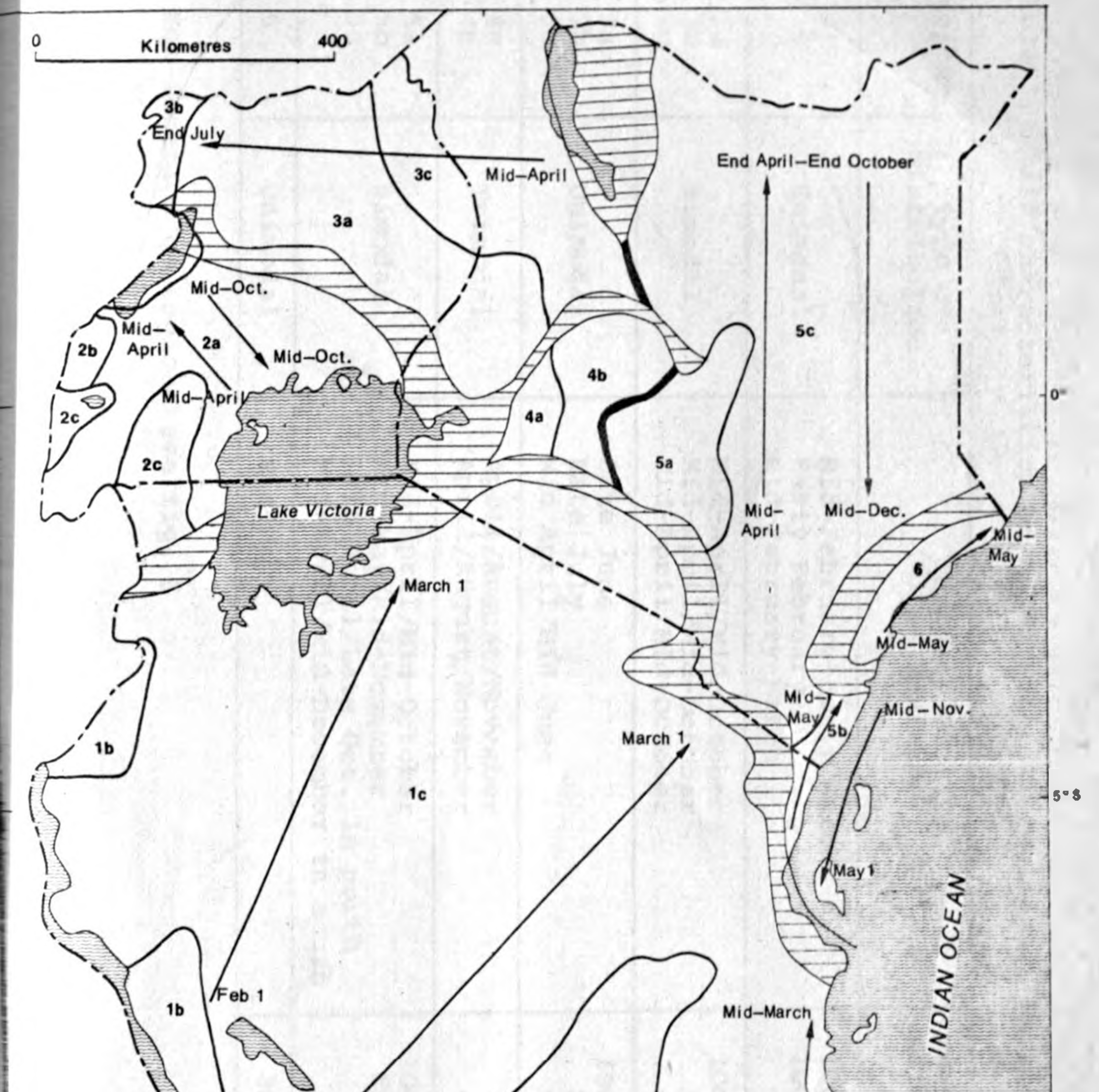


Table 7. Main characteristics of major rainfall regimes in East Africa (after Potts, 1971)

Region	Type of Distribution	Temporal Position of Maximum	Mean Annual Rainfall (mm)	Amplitude of Dominant Harmonic (mm)
1a	Unimodal	Mid-February-Early March	1000-2000+	100-190
1b		Early February	1000-1400	80-140
1c		Mid-February-March	<1000	50-110
2a	Bimodal	Mid-April/Mid-October	1000-1600+	40-70
2b		Mid-April/Mid-October	>1400	50-60
2c		Mid-April/Mid-October	<1000	<50
3a	Unimodal	Late June	1000-1600	50-80
3b		Late July	>1200+	40-70
3c		Mid April/Mid June	<1000	<50
4a	Trimodal	April/August/November	>1000	25-30
4b		April/August/November	<1000	30-35
5a	Bimodal	Mid-April/Mid-October	1000-1200	60-100
5b		Mid-May/Mid-November	800-1200+	50-80
5c		Late April/Late Oct. in north Mid-April/Mid-December in south	<800	<50
6	Unimodal	Mid-May	800-1000	60-90

For location of regions see fig. 8

mainly in northern Tanzania and south-east of the study area is another unimodal regime with peak rainfall in the period from mid-February to March.

Alusa (1978), following the method of Ilesanmi (1972), studied the onset, duration and cessation of the East African rains using pentad rainfall. Only five stations from the Kenyan part of the Lake Victoria Drainage Basin were included in this study. These stations are Kitale, Kisumu, Kericho, Kisii and Narok. The latter station is outside the Basin area. Kisumu, Kericho and Kisii are indicated as bimodal rainfall stations while Kitale and Narok are shown as monomodal types.

Atwoki (1975) used a factor analytic approach based on the annual march of 10-day lower quartile rainfall to define and delimit the seasonal rainfall regimes of Uganda. He identified and mapped six seasonal rainfall regimes for Uganda.

Ogallo (1980) on the other hand based his Principal Components Analysis (PCA) on annual rainfall totals to group the East African rainfall stations into homogenous groups (see fig. 9 and table 8).

Similar approaches as followed by Atwoki and Ogallo have been applied in different parts of the world, for example, the works of Gregory (1975), Steiner (1965), Preston-Whyte (1974), Horel (1981), Williams and Terjung (1981, Sellers (1968), Richman

Fig. 9 Regional classification from the orthogonal Varimax rotation
(after Ogallo,1980)

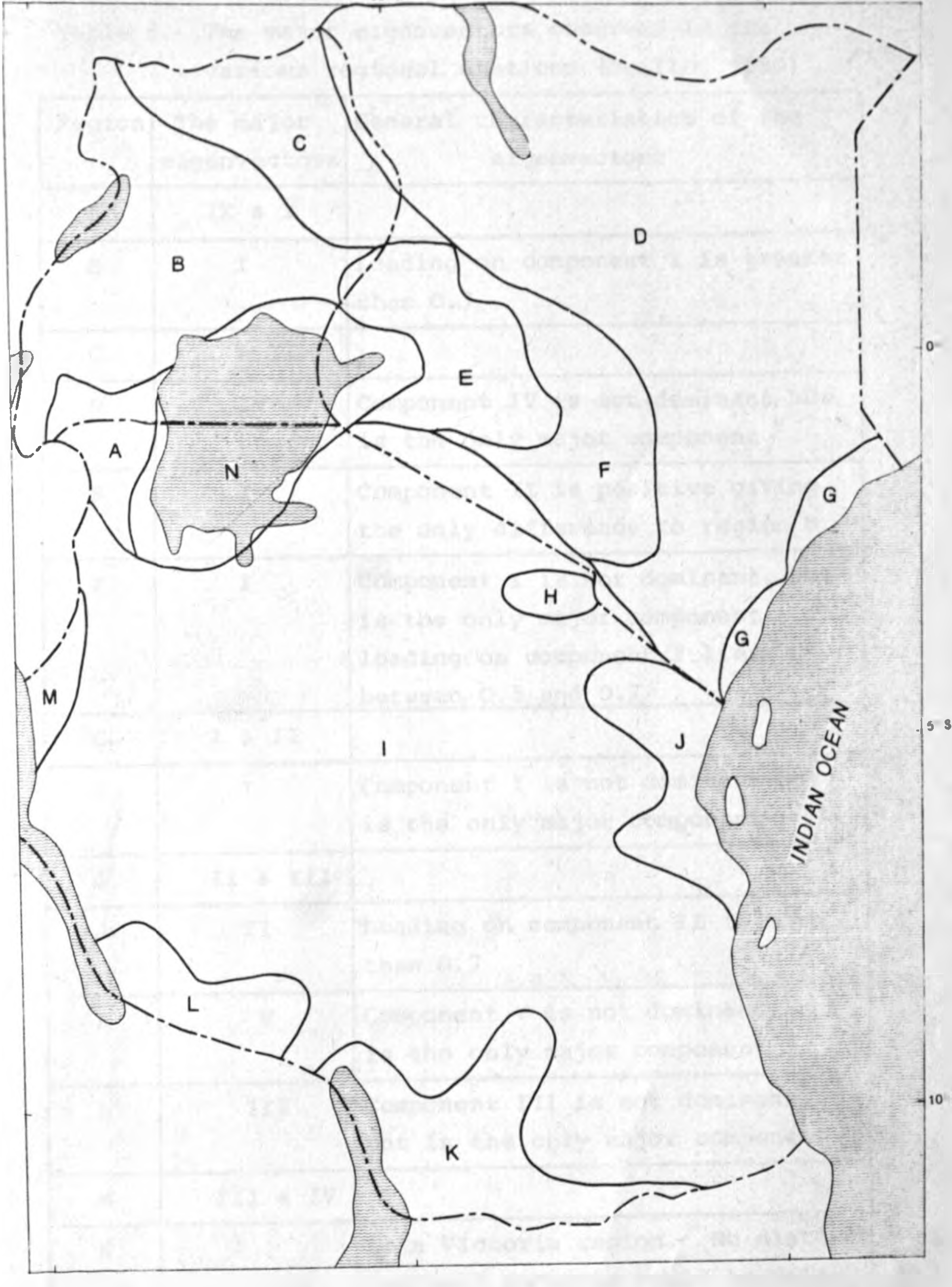


Table 8. The major eigenvectors observed in the various regional stations (Ogallo, 1980)

Region	The major eigenvectors	General characteristics of the eigenvectors
A	IX & I	
B	I	Loading on component I is greater than 0.7
C	I & II	
D	IV	Component IV is not dominant but is the only major component
E	I	Component II is positive giving the only difference to region B
F	I	Component I is not dominant, but is the only major component. The loading on component I lies between 0.5 and 0.7
G	I & II	
H	I	Component I is not dominant but is the only major component
I	II & III	
J	II	Loading on component II is more than 0.7
K	V	Component V is not dominant, but is the only major component
L	III	Component III is not dominant, but is the only major component
M	III & IV	
N		Lake Victoria region. No distinct regional patterns could be delineated but the characteristics of the lake stations were close to those of the bordering regions

(1981) and Walsh et al (1982) among others.

Apart from defining and indicating the spatial expression of the seasonal rainfall regimes occurring in an area, it is important for practical purposes, to study the rainfall characteristics in each regime. A rainfall characteristic of great importance to water resources utilization in general and to agriculture in particular is the occurrence and duration of wet and dry spells. Research work along these lines in East Africa is lacking except the initial work of Alusa et al (1978). Alusa and his collaborator studied the occurrence of dry spells during the East African "long rains". Following his earlier study (Alusa, 1978), they used a long rains season of the same duration (i.e. March to June) for the whole of Kenya. Results from this study indicate that dry spells are associated with topography which in turn influences the mean annual rainfall quite considerably in East Africa

Studies of the occurrence of wet and/or dry spells have been carried out in other parts of the world. Such studies include those of Jorgenson (1949), Williams (1952), Longley (1953), Gabriel and Neuwmann (1962), Caskey (1963, Weiss (1964), Hopkins et al (1964) and Basu (1971) among others.

Jorgenson (1949) based his study on a 20-year record of winter precipitation for San Fransisco. His results showed that persistency is a real meteorological phenomenon.

Williams (1952) found for five British stations that the dry spells were well represented by the logarithmic series but not the wet spells.

Longley (1953) concluded from his study of the length of wet and dry spells at some Canadian cities that the probability of a wet day, given the previous day wet, is constant no matter how long the wet spell has persisted. For weather following a dry day, there was a slight increase in the probability of dry weather with increasing length of the dry period. He obtained the least squares expression

$$\log y = a + bn$$

(where a is the intercept for the regression line; b is the regression coefficient of log y versus n, and n is the length of spells in days) for the frequency (y) of wet or dry days.

Gabriel and Neumann (1962) in their study of sequences of daily rainfall occurrence at Tel Aviv found them to fit well the Markov chain probability model. A similar conclusion was reached by Caskey (1963), Weiss (1964), Hopkins et al (1964), Basu (1971) and others who have applied the Markov chain probability model to daily precipitation data.

From this review of the rainfall studies in general, and of the definition and delineation of the seasonal rainfall regimes particularly in the study area, it can be concluded that an objective examination of rainfall seasonality in the Lake Victoria Drainage

Basin is required. This is more so given the divergent results of the various investigators regarding the onset, cessation and consequently the duration of the rainy seasons. It was noted also that studies of the occurrence and distribution of wet and dry spells of various lengths in East Africa are few. The practical significance of such studies hardly needs emphasis. This study set out to fill these gaps.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Station network

There is a close relationship between rain gauge distribution and population density in the study area. The establishment of rain gauges seems to have favoured particularly those areas which were occupied by the colonial settler community. These areas include the Kitale-Eldoret, Nandi-Kericho-Kisii and Muhoroni agricultural areas.

There are three types of rainfall stations in the study area. There are the rainfall stations which may be designated as meteorological/agrometeorological stations. There are other stations which are under voluntary observers and still others which can be designated as special purpose (or project) stations. The first category of stations are manned by the staff of the Kenya Meteorological Department and give weather reports, particularly the meteorological stations, for most of the synoptic hours. Some of these stations are also equipped with autographic rainfall recorders. The majority of the rainfall stations are under various government departments e.g. Forestry Departments, Agricultural stations, government administrative offices, railway stations, schools and mission hospitals. To improve the station network in the Lake Victoria catchment area, the UNDP/WMO (1974) Hydrometeorological Survey installed additional weather stations, a few of which were located in the Kenyan part of the basin. The data run for the stations varies from one to over fifty years. While some stations have since closed, a good number of the remaining ones do not have a continuous run of data. Some stations which had good and continuous records suddenly stopped observing rainfall because farm ownership had changed when local people bought the former settler farms. Even some of those stations which were started by the UNDP/WMO project do not show continuous runs of data.

3.1.1 Sampling procedures

With a large number of rainfall stations and the variable length of records available, it was important to adopt sampling procedures which took into account the spatial as well as temporal aspects. This was a practical consideration especially because of the time available to complete the study, which was short, as well as the limited financial resources.

3.1.2 Spatial sampling

The study area varies enormously with respect to altitude (see fig. 2); from the lake shores to over 3,500 metres on Mt. Elgon. In East Africa, it is well known that altitude is one of the topographic features that has a marked influence on the rainfall, particularly its frequency, of an area (see for example Trapnell et al, 1960; Thompson, 1966; Nieuwolt, 1974 and 1980;

and Mungai, 1976). It was therefore necessary to consider the variations in altitude during the selection of rainfall stations for this study. Areas with no marked altitudinal variations (i.e. level terrain) on average exhibit similar rainfall characteristics as opposed to the areas of rapidly changing relief which in contrast exhibit marked rainfall gradients over short distances (see also Jackson, 1969).

The considerations of altitude therefore, consistency and continuity of rainfall records were the major criteria used in the selection of the 67 rainfall stations for this study. Table 9 below gives the station distribution with respect to altitudinal zones occurring in the study area. Table 10 shows the selected stations, their altitude, co-ordinates and long term mean annual rainfall (see also figs. 2 and 4).

Table 9. Rain gauge distribution according to altitude

Altitude (in metres)	Area (in km^2)[1]	Number of Stations
<1220	7,508	7
1220-1525	9,786	7
1525-1830	13,561	6
1830-2135	7,446	27
2135-2440	4,585	10
2440-2745	2,529	7
2745-3050	477	3
3050-3355	115	-
3355-3660	94	-
3660-3965	57	-
Total	46,158	67[2]

1. Computation of area: calculated using "area computer" which is a grid of squares of known area. The total basin area of 46,158km^2 includes the area covered by the Lake - about 3,800km^2.

2. Total number of stations selected was 67 but 4 of them are slightly outside the basin boundaries. These stations are: Narok Meteorological Station (91.35001), Lengetia Farm (90.35138), Tambach, D.O. (89.35014) and Kapsowar (89.35002).

In spite of much flexibility during the sampling procedure, however, some areas remained still inadequately represented by rainfall stations. Such areas include the southern part of the study area along the Kenya-Tanzania border, the coastal areas around the Winam Gulf and the area between Kisumu and the Kericho highlands.

3.1.3 Temporal sampling

It has already been indicated in section 3.1 that although some stations have been in operation over a considerable number of years, the majority of them have broken records. If such records are used, it would be difficult to compare stations. Moreover, any statement about the rainfall characteristics (e.g. average rainfall, rainfall probability etc.) at a station or group of sta-

Table 10. List of rainfall stations selected for the study

Station Number	Station Name	Altitude (in metres)	Latitude		Longitude		Mean Annual Rainfall (mm)
			Deg.	Min.	Deg.	Min.	
88.34001*	Mt. Elgon	2227	1	08N	34	45E	1241
9	Elgon Downs	1922	1	04	34	52	1043
12	Sabwani	1861	1	05	34	54	1059
13	Chorlini	1983	1	02	34	48	1095
17	Namandala Farm	1830	1	03	34	56	1075
35	Kitale	2074	1	12	34	59	1016
88.35005*	Kipkoitet	1922	1	00	35	16	1096
16	Mlimani	1922	1	15	35	00	1070
24	Kitale Met.	1891	1	01	35	00	1187
89.34001*	Kakamega	1556	0	17	34	45	1958
5	Aral Estate	1922	0	59	34	50	1161
8	Gloucester Estate	1830	0	54	34	55	1381
16	Lugari Ltd.	1617	0	41	34	53	1482
23	Bungoma Vet.	1373	0	31	34	35	1567

Table 10 (cont'd.)

89.34078	Kaimosi T.T.C.	1708	0
82	Bungoma Agric.	1434	0
105	Busia Cotton	1190	0
89.35001	Kaabirir	1981	0
2	Kapsowar	2288	0
10	Kaptagat	2440	0
13	Koisagat	2074	0
14*	Tambach	1830	0
16	Kipsomba	1952	0
33	Savani	1830	0
61	Tilol	2440	0
62	Baraton	1983	0
67	Mvita	2440	0
71	Siret	2162	0
76	Selborne Est.	1891	0

11	34	57	2082
34	34	33	1555
28	34	07	1733
02	35	18	1444
49	35	33	1220
22	35	30	1270
04	35	09	1504
36	35	32	1214
46	35	11	1070
03	35	06	1580
18	35	27	1150
15	35	05	1574
24	35	29	1192
04	35	14	1560
39	35	01	1192

Table 10. (cont'd.)

89.35080	Nabkoi	2593
86	Eldoret	2085
95	Nandi Factory	2019
108	Kenley	2135
112	Nandi Forest St.	1983
117	Lolgarini	2501
120	Kibabet	2135
127	Kapiyet	1830
130	Nandi Tea Estates	1983
131	Chepkorio	2593
133	F.T.C. Eldoret	2135
137	Timboroa	2745
90.34004	Kisumu P.C.	1146
6	Asumbi	1424
7	Miwani II	1324

0	08	35	27	1140
0	31	35	17	1132
0	05	35	11	1457
0	48N	35	26E	933
0	10	35	06	1705
0	19	35	31	1269
0	07	35	17	1571
0	23	35	05	1371
0	08	35	11	1554
0	23	35	36	1598
0	34	35	18	1028
0	05	35	32	1347
0	06S	34	45	1120
0	37	34	37	1598
0	03	34	59	1386

Table 10. (cont'd.)

90.34008*	Miwani	1207
12	Miwani I	1220
13	Miwani III	1220
22	Asembo	1138
25	Kisumu Met.	1150
32	Moromba F.C.	1922
67	Nyakwere	1159
69	Kibos Water Supply	1156
81	Kibos Cotton	1173
90.35001*	Jamji Estate	1830
2*	Londiani	2318
3*	Kericho	1983
13*	Sotik	1825
28*	Maji Mazuri	2333
38*	Mau Summit	2538

0	03	34	57	1465
0	03	34	57	1375
0	02	34	58	1357
0	10	34	23	1079
0	05	34	45	1321
0	36	34	51	2001
0	21	34	47	1097
0	00	34	49	1644
0	04	34	49	1307
0	29	35	12	1653
0	10	35	35	1139
0	23	35	17	1865
0	40	35	05	1406
0	01	35	42	1235
0	10	35	40	1044

Table 10. (cont'd.)

90.35042	Langoni	2013	0	01	35	24	1591
46	Chemelil	1230	0	06	35	07	1331
49	Braeside	2349	0	11	35	37	1180
78	Hundred Acres	2318	0	12	35	35	1243
79	Renwik	2013	0	45	35	20	1380
129	Marindas Farm	2806	0	20	35	41	1200
138	Lengetia Farm	2745	0	35	35	57	1039
91.35001	Narok Met.	1586	1	06	35	52	741

Data source: Kenya Meteorological Department

* Daily rainfall data for these stations for the common 30-year period (1941-1970) were used to study wet and dry spells

tions has greater validity if it is based on many years' data. Thom (1966) recommends a period of 30 years as the minimum, particularly for annual rainfall totals. For time periods in the order of a month or shorter, data transformations have been found to be necessary to approximate a normal distribution (Manning, 1950; Hills, 1978).

A listing of all the rainfall stations and the years of available records was made. From this listing, a common 14-year period (1957-1970) was selected that gave the best group of stations in terms of their spatial distribution over the study area. Any other period would have given too few stations that were poorly distributed over the study area. The choice of the 14-year period, though primarily dictated by data availability, proved quite worthwhile given the interesting and valid results that were obtained in the determination of the seasonal rainfall regimes (see also section 3.4). For the study of the wet and dry spells however, a common 30-year period (1941-1970) was available for each of the eleven stations which were selected from the identified seasonal rainfall regimes.

3.2 Delineation of seasonal rainfall regimes

The daily rainfall totals during the period 1957-70 for the 67 sample stations were grouped into 10-day totals according to the scheme shown in table 11.

Table 11. The 10-day or "decade" calendar

Decade Number	Month	Date	Decade Number	Month	Date	Decade Number	Month	Date
1	January	1-10	14	May	10-19	27	September	17-26
2	"	11-20	15	"	20-29	28	Sept-Oct	27-6
3	"	21-30	16	May-June	30-8	29	October	7-16
4	Jan-Feb	31-9	17	June	9-18	30	"	17-26
5	February	10-19	18	"	19-28	31	Oct-Nov	27-5
6	"	20-29	19	June-July	29-8	32	November	6-15
7	March	1-10	20	July	9-18	33	"	16-25
8	"	11-20	21	"	19-28	34	Nov-Dec	26-5
9	"	21-30	22	July-Aug	29-7	35	December	6-15
10	March-April	31-9	23	August	8-17	36	"	16-25
11	April	10-19	24	"	18-27	37	"	26-31
12	"	20-29	25	Aug-Sept	28-6			
13	April-May	30-9	26	September	7-16			

Thus, each year had 37 such periods. This method of dividing the year into 10-day periods is different from that used by the Kenya Meteorological Department, also used by Lawes (1969). This method is rather arbitrary but surely superior to monthly time units. The method of the Kenya Meteorological Department is more arbitrary in that only the first two, and sometimes three 10-day periods in each month have exactly 10 days; the third period contains the remaining days of the month which can vary between 8 and 11 days. Moreover, weather events do not follow such periods.

It is realised that in the scheme shown in table 11, the last 10-day period (i.e. decade no. 37) has 6 days. It is usual to normalize the data to periods of equal length (Conrad, 1949 and Ogallo, personal communication). No normalization was effected in this study since decade number 37 is dry.

The sample mean, standard deviation, upper and lower quartiles, the median and the coefficients of skew and kurtosis were calculated for each station and period. Looking at these statistics, it was clear from the onset that the 10-day rainfall totals, particularly those of the dry periods and dry stations were skewed and therefore the traditional arithmetic average could not be used to represent the average expectation or character of rainfall throughout the year. This is in agreement with the findings of Hills (1978) and Atwoki

(1975). The latter investigator chose to use the lower quartile rainfall for Uganda stations. For this study, the median rainfall was used to characterize the annual march of rainfall. The median is less subject to the possible errors that may characterize the upper and lower quartile extremes. This resulted in a matrix of 67 x 37 which formed the basis of the Principal Component Analysis (PCA) to be described shortly.

The existence of seasonal rainfall regimes over an area is determined by the seasonal sequence and spatial characteristics of the weather systems which underly the distribution of rain over that area. The analysis of correlation coefficients of rainfall distribution throughout the year between different stations makes it possible to distinguish groups of stations which are identified by their rainfall regimes. To be able to define and delimit the seasonal rainfall regimes occurring in the study area, the method of Principal Components Analysis, described in section 3.2.1, was used. The median rainfall based on the 14-year period (1957-70) for each 10-day period for each station were placed in a P by N matrix, where P is the number of rows (or 67 rainfall stations) and N the columns (or median rainfall of the 37 periods).

3.2.1 The method of Principal Components Analysis (PCA)

Principal Components Analysis is a variant form of Factor Analysis. The method of Principal Components Analysis can employ either a covariance, correlation or cross-products input matrix. Each of these initial inputs into the PCA has its own advantages and disadvantages. The correlation matrix was preferred in this study because it has the principal advantage of weighting the stations equally. The PCA method can, however, bias the results when the station grid is non-uniform (Thomas et al, 1982).

The main difference between PCA and Factor Analysis is that unities are retained in the principal diagonal of the correlation matrix in the former procedure while in Factor Analysis, communality estimates are inserted in the principal diagonal. An assumption in Factor Analysis is that a variable should not have a correlation of 1.0 with itself since emphasis is placed on the covariances between variables within the input matrix rather than the variances. The rationale behind the use of communality estimates in Factor Analysis is purportedly to separate the common variance which in meteorological terms means separating the effects of large-scale systems from those of mesoscale systems, observational and instrument errors (Atwoki, 1975; Richman, 1981).

The Principal Components Analysis method has been applied in meteorology and climatology by a number of investigators (Christensen et al, 1966; Sellers, 1968; Gregory, 1975; Ogallo, 1980; Richman, 1981, among others). The controversy whether to use PCA or Factor Analysis has centred mainly on the method(s) of estimating the communalities and also whether or not the rotation of factors or components is necessary (Wallis, 1967; Matalas et al, 1967). Several investigators have however reported similar results arrived at by using both techniques (Gregory, 1975; Ogallo, 1980 and Richman, 1981). On the basis of the reported similarity of results obtained by using both techniques, it was decided to use Principal Components Analysis in this study.

3.2.2 Properties of Principal Components Analysis

(i) Principal Components Analysis transforms a set of observed independent variates into an orthogonal set of variates called Principal Components.

(ii) The number of Principal Components is equal to the rank of the observed correlation matrix. Each Principal Component is expressible as a weighted sum of the observed variates.

(iii) The first Principal Component accounts for as much as possible of the variance of the n observed variates. The second Principal Component accounts for as much as possible of the residual variance not accounted for by the first Principal Component. Each succeeding Principal Component accounts for as much as possible of the remaining variance not accounted for by all the previous Principal Components.

3.2.3 Formulation of Principal Components Analysis method

The observed variates $x_1, x_2, \ldots\ldots\ldots\ldots, x_n$ are expressed in terms of the Principal Components $z_1, z_2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots, z_n$ by

$$x = Wz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where,

x = (nx1) matrix of observed variates

W = (nxm) " " Component loadings

z = (mx1) " " Principal Components

Premultiplication of W by W' leads to

$$W'W = \lambda \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where,

λ = (mxm) diagonal matrix whose diagonal elements are the eigenvalues of the correlation matrix

Postmultiplication of W by W' leads to

$$WW' = I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where,

I = (nxn) identity matrix

The Principal Components are related to the observed variates by

$$Z = (\frac{1}{\lambda})\ W'x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where $(\frac{1}{\lambda})$ is an (mxm) diagonal matrix whose diagonal elements are the reciprocals of the eigenvalues. If m=n, then

$$(\frac{1}{\lambda})W' = W^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

and if m<n, then

$$(\frac{1}{\lambda})W' = (W'W)^{-1}W' \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The eigenvalues are proportional to the portion of variance explained by each Principal Component. If $\lambda j,j$, where $j=1,2,3, \ldots\ldots\ldots,m$, denotes the j^{th} eigenvalue corresponding to the j^{th} Principal Component, the ratio

$$\alpha j = \frac{\lambda j,j}{\sum_{t=1}^{m} \lambda t,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

is the portion of the total variance of the observed variates accounted for by the j^{th} Principal Component, where,

$$\alpha_1 > \alpha_2 > \alpha_3 > \ldots\ldots\ldots\ldots > m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Kaiser's (1961) criterion of an eigenvalue of 1.0 or more was used as the cut-off value of the major Principal Components. The remaining Principal Components were assumed to represent variance of little importance.

To be able to assign each station to its seasonal rainfall regime type, Kaiser's (1958) orthogonal Varimax rotation procedure was used. Varimax rotation yields a set of Component loadings such that the variance of the square or the loadings is a maximum.

3.3 Wet and dry spells analysis

3.3.1 Definition of a wet/dry day

10/14/18

A wet day has been variously defined by different investigators - see table 12 below. By defining a wet day on the basis of some threshold value, a dry day is also defined.

The choice of a threshold value is greatly determined by the purpose of the investigation. If for example one were studying rainfall in relation to the ability of the atmosphere to produce it, then it might be useful to consider all rainfall amounts as long as they are measurable, i.e. a rainy day would then be defined as a day on which a measurable quantity of rain

Table 12. Threshold values defining a wet day according to different investigators

Investigator(s)	Threshold value(s)			
	(1)	(2)	(3)	(4)
Williams, C.B. (1952)	0.005in	-	-	-
Weiss, L.L. (1964)	0.01in	0.10in	0.50in	1.0in
Feyerherm, <u>et al</u> (1965)	0.01in	0.20in	0.50in	-
Hopkins <u>et al</u> (1964)	0.01in	-	-	-
Basu, A.N. (1971)	0.10in	-	-	-
Katz, R.W. (1977)	0.01in	-	-	-
Buishand, T.A. (1978)	0.20mm	0.80mm	3.0mm	-
Alusa <u>et al</u> (1978)	1.0mm	-	-	-
McKay, G.A. (1979)	0.20mm	1.0mm	-	-
Swift <u>et al</u> (1981)	0.25mm	-	-	-

fell. However, for such applied areas as in agriculture, it is useful to select cut-off values that have the greatest significance to crop growth and development. A useful guide to selecting such values is to look at rainfall in relation to the likely losses due to evapotranspiration, run-off and deep drainage (beyond the rooting depth of crops) etc.

This study is concerned with rainfall as an income component. It does not therefore concern itself with the other components of the water balance equation but it is being suggested here that any information on the characteristics of rainfall, the most varying quantity of the water balance components, will give a first impression of the possibilities or lack of them of an agro-system. Farmers can, therefore, on the basis of the resulting agroclimatic information take the appropriate decisions to safeguard their crops against adverse weather.

Two cut-off values were used in this study to define a wet/dry day. First, a wet day was defined as one on which 1.0mm or more of rain fell. This is also the official definition of a rainy day in Kenya. The second definition limited a wet day to one on which 5.0mm or more of rain fell. A dry day was defined as a day when the daily fall was less than 1.0 and 5.0mm respectively. Wet or dry days refer to the 24-hour period from 9.00 am to 9.00 am of the following day.

It has been argued, for example by Buishand (1978), that using small rainfall amounts (less than 1.0mm) to define a wet day can cause some problems since small values can be due to fog or dew. Also, small rainfall amounts can be registered as zero depending on the observer. It is possible therefore, on account of these problems, to have differences in the wet/dry sequences. It is partly for this reason that the 1.0mm and 5.0mm cut-off values were chosen for this study.

Although the 1.0mm cut-off value is a suitable criterion for defining a wet day, it may be of less value in relation to evapotranspiration since such an amount will be lost quickly depending on the rainfall frequency and the evaporative demand of the atmosphere, among other things. In the study area, for example, the daily potential evaporation is in the order of 4-6mm. Another cut-off value of 5.0mm or more of rain was therefore chosen to define a wet day. It has to be borne in mind however that even if the 5.0mm cut-off value is better than any other, the effect of the wet/dry spells in farming operations will depend on such other factors as soil characteristics e.g. soil depth and soil moisture holding characteristics, the length of spells in relation to antecedent soil moisture conditions, etc.

3.3.2 Definition of wet/dry spells

A wet spell of length n is defined as a sequence of n wet days preceeded and followed by a dry (s). A dry spell is defined in the same way.

A total of 11 rainfall stations were used to study the frequency of occurrence and duration of wet and dry spells for the 30-year period (1941-70). These stations are shown in table 13 below.

A common period from March to mid-June was chosen for the study of the spells. This portion of the year constitutes a major growing season in a large

Table 13. Rainfall stations used in wet and dry spells analysis

Station No.	Station name	Altitude(m)	Mean annual rainfall(mm)
88.34001	Mt. Elgon	2227	1241
88.35005	Kipkoitet	1922	1096
89.34001	Kakamega	1556	1958
89.35014	Tambach	1830	1214
90.34008	Miwani	1207	1465
90.35001	Jamji Estate	1830	1653
90.35002	Londiani	2318	1139
90.35003	Kericho*	1983	1865
90.35013	Sotik	1825	1406
90.35028	Maji Mazuri	2333	1235
90.35038	Mau Summit*	2538	1044

* only the 1.0mm cut-off value was considered for these stations

part of the Lake Victoria Drainage Basin. No attempt was made to list the frequency of the spells by month although one would expect them to vary throughout the year. In fact several investigators have demonstrated that the probability of a wet or dry day has a seasonal component (Swift *et al*, 1981; Stern, 1982; Basu, 1971; Hopkins *et al*, 1964). One problem associated with the study of wet and dry spells on a monthly basis is that the spells often do not coincide with the calendar months. Often a spell will start in one month and terminate in the succeeding month(s). One way to solve the problem is to allocate the spell to the month in which it starts or to the month containing the greater part of the spell. This procedure has the disadvantage that the spells are broken to create more frequent short spells. In this study, such breaks of the spells occur only at the beginning and end of the season considered.

3.3.3 Determination of wet and dry spells

Let $fijk$ be the frequency of the i^{th} length of spell for the j^{th} season and the k^{th} year. Then,

$$fij = \sum_{j=p}^{m} fijk \dots\dots\dots\dots\dots\dots\dots (9)$$

p = 1st March and

m = 15th June

is the frequency of the i^{th} length of spell for the j^{th} season for a station. Hence,

$$fi = \sum_{k=1}^{30} fij \dots\dots\dots\dots\dots\dots\dots (10)$$

gives the i^{th} length of spell for the 30-year period (1941-70). The total frequency, f_T, of spells of all lengths for a given station for the period of study can be given as,

$$f_T = \sum_{i=1}^{n} \sum_{j=p}^{m} \sum_{k=1}^{30} fijk \dots\dots\dots\dots\dots (11)$$

n = spells of all lengths

3.3.4 Distribution of wet and dry spells

As is often the case with the durations of meteorological events, the frequencies of occurrence of the spells fall exponentially from the shortest duration to the longest. The exponential distribution and first order Markov chain probability models were fitted to the spells data. To find out how well these models fit the observed data, a goodness-of-fit test, using Chi-square (χ^2) was carried out.

The exponential distribution density function is given by

$$P_X(X) = \lambda e^{-\lambda(X)} \left.\begin{matrix} X>0 \\ \lambda>0 \end{matrix}\right\} \quad \text{........................(12)}$$

The mean of the exponential distribution is given by

$$E(X) = \frac{1}{\lambda} \text{ and the variance}$$

by

$$\mathrm{Var}(X) = \frac{1}{\lambda^2}$$

The exponential parameter, λ, is given by

$$\hat{\lambda} = \frac{1}{\bar{X}} \quad \text{..............................(13)}$$

and the mean ($\bar{X}$) by

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{k} X_i n_i \quad \text{.......................(14)}$$

where,

k = number of categories

n = number of observations (spells)

n_i = number of observations in the i^{th} group i.e. frequency

X_i = class mark of the i^{th} category

The expected relative frequency in each class is

$$f_{X_i} = \Delta_{X_i} P_X(X_i) \quad \text{.........................(15)}$$

where X_i is as defined above

$P_X(X_i)$ is the exponential distribution of spells which is given by

$$P_X(X_i) = \hat{\lambda} e^{-\hat{\lambda}(X_i)} \quad \text{.........................(16)}$$

The Markov chain probability model assumes that the probability of rain occurring on any day depends only on whether it did or did not occur on the previous day. The parameters of the model are the two conditional probabilities P_o and $(1-P_1)$, where P_o is the probability of a wet day, given the previous day dry; and $(1-P_1)$ is the probability of a dry day given the previous day wet:

$$P_1 = P_r(W/W); \; (1-P_1) = P_r(D/W) \quad \text{..............(17)}$$

$$P_o = P_r(W/D); \; (1-P_o) = P_r(D/D) \quad \text{..............(18)}$$

from which the probability of a wet spell of length n is

$$(1-P_1)P_1^{n-1} \quad \text{..................................(19)}$$

and of a dry spell of length n is

$$P_o(1-P_o)^{n-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

3.4 Research limitations

The main research problems which were experienced included the following: first, there was the problem of inadequate station coverage particularly in the southern portion of the study area as well as in the Lake Victoria littorals. The majority of the rainfall stations that can be found in these areas are recent and have therefore few years' data. Secondly, and affecting a good portion of the study area, was the problem of broken records. This problem, as it was discovered from the rainfall gazetteers at the Kenya Meteorological Department headquarters (Dagoretti Corner), became acute soon after Kenya's independence. This was because farm ownership had changed hands from the colonial settler community to African farmers. Dependent as agriculture is on weather, apparently the new farm owners were not as keen, or probably did not know or appreciate the importance of keeping continuous and correct weather records. Apart from this conspicuous period of data gaps and which is explicable in terms of the changes that took place at and after independence, there were other periods of data gaps which are related to raingauge loss, damage, improper siting of the instrument, absence of the observer or observational errors, etc. The third problem but whose impact on the outcome of the study is judged to have been of no major consequence is related to the fact that the author was seconded to McGill University, Canada, during the 1981/82 academic year. A request was therefore made to the Kenya Meteorological Department to copy all available daily rainfall data of the target stations in the study area into the author's own magnetic tapes for analysis in Canada. Unfortunately, the author discovered while in Canada that a considerable number of years' data had been left out. The data had been manually verified to exist for the missing years. This reason, together with the problem of broken records, was instrumental on choosing the 14-year period (1957-70) used for part of the analysis. As it has been pointed out already, the inadvertent omission of some of the data was not crucial given the results that were realised. Another problem related to the author's secondment to McGill University was that a considerable delay in data analysis was experienced due to the fact that the IBM computer at McGill could not read the author's magnetic tapes which had been created on the ICL computer at Chiromo (University of Nairobi). This problem was overcome towards the end of the 1981/82 academic year, a solution which enabled the author to use the excellent computing facilities at McGill University.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter presents an attempt of the definition and delineation of the seasonal rainfall regimes occurring in the Lake Victoria Drainage Basin. The seasonal rainfall regimes were determined via the method of Principal Components Analysis. The definition of the rainy seasons was done on the basis of the annual march of the 10-day (or decade) upper and lower quartite rainfall, a method which emphasizes both variability and reliability. The chapter also gives the results of the analysis of wet and dry spells.

4.1 The spatial structure of seasonal rainfall correlation

The square matrix of correlation coefficients between the 67 stations is shown in table 14. Excluding the leading diagonal's values, all of which have a value of unity, the correlation coefficient matrix is composed of 2, 211 correlation coefficients (according to the expression $n^2-n/2$, where n is the number of variables). Only one half of the matrix is shown since the other half is the mirror image of the first half. Figures 10, 11 and 12 illustrate the main characteristics of the spatial structure of the seasonal correlation of rainfall in the Lake Victoria Drainage Basin. The figures were derived from the mapping of the correlation coefficients between each

Table 14 The correlation coefficient matrix of 67 rainfall stations in the study area *(the correlation coefficients have been multiplied by 100)*

Station	88.34001	88.34009	88.34012	88.34013	88.34017	88.34035	88.35005	88.35016	88.35024	89.34001	89.34005	89.34009	89.34016	89.34023	89.34078	89.34082	89.34106	89.35001	89.35002	89.35010	89.35013	89.35014	89.35016	89.35033	89.35061	89.35062	89.35067	89.35071	89.35076	89.35080	89.35086	89.35096	89.35106	89.35112	89.35117	89.35120	89.35127	89.35130	89.35131	89.35133	89.35137	90.34004	90.34006	90.34007	90.34008	90.34012	90.34013	90.34022	90.34025	90.34032	90.34067	90.34069	90.34081	90.35001	90.35002	90.35003	90.35013	90.35028	90.35038	90.35042	90.35048	90.35049	90.35070	90.35075	90.35129	90.35138	91.35001
88.34001	100																																																																	
88.34009	98	100																																																																
88.34012	96	98	100																																																															
88.34013	92	93	89	100																																																														
88.34017	91	91	94	84	100																																																													
88.34035	92	94	92	89	87	100																																																												
88.35005	92	91	90	85	87	91	100																																																											
88.35016	94	92	92	89	88	93	92	100																																																										
88.35024	94	91	93	88	87	91	94	92	100																																																									
89.34001	84	76	82	78	75	76	75	79	85	100																																																								
89.34005	94	88	94	90	88	82	93	93	94	80	100																																																							
89.34009	82	79	81	74	74	76	80	81	82	76	87	100																																																						
89.34016	82	81	76	81	74	79	88	83	87	71	84	88	100																																																					
89.34023	74	67	70	67	69	73	67	72	74	84	69	67	81	100																																																				
89.34078	83	74	76	74	72	77	75	80	83	93	79	76	75	84	100																																																			
89.34082	75	68	71	64	72	70	69	72	75	84	71	67	59	91	85	100																																																		
89.34106	54	46	51	44	52	52	43	51	53	74	53	46	41	64	70	61	100																																																	
89.35001	81	76	81	72	82	81	81	80	85	87	81	78	72	80	87	80	69	100																																																
89.35002	73	67	76	62	71	70	61	70	69	78	67	52	40	80	78	78	79	76	100																																															
89.35010	88	83	88	77	82	85	83	85	87	88	81	78	70	79	84	75	64	88	85	100																																														
89.35013	84	79	88	76	78	76	77	83	88	89	82	78	71	79	89	76	72	89	92	83	100																																													
89.35014	73	71	76	67	70	76	68	70	72	76	88	80	47	77	73	70	68	82	91	90	82	100																																												
89.35016	84	88	81	85	78	86	88	88	87	69	87	80	89	52	69	54	28	71	45	74	71	54	100																																											
89.35033	79	72	78	68	73	71	72	73	80	87	76	75	67	76	88	77	69	90	75	83	89	76	80	100																																										
89.35061	89	91	90	85	84	85	87	88	89	77	87	78	78	80	74	57	43	81	68	90	84	76	86	76	100																																									
89.35062	84	80	83	74	79	80	86	82	91	83	87	88	83	76	86	77	67	85	67	82	86	69	73	81	80	100																																								
89.35067	86	83	86	79	83	83	86	84	89	80	84	78	73	68	78	68	54	91	78	95	89	86	79	82	93	83	100																																							
89.35071	76	72	79	65	71	77	71	77	81	85	74	76	63	82	84	75	72	83	82	88	91	84	60	86	75	84	81	100																																						
89.35076	80	84	77	83	79	81	82	80	85	74	85	80	91	57	74	54	40	77	45	73	73	53	90	69	84	78	78	83	100																																					
89.35080	82	85	83	82	81	77	88	80	86	73	84	79	81	52	71	53	38	80	54	81	80	65	84	75	94	77	86	85	88	100																																				
89.35086	86	89	86	86	81	83	88	84	88	88	87	81	82	46	83	44	26	73	50	78	75	84	90	68	93	76	87	88	87	92	100																																			
89.35096	89	84	87	79	81	84	82	86	90	93	89	84	75	84	89	84	74	90	79	89	93	80	76	90	82	88	87	87	75	78	75	100																																		
89.35106	86	85	86	79	85	91	84	88	88	78	85	76	74	89	76	65	53	82	74	87	81	78	81	73	89	77	89	82	80	78	82	81	100																																	
89.35112	78	73	77	68	78	69	77	70	83	85	75	83	76	72	84	75	62	83	63	77	81	69	67	81	75	88	78	79	75	75	72	82	71	100																																
89.35117	89	91	91	82	85	88	86	88	88	81	88	78	73	71	78	87	55	88	76	92	89	84	81	82	96	83	93	83	79	90	87	89	87	77	100																															
89.35120	89	89	91	86	83	87	85	90	91	85	90	79	77	72	83	70	56	84	77	89	90	80	83	79	91	84	90	84	79	83	84	89	69	77	91	100																														
89.35127	80	75	79	73	71	75	81	79	89	85	77	83	77	67	80	66	49	82	60	82	84	69	77	77	83	83	83	78	77	79	81	83	82	62	80	86	100																													
89.35130	83	82	83	72	81	77	78	78	84	86	82	77	70	73	82	73	88	88	76	86	91	77	71	87	83	85	86	84	75	79	75	92	77	80	89	85	81	100																												
89.35131	81	79	83	74	78	76	75	78	81	83	76	70	62	76	79	73	67	86	88	94	91	88	83	82	85	78	90	82	64	77	70	85	78	74	92	84	73	87	100																											
89.35133	88	87	90	79	85	87	88	87	91	77	85	82	80	60	74	57	40	82	66	88	83	76	87	77	94	80	93	79	82	87	92	83	91	78	92	91	85	81	81	100																										
89.35137	83	87	84	81	82	80	86	84	86	72	85	80	80	59	71	59	45	82	63	86	83	74	84	77	95	78	92	72	84	95	91	83	82	73	93	86	77	81	84	89	100																									
90.34004	35	25	34	24	32	34	29	35	37	59	32	35	21	64	62	61	73	60	72	33	60	70	13	64	36	51	53	70	25	27	22	57	43	55	45	41	43	55	59	38	38	100																								
90.34006	46	41	47	48	44	48	36	50	47	73	48	38	32	82	72	79	86	60	78	63	68	67	25	62	39	53	47	68	32	31	20	66	50	49	50	52	46	57	67	32	39	71	100																							
90.34007	40	30	40	27	38	36	26	35	35	63	32	29	19	66	63	62	78	58	78	61	64	66	11	66	36	47	48	70	21	23	17	56	45	53	47	48	39	55	65	38	32	87	75	100																						
90.34008	53	41	52	38	47	44	34	45	45	73	43	35	23	69	72	70	77	66	82	67	73	72	21	77	44	50	55	74	28	35	27	68	49	57	57	54	47	63	71	45	41	82	75	92	100																					
90.34012	43	35	44	33	38	40	30	43	37	61	39	30	19	64	64	68	76	58	80	63	69	71	16	66	41	46	52	70	24	29	23	60	47	46	54	49	37	55	68	39	39	83	75	91	91	100																				
90.34013	49	37	46	35	46	41	34	41	44	70	38	34	25	71	70	71	75	69	78	67	68	70	21	72	40	52	56	69	28	29	23	64	45	62	52	50	46	61	70	44	36	82	72	92	92	84	100																			
90.34022	43	35	44	40	41	43	29	43	41	64	37	27	20	70	81	63	80	63	82	66	69	76	18	62	44	48	57	68	27	34	26	59	51	46	55	49	43	58	74	38	42	81	86	80	81	83	78	100																		
90.34025	34	24	32	22	28	32	23	38	33	59	31	30	16	63	64	62	79	56	75	60	62	67	13	63	34	48	49	70	22	23	16	58	42	49	45	43	39	55	58	33	35	95	76	88	84	86	81	82	100																	
90.34032	50	43	47	46	48	48	41	46	46	71	50	42	40	78	73	78	88	70	72	61	67	70	27	74	42	61	53	67	42	41	28	68	48	61	56	52	43	61	68	38	46	74	84	79	80	76	79	82	76	100																
90.34067	50	42	50	45	48	52	43	55	51	68	46	45	36	73	69	72	71	72	75	73	70	74	33	73	49	57	63	78	37	41	36	69	57	54	58	55	50	63	69	49	51	88	78	77	81	78	80	83	85	77	100															
90.34069	41	30	38	27	39	34	30	39	38	61	35	35	25	70	64	66	80	59	73	60	64	62	14	65	32	50	48	66	25	24	17	60	38	54	45	38	35	54	62	31	35	87	76	85	84	89	86	78	86	78	77	100														
90.34081	43	33	42	31	40	39	32	41	42	68	37	38	23	70	69	65	79	67	81	70	71	75	17	73	43	53	59	75	27	32	24	65	48	56	53	51	46	60	71	43	41	93	78	94	92	93	93	85	92	80	87	90	100													
90.35001	58	47	64	51	51	51	46	55	55	78	54	51	41	78	75	77	84	77	79	70	76	76	35	81	50	62	65	71	42	45	39	79	54	62	63	60	56	72	76	50	55	81	80	80	85	81	84	85	82	87	84	80	86	100												
90.35002	86	88	86	86	84	84	89	86	90	73	86	82	86	59	74	57	38	80	68	85	78	70	87	74	95	80	89	71	88	94	93	78	86	77	90	87	83	78	79	91	94	32	35	27	35	30	32	37	28	40	48	26	34	48	100											
90.35003	72	64	70	58	73	70	68	74	74	83	72	68	58	86	83	67	80	86	81	82	85	75	56	81	63	81	74	87	59	56	52	86	71	74	74	74	67	82	78	64	64	73	76	71	75	70	78	70	73	77	81	77	77	79	60	100										
90.35013	47	45	50	40	48	44	40	48	50	65	48	48	39	57	65	57	62	72	65	69	73	66	38	78	55	56	83	69	48	51	45	88	54	61	66	55	55	73	72	53	60	76	60	73	77	79	74	71	78	67	78	73	80	80	51	70	100									
90.35028	73	72	78	71	74	72	70	70	75	76	70	62	56	69	72	68	62	80	84	90	81	88	56	78	81	71	87	78	62	72	69	78	80	72	82	82	72	74	89	79	78	66	61	67	69	66	68	71	62	87	71	57	72	72	78	69	69	100								
90.35038	83	84	83	84	80	80	88	87	89	77	85	85	86	63	76	61	47	84	61	86	85	70	86	77	92	81	91	73	87	93	90	82	83	76	90	86	84	80	83	89	95	37	43	32	41	39	38	45	35	46	52	36	41	57	95	66	59	76	100							
90.35042	85	88	83	79	81	82	88	82	89	84	86	84	82	69	81	69	56	88	63	85	86	73	85	82	91	86	89	77	87	93	86	89	82	83	92	89	86	89	81	88	92	36	45	38	47	36	45	42	37	55	50	35	43	59	90	72	57	73	90	100						
.35048	84	56	63	53	60	60	54	61	59	73	62	52	42	76	78	82	85	74	83	74	74	78	38	79	56	64	66	75	43	50	41	78	62	65	67	64	51	84	74	55	60	79	76	82	86	83	80	76	81	85	81	78	84	86	50	78	74	79	55	60	100					
																			61	88	84	73	89	78	94	80	92	75	90	94	90	83	87	80	91	87	85	82	80	92	93	37	40	34	43	38	41	42	35	47	51	32	43	52	94	86	56	76	93	95	54	100				
																																									91	48	47	42	50	41	48	48	44	54	63	37	50	80	92	72	58	81	91	93	63	97	100			
																																																												48	63	42	50	100		

of three selected stations and all the other stations. The selected stations were Mt. Elgon, Miwani and Narok Meteorological Station; Mt. Elgon is located in the extreme north-west while Narok is in the extreme south-east corner of the study area. Miwani station is in-between the two extremes. The following interesting features are discernible from figs. 10, 11 and 12:

(a) The alignment of the isopleths of correlation is generally in a north-west/south-east direction; the gradients, consequently, vary in a north-east/south-west direction.

(b) In each of the three maps, there exist narrow bands of steep gradients of correlation. Figures 10 and 12 are similar in that they identify a common area of strong covariation of seasonal rainfall ($r>0.70$) to the west and south of the study area. Fig. 11 on the other hand distinguishes the Kitale-Eldoret-Londiani area ($r>0.80$) from the rest of the study area.

It is pertinent to make a comment about the steep gradients of the isopleths of correlation coefficient. The steep gradients of correlation clearly coincide with the border areas where changes in the character of the seasonal regime of rainfall occurs.

Fig. 10 The correlation between Kisumu meteorological station and other stations

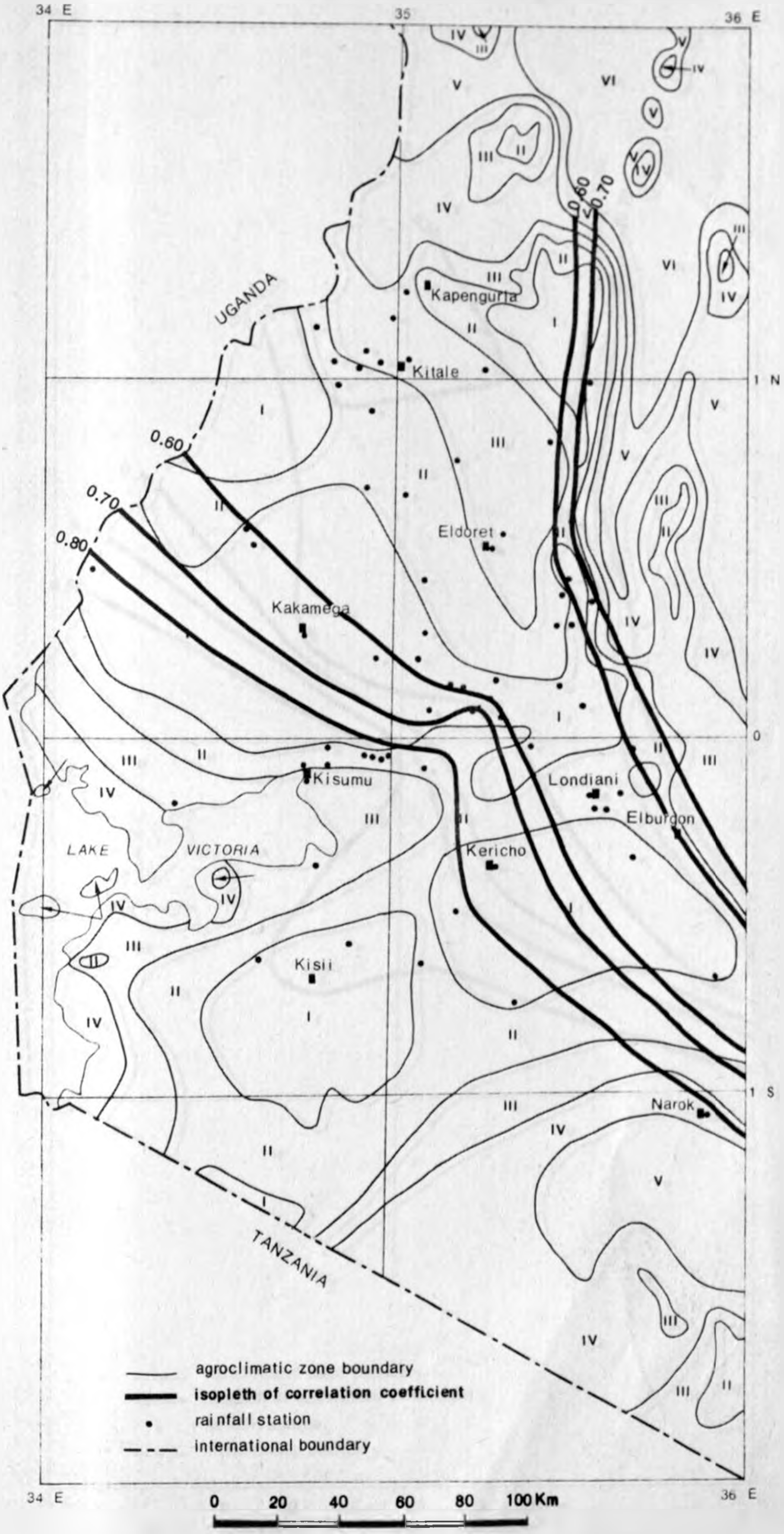


Fig 11. The correlation between Mt. Elgon Forest station and other stations

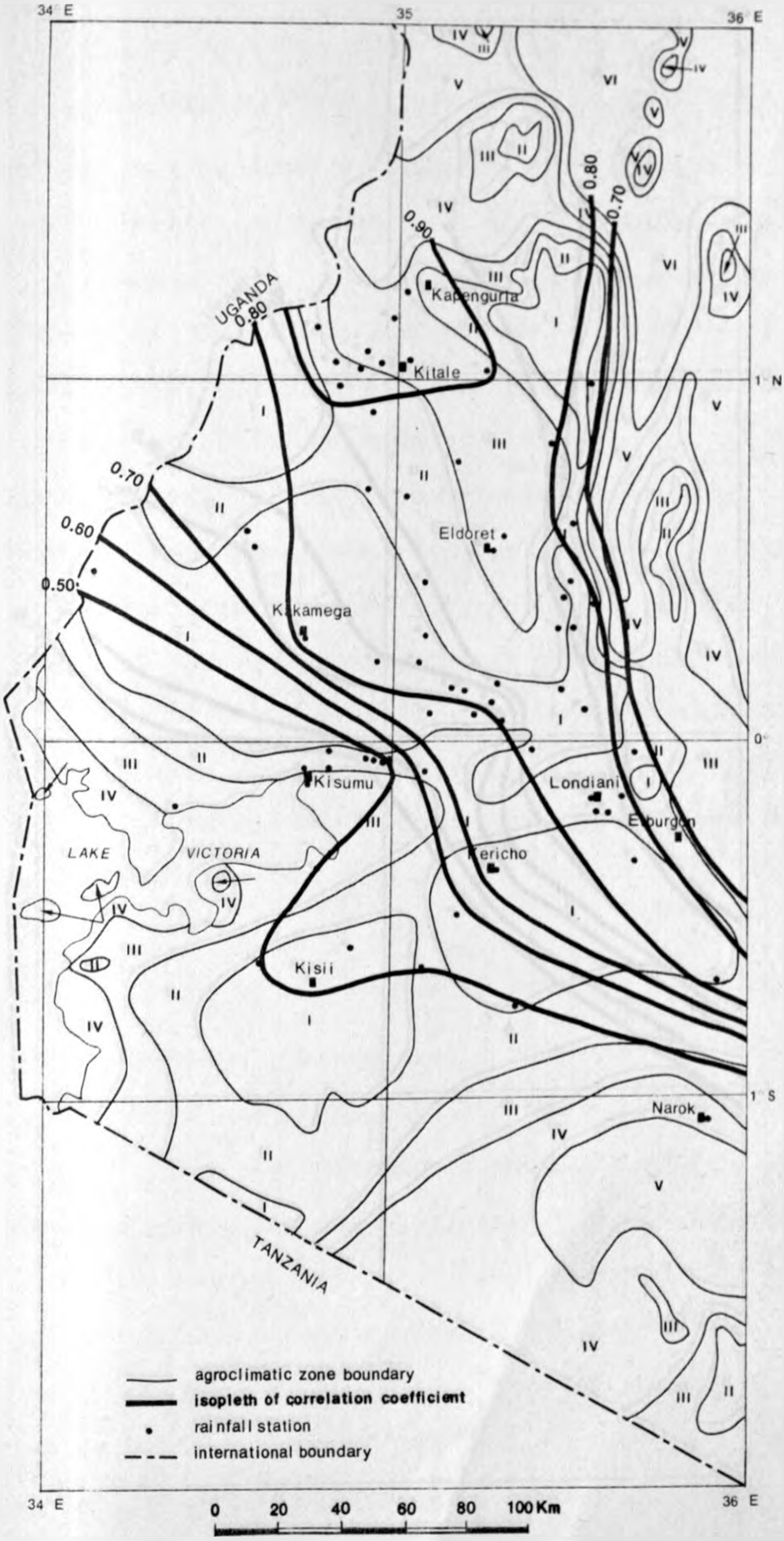
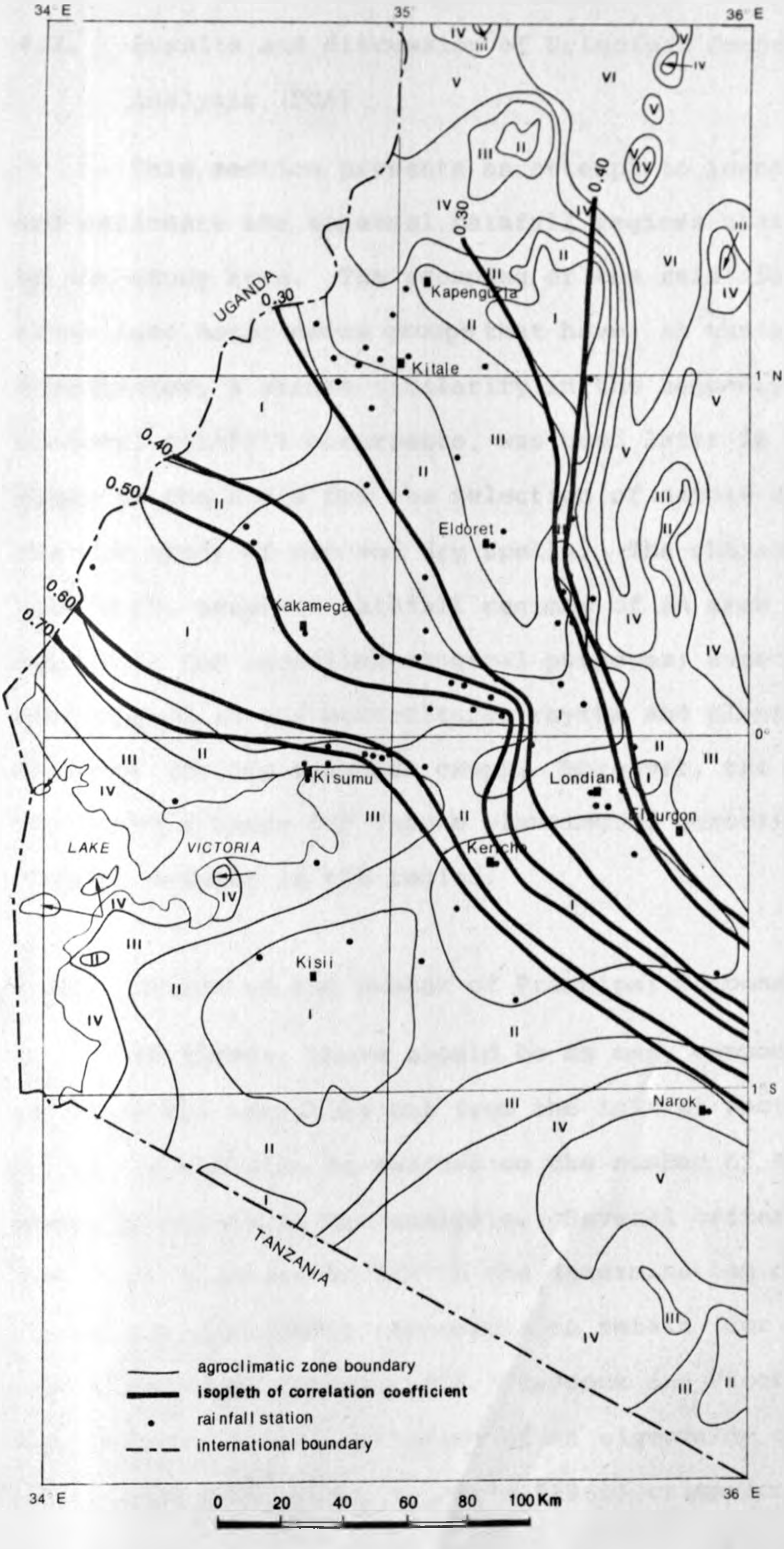


Fig. 12 The correlation between Narok meteorological station and other stations



4.2. Results and discussion of Principal Components Analysis (PCA)

This section presents an attempt to identify and delineate the seasonal rainfall regimes that occur in the study area. The grouping of the rainfall stations into homogeneous groups that have, as their common denominator, a strong similarity in the sequence of seasonal rainfall occurrence, was used later in the study as the basis for the selection of sample stations for the study of wet and dry spells. The characterization of the seasonal rainfall regimes of an area is important for agroclimatological purposes; especially with regard to the agricultural rhythm and planting dates of various seasonal crops. Moreover, the grouping forms a basis for future planning of agroclimatological network in the region.

4.2.1 Choice on the number of Principal Components

In theory, there should be as many components as there are variables but from the initial factor matrix, a decision is reached on the number of components to retain in the analysis. Several criteria have been proposed to aid in the determination of the number of significant components to retain (for example the scree test: Cattel, 1966; Craddock and Flood, 1969 and Kaiser's (1961) criterion of an eigenvalue of 1.0, etc.). In this study, Kaiser's (1961) criterion of an eigenvalue of 1.0 or more was used; the remaining Principal Components were assumed to represent variance of little importance. Table 15 shows the proportion of the variance accounted for by the first 10 Principal components while figure 13 shows the plot of the eigenvalues against factor (or component) number.

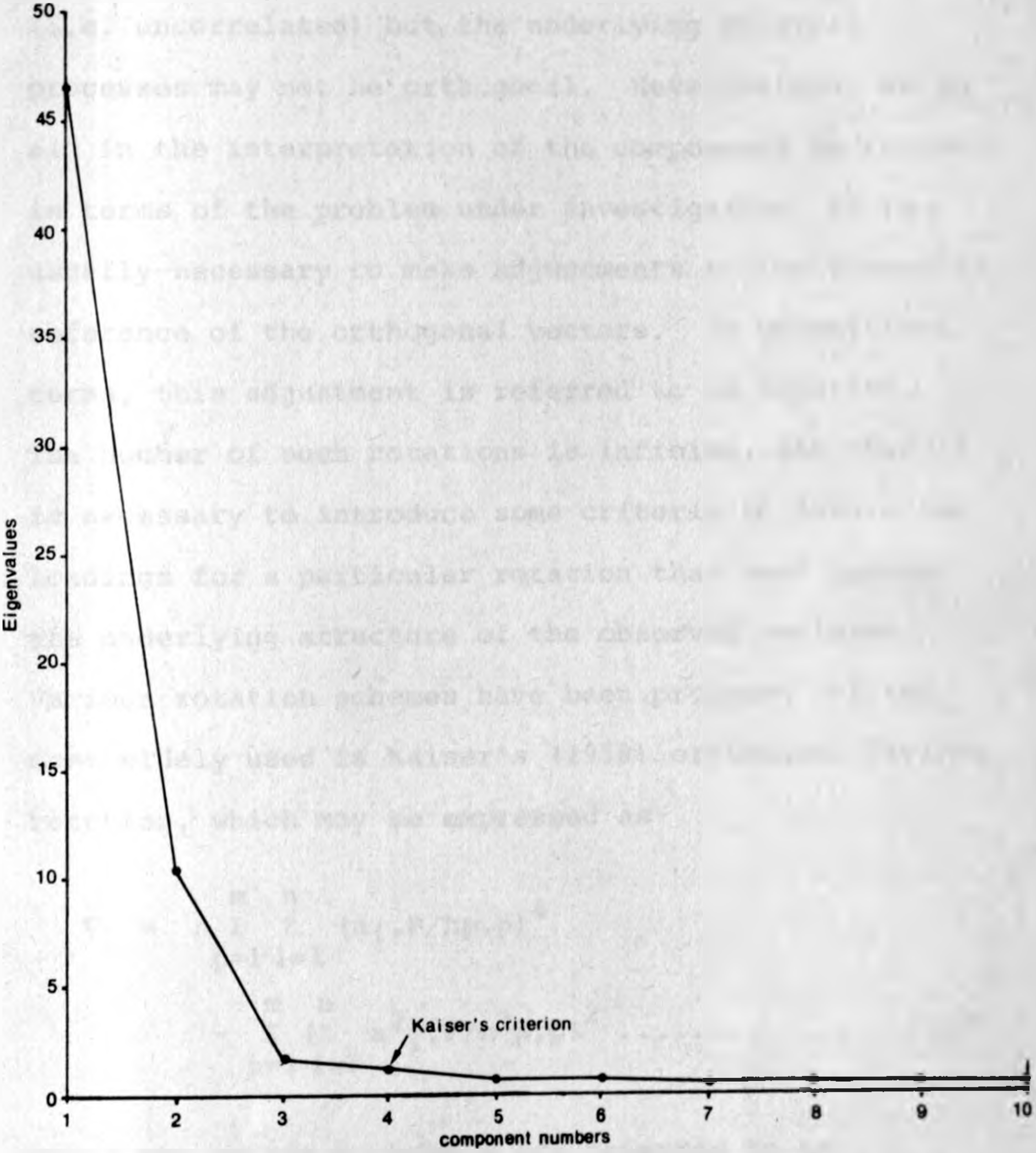
Table 15. Results of the PCA (showing only the first 10 components)

Eigenvalue number	Eigenvalue before rotation	% variance extracted	cumulative % of total variance
1	46.37	69.2	69.2
2	10.41	15.5	84.7
3	1.72	2.6	87.3
4	1.28	1.9	89.2
5	0.84	1.3	90.5
6	0.76	1.1	91.6
7	0.58	0.9	92.6
8	0.52	0.8	93.3
9	0.49	0.7	94.0
10	0.45	0.7	94.7

Note: Kaiser's criterion indicates a cut-off value at eigenvalue no. 4.

The 10 components taken together account for some 94.7% of the total variance while the first 4 components account for 89.2% of the system variance.

Fig.13 Graph of Eigenvalues against component numbers



4.2.2 Rotation of components

The eigenvectors are mathematically orthogonal (i.e. uncorrelated) but the underlying physical processes may not be orthogonal. Nevertheless, as an aid in the interpretation of the components or factors in terms of the problem under investigation, it is usually necessary to make adjustments to the frames of reference of the orthogonal vectors. In geometrical terms, this adjustment is referred to as rotation. The number of such rotations is infinite, and thus it is necessary to introduce some criteria to obtain the loadings for a particular rotation that best reveals the underlying structure of the observed variates. Various rotation schemes have been proposed but the most widely used is Kaiser's (1958) orthogonal Varimax rotation, which may be expressed as

$$V = n \sum_{p=1}^{m} \sum_{i=1}^{n} (a_{i},P/hp,p)^{4} - \sum_{p=1}^{m} (\sum_{i=1}^{n} a^{2}{}_{i},P/h^{2}p,p)^{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (21)$$

where the ratios a_{i},p/hp,p are referred to as "normalized" loadings. This rotation scheme yields a set of loadings such that the variance of the square of the loadings is a maximum. It is worthwhile to also mention that rotation does not affect the total or common explained variance.

Kaiser's (op.cit.) rotation procedure was used in this study and the results are shown in table 16 below:

Table 16. Percentage of total variance explained by each of the 4 initial and final (rotated) Principal Components

	% variance explained	
Component Number	Initial PC	Rotated PC
1	69.2	50.8
2	15.5	33.1
3	2.6	3.3
4	1.9	2.0
Total	89.2	89.2

4.2.3 The seasonal rainfall regimes

Often in a rotated factor solution, loadings are encountered whose values cannot be judged to be high or low. The tendency has been to choose a critical value such that all the loadings that are greater than the critical value are high and all loadings that are less than the critical value are low. A number of methods have been suggested for testing the statistical significance of the loadings (see for example Ogallo, 1980). Matalas *et al*, (1967) suggested that it is better to call a loading high or low, whichever seems to reveal best the underlying structure of the observed variates. The objectivity of the analysis, when such a procedure is used, is somewhat questionable in that the investigator imposes upon the analytical technique what the underlying structure is, rather than allowing the model to reveal the structure to the investigator.

On the basis of the magnitude of the component loading on each Principal Component and also the total variance explained by each component (see table 16 and 17), only the first two Principal Components appeared to give reasonable spatial coherence. The full matrix indicating the first four Varimax rotated Principal Components and the loadings of the rainfall stations on each component (or rainfall regime) are shown in table 17. The first Principal Component has loadings ranging from -0.02 (Narok Meteorological Station) to 0.97 (Eldoret Municipal Council). When the largest component loadings (generally >0.70) were noted and mapped, a very conspicuous region similar to the pattern in figs. 10-12 emerged; the region trends in a north-west/south-east direction along a line Kitale-Londiani. The rainfall stations loading highly on the second Principal Component showed a different and yet spatially coherent pattern. The magnitude of the component loadings ranged from 0.06 (Eldoret Municipal Council) to 0.96 (Kibos). An examination of components I and II led to the identification and delineation of the "Eldoret" and "Kibos" seasonal rainfall regimes.

Table 17. The first 4 Varimax Rotated Principal Components showing the loadings of the rainfall stations on each Component

	Components			
First rainfall regime	C_I	C_{II}	C_{III}	C_{IV}
Mt. Elgon	0.87	0.29	0.23	0.23
Elgon Downs	0.91	0.18	0.15	0.26
Sabwani	0.88	0.28	0.14	0.28
Chorlini	0.86	0.18	0.19	0.25
Namandala Farm	0.84	0.27	0.16	0.26
Kitale	0.86	0.26	0.19	0.26
Kipkoitet	0.92	0.16	0.21	0.09
Mlimani	0.87	0.28	0.21	0.20
Kitale Met.	0.91	0.27	0.22	0.04
Kakamega	0.69	0.58	0.28	-0.02
Aral Estate	0.89	0.23	0.26	0.15
Gloucester Estate	0.85	0.21	0.29	-0.18
Lugari Ltd.	0.87	0.08	0.31	-0.19
Kaimosi T.T.C.	0.67	0.59	0.33	-0.08
Kaabirir	0.75	0.57	0.10	-0.10
Kaptagat	0.78	0.56	-0.04	0.10
Koisagat	0.74	0.60	0.09	-0.06
Kipsomba	0.93	0.09	0.14	-0.01
Savani	0.67	0.63	0.09	-0.14
Tilol	0.94	0.25	-0.12	0.09
Baraton	0.78	0.40	0.31	-0.11
Mvita	0.86	0.43	-0.12	0.04
Selbourne Estate	0.90	0.12	0.14	-0.18
Nabkoi	0.94	0.16	-0.09	-0.07
Eldoret	0.97	0.06	-0.10	0.02
Nandi Factory	0.76	0.54	0.24	0.02
Kenley	0.84	0.35	0.01	0.15
Nandi Forest Stn.	0.73	0.43	0.24	-0.19
Lolgarini	0.88	0.40	-0.06	0.12
Kibabet	0.86	0.36	0.08	0.14

Table 17. (cont'd.)

Kapiyet	0.83	0.32	0.10	0.18
Nandi Tea Estate	0.76	0.50	0.09	-0.06
Chepkorio	0.71	0.61	-0.07	0.18
F.T.C. Eldoret	0.93	0.25	-0.09	0.05
Timboroa	0.92	0.26	-0.11	0.01
Londiani	0.95	0.18	-0.06	-0.03
Maji Mazuri	0.67	0.61	-0.18	0.18
Mau Summit	0.92	0.27	-0.03	-0.09
Langoni	0.90	0.30	0.10	-0.12
Braeside	0.93	0.26	-0.05	-0.12
Hundred Acres	0.88	0.36	-0.02	-0.07
Marindas Farm	0.94	0.10	-0.15	0.04
Lengetia Farm	0.91	0.15	-0.07	-0.09
<u>Second rainfall regime</u>				
Bungoma Vet	0.51	0.66	0.43	0.11
Bungoma Agric.	0.50	0.63	0.49	0.09
Busia Cotton	0.27	0.81	0.38	0.05
Kapsowar	0.48	0.76	0.04	0.36
Tambach	0.61	0.67	-0.12	0.23
Siret	0.64	0.65	0.11	0.03
Kisumu P.C.	0.14	0.92	-0.06	-0.13
Asumbi	0.21	0.81	0.32	0.15
Miwani II	0.12	0.92	0.06	0.07
Miwani	0.22	0.91	0.02	0.10
Miwani I	0.16	0.91	-0.06	0.15
Miwani III	0.19	0.90	0.07	0.04
Asembo	0.20	0.89	-0.06	-0.16
Kisumu Met.	0.10	0.94	-0.02	-0.10
Moromba F.C.	0.26	0.82	0.25	-0.01
Nyakwere	0.31	0.86	-0.06	-0.05
Kibos Water Supply	0.11	0.90	0.15	0.01
Kibos Cotton	0.18	0.96	-0.05	-0.02
Jamji Estate	0.34	0.86	0.12	-0.04
Kericho	0.52	0.72	0.29	-0.02
Sotik	0.39	0.76	-0.19	-0.23
Chemelil	0.38	0.81	0.13	0.13
Renwik	0.19	0.91	0.08	0.03
Narok Met.	-0.02	0.78	-0.17	-0.26

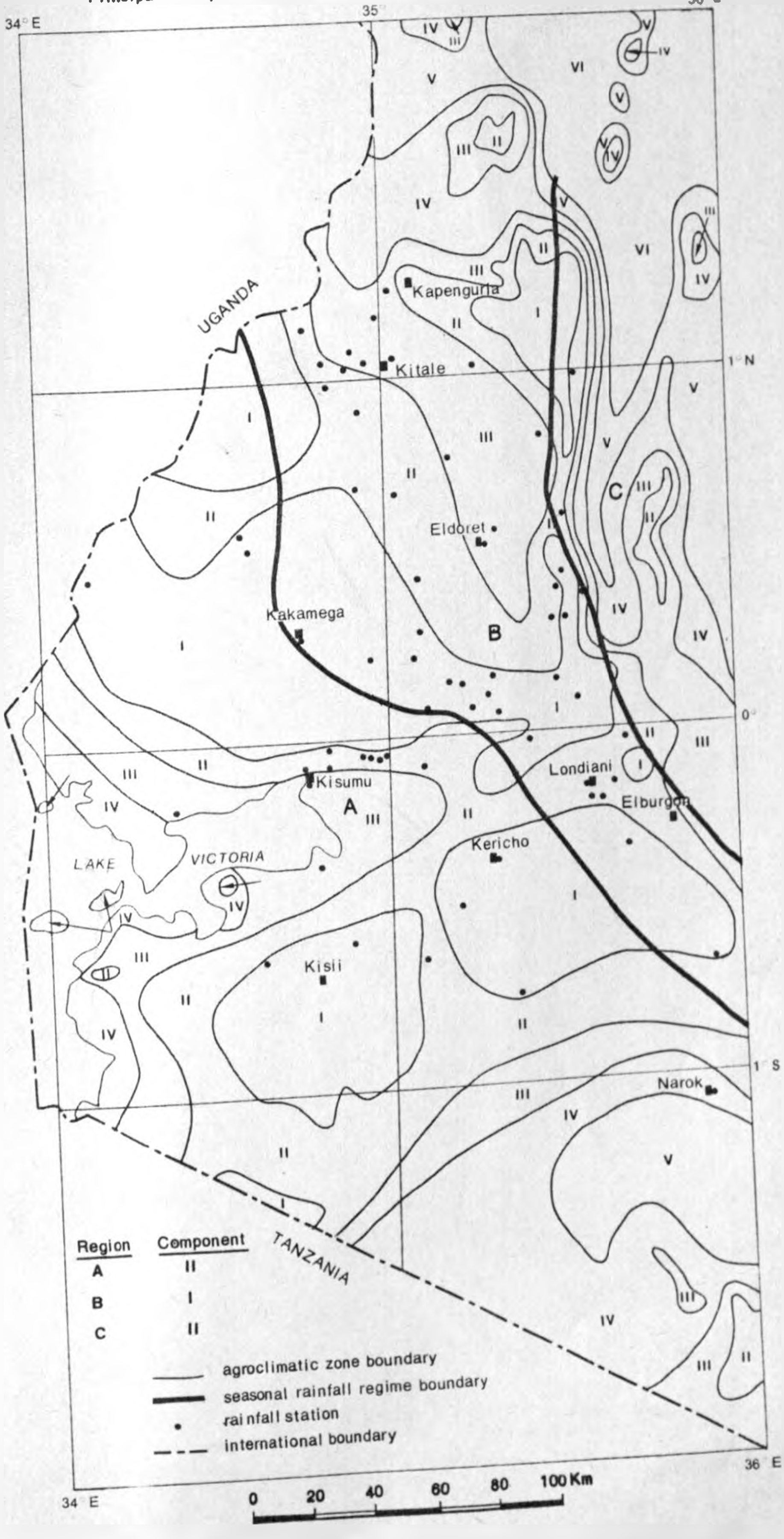
The regimes were assigned the name of the rainfall station with the highest loading on a component (rainfall regime), the rationale being that the station is in the "core area" of that rainfall regime. The seasonal rainfall regimes are shown in table 18 below and in figure 14.

Table 18. The major Principal Components (regimes of seasonal rainfall) observed and their characteristics - see also fig. 14.

Region	Major Principal Component	General characteristics
A	II	Loadings on this component generally higher than 0.70
B	I	Loadings >0.60
C	II	A transition zone but the stations have higher loadings on C_{II} than on C_I

A close examination of table 17 reveals that near the seasonal rainfall regime boundaries, there exist transitional zones. The transitional zones were identified by their nearly equal loadings on components I and II. The eastern extremity of the study area is one example of such a transitional zone. Other examples can be found around Kakamega, Nandi and Kericho. That Narok belongs to the "Kibos" regime is

Fig. 14 The seasonal rainfall regimes of the lake Victoria Drainage Basin according to Principal Components Analysis (PCA) with Varimax Rotation

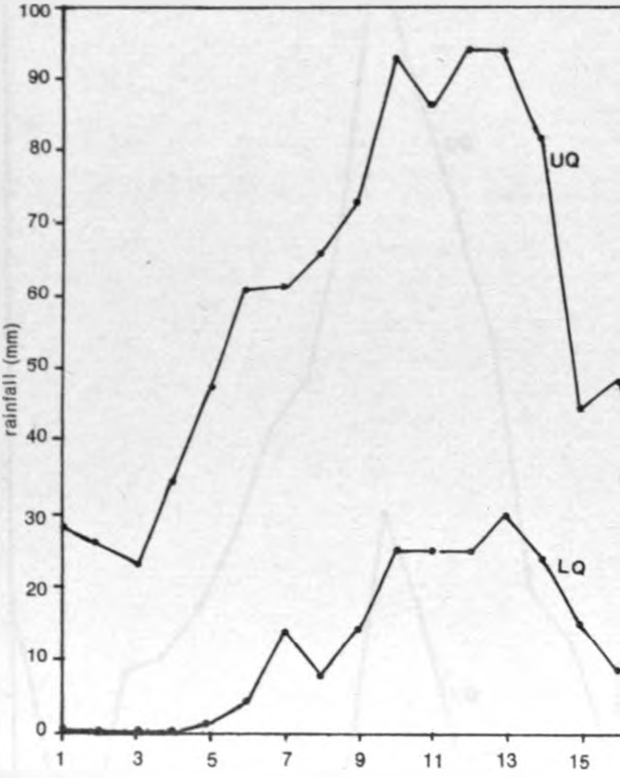


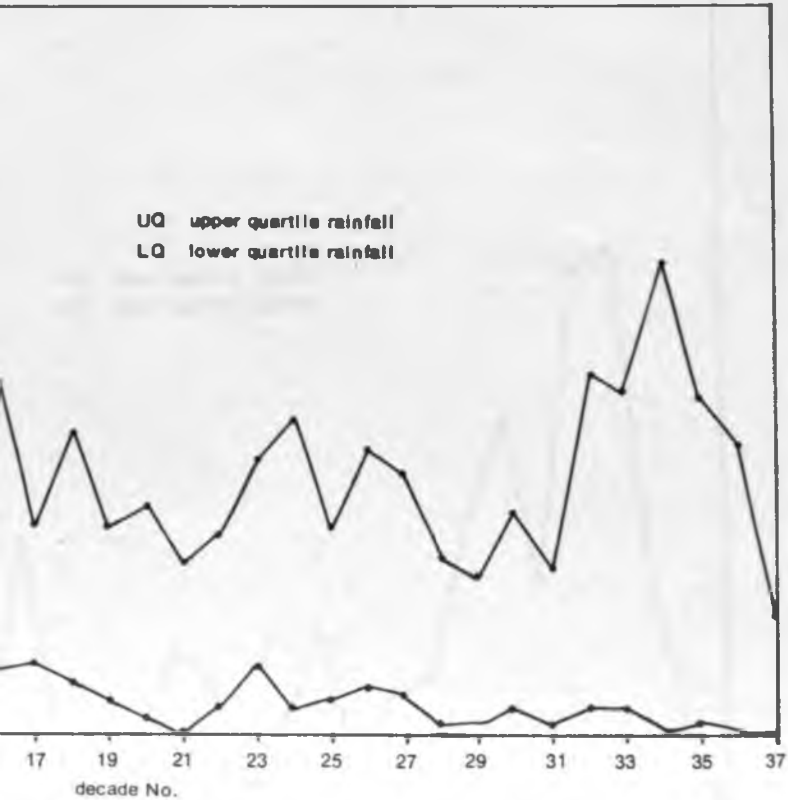
somewhat surprising because the mean monthly rainfall pattern indicates a November-May unimodal rainfall regime. This is not, however, wholly supported by fig. 15: (iv) which shows the seasonal regime of rainfall variability; the rainfall pattern throughout the year is similar to that of the stations close to Lake Victoria and hence the station's inclusion in the "Kibos" regime. The data of other stations representing each of the identified seasonal rainfall regimes are presented in fig. 15: (i-iii) and 15: (v-xi). The "Kibos" regime is mainly bimodal, see for example figs. 15: (ii), (iii) and (v); in some places, a weak third peak in August is discernible, see fig. 15: (ii). The "Eldoret" regime has two rainfall peaks falling within a single rainy season as is exemplified by the data of Londiani, fig. 15: (ix) and Mt. Elgon Forest Station, fig. 15: (vi). Kericho on the other hand is located close to the boundary between the "Kibos" and "Eldoret" regimes. From fig. 15: (x) it is clear that the area has rainfall virtually throughout the year. To a certain extent, Kakamega is similar to Kericho, see fig. 15: (xi).

From table 17, it can also be observed that 25 out of 67 stations used in the analysis had component loadings of more than 0.90; component I had 16, and component II, 9 such stations (see table 19). These stations are located in what may be termed as the "core areas" of the main seasonal regimes of rainfall

Fig. 15: (i) - (xi). The seasonal regime of rainfall variability for some stations in the study area. Upper and lower quartile rainfall is shown

Fig. 15 (i) Kisumu P.C. (90.34004)




UQ upper quartile rainfall
LQ lower quartile rainfall
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decade No.

Fig. 15 (ii) Asembo Dispensary (90.34022)

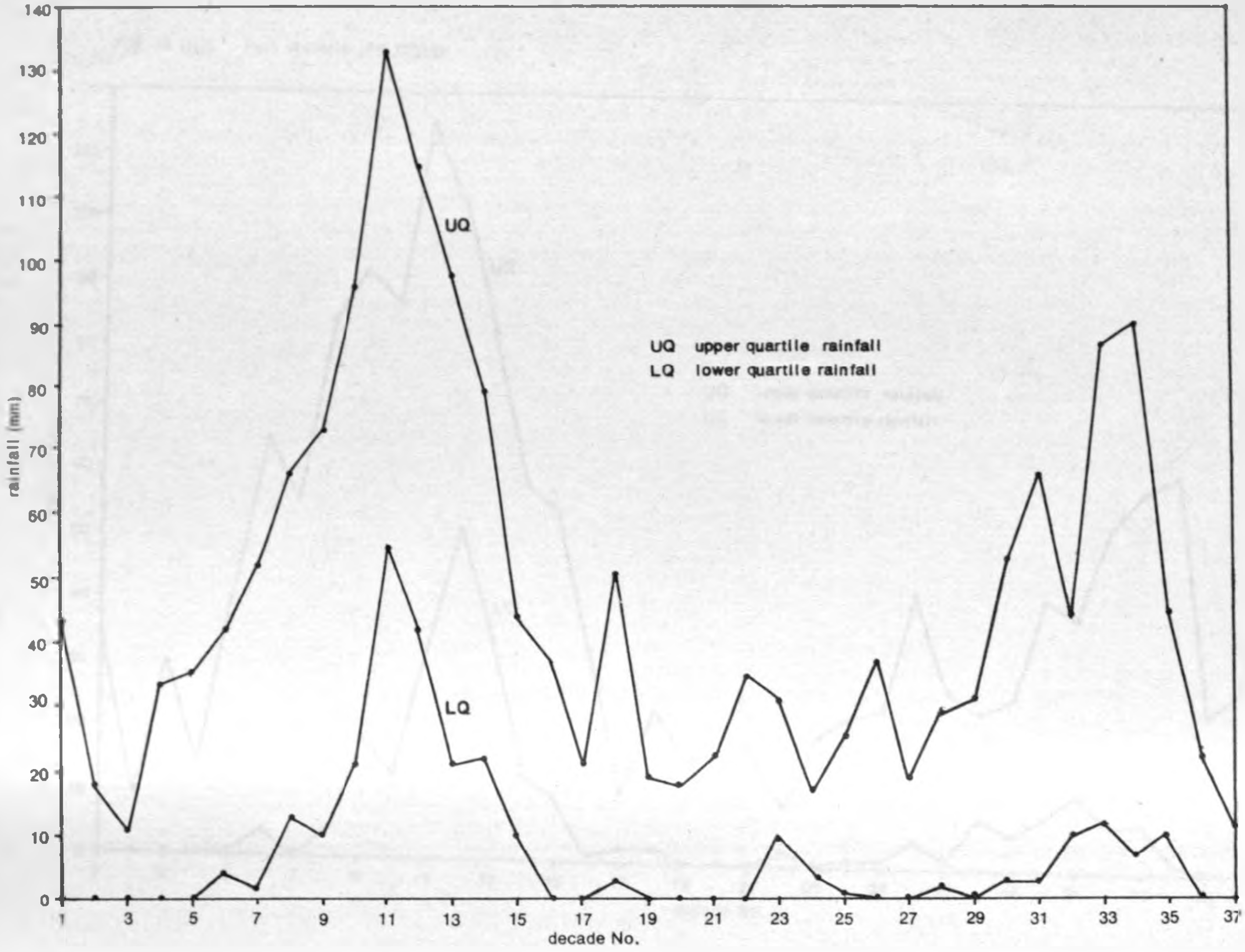
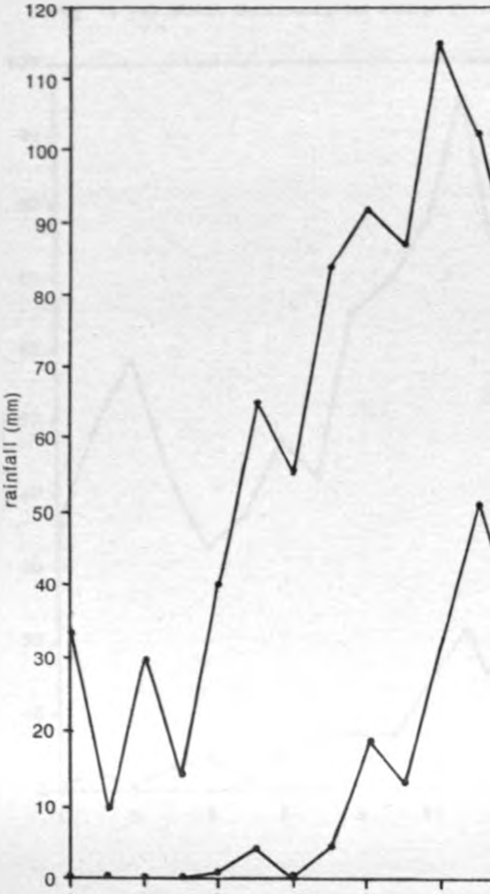


Fig. 15 (iii) Port Victoria (89.33026)



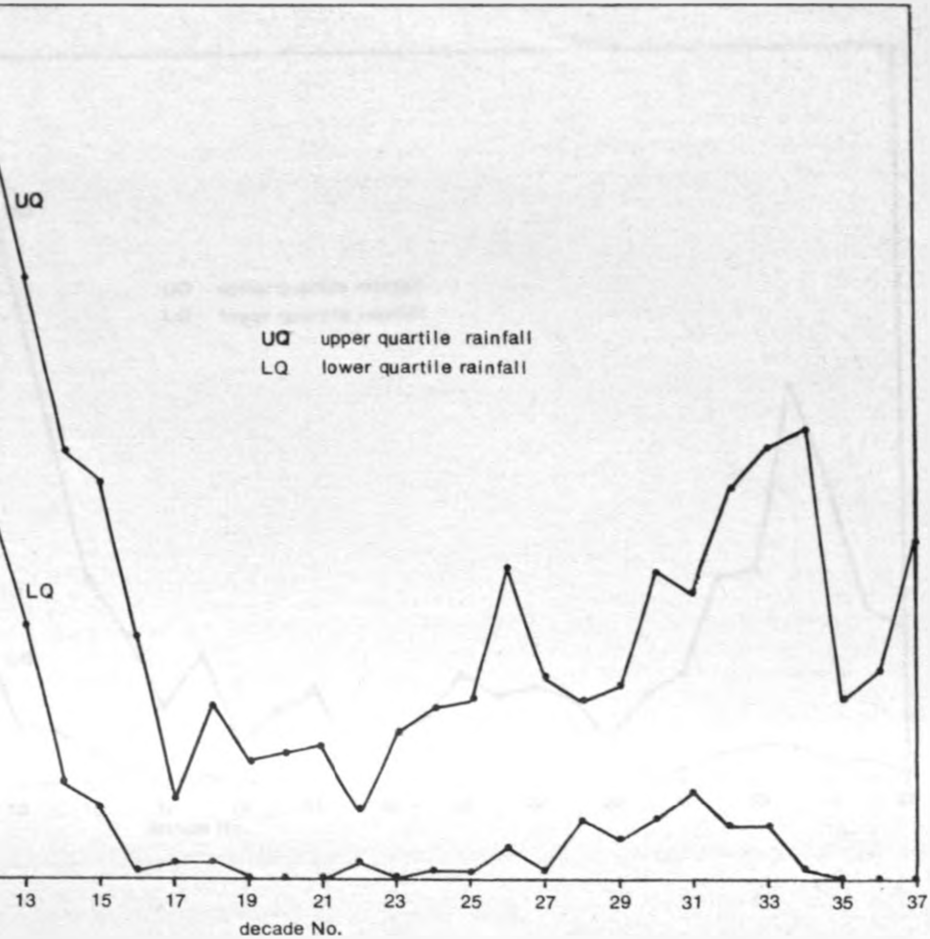

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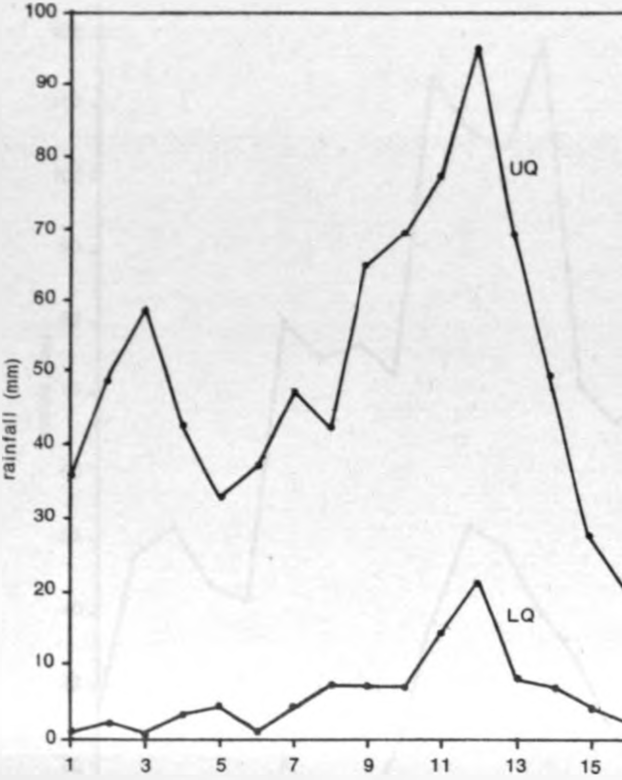
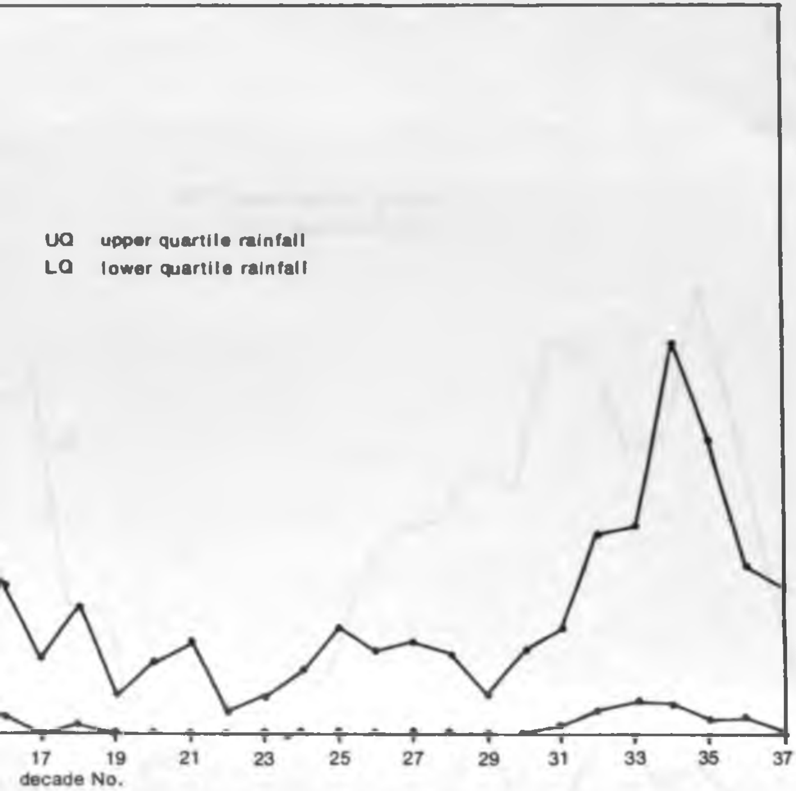
Fig. 15 (iv) Narok Meteorological station (91.35001)

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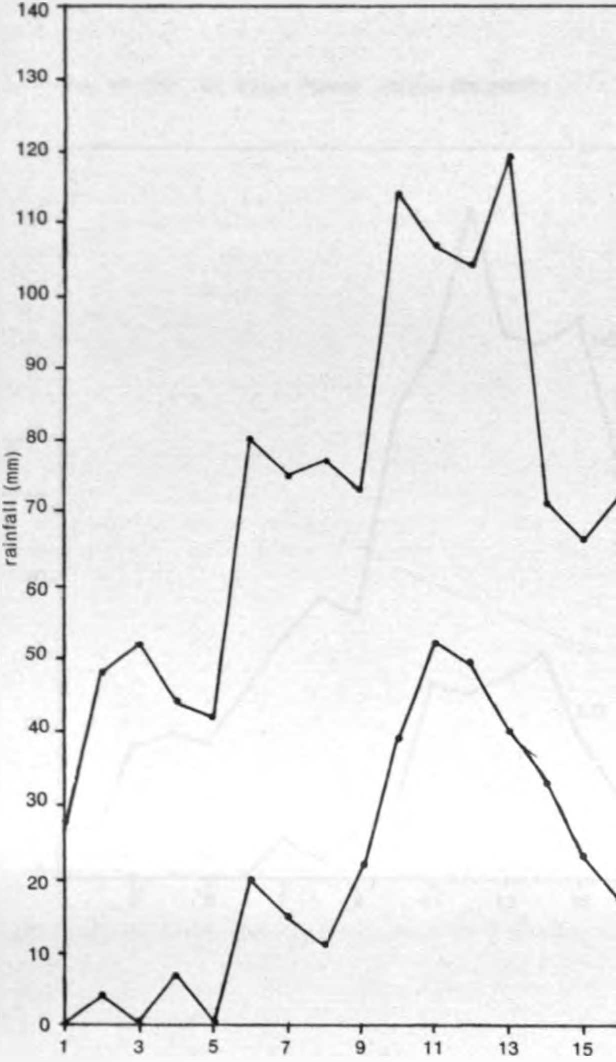
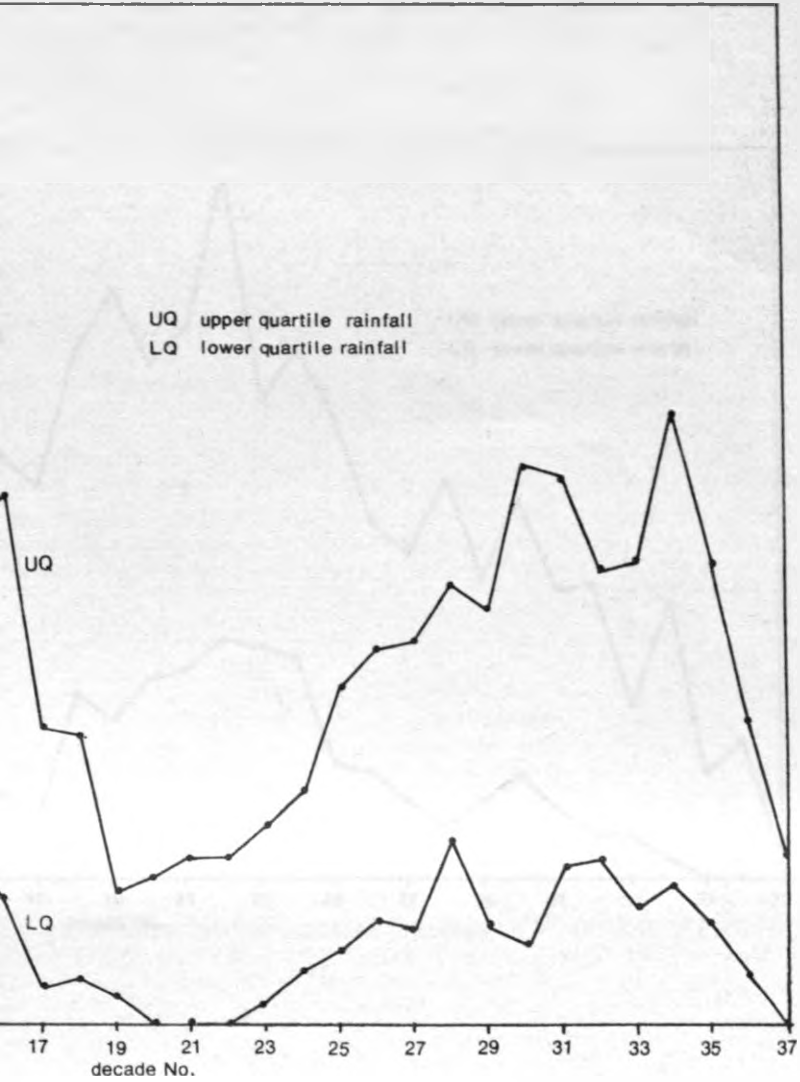
decade No.

Fig. 15 (v) Migori Agricultural office (91.34010)




UQ upper quartile rainfall
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decade No.

Fig. 15 (vi) Mt. Elgon Forest station (88.34001)

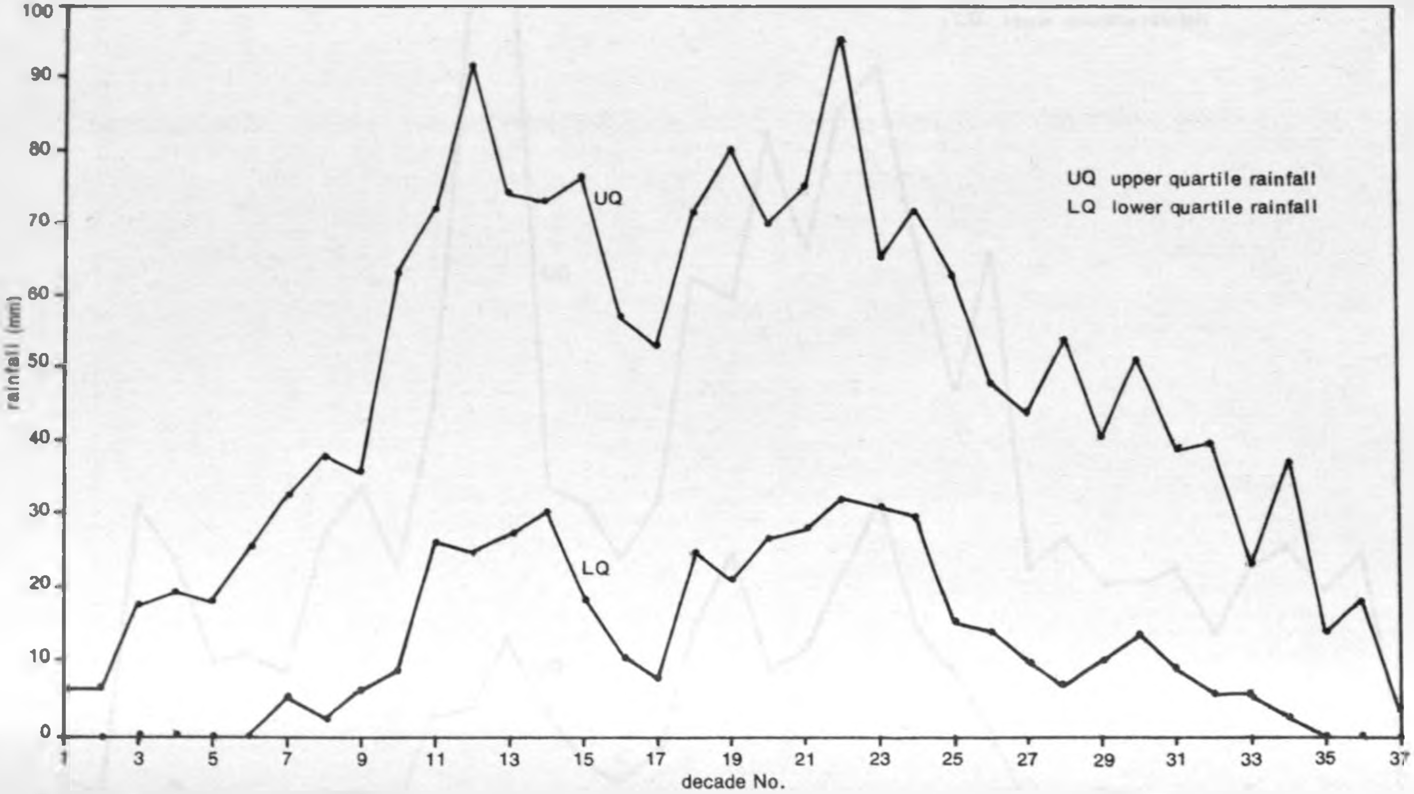
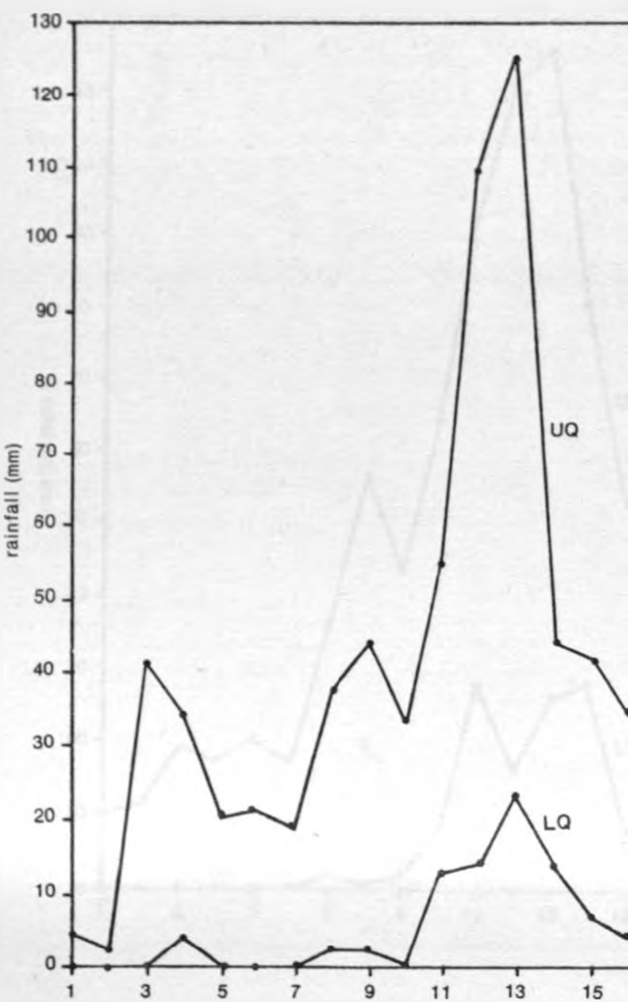
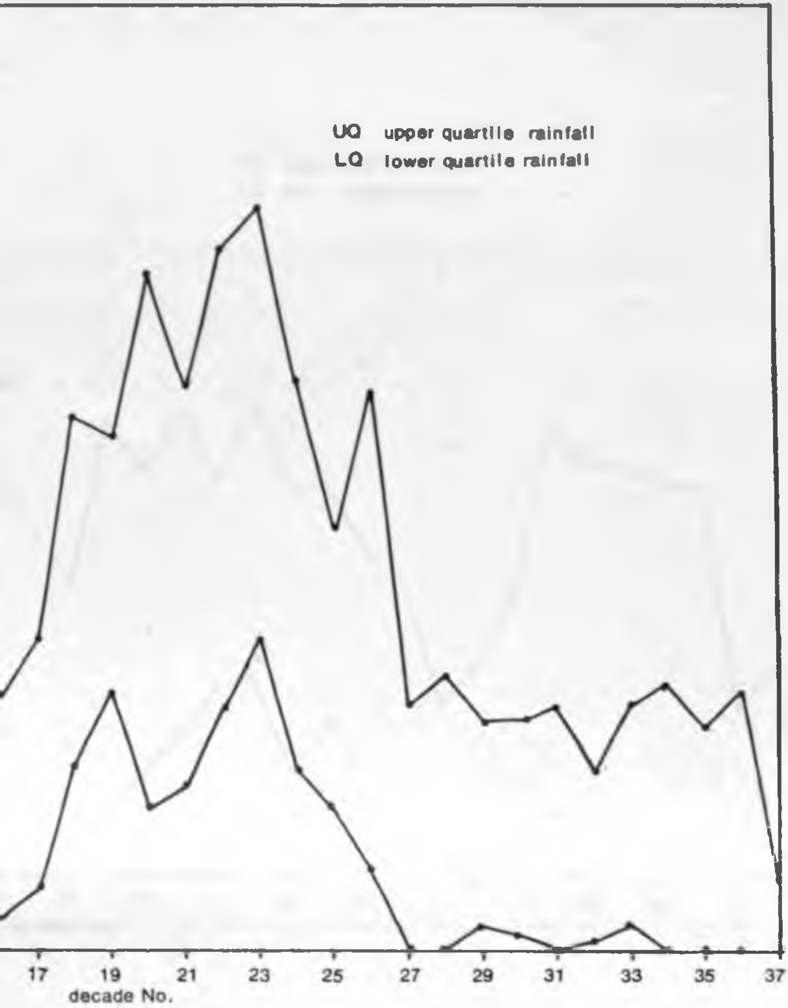


Fig. 15 (vii) Eldoret Municipal Council (89.35086)

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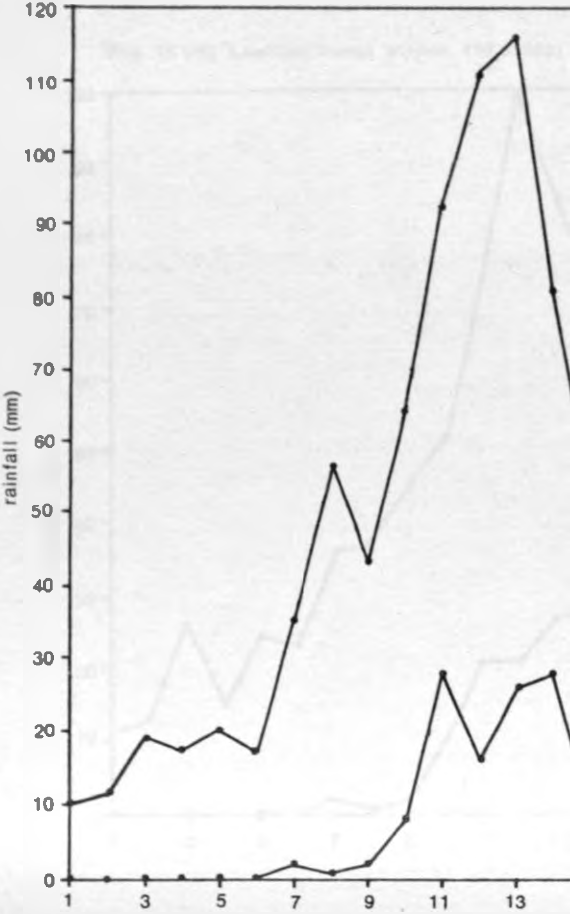

Fig. 15 (viii) Tambach D.O. (89.35014)

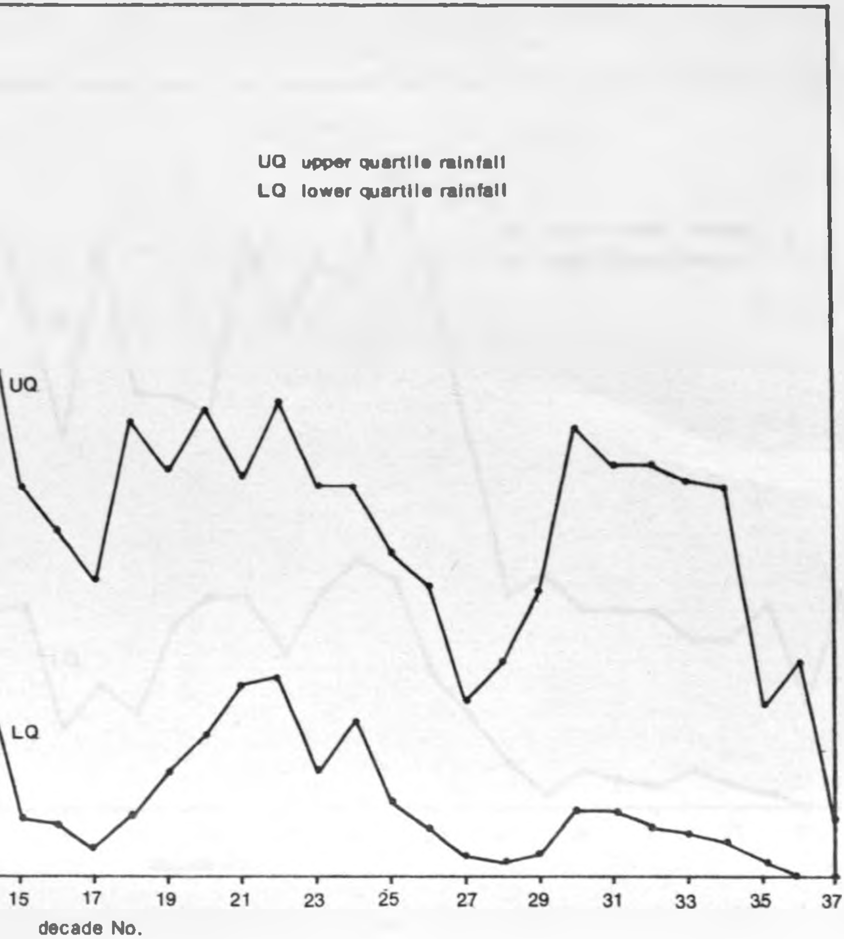
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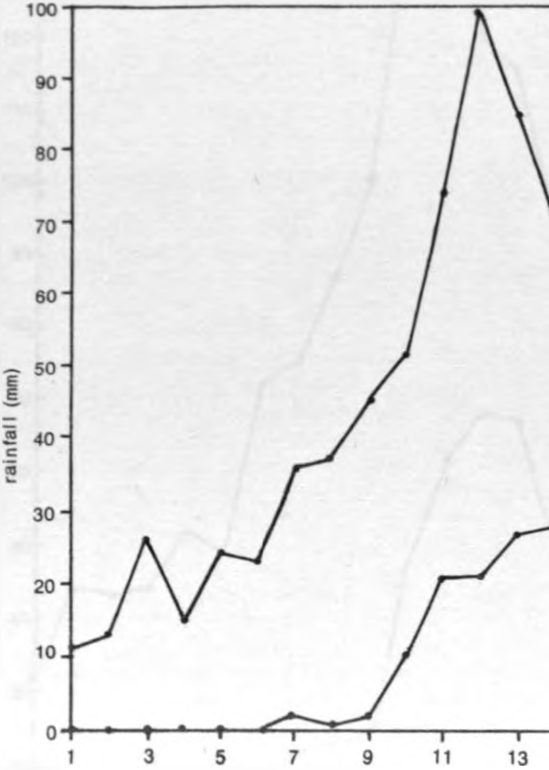
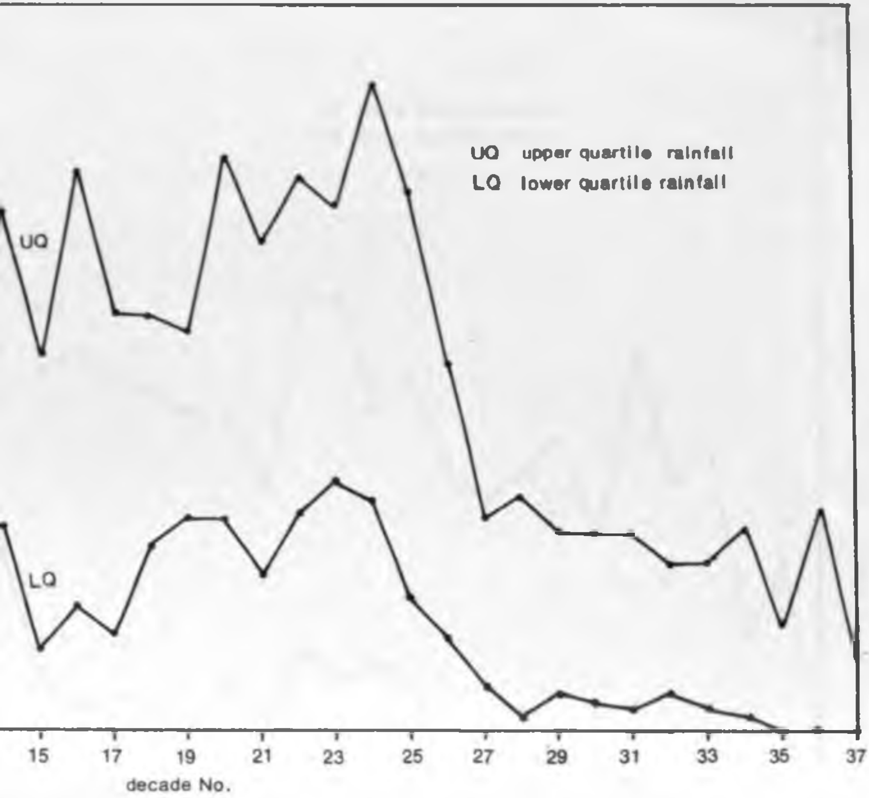
Fig. 15 (ix) Londiani forest station (90.35002)

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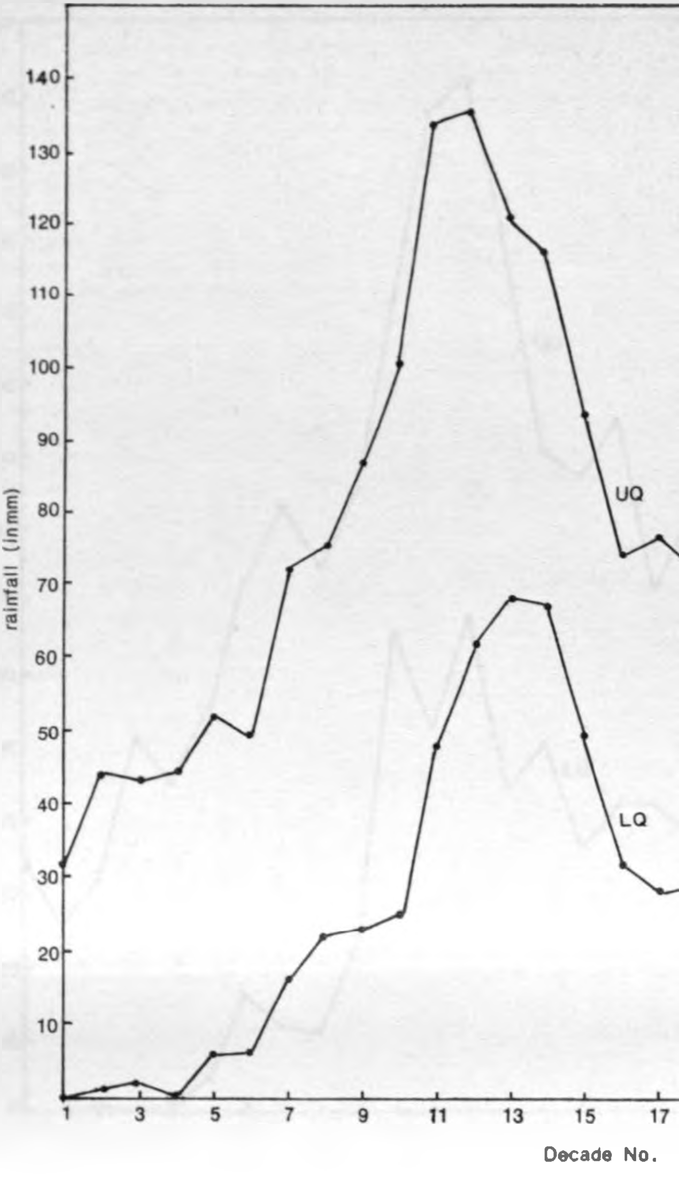
decade No.

Fig. 15 (x) Kericho D.O (90.35003)



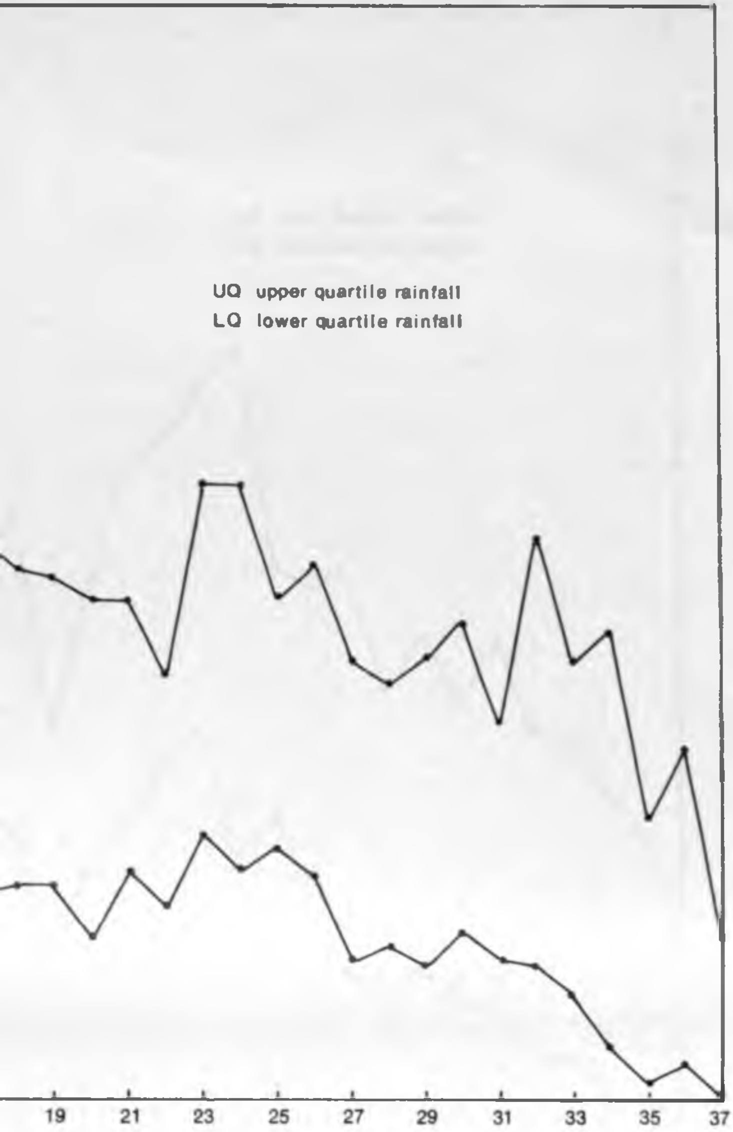

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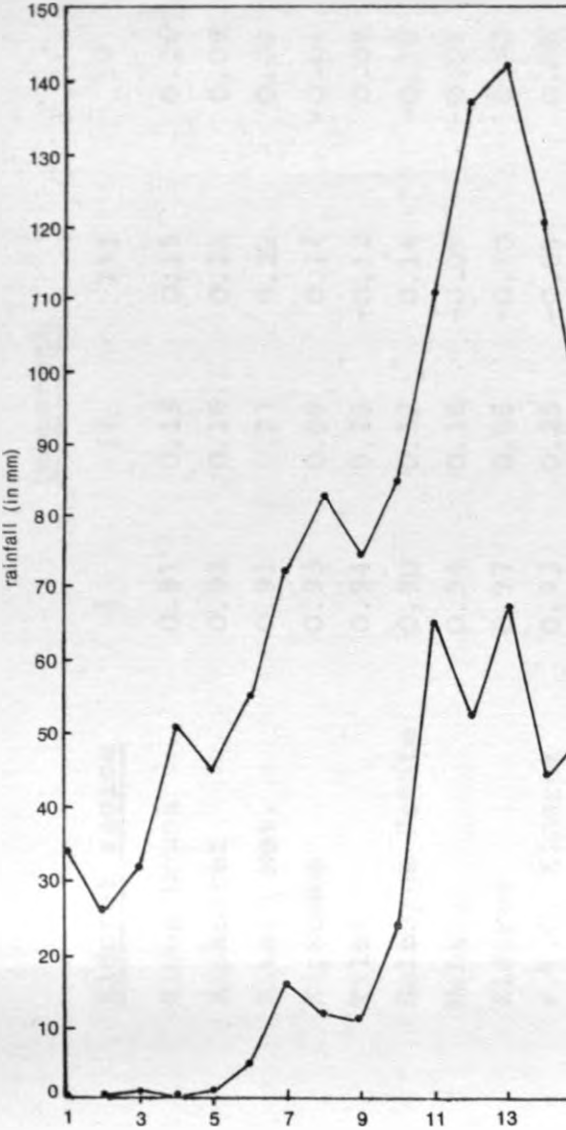
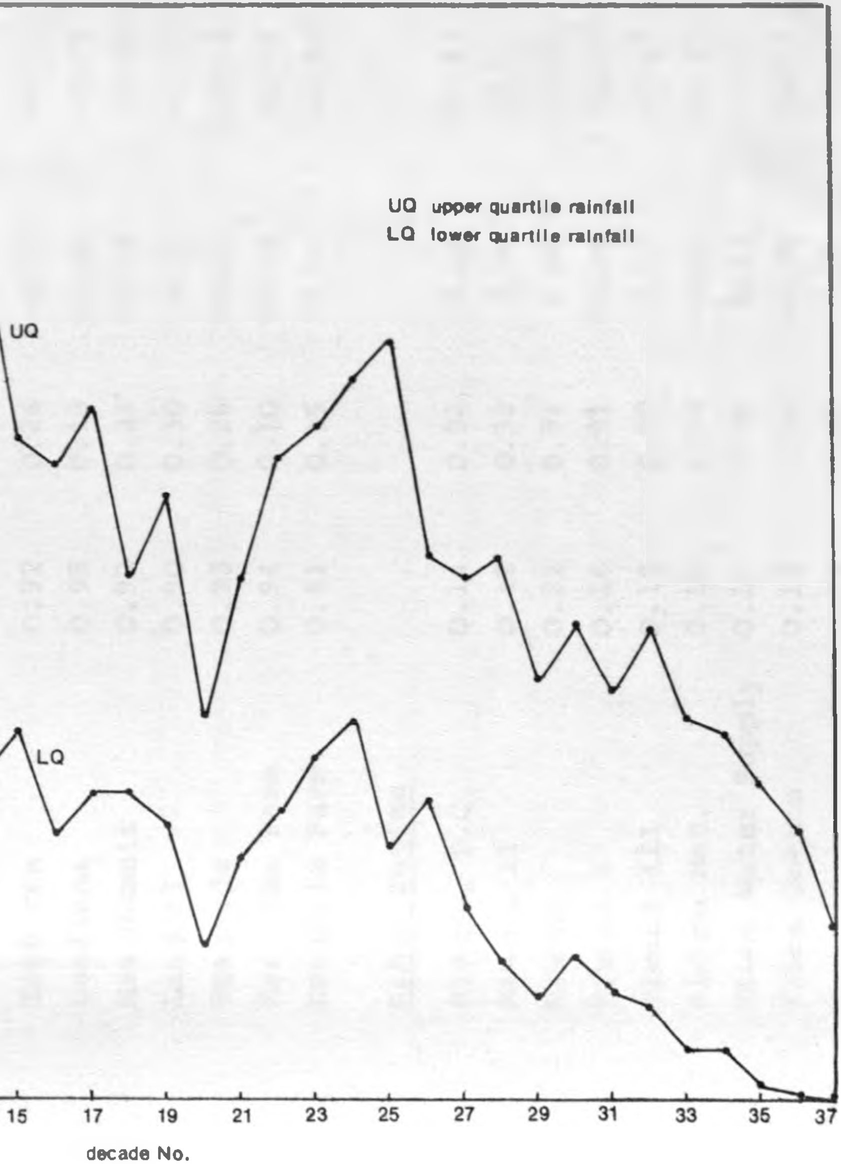
Fig. 15(xi) Kakamega D.O (89.34001)



UQ upper quartile rainfall
LQ lower quartile rainfall
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decade No.

Table 19. Rainfall stations with component loadings of 0.90 or more

	Component			
Eldoret regime	I	II	III	IV
Elgon Downs	0.91	0.18	0.15	0.26
Kipkoitet	0.92	0.16	0.21	0.09
Kitale Met.	0.91	0.27	0.22	0.04
Kipsomba	0.93	0.09	0.14	-0.01
Tilol	0.94	0.25	-0.12	0.09
Selborne Estate	0.90	0.12	0.14	-0.18
Nabkoi	0.94	0.16	-0.09	-0.07
Eldoret	0.97	0.06	-0.10	0.02
F.T.C. Eldoret	0.93	0.25	-0.09	0.05
Timboroa	0.92	0.26	-0.11	-0.01
Londiani	0.95	0.18	-0.06	-0.03
Mau Summit	0.92	0.27	-0.03	-0.09
Langoni	0.90	0.30	0.10	-0.12
Braeside	0.93	0.26	-0.05	-0.12
Marindas Farm	0.94	0.10	-0.15	0.04
Lengetia Farm	0.91	0.15	-0.07	-0.09
Kibos regime				
Kisumu, P.C.	0.14	0.92	-0.06	-0.13
Miwani II	0.12	0.92	0.06	0.07
Miwani	0.22	0.91	0.02	0.10
Miwani I	0.16	0.91	-0.06	0.15
Miwani III	0.19	0.90	0.07	0.04
Kisumu Met.	0.10	0.94	-0.02	-0.10
Kibos Water Supply	0.11	0.96	0.15	0.05
Kibos Cotton	0.18	0.96	-0.05	-0.02
Renwik	0.19	0.91	0.08	0.03

in the study area; they are highly correlated with a large number of other stations than with stations outside the "core" areas.

4.2.4 The spatial structure of the seasonal march of rainfall in the study area

From the results of the Principal Components Analysis and the seasonal rainfall patterns depicted in figs. 15: (i) to (xi), it is evident that the "Kibos" rainfall regime has its main rains in the March-May period with a rather brief "short rains" season during the October-December period. In some places within this zone, there is a relatively minor peak during August. In the "Eldoret" regime, the main rains occur from April to September with a dip in June. In the transitional areas, such as around Kericho and Kakamega, there is rainfall virtually throughout the year. Figs. 16-20 illustrate the spatial differences in the sequence of seasonal rainfall occurrence in the study area. The median rainfall, rather than the arithmetic average was mapped, because, as has been discussed elsewhere, the 10-day rainfall totals did not show the characteristics of a normal distribution. Fig. 16 shows the median rainfall during the second decade (January 11-20). Rainfall in the "Kibos" regime is more than 2mm (ranging from 2mm to 17mm). The north-eastern sector of the study area also has rainfall of more than 2mm while the "Eldoret" regime area has 1mm or less of rainfall.

Fig. 16 Median rainfall in the 2nd decade (Jan., 11–20)

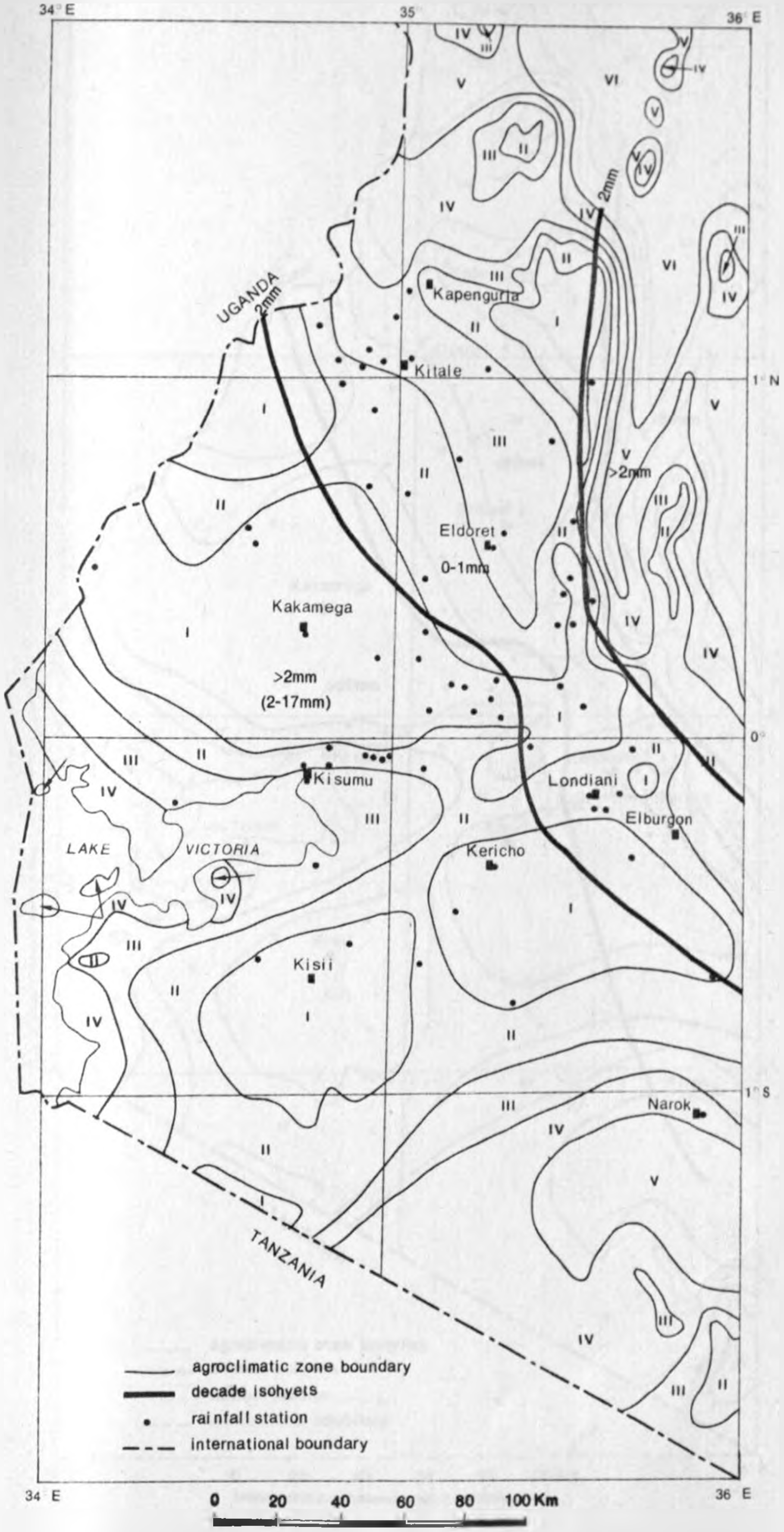


Fig. 17 Median rainfall in the 11th decade (April 10–19)

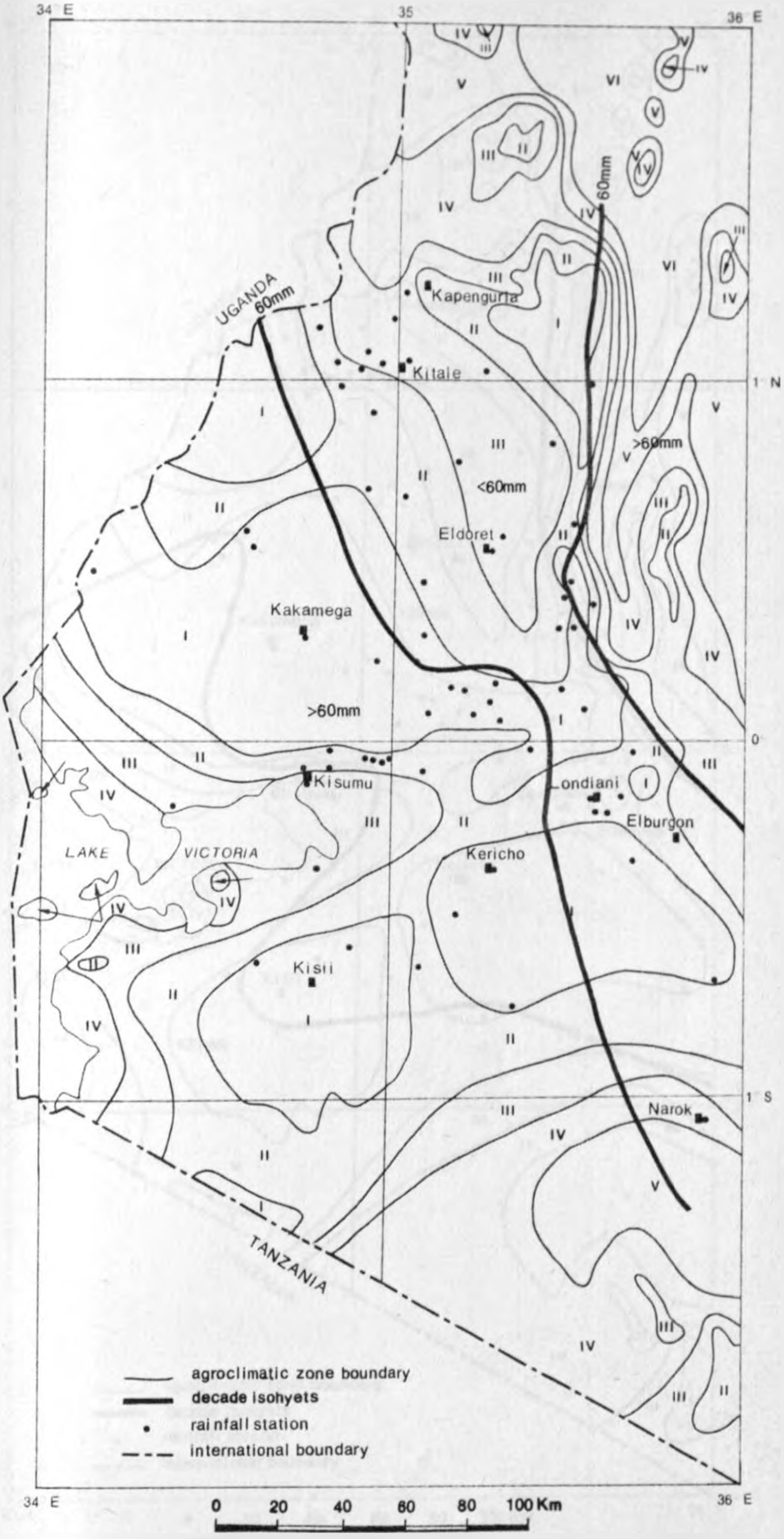


Fig. 18 Median rainfall in the 23rd decade (Aug., 8-17)

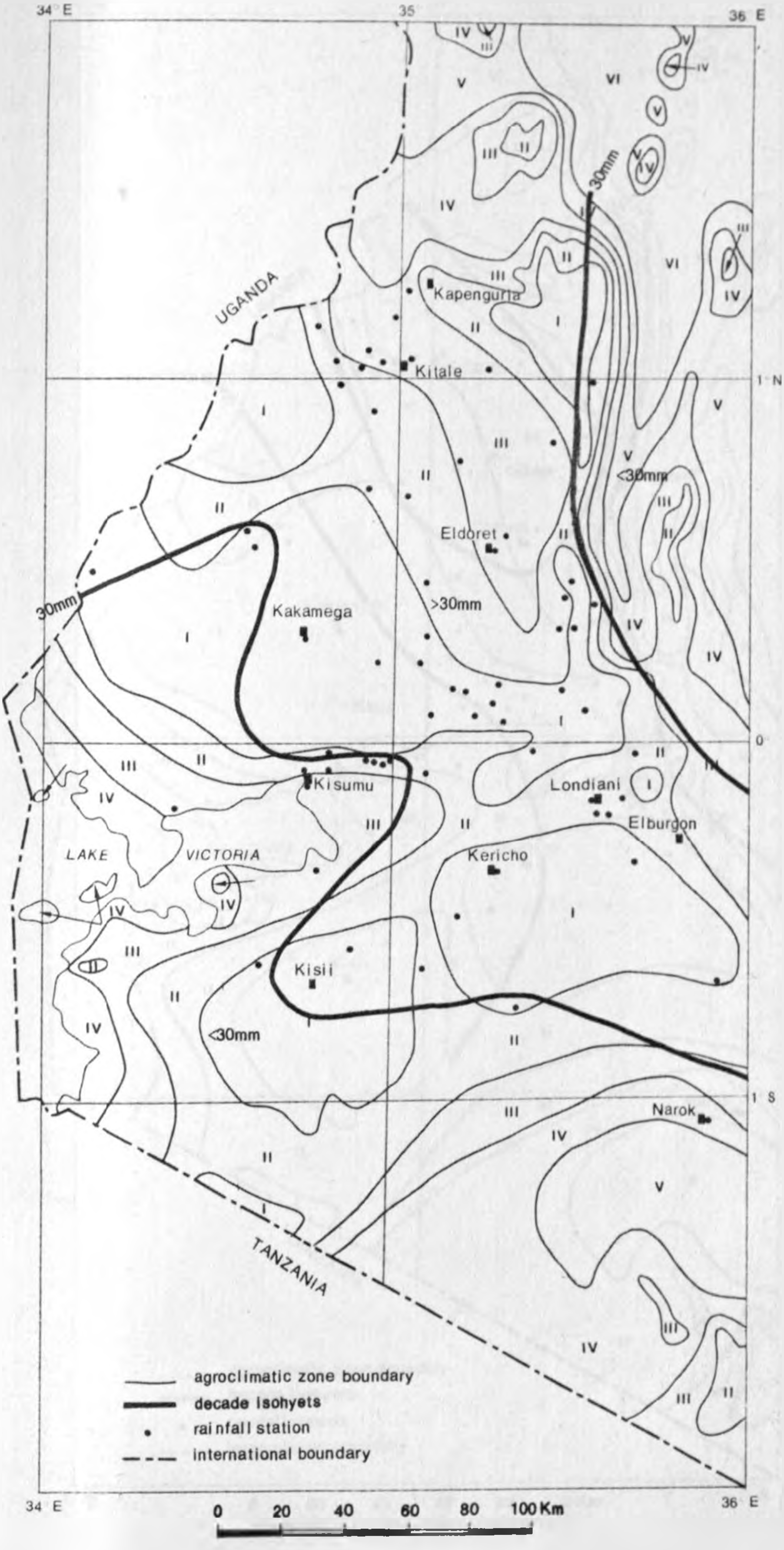


Fig. 19 Median rainfall in the 33rd decade (Nov., 16–25)

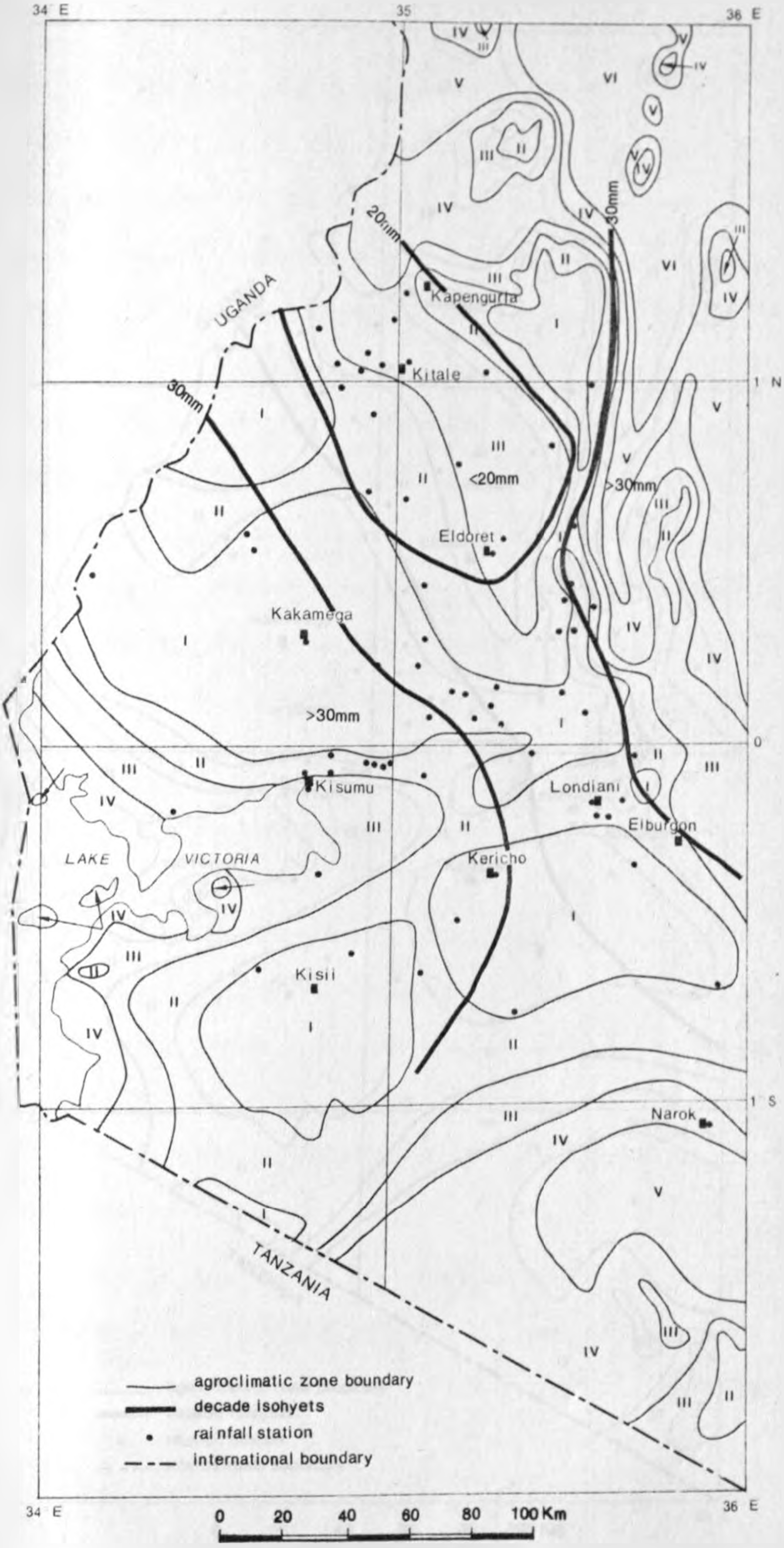
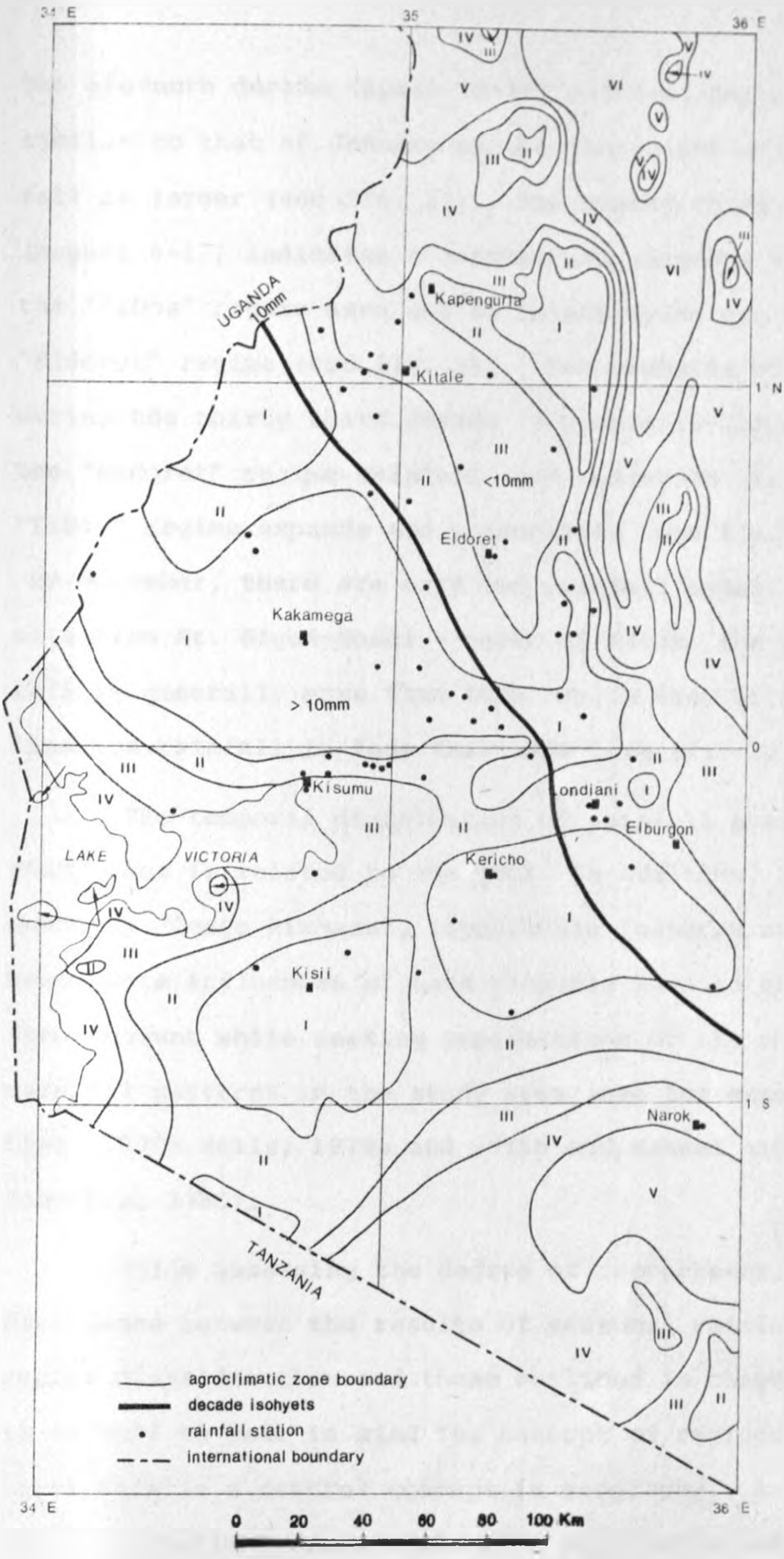


Fig. 20 Median rainfall in the 36th decade (Dec., 16–25)



The eleventh decade (April 10-19) rainfall pattern is similar to that of January except the amount of rainfall is larger (see fig. 17). The twenty third decade (August 8-17) indicates a contracting rainfall zone in the "Kibos" regime area and an intensifying one in the "Eldoret" regime (see fig. 18). The opposite occurs during the thirty third decade (November 16-25) when the "Eldoret" regime rainfall zone contracts while the "Kibos" regime expands and intensifies (see fig. 19). By December, there are only two rainfall areas; west of a line Mt. Elgon-Nandi - north of Narok, the rainfall is generally more than 10mm while east of that line the rainfall is less than 10mm (see fig. 20).

The temporal distribution of rainfall over the study area is related to the ITCZ. In addition, the westerly "Congo Airmass", topographic features and the meso-scale influences of Lake Victoria have to be taken into account while seeking explanations of the observed rainfall patterns in the study area (see for example Lumb, 1970; Hills, 1978a and 1978b and Asnani and Kinuthia, 1980).

While assessing the degree of concurrence or divergence between the results of seasonal rainfall regime classification and those outlined in chapter 2, it is well to bear in mind the concept of regionalization; this is a central concept in geography. As many rainfall stations as possible (67) were subjected to

Principal Components Analysis with the object of identifying the rainfall regions of the study area based on the seasonality of rainfall as the distinctive criterion. This was achieved through the analysis of the correlation coefficients of rainfall distribution throughout the year between different stations, thus distinguishing groups of stations which were identified by their seasonal rainfall regime. Each group of stations constitute a rainfall region. The variance between stations in a rainfall region is smaller than the variance between the stations in different rainfall regions. The significance of the results is that predictions can be made regarding the nature of rainfall seasonality, rainfall variability and reliability and the onset, duration and cessation of the rainy seasons. The importance of the results in agro- and hydro-climatology can hardly be overemphasized.

4.3 Wet and dry spells analysis

One of the objectives of the study was to identify and delineate, using the method of Principal Components Analysis, the seasonal rainfall regimes occurring in the Lake Victoria Drainage Basin. The attempt to discover regions of similar seasonal rainfall patterns was a necessary step because the resulting grouping formed the basis of the selection of a few sample stations for the study of wet and dry spells (see table 13). It is argued that the sample stations were more objectively selected compared to the approaches discussed in chapter 2. Any one rainfall station in the "core areas" of the identified seasonal rainfall regimes could have been chosen to illustrate the pattern of rainfall occurrence throughout the year as well as the wet and dry spell characteristics in a particular regime. From the results of the Principal Components Analysis, it was possible also to select stations that belonged to neither of the dominant rainfall regions.

4.3.1 Results of wet and dry spells analysis based on the 1.0mm criterion

The daily rainfall data of 11 stations were analysed for the frequency of occurrence and distribution of wet and dry spells for the March to mid-June (1941-1970) period. The observed frequency of wet spells is shown in table 20. The table reveals the following interesting features:

(a) the frequency of wet spells falls off exponentially from the shortest duration to the longest;

(b) high frequency of wet spells of short duration particularly at Miwani, Mt. Elgon and Sotik;

(c) wet spells of longer durations are more frequent in the highlands e.g. around Kericho, Kakamega

Table 20. Observed frequency of wet spells (based on the 1mm criterion)

Length of wet spell in days (n)	88.34001	88.35005	89.34001	89.35014	90.34008	90.35001	90.35002	90.35003	90.35013	90.35028	90.35038
1	247	232	208	205	330	185	201	212	244	208	211
2	101	108	109	112	131	95	109	119	126	102	90
3	77	56	70	63	82	54	64	71	83	53	55
4	45	32	49	26	43	41	29	52	56	43	37
5	25	23	29	19	26	33	18	37	34	22	14
6	16	20	27	12	22	21	17	22	30	18	13
7	10	8	12	9	6	22	11	13	18	7	8
8	3	10	9	8	3	6	5	13	6	9	3
9	7	8	8	5	2	9	5	9	6	8	3
10	3	1	6	5	5	10	2	6	3	3	5
11	0	3	6	2		9	5	6	4	3	2
12	1	1	3	2		5	4	2	2	6	1
13	0	0	1	1		5	1	1	2	2	1
14	0	0	1	0		6	1	1	1	1	0
15	1	1	1	0		0	1	2	0	2	1
16	0	0	2	1		1	2	1	1	1	0
17	1	1	2	0		1	1	2	0	0	0
18	0	0	0	0		2	1	0	0	0	0
19	1	0	2	0		2		1	0	0	0
20		1	0	1		4		1	0	0	0
21		0	0	0		0		1	0	1	1
22		1	0	0		3		0	0		
23			1	0		0		0	0		
24			0	0		0		0	1		
25			2	0		1		0			
26				0		1		0			
27				0		1		0			
28				0		0		0			
29				1		0		0			
30						0		0			
31						0		0			
32						0		0			
33						0		0			
34						0		0			
35						0		0			
36						0		0			
37						0		0			
38						0		1			
39						1		0			

and the Cherangani hills. This implies that rainfall is more persistent over the highlands as opposed to the lower areas around Lake Victoria. The latter area falls under the "Kibos" regime and is represented by Miwani (station number 90.34008).

The observed cumulative frequency of wet spells is shown in table 21. The data at the top of each column in table 21 indicates the total number of wet spells of all durations that occurred at each station during the 1941-1970 period. The summation of each column, from the shortest to the longest duration, gives the total number of rain days that occurred during the 30-year period considered at each station. The total number of rain days divided by the total number of days in the season (3210) gives the probability of a wet day, P(w). Corresponding frequencies were obtained in a similar manner for the dry spells.

Table 22 below gives further insight into the wet spells contrasts between the different rainfall regions in the study area. It is observed from the table that the highest probability of a wet day occurs in the Kericho highlands as well as around Kakamega. The lowest probability of a wet day on the other hand occurs at Mau Summit. The longest wet spells lasting 38 and 39 days occurred at Kericho and Jamji Estate, respectively. The shortest wet spell lasting 10 days occurred at Miwani. That the shortest wet spell

Table 21. Observed cumulative frequency of wet spells based on the 1.0mm criterion (wet spells lasting (n) days or longer)

Days (n)	90.35001	90.35003	89.35014	89.34001	90.35013	88.35005	90.35028	90.35038	88.34001	90.35002	90.34008
1	515	573	472	548	617	506	489	445	538	477	650
2	333	361	267	340	373	274	281	234	291	276	320
3	238	242	155	231	247	166	179	144	190	167	189
4	184	171	92	161	164	110	126	89	113	103	107
5	143	119	66	112	108	78	83	52	68	74	64
6	110	82	47	83	74	55	61	38	43	56	38
7	89	60	35	56	44	35	43	25	27	39	16
8	67	47	26	44	26	27	36	17	17	28	10
9	61	34	18	35	20	17	27	14	14	23	7
10	52	25	13	27	14	9	19	11	7	18	5
11	42	19	8	21	11	8	16	6	4	16	
12	33	13	6	15	7	5	13	4	4	11	
13	28	11	4	12	5	4	7	3	3	7	
14	23	10	3	11	3	4	5	2	3	6	
15	17	9	3	10	2	4	4	2	3	5	
16	17	7	3	9	2	3	2	1	2	4	
17	16	6	2	7	1	3	1	1	2	2	
18	15	4	2	5	1	2	1	1	1	2	
19	13	4	2	5	1	2	1	1	1	1	
20	11	3	2	3	1	2	1	1			
21	7	2	1	3	1	1	1	1			
22	7	1	1	3	1	1					
23	4	1	1	3	1						
24	4	1	1	2	1						
25	4	1	1	2							
26	3	1	1								
27	2	1	1								
28	1	1	1								
29	1	1	1								
30	1	1									
31	1	1									
32	1	1									
33	1	1									
34	1	1									
35	1	1									
36	1	1									
37	1	1									
38	1	1									
39	1										

Table 22. Wet season characteristics - wet spells

Station name	Number of wet spells	Number of wet days	Probability (in %) of a wet day	Longest wet spell lasted
Jamji Estate	515	2050	64	39 days
Kericho	573	1819	57	38 "
Tambach	472	1235	38	29 "
Kakamega	548	1748	54	25 "
Sotik	617	1725	54	23 "
Kipkoitet	506	1316	41	22 "
Maji Mazuri	489	1396	43	21 "
Mau Summit	445	1092	34	21 "
Mt. Elgon	538	1331	41	19 "
Londiani	477	1313	41	18 "
Miwani	650	1406	44	10 "

occurred at a station in the "Kibos" regime, very close to the lake, confirms the convective nature of rainfall in this area. Most of the rainfall occurs in frequent storms of limited durations as opposed to the highland areas where rainfall tends to persist for several days.

The results of the dry spells analysis are shown in tables 23 and 24. The frequency of dry spells, as was observed for the wet spells, falls off exponentially from the shortest duration to the longest. An interesting feature of the dry spells data is that they are longer than the wet spells except at Kakamega, Jamji

Table 23. Observed frequency of dry spells (based on the 1mm criterion)

Length of dry spell in days (n)	88.34001	88.35005	89.34001	89.35014	90.34008	90.35001	90.35002	90.35003	90.35013	90.35028	90.35038
1	206	193	263	180	286	291	177	317	305	206	161
2	106	106	125	77	135	88	79	107	145	87	73
3	51	61	55	48	83	50	58	60	65	57	43
4	51	38	33	42	55	39	38	30	38	37	44
5	39	25	23	30	29	14	28	19	19	34	23
6	24	23	21	27	22	12	28	11	15	14	22
7	19	11	8	13	9	7	11	9	8	12	13
8	13	9	3	9	11	1	15	8	10	11	10
9	10	16	6	13	14	5	4	4	7	10	12
10	6	8	4	5	5	3	5	3	4	6	11
11	5	4	3	7	3	0	8	0	1	5	6
12	4	5	0	5	1	0	4	2	0	3	5
13	2	2	2	7	2	2	5	1	1	4	3
14	4	3	1	2	2	1	3	2	2	2	9
15	1	3	2	3	1	0	5	1	1	4	2
16	1	1	1	0	1	1	0	2	1	2	3
17	0	1	1	4	0	0	2	1	1	2	2
18	2	1	1	1	0	2	2	3	0	1	3
19	0	1	1	2	0	0	3	0	1	2	4
20	2	1	1	4	0	0	0	0		1	3
21	2	0	0	1	0	1	3	0		2	0
22	2	3	2	0	1		0	0		0	2
23		2		0	1		0	1		1	1
24		3		3			1			0	3
25		0		2			0			3	1
26		0		0			1			1	1
27		1		0			0				0
28				0			1				1
29				0			1				1
30				0			1				1
31				0							
32				0							
33				0							
34				0							
35				0							
36				0							
37				0							
38				0							
39				1							

Table 24. Observed cumulative frequency of dry spells based on the 1mm criterion (dry spells lasting (n) days or longer)

Days (n)	89.35014	90.35002	90.35038	88.35005	90.35028	90.34008	90.35003	89.34001	88.34001	90.35001	90.35013
1	486	483	463	521	507	661	581	556	550	517	624
2	306	306	302	328	301	375	264	293	344	226	319
3	229	227	229	222	214	240	157	168	238	138	174
4	181	169	186	161	157	157	97	113	187	88	109
5	139	131	142	123	120	102	67	80	136	49	71
6	109	103	119	98	86	73	48	57	97	35	52
7	82	75	97	75	72	51	37	36	73	23	37
8	69	64	84	64	60	42	28	28	54	16	29
9	60	49	74	55	49	31	20	25	41	15	19
10	47	45	62	39	39	17	16	19	31	10	12
11	42	40	51	31	33	12	13	15	25	7	8
12	35	32	45	27	28	9	13	12	20	7	7
13	30	28	40	22	25	8	11	12	16	7	7
14	23	23	37	20	21	6	10	10	14	5	6
15	21	20	28	17	19	4	8	9	10	4	4
16	18	15	26	14	15	3	7	7	9	4	3
17	18	15	23	13	13	2	5	6	8	3	2
18	14	13	21	12	11	2	4	5	8	3	1
19	13	11	18	11	10	2	1	4	6	1	1
20	11	8	14	10	8	2	1	3	6	1	
21	7	8	11	9	7	2	1	2	4	1	
22	6	5	11	9	5	2	1	2	2		
23	6	5	9	6	5	1	1				
24	6	5	8	4	4						
25	3	4	5	1	4						
26	1	4	4	1	1						
27	1	3	3	1							
28	1	3	3								
29	1	2	2								
30	1	1	1								
31	1										
32	1										
33	1										
34	1										
35	1										
36	1										
37	1										
38	1										
39	1										

Estate, Kericho and Sotik. Also notable is the high frequency of short duration spells particularly at the lake stations; this is exemplified by the data of Sotik, Kericho and Miwani. The stations in the "Eldoret" rainfall region have on the other hand a lower frequency of dry spells of short durations but a higher frequency of dry spells of longer durations. These results, together with the maximum dry spells duration data shown in table 25 have important implications for agriculture; they can be interpreted as indices of drought potential for the areas represented by the sample stations. It can also be observed in table 25 that some stations e.g. Sotik, Miwani, Kericho and Jamji Estate have some of the highest dry spell frequencies and lowest probabilities of a dry day. This is explained by the fact that these stations have lower frequencies of dry spells of long durations and hence a lower total number of dry days.

4.3.2 Wet and dry spells probabilities

From the cumulative frequencies shown in table 21 and 24, the percentage of times a period of a given type of weather (wet or dry spell) is followed by the same type of weather can be evaluated. An example will be given using the wet and dry spells data of Mt. Elgon station (88.34001). Out of the 538 cases of wet spells of at least 1 day duration, 291 cases, or 54%,

Table 25. Wet season characteristics - dry spells

Station name	Number of dry spells	Number of dry days	Probability (in %) of a dry day	longest dry spell lasted
Tambach	486	1975	62	39 days
Londiani	483	1897	59	30 "
Mau Summit	463	2118	66	30 "
Kipkoitet	521	1894	59	27 "
Maji Mazuri	507	1814	57	26 "
Miwani	661	1804	56	23 "
Kericho	581	1391	43	23 "
Kakamega	556	1462	46	22 "
Mt. Elgon	550	1879	59	22 "
Jamji Estate	517	1160	36	21 "
Sotik	624	1485	46	19 "

were at least of 2 days duration; 190 cases, or 35%, were at least of 3 days duration; and 113 cases, or 21% were of at least 4 days duration, etc. Of the 291 cases lasting 2 days or more, 190 cases, or 65%, lasted at least 3 days; 113 cases, or 39%, lasted at least 4 days, etc. For the dry spells, out of 550 cases of at least 1 day duration, 344 cases, or 63%, were of at least 2 days duration; 238 cases, or 43%, were of at least 3 days duration, etc. Of the 344 cases lasting 2 days or more, 238 cases, or 69%, lasted at least 3 days; 187 cases, or 54%, lasted at least 4 days; etc. Corresponding probabilities were obtained in a similar manner for the rest of the stations. An example of the results obtained is shown in table 26: (a-b); the results for the rest of the stations are included in appendix 1. From the data of appendix 1, it is observed that the probability of a type of weather recurring is higher the longer that type of weather has persisted. For example, if a wet spell has lasted at least 1 day at Mt. Elgon station, the probability of the spell lasting another day is 54%; if the spell has lasted 2 days, the probability is 65% that it will continue for another day. A similar interpretation can be made for the dry spells. The rise in probability with increased durations of the spells, as Alusa et al (1978) observed, is due to persistence. Noticeable in the data in appendix 1 is the fact that the probabilities decrease as the number of days (N) following the observed wet/dry spells increases. The probabilities of 1,3,5,7 and 10 or more days given a particular spell has lasted 1,3,5 and 7 days were extracted from the tables in appendix 1 and are given in tables 27: (a-d) and 28: (a-d). The data offer an opportunity to see the spatial contrasts existing in the study area; the contrast between the "core" areas of the different rainfall regions is particularly striking.

Table 26: (a). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Mt. Elgon (88.34001) during the March to mid-June period

M								
9	50	29	29	21	21	21	14	14
8	82	41	24	24	18	18	18	12
7	63	52	26	15	15	11	11	11
6	63	40	33	16	9	9	7	7
5	63	40	25	21	10	6	6	4
4	60	38	24	15	12	6	3	3
3	59	36	23	14	9	7	4	2
2	65	39	23	15	9	6	5	2
1	54	35	21	13	8	5	3	3
	1	2	3	4	5	6	7	8

N

M = length of the preceding wet spell in days
N = number of wet days following a wet spell of M days

Table 26: (b). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Mt. Elgon (88.34001) during the March to mid-June period

M																
12	80	70	50	45	40	40	30	30	20	10						
11	80	64	56	40	36	32	32	24	24	16	8					
10	81	64	52	45	32	29	26	26	19	19	13	6				
9	76	61	49	39	34	24	22	19	19	15	15	10	5			
8	76	57	46	37	30	26	19	17	15	15	11	11	7	4		
7	74	56	42	34	27	22	19	14	12	11	11	8	8	5	3	
6	75	56	42	32	26	21	16	14	10	9	8	8	6	6	4	2
5	71	54	40	30	23	18	15	12	10	7	7	6	6	4	4	3
4	73	52	39	29	22	17	13	11	8	7	5	5	4	4	3	3
3	79	57	41	31	23	17	13	11	8	7	6	4	4	3	3	3
2	69	54	39	28	21	16	12	9	7	6	5	4	3	3	2	2
1	63	43	34	25	18	13	10	7	6	5	4	3	3	2	2	1
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

N

M = length of the preceding dry spell in days
N = number of dry days following a dry spell of M days

Table 27(a). Probability (in %) of 1 or more days, 3 or more days etc given a wet spell has lasted one day

Station	1	3	5	7	10
Mt. Elgon	54	21	8	3	-
Kipkoitet	54	22	11	5	-
Kakamega	62	29	15	8	4
Tambach	57	19	10	8	4
Miwani	49	16	6	-	-
Jamji Estate	65	36	21	13	8
Londiani	58	22	12	6	3
Kericho	63	30	14	8	3
Sotik	60	27	12	4	-
Maji Mazuri	57	26	12	7	3
Mau Summit	52	20	9	4	1

Table 27(b). Probability (in %) of 1 or more days, 3 or more days etc given a wet spell has lasted three days

Station	1	3	5	7	10
Mt. Elgon	59	23	9	4	-
Kipkoitet	66	33	16	5	-
Kakamega	70	36	19	12	5
Tambach	59	30	17	8	3
Miwani	57	20	5	-	-
Jamji Estate	77	46	28	22	12
Londinai	62	34	17	11	4
Kericho	71	34	19	10	5
Sotik	66	30	11	6	-
Maji Mazuri	70	34	20	11	4
Mau Summit	62	26	12	8	2

Table 27(c). Probability (in %) of 1 or more days, 3 or more days etc given a wet spell has lasted five days

Station	1	3	5	7	10
Mt. Elgon	63	25	10	6	-
Kipkoitet	71	32	15	7	-
Kakamega	74	39	24	13	9
Tambach	71	39	20	9	-
Miwani	59	16	8	-	-
Jamji Estate	77	47	36	23	12
Londiani	76	38	24	15	6
Kericho	69	39	21	11	8
Sotik	69	24	13	6	-
Maji Mazuri	73	43	23	16	5
Mau Summit	73	33	21	8	-

Table 27(d). Probability (in %) of 1 or more days, 3 or more days etc. given a wet spell has lasted seven days

Station	1	3	5	7	10
Mt. Elgon	63	26	15	11	-
Kipkoitet	77	26	14	-	-
Kakamega	79	48	27	20	12
Tambach	74	37	17	9	-
Miwani	-	-	-	-	-
Jamji Estate	75	58	37	26	-
Londiani	72	46	28	15	5
Kericho	78	42	22	17	10
Sotik	59	32	16	7	-
Maji Mazuri	84	44	30	12	2
Mau Summit	68	44	16	8	-

Table 28(a). Probability (in %) of 1 or more days, 3 or more days etc. given a dry spell has lasted one day

Station	1	3	5	7	10
Mt. Elgon	63	34	18	10	5
Kipkoitet	63	31	19	12	6
Kakamega	53	20	10	5	3
Tambach	63	37	22	14	9
Miwani	57	24	11	6	2
Jamji Estate	44	17	7	3	-
Londiani	63	35	21	13	8
Kericho	45	17	8	5	-
Sotik	51	17	8	5	1
Maji Mazuri	59	31	17	12	7
Mau Summit	65	40	26	18	11

Table 28(b). Probability (in %) of 1 or more days, 3 or more days etc. given a dry spell has lasted three days

Station	1	3	5	7	10
Mt. Elgon	79	41	23	13	7
Kipkoitet	72	44	29	18	10
Kakamega	67	34	17	11	7
Tambach	79	48	30	21	13
Miwani	65	30	17	7	3
Jamji Estate	64	25	12	7	-
Londiani	74	45	28	20	12
Kericho	62	31	18	10	-
Sotik	63	30	17	7	4
Maji Mazuri	73	40	28	18	12
Mau Summit	81	52	37	27	17

Table 28(c). Probability (in %) of 1 or more days, 3 or more days etc. given a dry spell has lasted five days

Station	1	3	5	7	10
Mt. Elgon	71	40	23	15	7
Kipkoitet	80	52	32	22	14
Kakamega	71	35	24	15	11
Tambach	78	50	34	25	15
Miwani	72	41	17	9	4
Jamji Estate	71	33	20	1	-
Londiani	79	49	34	24	15
Kericho	72	42	24	19	-
Sotik	73	41	17	10	6
Maji Mazuri	72	50	33	23	16
Mau Summit	84	59	44	32	20

Table 28(d). Probability (in %) of 1 or more days, 3 or more days etc. given a dry spell has lasted seven days

Station	1	3	5	7	10
Mt. Elgon	74	42	27	19	11
Kipkoitet	85	52	36	27	17
Kakamega	78	53	33	28	17
Tambach	84	57	43	28	22
Miwani	82	33	18	12	4
Jamji Estate	-	-	-	-	-
Londiani	85	60	43	31	-
Kericho	76	43	35	27	-
Sotik	78	32	19	16	5
Maji Mazuri	83	54	39	29	18
Mau Summit	87	64	46	38	24

4.3.3 Fitting of the Markov chain probability and Exponential distribution models to the observed sequences of wet and dry spells

The Chi-square (χ^2) test was used as a measure of goodness of fit of the theoretical probability distributions to observed ones. Other tests to be noted, but were not used, include: Smirnov statistics, all observations involved; Kolgomorov statistics, only maximum departure involved; (Haan, 1977) and the Dubin-Watson statistic, residuals or departures involved (Kendall, 1976).

The basic concept of the Chi-square test can be summarized as follows: The total range of sample observations is divided into, say, k mutually exclusive and exhaustive class intervals, each having the observed class frequency O_j and corresponding class probability $E_j (j=1,2, ...k)$. Using the expected value E_j as the norm of any class interval, the quantity $(O_j-E_j)^2$ is used as a measure of departure from the norm. The magnitudes of the squared deviations (O_j-E_j) would not be comparable from one class to another, since the scale of each is nearly proportional to the expected value; therefore a suitable measure is expressed by

$$\frac{(O_j-E_j)^2}{E_j} \quad .... (21)$$

and the measure of total discrepancy between the observed and expected values, χ^2, becomes

$$\chi^2 = \sum_{j=1}^{k} \frac{(O_j - E_j)^2}{E_j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(22)$$

with k-p-1 degrees of freedom where p is the number of parameters estimated from the data. The hypothesis that the data are from the specified distribution is rejected if

$$\chi^2_c > \chi^2_{1-\alpha,k-p-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(23)$$

The fit of the observed wet spells to the Markov chain model was better at Mt. Elgon, Tambach, Miwani, Sotik and Mau Summit stations compared to the other stations. For the dry spells, the fit was poor for the data of all stations. With regard to the exponential distribution model, the best fit was observed at Mt. Elgon, Kakamega, Kericho, Sotik and Mau Summit stations. Both models gave a poor fit for the dry spells. The results of the goodness-of-fit test (χ^2) are summarized in tables 29 and 30 below; more details which allow a comparison between the observed frequencies and the computed ones are given in Appendix 2. The results in Appendix 2 show that the largest discrepancy between the observed and the computed frequencies occurs for spells (both wet and dry) of short duration; for longer durations, there is considerable agreement between the two models on the one hand, and between the observed and computed fre-

Table 29. Summary of the goodness-of-fit test (using χ^2) for wet spells - threshold value, 1.0mm

Station	Markov Chain model			Exponential distrib. model		
	χ^2	D.F	P	χ^2	D.F	P
Mt. Elgon	15.09	7	0.02-0.05	13.10	7	0.05-0.10
Kipkoitet	124.67	6	<0.001	20.95	7	0.001-0.005
Kakamega	22.69	9	0.001-0.01	18.00	9	0.02-0.05
Tambach	18.37	7	0.01-0.02	17.65	7	0.01-0.02
Miwani	15.91	6	0.01-0.02	20.89	6	0.001-0.005
Jamji Estate	50.28	11	<0.001	47.89	11	<0.001
Londiani	21.05	7	0.001-0.005	20.89	8	0.005-0.01
Kericho	14.52	9	0.10-0.20	13.53	9	0.10-0.20
Sotik	9.03	8	0.30-0.50	10.89	8	0.20-0.30
Maji Mazuri	28.96	8	<0.001	23.24	8	0.001-0.002
Mau Summit	12.96	6	0.02-0.05	15.14	7	0.02-0.05

Table 30. Summary of the goodness-of-fit test (using χ^2) for dry spells - threshold value, 1.0mm

Station	Markov Chain model			Exponential distrib. model		
	χ^2	D.F	P	χ^2	D.F	P
Mt. Elgon	29.99	10	<0.001	25.83	10	0.001-0.005
Kipkoitet	52.32	10	"	147.31	7	<0.001
Kakamega	50.15	8	"	40.72	8	"
Tambach	79.17	10	"	60.67	11	"
Miwani	29.43	8	"	30.94	8	"
Jamji Estate	47.84	6	"	42.23	6	"
Londiani	58.50	11	"	56.19	11	"
Kericho	72.49	7	"	55.26	7	"
Sotik	39.16	7	"	29.92	7	"
Maji Mazuri	67.10	10	"	63.10	10	"
Mau Summit	83.66	13	"	78.62	12	"

quencies on the other.

4.4. Results of wet and dry spells analysis based on the 5.0mm criterion

Nine stations' daily rainfall data were used to study the frequency and distribution of wet and dry spells, based on the 5.0mm cut-off value. The observed frequencies of wet and dry spells are shown in tables 31 and 32. From both sets of data, the following conclusions can be made:

(a) the duration of wet spells, as one would expect, is much shorter than when the 1.0mm criterion was used. The longest wet spell lasted 15 days (at Kakamega and Tambach). The shortest duration was 5 days (at Miwani). It is interesting to note that even when both the 1.0mm and 5.0mm cut-off values were considered, the shortest durations of wet spells occurred at a lake station i.e. Miwani (see table 33).

(b) dry spells on the other hand are much longer than those shown in table 23. The longest dry spell lasted 64 days (at Kipkoitet) while the shortest lasted 24 days (at Sotik) - see table 34. Kakamega and Jamji Estate have higher frequencies of dry spells of short durations and relatively lower frequencies of dry spells of longer durations.

Table 31. Observed frequency of wet spells (based on the 5.0mm criterion)

Length of wet spell in days (n)	88.34001	88.35005	89.34001	89.35014	90.34008	90.35001	90.35002	90.35013	90.35028
1	243	276	317	231	359	348	224	362	246
2	107	76	128	84	112	118	100	125	106
3	47	37	64	52	48	69	46	44	37
4	29	20	28	17	17	29	16	30	24
5	8	7	26	14	11	20	12	5	12
6	6	6	14	3	-	17	4	8	4
7	2	0	9	0	-	8	0	6	6
8	0	1	3	5	-	9	5	1	1
9	2	0	3	3	-	0	2	1	2
10	-	0	2	0	-	1	1	-	1
11	-	1	0	1	-	0	-	-	-
12	-	-	1	0	-	1	-	-	-
13	-	-	0	0	-	-	-	-	-
14	-	-	0	0	-	-	-	-	-
15	-	-	1	1	-	-	-	-	-

Table 32. Observed frequency of dry spells (based on the 5.0mm criterion)

Length of dry spell in days (n)	88.34801	88.35005	89.34001	89.34014	90.34008	90.35001	90.35002	90.35013	90.35028
1	128	136	247	136	161	284	128	191	153
2	81	73	129	59	103	104	62	128	68
3	43	28	64	32	66	76	47	91	37
4	36	33	42	31	60	59	31	48	35
5	23	20	30	28	40	32	20	26	41
6	28	34	30	29	28	21	22	21	17
7	13	17	15	14	12	13	16	18	12
8	23	15	10	15	18	9	11	13	12
9	15	9	10	12	16	12	11	12	14
10	13	11	10	8	15	10	8	13	10
11	4	11	3	11	11	5	7	6	15
12	9	11	0	6	8	3	6	5	5
13	8	3	3	5	5	4	8	3	4
14	5	7	2	6	5	2	7	7	8
15	6	2	3	7	7	1	8	3	3
16	7	3	3	2	3	1	1	1	1
17	6	6	0	3	2	0	4	4	3
18	4	1	0	5	1	1	3	0	1
19	1	2	1	2	1	0	3	2	3
20	2	5	0	0	0	2	7	2	4
21	3	0	0	6	0	1	1	4	1
22	0	4	1	0	0	0	0	0	1
23	0	1	1	1	0	0	3	0	0
24	1	3	1	1	0	1	3	1	1
25	0	1	2	2	0	0	2	-	1
26	0	1	0	2	0	0	3	-	3
27	0	0	0	0	1	0	0	-	1
28	2	2	1	0	0	0	0	-	1
29	1	0	1	1	0	0	0	-	0
30	0	0	-	2	0	0	2	-	1
over 30	2	6	-	5	2	1	4	-	6

Table 33. Wet season characteristics - wet spells

Station	Number of wet spells	Number of wet days	Probability (in %) of a wet day	Longest wet spell lasted
Mt. Elgon	444	822	26	9
Kipkoitet	424	709	22	11
Kakamega	596	1252	39	15
Tambach	411	804	25	15
Miwani	547	850	26	5
Jamji Estate	620	1259	39	12
Londiani	410	778	24	10
Sotik	582	996	31	9
Maji Mazuri	439	827	26	10

Table 34. Wet season characteristics - dry spells

Station	Number of wet spells	Number of dry days	Probability (in %) of a dry day	Longest dry spell lasted
Mt. Elgon	464	2388	74	35
Kipkoitet	445	2501	78	64
Kakamega	609	1958	61	29
Tambach	431	2406	75	46
Miwani	565	2360	74	31
Jamji Estate	642	1951	61	33
Londiani	428	2432	76	42
Sotik	599	2214	69	24
Maji Mazuri	462	2383	74	42

4.4.1 Wet and dry spell probabilities

From the observed cumulative frequencies of wet and dry spells shown in tables 36 and 37, the percentage of times a period of a given type of weather is followed by the same type of weather was evaluated using the procedure discussed in section 4.3.2. An example of the results obtained is shown in table 35: (a) and (b). The full results are shown in Appendix 3.

Table 35: (a). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Mt. Elgon Forest station (88.34001) during the March to mid-June period

	6	40	20	20		
	5	56	22	11	11	
M	4	38	21	9	4	4
	3	50	19	11	4	2
	2	47	23	9	5	2
	1	45	21	11	4	2
		1	2	3	4	5
				N		

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 35: (b). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Mt. Elgon Forest station (88.34001) during the March to mid-June period

	8	79	66	54	51	43	36	31	26	20	14
	7	90	71	59	49	46	38	32	28	23	18
	6	82	73	58	48	40	37	31	26	23	19
M	5	87	71	64	51	42	35	32	27	23	20
	4	83	73	59	53	42	35	29	27	23	19
	3	83	69	60	49	44	35	29	24	22	19
	2	76	63	52	46	37	33	26	22	18	17
	1	72	55	46	38	33	27	24	19	16	13
		1	2	3	4	5	6	7	8	9	10
						N					

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Although the magnitudes of the probability values are different, similar conclusions as were reached when the 1.0mm cut-off values was used, can be made about the data of table 35: (a) and (b) and also Appendix 3. A comparison of the data in Appendix 1 with that in Appendix 3 shows that the probability of a dry day is higher when the 5.0mm criterion is used; the probability of a wet day on the other hand is lower. The probabilities were not evaluated for Miwani (90.34008) for the wet spells since the longest wet spell lasted only 5 days.

Table 36. Observed cumulative frequency of wet spells - based on the 5.0mm criterion (wet spells lasting (n) days or longer)

Days (n)	89.34001	89.35014	90.35001	88.35005	90.35028	90.35002	90.35013	88.34001	90.34008
1	596	411	620	424	439	410	582	444	547
2	279	180	272	148	193	186	220	201	188
3	151	96	154	72	87	86	95	94	76
4	87	44	85	35	50	40	51	47	28
5	59	27	56	15	26	24	21	18	11
6	33	13	36	8	14	12	16	10	
7	19	10	19	2	10	8	8	4	
8	10	10	11	2	4	8	2	2	
9	7	5	2	1	3	3	1	2	
10	4	2	2	1	1	1			
11	2	2	1	1					
12	2	1	1						
13	1	1							
14	1	1							
15	1	1							

Table 37. Observed cumulative frequency of dry spells - based on the 5.0mm criterion (dry spells lasting (n) days or longer)

Days (n)	88.34001	88.35005	89.34001	89.35014	90.34008	90.35001	90.35002	90.35013	90.35028
1	464	445	609	431	565	642	428	599	462
2	336	309	362	295	404	358	300	408	309
3	255	236	233	236	301	254	238	280	241
4	212	208	169	204	235	178	191	189	204
5	176	175	127	173	175	119	160	141	169
6	153	155	97	145	135	87	140	115	128
7	125	121	67	116	107	66	118	94	111
8	112	104	52	102	95	53	102	76	99
9	89	89	42	87	77	44	91	63	87
10	74	80	32	75	61	32	80	51	73
11	61	69	22	67	46	22	72	38	63
12	57	58	19	56	35	17	65	32	48
13	48	47	19	50	27	14	59	27	43
14	40	44	16	45	22	10	51	24	39
15	35	37	14	39	17	8	44	17	31
16	29	35	11	32	10	7	36	14	28
17	22	32	8	30	7	6	35	13	27
18	16	26	8	27	5	6	31	9	24
19	12	25	8	22	4	5	28	9	23
20	11	23	7	20	3	5	25	7	20
21	9	18	7	20	3	3	18	5	16
22	6	18	7	14	3	2	17	1	15
23	6	14	6	14	3	2	17	1	14
24	6	13	5	13	3	2	14	1	14
25	5	10	4	12	3	1	11	-	13
26	5	9	2	10	3	1	9	-	12
27	5	8	2	8	3	1	6	-	9
28	5	8	2	8	2	1	6	-	8
29	3	6	1	8	2	1	6	-	7
30	2	6	-	7	2	1	6	-	7
over 30	9	73	-	22	2	3	18	-	25

4.4.2 Fitting of the Markov chain probability and Exponential distribution models to the observed sequences of wet and dry spells

The fit of the observed wet spells to the Markov chain probability model was good at Mt. Elgon, Miwani, Londiani and Maji Mazuri; for the dry spells, only Miwani had a good fit. The exponential distribution model fitted well the wet spells data of Mt. Elgon, Tambach, Miwani, Londiani and Maji Mazuri; the fit of the dry spells to the model was good only at Miwani. A summary of the goodness-of-fit test (χ^2) is given in table 38 for the wet spells and table 39 for the dry spells.

The observed frequencies of wet and dry spells together with those computed with the Markov chain probability and Exponential distribution models are shown in Appendix 4.

Table 38. Summary of the goodness-of-fit test (using χ^2) for wet spells - threshold value, 5.0mm

Station	Markov chain model			Exponential distrib. model		
	χ^2	D.F	P	χ^2	D.F	P
Mt. Elgon	3.86	4	0.30-0.50	10.73	5	0.05-0.10
Kipkoitet	27.02	4	<0.001	20.89	4	<0.001
Kakamega	21.70	6	0.001-0.005	21.05	6	0.001-0.005
Tambach	23.94	5	<0.001	14.65	5	0.01-0.02
Miwani	9.69	3	0.02-0.05	7.86	3	0.02-0.05
Jamji Estate	32.89	5	<0.001	30.39	6	<0.001
Londiani	3.20	4	0.50-0.70	8.74	5	0.10-0.20
Sotik	26.02	4	<0.001	25.64	5	0.05-0.10
Maji Mazuri	10.99	4	0.02-0.05	10.12	5	0.05-0.10

Table 39. Summary of the goodness-of-fit test (using χ^2) for dry spells - threshold value, 5.0mm

Station	Markov chain model			Exponential distrib. model		
	χ^2	D.F	P	χ^2	D.F	P
Mt. Elgon	48.74	14	<0.001	44.57	13	<0.001
Kipkoitet	92.66	15	"	79.70	14	"
Kakamega	52.76	10	"	42.95	10	"
Tambach	80.20	14	"	69.48	14	"
Miwani	21.64	12	0.02-0.05	19.34	12	0.05-0.10
Jamji Estate	62.50	9	<0.001	55.03	9	<0.001
Londiani	71.81	14	"	71.36	14	"
Sotik	44.10	11	"	35.84	11	"
Maji Mazuri	94.34	14	"	87.99	14	"

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The objective of this study was two-fold, namely,

a) to identify and delineate the seasonal rainfall regimes that occur in the Kenyan part of the Lake Victoria Drainage Basin using the method of Principal Components Analysis (PCA) and

b) to study the frequency of occurrence of wet and dry spells of various lengths using sample stations from each of the identified seasonal rainfall regimes.

5.1.1 Determination of the seasonal rainfall regimes

From the results of the PCA, the following rainfall regions were distinguished,

a) the "Kibos" rainfall region. An examination of the annual march of the decade (or 10-day) median, upper and lower quartile rainfall for some selected stations in this region indicated that the "Kibos regime" is in the main bimodal, the rainy seasons being March-May and October-December. March-May is the principal rainy season. For some stations, there is a third but relatively unimportant peak in August.

b) the "Eldoret" rainfall region. This regime has two rainfall peaks within a single rainy season which extends from April to September.

c) the transitional areas around Kericho, Nandi and Kakamega which have rainfall almost throughout the year. The rainfall climatology of the extreme eastern part of the study area is rather complex but from the component loadings, the area was grouped together with the "Kibos" regime.

5.1.2 Wet and dry spells analysis

The analysis of the wet and dry spells gave the following results:

a) the frequency of both wet and dry spells fell off exponentially from the shortest duration to the longest.

b) wet and dry spells of shorter durations were more frequent in the "Kibos regime". Dry spells of longer durations on the other hand were the rule, rather than the exception, in the "Eldoret regime".

c) in general terms, dry spells were longer than wet spells.

From the cumulative frequencies of wet and dry spells, it was found that the probability of a type of weather (wet or dry spell) continuing is higher the longer that type of weather has persisted. The probabilities vary with the amount of rainfall chosen as the cut-off value. The probabilities also have a spatial expression.

According to the Chi-square (χ^2) goodness-of-fit test, the wet spells data fitted well the first order Markov chain probability and Exponential distribution models for some stations. The fit of the dry spells data was poor in almost all cases.

5.2 Conclusions

The Principal Components Analysis (PCA) method with Varimax Rotation was applied to the 67x67 interstation correlation matrix based on the median 10-day (or decade) rainfall of some 67 raingauges in the Lake Victoria Basin. An initial investigation of the interstation correlation matrix revealed that it was possible to map out the seasonal rainfall regimes using the correlations alone, thus avoiding the expense (in computer time and money) that the method usually involves and more importantly, one can avoid some of the theoretical problems associated with certain computational procedures of most factorial solutions, including the PCA method.

The synoptic conditions governing the rainfall climatology of the study area are rather complex but the presence of a large water body surrounded by highlands to the north, east and south (and the resultant meso-scale circulation systems) plus the large-scale circulation patterns (from the east and west) play a major role to give the observed seasonal rainfall patterns.

For water resources planning, particularly in agriculture, due regard should be taken of rainfall regions occurring in the study area. Particularly useful to take into account are the characteristics of the wet and dry spells in terms of their durations and frequency of occurrence. The wet and dry spells data also indicate differences in patterns of rainfall occurrence (reflecting different causal mechanisms) between the various rainfall regions.

Most of the previous studies cited in Chapter 2 indicated good fit of the observed sequences of wet/dry spells to various theoretical distributions. Some of the studies however did not employ any criteria or test of goodness-of-fit, apart from a visual graphical approach. When the wet/dry spells data in this study were subjected to a goodness-of-fit test (χ^2), it was found that some of the data, particularly the dry spells data, were not so well described by the chosen theoretical distributions.

RECOMMENDATIONS

(a) Recommendations to Government policy makers

The economy of the study area, and indeed that of Kenya, depends largely on agricultural production. The agricultural production of an area in turn depends on, apart from the physical and chemical characteristics of the soils and the socio-economic set up, the prevailing climatic conditions. Rainfall plays a very important role in crop and animal production in terms of its seasonality, amount, frequency and reliability. The results that were obtained in this study should be of interest to the agricultural planners in that the seasonal rainfall regimes occurring in the area have been identified and mapped. The rainy seasons (and hence the growing seasons) have also been defined. Of interest to agricultural planners, especially the field agriculturalists, is the data of wet and dry spells. These data can guide in crop selection, and crop and soil management strategies to optimize yields. The dry spells data are also of interest to the forester in that they can assist him in the abatement of forest fires.

(b) Recommendations for future research

(i) The definition of wet and dry spells, particularly for the purpose of agricultural production, requires the incorporation of more factors, e.g. the crop-water requirement estimates and the incorporation of the soil moisture storage capacity factor. There is scope for their inclusion to further refine what this study has achieved. Also, other seasons (dry or wet) should be analysed.

(ii) It would be worthwhile, in a future similar study, to incorporate the causal mechanisms behind the rainfall climatology of the Lake Basin. This calls for more and better equipped meteorological stations in the region that will observe not only what is happening at the surface but also at higher altitudes.

(iii) There is scope also for the study of the various distribution models in relation to daily rainfall to find out which fits best the wet and dry spells, and also the daily rainfall amounts.

(c) Matters of interest to the academic community

The results of this study give rainfall information of a very interesting area which can be of use to the academic community in general. The information given pertains to:

i) definition and delineation of the seasonal rainfall regimes, and

ii) the frequency of occurrence and distribution of wet and dry spells and

iii) the recommendations especially those pertaining to future research

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APPENDIX 1A: Table 40: (a) - (k)

The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at the indicated sample stations

Table 40: (a). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Mt. Elgon Forest Station (88.34001) during the March to mid-June period

	9	50	29	29	21	21	21	14	14
	8	82	41	24	24	18	18	18	12
	7	63	52	26	15	15	11	11	11
	6	63	40	33	16	9	9	7	7
M	5	63	40	25	21	10	6	6	4
	4	60	38	24	15	12	6	3	3
	3	59	36	23	14	9	7	4	2
	2	65	39	23	15	9	6	5	2
	1	54	35	21	13	8	5	3	3
		1	2	3	4	5	6	7	8

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (b). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Kipkoitet (88.35005) during the March to mid-June period

M

8	63	33	30	19	15				
7	77	49	26	23	14	11			
6	64	49	31	16	14	9	7		
5	71	45	35	22	11	10	6	5	
4	71	50	32	24	15	8	7	5	4
3	66	47	33	21	16	10	5	5	3
2	61	40	28	20	13	10	6	3	3
1	54	33	22	15	11	7	5	3	2
	1	2	3	4	5	6	7	8	9

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (c). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Kakamega (89.34001) during the March to mid-June period

M

8	80	61	48	34	27	25	23	20	16	11	11	7
7	79	62	48	37	27	21	20	18	16	12	9	9
6	67	53	42	32	25	18	14	13	12	11	8	6
5	74	50	39	31	24	19	13	11	10	9	8	6
4	70	52	35	27	22	17	13	9	7	7	6	6
3	70	48	36	24	19	15	12	9	6	5	5	4
2	68	47	33	24	16	13	10	8	6	4	3	3
1	62	42	29	20	15	10	8	6	5	4	3	2
	1	2	3	4	5	6	7	8	9	10	11	12

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (d). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Tambach (89.35014) during the March to mid-June period

	8	69	50	31	23	15	11					
	7	74	51	37	23	17	11	9				
	6	74	55	38	28	17	13	9	6			
M	5	71	53	39	27	20	12	9	6	5		
	4	72	51	38	28	20	14	9	7	4	3	
	3	59	43	30	23	17	12	8	5	4	3	2
	2	58	34	25	18	13	10	7	5	3	2	1
	1	57	33	19	14	10	7	6	4	3	2	1
		1	2	3	4	5	6	7	8	9	10	11
							N					

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40:(e). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Miwani (90.34008) during the March to mid-June period

	6	42	26	18	13		
	5	59	25	16	11	8	
M	4	60	36	15	9	7	5
	3	57	34	20	8	5	4
	2	59	33	20	12	5	3
	1	49	29	16	10	6	2
		1	2	3	4	5	6
					N		

M = length of the preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (f). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Jamji Estate (90.35001) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	81	63	54	44	33									
9	85	69	54	46	38	28								
8	91	78	63	49	42	34	25							
7	75	69	58	47	42	34	25							
6	81	61	55	47	38	30	25	21	15					
5	77	62	47	43	36	29	23	20	16	12				
4	78	60	48	36	33	28	23	18	15	13	9			
3	77	60	46	37	28	26	22	18	14	12	10	7		
2	71	55	43	33	27	20	18	16	13	10	8	7	5	
1	65	46	36	28	21	17	13	12	10	8	6	5	4	3

N

M = length of the preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (g). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Londiani (90.35002) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10	11
8	82	64	57	39	25	21	18	14	7	4	
7	72	59	46	41	28	18	15	13	10	5	3
6	70	50	41	32	29	20	12	11	9	7	4
5	76	53	38	31	24	22	15	9	8	6	5
4	72	54	38	27	22	17	16	11	7	6	5
3	62	44	34	23	17	14	11	10	7	4	3
2	61	37	27	20	14	10	8	7	6	4	3
1	58	35	22	16	12	8	6	5	4	3	2

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (h). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Kericho (90.35003) during the March to mid-June period

	11	68	58	53	47	37	32	21	21	16	11	5
	10	76	52	44	40	36	28	24	16	16	12	8
	9	74	56	38	32	29	26	21	18	12	12	9
	8	72	53	40	28	23	21	19	15	13	9	9
M	7	78	57	42	32	22	18	17	15	12	10	7
	6	73	57	41	30	23	16	13	12	11	9	7
	5	69	50	39	29	21	16	11	9	8	8	6
	4	70	48	35	27	20	15	11	8	6	6	5
	3	71	49	34	25	19	14	10	8	5	5	4
	2	67	47	33	23	17	13	9	7	5	4	3
	1	63	42	30	21	14	10	8	6	4	3	2
		1	2	3	4	5	6	7	8	9	10	11

N

M = length of the preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (i). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Sotik (90.35013) during the March to mid-June period

	7	59	45	32	25	16	11	7	5	
	6	59	35	27	19	15	9	7	4	3
	5	69	41	24	19	13	10	6	5	3
M	4	66	45	27	16	12	9	7	4	3
	3	66	44	30	18	11	8	6	4	3
	2	66	44	29	20	12	7	5	4	3
	1	60	40	27	18	12	7	4	3	2
		1	2	3	4	5	6	7	8	9

N

M = length of preceding wet spell in days

N = number of days following a wet spell of M days

Table 40: (j). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Maji Mazuri (90.35028) during the March to mid-June period

	N									
M	1	2	3	4	5	6	7	8	9	10
9	70	59	48	26	19	15	7	4		
8	75	53	44	36	19	14	11	6	3	
7	84	63	44	37	30	16	12	9	5	2
6	70	59	44	31	26	21	11	8	7	3
5	73	52	43	33	23	19	16	8	6	5
4	66	48	34	29	21	15	13	10	6	4
3	70	46	34	24	20	15	11	9	7	4
2	64	45	30	22	15	13	10	7	6	5
1	57	37	26	17	12	9	7	6	4	3

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 40: (k). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Mau Summit (90.35038) during the March to mid-June period

	N									
M	1	2	3	4	5	6	7	8	9	10
7	68	56	44	24	16	12	8			
6	66	45	37	29	16	11	8	5		
5	73	48	33	27	21	12	8	6		
4	58	43	28	19	16	12	7	4	3	2
3	62	36	26	17	12	10	8	4	3	2
2	62	38	22	16	11	7	6	5	3	2
1	52	32	20	12	9	6	4	3	2	1

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

APPENDIX 1B: Table 41: (a) - (k)

The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at the indicated sample stations.

Table 41: (a). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Mt. Elgon Forest Station (88.34001) during the March to mid-June period

	12	80	70	50	45	40	40	30	30	20	10						
	11	80	64	56	40	36	32	32	24	24	16	8					
	10	81	64	52	45	32	29	26	26	19	19	13	6				
	9	76	61	49	39	34	24	22	19	19	15	15	10	5			
	8	76	57	46	37	30	26	19	17	15	15	11	11	7	4		
M	7	74	56	42	34	27	22	19	14	12	11	11	8	8	5	3	
	6	75	56	42	32	26	21	16	14	10	9	8	8	6	6	4	2
	5	71	54	40	30	23	18	15	12	10	7	7	6	6	4	4	3
	4	73	52	39	29	22	17	13	11	8	7	5	5	4	4	3	3
	3	79	57	41	31	23	17	13	11	8	7	6	4	4	3	3	3
	2	69	54	39	28	21	16	12	9	7	6	5	4	3	3	2	2
	1	63	43	34	25	18	13	10	7	6	5	4	3	3	2	2	1
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

N

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (b). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Kipkoitet (88.35005) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14
12	81	74	63	52	48	44	41	37	33					
11	87	70	64	55	45	42	39	35	32	29				
10	79	69	56	51	44	36	33	31	28	26	23			
9	71	56	49	40	36	31	25	24	22	20	18	16		
8	86	61	48	42	34	31	27	22	20	19	17	16	14	
7	85	73	52	41	36	29	27	23	19	17	16	15	13	12
6	77	65	56	40	32	28	22	20	17	14	13	12	11	10
5	80	61	52	45	32	25	22	18	16	14	11	11	10	9
4	76	61	47	40	34	24	19	17	14	12	11	9	8	7
3	72	55	44	34	29	25	18	14	12	10	9	8	6	6
2	68	49	38	30	23	19	17	12	9	8	7	6	5	4
1	63	43	31	24	19	14	12	11	7	6	5	4	4	3

N

M = length of the preceding dry spell in days

N = numberof dry days following a dry spell of M days

Table 41: (c). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Kakamega (89.34001) during the March to mid-June period

9	76	60	48	48	40	36	28	24	20	16	12	8
8	89	68	54	43	43	36	32	25	21	18	14	11
7	78	69	53	42	33	33	28	25	19	17	14	11
6	63	49	44	33	26	21	21	17	16	12	10	9
5	71	45	35	31	24	19	15	15	12	11	9	7
4	71	50	32	25	22	17	13	11	11	9	8	6
3	67	48	34	21	17	15	11	9	7	7	6	5
2	57	39	27	19	12	10	8	6	5	4	4	3
1	53	30	20	14	10	6	5	4	3	3	2	2
	1	2	3	4	5	6	7	8	9	10	11	12

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (d). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Tambach (89.35014) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10	11
11	83	71	55	50	43	43	33	31	26	17	14
10	89	74	64	49	45	38	38	30	28	23	15
9	78	70	58	50	38	35	30	30	23	22	18
8	87	68	61	51	43	33	30	26	26	20	19
7	84	73	57	51	43	37	28	26	22	22	17
6	75	63	55	43	38	32	27	21	19	17	17
5	78	59	50	43	34	30	25	22	17	15	13
4	77	60	45	38	33	26	23	19	17	13	12
3	79	61	48	36	30	26	21	18	15	13	10
2	75	59	45	36	27	23	20	15	14	11	10
1	63	47	37	29	22	17	14	12	10	9	7

N

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (e). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Miwani (90.34008) during the March to mid-June period

	9	55	39	29	26	19	13	10	6		
	8	74	40	29	21	19	14	9	7	5	5
	7	82	61	33	24	18	16	12	8	6	4
	6	70	57	42	23	16	12	11	8	5	4
M	5	72	50	41	30	17	12	9	8	6	4
	4	65	46	32	27	20	11	8	6	5	4
	3	65	43	30	21	17	13	7	5	4	3
	2	64	42	27	19	14	11	8	5	3	2
	1	57	36	24	15	11	8	6	5	3	2
		1	2	3	4	5	6	7	8	9	10

N

M = length of dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (f). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Jamji Estate (90.35001) during the March to mid-June period

	6	66	46	43	29	20		
	5	71	47	33	31	20	14	
M	4	56	40	26	18	17	11	8
	3	64	36	25	17	12	11	7
	2	61	39	22	15	10	7	6
	1	44	27	17	9	7	4	3
		1	2	3	4	5	6	7

N

M = length of preceding dry spell

N = number of dry days following a dry spell of M days

Table 41: (g). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Londiani (90.35002) during the March to mid-June period

	10	89	71	62	51	44	33								
	9	92	82	65	57	47	41	31							
	8	77	70	63	50	44	36	31	23						
	7	85	65	60	53	43	37	31	27	20					
	6	73	62	48	44	39	31	27	22	19	15				
M	5	79	57	49	37	34	31	24	21	18	12	9			
	4	78	61	44	38	29	27	24	19	17	14	12	9		
	3	74	58	45	33	28	22	20	18	14	12	10	9	7	
	2	74	55	43	34	25	21	16	15	13	10	9	8	7	5
	1	63	47	35	27	21	16	13	10	9	8	7	6	5	4
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

N

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (h). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Kericho (90.35003) during the March to mid-June period

	10	81	81	69	63	50	44	31	25	6
	9	80	65	65	55	50	40	35	25	20
	8	71	57	46	46	39	36	29	25	18
	7	76	54	43	35	35	30	27	22	19
	6	77	58	42	33	27	27	23	21	17
M	5	72	55	42	30	24	19	19	16	15
	4	69	49	38	29	21	16	13	13	11
	3	62	43	31	24	18	13	10	8	8
	2	59	37	25	18	14	11	8	6	5
	1	45	27	17	12	8	6	5	3	3
		1	2	3	4	5	6	7	8	9
						N				

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (i). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Sotik (90.35013) during the March to mid-June period

	9	63	42	37	37	32	21	16	11	5	
	8	66	41	28	24	24	21	14	10	7	3
	7	78	51	32	22	19	19	16	11	8	5
	6	71	56	37	23	15	13	13	12	8	6
M	5	73	52	41	27	17	11	10	10	8	6
	4	65	48	34	27	17	11	7	6	6	6
	3	63	41	30	21	17	11	7	5	4	4
	2	55	34	22	16	12	9	6	4	3	2
	1	51	28	17	11	8	6	5	3	2	1
		1	2	3	4	5	6	7	8	9	10
						N					

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (j). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Maji Mazuri (90.35028) during the March to mid-June period

	13	84	76	60	52	44	40	32	28	20				
	12	89	75	68	54	46	39	36	29	25	18			
	11	85	76	64	58	45	39	33	30	24	21	15		
	10	85	72	64	54	49	38	33	28	26	21	18	13	
	9	80	67	57	51	43	39	31	27	22	20	16	14	10
	8	82	65	55	47	42	35	32	25	22	18	17	13	12
M	7	83	68	54	46	39	35	29	26	21	18	15	14	11
	6	84	70	57	45	38	33	29	24	22	17	15	13	12
	5	72	60	50	41	33	28	23	21	18	16	13	11	9
	4	76	55	46	38	31	25	21	18	16	13	12	10	8
	3	73	56	40	34	28	23	18	15	13	12	10	9	7
	2	71	52	40	29	24	20	16	13	11	9	8	7	6
	1	59	42	31	24	17	14	12	10	8	7	6	5	4
		1	2	3	4	5	6	7	8	9	10	11	12	13
								N						

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 41: (k). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Mau Summit (90.35038) during the March to mid-June period

	10	82	73	65	60	45	42	37	34	29	23	18			
	9	84	69	61	54	50	38	35	31	28	24	19	15		
	8	88	74	61	54	48	44	33	31	27	25	21	17	13	
	7	87	76	64	53	46	41	38	29	27	24	22	19	14	11
M	6	82	71	62	52	43	38	34	31	24	22	19	18	15	12
	5	84	68	59	52	44	36	32	28	26	20	18	16	15	13
	4	76	64	52	45	40	33	27	24	22	20	15	14	12	11
	3	81	62	52	42	37	32	27	22	20	17	16	12	11	10
	2	76	62	47	39	32	28	25	21	17	15	13	12	9	9
	1	65	49	40	31	26	21	18	16	13	11	10	9	8	6
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

N

M = length of the preceding dry spell in days

N = number of dry days following a dry spell of M days

APPENDIX 2: Tables 42: (a) - (v)

Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by Markov chain probability and Exponential distribution models.

Table 42: (a). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Mt. Elgon Forest Station (88.34001)

WET SPELLS ($r>1.0$mm)		
length of spell (in days)	WO	WC
1	247	221
2	101	130
3	77	77
4	45	45
5	25	27
6	16	16
7	10	9
8	3	5
9	7	3
10	3	2
11	0	1
12	1	*
13	0	*
14	0	*
15	1	*
16	0	*
17	1	*
18	0	*
19	1	*
Total	538	
χ^2		15.09
D.F.		7
P		0.02-0.05

DRY SPELLS ($r<1.0$mm)		
length of spell (in days)	DO	DC
1	206	160
2	106	113
3	51	80
4	51	57
5	39	41
6	24	29
7	19	20
8	13	15
9	10	10
10	6	7
11	5	5
12	4	4
13	2	3
14	4	2
15	1	1
16	1	*
17	0	*
18	2	*
19	0	*
20	2	*
21	2	*
22	2	*
Total	550	
χ^2		29.99
D.F.		10
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 42: (b). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Mt. Elgon Forest Station (88.34001)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)		
length of spell (in days)	WO	WC	length of spell (in days)	DO	DC
1	247	213	1	206	158
2	101	128	2	106	112
3	77	77	3	51	80
4	45	46	4	51	57
5	25	28	5	39	40
6	16	17	6	24	29
7	10	10	7	19	21
8	3	6	8	13	15
9	7	4	9	10	10
10	3	2	10	6	7
11	0	1	11	5	5
12	1	*	12	4	4
13	0	*	13	2	3
14	0	*	14	4	2
15	1	*	15	1	1
16	0	*	16	1	*
17	1	*	17	0	*
18	0	*	18	2	*
19	1	*	over 18	6	*
Total	538		Total	550	
χ^2		13.10	χ^2		25.83
D.F.	7		D.F.	10	
P		0.05-0.10	P		0.001-0.005

* less than 1.0

D.F. degrees of freedom

Table 42: (c). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Kipkoitet (88.35005)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)		
length of spell (in days)	WO	WC	length of spell (in days)	DO	DC
1	232	202	1	193	141
2	108	121	2	106	103
3	56	73	3	61	75
4	32	44	4	38	55
5	23	26	5	25	40
6	20	16	6	23	29
7	8	9	7	11	21
8	10	6	8	9	16
9	8	3	9	16	11
10	1	2	10	8	8
11	3	1	11	4	6
12	1	*	12	5	4
13	0	*	13	2	3
14	0	*	14	3	2
15	1	*	15	3	2
16	0	*	16	1	1
17	1	*	17	1	*
18	0	*	18	1	*
19	0	*	19	1	*
20	1	*	20	1	*
21	0	*	21	0	*
22	1	*	over 21	9	*
Total	506		Total	521	
χ^2		124.67	χ^2		52.32
D.F.		6	D.F.		10
P		<0.001	P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 42: (d). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Kipkoitet (88.35005)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)		
length of spell (in days)	WO	WC	length of spell (in days)	DO	DC
1	232	191	1	193	206
2	108	118	2	106	124
3	56	73	3	61	74
4	32	45	4	38	45
5	23	28	5	25	27
6	20	17	6	23	16
7	8	11	7	11	10
8	10	7	8	9	6
9	8	4	9	16	3
10	1	3	10	8	2
11	3	2	11	4	1
12	1	*	12	5	*
13	0	*	13	2	*
14	0	*	14	3	*
15	1	*	15	3	*
16	0	*	16	1	*
17	1	*	17	1	*
18	0	*	18	1	*
19	0	*	19	1	*
20	1	*	20	1	*
21	0	*	21	0	*
22	1	*	over 21	9	*
Total	506		Total	521	
χ^2	20.95		χ^2	147.31	
D.F.	7		D.F.	7	
P	0.001-0.005		P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (e). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Kakamega (89.34001)

WET SPELLS (r>1.0mm)		
length of spell (in days)	WO	WC
1	208	175
2	109	119
3	70	81
4	49	55
5	29	38
6	27	26
7	12	17
8	9	12
9	8	8
10	6	6
11	6	4
12	3	3
13	1	2
14	1	1
15	1	*
16	2	*
17	2	*
18	0	*
19	2	*
20	0	*
21	0	*
22	0	*
over 22	3	*
Total	548	
χ^2	22.69	
D.F.	9	
P	0.001-0.01	

DRY SPELLS (r<1.0mm)		
length of spell (in days)	DO	DC
1	263	206
2	125	130
3	55	82
4	33	51
5	23	32
6	21	20
7	8	13
8	3	8
9	6	5
10	4	3
11	3	2
12	0	1
13	2	*
14	1	*
15	2	*
16	1	*
17	1	*
18	1	*
19	1	*
20	1	*
21	0	*
22	2	*
Total	556	
χ^2	50.15	
D.F.	8	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (f). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Kakamega (89.34001)

WET SPELLS ($r>1.0$mm)			DRY SPELLS ($r<1.0$mm)	
length of spell (in days)	WO	WC	DO	DC
1	208	169	263	207
2	109	116	125	129
3	70	80	55	81
4	49	56	33	50
5	29	38	23	32
6	27	26	21	20
7	12	18	8	12
8	9	13	3	8
9	8	9	6	5
10	6	6	4	3
11	6	4	3	2
12	3	3	0	1
13	1	2	2	*
14	1	1	1	*
15	1	*	2	*
16	2	*	1	*
17	2	*	1	*
18	0	*	1	*
19	2	*	1	*
20	0	*	1	*
21	0	*	0	*
over 22	3	*	2	*
Total	548		556	
χ^2	18.00		40.72	
D.F.	9		8	
P	0.02-0.05		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (g). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Tambach (89.35014)

WET SPELLS ($r>1.0$mm)			DRY SPELLS ($r<1.0$mm)	
length of spell (in days)	WO	WC	DO	DC
1	205	184	180	117
2	112	112	77	89
3	63	68	48	67
4	26	42	42	51
5	19	25	30	39
6	12	16	27	30
7	9	9	13	22
8	8	6	9	17
9	5	4	13	13
10	5	2	5	10
11	2	1	7	7
12	2	1	5	6
13	1	*	7	4
14	0	*	2	3
15	0	*	3	3
16	1	*	0	2
17	0	*	4	1
18	0	*	1	1
19	0	*	2	*
20	1	*	4	*
21	0	*	1	*
22	0	*	0	*
23	0	*	0	*
24	0	*	3	*
25	0	*	2	*
over 25	1	*	1	*
Total	472		486	
χ^2	18.37		63.01	
D.F.	7		11	
P	0.01-0.02		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (h). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Tambach (89.35014)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	205	175	180	118
2	112	110	77	89
3	63	69	48	68
4	26	43	42	51
5	19	27	30	39
6	12	17	27	29
7	9	10	13	22
8	8	7	9	17
9	5	4	13	13
10	5	3	5	10
11	2	2	7	7
12	2	*	5	5
13	1	*	7	4
14	0	*	2	3
15	0	*	3	2
16	1	*	0	2
17	0	*	4	1
18	0	*	1	1
19	0	*	2	*
20	1	*	4	*
over 20	1	*	7	*
Total	472		486	
χ^2	17.65		60.67	
D.F.	7		11	
P	0.01-0.02		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (i). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Miwani (90.34008)

WET SPELLS ($r>1.0$mm)		
length of spell (in days)	WO	WC
1	330	306
2	131	162
3	82	86
4	43	45
5	26	24
6	22	13
7	6	7
8	3	4
9	2	2
10	5	1
Total	650	
χ^2		15.91
D.F.		6
P		0.01-0.02

DRY SPELLS ($r<1.0$mm)		
length of spell (in days)	DO	DC
1	286	238
2	135	152
3	83	97
4	55	62
5	29	40
6	22	26
7	9	16
8	11	10
9	14	7
10	5	4
11	3	3
12	1	2
13	2	1
14	2	*
15	1	*
16	1	*
17	0	*
18	0	*
19	0	*
20	0	*
21	0	*
22	1	*
23	1	*
Total	661	
χ^2		29.43
D.F.		8
P		<0.001

*	less than 1.0
D.F.	degrees of freedom

Table 42: (j). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Miwani (90.34008)

WET SPELLS (r>1.0mm)		
length of spell (in days)	WO	WC
1	330	289
2	131	159
3	82	87
4	43	48
5	26	26
6	22	14
7	6	8
8	3	4
9	2	2
10	5	1
Total	650	
χ^2	20.89	
D.F.	6	
P	0.001-0.005	

DRY SPELLS (r<1.0mm)		
length of spell (in days)	DO	DC
1	286	238
2	135	151
3	83	97
4	55	62
5	29	39
6	22	25
7	9	16
8	11	10
9	14	6
10	5	4
11	3	3
12	1	2
13	2	1
14	2	*
over 14	4	*
Total	661	
χ^2	30.94	
D.F.	8	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (k). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Jamji Estate (90.35001)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	182	129	291	227
2	95	96	88	127
3	54	72	50	71
4	41	54	39	40
5	33	41	14	22
6	21	31	12	13
7	22	23	7	7
8	6	17	1	4
9	9	13	5	2
10	10	10	3	1
11	9	7	0	*
12	5	5	0	*
13	5	4	2	*
14	6	3	1	*
15	0	2	0	*
16	1	2	1	*
17	1	1	0	*
18	2	1	2	*
19	2	1	0	*
20	4	*	0	*
over 20	7	*	1	*
Total	515		517	
χ^2	50.28		42.84	
D.F.	11		6	
P	<0.001		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (1). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Jamji Estate (90.35001)

WET SPELLS ($r>1.0$mm)			DRY SPELLS ($r<1.0$mm)	
length of spell (in days)	WO	WC	DO	DC
1	182	129	291	222
2	95	97	88	125
3	54	72	50	71
4	41	54	39	40
5	33	40	14	23
6	21	30	12	13
7	22	23	7	7
8	6	17	1	4
9	9	13	5	2
10	10	10	3	1
11	9	7	0	*
12	5	5	0	*
13	5	4	2	*
14	6	3	1	*
15	0	2	0	*
16	1	2	1	*
17	1	1	0	*
18	2	*	2	*
19	2	*	0	*
20	4	*	0	*
over 20	7	*	1	*
Total	515		517	
χ^2	47.89		42.23	
D.F.	11		6	
P	<0.001		<0.001	

* less than 1.0

D.F. degree of freedom

Table 42: (m). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Londiani (90.35002)

WET SPELLS (r>1.0mm)		
length of spell (in days)	WO	WC
1	201	176
2	109	111
3	64	70
4	29	44
5	18	28
6	17	17
7	11	11
8	5	7
9	5	4
10	2	3
11	5	2
12	4	1
13	1	1
14	1	*
15	1	*
16	2	*
17	1	*
18	1	*
Total	477	
X^2		21.05
D.F.		7
P		0.001-0.005

DRY SPELLS (r<1.0mm)		
length of spell (in days)	DO	DC
1	177	121
2	79	91
3	58	68
4	38	51
5	28	38
6	28	29
7	11	21
8	15	16
9	4	12
10	5	9
11	8	7
12	4	5
13	5	4
14	3	3
15	5	2
16	0	2
17	2	1
18	2	*
19	3	*
20	0	*
over 20	8	*
Total	483	
X^2		58.50
D.F.		11
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 42: (n). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Londiani (90.35002)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	201	168	177	121
2	109	108	79	91
3	64	70	58	68
4	29	45	38	51
5	18	29	28	38
6	17	19	28	28
7	11	12	11	21
8	5	8	15	16
9	5	5	4	12
10	2	3	5	9
11	5	2	8	7
12	4	1	4	5
13	1	*	5	4
14	1	*	3	3
15	1	*	5	2
16	2	*	0	2
17	1	*	2	1
over 17	1	*	13	*
Total	477		483	
χ^2	20.21		56.19	
D.F.	8		11	
P	0.005-0.01		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (o). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Kericho (90.35003)

WET SPELLS ($r>1.0$mm)			DRY SPELLS ($r<1.0$mm)	
length of spell (in days)	WO	WC	DO	DC
1	212	183	317	238
2	119	125	107	141
3	71	85	60	83
4	52	58	30	49
5	37	39	19	29
6	22	27	11	17
7	13	18	9	10
8	13	12	8	6
9	9	8	4	3
10	6	6	3	2
11	6	4	0	1
12	2	3	2	*
13	1	2	1	*
14	1	1	2	*
15	2	*	1	*
16	1	*	2	*
17	2	*	1	*
18	0	*	3	*
19	1	*	0	*
20	1	*	0	*
over 20	2	*	1	*
Total	573		581	
χ^2	14.52		72.49	
D.F.	9		7	
P	0.10-0.20		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (p). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Kericho (90.35003)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	212	176	317	236
2	119	122	107	139
3	71	84	60	82
4	52	58	30	48
5	37	40	19	28
6	22	28	11	17
7	13	19	9	10
8	13	13	8	6
9	9	9	4	3
10	6	6	3	2
11	6	4	0	1
12	2	3	2	*
13	1	2	1	*
14	1	1	2	*
15	2	*	1	*
16	1	*	2	*
17	2	*	1	*
18	0	*	3	*
19	1	*	0	*
20	1	*	0	*
over 20	2	*	1	*
Total	573		581	
χ^2	13.53		55.26	
D.F.	9		7	
P	0.10-0.20		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (q). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Sotik (90.35013)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	244	222	305	262
2	126	142	145	152
3	83	91	65	88
4	56	58	38	51
5	34	37	19	30
6	30	24	15	17
7	18	15	8	10
8	6	10	10	6
9	6	6	7	3
10	3	4	4	2
11	4	3	1	1
12	2	2	0	*
13	2	1	1	*
14	1	*	2	*
15	0	*	1	*
over 15	2	*	3	*
Total	617		624	
χ^2	9.03		39.16	
D.F.	8		7	
P	0.30-0.50		<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (r). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Sotik (90.35013)

WET SPELLS ($r > 1.0$mm)			DRY SPELLS ($r < 1.0$mm)	
length of spell (in days)	WO	WC	DO	DC
1	244	214	305	254
2	126	139	145	149
3	83	91	65	88
4	56	59	38	52
5	34	38	19	30
6	30	25	15	18
7	18	16	8	11
8	6	11	10	6
9	6	7	7	4
10	3	4	4	2
11	4	3	1	1
12	2	2	0	*
13	2	1	1	*
14	1	*	2	*
15	0	*	1	*
over 15	2	*	3	*
Total	617		624	
χ^2	10.89		χ^2	29.92
D.F.	8		D.F.	7
P	0.20-0.30		P	<0.001

* less than 1.0

D.F. degree of freedom

Table 42: (s). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Maji Mazuri (90.35028)

WET SPELLS ($r > 1.0$mm)		
length of spell (in days)	WO	WC
1	208	176
2	102	113
3	53	72
4	43	46
5	22	29
6	18	19
7	7	12
8	9	8
9	8	5
10	3	3
11	3	2
12	6	1
13	2	*
14	1	*
15	2	*
over 15	2	*
Total	489	
χ^2	28.96	
D.F.	8	
P	<0.001	

DRY SPELLS ($r<1.0$mm)		
length of spell (in days)	DO	DC
1	206	137
2	87	100
3	57	73
4	37	53
5	34	39
6	14	28
7	12	21
8	11	15
9	10	11
10	6	8
11	5	6
12	3	4
13	4	3
14	2	2
15	4	2
16	2	1
over 16	13	*
Total	507	
χ^2	67.10	
D.F.	10	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 42: (t). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Maji Mazuri (90.35028)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	208	170	206	138
2	102	110	87	100
3	53	72	57	73
4	43	47	37	53
5	22	30	34	38
6	18	20	14	28
7	7	13	12	20
8	9	8	11	15
9	8	5	10	11
10	3	4	6	8
11	3	2	5	6
12	6	1	3	4
13	2	*	4	3
14	1	*	2	2
15	2	*	4	2
16	1	*	2	1
17	0	*	2	*
18	0	*	1	*
19	0	*	2	*
20	0	*	1	*
over 20	1	*	7	*
Total	489		507	
χ^2	23.24		63.10	
D.F.	8		10	
P	0.001-0.002		<0.001	

* less than 1.0

D.F. degree of freedom

Table 42: (u). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Mau Summit (90.35038)

WET SPELLS (r>1.0mm)		
length of spell (in days)	WO	WC
1	211	187
2	90	108
3	55	63
4	37	36
5	14	21
6	13	12
7	8	7
8	3	4
9	3	2
10	5	1
11	2	*
12	1	*
13	1	*
14	0	*
15	1	*
over 15	1	*
Total	445	
χ^2	12.96	
D.F.	6	
P	0.02-0.05	

DRY SPELLS (r<1.0mm)		
length of spell (in days)	DO	DC
1	161	97
2	73	77
3	43	61
4	44	48
5	23	38
6	22	30
7	13	24
8	10	19
9	12	15
10	11	12
11	6	9
12	5	7
13	3	6
14	9	5
15	2	4
16	3	3
17	2	2
18	3	2
19	4	1
20	3	1
over 20	11	*
Total	463	
χ^2	83.66	
D.F.	13	
P	<0.00.	

* less than 1.0

D.F. degree of freedom

Table 42: (v). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Mau Summit (90.34038)

WET SPELLS (r>1.0mm)			DRY SPELLS (r<1.0mm)	
length of spell (in days)	WO	WC	DO	DC
1	211	176	161	102
2	90	106	73	80
3	55	63	43	62
4	37	38	44	48
5	14	23	23	38
6	13	14	22	29
7	8	8	12	23
8	3	5	10	18
9	3	3	12	14
10	5	2	11	11
11	2	1	6	8
12	1	*	5	7
13	1	*	3	5
14	0	*	9	4
15	1	*	2	3
16	0	*	3	2
17	0	*	2	2
18	0	*	3	1
19	0	*	4	1
20	0	*	3	*
over 20	1	*	11	*
Total	445		463	
χ^2	15.14		78.62	
D.F.	7		12	
P	0.02-0.05		<0.001	

* less than 1.0

D.F. degree of freedom

APPENDIX 3A: Table 43: (a) - (h)

The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at the indicated sample stations

Table 43: (a). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Mt. Elgon Forest Station (88.34001) during the March to mid-June period

M					
6	40	20	20		
5	56	22	11	11	
4	38	21	9	4	4
3	50	19	11	4	2
2	47	23	9	5	2
1	45	21	11	4	2
N	1	2	3	4	5

M = length of the preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (b). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Kipkoitet (88.35005) during the March to mid-June period

M				
4	43	23	6	6
3	49	21	11	3
2	49	24	10	5
1	35	17	8	4
N	1	2	3	4

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (c). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Kakamega (89.34001) during the March to mid-June period

	5	56	32	17	12	7	3
	4	68	38	22	11	8	5
M	3	58	39	22	13	7	5
	2	54	31	21	12	7	4
	1	47	25	15	10	6	3
		1	2	3	4	5	6
				N			

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (d). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Tambach (89.35014) during the March to mid-June period

	5	48	37				
	4	61	30	23			
M	3	46	28	14	10		
	2	53	24	15	7	6	
	1	44	23	11	7	3	2
		1	2	3	4	5	6
				N			

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (e). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Jamji Estate (90.35001) during the March to mid-June period

M		1	2	3	4	5	6
	5	64	34	20	4		
	4	66	42	22	13	2	
	3	55	36	23	12	7	1
	2	57	31	21	13	7	4
	1	44	25	14	9	6	3

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (f). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Londiani (90.35002) during the March to mid-June period

M		1	2	3	4	5	6
	5	50	33	33	13	4	
	4	60	30	20	20	8	3
	3	47	28	14	9	9	3
	2	46	22	13	6	4	4
	1	45	21	10	6	3	2

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (g). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Sotik (90.35013) during the March to mid-June period

	4	41	31	16	4	2
M	3	54	22	17	8	2
	2	43	23	10	7	4
	1	38	16	9	4	3
		1	2	3	4	5

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

Table 43: (h). The probability (in percentage) of a wet spell of N or more days following a wet spell of M days at Maji Mazuri (90.35028) during the March to mid-June period

	4	52	28	20	8	6	2
	3	57	30	16	11	5	3
M	2	45	26	13	7	5	2
	1	44	20	11	6	3	2
		1	2	3	4	5	6

N

M = length of preceding wet spell in days

N = number of wet days following a wet spell of M days

APPENDIX 3B: Table 44: (a) - (i)

The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at the indicated sample stations

Table 44: (a). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Mt. Elgon Forest Station (88.34001) during the March to mid-June period

	8	79	66	54	51	43	36	31	26	20	14
	7	90	71	59	49	46	38	32	28	23	18
	6	82	73	58	48	40	37	31	26	23	19
M	5	87	71	64	51	42	35	32	27	23	20
	4	83	73	59	53	42	35	29	27	23	19
	3	83	69	60	49	44	35	29	24	22	19
	2	76	63	52	46	37	33	26	22	18	17
	1	72	55	46	38	33	27	24	19	16	13
		1	2	3	4	5	6	7	8	9	10
						N					

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (b). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Kipkoitet (88.35005) during the March to mid-June period

	6	78	67	57	52	45	37	30	28
	5	89	69	59	51	46	39	33	27
M	4	84	75	58	50	43	38	33	28
	3	88	74	66	51	44	38	34	29
	2	76	67	57	50	39	34	29	26
	1	69	53	47	39	35	27	23	20
		1	2	3	4	5	6	7	8
					N				

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (c). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Kakamega (89.34001) during the March to mid-June period

M	1	2	3	4	5	6	7	8
6	69	54	43	33	23	20		
5	76	53	41	33	25	17	15	
4	75	57	40	31	25	19	13	11
3	73	55	42	29	22	18	14	9
2	64	47	35	27	19	14	12	9
1	59	38	28	21	16	11	9	7

N

M = length of preceding dry spell in days

N = number of dry days following a wet spell of M days

Table 44: (d). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Tambach (89.35014) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9
8	85	74	66	55	49	44	38	31	29
7	88	75	65	58	48	43	39	34	28
6	80	70	60	52	46	39	34	31	27
5	84	67	59	50	43	39	32	29	26
4	85	71	57	50	43	37	33	27	25
3	86	73	61	49	43	37	32	28	24
2	80	69	59	49	39	35	29	25	23
1	68	55	47	40	34	27	24	20	17

N

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (e). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Miwani (90.34008) during the March to mid-June period

	10	75	57	44	36	28	16	11	8	7	5
	9	79	60	45	35	29	22	13	9	6	5
	8	81	64	48	37	28	23	18	11	7	5
	7	89	72	57	43	33	25	21	16	9	7
	6	79	70	57	45	34	26	20	16	13	7
M	5	77	61	54	44	35	26	20	15	13	10
	4	74	57	46	40	33	26	20	15	11	9
	3	78	58	45	36	32	26	20	15	12	9
	2	75	58	43	33	26	24	19	15	11	9
	1	72	53	42	31	24	19	17	14	11	8
		1	2	3	4	5	6	7	8	9	10

N

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (f). The probability (in percentage) of of a dry spell of N or more days following a dry spell of M days at Jamji Estate (90.35001) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10
10	69	53	44	31	25	22	19			
9	73	50	39	32	23	18	16	14		
8	83	60	42	32	26	19	15	13	11	
7	80	67	48	33	26	21	15	12	11	9
6	76	61	51	37	25	20	16	11	9	8
5	73	55	45	37	27	18	14	12	8	7
4	67	49	37	30	25	18	12	10	8	6
3	70	47	34	26	21	17	13	9	7	6
2	71	50	33	24	18	15	12	9	6	5
1	56	40	28	19	14	10	8	7	5	3

N

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (g). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Londiani (90.35002) during the March to mid-June period

	11	91	78	68	55	54	48	43	38	28	26
	10	90	82	71	61	50	49	43	39	35	25
	9	88	79	71	65	56	48	40	38	34	31
	8	89	78	71	64	58	50	43	35	34	30
	7	86	77	68	61	55	50	43	37	31	30
M	6	84	73	65	57	51	46	42	36	31	26
	5	88	74	64	57	50	45	41	37	32	28
	4	84	73	62	53	48	42	38	34	31	27
	3	80	67	59	50	43	38	34	30	27	25
	2	79	64	53	47	39	34	30	27	24	22
	1	70	56	45	37	33	28	24	21	19	17
		1	2	3	4	5	6	7	8	9	10
							N				

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (h). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Sotik (90.35013) during the March to mid-June period

	10	75	63	53	47	33	27	25	18		
	9	81	60	51	43	38	27	22	21	14	
	8	83	67	50	42	36	32	22	18	17	12
	7	81	67	54	40	34	29	26	18	15	14
M	6	82	66	55	44	33	28	23	21	15	12
	5	82	67	54	45	36	27	23	19	17	12
	4	75	61	50	40	33	27	20	17	14	13
	3	68	50	41	34	27	23	18	14	11	10
	2	69	46	35	28	23	19	15	13	9	8
	1	68	47	32	24	19	16	13	11	9	6
		1	2	3	4	5	6	7	8	9	10

N

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

Table 44: (i). The probability (in percentage) of a dry spell of N or more days following a dry spell of M days at Maji Mazuri (90.35028) during the March to mid-June period

M	1	2	3	4	5	6	7	8	9	10
10	86	66	59	53	42	38	37	33	32	27
9	84	72	55	49	45	36	32	31	28	26
8	88	74	64	48	43	39	31	28	27	24
7	89	78	66	57	43	39	35	28	25	24
6	87	77	68	57	49	38	34	30	24	22
5	76	66	59	51	43	37	28	25	23	18
4	83	63	54	49	43	36	31	24	21	19
3	85	70	53	46	41	36	30	26	20	18
2	78	66	55	41	36	32	28	24	20	16
1	67	52	44	37	28	24	21	19	16	14

N

M = length of preceding dry spell in days

N = number of dry days following a dry spell of M days

APPENDIX 4: Table 45: (a) - (r)

Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by Markov chain probability and Exponential distribution models.

Table 45: (a). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Mt. Elgon Forest Station (88.34001)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	243	249
2	107	109
3	47	48
4	29	21
5	8	9
6	6	4
7	2	2
8	0	*
9	2	*
Total	444	
χ^2	3.86	
D.F.	4	
P	0.30-0.50	

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	128	88
2	81	71
3	43	58
4	36	47
5	23	38
6	28	31
7	13	25
8	23	20
9	15	16
10	13	13
11	4	11
12	9	9
13	8	7
14	5	6
15	6	5
16	7	4
17	6	3
18	4	2
19	1	2
20	2	2
21	3	1
22	0	1
over 22	6	*
Total	464	
χ^2		48.74
D.F.		14
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (b). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Mt. Elgon Forest Station (88.34001)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	243	227
2	107	108
3	47	52
4	29	25
5	8	12
6	6	6
7	2	3
8	0	1
9	2	*
Total	444	
χ^2	10.73	
D.F.	5	
P	0.05-0.10	

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	128	91
2	81	73
3	43	59
4	36	47
5	23	38
6	28	30
7	13	24
8	23	20
9	15	16
10	13	13
11	4	10
12	9	8
13	8	7
14	5	5
15	6	4
16	7	3
17	6	3
18	4	2
19	1	2
20	2	1
21	3	1
22	0	*
23	0	*
24	1	*
25	0	*
over 25	5	*
Total	464	
χ^2		44.57
D.F.		13
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (c). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Kipkoitet (88.35005)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	276	267
2	76	99
3	37	37
4	20	14
5	7	5
6	6	2
7	0	0
8	1	0
9	0	0
10	0	0
11	1	0
Total	424	
χ^2	27.02	
D.F.	4	
P	<0.001	

DRY SPELLS (r<5.0mm)		
length of spell (in days	DO	DC
1	136	76
2	73	63
3	28	52
4	33	43
5	20	36
6	34	30
7	17	25
8	15	21
9	9	17
10	11	14
11	11	12
12	11	10
13	3	8
14	7	7
15	2	6
16	3	5
17	6	4
18	1	3
19	2	3
20	5	2
21	0	2
22	4	2
23	1	1
24	3	1
25	1	*
over 25	9	*
Total	445	
χ^2	92.66	
D.F.	15	
P	<0.001	

*	less than 1.0mm
D.F.	degrees of freedom

Table 45: (d). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Kipkoitet (88.35005)

WET SPELLS (r>5.0mm)		
length of spell (day)	WO	WC
1	276	235
2	76	101
3	37	43
4	20	18
5	7	8
6	6	3
7	0	1
8	1	*
9	0	*
10	0	*
11	1	*
Total	424	
X^2		20.89
D.F.		4
P		<0.001

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	136	81
2	73	66
3	28	54
4	33	44
5	20	36
6	34	30
7	17	24
8	15	20
9	9	16
10	11	13
11	11	11
12	11	10
13	3	7
14	7	6
15	2	5
16	3	4
17	6	3
18	1	3
19	2	2
20	5	2
21	0	1
22	4	1
over 22	14	*
Total	445	
X^2		79.70
D.F.		14
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (e). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Kakamega (89.34001)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	317	292
2	128	149
3	64	76
4	28	39
5	26	20
6	14	10
7	9	5
8	3	3
9	3	1
10	2	*
11	0	*
12	1	*
13	0	*
14	0	*
15	1	*
Total	596	
X^2		21.70
D.F.		6
P		0.001-0.005

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	247	183
2	129	128
3	64	90
4	42	63
5	30	44
6	30	31
7	15	21
8	10	15
9	10	11
10	10	7
11	3	5
12	0	4
13	3	3
14	2	2
15	3	1
16	3	*
over 16	8	*
Total	609	
X^2		52.76
D.F.		10
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (f). Comparison of observed sequences (O) of wet (W) and dry (D) days with those calculated (CO) by the Exponential distribution model at Kakamega (89.34001)

WET SPELLS ($r>5.0$mm)		
length of spell (days)	WO	WC
1	317	274
2	128	146
3	64	78
4	28	41
5	26	22
6	14	12
7	9	6
8	3	3
9	3	2
10	2	*
11	0	*
12	1	*
13	0	*
14	0	*
15	1	*
Total	596	
χ^2		21.05
D.F.		6
P		0.001-0.005

DRY SPELLS ($r<5.0$mm)		
length of spell (days)	DO	DC
1	247	187
2	129	129
3	64	89
4	42	62
5	30	43
6	30	29
7	15	20
8	10	14
9	10	10
10	10	7
11	3	5
12	0	3
13	3	2
14	2	2
15	3	1
16	3	*
17	0	*
18	0	*
19	1	*
20	0	*
over 20	7	*
Total	609	
χ^2		42.95
D.F.		10
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (g). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Tambach (89.35014)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	231	222
2	84	102
3	52	47
4	17	22
5	14	10
6	3	5
7	0	2
8	5	*
9	3	*
10	0	*
11	1	*
12	0	*
13	0	*
14	0	*
15	1	*
Total	411	
X^2		23.94
D.F.		5
P		<0.001

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	136	73
2	59	61
3	32	50
4	31	42
5	28	35
6	29	29
7	14	24
8	15	20
9	12	17
10	8	14
11	11	11
12	6	9
13	5	8
14	6	7
15	7	5
16	2	4
17	3	4
18	5	3
19	2	3
20	0	2
21	6	2
22	2	1
23	1	1
24	1	1
25	2	*
over 25	10	*
Total	431	
X^2		80.20
D.F.		14
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (h). Comparison of observed sequence (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Tambach (89.35014)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	231	199
2	84	101
3	52	51
4	17	26
5	14	13
6	3	7
7	0	3
8	5	2
9	3	*
10	0	*
11	1	*
12	0	*
13	0	*
14	0	*
15	1	*
Total	411	
χ^2		14.65
D.F.		5
P		0.01-0.02

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	136	78
2	59	64
3	32	52
4	31	43
5	28	35
6	29	29
7	14	23
8	15	19
9	12	16
10	8	13
11	11	11
12	6	9
13	5	7
14	6	6
15	7	5
16	2	4
17	3	3
18	5	3
19	2	2
20	0	2
21	6	1
22	0	1
over 22	14	*
Total	431	
χ^2		69.48
D.F.		14
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (i). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Miwani (90.34008)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	359	361
2	112	123
3	48	42
4	17	14
5	11	5
Total	547	
X^2	9.69	
D.F.	3	
P	0.02-0.05	

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	161	130
2	103	100
3	66	77
4	60	59
5	40	46
6	28	35
7	12	27
8	18	21
9	16	16
10	15	12
11	11	10
12	8	7
13	5	6
14	5	4
15	7	3
16	3	3
17	2	2
18	1	2
19	1	1
20	0	*
over 20	3	*
Total	565	
X^2	21.64	
D.F.	12	
P	0.02-0.05	

* less than 1.0

D.F. degrees of freedom

Table 45: (j). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Miwani (90.34008)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	359	323
2	112	125
3	48	48
4	17	19
5	11	7
Total	547	
χ^2	7.86	
D.F.	3	
P	0.02-0.05	

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	161	133
2	103	102
3	66	78
4	60	59
5	40	45
6	28	35
7	12	26
8	18	20
9	16	15
10	15	12
11	11	9
12	8	7
13	5	5
14	5	4
15	7	3
16	3	2
17	2	2
18	1	1
19	1	1
2P	0	*
21	0	*
22	0	*
over 22	3	*
Total	565	
χ^2	19.34	
D.F.	12	
P	0.05-0.10	

* less than 1.0

D.F. degrees of freedom

Table 45: (k). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Jamji Estate (90.35001)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	348	316
2	118	155
3	69	76
4	29	37
5	20	18
6	17	9
7	8	4
8	9	2
9	0	1
10	1	*
11	0	*
12	1	*
Total	620	
χ^2	32.89	
D.F.	5	
P	<0.001	

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	285	205
2	104	140
3	76	95
4	59	65
5	32	44
6	21	30
7	13	20
8	9	14
9	12	9
10	10	6
11	5	4
12	3	3
13	4	2
14	2	1
15	1	*
over 15	7	*
Total	642	
χ^2	62.50	
D.F.	9	
P	<0.001	

*	less than 1.0
D.F.	degrees of freedom

Table 45: (1). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Jamji Estate (90.35001)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	348	291
2	118	152
3	69	79
4	29	41
5	20	22
6	17	11
7	8	6
8	9	3
9	0	2
10	1	*
11	0	*
12	1	*
Total	620	
X^2		30.39
D.F.		6
P		<0.001

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	284	206
2	104	139
3	76	94
4	59	64
5	32	43
6	21	29
7	13	20
8	9	13
9	12	9
10	10	6
11	5	4
12	3	3
13	4	2
14	2	1
15	1	*
16	1	*
17	0	*
18	1	*
19	0	*
20	2	*
over 20	3	*
Total	642	
X^2		55.03
D.F.		9
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (m). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Londiani (90.35002)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	224	226
2	100	101
3	46	46
4	16	21
5	12	9
6	4	4
7	0	2
8	5	*
9	2	*
10	1	*
Total	410	
χ^2	3.20	
D.F.	4	
P	0.50-0.70	

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	128	73
2	62	60
3	47	50
4	31	42
5	20	35
6	22	29
7	16	24
8	11	20
9	11	16
10	8	14
11	7	11
12	6	9
13	8	8
14	7	6
15	8	5
16	1	4
17	4	4
18	3	3
19	3	3
20	7	2
21	1	2
22	0	1
23	3	1
24	3	1
25	2	*
over 25	9	*
Total	428	
χ^2	71.81	
D.F.	14	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 45: (n). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed by the Exponential distribution model at Londiani (90.35002)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	224	204
2	100	100
3	46	49
4	16	24
5	12	12
6	4	6
7	0	3
8	5	1
9	2	*
10	1	*
Total	410	
χ^2	8.74	
D.F.	5	
P	0.10-0.20	

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	128	74
2	62	61
3	47	51
4	31	42
5	20	35
6	22	29
7	16	24
8	11	20
9	11	16
10	8	13
11	7	11
12	6	9
13	8	8
14	7	6
15	8	5
16	1	4
17	4	4
18	3	3
19	3	2
20	7	2
21	1	2
22	0	1
23	3	1
24	3	*
25	2	*
over 25	9	*
Total	428	
χ^2	71.36	
D.F.	14	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 45: (o). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Sotik (90.35013)

WET SPELLS (r>5.0mm)		
length of spell (in days)	WO	WC
1	362	349
2	125	140
3	44	56
4	30	22
5	5	9
6	8	4
7	6	1
8	1	*
9	1	*
Total	582	
χ^2		26.02
D.F.		4
P		<0.001

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	191	156
2	128	115
3	91	85
4	48	63
5	26	47
6	21	35
7	18	26
8	13	19
9	12	14
10	13	10
11	6	8
12	5	6
13	3	4
14	7	3
15	3	2
16	1	2
17	4	1
18	0	*
over 18	9	*
Total	599	
χ^2		44.10
D.F.		11
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (p). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Sotik (90.35013)

WET SPELLS (r>5.0mm)		
length of spell (days	WO	WC
1	362	319
2	125	139
3	44	61
4	30	26
5	5	12
6	8	5
7	6	2
8	1	*
9	1	*
Total	582	
χ^2		25.64
D.F.		5
P		<0.001

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	191	159
2	128	117
3	91	86
4	48	63
5	26	46
6	21	34
7	18	25
8	13	18
9	12	13
10	13	10
11	6	7
12	5	5
13	3	4
14	7	3
15	3	2
16	1	2
17	4	1
18	0	*
19	2	*
20	2	*
21	4	*
22	0	*
23	0	*
24	1	*
Total	599	
χ^2		35.84
D.F.		11
P		<0.001

* less than 1.0

D.F. degrees of freedom

Table 45: (q). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by a Markov chain probability model at Maji Mazuri (90.35028)

WET SPELLS (r>5.0mm)		
length of spell (in days	WO	WC
1	246	246
2	106	108
3	37	48
4	24	21
5	12	9
6	4	4
7	6	2
8	1	*
9	2	*
10	1	*
Total	439	
χ^2	10.99	
D.F.	4	
P	0.02-0.05	

DRY SPELLS (r<5.0mm)		
length of spell (in days)	DO	DC
1	153	83
2	68	68
3	37	56
4	35	46
5	41	38
6	17	31
7	12	25
8	12	21
9	14	17
10	10	14
11	15	11
12	5	9
13	4	8
14	8	6
15	3	5
16	1	4
17	3	3
18	1	3
19	3	2
20	4	2
21	1	2
22	1	1
23	0	1
24	1	*
over 24	13	*
Total	462	
χ^2	94.34	
D.F.	14	
P	<0.001	

* less than 1.0

D.F. degrees of freedom

Table 45: (r). Comparison of observed sequences (O) of wet (W) and dry (D) days with those computed (C) by the Exponential distribution model at Maji Mazuri (90.35028)

WET SPELLS (r>5.0mm)		
length of spell (days)	WO	WC
1	246	221
2	106	107
3	37	52
4	24	25
5	12	12
6	4	6
7	6	3
8	1	1
9	2	*
10	1	*
Total	439	
χ^2		10.12
D.F.		5
P		0.05-0.10

DRY SPELLS (r<5.0mm)		
length of spell (days)	DO	DC
1	153	87
2	68	71
3	37	57
4	35	47
5	41	38
6	17	31
7	12	25
8	12	20
9	14	16
10	10	13
11	15	11
12	5	9
13	4	7
14	8	6
15	3	5
16	1	4
17	3	3
18	1	2
19	3	2
20	4	2
21	1	1
22	1	1
23	0	*
24	1	*
25	1	*
over 25	12	*
Total	462	
χ^2		87.99
D.F.		14
P		<0.001

* less than 1.0

D.F. degrees of freedom