DETERMINING THE ONSET AND CESSATION OF SEASONAL RAINS IN MALAWI

BY

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Declaration

This research project is my original work and has not been presented for a degree in any other university

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This research project has been submitted with our approval as university supervisors.

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Dedication

To my dad, Jeremiah Kazembe,

for his unconditional love.

Acknowledgement

Firstly I would like to forward my gratitude to Prof. Ininda for his constructive advices, generous suggestions and comments during the research project.

I would also like to extend my appreciation to Mss Bosire, who made me an expert on Instat software.

I also offer gratitude to the Department of Climate Change and Meteorological Services of Malawi for providing daily data and for their cooperation.

Lastly I would like to thank my family and friends for their encouragement and support. I also would like thank Dr. Raphael E. Okoola for his support.

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ABSTRACT

The country ofMalawi has a sub-tropical climate, which is relatively dry and strongly seasonal. The warm-wet seasonal stretches from November to April, during which 95% of the annual precipitation takes place.

A cool, dry winter season usually starts from May to August and a hot, dry season is experienced from September up to October.

Over the years there has been some slight changes on the onset of rainfall, this has affected the country of Malawi greatly since it fully depends on rain fed agriculture.

The onset and cessation dates were generated by using Instat. In the northern region the result shows that on average the onset occurred between 5th-18 December. Cessation on average occurred between 19th April-2nd May. In the central region of the study area the results shows that on average the onset occurred between 7th -10th December. Cessation on average occurred between 8th-20th April. In the southern region on average the onset occurred between 25thNovember -2nd December. Cessation on average occurred between 5th April-3rd May.

The study also showed increasing/decreasing trends in the onset/cessation dates. When we have late onset and early cessation, it means that the length of growing season is decreasing.

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CHAPTER ONE

1.0 INTRODUCTION

Malawi is situated south of the equator, on the southeast of Africa. The latitude and longitude are 13.8 ↔S, 34.4 E↔. The land area is about 118,484□□$^{□}$. The country is bordered by Zambia to the northwest, Tanzania to the northeast, and Mozambique on the east, south and west.

Rainfall in Malawi is produced by mesoscale synoptic systems as well as large-scale systems associated with the seasonal movement of the Inter-tropical Convergence Zone (ITCZ). Malawi has only two main season the dry season and wet season.

The economy of Malawi is predominantly agricultural, with about 90% of the population living in rural areas. Agriculture accounts for 37% of GDP and 85% of export revenues. The success of agricultural production has, therefore large implications, ranging from the state of the countrywide economy to the survival of the subsistence farmers.

Rainfall is a valuable water resource in Malawi but it is limited to few months per year and usually short from November to April. It is important to sow as early as possible to avoid wasting valuable growth time. The determination of the onset and the cessation of the rainy season is therefore of crucial importance for sustainable food production

1.1 Statement of the problem

The economies of most countries of southern Africa are heavily dependenton agriculture and most of the crops are rain-fed and the food security in these countries revolves around climate as a resource. Water is a limited commodity.

Malawi as one of the southern African country heavily depends on natural rainfall as its main source of water for crop production. Understanding rainfall characteristics of Malawi will enhance food production which will contribute to the countryĝs food security. The determining of the onset and end of seasonal rains is of interest mainly because of its importance in agriculture. The knowledge will be of great help to the farming community, water resources managers and agriculturalists in the proper planning endeavours for effective management of water resources

1.2 General objective

The main objective of this study is to determine the onset, and end of the seasonal rains in Malawi.

1.2.1 Specific objective

Specific objective include:

- To determine the onset and cessation of seasonal rains in Malawi
- To classify the occurrence of onsetand cessation dates into various classes namely; early, normal and late.

1.3 Justification of the study

In the country of Malawi the social-economic activities is largely determined by the amount, distribution and reliability of rainfall The yields of crops such as maize, tobacco and beans which are mainly grown in the rainy season depends on the timing of the onset, and end of the seasonal rains and its distribution.

A season with the above average rainfall may not necessarily be better than a below average season over agriculture region if the rainfall are not well distributed in space and time. Crops are likely to do well with evenly distributed light rains than a few isolated heavy rainfall interrupted by prolonged dry periods. For crop cultivation, the consistency with which minimally required rainfall is received is more important than total rainfall received. Therefore there is need to determine accurately the onset, cessation and hence distribution of the rainfall season for any given place.

The farmers need to be educated on how to fully utilise the seasonal rains. This will help in improving the economy of the country as well as enhancing food production that will lead to food security for the increasing population in the country.

1.4 Area of study

The area of study is the country of Malawi located within the latitude and longitude 13.8 S, 34.4 E.

1.4.1 Physical features of the area of study

Malawi is a landlocked country in Southern Africa. The whole country is part of the Zambezi River Basin, contributing to about 8% of the Zambezi basinôs catchment area. Lake Malawi is dominant water resources feature of the country, covering about one fifth of the countryôs area of 118,000□□ □and two thirds of the countryôs length. The Lake is in the East Africa Rift Valley at about 474m above sea level, with a surface area of 2.8×104□□ □, a volume of 8×103□□ □, a land catchment area of 9.6×104□□ □, a length of 550 km and a breadth area of 15ï80 km; it forms borders between Malawi, Mozambique and Tanzania. Six small rivers create an annual inflow of approximately 360□ □□□□of the lake. The Shire River drains the lake southward over a weir to the Zambezi River (Jury and Gwazantini, 2002; Jury and Mwafulirwa 2002).

1.4.2 Climatology of rainfall over the study area

Malawi climate is tropical wet and dry, also known as savannah. It is mostly dominated by the north-south migration of the Inter-tropical Convergence Zone (ITCZ). The ITCZ is marked by the convergence of north-easterly monsoon and south-easterly trade winds. The ITCZ works in collaboration with the Congo Air Boundary, the northwest winter monsoons comprising recurving tropical Atlantic Air that reaches Malawi through the Congo Basin. The main rain season is from November to April and the dry season is from May to October.

The tropical cyclones originating from the Indian Ocean are frequent during the main rain season from May to October. Tropical cyclones originating from the Indian Ocean are frequent during the main rain season, and these bring in very intense rainfall activities over a few days.

Annual rainfall in Malawi varies from 700mm in the low-lying areas to 2,500 mm in the southern and parts of the northern highlands. Some areas, especially the highland to the south of the country, especially the highlands to the south of the country, experience sporadic winter rains locally called Chiperone between May and August. These rains originate from an influx of cool moist southeast winds.

1.6 LITERATURE REVIEW

Several studies have been undertaking on determining the onset, and cessation of the rainfall they include the work of Alves(2011) In his study, 30 year daily rainfall data was used to statistically determine the start of the May-June rainy season of the Guyana country by considering the mean as the most probable date of start of the May-June rainy season, it was found that there is a 95% probability that the season can begin between May 17 and June 2, when all years are considered and May 15-26, when the years of strong El Nino is not considered. He also determined that the late start of the rainy season has a return period of 4 years and the false start one year in 15 years, the Binomial model reports that there is 95% confidence level 0f 0.123-0.459,0.008-0.221 for these two events respectively.

Lima and Lall(2009) rainy season onset, peak and end in Brazil was determined using hierarchical Bayesian modelling of multisite daily rainfall occurrence. The rainfall onset was identified by finding the first day of the year in which the estimated probability of rainfall is greater than a specified number, e.g., 0.5. The determination of the end of the rainy season followed a similar procedure.

Studies have also been undertaken on the length of season in East Africa region they include the work of Alusa and Mushi (1994) and Alusa and Mushi (1974) and Alusa (1978). Following Hesanmi (1972), they identified the onset of the rains in several East Africa stations as the first maximum curvature on a cumulative rainfall plot. The onset was defined as the first pentad whose rainfall amount exceeded 1/73 of the mean annual rainfall. They found out that the onset was around pentad 15 (12-16 March) for Kenya with the exception of the coast while the withdrawal occurred around pentads 27-28(11-20 May) (Asanani 1993).

Okoola(1998) studied the rainfall season onsets and withdrawals during 1981 and 1984. He used mass curves of pentad rainfall at Arusha representing northern Tanzania, Marsabit representing northern Kenya and Kakamega representing western Kenya. The long rains onset occurred during the 15^{th} (12-16 March) and 19^{th} (1-5 April) pentads in 1981 and 1984 respectively. Okoola (1998) found out that western Kenya which was represented by Kakamega had delayed onsets during the dry year of 1984 for the long rains compared to 1981 which was a wet year. Withdrawal was early in 1984 and delayed in 1981.

Camberlin and okoola (2003) undertook a study on the onset and cessation of long rains in eastern Africa and their inter-annual variability. The accumulated the principal component (PCA) scores to determine the onset and cessation dates. The study found out that on average over the years 1958-1987, onset occurs on March 25^{th} and the cessation on 21^{st} May (for the long rains) which gave duration of no more than 57 days. They also found out that over the years 1958 to 1987, there was a small trend toward a delayed onset of the rains. The study considered only long rains season.

The current study will use most recent data (1980-2011) which will bring out any changes in the onset, and cessation dates due to climate change.

1.7 SYSTEMS THAT INFLUNCE RAINFALL OVER MALAWI

Rainfall in Malawi is seasonal and is produced by large-scale systems associated with the seasonal movement of the Inter -tropical Convergence Zone (ITCZ). There is only one rainfall season which occurs in the period November to April.

According to Torrance (1972) the climate of Malawi depends on the ITCZ, the subtropical high pressure belt in the south between 25° and 35°S, and its topography .Malawi is usually being affected by a broad belt of strong convective activity during the rainy season. This ITCZ belt, which is the main rain bearing system, marks the converging point of north-easterly monsoon of the Northern Hemisphere and the south-easterly trade winds of the Southern Hemisphere. The belt is known as Inter-tropical Convergence Zone (lTCZ), lagging behind the sun by a month or so (Hsu and Wallace, 1976; Kidsoll, 1977). It invades the country from the north on its southwards movement to its southern limit in February and then moves back to the north. During the rainy season the ITCZ may oscillate over the southern tropical areas in association with pressure changes usually across South Africa.

The other main rain bearing system for Malawi weather during the rainy season is the Congo Air Boundary (CAB) which marks the confluence between the Indian Ocean southeast tradewind and recurved South Atlantic air that reaches Malawi as north-westerly air mass through the Democratic Republic of Congo. This system brings well-distributed rainfall over the country and even floods may be experienced in some areas especially if it is associated with the ITCZ. There are times when the country is affected by tropical cyclone originating from the Indian Ocean. Depending on its position over the Indian Ocean, a cyclone may result in having either a dry or a wet spell over Malawi.

The other weather features of significance are easterly and westerly waves, and temperate weather systems. The extra-tropical waves are believed to be active during the start and end of the rainy season. During winter Malawi is influenced by a divergent south-easterly airmass driven by high-pressure cells southeast of Africa. A strong high pressure cell over the eastern South African coast draws a cool moist easterly airmass into the country causing overcast conditions with drizzle over highlands and east facing escarpments near Lake Malawi, locally called "chiperoni". These weather conditions usually last for two to three days.

CHAPTER TWO

2.0 DATA AND METHODOLOGY

In this section the data type, sources and various methodsused in this study to achieve outlined objectives are presented

2.1 Data type and source

The data used in this study was daily rainfall for 12 stations, distributed in each of the three main regions of Malawi; northern, central and southern region. The data covered the period from January 1980 to December 2011. It was provided in Excel format by the Department of Climate Change and Meteorological Services of Malawi. Table 1 shows the location and altitudinal details of the four rainfall stations while Figure 1 shows the location of the study area

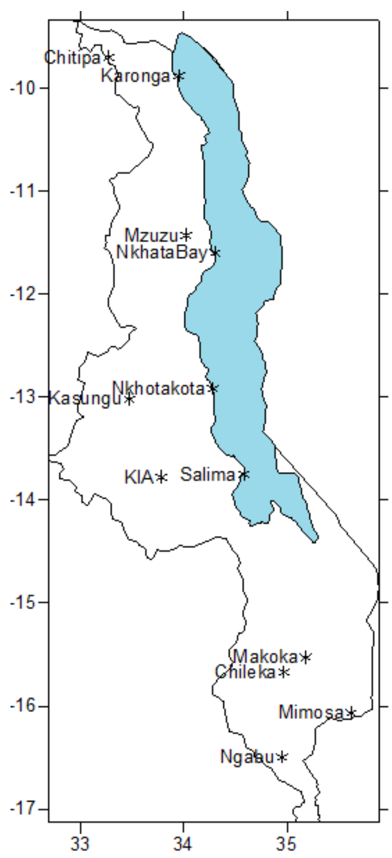


Figure 1: Map of Malawi showing stations used in the study.

Table 1: Location and altitudinal details of the rainfall stations used in the study

STATION	LATITUDE	LONGITUDE	ELEVATION IN M(AMSL)
Northern Region			
Chitipa	-9.7	33.95	1285
Karonga	-9.88	33.95	529
Mzuzu	-11.43	34.02	1254
Khatabay	-11.6	34.3	500
Central Region			
KIA	-13.78	33.78	1229
Salima	-13.75	34.58	512
Khotakota	-12.92	34.28	500
Kasungu	-13.02	33.47	1058
Southern Region			
Makoka	-15.53	35.18	1029
Chileka	-15.67	34.97	767
Ngabu	-16.5	34.95	102
Mimosa	-16.07	35.62	652

2.2 METHODOLOGY

2.2.1 Estimation of missing data

Arithmetic Mean method was the proposed method to be used for estimation of missing data.

$$□_{□} = □\frac{\bar{□}}{□_{□}}□\ □_{□}$$

$□_{□}$ = The missing data

$□_{□}$= Available data of the station Y with the highest correlation with the station whose data is missing

$\overline{□_{□}}$= Mean value for the station Y with complete data and

$\bar{□}$ = Mean value for station X with missing data

2.2.2 Data Quality Control

The data has been examinedby the department of climate change and meteorological services to ensure its quality. A detailed inspection and regular cross checking policy was implemented in order to clean the data from any erroneous values whenever necessary. However in this study the consistence of data was examined. Single mass curves of cumulative values of the observed data against time were used to test the homogeneity or consistence and accuracy in meteorological data for each station.

2.2.3 Determination of onset and cessation

To meet the first objective in section 1.2.1, a statistical analysis of daily rainfall data for Malawi for the period 1980 -2011 was done. The data was organised in a format required by Instat Software Program.

Instatis a statistical program which was developed by the University of Reading in 2002 in United Kingdom

The data was very good it had no negative or missing values. The tools offered by Instat and the under-mentioned criteria were used to answer the questions implied by the objectives.

2.2.3.1 Onset

The following criterion was used to determine onset;

-Rainfall total of 20 mm or more and a length of 5 days or more:

- No dry spell of duration of 9 days or no more in the next 30 days:

- should occur with an earliest starting day of October 1:

- A threshold value of 0.85 mm

2.2.3.2Cessation

The following criterion was used to determine cessation;

The estimation of the end of the rainy seasons are based on the earliest possible day of April 1, the capacity of soil to persist precipitation with a water balance equal to zero is 100mm.

2.2.4 Classification of onset and cessation

The specific objective 2 in section 1.2.1 was to classify onset and cessation to early, normal and late.

In order to carry out this exercise the onset and cessation dates were transformed into standardised anomalies, given by question 1

$$z=\frac{X-\bar{X}}{\sigma} \quad \text{é é é é é é é é é é é é é é é é é ..} \quad (1)$$

where

X = the observed value

$\bar{X}$= mean of the observed values

σ = standard deviation of the observed values

Z= the standardised anomaly

Table 2: The range and classification of onsets and cessation

Range	Class
$z > 1$	late
$1 \geq z \geq -1$	normal
$z < -1$	early

CHAPTER THREE

3.0 RESULTS AND DISCUSSION

The results obtained using the methodology described in chapter two are presented and discussed in this chapter.

3.1 Results from data quality control

Figure 2 shows the single mass curve for the rainfall values of three stations of the twelfth stations used in this study. The trend line indicates that the data is homogeneous and hence suitable for climatological analysis

(a) (b)

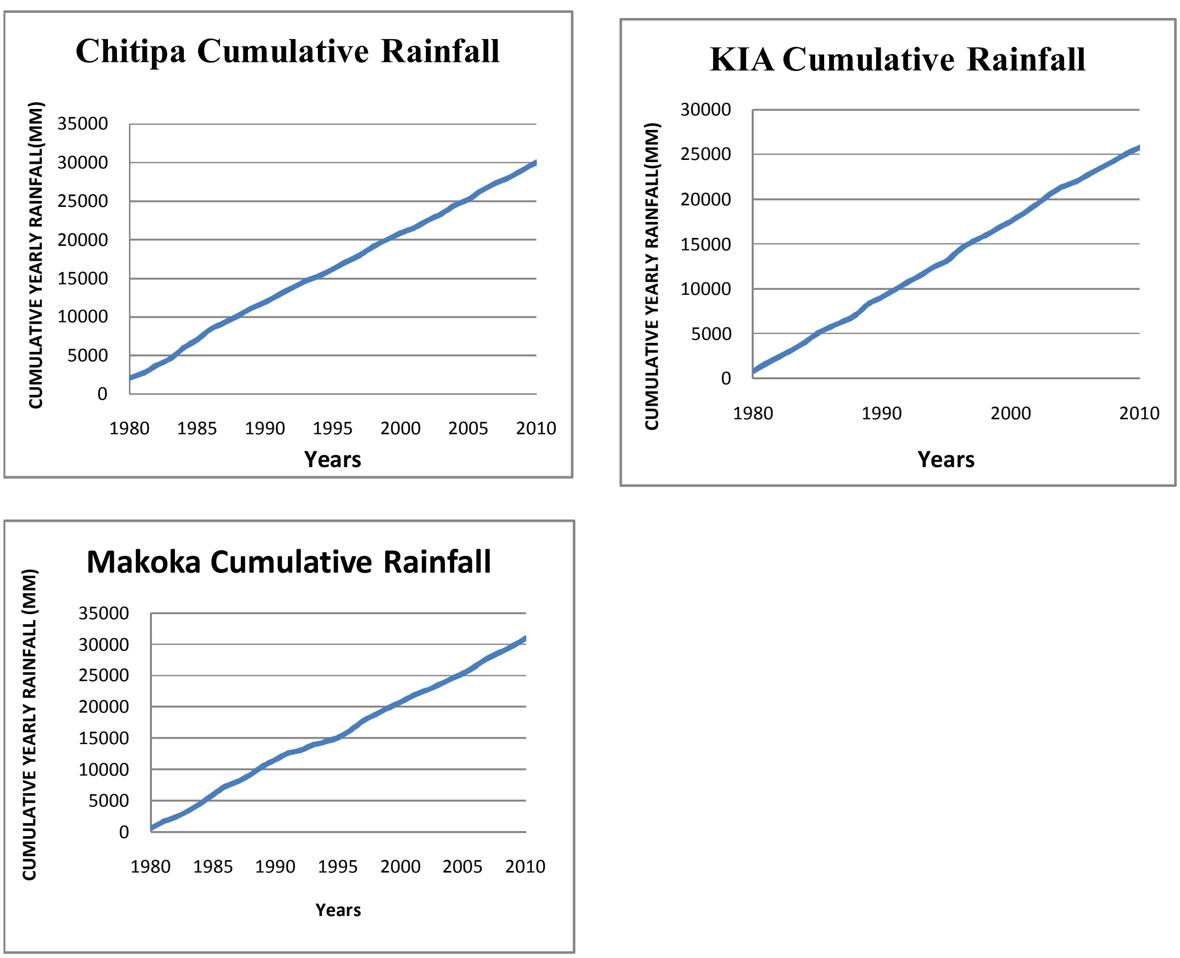


Figure 2: Results of the single mass curve analysis over the study area as shown by (a) Chitipa, (b) KIA, (c) Makoka.

3.2 Dates of Onset and Cessation of the rains

This section discusses the results obtained from the analysis of daily rainfall data using instant, the methods are explained in section 2.2.3.1 Onset and 2.2.3.2 Cessation.

Figures below ware generated from the analysis carried out on the daily rainfall in the study area. Figure 3, 4, 5 are for the three stations used as sample selected from the northern, central and southern region of the study area respectively. The same was done for the rest of the stations to come up with the onset and cessation dates in the study area as shown in Tables 3, 4 and 5.

Figure 3 shows that Chitipa had early onset in the year 1986 and 2001. Late onset occurred in the year 1999 and 1994. The inter-annual variability of the cessation shows that it had early cessation in the year 1987 and 2001; late cessation occurred in the year 1998 and 1999.

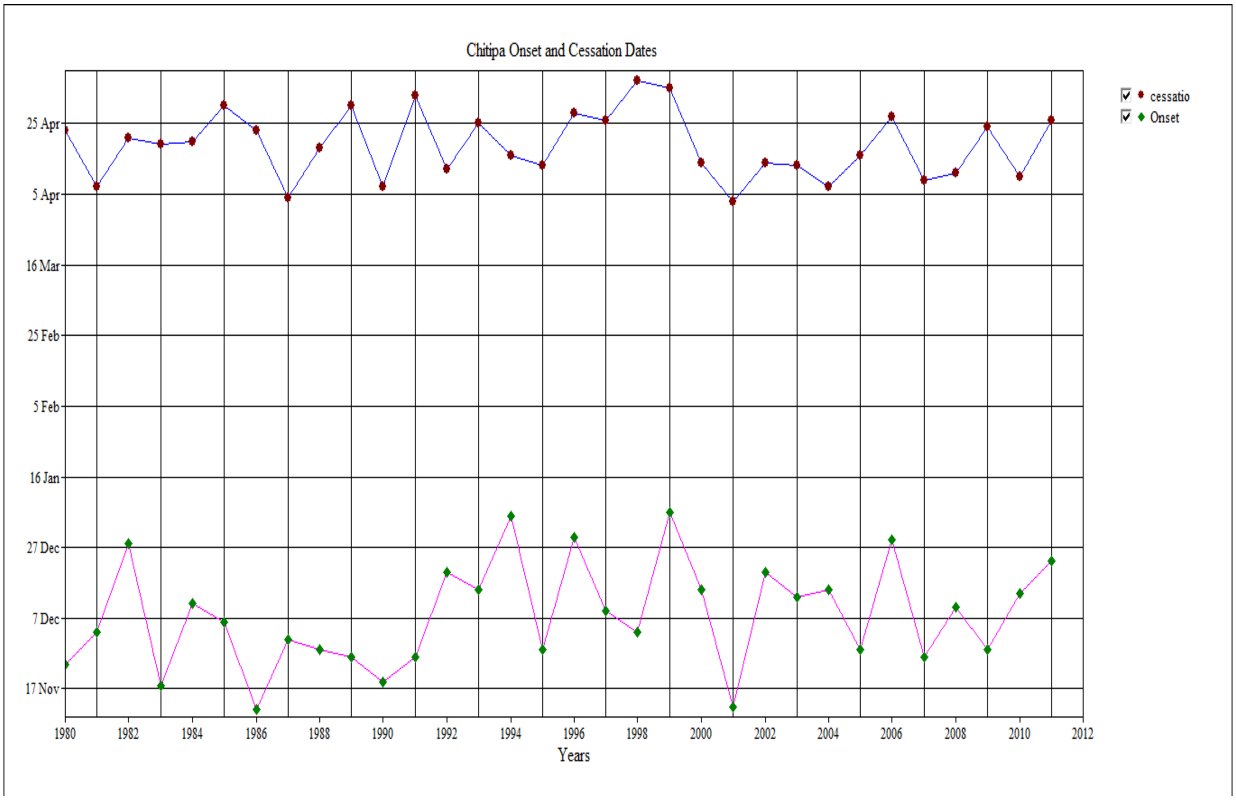


Figure 3: Chitipa Onset and Cessation Dates

Chitipa is a station located in the northern region of Malawi. It was sampled from the four stations representing the northern region of the study area. It can be observed from table 3 that the early onset occurredbetween11th-19thNovember, normal onset occurred between 24thNovember-20thDecember and late onset occurred between 23rd December-6 January. Early cessation occurred between 3rd-9th April, normal cessation occurred between 10th-28th April and late cessation occurred between 30th April-7 May. In the northern region of the study area the results shows that on average the onset occurred between 5th-18 December. Cessation on average occurred between 19th April-5nd May.

Table 3: onset and cessation over Chitipa (Early=E, Normal=N, Late=L)

Chitipa							
YEAR	DAY	ONSET		DAY	CESSATION		DURATION
1980	147	24-Nov	N	298	23-Apr	N	152
1981	156	03-Dec	N	282	07-Apr	E	128
1982	181	28-Dec	L	296	21-Apr	N	117
1983	141	18-Nov	E	294	19-Apr	N	179
1984	164	11-Dec	N	295	20-Apr	N	132
1985	159	06-Dec	N	305	30-Apr	L	147
1986	134	11-Nov	E	298	23-Apr	N	165
1987	154	01-Dec	N	279	04-Apr	E	161
1988	151	28-Nov	N	293	18-Apr	N	142
1989	149	26-Nov	N	305	30-Apr	L	159
1990	142	19-Nov	E	282	07-Apr	E	140
1991	149	26-Nov	N	308	03-May	L	162
1992	173	20-Dec	N	287	12-Apr	N	114
1993	168	15-Dec	N	300	25-Apr	N	134
1994	189	05-Jan	L	291	16-Apr	N	113
1995	151	28-Nov	N	288	13-Apr	N	139
1996	183	30-Dec	L	303	28-Apr	N	120
1997	162	09-Dec	N	301	26-Apr	N	140
1998	156	03-Dec	N	312	07-May	L	156
1999	190	06-Jan	L	310	05-May	L	135
2000	168	15-Dec	N	289	14-Apr	N	124
2001	135	12-Nov	E	278	03-Apr	E	143
2002	173	20-Dec	N	289	14-Apr	N	116
2003	166	13-Dec	N	288	13-Apr	N	125
2004	168	15-Dec	N	282	07-Apr	E	124
2005	151	28-Nov	N	291	16-Apr	N	141
2006	182	29-Dec	L	302	27-Apr	N	128
2007	149	26-Nov	N	284	09-Apr	E	136
2008	163	10-Dec	N	286	11-Apr	N	123
2009	151	28-Nov	N	299	24-Apr	N	148
2010	167	14-Dec	N	285	10-Apr	N	120
2011	176	23-Dec	L	301	26-Apr	N	125

Figure 4 shows the inter-annul variability of the onset and cessation of seasonal rains of KIA. In the year 1990 as well as 1992 it had early onset and 1994 and 2000 it had late onset. In the year 1985 it experienced late cessation.

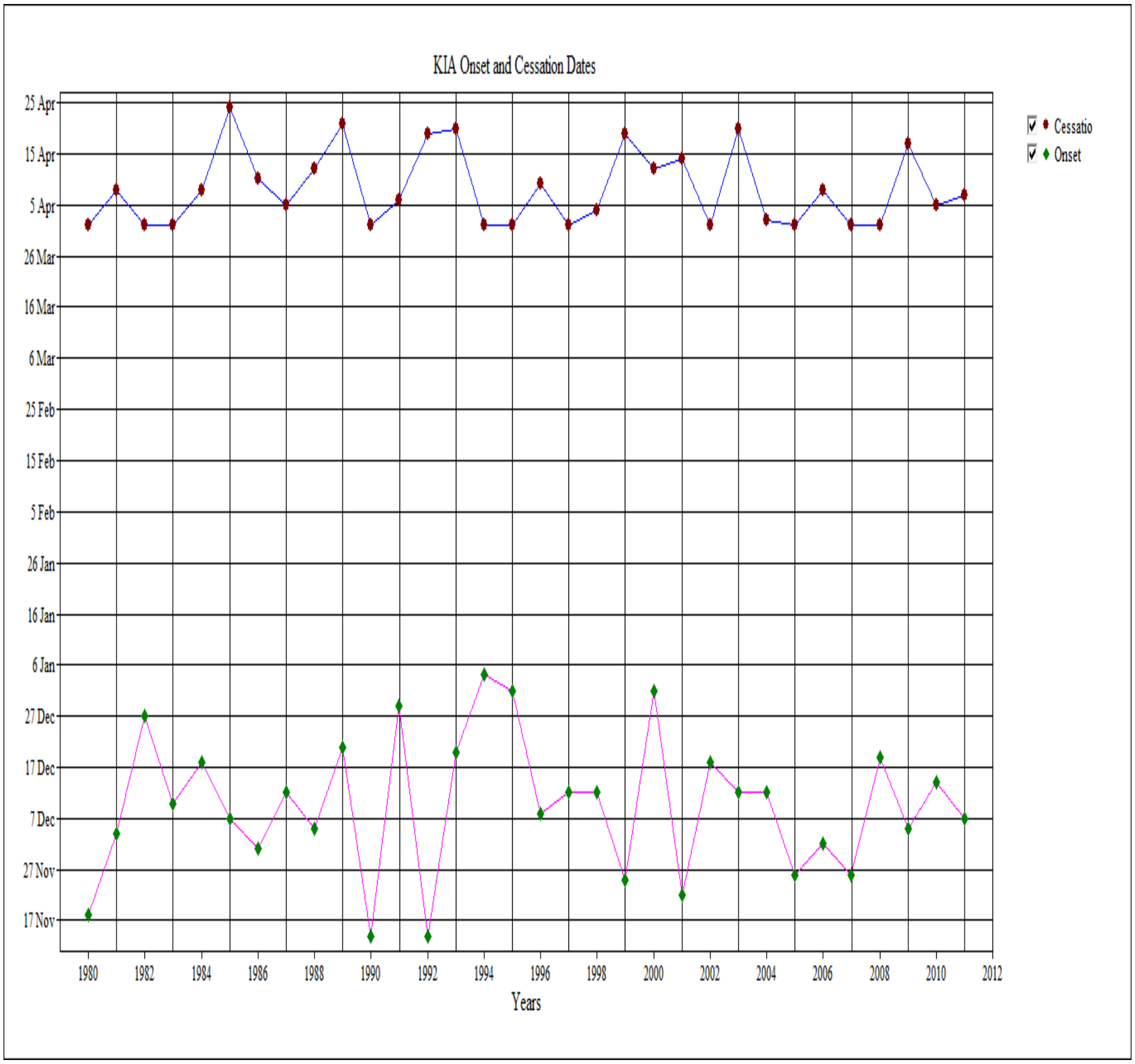


Figure 4: KIA onset and cessation dates

KIA was also samples from the four stations representing the central region of the study area. Table 4 shows early onset occurred between 14th-26th November, normal onset occurred between 1st-21 December, late onset occurred between 1st-4 January. Cessation occurred normally between 1st-14thApril and late cessation was from 17th-24th April. In the central region of the study area the results shows that on average the onset occurred between 7th -15th December. Cessation on average occurred between 8th-20th April.

Table 4: Onset and cessation occurrence over KIA (Early=E, Normal=N, Late=L)

KIA							
YEAR	DAY	ONSET		DAY	CESSATION		DURATION
1980	141	18-Nov	E	276	01-Apr	N	135
1981	157	04-Dec	N	283	08-Apr	N	126
1982	180	30-Nov	E	276	01-Apr	N	123
1983	163	10-Dec	N	276	01-Apr	N	113
1984	171	18-Dec	N	283	08-Apr	N	112
1985	160	07-Dec	N	299	24-Apr	L	166
1986	154	01-Dec	N	285	10-Apr	N	141
1987	165	12-Dec	N	280	05-Apr	N	160
1988	158	05-Dec	N	287	12-Apr	N	129
1989	174	21-Dec	N	296	21-Apr	L	122
1990	137	14-Nov	E	276	01-Apr	N	139
1991	182	29-Dec	L	281	06-Apr	N	130
1992	137	14-Nov	E	294	19-Apr	L	157
1993	173	20-Dec	N	295	20-Apr	L	122
1994	188	04-Jan	L	276	01-Apr	N	140
1995	185	01-Jan	L	276	01-Apr	N	141
1996	161	08-Dec	N	284	09-Apr	N	123
1997	165	12-Dec	N	276	01-Apr	N	111
1998	165	12-Dec	N	279	04-Apr	N	143
1999	148	25-Nov	E	294	19-Apr	L	146
2000	185	01-Jan	L	287	12-Apr	N	121
2001	145	22-Nov	E	289	14-Apr	N	144
2002	171	18-Dec	N	276	01-Apr	N	105
2003	165	12-Dec	N	295	20-Apr	L	130
2004	165	12-Dec	N	277	02-Apr	N	112
2005	149	26-Nov	E	276	01-Apr	N	127
2006	155	02-Dec	N	283	08-Apr	N	128
2007	149	26-Nov	E	276	01-Apr	N	128
2008	172	19-Dec	N	276	01-Apr	N	104
2009	158	05-Dec	N	292	17-Apr	L	134
2010	167	14-Dec	N	280	05-Apr	N	113
2011	160	07-Dec	N	282	07-Apr	N	122

Figure 5 shows the inter-annual variability of onset and cessation for Makoka. It shows that it had early onset in the year 1999 and late onset in 1988. Late cessation was experienced in the year 2010.

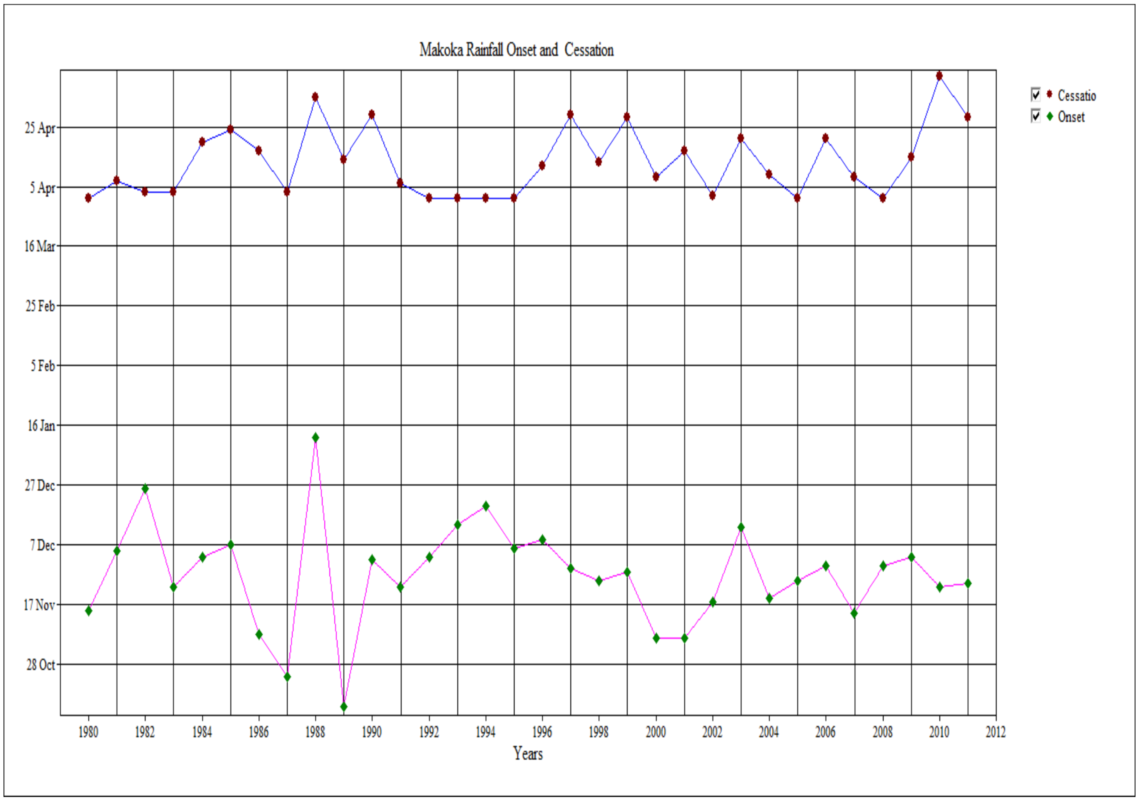


Figure 5: Makoka onset and cessation dates

Makoka had the early onset between 14th October-7th November. Normal rainfall was between 14th November-14thDecember, late onset was between 20th December-12th January. Early cessation was around 1st April. Normal cessation was between 2nd-24th April and late cessation was between 28th April-5th May as shown in Table 5. In the southern region of the study area the results shows that on average the onset occurred between 25thNovember -2nd December. Cessation on average occurred between 5th April-3rd May.

Table 5: onset and cessation occurrence over Makoka (Early=E, Normal=N, Late=L)

Makoka							
YEAR	DAY	ONSET		DAY	CESSATION		DURATION
1980	138	15-Nov	N	276	01-Apr	E	138
1981	158	05-Dec	N	282	07-Apr	N	124
1982	179	26-Dec	L	278	03-Apr	N	167
1983	146	23-Nov	N	278	03-Apr	N	132
1984	156	03-Dec	N	295	20-Apr	N	139
1985	160	07-Dec	N	299	24-Apr	N	169
1986	130	07-Nov	E	292	17-Apr	N	162
1987	116	24-Oct	E	278	03-Apr	N	162
1988	196	12-Jan	L	310	05-May	L	159
1989	106	14-Oct	E	289	14-Apr	N	183
1990	155	02-Dec	N	304	29-Apr	L	149
1991	146	23-Nov	N	281	06-Apr	N	135
1992	156	03-Dec	N	276	01-Apr	E	120
1993	167	14-Dec	N	276	01-Apr	E	109
1994	173	20-Dec	L	276	01-Apr	E	103
1995	159	06-Dec	N	276	01-Apr	E	117
1996	162	09-Dec	N	287	12-Apr	N	125
1997	152	29-Nov	N	304	29-Apr	L	152
1998	148	25-Nov	N	288	13-Apr	N	172
1999	151	28-Nov	N	303	28-Apr	L	152
2000	129	06-Nov	E	283	08-Apr	N	154
2001	129	06-Nov	E	292	17-Apr	N	163
2002	141	18-Nov	N	277	02-Apr	N	136
2003	166	13-Dec	N	296	21-Apr	N	130
2004	142	19-Nov	N	284	09-Apr	N	142
2005	148	25-Nov	N	276	01-Apr	E	128
2006	153	30-Nov	N	296	21-Apr	N	165
2007	137	14-Nov	N	283	08-Apr	N	146
2008	153	30-Nov	N	276	01-Apr	E	123
2009	156	03-Dec	N	290	15-Apr	N	134
2010	146	23-Nov	N	317	12-May	L	171
2011	147	24-Nov	N	303	28-Apr	L	156

Knowledge of duration of rainy season is important for best planning of agriculture activities. The duration as well as the mean duration had been determined using instat. Table 6 shows the mean onset, cessation and duration as well as the variation of the onset, cessation and duration of 12 stations representing the study area. It is shown than the southern region has the earliest onset ranging from 25^{th} November- 2^{nd} December. The southern region also has the largest variation this is shown by the highest standard deviation in both onset and duration.

3.3.1 Mean Onset Cessation and Duration of the rains

Table 6: Mean onset, mean cessation and mean duration of the seasonal rains of the stations in the study area

STATION	MEAN-ONSET	DAY	MEAN-CESSATION	DAY	MEAN-DURATION	STD-ONSET	STD-CESSATION	STD-DURATION
Northern Region								
Chitipa	08-Dec	161	19-Apr	294	138	15.007	9.342	16.739
Karonga	18-Dec	171	02-May	307	135	21.042	12.799	24.688
Mzuzu	07-Dec	160	05-May	310	150	16.307	17.822	22.055
Khatabay	05-Dec	158	22-May	328	170	18.028	18.211	24.763
Central Region								
KIA	10-Dec	163	08-Apr	283	121	13.602	7.4536	16.394
Salima	15-Dec	168	20-Apr	295	127	17.732	12.745	20.947
Khotakota	07-Dec	160	03-May	308	147	13.336	13.4	20.724
Kasungu	14-Dec	167	8-Aprl	283	117	21.794	8.9549	21.928
Southern Region								
Chileka	30-Nov	153	11-Apr	286	132	24.51	11.262	30.619
Ngabu	02-Dec	155	5-Aprl	280	125	46.163	7.3044	46.364
Mimosa	25-Nov	148	03-May	308	160	16.934	19.83	25.922
Makoka	27-Nov	150	13-Apr	288	138	17.481	11.643	19.544

3.3 The classification of occurrence of onset and cessation dates into various classes (early, normal and late)

Instat was used to come up with the summary statistics described in section 3.3 this section achieves objective number two under section 1.2.1. Tables 3, 4 and 6 shows the various classifications. It can be seen from the tables that various stations had early onset as well as early cessation in some years and in other years it had normal onset as well as cessation and late onset as well as cessation.

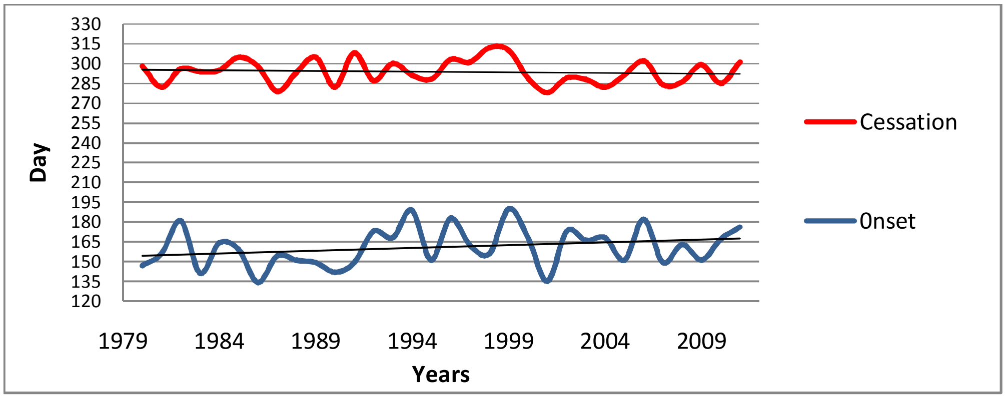
3.4 Trend analysis

Figure 6 shows the trend analysis of the three stations; Chitipa, KIA and Makoka. Chitipa shows an increasing trend in the onset with years, it indicates a delayed start of rains. It also shows a decreasing trend in the cessation dates this shows early withdrawal of the rains. In the northern region of the study area on average there is an increasing trend in the onset and a decreasing trend in cessation. It clearly shows that there is a reduction of the growing season since rainfall duration has decreased.

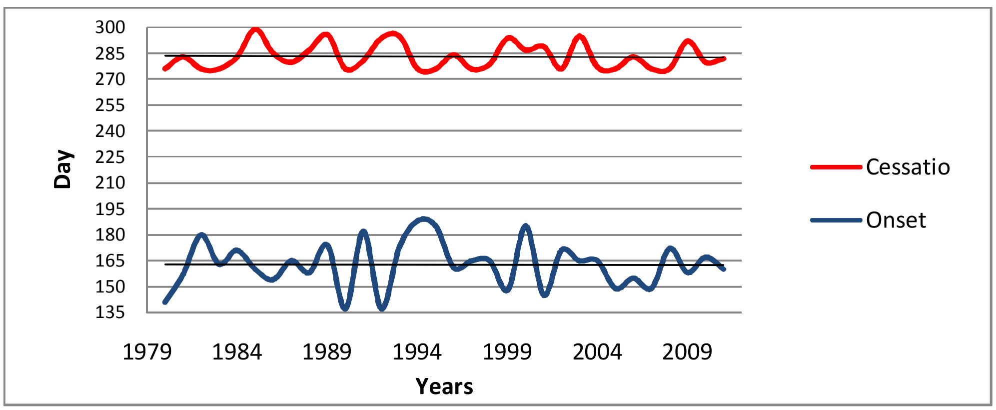
KIA shows a constant trend in the onset with the years. Cessation shows a decreasing trend this shows an early end of the rains. In the central region of the study area on average there is an increasing trend in the onset and a decreasing trend in the cessation.

Makoka shows a constant trend in the onset and cessation. It shows that there are no significant variations in the onset and cessation dates.

(a)



(b)



(c)

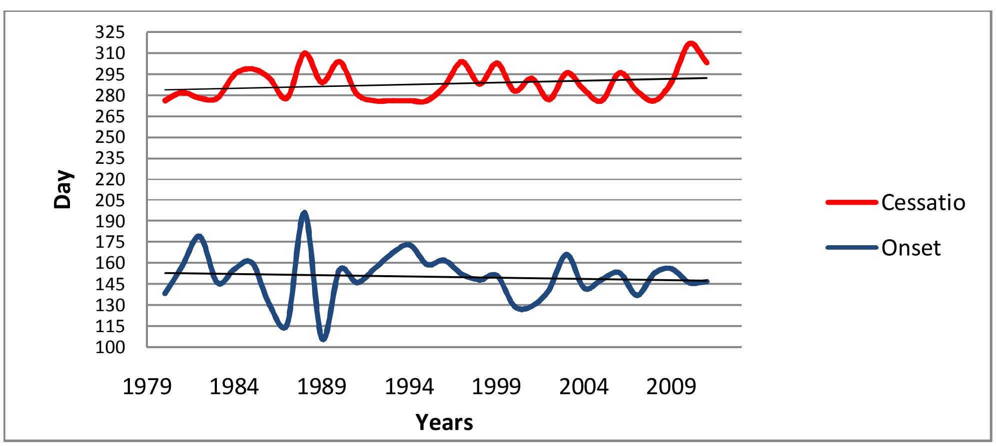


Figure 6: The trend of onset and cessation dates of the three stations over the study area; (a) Chitipa, (b) KIA and (c) Makoka

CHAPTER FOUR

4.0SUMMARY, CONCLUSION AND RECOMMENDATIONS

4.1 SUMMARY

In this study we examined the onset and cessation over Malawi. Chapter one presents the problem statement,objectives and justification.

The data and methodology used in the study are described in chapter two, while the results and discussion are given in chapter three.

The data was observed to be homogeneous making it suitable for climatological analysis.

The onset occurred from south progressing northwards. The cessation occurred earlier in the central region compared to the southern and northern region. The southern region has the longest duration followed by the northern region and lastly central region.

The inter-annual variability of onset and cessation was observed in all the three region however the southern region had the largest standard deviation.

From the classification of the onset and cessation it was observed that most years where grouped under the normal category however afew years lied on the extreme cases. The notable years with early onset included 1986, 1990, 2001 while years with late onset include 1982 and 1994.The years with the early withdrawal include 1986 and 2001while the years with the late cessation include 1980, 1999 and 2007.

In the central region on average most stations had an increasing trend on onset and decreasing trend on the cessation the same applies to the northern and southern region.

4.2 CONCLUSIONS

The rainfall generating mechanism which is mainly the ITCZ starts from the southern region and progresses northwards. The earlier onset of rains in the south suggests a complex interaction between the mesoscale, synoptic and large scale systems.The southern region part could be benefiting from the extra-tropical systems which include the low pressuresystems thatis why it has also a late onset compared to the central region.

It has been noted that the majority of the years lie within the normal category however some years are observed to have early or late onset which could be linked to global interconnections e.g.Lanina or El-nino.

The inter-annul variability onset cannot be fixed but it can be given as a range. The results indicate that the rainfall usually starts from the southern region of the study area this is indicated by the average onset which occurred between 25thNovember -2nd December. Cessation on average occurred between 5th April-3rd May.

In the central region of the study area the results shows that on average the onset occurred between 7th -15th December. Cessation on average occurred between 8th-20th April. This indicates that central region has the least rainfall duration and it has the late onset compared to the southern and northern region

In the northern region of the study area the results shows that on average the onset occurred between 5th-18 December. Cessation on average occurred between 19th April-5nd May.

There is an indication of an increasing trend on onset and decreasing trend on the cessation making the growing season shorter this could be attributed to climate change.

4.3 RECOMMENDATIONS

This research project may serve as a guiding tool for the crop planting dates and may also be used for research purposes by future scientists and meteorologists.

Studies should be done in this study area considering all the current twenty three station since this research project only considered twelfth stations.

Studies shouldalso be done to identify the systems that influence early onsetof seasonal rainfall in the southern region of Malawi.

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