DETERMINING THE ONSET AND CESSATION OF SEASONAL RAINS IN SHIRE VALLEY, SOUTHERN MALAWI

MERCY VALLE

(MEC/011/17)

Thyolo, Malawi

Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the award of the Bachelor of Science Degree in Meteorology and Climate Science.

July, 2021

DECLARATION

I *Mercy Valle* confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.



Signature _____

Date 19 JULY 2021

DISSERTATION APPROVED BY:

SUPERVISORS:

Dr. M. Fulakeza Signature 



Mr. M. Mkandawire Signature: _____

ASSESSOR:

Title, Initial, Name Signature: _____

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DEDICATION

I dedicate this dissertation to my beloved mother Dorophy Ansity Kumkwawa; my beloved brother Kondwani Masache; my beloved twin sister Maureen Valle (Biomedical Engineer). This study is also dedicated to the people who gave me a hand in making possible the success of my final work especially my supervisors Dr. M. Fulakeza and Mr. M. Mkandawire.

ABSTRACT

Agricultural activities in Malawi depend largely on rainfall-fed. Rainfall onset is defined as the period, at the beginning of the rainy season, when rainfall distribution has become adequate for crop development while rainfall cessation refers to the period, towards the end of the rainy season, when rainfall distribution may no longer sustain crop growth. Malawi has a tropical savannah climate with distinct rainy season from November to April during which 95% of the seasonal precipitation takes place and dry seasons from May to October, however from May to July it is relatively cool and in some high altitude areas drizzles (chiperoni rains) are common.

This study determined the onset and cessation of seasonal rains in shire valley, southern Malawi, with the objectives of characterizing the rainfall variables for seasonal rains in Shire Valley, southern Malawi from 1990 to 2019, analyzing the trends in the onset, cessation and length of rainy season and classifying onset and cessation dates. Daily rainfall data from 1990-2019 were obtained from the Department of Climate Change and Meteorological services. The onset and cessation dates were generated by using R-Instat. The summary of the averages of onset dates and cessation dates shows that rainfall first occur in Nsanje on 28 November followed by Ngabu on 7 December then Nchalo on 9 December. The cessation date of rainfall is almost the same in all stations with Nchalo and Ngabu on 3 April while Nsanje has its cessation date as 5 April. 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-Niño.

The Mann-Kendall analysis, it shows that Ngabu and Nsanje has an increasing trend that indicates a delayed start of rains but insignificantly while Nchalo shows a decrease in trend which means that there is early onset in the station. The onset dates have shifted but insignificantly. There is an increase in trend in the cessation for the three stations which means that there is late withdraw of rains. Ngabu and Nchalo show an increasing trend in the length of the growing season while Nsanje shows a decreasing trend in the length of the growing season. These findings would therefore contribute significantly to the effective management and sustainable development of the national and district social economic activities.

ACKNOWLEDGEMENTS

I express my gratitude to the almighty God, for granting me the capacity and ability throughout the period of studies and during this research. This research is the result of valuable support from many individuals. Their assistances in different ways have helped in the successful accomplishment of this research.

It is my pleasure to acknowledge Dr. M. Fulakeza and Mr. Malazi Mkandawire for their constructive advices, generous suggestions and comments during the writing of this paper.

I am deeply indebted to my mother, siblings and friends for their moral support and continuous encouragement towards my dissertation work.

I also thank the Department of Climate Change and Meteorological Services of Malawi for providing daily rainfall data.

My special gratitude goes to Mr. Kasiya; Kondwani Masache; Patrick Chikoti and Gloria Chikoti for their support and assistance financially and morally towards the successful completion of this studies.

Now to him who is able to do immeasurably more than all we ask or imagine, according to his power that is at work within us, to him be glory throughout all generations, for ever and ever! Ephesians 3:20-21.

Table of Contents

CHAPTER 1. INTRODUCTION 1
1.1 RESEARCH BACKGROUND 1
1.2 PROBLEM STATEMENT 3
1.3 RESEARCH OBJECTIVES 4
1.3.1 Main objective 4
1.3.2 Specific objectives 4
1.4 RESEARCH QUESTIONS 5
1.5 SIGNIFICANCE OF STUDY 5
CHAPTER 2. LITERATURE REVIEW 7
2.1 INTRODUCTION 7
2.2 SYSTEMS THAT INFLUENCE RAINFALL OVER MALAWI 8
2.3 CRITERIA FOR DETERMINING THE ONSET AND CESSATION OF RAINFALL 10
2.4 IMPORTANCE OF DETERMINING ONSET(OS) AND CESSATION(CS) OF RAINS 12
2.5 SUMMARY 13
CHAPTER 3. METHODOLOGY 14
3.1 STUDY SITE 14
3.2 RESEARCH DESIGN 15
3.3 SAMPLING TECHNIQUE 15
3.4 METHOD OF DATA COLLECTION 15
3.5 DATA ANALYSIS 15
3.5.1 Characterization of rainfall variables 15
3.5.2 Rainfall trend analysis 16
3.5.3 Classification of rainfall variables 18
CHAPTER 4. RESULTS AND DISCUSSION 19
4.1 DATES OF ONSET AND CESSATION OF THE RAINS 19
4.2 DISCUSSIONS 30
4.3 LENGTH OF THE SEASON 32
Chapter 5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 41
5.0. INTRODUCTION 41
5.1 SUMMARY 41
5.2 CONCLUSIONS 42
5.3 LIMITATIONS 43

5.4 RECOMMENDATIONS 44
REFERENCE 45
APPENDICES 50

ACRONYMS AND ABBREVIATIONS

CAB	Congo Air Boundary
DCCMS	Department of Climate Change and Meteorological Services
ENSO	Eli-Niño Southern Oscillation
ITCZ	Inter-Tropical Convergence Zone
PET	Potential Evaporation Transpiration
SSTS	Sea Surface Temperatures
OS	Onset date of rainy season
CS	Cessation date of rainy season

LIST OF FIGURES

Figure 1: Map of the study area 15
Figure 2 : Ngabu onset and cessation dates 20
Figure 3 :Nchalo onset and cessation dates 22
Figure 4:Nsanje onset and cessation dates 26
Figure 5: Graph for Ngabu, Nchalo and Nsanje onset 29
Figure 6: Graph for Ngabu, Nchalo and Nsanje cessation 30
Figure 7: Length of season 33
Figure 8: Graph for Ngabu onset dates trend analysis 35
Figure 9: Graph for Nchalo onset dates trend analysis 35
Figure 10: Graph for Nsanje onset dates trend nalysis 36
Figure 11: Graph for Ngabu cessation dates trend analysis 37
Figure 12: Graph for Nchalo cessation dates trend analysis 37
Figure 13: Graph for Nsanje cessation dates trend analysis 38

LIST OF TABLES

Table 1: The range and classification of onset and cessation 18
Table 2 : Onset and cessation occurrence over Ngabu 20
Table 3:Onset and cessation occurrence over Nchalo 23
Table 4: Onset and cessation occurrence over Nsanje 26
Table 5: Mean onset, cessation and duration 30
Table 6: shows the length of the rainy season for Ngabu, Nchalo and Nsanje 32
Table 7: Mann-Kendall test analysis for Onset 34
Table 8:Mann-Kendall test analysis for Cessation 36
Table 9:Mann-Kendall test analysis for Length 38

CHAPTER 1. INTRODUCTION

This chapter presents the background of the study, problem statement, research objectives, research question and significance of the study.

1.1 RESEARCH BACKGROUND

Malawi has a tropical savannah climate with distinct rainy season from November to April during which 95% of the seasonal precipitation takes place and dry seasons from May to October. However, from May to July it is relatively cool and in some high altitude areas drizzles (chiperoni rains) are common. However, the dry season is subdivided into two parts namely cool and wet (May to August) and hot and dry (September to October) (Kachaje, Kasulo, & Chavula, 2016). It is mostly dominated by the north-south migration of the inter-tropical convergence zone (ITCZ). The ITCZ is marked by the convergence zone 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 (Ngongondo, Xu, Gottschalk, & Alemaw, 2011). The main rains start from November in the south and progressively spreading northwards during this period, the main rain bearing systems that influence rainfall in Malawi include the ITCZ, Congo air mass, easterly waves and tropical cyclones and the key driving factors on rainfall systems over Malawi include sea surface temperatures(SSTs) over the pacific, Indian and Atlantic tropical oceans (Fabiano, Katengeza, & Mkandawire, 2017) .

Malawi seasonal average rainfall varies from 725mm to 2,500mm and its distribution is influenced by topography and proximity to the lake however least rainfall is registered in rain shadow areas such as in the Shire valley, west of shire highlands and zomba plateau, northwest of both Viphya and Nyika plateau (DCCMS, 2020). Highest rainfall is registered in high altitudes areas for instance Mulanje, Nyika and Viphya plateau. Malawi has rainfall that vary within and between season (intra and inter seasonal rainfall variability) with extreme events such as drought and floods occurring frequently (Jury & Pathack, 1993). An understanding of the temporal and spatial characteristics of rainfall is central to water resources management, agricultural planning, infrastructure development, flood frequently analysis, food hazard

mapping, hydrological modeling, water resource assessments and other environmental assessments (Michaelides, Tymvios, & Michaelidou, 2009).

The study area was chosen based on the fact that within the valley there is shire river, Malawi's, largest and longest river (390km long) which flows out of Lake Malawi and joins the Zambezi river (Phiri & Saka, 2008). The river plays a great role to the life of many Malawians in the sense that it acts as a source of electrical energy for the country and is also used for agricultural activities to the people who live along the river. Shire valley is one of the areas already affected by changes in the climate elements which ranges from severe drought as in 1991/92 and extreme flooding events in 2000/01 (Vanya, 2012). Shire valley experiences quite frequent dry spells. Flooding, droughts and comprises of large closed area of degraded land that gives rise to increase crop failure leading to food insecurity. The ecological environmental problems of Shire valley include deforestation, overgrazing, soil degradation, flooding and water pollution in the area with wider ramifications on land and general productivity (Vanya, 2012).

1.1.2 CLIMATE OF SHIRE VALLEY

In the Shire valley the wet season begins in November and ends in April and is characterized by heavy rain(reaching a maximum around 425mm in January), high humidity(75-95%) and air temperatures that are generally above the annual average 22°C, thunderstorms occur in the transition periods between the two seasons, accompanied by short periods of strong winds and heavy rain (Africa Development Bank Group Malawi, 2008). Month of May there is no rain at all and October is the hottest month when temperatures reaches the annual maximum of 40°C. Between September and November, conditions are bit modified by dry dust-laden winds that blow from southwest intermittent for periods of up to a few days. The shire valley is characterized by generally low elevation where the relief profile ranges from 50m to 150m above sea level.

Malawi has an economy based on rain-fed agriculture in which crop production and the choice of crops that can be grown are largely determined by climatic and soil factors (Kumbuyo, Yasuda, Kitamula, & Shimizu, 2014). Therefore, a detailed knowledge of the

precipitation regime in Malawi is an important prerequisite for agricultural planning and economic development (Ngongondo et al., 2011).

1.1.3 IMPORTANCE OF RAINFALL AND ITS SEASONALITY FOR SOCIETY

Rainfall is the most critical meteorological phenomenon on earth for the natural environment and human life, making it the most vital ecological factor (Twisa & Buchroithner, 2019). The Malawian summer (October to April) rainfall is very crucial for the economic development, electricity generation, disaster management and hydrological planning for the country (Fabiano, Katengeza, & Mkandawire, 2017). The timing of the seasonal rainfall, and in particular the onset, affects the planting date of crops and therefore has implications for agronomic management and for crop yield, since a shorter season may mean that crops fail to reach full maturity and yields are reduced (Dunnning, 2018). Seasonal rainfall over Malawi is critical for rain-fed agriculture, domestic water use, energy production, health and rainfall is an important element for plant development. Rainfall leads to surface and sub-surface recharge, and for rain-fed agricultural production (Tarhule & Woo, 2002).

Knowing onset and cessation dates during a particular season is important as it helps farmers to know what time to prepare for cultivation and what time to rest. The onset of rainy seasons is a key for examining shifts in rain patterns and at the same time are also important indicators to farmers activities (Simelton, et al., 2011). It is vital to grow crops as early as possible to avoid wasting valuable growth time. Determining the onset and cessation of rainfall season is therefore of crucial importance for sustainable food production.

1.2 PROBLEM STATEMENT

Farmers lack knowledge on how to know this is the first rains, hence after receiving the first rains they just start planting their crops without knowing how many dry spells will follow after planting. In Malawi, crops are mostly grown in wet season and most farmers depend on this season to cultivate their crops and confusion in farmers on which dates to plant.

However, farmers have end up wasting their resources (capital or seeds, labor) due to compromised wet season. Rains can start early November and farmers start preparation by ploughing and planting seeds but within few days the rains are gone. Malawi as a country we depend on rain fed agriculture, therefore rainfall is the important factor as far as agriculture is concerned. Farmers do not depend on irrigation, rather on rainfall so there is a need to have knowledge on the onset and cessation of rainfall to avoid wasting agricultural resources. There is also lack of knowledge in knowing the length of season, farmers are supposed to know if rains start early will have long or short rain season as well as on dry spells they need to understand what happens with it and knowing the length of season helps them to prepare and manage well the agriculture resources they would like to use in that particular season.

Scientifically we cannot say that there is lack of awareness on onset, cessation and length of rainfall season amongst farmers in the sense that a similar research was done by Anne Kazembe (2014) in her research, a large-scale study area was considered of which farming decision making are much focused on small scales. In her study there was only one station from the Shire valley station and based on the approach she used on determining onset and cessation is different from the one this study has adopted which is according to the department of climate change and meteorological services.

The existing studies mainly focus on determining the onset and cessation of rain season at a large scale. Therefore, more proper studies on determining the onset and cessation of rainfall season at a small scale is also required.

1.3 RESEARCH OBJECTIVES

1.3.1 MAIN OBJECTIVE

The main objective of the study was to determine the onset and cessation of the seasonal rains in Shire Valley, Southern Malawi.

1.3.2 SPECIFIC OBJECTIVES

- To characterize the onset, cessation and length of seasonal rains in Shire Valley, southern Malawi between 1990 and 2019.

- To analyze the trends in onset, cessation and length of rainy season.
- To classify onset and cessation dates into various classes namely; early, normal and late.

1.4 RESEARCH QUESTIONS

1. What were the onset dates, cessation dates and length of seasonal rains in shire valley?
2. What was the trend in the onset, cessation and length of rainy season over the study period for the area?
3. What was the output on the classification of onset and cessation dates?

1.5 SIGNIFICANCE OF STUDY

The onset of rainfall is very vital to farmers as it answers the question "when to plant?" (Mawunya et al., 2011). Rainfall is a major determinant of agricultural production in any agro-ecological zone anywhere in the world, its seasonal and annual characteristics such as the onset and intra-seasonal rainfall distribution that promote good crop yields are, however, characterized by marked fluctuations (Mawunya et al., 2011).

Knowledge on onset, cessation and length of rain season in southern Malawi, is very vital for crop management decisions. Information about the beginning of rains is vital for appropriate agricultural decision making in the sense that reduction in yield of the crops is avoided by taking appropriate action.

Knowledge on onset and cessation build the confidence of farmers on understanding how, where and what they can do in so doing they are able to know which months to start preparing for cultivation and which months to rest. An analysis of rainfall variability is also important in various decision making process related to agriculture (Mathugama & Peiris, 2011) .Knowledge of rainfall variability is also important in irrigation schemes planning for supplementary irrigation during a rainy season as well as dry season forecasting irrigation demand (Simba, et al., 2012). A good knowledge of rainfall variability and its trends can make the community social and economic activities to strategies mitigation and recovery approaches in case of losses (Mokrech et al., 2014). The presence of a relationship between

onset and cessation dates is relevant for planning activities in the season (Magulavai, Kipkorir, Raes, & Rao, 2008). Farmers need information about rainfall so that they can make plans regarding choice of crops to plant, time to start land preparation and planting activities. The findings of this study will be of significant to all kind of people including farmers, business people and all stakeholders. Therefore, there is need to determine accurately the onset, cessation and hence distribution of the rainfall season for any given place.

CHAPTER 2. LITERATURE REVIEW

2.1 INTRODUCTION

The literature has produced a confounding number of findings such as the relative lengths and rainfall amounts of the wet and dry seasons and the arrival dates of the 25th and 75th percent of seasonal rainfall which are often produced for large regions but rarely applied systematically over specific locations (Adejuwon & Odekunle, 2006). Ngongondo et al., (2011) explains that annual rainfall over 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 highlands to the south of the country, experience sporadic winter rains locally called Chiperoni between May and august. The assessment and prediction of the onset and cessation dates of the rainy season is therefore crucial to the success of agricultural activities in Ghana (Amekudzi, et al., 2015). Rainy season onset and cessation dates affect the transmission of vector-borne diseases, such as the life-cycle of the disease transmission vectors which are sensitive to the variability and changes in temperature and rainfall. (Amekudzi, et al., 2015). Extra tropical westerly waves are thought to be most active at the beginning and end of rainy season (Jury & Gwazantini, 2002). Previous studies have also investigated within season dry spell and their impact on planting dates and crop yield, the main findings of these studies include variations in dates of onset, small proportion of rainy days supplying high proportion of rainfall and occurrence of dry spells that disrupt crop development and lower yield (Recha, Makokha, Traole, Shisanya, & Sako, 2011).

Studies conducted in semi-arid parts of Africa indicated there is significant relationship between the start of rains and the length of the rainy season (Amekudzi, et al., 2015) thus earlier onset most often leads to longer rainy season. This is an indication that the length of the rainy season is more dependent on the rainfall onset than its cessation.

According to a study on the onset and cessation of long rains in eastern Africa and their inter-annual variability (Camberlin, Moron, Okoola, & Gitau, 2009). The accumulated principal component scores to determine the onset and cessation dates. The study found out that

average over the years (1958-1987), onset occurs on march 25th and the cessation on 21st may (for the long rains) which gave a duration of no more than 57 days. A widespread perception among vulnerable rural communities in southern Africa and Malawi is that of significant changes in the rainfall onset, cessation and growing season length (Silmeton et al, 2011).

Research on determining onset and cessation of seasonal rains in Malawi was done by Anne Kazembe (2014) and effect of rainfall variability on the length of the crop growing period over the past three decades in central Malawi while (Lameck et al., 2014) investigated the onset, cessation and length of rainfall season in Malawi and central region respectively. In her study, Kazembe (2014), explored 27 years daily rainfall data to statistically determine the onset of the rainy season of Malawi targeting 12 stations representing the study area. It was concluded that southern region had the earlier onset ranging from 25th November to 2nd December and had the largest variation. It was shown by the highest standard deviation in both onset and duration.

2.2 SYSTEMS THAT INFLUENCE RAINFALL OVER MALAWI

The region of south east Africa experiences one main rainfall season from October to April (Omeny, Ogallo, & Okoola, 2008) . Systems that influence rainfall of south east Africa include inter tropical convergence zone(ITCZ), subtropical high-pressure systems, tropical cyclones El-Nino southern oscillation(ENSO) and other small scale factors like topography set up of the area. The climate of Malawi depends on the ITCZ, subtropical high pressure belt in the south between 25° and 35°, and its topography. Malawi is usually being affected by a road belt of strong convective activity during the rainy season (Torrance, 1972)

According to DCCMS the main rain bearing system in Malawi is the INTERTROPICAL CONVEGENCE ZONE(ITCZ), this is a low pressure belt around the equator which tile north-easterly and south-easterly trade winds of the two hemispheres converge, it oscillates randomly across the country during rainy season and produces widespread rainfall. 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 (Ngongondo, Xu, Gottschalk, & Alemaw, 2011). Other rain bearing systems in Malawi: Congo air boundary(CAB)- a recurred south Atlantic south-east trade winds which after picking moisture over the Atlantic and Congo rain forests arrives in Malawi via Zambia as a moist north-westerly wind bringing widespread rainfall and TROPICAL CYCLONES- are intense low-pressure cells that originate in the Indian ocean and move from east to west and can bring widespread heavy rainfall mainly in the south, depending on the position in the Mozambique channel, these rains result in flooding. CONVERGENCE AHEAD OF PRESSURE SURGES- high pressure cells continue to move over the southern tip of the sub-continent, convergence develops ahead of pressure surges causing isolated but locally heavy rains that precede the onset of the rainy season i.e. before the ITCZ becomes established over the country hence rains move from south going to north (Ngongondo, Xu, Gottschalk, & Alemaw, 2011).

The long rains are linked with the information of the Somali jet over the western Indian ocean, in April the meridional branch of the Somali jet transports moisture to east Africa, which forms prior to the northern zonal branch of the Somali jet, that acts to divert moisture eastward away from east Africa (Riddle & Cook, 2008). Surface wind pattern during the short rains include north-easterlies across the horn of Africa and South-Easterlies to the south, unlike the long rains, the short rains are linked with large scale models of climate variability, including ENSO and the Indian Ocean dipole (Black, Slingo, & Sperber, 2003).

Early onset is linked to the development of convergence ahead pressure surges- as high pressure continue to move over the southern tip of the sub-continent, converges develops ahead of pressure surges, causing isolated, but locally heavy rains that precede the onset on the rainy season i.e. before ITCZ Becomes established over the country (www.sdnp.org.mw).

Normal rains are linked to the development of ITCZ that reaches Malawi in November of which is also a main rain bearing system in Malawi

Early cessation/Late cessation is linked to the changes in the development of easterly waves which develops towards the end of the rainy season, around march and April. It exists in the

upper levels of the atmosphere resulting in isolated but locally heavy rains in some parts of the country(www.sdnp.org.mw).

In the predominantly semi-Arid Southern African region, rainfall varies significantly from year to year, with pronounced seasonal cycle. The rainy season generally extends from October/November to April reaching a peak between December and February. Fluctuations in seasonal rains are linked to regional sea surface temperatures and the global ENSO phenomenon (Clay, Buhn, De Armas, Kabambe, & Tchale, 2003).

2.3 CRITERIA FOR DETERMINING THE ONSET AND CESSATION OF RAINFALL

The most important characteristics of rainfall are onset date, cessation date, length of the rain season, mean annual precipitation, hydrological ratio, number of rainy days, rainfall intensity and specific water consumption (Odekunle, 2004). The definition of rainy season onset/cessation is very satile (Smith, Wilson, & Suppiah, 2008). Climatologists, agronomists or hydrologists have proposed different definitions. For instance, agro climatologists usually define the onset at the rain gauge scale, using a variety of empirical thresholds (Marteau, Moron, & Philippon, 2009). They consider that the rainy season onset is the first wet day of a spell receiving given rainfall amount and not followed by a long dry spell during the subsequent weeks. Odekunle (2004) showed that even at a single synoptic station, the annual rainfall in the onset dates could be up to 70 days (10 weeks). therefore, defining the onset date of the rainy season can sometimes be very challenging, as the onset characteristics can vary drastically with isolated showers or heavy rainfall varying intensity being accompanied by extended dry spells.

Similarly, Omotosho, Balogun and Ogunjobi (2000), further expanded this definition to encompass various groups that have moisture requirement for germination above 10mm and more frequency of rainfall. Subsequently they defined onset as the beginning of the first two rains totaling 20mm or more, within 7days, followed by 2-3 weeks each with at least 50% of weekly crop water requirement. Odekunle et al., (2005) defined rainfall cessation as the period towards the end of the rainy season, when the distribution of rainfall may no longer sustain crop growth. However (Nnoli, 1996) defined the cessation of rainy season as any

day(after 1 September) that was the last day of rain or any day after which there existed a dry spell of 20 days or more. Omotosho et al (2000) defined cessation of rainfall as any day from 1 September after which there are 21 or more consecutive days of rainfall less than 50% of the decadal crop requirement.

Onset was determined after 5% of the total annual rainfall amount reached and the end of the season was determined after 95% of the annual total rainfall amount fallen with a threshold value of 0.1mm, then onset date corresponds to the date of the rainfall higher than average of annual first rainfall events over the entire period and not following by a dry spell longer than the median of the mean dry spell durations at the station or grid point. End of season is marked by a rainfall event occurring after or completing the 95% of the annual rainfall amount and followed by a dry spell duration at the station or grid point (Ibrahim, Polcher, karambiri, & Rockes, 2012).

According to Mugulavai et al., (2008), the criteria for onset considered a cumulative rainfall depth that brought the top 0.25m of the soil profile to field capacity during a maximum of 4 days. The corresponding threshold rainfall quantifies the field inspection method by farmers to determine whether conditions are favorable for wet sowing. This was achieved by digging a test hole, usually a day after a rain event. Evaluate of onset criteria revealed that a threshold value of 40mm rainfall during a maximum of 4 days was appropriate for the study area. Cessation was quantified by considering the date on which the water stress in the root zone of a maize crop exceeds a threshold value.

Mean onset and cessation dates of seasonal rainfall was estimated using percentage cumulative mean rainfall approach as used by (Odenkunle, 2006) .

The rainfall onset and cessation dates are defined using a modified version of the food and agricultural organization method (Ngongondo, Tallaksen, & Chong-YU, 2014). where they said that onset, cessation and length of rain season can also be obtained by not using only the monthly threshold value but also a modified version where rainfall (R) is defined to be

greater than half the potential evapotranspiration(PET) = (R > $^{PET}/_{2}$), accumulative daily threshold was used based on the hydrological year(1 October- 30 September). The rainfall onset was defined as the day n after 1 October (1) when;

$$\sum_{i=1}^{n} R > \sum_{i=1}^{n} PET/2$$

(2) Rainfall cessation was defined as the period when this relationship no longer holds. The length of the growing season is simply defined as the number of days between the onset and cessation.

A study by (Fabiano, Katengeza, & Mkandawire, 2017) adopted the threshold method to come up with the onset date where the rainfall station had to record an average of >12.6mm of rainfall within 7 days, also there must not be dry spell of more than 3 days within the given days, in additional to that within those days the precipitation should not be equal to evaporation. The cessation was the last date of rainfall recorded which is followed up to 15 days of no rainfall recorded and length the number of all days from the beginning of the rain season to the day when the season end.

Kazembe (2014) determined the onset and cessation of seasonal rains in Malawi and used a threshold value of 0.85mm, with the amount of 20mm should occur in a single day or totaled for 5 days with no dry spells should exceed 9 days or more within a period of 30 days starting from October 1. The estimation of the end of the rainy seasons were based on the earliest possible day of April 1, the capacity of soil to persist precipitation with a water balance equal to zero was 100mm.

2.4 IMPORTANCE OF DETERMINING ONSET(OS) AND CESSATION(CS) OF RAINS

Good knowledge of rainfall variability and its trends can make the community social and economic activities to strategies mitigation and recovery approaches in cases of losses (Mockrech, et al., 2014). Smallholder subsistence farmers, having knowledge about onset

dates of rains is very useful for planning and timely preparation of fields. This also help farmers to decide a less risky planting date or planting method, or sowing of less risky types of crops, it also minimizes the risks involved in planting too early or too late (Omotosho, Balogun, & Ogunjobi, 2000). Knowing cessation dates helps farmers to assess the possible length of growing season, it also provides information for the optimal harvesting and subsequent storage of crops expected late rains can cause these to spoil (Hachigonta, Reason, & Tadross, 2008). Knowledge of the early phases of previous rainy seasons can be applied to advise farmers on the use, type, rates and timing of fertilizer additions and on adapting sowing densities/patterns and, later in the season, on plant densities by thinning (Ezenekwe, Ezemonye, & Emeribe, 2013).

2.5 SUMMARY

Rainfall is a major determinant of agricultural production in any agro-ecological zone anywhere in the world and is a dominant mode of food production in the majority of rural sub-Saharan Africa (Cooper, et al., 2008). Past studies have also highlighted the knowledge gap in the understanding of rainfall characteristics especially in many developing countries including Malawi (Desa & Niemicynowidz, 1996). Knowledge of localized rainfall behavior is critical for agriculture and other water dependent sectors, Ngongondo et al., (2011) recommends that rainfall analysis should be carried out at a global, national and local scales using different methodologies. In Malawi many studies only consider large scale part of the country with meteorological rain gauge data used.

CHAPTER 3.0 METHODOLOGY

This section outlines how the study was conducted. It covers the data required and their sources, research design and various methods which were adopted and applied to achieve the objectives of the study.

3.1 STUDY SITE

The study was conducted in shire valley, southern Malawi. It constitutes district such as: Chikwawa, Mangochi, Nsanje, Balaka and Machinga this is according to Department of Climate Change and Meteorological Services categorization. The shire valley is located in south western Malawi and extends into Mozambique as part of the Great Rift Valley systems of Africa. It covers an area of some 250, 000 ha in the two administrative districts such as Chikwawa and Nsanje. The valley has an elongated plain with a width of between 8 to 40 km and lies altitudes of between 30 and 150m above seas level (Phiri & Saka, 2008). According to Vanya (2012) also said to that variability in climate associated with increased weather extremes resulted in shifts of rainfall onset dates, reducing crop growing period.

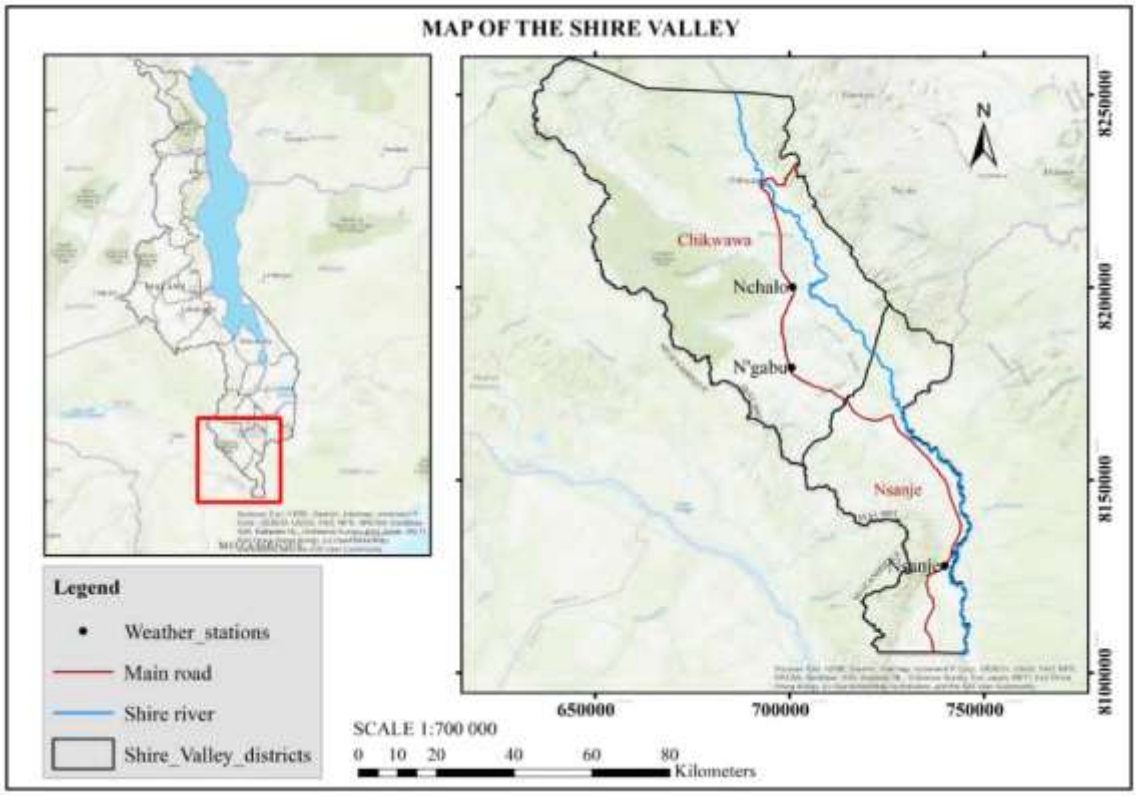


Figure 1: Map of the study area

3.2 RESEARCH DESIGN

Quantitative study design was used in this research, with secondary daily rainfall data from three Shire Valley stations, which are as follows: Ngabu, Nchalo and Nsanje. The data was obtained from the Department of Climate Change and Meteorological Services for the period 1990-2019 because of their availability and quality data. The onset, cessation and length of rainy season was analyzed and presented using tables and graphs.

3.3 SAMPLING TECHNIQUE

The stations were purposively sampled by the department of climate change and meteorological services; based on the availability of complete data the researcher wanted within the study area.

3.4 METHOD OF DATA COLLECTION

An electronic record of daily rainfall data was collected from DCCMS and was provided in an excel format. The data were used for computing onset date, cessation date and length of rainy season in R-INSTAT software. The mean rainfall onset date was determined using the daily rainfall data from 2000 to 2019, while the onset dates of individual years were determined using the daily rainfall data from 1990 to 2019 for Ngabu, and 2000 t0 2019 for Nsanje and Nchalo.

3.5 DATA ANALYSIS

3.5.1 CHARACTERIZATION OF RAINFALL VARIABLES

The onset of rainfall is described as the possible start of rainfall in a year, whereas the cessation is a period that is characterized by the end of rainfall in a year. Rainfall onset is defined as the period, at the beginning of the rainy season, when rainfall distribution has become adequate for crop development while rainfall cessation refers to the period, towards the end of the rainy season, when rainfall distribution may no longer sustain crop growth (Abdulkareem , 2018).

To achieve objective number one (1) which is to characterize the rainfall variables for seasonal rains in Shire Valley, southern Malawi from 1990 to 2019, the statistical analysis of data was done and organized in a format required by the R-INSTAT software program.

Onset criteria(OS)

The following criterion was used to determine onset, this was According to Department of Climate Change and Meteorological Services (**www.metmalawi.gov.mw**). DCCMS standards has a threshold value of 0.3mm, hence they are working with different sectors, they leave there standard aside setting a threshold value of 1mm taking into consideration the agriculture sector at least 1mm amount of rainfall is good for crops and they assume that it can germinate, however defining onset on the construction industry 1mm amount of rainfall cannot be applied.

- Rainfall total of 25 mm or more on a single day or totaled for 3 days:
- Dry spell should not exceed 9 days or more in the next 21 days:
- should occur with an earliest starting day of October 1:
- A threshold value of 1.00 mm

Cessation criteria(CS)

Cessation /end of rains of rainy season was defined by DCCMS as the last day with 10mm amount of rainfall or more from the beginning of season to the last day of April that day was regarded as the end of the rain season in that particular year.

Calculating length of season

The length of season was found by subtracting onset date from cessation date:

Length = Cessation date – onset date.

3.5.2 RAINFALL TREND ANALYSIS

To meet the second objective (2) which is to analyze the trends of the onset, cessation and length of the rainy season, Mann-Kendall trend analysis test was used. Mann-Kendall test is a non-parametric approach that has been widely used for detection of trends in different fields

of research including hydrology and climatology (Ampitiyawatta & Guo, 2009). It is used for identifying trends in time series data. The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. The MK test statistic (S) is given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k)$$

In the Mann-Kendall test statistics, $x_j and x_k$ are sequential data values of the time series in the years j and k (k>j), n is the length of the time series sign $(x_j - x_k)$ is the sign function is given as:

$$sgn(x_j = x_k) = \begin{matrix} +1 & if & x_j - x_k = 0 \\ 0 & if & x_j - x_k = 0 \\ -1 & if & x_j - x_k = 0 \end{matrix}$$

A positive S value indicates an increasing trend and a negative value indicates a decreasing trend in the data series. The S statistic, in the cases where the sample size n is larger than 10, is assumed to be asymptotically normal, with E(S)=0 and the variance of S is computed by the equation below (Taiwo, E, & T, 2018).

$$var(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]$$

where t refers to the extent of any given tie and Σt states the summation over all ties. A tie is the sample data having the same value and the summation is over all ties. The standard normal deviate Z is computed by

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if S > 0 \\ 0 \quad if S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} if S < 0 \end{cases}$$

The presence of statistically significant trend is evaluated using the Z value. A positive ZMK indicates an increasing trend whereas a negative ZMK indicates a decreasing trend. The statistical ZMK has a normal distribution to test for either increasing or decreasing monotonic trend at α level of significance (usually 5% with Z0.025=1.96). In a two-sided test for trend,

the null hypothesis H_0 should be accepted if $[Z]>Z_{\alpha/2}$, at the level of significance. In this analysis, the hypothesis will be tested at 95 % confidence level.

3.5.3 CLASSIFICATION OF RAINFALL VARIABLES

The third objective (3) which is to classify the onset and cessation as: early, normal and late. Classfication of length of the season as short, normal and long, excel was also used. The data for each station was organized in a format required by excel. To come up with the number of days a Julian calendar was used in R-INSTAT where format summary statistics was done of which mean and standard deviation for onset and cessation dates were calculated. The standard deviation was used to determine the variability of the number of days. The smaller the standard deviation the smaller the variability of onset and cessation and vice versa.

The onset and cessation dates were transformed into standardized anomalies, (Anne Kazembe, 2014)

$Z= \frac{Value-Mean}{Standard\ deviation}$ where z= the standardized anomaly

Table 1: The range and classification of onset and cessation

Range	Class(onset and cessation)	Class(Length)
$Z > 1$	Late	Long
$1 \geq Z \geq -1$	Normal	Normal
$Z<-1$	Early	Short

The days above the range of the normal dates were regarded as late, the days within the range of the normal dates which is within the mean were regarded as normal dates. The days before the range of the normal dates were regarded as early. Number of days with a z value>1 was regarded as long season, number of days with Z< -1 were regarded as short season and days with Z value between -1 and + 1 were regarded as normal season.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Results

The objective of this study forms the basis of all the analysis carried out in this chapter. The results are presented in form of graphs and statistical tables.

4.1 DATES OF ONSET AND CESSATION OF THE RAINS

The discussion is based on the results obtained after the analysis of daily rainfall data using R-INSTAT and Excel.

The onset and cessation dates for Ngabu, Nchalo and Nsanje are presented in the figures below.

4.1.1 NGABU

Figure 2 shows that **NGABU** had an early onset in the year 1993 and 2000 and late onset occurred in the year 1991 and 2003. It also shows that early cessation occurred in the year 1996, 2003 and 2005 while late cessation occurred in the year 1992, 1999 and 2014.

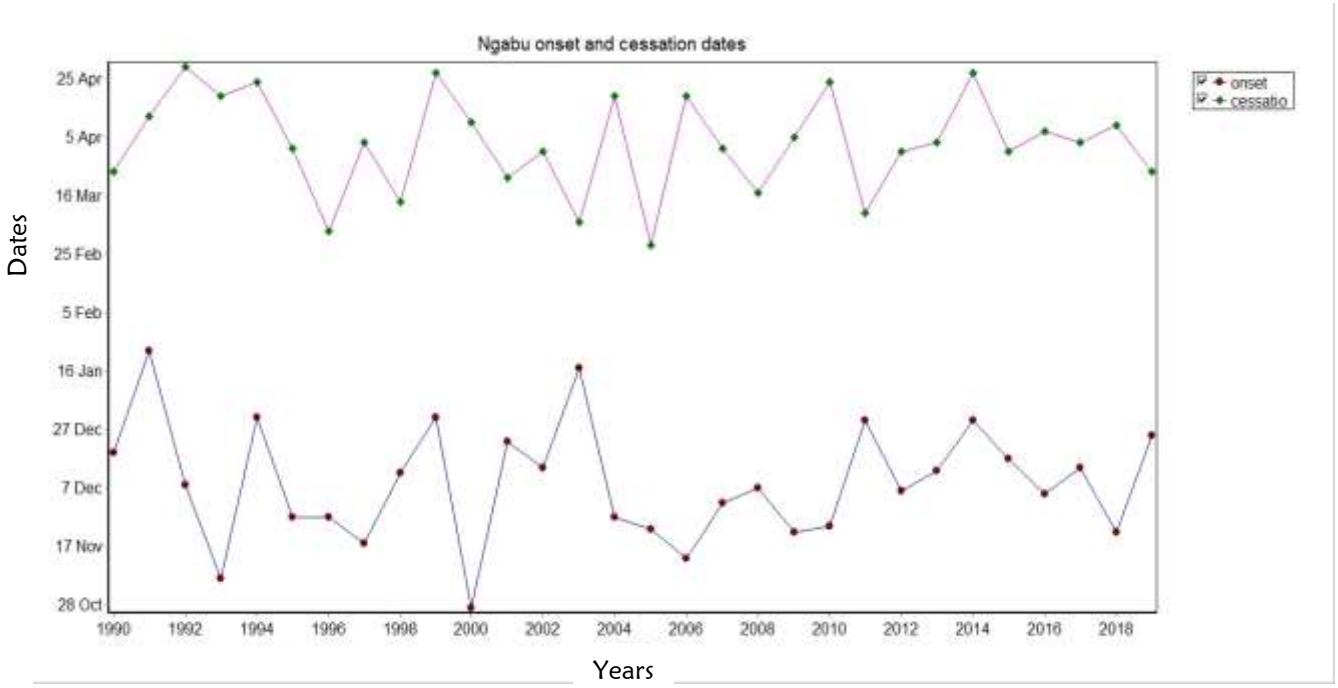


Figure 2 : NGABU onset and cessation dates

Table 2 : Onset and cessation occurrence over NGABU (Early=E, Normal=N, Late=L)

The table 2 below shows that early onset occurred between 27th 0ctober- 18th November, normal onset occurred between 22nd November- 25th December and late onset occurred between 30th December- 23rd January. Early cessation occurred between 28th February- 17th March, normal cessation occurred between 24th March- 19th April and late cessation occurred between 24th April- 29th April.

YEAR	ONSET	CATEGORY	CESSATION	CATEGORY
1990	19-Dec	N	24-Mar	N
1991	23-Jan	L	12-Apr	N
1992	08-Dec	N	29-Apr	L
1993	06-Nov	E	19-Apr	N
1994	31-Dec	L	24-Apr	L

1995	27-Nov	N	1-Apr	N
1996	27-Nov	N	4-Mar	E
1997	18-Nov	E	3-Apr	N
1998	12-Dec	N	14-Mar	E
1999	31-Dec	L	27-Apr	L
2000	27-Oct	E	10-Apr	N
2001	23-Dec	N	22-Mar	N
2002	14-Dec	N	31-Mar	N
2003	17-Jan	L	7-Mar	E
2004	27-Nov	N	19-Apr	N
2005	23-Nov	N	28-Feb	E
2006	13-Nov	E	19-Apr	N
2007	2-Dec	N	1-Apr	N
2008	7-Dec	N	17-Mar	E
2009	22-Nov	N	5-Apr	N
2010	24-Nov	N	24-Apr	L
2011	30-Dec	L	10-Mar	E
2012	06-Dec	N	31-Mar	N
2013	13-Dec	N	3-Apr	N
2014	30-Dec	L	27-Apr	L
2015	17-Dec	N	31-Mar	N
2016	5-Dec	N	7-Apr	N
2017	14-Dec	N	3-Apr	N
2018	22-Nov	N	9-Apr	N

2019	25-Dec	N	24-Mar	N

4.1.2 NCHALO

Figure 3 shows that **NCHALO** had an early onset in the year 2000, 2006 and 2009 and late onset occurred in the year 2003. It also shows that early cessation occurred in the year 2005, 2008 and 2015 while late cessation occurred in the year 2002 and 2010.

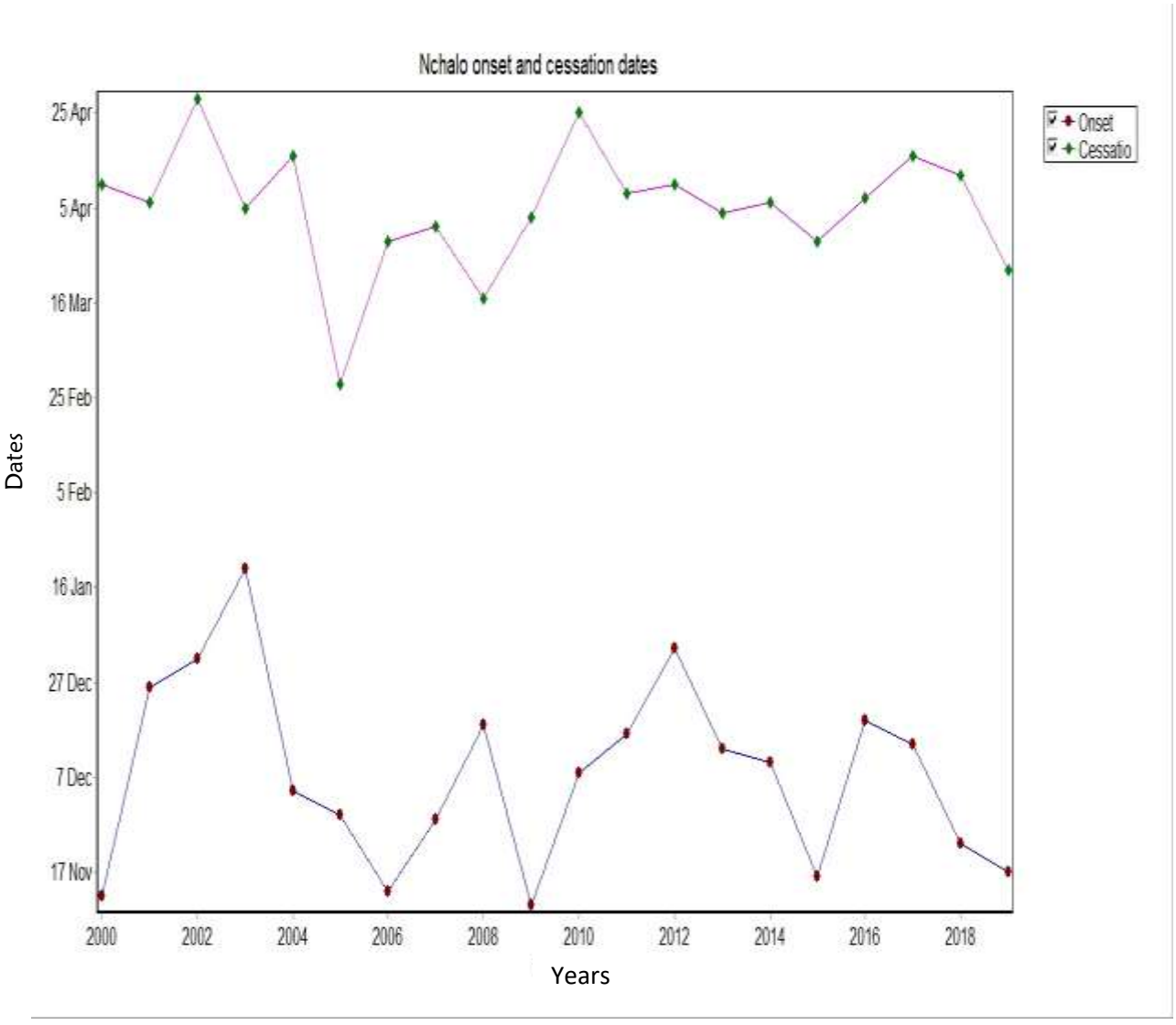


Figure 3 :NCHALO onset and cessation dates

Table 3:Onset and cessation occurrence over NCHALO(Early=E, Normal=N, Late=L)

NCHALO shows that early onset occurred between 10th November- 17th November, normal onset occurred between 23rd November- 26th December and late onset occurred between 1st January- 20th January. Early cessation occurred between 28th February- 23rd March, normal cessation occurred between 29th March- 16th April and late cessation occurred between 25th April- 28th April.

YEAR	ONSET	CATEGORY	CESSATION	CATEGORY
2000	12-Nov	E	10-Apr	N
2001	26-Dec	N	6-Apr	N
2002	1-Jan	L	28-Apr	L
2003	20-Jan	L	5-Apr	N
2004	4-Dec	N	16-Apr	N
2005	29-Nov	N	28-Feb	E

2006	13-Nov	E	29-Mar	N
2007	28-Nov	N	1-Apr	N
2008	18-Dec	N	17-Mar	E
2009	10-Nov	E	3-Apr	N
2010	8-Dec	N	25-Apr	L
2011	16-Dec	N	8-Apr	N
2012	3-Jan	L	10-Apr	N
2013	13-Dec	N	4-Apr	N
2014		N		N

	10-Dec		6-Apr	
2015	16-Nov	E	29-Mar	N
2016	19-Dec	N	7-Apr	N
2017	14-Dec	N	16-Apr	N
2018	23-Nov	N	12-Apr	N
2019	17-Nov	E	23-Mar	E

4.1.3 NSANJE

Figure 4 shows that **NSANJE** had an early onset in the year 2000, 2003 and 2004 and late onset occurred in the year 2002 and 2011. It also shows that early cessation occurred in the year 2005 and 2008 while late cessation occurred in the year 2011 and 2019.

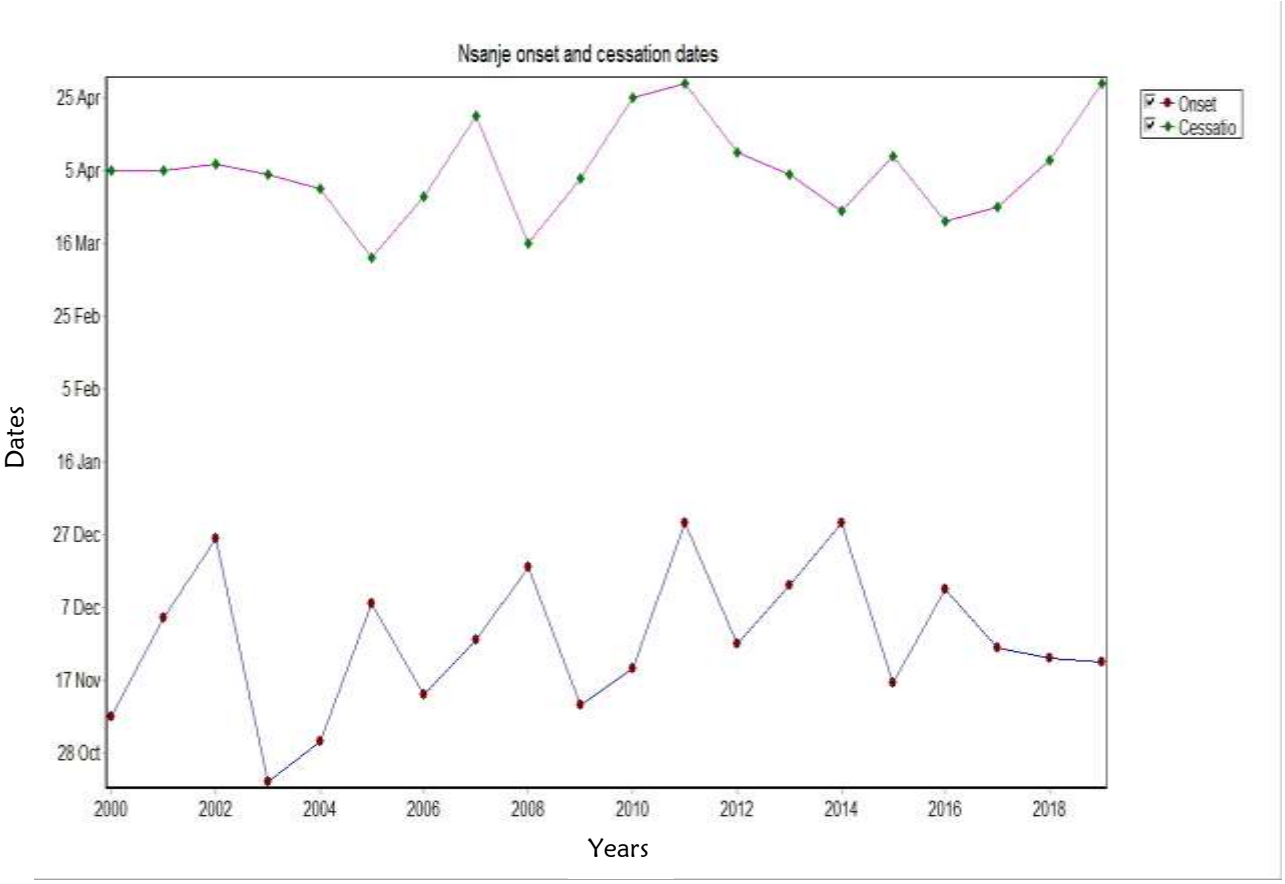


Figure 4:NSANJE onset and cessation dates

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

The table 4 below shows that in Nsanje early onset occurred between 20th 0ctober- 7th November, normal onset occurred between 10th November- 18th December and late onset occurred between 26th December- 30th December. Early cessation occurred between 12th March- 22nd March, normal cessation occurred between 25th March- 20th April and late cessation occurred between 25th April- 29th April.

YEAR	ONSET	CATEGORY	CESSATION	CATEGORY
2000	7-Nov	E	5-Apr	N

2001	4-Dec	N	5-Apr	N
2002	26-Dec	L	7-Apr	N
2003	20-Oct	E	4-Apr	N
2004	31-Oct	E	31-Mar	N
2005	08-Dec	N	12-Mar	E
2006	13-Nov	E	29-Mar	N
2007	28-Nov	N	20-Apr	L
2008	18-Dec	N	17-Mar	E
2009		N	3-Apr	N

	10-Nov			
2010	20-Nov	N	25-Apr	L
2011	30-Dec	L	29-Apr	L
2012	27-Nov	N	10-Apr	N
2013	13-Dec	N	4-Apr	N
2014	30-Dec	L	25-Mar	N
2015	16-Nov	N	9-Apr	N
2016	12-Dec	N	22-Mar	E
2017		N	26-Mar	N

	26-Nov			
2018	23-Nov	N	8-Apr	N
2019	22-Nov	N	29-Apr	L

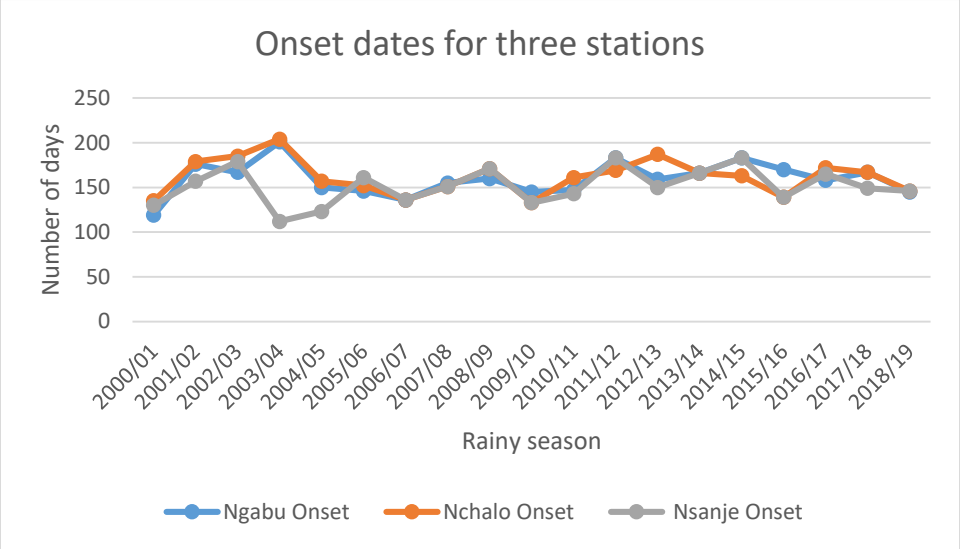


Figure 5: Graph for Ngabu, Nchalo and Nsanje onset

It is observed that the pattern of the onset date varies between seasons within the stations. The general onset pattern in the study area reveal to be good in the sense that all onset dates fall under normal dates, from the graph it shows that in 2000/01 season in all the station the onset occurred early. There is no much difference on the onset of Nchalo and Ngabu but a slight difference on the onset dates of Nsanje. On average in Ngabu the onset date could be on 7 December, Nchalo 9 December and Nsanje on 28 November.

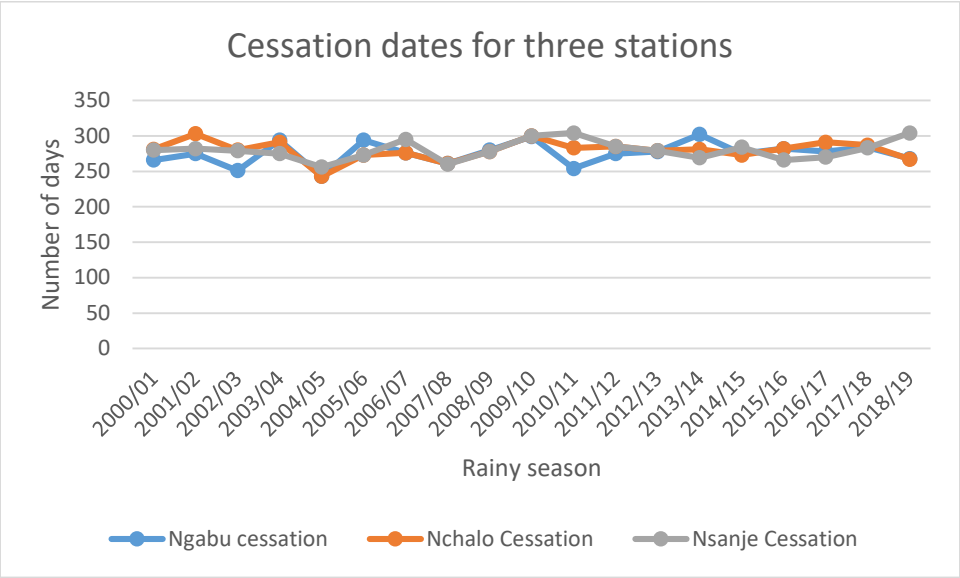


Figure 6: Graph for Ngabu, Nchalo and Nsanje cessation

It is observed from the graph that the cessation dates in all the three stations fall under normal dates however some stations had an early cessation and late cessation. On average the cessation had to occur on 3 April in Ngabu and Nchalo, and Nsanje on 5 April.

Table 5: Mean onset, cessation and

Station	Mean onset	Mean cessation	Mean Length	STD-Onset	STD-Cessation	STD-LENGTH
Ngabu	7-Dec	3-Apr	117	19.4	13.5	20.8
Nsanje	28-Nov	5-Apr	129	22.2	17.1	24.3
Nchalo	9-Dec	3-Apr	118	20.2	13.5	21.9

4.2 DISCUSSIONS

The findings of this study shows that in all stations the onset and cessation dates fall under normal dates, however in some years there were early, late onset as well as cessation. Having early onset is good news for farmers in the study area as crops will have adequate moisture

available for crop development. Normal rainfall is conducive for farming as far as agriculture is concerned, this helps to avoid wastage of agricultural resources hence the wet season is not compromised.

In the year 2000, the graphs indicate that in all the three stations occurred an early onset, starting with an earliest date occurred on 27th October in Ngabu. Ngabu had an early onset in the years 2000, 2002, 2005, 2008, 2016 and 2018.Nsanje had an early onset in 2001,2003, 2004, 2010,2012 and 2017.Nchalo showed early onset in 2011, 2014 and 2019. In 2006 and 2007 Ngabu, Nchalo and Nsanje had an early onset and occurred on the same date. In 2009 Nsanje and Nchalo also had an early onset which occurred on the same date.

The results also show that in all stations the date for rainfall onset and cessation however keeps on changing each and every year that tells farmers to be very observant on each and every year not just to stick to the last year's date. In each and every season, farmers in the study area should always be on alert to make solid decisions on the sowing dates.

In agreement with these observations, Kazembe (2014) showed the inter-annual variability of onset and cessation was observed in all the three region and from the classification of the onset and cessation it was observed that most years were grouped under normal category however few years lied on the extreme ones.

According to the study by Fabiano (2017) showed that on average, the onset of the El-nino rainy season was found to be the month of November which agrees with the results found in this study during the season of El-nino, 2010-2011 and 2015-2016 the onset was in November.

From the findings it also shows that on average the onset of rains could possibly start with Nsanje and also late cessation in the same station compared to Nchalo and Ngabu.

Changes in onset and cessation depends on the development of the systems that influence rainfall in Malawi. Delayed development of the rain bearing system also leads to delayed onset as well as cessation.

4.3 LENGTH OF THE SEASON

Table 6: shows the length of the rainy season for Ngabu, Nchalo and Nsanje where (S=short, N=Normal, L=Long,)

Rainy season	Ngabu		Nchalo		Nsanje	
	Number of days	Category	Number of days	Category	Number of days	Category
2000/01	147	L	146	L	150	L
2001/02	99	N	124	N	125	N
2002/03	84	S	95	S	100	S
2003/04	93	S	87	S	163	L
2004/05	93	S	86	S	133	N
2005/06	148	L	121	N	112	N
2006/07	140	L	140	L	159	L
2007/08	106	N	110	N	109	N
2008/09	120	N	107	N	107	N
2009/10	154	L	167	L	167	L
2010/11	107	N	122	N	161	L
2011/12	92	S	116	N	102	S
2012/13	119	N	92	S	129	N
2013/14	136	N	115	N	103	S
2014/15	92	S	110	N	101	S
2015/16	112	N	143	L	127	N
2016/17	120	N	119	N	105	N
2017/18	117	N	120	N	134	N
2018/19	123	N	121	N	158	L

From the table above, it shows that in all the three stations in the season 2002/2003, 2003/2004 and 2004/2005 there were short seasons, in 2000/01, 2005/06, 2006/07 and 2009/10 all the stations had long rainfall season however other years shows normal season. In most stations, it falls under normal season of which is very vital for farmers because it reduces crop failures. It is very advantageous for farmers to have prior knowledge to the season of rains in the sense that it helps to know which crops to plant and they are able to know when to harvest. This therefore helps farmers to know which crops to plant depending on the duration of the season.

Figure 7 shows the variability in the length of the rainy season for Ngabu, Nsanje and Nchalo.

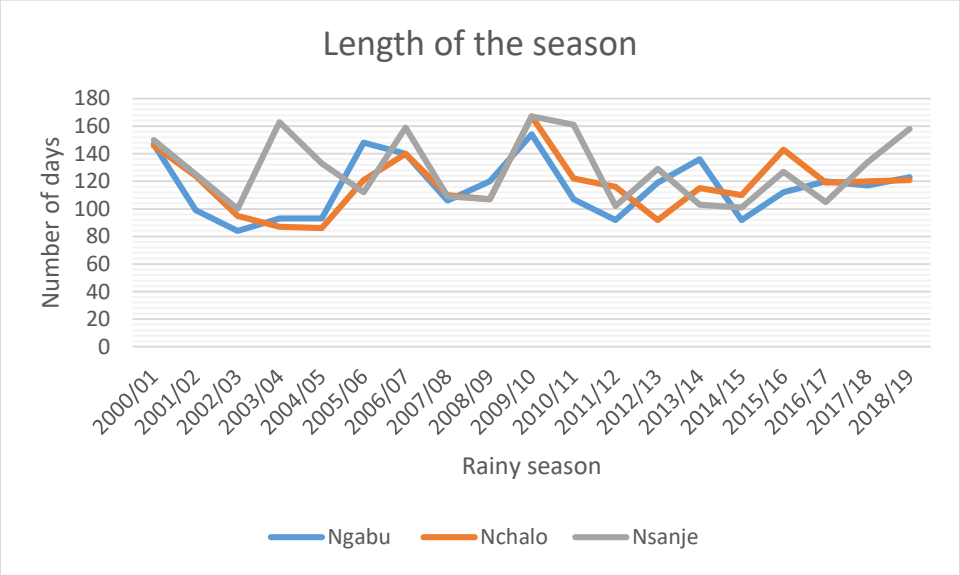


Figure 7: Length of season

From the graph above it clearly shows that duration of rainy season follows under normal season in most all seasons however in some stations there are short and long season. It is noted that in 2004/2005 season Nsanje had a long season than any station. In 2002/03 season it is clearly seen that Ngabu had the shortest season, however Nsanje shows that there are much variations as compared to Nchalo and Ngabu due to its highest standard deviation. Nsanje has a longer season than any of the two stations this complement with the average date of onset and cessation that rains mostly has an early onset in Nsanje and ends late than the two stations.

4.4 TREND ANALYSIS

Table 7: Mann-Kendall test analysis for Onset

Station	Z-test value	P-value	Alpha(∝)	Significance of trend
Ngabu	0.53	0.6	0.05	Increasing insignificant
Nchalo	-0.14	0.89	0.05	Decreasing insignificant
Nsanje	1.02	0.31	0.05	Increasing insignificant

From the Mann-Kendall analysis shows that Ngabu and Nsanje has an increasing trend with no significance while Nchalo has a decreasing trend with no significance meaning to say that in Ngabu and Nsanje in the past years the study areas were experiencing early onset but this has changed with time, present years shows that the areas are experiencing late onset. However, Nchalo with a decreasing trend shows that in the past years the area occurred late onset than in the present years that shows the area is experiencing early onset. In Ngabu and Nsanje shows a delayed start of rains. There are no great variations in the dates of onset in all the three stations. Based on the Z-value, Nsanje has the highest Z-value than Ngabu and Nchalo. Having found that P-value > alpha(significance level) means that there is no significance in the trend.

Onset dates has shifted but with no significance, in the past years some areas in the study area were experiencing early onset but with time it has changed those areas are experiencing late onsets in the present years.

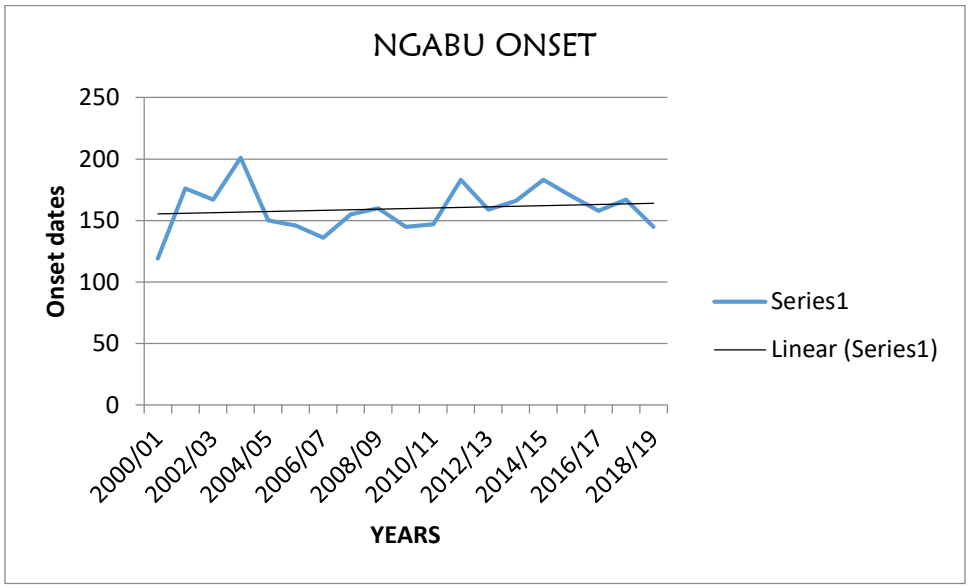


Figure 8: Graph for Ngabu onset dates trend analysis

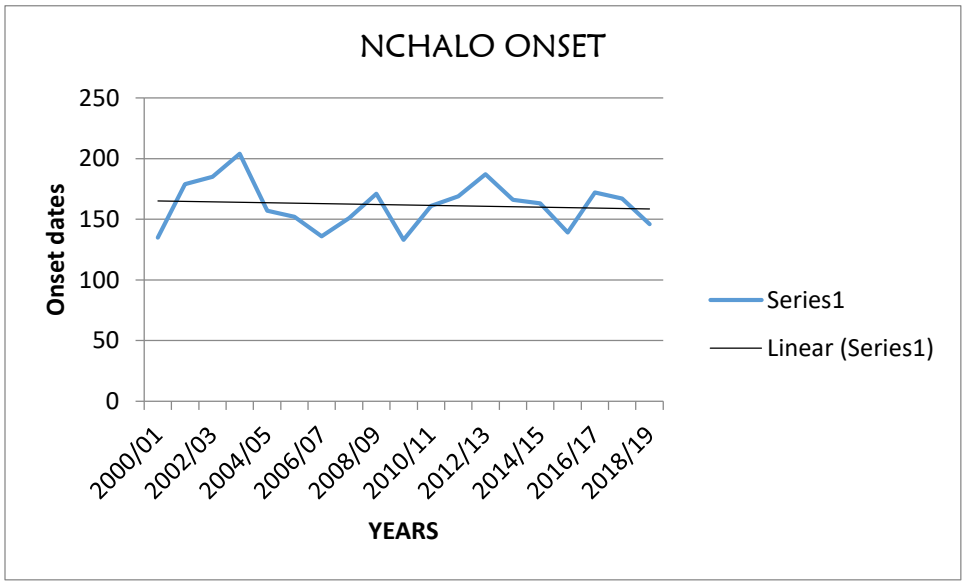


Figure 9: Graph for Nchalo onset dates trend analysis

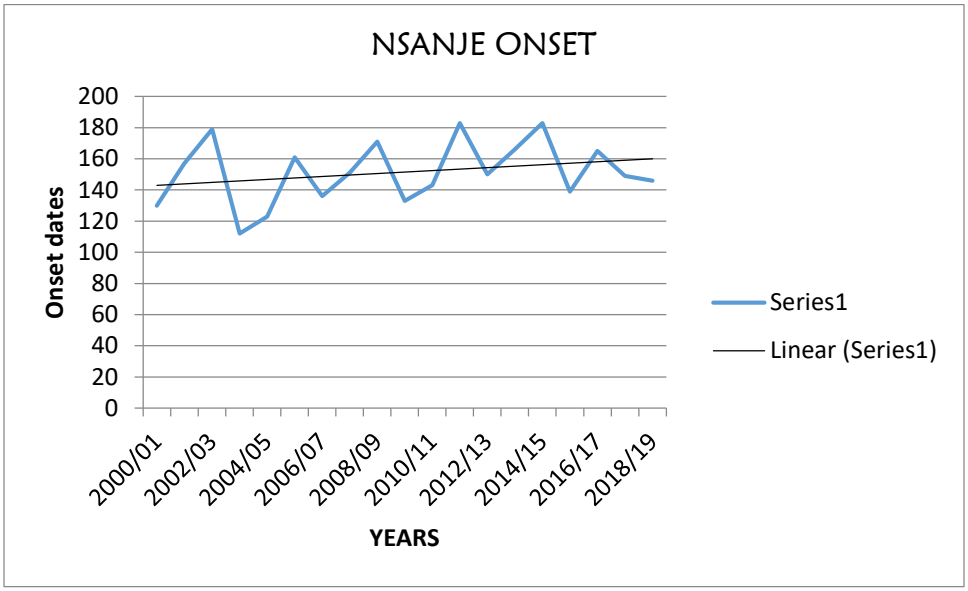


Figure 10: Graph for Nsanje onset dates trend nalysis

Table 8:Mann-Kendall test analysis for Cessation

Station	Z-test value	P-value	Alpha(∝)	Significance of trend
Ngabu	1.16	0.247	0.05	Increasing insignificant
Nchalo	0.12	0.916	0.05	Increasing insignificant
Nsanje	0.49	0.624	0.05	Increasing insignificant

All the three stations show the increasing trend of cessation insignificantly meaning that in the past years there was early withdraw of rains and this has changed with time, the study area is experiencing late withdraw of rains. However, Ngabu has the highest Z-value than Nchalo and Nsanje. P-value was found to be greater than the alpha meaning that no significance for the trend.

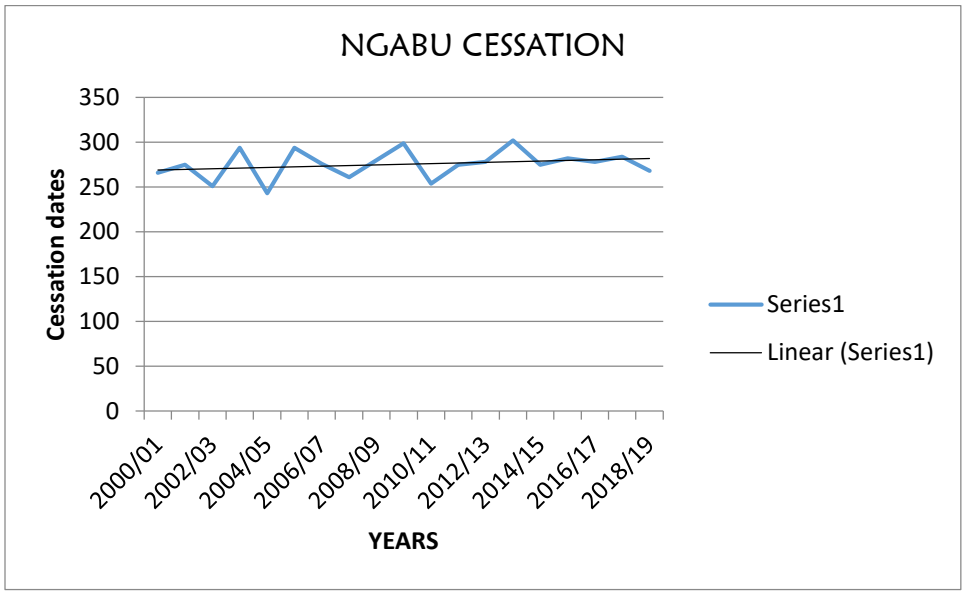


Figure 11: Graph for Ngabu cessation dates trend analysis

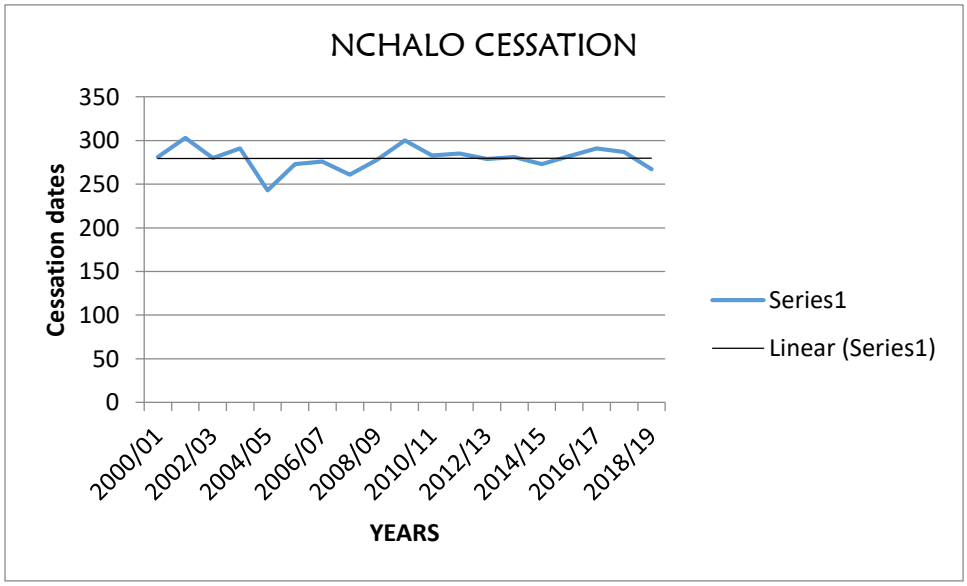


Figure 12: Graph for Nchalo cessation dates trend analysis

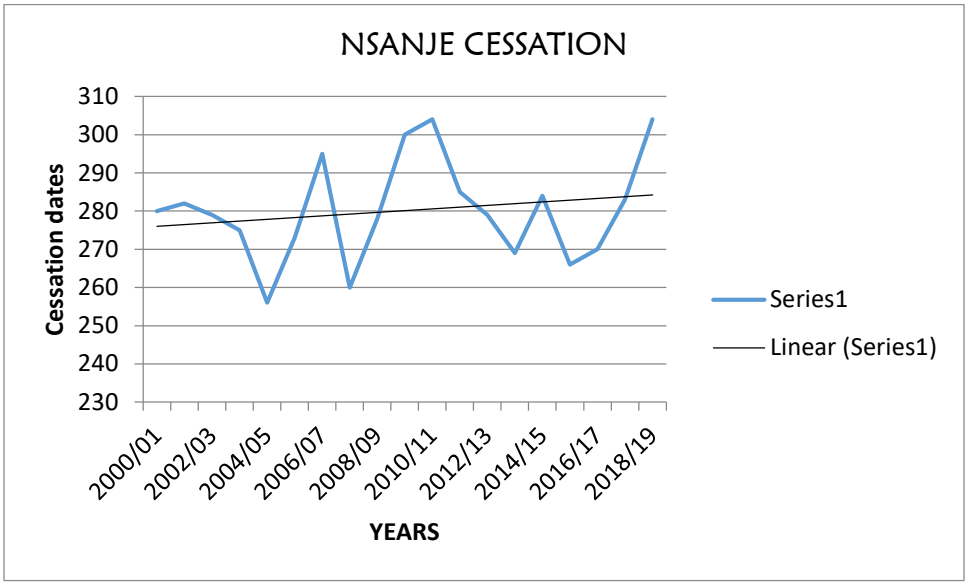


Figure 13: Graph for Nsanje cessation dates trend analysis

Table 9:Mann-Kendall test analysis for Length

Station	Z-test value	P-value	Alpha(∝)	Significance of trend
Ngabu	0.53	0.6	0.05	Increasing insignificant
Nchalo	0.35	0.73	0.05	Increasing insignificant
Nsanje	-0.49	0.62	0.05	Decreasing insignificant

Mann-Kendall analysis shows that there is a reduction in the growing season since rainfall duration has decreased in Nsanje. Ngabu and Nchalo shows increasing trend in the length of the season which means that the rainfall duration has increased in these two stations. From the analysis it clearly shows that the season has shifted with years.

4.5 CLASSIFICATION OF ONSET AND CESSATION DATES FOR NGABU, NCHALO AND NSANJE

Excel was used to come up with the values by translating it to standardized anomalies as described in 3.6.3. Tables 2,3 and 4 shows various classifications. It is 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. Having found Z value less than -1 this was categorized into early onset/cessation, Z-Values between –l and +1 were grouped as normal and Z-values greater than +1 were categorized as late onset/cessation.

4.5.1 In Ngabu, dates were classified as follows:

From 18th November and below were classified as early onset, dates between 18th November and 26th December were classified as normal dates of onset and from 28th December and above were classified as late onset dates. From 17th March and below dates were classified as early cessation dates, between 17th March and 20th April this were regarded as normal dates while from 20th April and above were classified as late dates. From the data analysis, there is a clear indication that most of the rainfall seasons in Ngabu fall under normal season with minimal variations in onset and cessation. This is to an advantage of the activities in the area that solely depends on rainfall. Most importantly, agriculture which is rain-fed would do well for people in Ngabu due to kinds of seasons.

4.5.2 In Nchalo, dates were classified as follows:

From 19th November and below were classified as early onset, dates between 19th November and 27th December were classified as normal dates of onset and from 27th December and above were classified as late onset dates. From 23rd March and below dates were classified as early cessation dates, between 23rd March and 18th April this were regarded as normal dates while from 18th April and above were classified as late dates.

4.5.3 In Nsanje, dates were classified as follows:

From 8th November and below were classified as early onset, dates between 8th November and 18th December were classified as normal dates of onset and from 18th December and above were classified as late onset dates. From 23rd March and below dates were classified as early cessation dates, between 23rd March and 18th April this were regarded as normal dates while from 18th April and above were classified as late dates.

Chapter 5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0. INTRODUCTION

This section presents the summary and conclusions drawn from the study, the limitation of the study and recommendations.

5.1 SUMMARY

This study examined the onset and cessation over shire valley, based on the findings, the classification of onset and cessation it was observed that most years in all the 3 stations were grouped under the normal category however a few years lied on the extreme cases. The notable years with early onset include 1993, 200 and 2003 while years with late onset include 1991 and 2003. The years with the early cessation include 1996, 2003 and 2005 while the years with the late cessation include 2010, 2011 and 2008.

The study used daily rainfall records sourced from Department of climate change and meteorological services from 1990-2019 data, however only Ngabu had 1990-2019 data, while Nchalo and Nsanje only had data from 2000-2019 that was available. The onset and cessation dates of rainfall and its availability was analyzed using R-INSTAT and Microsoft excel. R-INSTAT was used to come with the onset and cessation dates while excel was used to come up with the classifications of the dates as early, normal and late and as well as the length of the season.

The result shows that there is no fixed date for the onset and cessation of rains in the study area, the dates keeps on varying this is to advise farmers that it's good to have knowledge on how to determine the onset of rains to avoid wastage of agricultural resources.

The summary of the averages of onset dates and cessation dates shows that rainfall first occur in Nsanje on 28 November followed by Ngabu on 7 December then Nchalo on 9 December. The cessation date of rainfall is almost the same in all stations with Nchalo and Ngabu on 3 April while Nsanje has its cessation date as 5 April.

Nsanje has the longest length of rainy season with 129 days followed by Nchalo with 118 days and then Ngabu with 116 days. It means in all the three stations there is sufficient length

of rainy season that will support agriculture. Because the cessation is almost uniform it makes it easier for farmers to be able to plan their cropping season well in other not to be taken unaware by sudden cessation of rains.

The Mann-Kendall analysis, it shows that Ngabu and Nsanje has an increasing trend that indicates a delayed start of rains but insignificantly while Nchalo shows a decrease in trend which means that there is early onset in the station. The onset dates have shifted but insignificantly. There is an increase in trend in the cessation for the three stations which means that there is late withdraw of rains. Ngabu and Nchalo show an increasing trend in the length of the growing season while Nsanje shows a decreasing trend in the length of the growing season.

This information is very important to farmers in the region on deciding the types of crops to be cultivated and on planning sowing dates as a function of observed onset dates. The onset date is very vital it helps in determining farming activities than the cessation date.

5.2 CONCLUSIONS

The dates of onset vary in all the three stations while the dates of cessation do not significantly differ in all the three stations based on the mean that was calculated. This finding reveals that the date of onset and cessation is not reliable and predictable as it used to be in the past.

There is delayed start of rains in Nsanje and Ngabu and late withdraw of rains in all the three stations.

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-Niño.

The findings of this study are vital to the agriculture sector. Malawi as a country that depend on agriculture as a backbone for its economy, hence accurate knowledge in the onset and cessation dates as well as the duration of the rainfall season is very vital for it helps to plan and make agricultural decision. Therefore, this study helps to solve problems in the study area such as (a)wastage of agricultural resources (b)compromised planting dates. Shire valley

experiences higher temperatures and are highly associated with meteorological drought. Therefore, having prior knowledge to the duration of the rainy season helps farmers to adopt crop husbandry practices that suit long or short season.

5.3 LIMITATIONS

- For efficiency purposes and a good and true representation of the rainfall onset, cessation and length in Malawi, the study was supposed to be conducted on a national level so as to include all the meteorological stations in Malawi. However, the researcher wishes to recognize the limited resources and time that made it difficult but not impossible to proceed with the research. Therefore, due to these limitations, the study was done on a narrower scale to meet the available time and resources. The researcher would also want to make it clear that to get daily rainfall data for more than one station from the department of climate change and meteorological services was also a challenge because the managing team and the policies in play does not allow department to give daily data to students hence the number of years the researcher wanted was denied, the team provided 19 years' data instead of 30 years.
- For completeness' sake, Shire valley is known to constitute five districts. Therefore, to do a research on rainfall's onset, cessation and length in shire valley, it is of a reasonable basis to include all the five districts. However, the researcher would want to pin point it here clearly that the data that was available only allowed the research to be done in two districts out of the five districts. As such, this data from these two districts only of the study area contributed to some problems when comparing the onset and cessation dates within the study area because the data was incomplete.
- The researcher would also want to recognize the scarcity of data during the research. It was in the best interest of the researcher to analyze 30 years' data, unfortunately the data that was available was only for 19 years for the two stations Nchalo and Nsanje, while Ngabu had 30 years' data. Certainly, this forced the researcher to conduct the study based on the 19 years' data as opposed to the prior intentions of the research.

5.4 RECOMMENDATIONS

Following the findings and conclusion made in the study, the following recommendations are made:

- Further studies on the same topic should be done with data for 50 years or more to see if the mean onset and cessation dates will remain the same
- The information derived should be utilized to enable farmers plan earlier for cropping season undertake improved land management, soil conservation, flood control method and improve farmer's knowledge about proper use of weather information etc. that apparently to minimize risks of climate related hazard or seasonal rainfall variability.
- To find out what factors influence two stations to have the same cessation date in case of Nchalo and Ngabu and factors that influence early or late onset.
- There is a need for a continuous monitoring of the rainfall scenarios to effectively communicate it exact effective date to rain-fed farmers for proper agricultural planning.
- Due to the changes in the onset and cessation of rains, the farmers could also be recommended to change planting dates.
- In the station that is showing reduction of the growing season, farmers should use early maturity crop varieties.

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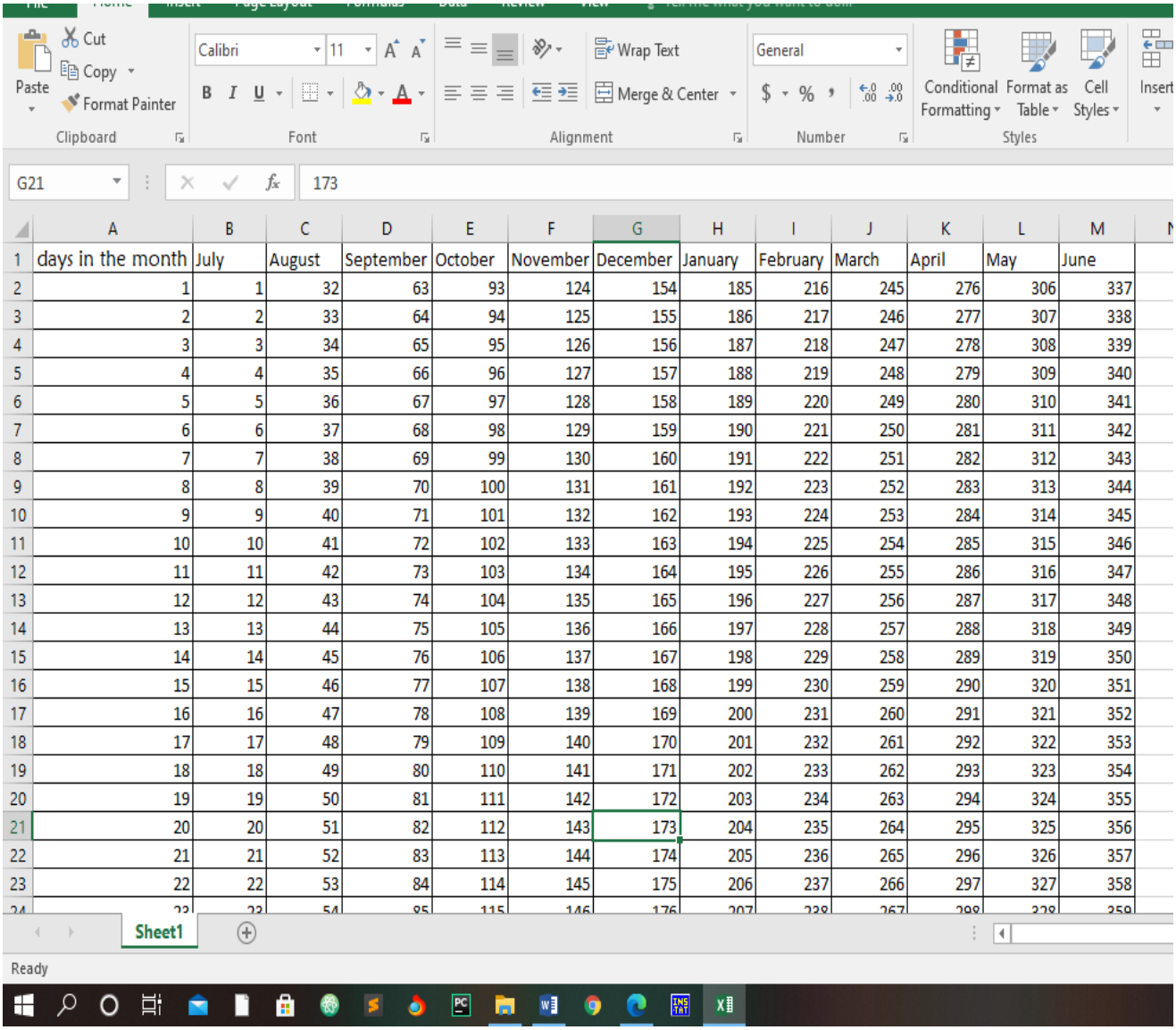
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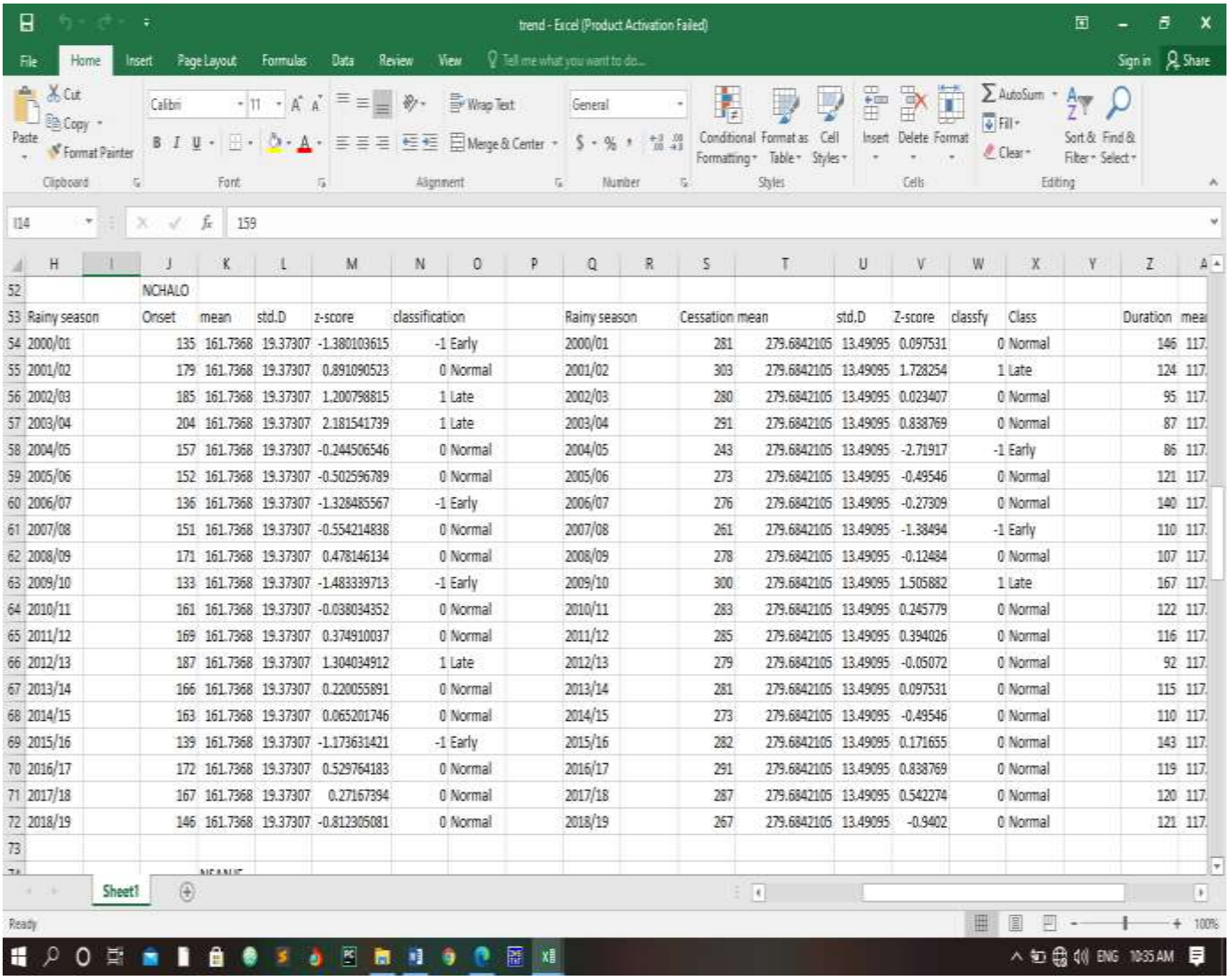
APPENDICES

Appendix I: Julian calendar used for the onset and cessation dates



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	days in the month	July	August	September	October	November	December	January	February	March	April	May	June
2	1	1	32	63	93	124	154	185	216	245	276	306	337
3	2	2	33	64	94	125	155	186	217	246	277	307	338
4	3	3	34	65	95	126	156	187	218	247	278	308	339
5	4	4	35	66	96	127	157	188	219	248	279	309	340
6	5	5	36	67	97	128	158	189	220	249	280	310	341
7	6	6	37	68	98	129	159	190	221	250	281	311	342
8	7	7	38	69	99	130	160	191	222	251	282	312	343
9	8	8	39	70	100	131	161	192	223	252	283	313	344
10	9	9	40	71	101	132	162	193	224	253	284	314	345
11	10	10	41	72	102	133	163	194	225	254	285	315	346
12	11	11	42	73	103	134	164	195	226	255	286	316	347
13	12	12	43	74	104	135	165	196	227	256	287	317	348
14	13	13	44	75	105	136	166	197	228	257	288	318	349
15	14	14	45	76	106	137	167	198	229	258	289	319	350
16	15	15	46	77	107	138	168	199	230	259	290	320	351
17	16	16	47	78	108	139	169	200	231	260	291	321	352
18	17	17	48	79	109	140	170	201	232	261	292	322	353
19	18	18	49	80	110	141	171	202	233	262	293	323	354
20	19	19	50	81	111	142	172	203	234	263	294	324	355
21	20	20	51	82	112	143	173	204	235	264	295	325	356
22	21	21	52	83	113	144	174	205	236	265	296	326	357
23	22	22	53	84	114	145	175	206	237	266	297	327	358

Appendix I: Excel analysis on classifying the dates



trend - Excel (Product Activation Failed)

52		NCHALO																	
53	Rainy season	Onset	mean	std.D	z-score	classification		Rainy season	Cessation mean		std.D	Z-score	classfy	Class		Duration	mea		
54	2000/01	135	161.7368	19.37307	-1.380103615	-1	Early	2000/01	281	279.6842105	13.49095	0.097531	0	Normal		146	117.		
55	2001/02	179	161.7368	19.37307	0.891090523	0	Normal	2001/02	303	279.6842105	13.49095	1.728254	1	Late		124	117.		
56	2002/03	185	161.7368	19.37307	1.200798815	1	Late	2002/03	280	279.6842105	13.49095	0.023407	0	Normal		95	117.		
57	2003/04	204	161.7368	19.37307	2.181541739	1	Late	2003/04	291	279.6842105	13.49095	0.838769	0	Normal		87	117.		
58	2004/05	157	161.7368	19.37307	-0.244506546	0	Normal	2004/05	243	279.6842105	13.49095	-2.71917	-1	Early		86	117.		
59	2005/06	152	161.7368	19.37307	-0.502596789	0	Normal	2005/06	273	279.6842105	13.49095	-0.49546	0	Normal		121	117.		
60	2006/07	136	161.7368	19.37307	-1.328485567	-1	Early	2006/07	276	279.6842105	13.49095	-0.27309	0	Normal		140	117.		
61	2007/08	151	161.7368	19.37307	-0.554214838	0	Normal	2007/08	261	279.6842105	13.49095	-1.38494	-1	Early		110	117.		
62	2008/09	171	161.7368	19.37307	0.478146134	0	Normal	2008/09	278	279.6842105	13.49095	-0.12484	0	Normal		107	117.		
63	2009/10	133	161.7368	19.37307	-1.483339713	-1	Early	2009/10	300	279.6842105	13.49095	1.505882	1	Late		167	117.		
64	2010/11	161	161.7368	19.37307	-0.038034352	0	Normal	2010/11	283	279.6842105	13.49095	0.245779	0	Normal		122	117.		
65	2011/12	169	161.7368	19.37307	0.374910037	0	Normal	2011/12	285	279.6842105	13.49095	0.394026	0	Normal		116	117.		
66	2012/13	187	161.7368	19.37307	1.304034912	1	Late	2012/13	279	279.6842105	13.49095	-0.05072	0	Normal		92	117.		
67	2013/14	166	161.7368	19.37307	0.220055891	0	Normal	2013/14	281	279.6842105	13.49095	0.097531	0	Normal		115	117.		
68	2014/15	163	161.7368	19.37307	0.065201746	0	Normal	2014/15	273	279.6842105	13.49095	-0.49546	0	Normal		110	117.		
69	2015/16	139	161.7368	19.37307	-1.173631421	-1	Early	2015/16	282	279.6842105	13.49095	0.171655	0	Normal		143	117.		
70	2016/17	172	161.7368	19.37307	0.529764183	0	Normal	2016/17	291	279.6842105	13.49095	0.838769	0	Normal		119	117.		
71	2017/18	167	161.7368	19.37307	0.27167394	0	Normal	2017/18	287	279.6842105	13.49095	0.542274	0	Normal		120	117.		
72	2018/19	146	161.7368	19.37307	-0.812305081	0	Normal	2018/19	267	279.6842105	13.49095	-0.9402	0	Normal		121	117.		
73																			