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MORALITY BEFORE KNOWLEDGE

Determining the onset and cessation of seasonal rains in Shire Valley, Southern Malawi

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ABSTRACT
Background: Malawi's agricultural activities rely heavily on rainfall. Rain signals the start of a distribution of rain that is unsuitable for plant development, whereas lighting marks the end of rain's ability to support plants. Malawi's tropical savanna climate has a rainy season from November to April, accounting for 95% of total annual rainfall, and a dry season from May to October, with milder temperatures and occasional showers at higher elevations from May to July. **Methods:** This study examines the commencement and cessation of seasonal rainfall in the Shire Valley, southern Malawi, between 1990 and 2019. The objectives include identifying rainfall characteristics, examining trends in the start, closure, and length of the rainy season, and categorizing onset and narrative dates. The Department of Climate Change and Meteorological Services provided daily rainfall data, and dates were determined using R-Instat. **Findings:** Rain often begins in Nsanje on November 28, followed by Ngabu on December 7, and Nchalo on December 9. The advertising dates are comparable across stations: April 3 for Nchalo and Ngabu, and April 5 for Nsanje. While most years fall within the typical range, global phenomena like La Niña and El Niño can cause early or late results. **Conclusion:** These insights are crucial for sustainably managing and developing socioeconomic activities at the national and district levels in Malawi. **Novelty/Originality of this Study:** This study provides a comprehensive analysis of the onset and cessation dates of the rainy season, utilizing long-term rainfall data spanning from 1990 to 2019. This localized analysis addresses existing gaps in the understanding of regional rainfall characteristics, which is essential for enhancing agricultural planning and mitigating resource wastage in an area heavily reliant on rain-fed agriculture.

KEYWORDS: agricultural impact; cessation; rainfall; tropical savanna.

1. Introduction

Malawi has a tropical savanna climate, with a distinct rainy season from November to April, accounting for 95% of total seasonal rainfall, and a dry season from May to October. Between May and July, the weather is quite cool, with drizzles (known as chiperoni rain) common in higher elevations. The dry season is further separated into two parts: cold and wet (May-August) and hot and dry (September – October) (Kachaje et al., 2016). The climate is principally controlled by the north-south migration of the intertropical convergence zone (ITCZ), which is defined by the convergence of northeast monsoon and southeast trade winds. The Intertropical Convergence Zone (ITCZ) interacts with the Congo air masses and the northwesterly winds, which bring tropical Atlantic air to Malawi via the Congo Basin (Ngongondo, 2011). The biggest rains start in November in the south and progressively move north. During this time, ITCZ, Congo air masses, easterly waves, and tropical cyclones all have an impact on rainfall in Malawi, with sea surface temperatures (SST) throughout

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the tropical Pacific, Indian, and Atlantic oceans playing a significant role (Fabiano et al., 2017).

The onset of rainfall is defined as the probability of rainfall occurring in a given year, while the cessation of rainfall is the period marked by the end of rainfall in that year. The onset of rainfall occurs at the beginning of the rainy season, when the distribution of rainfall is sufficient to support plant growth. On the other hand, the cessation of rainfall refers to the period towards the end of the rainy season, when the distribution of rainfall may no longer be able to support plant growth (Ibebuchi & Abu, 2023).

Malawi's average seasonal rainfall ranges from 725 mm to 2,500 mm, with distribution determined by geography and proximity to lakes. Rainfall was lowest in rain shadow locations, including the Shire Valley, western Highlands Shire and Zomba Plateau, and northwestern Viphya and Nyika Plateaus (DCCMS, 2020). High-altitude locations such as Mulanje, Nyika, and Plateau Viphya saw the most rainfall. Malawi's rainfall varies both within and between seasons (intra- and inter-seasonal variability), with regular extreme occurrences like droughts and floods (Jury & Pathack, 1993). Understanding the temporal and spatial characteristics of rainfall is essential for water resource management, agricultural planning, infrastructure development, flood frequency analysis, food hazard maps, hydrological modeling, water resource assessment, and other environmental assessments (Michaelides et al., 2009).

The study location was chosen because of the Shire River, Malawi's largest and longest river (390 km), which runs out of Lake Malawi and enters the Zambezi River (Ibrahim & Alex, 2008). The river has a tremendous impact on the lives of many Malawians because it provides electricity and supports agricultural operations for those who live along its banks. The Shire Valley has already been influenced by climate change, with severe droughts in 1991/92 and heavy flooding in 2000/01 (Vanya, 2012). Droughts, floods, and substantial soil degradation occur frequently in the Shire Valley, resulting in increased crop failure and food poverty. Deforestation, overgrazing, soil degradation, flooding, and river pollution are all major ecological and environmental issues in the Shire Valley, affecting land and total production (Vanya, 2012).

The wet season in the Shire valley lasts from November to April and is marked by heavy rainfall (a maximum of around 425 mm in January), high humidity (75-95%), and air temperatures that are generally higher than the annual average of 22° C. Storms occur during the transition period between the two seasons, accompanied by brief periods of strong winds and heavy rain (African Development Bank Group, Malawi, 2008). May sees no rain at all, while October is the hottest month, with temperatures reaching an annual high of 40 °C. Between September and November, conditions are mildly influenced by dry, dusty winds blowing intermittently from the southwest for up to several days. The Shire Valley has usually low elevations, with relief profiles ranging from 50m to 150m above sea level. Malawi's economy is centered on rain farming, with crop productivity and crop choice heavily influenced by climate and soil conditions (Kumbuyo et al, 2014). As a result, a thorough understanding of Malawi's rainfall regime is essential for agricultural planning and economic development (Ngongondo et al. 2011).

Rain is crucial for both the natural environment and human existence, making it an important ecological component (Twisa & Buchroithner, 2019). Summer rains in Malawi (October to April) are crucial to economic development, power generation, disaster management, and hydrological planning (Fabiano et al., 2017). The time of seasonal rains, particularly their start, influences crop planting dates and production since a shorter season prevents crops from achieving maximum fertility (Dunning, 2018). Rain is also vital for domestic water consumption, energy generation, health, and crop development, since it helps to recharge surface and subsurface water bodies (Tarhule & Woo, 2002). Understanding the start and finish dates of rainfall is vital for farmers to prepare farms and optimize crop growth, making it an important aspect in sustainable food production (Similton et al., 2011).

The literature has produced a number of confusing conclusions, such as the relative length and amount of rainfall throughout the wet and dry seasons, as well as the arrival dates of the 25 and 75 percent of seasonal rainfall, which are frequently created for vast areas but seldom applied consistently at individual sites (Adejuwon & Odekunle, 2006). According to Ngongondo et al. (2011), yearly rainfall in Malawi varies between 700 mm in the lowlands to 2,500 mm in the southern and northern highlands. Between May and August, some places, particularly the country's southern highlands, get intermittent winter showers known as Chiperoni. As a result, determining and forecasting the start and finish dates of the rainy season is crucial to the performance of agricultural activities in Ghana (Amekudzi et al. 2015).

The start and end dates of the rainy season have an impact on vector-borne disease transmission because disease life cycle transmission vectors are susceptible to temperature and rainfall variations (Amekudzi et al. 2015). Westerly tropical waves are thought to be most active around the start and end of the rainy season (Jury & Gwazantini, 2002). Previous research has also looked into the wonders of dry spells and their impact on planting dates and crop yields. Key findings from these studies include variations in onset dates, a small proportion of rainy days contributing to a large proportion of the total rainfall, and the occurrence of dry spells that disrupt crop development and reduce yields (Recha et al., 2011).

Studies undertaken in semi-arid regions of Africa demonstrate a substantial association between the beginning of rainfall and the length of the rainy season (Amekudzi et al., 2015). Thus, an earlier start usually results in a longer rainy season. This indicates that the length of the rainy season is determined by the onset of rainfall rather than its ending. According to a study on the commencement and termination of lengthy rains in East Africa, as well as their annual variability (Camberlin et al., 2009). The principal component scores are added together to determine the start and end dates. This study discovered that the average start date for the year (1958-1987) was March 25 and the cessation date was May 21 (for long rains), for a total period of no more than 57 days. The majority of vulnerable rural people in South Africa and Malawi believe that rainfall onset, cessation, and growing season length have changed significantly (Silmeton et al. 2011).

Kazembe (2014) conducted research on the onset and cessation of winter rains in Malawi, as well as the effects of rainfall variability on the length of the crop growth period over the last three decades in central Malawi, whereas Lameck et al. (2014) investigated the start, completion, and duration of season rain in Malaysia and the respective central regions. Kazembe (2014) studied daily rainfall data for 27 years to statistically determine the start of the rainy season in Malawi, focusing on 12 stations representative of the research area. He concluded that the southern region began earlier, from November 25 to December 2, and had the most variety. This is seen by the greatest standard deviations in both start and duration.

The primary goal of this study is to identify the onset and cessation of the rainy season in Shire Valley, Southern Malawi, by analyzing rainfall data from 1990 to 2019. The research focuses on characterizing the patterns of the rainy season, including the onset, cessation, and duration of the season, as well as evaluating the trends over this period. By classifying these dates into early, normal, and late categories, the study aims to help local farmers gain a better understanding of the rainy season patterns, enabling them to plan agricultural activities more efficiently and reduce resource wastage.

Rainfall significantly influences agricultural production across all agro-ecological zones worldwide and is a primary method of food production in much of rural sub-Saharan Africa (Marteau et al., 2009; Cooper et al., 2008). Previous research has pointed out a lack of understanding of rainfall characteristics, particularly in many developing countries, including Malawi (Desa & Niemicynowidz, 1996). Understanding localized rainfall patterns is crucial for agriculture and other sectors dependent on water. Ngongondo et al. (2011) suggest that rainfall should be analyzed at global, national, and local levels using various methodologies. In Malawi, many studies focus solely on large-scale regions of the country using data from meteorological rain gauges.

2. Methods

This study was carried out in Shire Valley, southern Malawi. According to the Department of Climate Change and Meteorological Services, districts include Chikwawa, Mangochi, Nsanje, Balaka, and Machinga. The Shire Valley is southwest of Malawi and stretches into Mozambique as part of Africa's Great Rift Valley System. It spans around 250,000 acres over two administrative districts, namely Chikwawa and Nsanje. This valley has a lengthy plain ranging in breadth from 8 to 40 kilometers and an elevation of 30 to 150 meters above sea level (Ibrahim & Alex, 2008). According to Vanya (2012), climate variability associated with increased weather extremes causes variations in the commencement date of rainfall, shortening the period of plant growth.

This study employed a quantitative research approach, using secondary daily rainfall data collected from three Shire Valley stations, namely Ngabu, Nchalo, and Nsanje. Due to data availability and quality, the Department of Climate Change and Meteorological Services provided the data for the period 1990-2019. The beginning, end, and duration of the rainy season are analyzed and displayed using tables and graphs. The stations were purposefully selected by the Department of Climate Change and Meteorological Services based on the availability of complete data required by researchers in the research region. DCCMS collects electronic records of daily rainfall data and provides them in Excel format. The R-INSTAT software uses this information to calculate the start date, end date, and length of the rainy season. The average start date of rainfall was calculated using daily rainfall data from 2000 to 2019, whereas individual year start dates were computed using daily rainfall data from 1990 to 2019 for Ngabu and 2000 to 2019 for Nsanje and Nchalo.

Onset Criteria (OS), the following criteria were used to determine the onset of the rainy season, according to the Department of Climate Change and Meteorological Services (www.metmalawi.gov.mw). The DCCMS standard threshold value is 0.3 mm, but they adjust this to 1 mm in collaboration with various sectors, particularly considering the agricultural sector, where at least 1 mm of rainfall is beneficial for crop germination. However, this 1 mm threshold is not applicable to the construction industry. The onset criteria include: a total rainfall of 25 mm or more in a single day or over three days, no dry spell exceeding 9 days within the next 21 days, occurring no earlier than October 1, and a minimum threshold of 1 mm.

Cessation Criteria (CS) and Season Length, the cessation of the rainy season, as defined by DCCMS, is the last day with 10 mm or more of rainfall from the beginning of the season until the last day of April. This date marks the end of the rainy season for that particular year. The length of the season is calculated by subtracting the onset date from the cessation date, using the Equation 1.

$$Length = Cessation\ date - Onset\ date \quad \text{(Eq. 1)}$$

The Mann-Kendall trend analysis test was employed to achieve the second objective (2), which was to analyze patterns in the beginning, end, and duration of the rainy season. The Mann-Kendall test is a nonparametric method that has been frequently used to find trends in a variety of study domains, including hydrology and climatology (Ampitiyawatta and Guo, 2009). It identifies trends in time series data. MK testing compares the null hypothesis of no trend against the alternative hypothesis of either an increasing or decreasing trend. The MK(S) test statistics are provided by Equation 2.

$$S = \sum_{k-1}^{n-1} \sum_{j=k+1}^{n} sgn\ (x_j - x_k) \quad \text{(Eq. 2)}$$

In the Mann-Kendall test statistics, x_j and x_k represent sequential data values of the time series corresponding to the years j and k where $(k > j)$. The variable n denotes the length of the time series under consideration. Additionally, the Equation 3 plays a crucial role in the analysis, allowing for the evaluation of trends within the dataset by assessing the relative values of the sequential data points.

$$Sgn\left(x_j = x_k\right) = \begin{matrix} +1 & if & x_j - x_k = 0 \\ 0 & if & x_j - x_k = 0 \\ -1 & if & x_j - x_k = 0 \end{matrix} \quad \text{(Eq. 3)}$$

A positive value of S indicates an increasing trend, while a negative value indicates a decreasing trend in the data set. In cases where the sample size n is greater than 10, the statistic S is assumed to follow an asymptotic normal distribution, with $E(S) = 0$, and its variance is calculated using the equation given below. Knowledge of the distribution of this statistic is important for trend analysis, as it helps in identifying patterns in the data as well as assessing the significance of observed changes (Adedeji Taiwo et al., 2018). Where t refers to the number of each bond present and $\sum t$ represents the sum of all those bonds. A bond is a sample of data that has the same value, and the summation is performed over all bonds present in the dataset (Equation 4). Next, the standard normal deviation Z is calculated using Equation 5, which allows further analysis of the data distribution and determination of the significance of the results obtained.

$$var(S) = \frac{1}{18}[\![n(n-1)(2n+5) - \sum t\,(t-1)(2t+5)]\!] \quad \text{(Eq. 4)}$$

The presence of a statistically significant trend was determined using the Z value. Positive ZMK showed an upward tendency, whilst negative ZMC suggested a downward trend. The ZMK statistic uses a normal distribution to determine if a trend is monotonically increasing or decreasing at a significance threshold α (often 5%, Z 0.025 = 1.96). For a two-sided trend test, accept the null hypothesis (H0) if *[Z] > Zα/2* at the significance level. In this analysis, the hypothesis will be tested with a 95% confidence level.

$$Z = \begin{cases} \frac{S-1}{\sqrt{var\,(s)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{S+1}{\sqrt{var\,(s)}} & if\ s < 0 \end{cases} \quad \text{(Eq. 5)}$$

The third objective is to categorize beginning and termination as early, typical, or late. Excel may also be used to classify season length as short, normal, or long. The data for each station is structured in the way specified by Excel. In R-INSTAT, the Julian calendar is utilized to calculate the number of days, followed by a summary statistics format that yields the mean and standard deviation for the start and end dates. The standard deviation is used to assess the variability of the number of days. The smaller the standard deviation, the lower the beginning and ultimate variability, and vice versa (Equation 6). Start and finish dates are converted to standard anomalies (Kazembe, 2014).

$$z = \frac{Value - Mean}{Standard\ deviation} \quad \text{(Eq. 6)}$$

Days over the typical date range are regarded late, whereas days within the normal day range that are within the average are considered normal. Days preceding the normal date range are considered early. A long season is defined as days with a Z >1, a short period as days with a Z < -1, and a typical season as days with a Z between -1 and +1 (Table 1).

Table 1. The range and classification of onset and cessation

Range	Class (Onset and Cessation)	Class (Length)
Z > 1	Late	Long
1 ≥ Z ≥ -1	Normal	Normal
Z <- 1	Early	Short

3. Results and Discussion

3.1 Dates Of Onset And Cessation of The Rains

The start and end dates for this discussion are based on findings from the analysis of daily rainfall data using R-INSTAT and Excel. The figure below shows the start and end dates for Ngabu, Nchalo, and Nsanje stations, as well as the days of rainfall recorded. This data provides important insights into rainfall patterns at each site, which can be used for agricultural planning and resource management.

3.1.1 Ngabu

Ngabu started early in 1993 and 2000, and ended early in 1991 and 2003. It also demonstrates that early closure occurred in 1996, 2003, and 2005, whereas late closure occurred in 1992, 1999, and 2014. Table 2 shows that early starts are between October 27 and November 18, normal starts are between November 22 and December 25, and late starts are between December 30 and January 23. Early shutdowns occur from February 28 to March 17, typical shutdowns from March 24 to April 19, and late shutdowns from April 24 to April 29.

Table 2. Start and Stop Events Above NGABU (Early = E; Normal = N; Late = L).

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	02 Dec	N	01 Apr	N
2008	07 Dec	N	17 Mar	E
2009	22 Nov	N	05 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	05 Dec	N	07 Apr	N
2017	14 Dec	N	03 Apr	N
2018	22 Nov	N	09 Apr	N
2019	25 Dec	N	24 Mar	N

3.1.2 Nchalo

Nchalo's early start in 2000, 2006, and 2009, as well as its late start in 2003. It also demonstrates that early closure happened in 2005, 2008, and 2015, with late closure occurring in 2002 and 2010. In Table 3 Nchalo indicates that early starts occur between

November 10 and November 17, regular starts occur between November 23 and December 26, and late starts occur between January 1 and January 20. Early shutdowns occur from February 28 to March 23, typical shutdowns from March 29 to April 16, and late shutdowns from April 25 to April 28.

Table 3. Checking and stopping happen on NCHALO (Early = E, Normal = N, Late = L)

Year	Onset	Category	Cessation	Category
2000	12 Nov	E	10 Apr	N
2001	26 Dec	N	06 Apr	N
2002	01 Jan	L	28 Apr	L
2003	20 Jan	L	05 Apr	N
2004	04 Dec	N	16 Apr	N
2005	29 Nov	N	28 Feb	E
2006	13 Nov	E	29 Mar	N
2007	28 Nov	N	01 Apr	N
2008	18 Dec	N	17 Mar	E
2009	10 Nov	E	03 Apr	N
2010	08 Dec	N	25 Apr	L
2011	16 Dec	N	08 Apr	N
2012	03 Jan	L	10 Apr	N
2013	13 Dec	N	04 Apr	N
2014	10 Dec	N	06 Apr	N
2015	16 Nov	E	29 Mar	N
2016	19 Dec	N	07 Apr	N
2017	14 Dec	N	16 Apr	N
2018	23 Nov	N	12 Apr	N
2019	17 Nov	E	23 Mar	E

3.1.3 Nsanje

Table 4 illustrates that in Nsanje, the early onset of the event occurred between October 20th and November 7th, the normal onset occurred between November 10th and December 18th, and the late onset occurred between December 26th and December 30th. The early cessation occurred between March 12th and March 22nd, the normal cessation occurred between March 25th and April 20th, and the late cessation occurred between April 25th and April 29th.

Table 4. Onset and cessation over Nsanje (Early=E, Normal=N, Late=L)

Year	Onset	Category	Cessation	Category
2000	07 Nov	E	05 Apr	N
2001	04 Dec	N	05 Apr	N
2002	26 Dec	L	07 Apr	N
2003	20 Oct	E	04 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	10 Nov	N	03 Apr	N
2010	20 Nov	N	25 Apr	L
2011	30 Dec	L	29 Apr	L
2012	27 Nov	N	10Apr	N
2013	13 Dec	N	04 Apr	N
2014	30 Dec	L	25 Mar	N
2015	16 Nov	N	09 Apr	N
2016	12 Dec	N	22 Mar	E
2017	26 Nov	N	26 Mar	N
2018	23 Nov	N	08 Apr	N
2019	22 Nov	N	29 Apr	L

The arrangement of commencement dates within stations varies depending on the season. The general start pattern in the research area is positive in the sense that all start dates are below the typical date; the graph shows that all start dates occurred earlier in the 2000/01 season. The early dates of Nchalo and Ngabu differ very little from those of Nsanje. Ngabu's average start date might be December 7, Nchalo on December 9, and Nsanje on November 28. The graph shows that the termination dates at all three stations are below the normal dates, yet some stations have early and late closings. The typical shutdown in Ngabu and Nchalo should take place on April 3, with Nsanje following on April 5 (Table 5).

Table 5. Mean onset, cessation and length

Station	Mean Onset	Mean Cessation	Mean Length	STD-Onset	STD- Cessation	STD- Length
Ngabu	07 Dec	3 Apr	117	19.4	13.5	20.8
Nsanje	28 Nov	5 Apr	129	22.2	17.1	24.3
Nchalo	09 Dec	3 Apr	118	20.2	13.5	21.9

3.2 Discussion

The study's findings revealed that the start and end dates of rainfall at all locations were within the typical range. However, some years have earlier and later start or end dates. Early beginnings benefit farmers because they ensure adequate moisture for plant development. Normal rain patterns benefit agriculture by reducing waste and preserving the wet season's integrity. Data from 2000 reveal that all three stations began their operations early, with Ngabu beginning on October 27. Ngabu also made an early start in 2000, 2002, 2005, 2008, 2016, and 2018. Nsanje had early starts in 2001, 2003, 2004, 2010, 2012, and 2017, whilst Nchalo had early starts in 2011, 2014, and 2019. Notably, in 2006 and 2007, Ngabu, Nchalo, and Nsanje all began on the same day, as did Nsanje and Nchalu in 2009. The unpredictability in start and stop dates throughout time underscores the importance for farmers to be watchful each season rather than depending on past years' dates.

In support of these findings, Kazembe (2014) studied annual fluctuation in start and finish dates in three regions, classifying the majority of years as normal but highlighting several severe years. According to Fabiano's (2017) study, the El Niño rainy season often begins in November, which is consistent with previous findings from the 2010-2011 and 2015-2016 seasons. The study also found that, on average, Nsanje has the earliest commencement and latest cessation of rainfall compared to Nchalo and Ngabu. Changes in start and stop are influenced by system development, which influences rainfall in Malawi, with delayed system development resulting in delays in start and close.

3.2.1 Length of the season

Table 6 indicates that during the 2002/2003, 2003/2004, and 2004/2005 seasons, all three stations experienced shorter rainy seasons. Conversely, in the 2000/2001, 2005/2006, 2006/2007, and 2009/2010 seasons, the stations experienced longer rainy seasons, while other years exhibited normal rainfall patterns. Most stations fall under the normal season category, which is crucial for farmers as it reduces the risk of crop failure. Having prior knowledge of the expected rainy season is highly advantageous for farmers, as it informs their decisions on which crops to plant and the appropriate time to harvest. Consequently, this helps farmers select crops that are best suited to the season's duration.

Figure 1 clearly indicates that the duration of the rainy season generally aligns with the normal season in most cases. However, some stations experience variations, with either shorter or longer seasons. Notably, during the 2004/2005 season, Nsanje had a longer rainy season than any other station. In contrast, during the 2002/2003 season, Ngabu had the shortest season. Nevertheless, Nsanje shows more significant variability compared to Nchalo and Ngabu, as evidenced by its higher standard deviation. This variability is consistent with the average onset and cessation dates, where rainfall in Nsanje tends to begin earlier and end later than in the other two stations.

Table 6. 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

The onset of rainfall is crucial for farmers as it answers the question of "when to plant?" (Mawunya et al., 2011). Rainfall serves as a primary determinant of agricultural production across various agro-ecological zones globally, but its seasonal and annual characteristics, including onset and intra-seasonal rainfall distribution, are often marked by significant fluctuations that can affect crop yields (Mawunya et al., 2011).

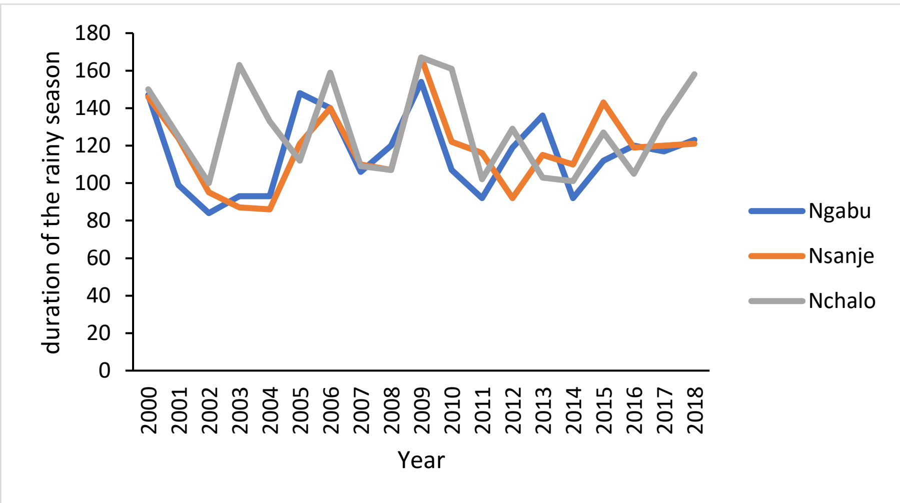

Fig. 1 Length of the rainy season for Ngabu, Nsanje, and Nchalo

Understanding the onset, cessation, and length of the rainy season in southern Malawi is essential for effective crop management decisions. Accurate information regarding the beginning of rains is vital for making informed agricultural decisions, as it helps prevent yield reductions by enabling timely actions. Knowledge of onset and cessation dates builds farmers' confidence in understanding how, where, and what actions to take, allowing them to know which months to prepare for cultivation and when to rest. Analyzing rainfall variability is also crucial for various agricultural decision-making processes. Furthermore, awareness of rainfall variability is important for planning irrigation schemes, ensuring supplementary irrigation during the rainy season, and forecasting irrigation demands during dry periods. A solid understanding of rainfall variability and its trends can help communities develop strategies for mitigating losses and recovering from adverse conditions (Mokrech et al., 2014).

The relationship between onset and cessation dates is relevant for planning seasonal activities (Magulavai et al., 2008). Farmers require accurate rainfall information to make informed choices regarding crop selection, land preparation timing, and planting activities. The findings of this study will significantly benefit farmers, business people, and all stakeholders involved in agriculture. Therefore, it is essential to accurately determine the onset, cessation, and distribution of the rainfall season for any given location.

3.2.2 Trend analysis

The Mann-Kendall analysis indicates that Ngabu and Nsanje exhibit an increasing trend, though it is not statistically significant. Conversely, Nchalo shows a decreasing trend, also without statistical significance. This suggests that in past years, Ngabu and Nsanje experienced earlier onset of rains, but over time, this has shifted, with recent years showing a tendency toward later onset. In contrast, Nchalo's decreasing trend indicates that the area previously experienced later onset of rains, whereas now it is experiencing earlier onset. Both Ngabu and Nsanje are showing a delayed start to the rainy season. However, there are no significant variations in the onset dates across the three stations. Among them, Nsanje has the highest Z-value, followed by Ngabu and Nchalo. Since the P-value is greater than the alpha (significance level), the trends observed are not statistically significant (Table 7).

Table 7. Mann- Kendall test analysis for onset.

Station	Z-test value	P-value	Alpha (α)	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

Table 8 indicates that all three stations exhibit a trend of increasing cessation, though this trend is not statistically significant. This suggests that in recent years, the onset of rain withdrawal has occurred earlier, but over time, the study area has experienced a delay in the withdrawal of rains. Notably, Ngabu has a higher Z-value compared to Nchalo and Nsanje. The P-value, being greater than the alpha level, indicates that the trend is not statistically significant.

Table 8. Mann- Kendall test analysis for cessation

Station	Z-test value	P-value	Alpha (α)	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

3.2.3 *Classification of onset and cessation dates for ngabu, nchalo and nsanje*

This study uses Excel to calculate the values by converting them into standardized anomalies, as detailed in section 3.6.3. Tables 2, 3, and 4 present various classifications. These tables reveal that some stations experienced early onset and cessation in certain years, while in other years, they had normal or late onset and cessation. Stations with Z-values less than -1 were categorized as having early onset/cessation, those with Z-values between -1 and +1 were classified as normal, and stations with Z-values greater than +1 were categorized as having late onset/cessation.

In Ngabu, onset dates on or before November 18th were classified as early, dates between November 18th and December 26th were considered normal, and dates on or after December 28th were classified as late. Cessation dates on or before March 17th were classified as early, dates between March 17th and April 20th were regarded as normal, and dates on or after April 20th were classified as late. Data analysis indicates that most rainfall seasons in Ngabu fall within the normal range, with minimal variations in onset and cessation. This is advantageous for local activities, particularly agriculture, which relies heavily on rainfall. In Nchalo, Onset dates on or before November 19th were classified as early, dates between November 19th and December 27th were considered normal, and dates on or after December 27th were classified as late. Cessation dates on or before March 23rd were classified as early, dates between March 23rd and April 18th were regarded as normal, and dates on or after April 18th were classified as late. In Nsanje, Onset dates on or before November 8th were classified as early, dates between November 8th and December 18th were considered normal, and dates on or after December 18th were classified as late. Cessation dates on or before March 23rd were classified as early, dates between March 23rd and April 18th were regarded as normal, and dates on or after April 18th were classified as late.

4. Conclusions

The start date varies amongst the three locations, but the stop date does not change much based on the estimated average. These findings show that start and finish dates are less trustworthy and predictable than they once were. Rain started later at Nsanje and Ngabu, and it took longer to stop at all three stations. Most years fall into the regular category, however some have an early or late start due to worldwide interconnections, such as La Nina or El-Niño.

The findings of this study are critical for the agricultural sector. Malawi's economy is built on agriculture, therefore having an accurate understanding of the start and finish dates, as well as the duration of the rainy season, is critical for planning and making agricultural decisions. As a result, this study contributes to the resolution of issues in the field of study, such as (a) agricultural resource waste and (b) threatening planting dates. The Shire Valley has greater temperatures and is strongly related with meteorological droughts. As a result, knowing how long the rainy season will last allows farmers to choose crop growing strategies that are appropriate for long or short seasons.

To obtain an accurate representation of the onset, end and duration of the rainy season in Malawi, the study would ideally have been conducted at a national level involving all meteorological stations. However, due to resource and time constraints, the study was conducted on a narrower scale. In addition, the collection of daily data from the Department of Climate Change and Meteorological Services was constrained by a policy that did not allow daily data to be provided to students, resulting in only 19 years of data being obtained instead of the expected 30 years. In the Shire Valley region, which consists of five districts, the study would ideally have covered all districts, but the available data only allowed for the study in two districts, limiting comparisons of the onset and end dates of the rainy season across the study area. Although the researchers had originally planned to analyze 30 years of data, data limitations meant that the analysis could only be based on 19 years of available data.

Based on the findings of this study, several recommendations are suggested. Further research should use data from 50 years or more to see if the average start and end dates of the rainy season remain consistent. These findings should also be used to help farmers plan their planting seasons, improve land management, soil conservation, flood control, and improve farmers' understanding of weather information to reduce climate-related risks. It is also important to examine the factors that cause Nchalo and Ngabu stations to have similar end dates of the rainy season, as well as the factors that influence the start of the rainy season. Continuous monitoring of rainfall patterns is needed so that accurate information can be conveyed to farmers who depend on rainfall for better agricultural planning. Farmers are also advised to adjust their planting dates according to changes in the start and end of the rainy season, and to use early-maturing crop varieties in areas that show a reduced growing season.

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