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Variability in Rainfall Onset, Cessation and Duration in Lukuledi River Catchment, Southern Coast of Tanzania

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Abstract

Most rural coastal communities in Tanzania rely heavily on agriculture for their livelihoods, and yet have limited climatological information on inter-seasonal variability of rainfall onset, cessation, and duration. This paper analyses rainfall onset, cessation, and duration of the Lukuledi river catchment, which has nearly 87% of its community depending on rainfed agriculture; and where rainfall uncertainties are reported to have negatively impacted agricultural activities. The paper used daily rainfall data from 1970 to 2015, standard deviations, coefficients of variation, and Mann Kendall statistics to identify variabilities and trends of rainfall onsets, cessation, and duration. Onset-duration relationship was also established. Results show that rainfall onset is more variable than cessation, with standard deviation ranging from 22 to 29 days; while that of cessation was between 11 and 16 days. Coefficients of variation of the onsets were between 27% and 44%; while those of cessation ranged from 5% to 8%. The period between 1970 and mid-1980s had early onsets, which shifted to late onsets in post-1985, with increasing incidences of fake onsets. Onset and rainfall duration had negative correlation, whereby one of the stations (Narunyu) had a weak correlation, $r\,(38) = -0.19, p = .24$; and the remaining stations depicted very strong correlations: Nachingwea, $r\,(44) = -0.88, p < .00001$; Mahiwa, $r\,(29) = -0.86; p < .00001$; and Masasi, $r\,(14) = -0.86, p = 0.000019$. All this indicates that onsets can be good predictors of rainfall duration. Thus, we suggest the use of observed onset-duration relationship, in combination with climate forecasts, to enhance agricultural plans and decisions.

Keywords: *rainfall variability, onset, cessation, duration.*

1. Introduction

Climates in the tropical regions are inherently variable and increasingly uncertain, a situation linking them to the influence of the El Niño Southern Oscillations, and the likely influence of global climatic changes (Nicholson, 2001; Meinke & Stone, 2005; Haile, 2005; Nicholson, 2017). The East African region is experiencing more incidences of variations in rain seasons, with some evidences associating them with disastrous long-term climatic changes

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(Nicholson, 2017). In Tanzania, a growing number of researches have reported rainfall unpredictability, rainfall shortages, increase in rainfall intensities, as well as prolonged droughts and floods (Adger, et al., 2003; Loisulie, 2006; URT, 2007; Mongi et al., 2010; Davies & Thornton, 2011; URT, 2012; Kangalawe & Lyimo, 2013; Kashaigili et al., 2013).

Since the EA regional agricultural system is predominantly rain-fed, rainfall variations become the key determinant of the general schedule of agricultural activities (Buhaug, et al., 2015; Nicholson, 2017). Rainfall is the key source of soil moisture, hence its variations determine the type of crops to be grown, amount of yields, and length of growing season (Omotosho et al., 2000; Mugalavai et al., 2008; Lotfie et al., 2018). Therefore, any deviation from the normal rainfall behaviour is likely to cause serious impacts on agriculture (Haile, 2005; Mall et al., 2006; Afifi et al., 2013).

Some of the important rainfall indices for farmers include rain onsets, cessation, and duration (Ingram et al., 2002). Unexpected events like late onset, early cessation, and dry spells within a growing season can have a substantial impacts on agricultural activities and crop yields (Camberlin & Okoola, 2003; Mugalavai et al., 2008). Knowledge and understanding of rainfall variabilities—particularly rain onsets, cessation, and duration—is thus important in reducing agricultural risks of rain-fed agriculture (Omotosho et al., 2000; Meinke et al., 2005; Rowhani,et al., 2011).

Despite the acknowledged importance of rainfall in rain-fed agriculture, some information of inter-annual variations of rainfall onsets, cessation, and duration are limited in most developing countries. In Tanzania, most of the studies on rainfall have either focused on aspects like variability in rainfall amounts, and/or on the bimodal rainfall zone of the country. For example, Beltrando (1990) and Kabanda and Jury (1999) studied the variability of rainfall, but concentrated on rainfall amount in East Africa and Northern Tanzania, respectively. Zorita and Tillya (2002) focused on factors influencing variability of long rainfall amount in Northern Tanzania. On their part, Mapande and Reason (2005) studied the inter-annual rainfall variability in Western Tanzania, concentrating on factors determining these variabilities; while Francis and Mahongo (2012) concentrated on rainfall amounts in the coastal region. Camberlin and Okoola (2003; 2009), Kijazi and Reason (2012), Owiti and Zhu 2012, Kihupi et al., (2015), and Nicholson (2017) studied seasonal variability of rainfall, but focused on the bimodal rainfall zones of the country. While Dunning et al. (2016) studied the onsets and cessation over the entire Africa, they focussed on developing a method for determing onsets and cessation, leaving out the aspect of rainfall variabilities in the region.

Therefore, there is still limited scientific information on the variability of rainfall onsets, cessation, and duration. Additionally, no clear scientific approach exists that can help predict the length of a rainfall duration. Most farming communities depend highly on their individual narrative information on climate behaviour, which does not always indicate actual meteorological variabilities. This paper intends to fill this knowledge gap. The main argument is that climatological information on the behaviour of rainfall onset, cessation, and duration is crucial for a scientific understanding of seasonal rainfall behaviours. Once this information is available, it can enhance agricultural decisions, thus reducing the vulnerability of agricultural activities to rainfall variabilities and changes.

This paper draws from a PhD study, which aimed at promoting adaptation to climate change and resilient livelihoods among coastal communities in mainland Tanzania and Zanzibar. Among the key aims of the project was to generate important climate information necessary to promote adaptation to climate change. This paper presents an analysis of the inter-annual trends and variations of rainfall onset, cessation, and duration of the Lukuledi river catchment found in the Ruvuma River and Southern Coast Basin. The relationship between onsets and rainfall cessation was also evaluated as an attempt to establish an easy approach for predicting the expected duration of a rainfall season.

The paper consists of five main sections. Following this section, the second describes the context of the case study, data and the methodological approach used in identifying and analysing rainfall onsets, cessations, and durations. Section three presents result on the statistical characteristics of trend and variability of onsets, cessations, and durations; and incidences of fake onsets, as well as the established correlation of rainfall onset and duration. The obtained statistical characteristics are then discussed in section four. Section five concludes and provides recommendation on the use of the generated climate information.

2. Context and Methods

2.1 Study Area

Most coastal communities in Tanzania are poor and their livelihoods highly depend on harnessing of ecosystem services predominantly through agriculture and fishing (Devisscher, 2010; Kebede et al., 2010; Mung'ong'o & Moshy, 2019). They are also characterized by high illiterate rates and low schooling as compared to other regions in the country (Kebede et al., 2010; Mung'ong'o & Moshy, 2019). Despite their high reliance on agriculture for livelihoods, these communities are still among the least prepared groups when it comes to dealing with the impacts of climate variabilities and changes on agriculture. They usually have limited climatological information on the most important rainfall indices such as rain onsets, cessation, and duration behaviours.

The Lukuledi river catchment is in the Ruvuma River and Southern Coast basin of Tanzania (Figure 1), covering approximately 4858km^2. The river basin is characterized by unimodal rainfall pattern; with rains starting in late November/early December, to late April/early May. Ten sub-catchments are found in the basin, with Lukuledi being the mostly populated catchment with an estimate of more than 380000 people in 2015 (RRSCB, 2015).

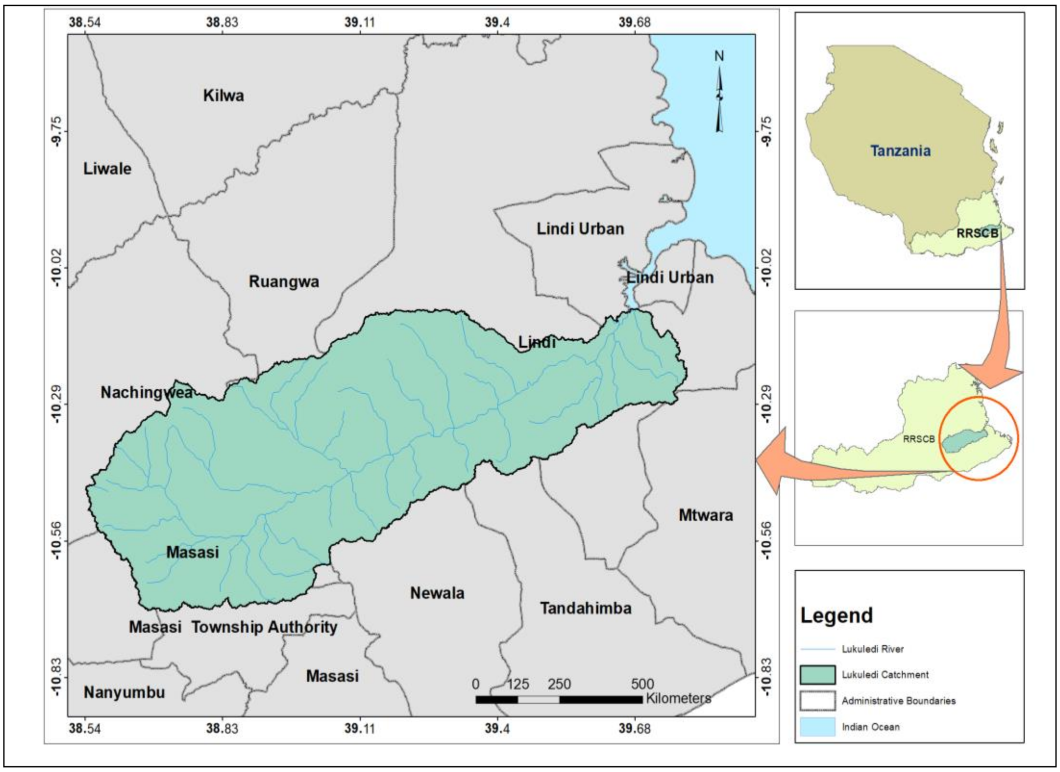


Figure 1: Location of the Lukuledi Catchment Area

Around 87% of the population lives in rural areas, mostly depending on agriculture for livelihood. Even though the Lukuledi River runs in the catchment, rainfall is still the key source of water for agricultural activities as irrigation is practiced in less than 0.1% of the agricultural land in the area (RRSCB, 2015). However, rainfall seasons are increasingly becoming unpredictable, making agricultural activities and the community highly vulnerable to uncertainties (RRSCB, 2015). Additionally, farmers in the area have limited climatological information on the behaviour of seasonal rainfall, and lack a clear scientific approach to predict the likely duration of the season, leaving them highly vulnerable to seasonal rainfall variabilities.

2.2 Data Set

This paper analysed daily rainfall data from four stations. The data were collected from the Tanzania Meteorological Agency (TMA), and ranged from 1970 to 2015. Due to a challenge of the existence of similar length of data caused by misses in data and stopping of observations in the stations, analyses periods per station were selected as follows: Masasi Mission (1970–1985), Nachingwea (1970–2015), Narunyu (1970–2010), and Mahiwa (1970–2000). The year 1970 was chosen as the beginning year for analysis as the period following that year had a good record of data. Additionally, using data from year 1970 enabled a minimum of 30 years for climate analysis as recommended by the World Meteorological Organization (WMO, 2017). The end year was determined by data availability in each station. Even though the Masasi Mission station had less than 30 years of records, the analysis of the station was considered necessary to add an understanding on the variability of rainfall in the river catchment.

2.3 Determination of Rainfall Onset, Cessation, and Duration

One of the well-known method used in determining the start and end of a rainfall season involves the use of purely rainfall information by observing agricultural definitions of sufficiently high rainfall to support take-off of agricultural activities in a specified period, followed by the absence of consecutive dry days for a certain length of time (Stern, 1981; Dodd & Jolliffe, 2001; Valimba, 2005; Marteau et al., 2009; Yamada et al., 2013; Ngetich et al., 2014). Others are methods based on minima and maxima of cumulative daily precipitations during the rain seasons (Liebmann & Marengo, 2001; Camberlin et al., 2009; Dunning et al., 2016); those involving the use of agro-climatic characteristics (Mugalavai et al., 2008); and those using various climatic variables like winds and convections (Camberlin et al., 2003). This paper chose the purely rainfall-based method (Valimba 2005; Marteau et al., 2009; Ngetich et al., 2014) since the others require some additional agronomic and climatic data that were a challenge in the study area. In addition, the method is easy to apply, works well in local climate behaviours, and is more useful in supporting local agricultural decisions (Dunning et al., 2016). The approach has the further advantage of having a room for taking into account incidences of fake rain onsets, an attribute that is important for agricultural decisions (ibid.).

This paper adopts the definition of onset and cessation of rainy seasons from Valimba (2005: 128). According to the definition, rainfall *onset* is defined as "… the second day when the average rainfall intensity of two consecutive days exceeds All record Average Daily Intensity (AADI) and after which, there is no 15 consecutive dry days in the following 45 days." The AADI is the seasonal expected daily amount of rainfall intensity of a place calculated from the average of all daily rainfall intensities (ibid.). Rainfall *cessation* is defined as "… the last day after which the daily intensity falls below AADI and is followed by a sequence of at least 28 out of 30 days whose intensities are below 1mm."

The rainfall *duration* of a season is the difference between the *onset* and *cessation* dates. False rainfall onset is a one in which the intensity of two consecutive days exceeds the AADI, and so meets the onset requirement but this is followed by more than 15 days of dry spell within the next 45 days (ibid.).

2.4 Analysis of Established Rainfall Onset, Cessation, and Duration

Following the hydrological year calendar of the study area (October–September), the established onset, cessation, and duration were analysed for the following statistical indices: mean, standard deviation, coefficient of variation, and trend (Hirsch et al., 1982; USGS, 2002; Kothari, 2004; Buhaug et al., 2015). Standard deviation is useful in showing the average deviation of data from the mean. It is given by:

$$SD = \sqrt{\frac{\sum(X-\mu)^2}{N}}$$

Whereby X is the value in the data set, μ is the mean of data set, and N is the number of data points.

A coefficient of variation measures the relative variability of data series around the mean. In rainfall analysis, a coefficient of variation represents the value of standard deviation divided by the average annual rainfall. Since the coefficient of variation can compare results from datasets that have different scoring mechanisms, it was important in comparing the variations between the rainfall onsets, cessation, and duration; as well as well as the variations between stations. The higher the coefficient of variation, the higher the rainfall fluctuations, and vice versa. The coefficient of variation is given by:

$$CV = \frac{SD}{\mu}$$

Whereby CV is the coefficient of variation, SD is the standard deviation, and μ is the population mean.

The Mann Kendall (MK), a non-parametric test statistic for trend, was used to show the direction of trend and its statistical significance. The test statistic is computed by, first, finding the value of S, which is the number of positive differences minus the negative differences in data series. This S is given by:

$$S = \sum_{i=1}^{n-1} \sum_{J=i+1}^{n} sgn(x_j - x_i)$$

Whereby n is the number of data points, and x_i and x_j are the data values in the time series i and $j(j > i)$, respectively.

The function $sgn(x_j - x_i)$ is given by:

$$sgn(x_j - x_i) = \begin{Bmatrix} +1 \; if \; x_i < x_j \\ 0 \; if \; x_i = x_j \\ -1 \; if \; x_i > x_j \end{Bmatrix}$$

The variance of S is then calculated as:

$$VAR(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i - 1)(2t_i + 5)}{18}$$

Whereby n is the number of data points, p is the number of tied groups, and t_i is the number of data values in the p^{th} group.

After obtaining the value and variance of S, the MK test statistic (Zs) is then computed as:

$$Zs = \begin{Bmatrix} \frac{S-1}{\sqrt{Var(S)}}, if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, if \; S < 0 \end{Bmatrix}$$

A correlation analysis using Pearson correlation coefficient was also performed to establish the relationship between onsets and duration in the study area. The correlation coefficient is given by:

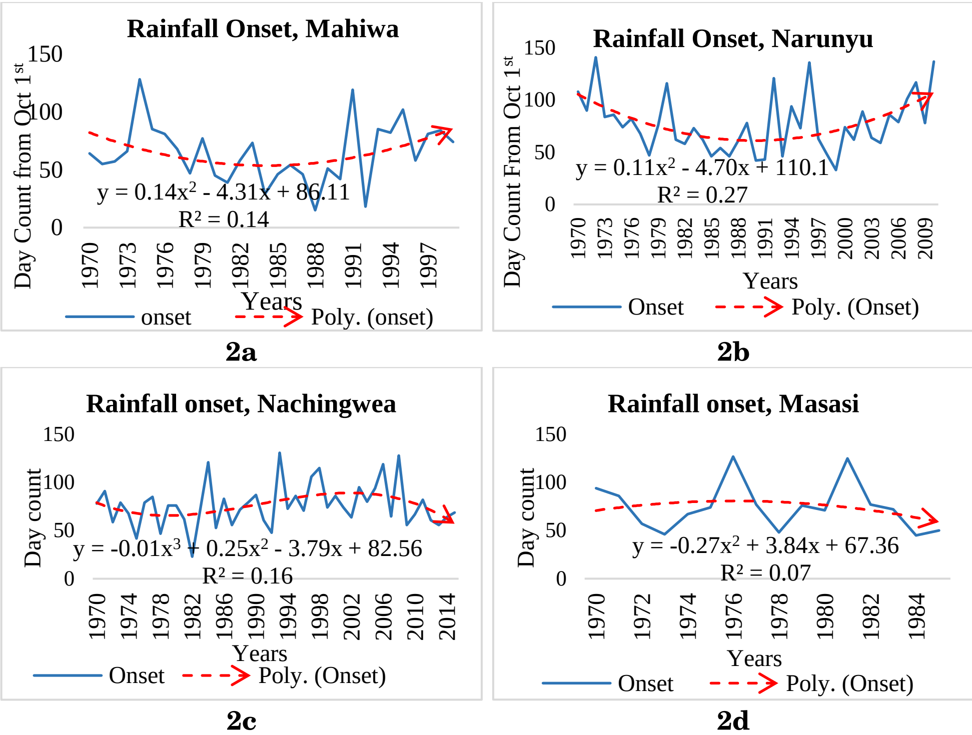
$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

Whereby N is the number of pairs of scores, and x and y are the x and y scores, respectively.

3. Results

3.1 Rainfall Onset Characteristics

The rainfall onset was observed to occur in December, anytime between the 1st and 3rd week (1st Dec. to 21st Dec.) (Figures 2a, 2b, 2c, 2d). Some few incidences of very early and/or very late onsets were also observed; with the earliest onsets recorded on 15th of October, and the latest on 18th February. The rainfall onset is also characterized with a high variability as indicated by the high standard deviation that ranged between 22 to 29 days (Tables 1 and 2). The erratic behaviour of the onsets is experienced in all stations as depicted in the high coefficients of variations that range from 27% to 44% (Tables 1 and 2), as well as the increasing incidences of fake onsets. Moving from 1970 to 2015, each decade had at least one incident of fake rainfall onset (Figure 3).



Figures 2: Observed Rainfall Onset in the Studied Station

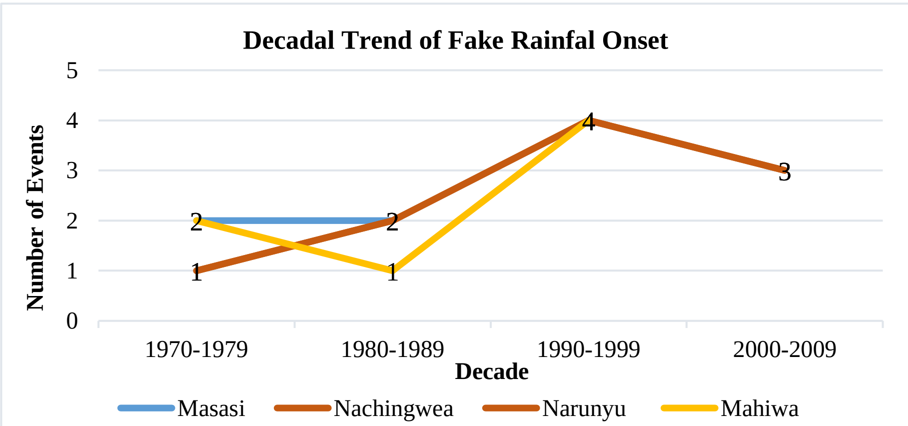


Figure 3: Decadal Trend of Fake Rain Onset

Two key trends were depicted in onsets: a trend towards early onset observed from the 1970s to the mid-1980s, and that towards late onsets from mid-1980s onwards (see Figures 2a, 2b, 2c, 2d). This led to a division of the analysis into two periods: the period 1970–1985, and the post-1985 period.

Table 1: Rainfall Onset Characteristics for the Period 1970–1985.

	Minimum Onset Day*/Date	Maximum Onset Day*/Date	Annual Mean Onset day*	Standard Deviation (Days)	Coefficient of Variation	Trend, MK
Masasi	45 *(14th Nov)*	127 *(4th Feb)*	74 *(13th Dec)*	25	33%	Z = -0.8, p >0.1
Nachingwea	23 *(23rd Oct)*	121 *(29th Jan)*	69 *(8th Dec)*	22	32%	Z = -0.86 p >0.1
Narunyu	46 *(15th Nov)*	141 *(18th Feb)*	80 *(19th Dec)*	25	32%	Z = -3.15, p < 0.01
Mahiwa	29 *(29th Oct)*	128 *(5th Feb)*	63 *(1st Dec)*	23	36%	Z = -1.49, p < 0.05

Note: * Day count is from 1st of October.

Table 2: Rainfall Onset Characteristics for the Period 1986–2015.

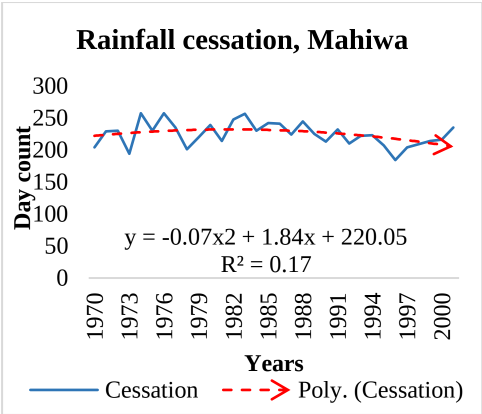
	Minimum Onset Day*/Date	Maximum Onset Day*/Date	Annual Mean Onset day*	Standard Deviation (Days)	Coefficient of Variation	Trend MK
Nachingwea	48 *(17th Nov)*	131 *(8th Feb)*	82 *(21st Dec)*	22	27%	Z = 0.55, p > 0.1
Narunyu	33 *(2nd Nov)*	137 *(14th Feb)*	75 *(14th Dec)*	29	38%	Z = 2.49, p < 0.05
Mahiwa	15 *(15th Oct)*	119 *(27th Jan)*	64 *(3rd Dec)*	28	44%	Z = 1.19, p < 0.1

Note: * Day count is from 1st of October.

In the 1970–1985 period, all four stations showed a trend towards early onset. Two of these were statistically significant: Mahiwa (Z = -1.49, p < 0.05); and Narunyu (Z = -3.15, p < 0.01) (Table, 1). The post-1985 period showed a trend towards late onset, with that of Narunyu and Mahiwa being statistically significant at Z = 2.49, p < 0.05 and Z =1.19, p < 0.1, respectively (Table 2).

3.2 Rainfall Cessation

The observed cessation ranged from the second week of April to the first week of June. It is characterized by a slight trend towards early cessation with minimal variability (Figures 4a, 4b, 4c, 4d), as compared to the onsets. That is evident in their smaller standard deviations and coefficients of variation as compared to those of rainfall onsets. The average deviations from the mean cessation dates range from 11 to 16 days (Tables 3 and 4). In the period 1970–1985, Mahiwa and Narunyu had a weak trend towards late cessation: Z = 1.3, p < 0.1, and Z = 0.36, p > 0.1, respectively. On the contrary, Nachingwea had a weak trend towards early cessation (Z = -1.19, p > 0.1), and Masasi had no trend (Z = 0.0, p > 0.1). In the post-1985 period, all stations showed a trend towards early cessation, although not statistically significant except for the Mahiwa station, which was statistically significant at Z = -1.67, p > 0.05 (Table 4).



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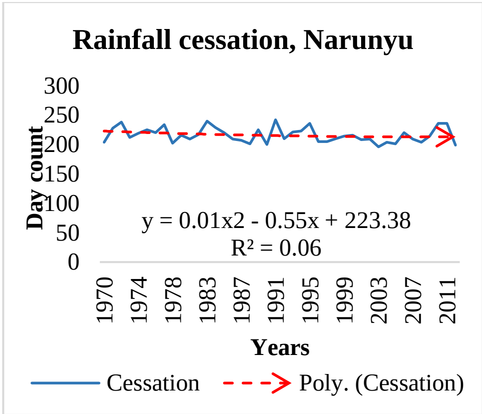

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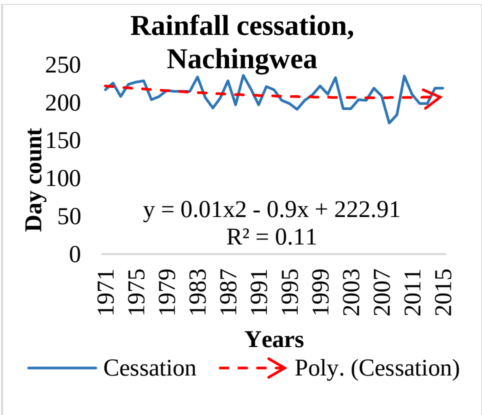

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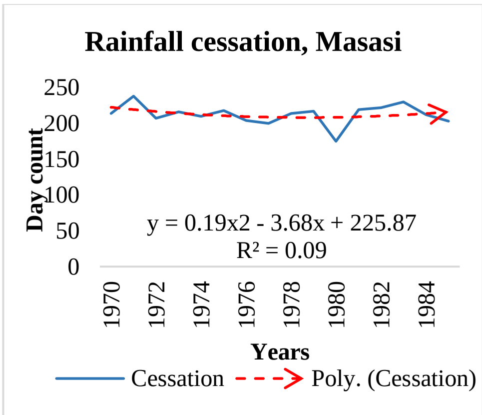


4d

Figures 4: Trend in Rainfall Cessation in the Studied Rainfall Stations

Table 3: Rainfall Cessation Characteristics, 1970–985

	Minimum Cessation Day*	Maximum Cessation Day*	Mean Cessation Day*	Standard Deviation (Days)	Coefficient of Variation	Trend MK
Masasi	175 *(24th March)*	238 *(26th May)*	212 *(29th April)*	14	6%	$Z = 0.0$, $p>0.1$
Nachingwea	193 *(10th April)*	234 *(21st May)*	215 *(3rd May)*	11	5%	$Z = -1.19$, $p > 0.1$
Narunyu	202 *(19th April)*	240 *(27th May)*	221 *(9th May)*	12	6%	$Z = 0.36$, $p > 0.1$
Mahiwa	194 *(12th April)*	257 *(14th June)*	230 *(18th May)*	20	8%	$Z = 1.3$, $p > 0.1$

Note: * Day count is from 1st of October.

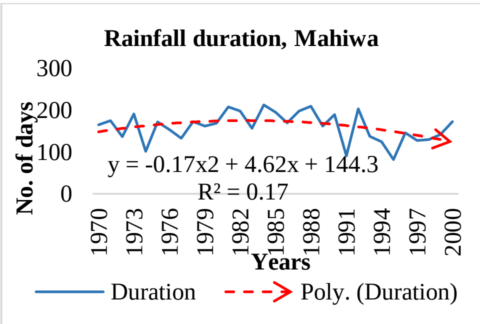
Table 4: Rainfall Cessation Characteristics, 1986–2015

	Minimum Cessation Day*	Maximum Cessation Day*	Mean Cessation Day*	Standard Deviation (Days)	Coefficient of Variation	Trend MK
Nachingwea	173 *(22nd March)*	235 *(23rd May)*	205 *(23rd April)*	16	7%	$Z = 0.46, p > 0.1$
Narunyu	196 *(14th April)*	242 *(30th May)*	213 *(1st May)*	13	6%	$Z = 0.31, p > 0.1$
Mahiwa	184 *(2nd April)*	244 *(1st June)*	217 *(5th May)*	15	6%	$Z = 1.67, p > 0.05$

Note: * Day count is from 1st of October.

3.3 Rainfall Duration Characteristics

The rainfall duration ranged between 56 to 213 days, with a mean duration ranging from 129–69 days, and standard deviation of 17–30 days. In the period 1970–1985, three stations (Masasi, Narunyu, and Mahiwa) showed an increasing trend in rainfall duration, while Nachingwea had no trend. In the post-1985 period, there was a shift towards a decreasing trend for Narunyu and Mahiwa stations. Nachingwea station had a very slight increasing trend in this duration, although not statistically significant (Figures 5(a-d), and Tables 5 and 6).



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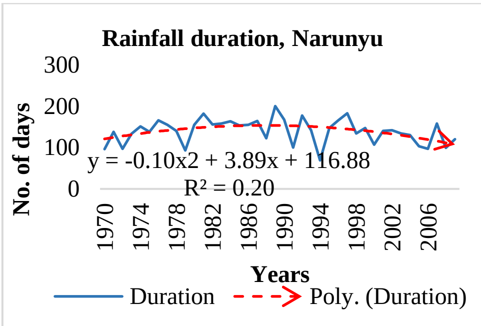

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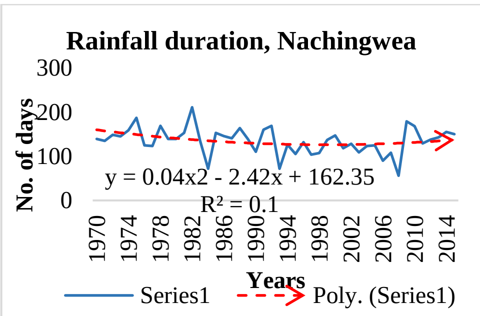

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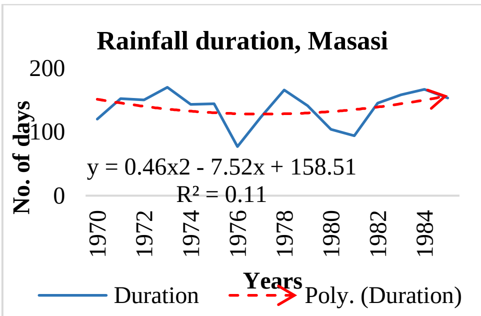

5d

Figures 5: Trend in Rainfall Duration for Studied Rainfall Stations

Table 5: Rainfall Duration (days) Characteristics, 1970–1985

	Minimum Rainfall Duration	Maximum Rainfall Duration	Mean Duration	Standard Deviation (Days)	Coefficient of Variation	Trend MK
Masasi	77	170	138	27	19%	$Z = 0.4, p > 0.1$
Nachingwea	72	211	146	30	20%	$Z = 0, p > 0.1$
Narunyu	93	182	142	26	18%	$Z = 2.57, p > 0.01$
Mahiwa	102	213	169	17	29%	$Z = 1.58, p > 0.05$

Table 6: Rainfall Duration Characteristics, 1986–2015

	Minimum Duration	Maximum Duration	Mean Duration	Standard Deviation (Days)	Coefficient of Variation	Trend MK
Nachingwea	56	179	129	28	22%	$Z = 0.07, p > 0.1$
Narunyu	69	200	137	32	23%	$Z = -2.28, p > 0.05$
Mahiwa	82	210	152	39	26%	$Z = -1.29, p > 0.1$

A negative correlation between rain onsets and durations was observed in all the rainfall stations. The correlations in Mahiwa, Masasi, and Nachingwea were strong and statistically significant (Table 7).

Table 7: Correlation Between Rainfall Onset Day and Length of Rainfall Duration

Station	Correlation, rainfall onset day and duration
Mahiwa	r (29) = -0.86, p > .00001
Masasi	r (14) = -0.86, p = 0.000019
Nachingwea	r (44) = -0.88, p > .00001
Narunyu	r (38) = -0.19, p = .24

3. Discussion

The study findings show a high variability in onsets, which is indicated by the high standard deviation. This variability is experienced in all stations as shown by the high coefficients of variation. However, the rainfall onsets were more erratic than the cessations. This situation can be linked to the influence of external forcing on onsets than cessation. A number of previous studies suggests that variations in onset and cessation can be attributed to the influence of a combination of external forcing, particularly the position of an area relative to the amplitude of inter-tropical convergence zone (ITCZ); changes in sea surface temperatures (SSTs) in the tropical Atlantic, Indian Ocean or Pacific region; as well as some local factors like forests, hills, surface albedo and soil moisture (Nicholson, 2001; Camberlin et al., 2009; Lyon & Dewitt, 2012; Recha et al., 2012; Ngetich et al., 2014; Dunning et al., 2016). However, the influence of the external forcing is more powerful in rainfall onsets than cessations. On the contrary, the cessation can be highly influenced by positive feedbacks from local conditions like vegetation and wetland surface (Camberlin et al., 2009). This influence of local factors on local atmospheric conditions is the possible reason behind the observed less variability of the rain cessations.

The relative influence of external forcing and local environment conditions on rainfall onsets and cessations can also be behind the existence of two trends on rainfall onsets (trend towards early onsets from the year 1970 to mid-1980s, and late onsets from mid-1980s) and minimal trend in cessation. According to Kijazi et al. (2005), onsets during the El Niño phases in coastal Tanzania can be as early as 4 pentads earlier, while cessation depicts minimal changes. On the other hand, the La Niña onsets can delay as late as 2 pentads with minimal changes in cessations. Therefore, it is possible that the varied incidences of external forcing of cold and warm ENSO (La Niña and El Niño) between the two periods (1970 to mid-1980s, and the period after) have influenced the observed trend. Global weather data from NOAA (2020) show that the period 1970 to mid-1980s was characterized by more occurrences of El Niño than La Niña. According to these data, the period 1975–1987 had 6 incidences of El Niño, ranging from weak to very strong ones. On the contrary, La Niña occurred in only 3 years. Moving from year 1987 to 2015, incidences of La Niña increased to 8 incidences, while El-Nino increased by one incidence to make 7 occurrences. Thus, this can be a possible explanation of the observed trend towards early onsets in the period 1970 to mid-1980s, and the trend towards late onsets from mid-1980s to 2015.

The observed slight trend towards early cessation from 1985 can be linked to the continuing disturbances on the natural vegetation in the study area, which disturb the local environment. Richness in vegetation cover in the area before 1985 possibly contributed to stable rainfall cessations. However, overtime, there has occurred an increasing demand of land for agricultural activities to meet food requirements of the rising population, which takes place at the expense of natural vegetation (RRSCB, 2015). This has consequently led into a disturbance in the local conditions such as soil moisture and surface albedo. As a result, the land moisture feedback to the atmosphere is decreasing as compared to the past, and hence the trend towards early cessations.

Whilst acknowledging the role of ITCZ, SST, and the local environment in influencing seasonal rainfall behaviour, the role of climate change cannot be ignored. According to the IPCC (2014), climate change is also likely to cause a decrease in total rainfall with increases in seasonal variabilities for most parts of sub-Saharan Africa. This is also a likely reason behind the observed increasing variabilities and incidences of fake rainfall onsets in the study area.

Camberlin et al. (2009) has also observed more variability in onsets in the long rains of bimodal parts of Tanzania. Even though these results also corroborate the findings of several other studies in other parts of Africa—such as by Camberlin and Okoola (2003), Recha et al. (2012), Oguntunde (2014), Dunning et al. (2016), Mugo et al. (2016), and Byakatonda et al. (2019)—this cannot be taken to mean that there exists a uniform behaviour of rainfall onsets and cessations. A different onset behaviour was found by Mugalavai et al. (2008) in Western Kenya, who found a homogeneous onset in the area for the period 1974–1993. A study by Ngetich et al., (2014) also reported no shift in rainfall onset and cessation in the period 1999–2009. This shows that there exists a spatially heterogeneous rainfall seasonal behaviour in the region. Therefore, it is important to have more local specific studies of seasonal rainfall characteristics.

In terms of the characteristics of rainfall duration, the trend has indicated that the period characterized by a trend towards early onset (1970–1985) was also marked with long rainfall duration. Similarly, the period with late onset (1985–2015) was associated with short rainfall duration. In addition, the correlation analysis indicated a strong negative relationship between onsets and rainfall durations, indicating that late onsets are associated with short rainfall durations and vice versa. This implies that onsets can be a good indicator of expected rainfall duration. While some scholars—e.g., Camberlin et al. (2009)—argue that early onsets are not necessarily an indicator of good rainfall seasons, evidences from others suggest that on-time rainfall onset tend to be associated with normal rainfall duration and amount; and late onsets are associated with below normal rainfall duration and amount (Camberlin & Okoola, 2003; Mugalavai, 2008; Oguntunde et al., 2014; Mugo et al., 2016; Nicholson, 2017; Byakatonda et al., 2019). With this observation, therefore, on-time onsets can also be reliable indicators of normal rainfall seasons.

4. Conclusion

This paper has identified the characteristics of rainfall onsets, cessation, and duration for the Lukuledi river catchment in the Ruvuma River and Southern Coast Basin of Tanzania from 1970 to 2015. The analyses provide evidence to conclude that rain onset is more erratic than the cessation. An increasing occurrence of fake rainfall onsets is a situation likely to be linked to the influence of external forcing, while local environments influence cessation. Also, rainfall durations are positively correlated to rainfall onsets. Due to the importance of onsets in guiding agricultural plans—particularly the take-off of farming activities and selection of crops—the onset-duration relationship can be helpful in guiding seasonal agricultural plans and decisions, as well as assessing local agricultural risks. However, it is important to be aware of the likely impacts of climate change in seasonal rainfall characteristics. Efforts should be taken to make climate forecast information more available and reliable. That information, together with the observed onsets-duration relationship, can enhance agricultural plans and decisions.

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