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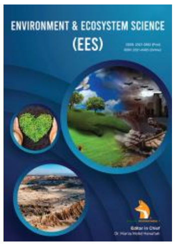

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RESEARCH ARTICLE

RAINFALL RELIABILITY IN THE BAMENDA HIGHLANDS AND COASTAL LOWLANDS OF CAMEROON: INSIGHTS FROM NDU AND DOUALA (1957-2016)

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ABSTRACT

Rainfall in coastal areas is influenced by exposure to the ocean, while the climates of the interiors are influenced by continentality. The paper bridges some methodological gaps in previous studies on Cameroon's rainfall that emphasized interannual variability without any indices between ecological zones. The objective of this study is to compare the rainfall reliability of Douala and Ndu. Ground surface measures of mean monthly rainfall data were collected from the National Meteorological Service (Douala) and the Cameroon Tea Estate Plantation, Ndu for 60 years (1957-2016). The data were analysed using monthly averages, interannual and decadal trends, Standard Deviation (SD), Coefficient of Variation (CV) and Standardized Precipitation Index (SPI). Results revealed that the mean annual rainfall is 305.33 mm and 165.04 mm for Douala and Ndu, respectively. The interannual rainfall trend decline is steeper in Douala than in Ndu. Both stations show more dry weather conditions than the anticipated wet conditions, viz, 24 episodes of mild dryness (40%), moderate dryness 3(5%), severe dryness 3(5%) and extreme dryness 2 (3.33%) in Douala; while Ndu showed 23 episodes of mild dryness (38.33%), moderate dryness 7 (11.67%) and 1 incident of extreme dryness (1.67%). This gives 53.33% and 51.67% dry episodes for Douala and Ndu respectively. Despite these recurrent agro-meteorological droughts, rainfall is still reliable with CVs of 14.67% and 13.09% for Douala and Ndu respectively. These dynamics have implications for water-related developments. The populations are called upon to embrace sustainable environmental practices that can enhance rainfall as climate change is looming.

KEYWORDS

Climate variability, continentality, rainfall index.

1. INTRODUCTION

Rainfall is unevenly distributed owing to various reasons and such variation is reflective of the availability of water for human use and the cycles of activities like agriculture (Tume, 2023; Ayoade, 1998). In this era of ***'glocal'*** environmental vagaries, a sound knowledge of rainfall characteristics is indispensable (Ahrens and Henson, 2019). Rainfall reliability and variability, the change in the amount of rain received in a particular geographical region within a defined period, can be daily, monthly, seasonal or annual. The change in the precipitation averaged over the global land areas was observed to be low before 1951 and medium afterwards because of insufficient data, particularly in the earlier periods of the records (Strangeways, 2006). The long-term mean rainfall for a month, season, or year does not often indicate the regularity with which given amounts of rainfall can be expected, especially in the low latitudes where rainfall is known to be highly variable in incidence from one year to another (Ayoade, 1998). In the tropics, rainfall tends to be more variable seasonally than annually (World Meteorological Organization, 2008; 2011). Rainfall reliability measures the likelihood that the mean amount of rainfall might be repeated each year, season or month depending on the period under consideration (Barry and Chorley, 2003).

This study bridges some of the methodological and empirical gaps in the previous studies on climate variability in Cameroon. It has analyzed the rainfall probability and reliability over Cameroon, using standard deviation (SD) and coefficient of variation (CV), with no other climatic index (Ngakfumbe, 2001). Another study performed a descriptive analysis of rainfall variability and its impact on the water resources in Cameroon and observed that the mean annual rainfall decreases inversely with latitude, without specifying the indices that show regional variations (Mulua and Lambi, 2006). Two other studies assessed the susceptibility of water resources to climate variability on the Bui Plateau, using the rainfall seasonality index (SI) and SPI, but failed to reveal the regional disparities at the mesoscale (Tume, 2019; 2021). Such indices need to be easy to calculate and statistically relevant. In another study, attempted a standardized precipitation index comparison along the Limbe-Bamenda Axis using data for 30 years (1985-2015), which is not long enough to establish meaningful changes (Tume, 2022a). This study complements the shortcomings of the previous paper by using data from (1957-2016).

Hereby proposed the SPI parameter to compare rainfall characteristics, in which precipitation is the only required input parameter for analyzing wet and dry cycles (McKee et al., 1993). Datasets required to compute SPI require 90% or at least 85% complete records. SPI was designed to quantify the precipitation deficits for multiple timescales that best reflect the impact of droughts on different sectors of the man-environment nexus. Soil moisture conditions, for example, respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage on the other hand reflect the longer-term precipitation anomalies.

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originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales (McKee et al., 1993). Positive SPI values indicated greater than median precipitation, whereas negative values indicated less than median precipitation. Since the SPI is normalized, wetter and drier climates could be represented in the same way.

2. Study Area and Methodology

The study area includes two distinct topographic units- Ndu in the Bamenda Highlands and Douala in the coastal region of Cameroon (Figure 1). Ndu is located between latitudes 6°20” and 6°40” N and Longitudes 6°25” and 11°20”E of the Greenwich Meridian. It covers a total surface area of 1,350 km^2 and lies at an average altitude of 2,057 m above sea level. Ndu is bounded to the North by Nkambe Central Sub-Division, to the west by Nwa, and the east by Nkum. Douala is situated on the Southeastern Shore of the Wouri River estuary, on the Atlantic coast. It is located on latitude 4°.0483N and 4.°2.896’N and longitude 9°.70428E and 9°42.257’E. Douala with a tropical monsoon climate has an average elevation of 15 m above sea level and an annual temperature of 29.61°C (Tume, 2023).

The main tool used in this comparative study is the SPI, which was developed primarily for defining and monitoring drought. It allows an analyst to determine the rarity of a drought at a given temporal resolution of interest for any rainfall station with historic data (1957-2016), as well as periods of anomalously wet events (Table 1).

Table 1: Standardized Precipitation Index Classification

SPI Value	Category	Probability (%)	Freq. in 100 years
>2.00	Extreme wet	2.3	100
1.5 to 1.99	Severely wet	4.4	70
1.00 to 1.49	Moderately wet	9.2	50
0 to 0.99	Mildly Wet	34.1	45
-0.1 to -0.99	Mild dryness	34.1	33
-1.00 to -1.49	Moderate dryness	9.2	10
-1.50 to -1.99	Severe dryness	4.4	5
<-2	Extreme dryness	2.3	2.5

Source: (McKee et al., 1993)

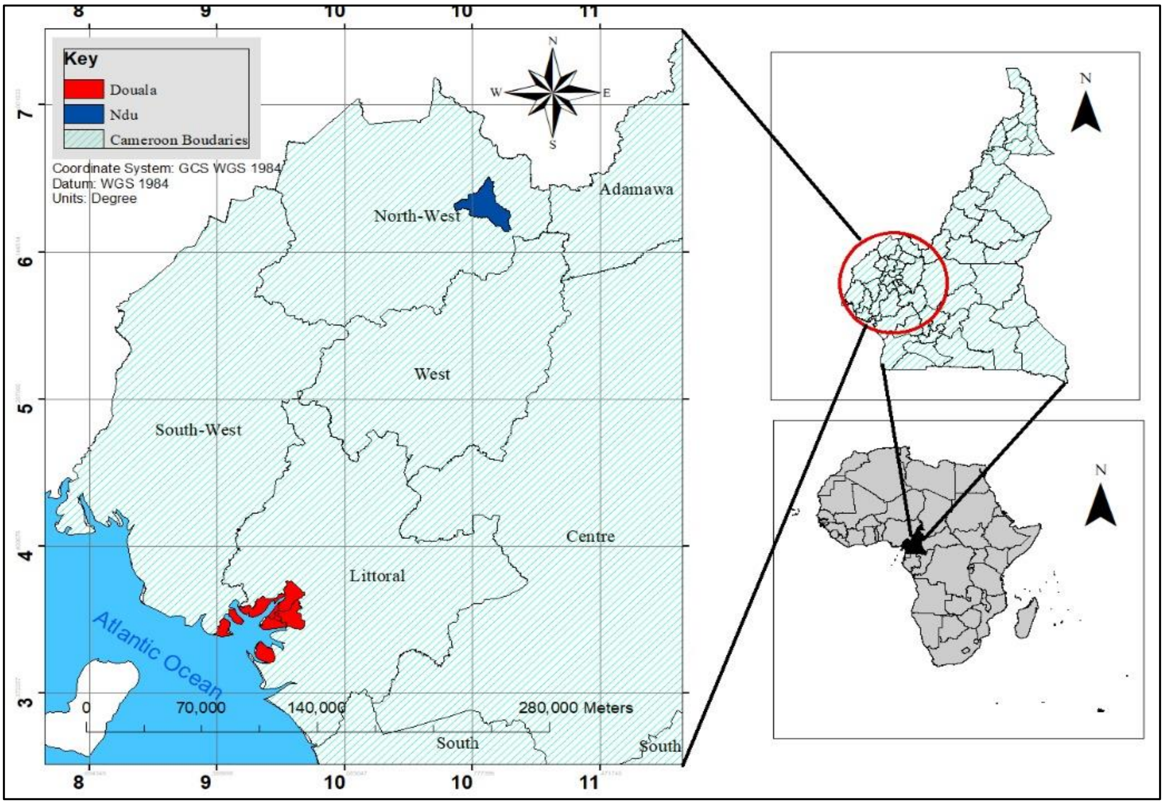

Figure 1: Location of Douala and Ndu

Source: Administrative Map of Cameroon, 2021

Conceptually, SPI is the number of standard deviations by which the precipitation values recorded for a location would differ from the mean over certain periods. In statistical terms, the SPI is equivalent to the Z-score:

$$\mathrm{Z-score} = \mathrm{x} - \frac{\mu}{\delta}$$

Where:

Z-score expresses the *x* score’s distance from the mean (μ) in standard deviation (δ) units. The SPI is based on the cumulative probability of a given rainfall event occurring at a station. Other measures of central tendencies included Standard Deviation (σ), Variance and Coefficient of Variation (CV). CV is calculated thus:

$$\sigma = \frac{\sqrt{\Sigma(\mathrm{Y} - \bar{\mathrm{Y}})}^2}{\mathrm{N}}$$

$$CV = \sigma * \frac{100}{\bar{\mathrm{Y}}}$$

Where:

$\bar{Y}$ = mean

N = sample size

Characteristics such as the standard deviation and coefficient of variation were used to establish the *reliability* of rainfall for Ndu and Douala, located in contrasting geographic zones of Cameroon, where the local climatic conditions are determined by continentality and nearness to the sea respectively. Ndu is located in the hinterland of Cameroon, and Douala is located along the Atlantic southwest coast of Cameroon. These positions show differences in their climatic conditions evaluated using the SPI. Rainfall is relatively abundant in these locations and appears to be reliable. Conversely, the impact of continentality needs to be understood even on a smaller scale using an innovative statistical tool such as SPI.

3. Results

3.1 Mean Monthly And Interannual Rainfall Trends

The pattern of mean monthly rainfall pattern for Ndu and Douala is the same (Figure 1). There is a gradual increase from the onset of the wet season to a peak in July-August-September.

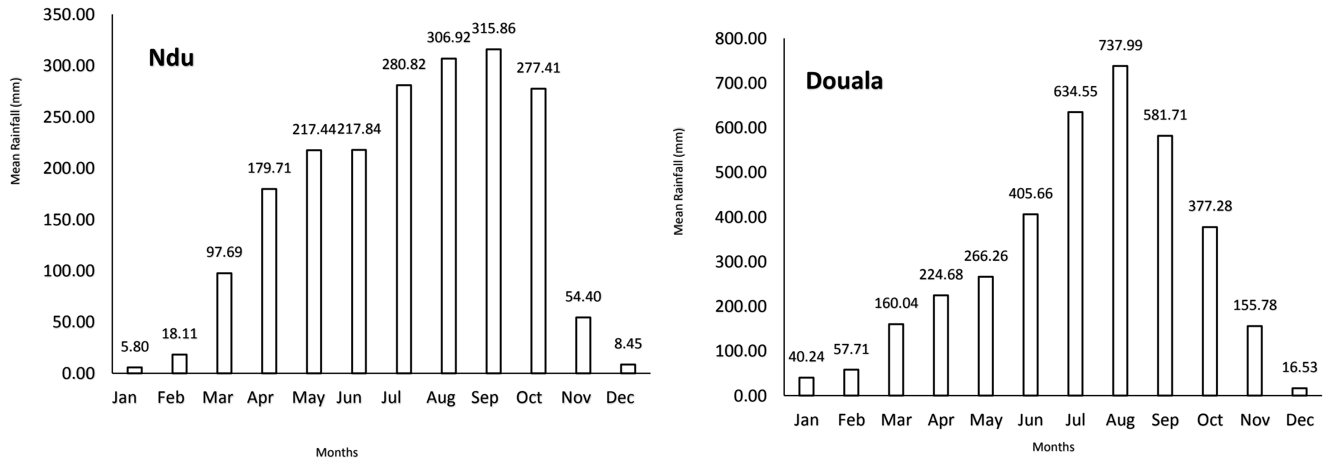

Figure 1: Mean monthly rainfall for Ndu and Douala

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The difference is in the amount of rainfall. Ndu receives less rainfall than Douala because of the distance from the Atlantic Ocean (continentality). While the interannual rainfall trend in Ndu has been near stable, the trend has been decreasing in Douala (Figure 2). Despite the decreasing trend in interannual rainfall in Douala, Douala receives more rainfall than Ndu due to its coastal location and the effect of continentality on Ndu.

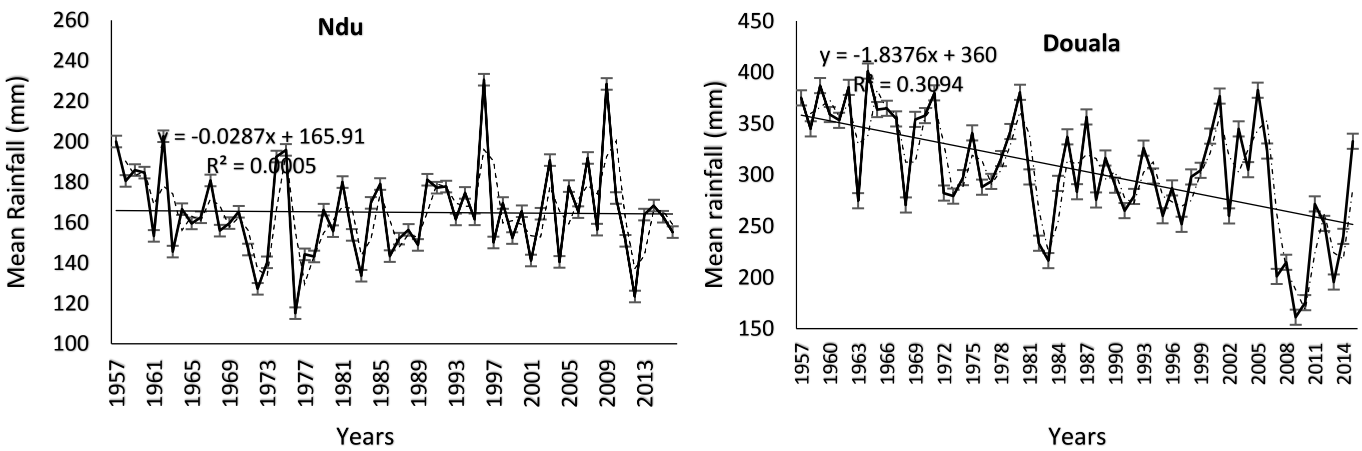

Figure 2: Interannual rainfall variation for Ndu and Douala (1957-2016)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

3.2 Rainfall Reliability

Tropical rainfall reliability is measured by the CV. CV thresholds of <20% correspond to rainfall reliability, while thresholds of >20% correspond to rainfall unreliability. An interannual CV may not give a clear picture of the actual situation because of much generalisation. In this study, a detailed scenario is presented decadally (Figure 3).

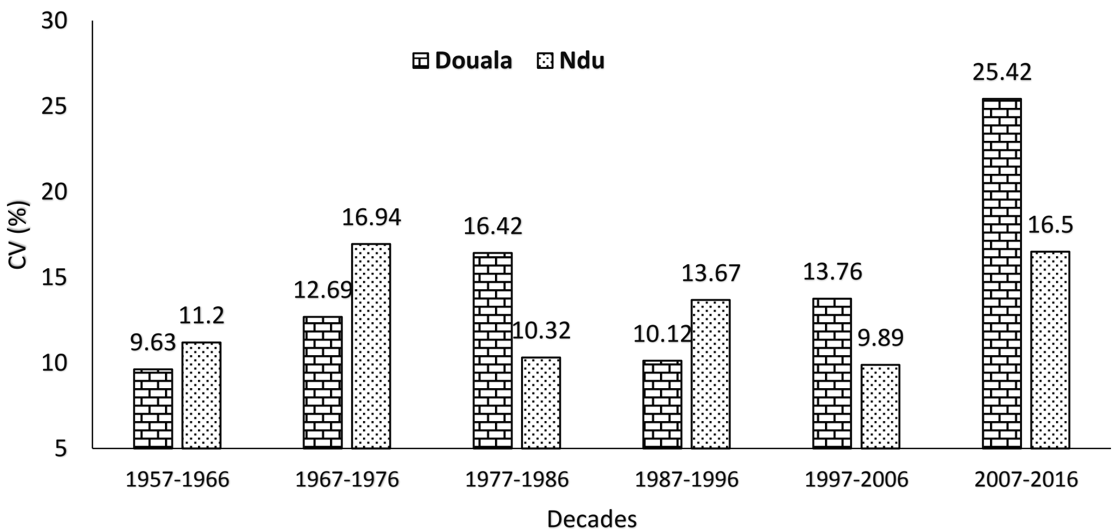

Figure 3: Coefficients of Variation for Douala and Ndu (1957-2016)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

In the decade 1957-1966 I had reliable CVs of 9.63% and 11.2% for Douala and Ndu respectively. From 1967-1976, the CVs were 12.69% and 16.94% for Douala and Ndu respectively. In the 1977-1986 decade, Douala had a CV of 16.42%, while Ndu had 10.32%. The proceeding decade's CVs were 10.12% for Douala and 13.67% for Ndu. The 1997-2006 decade had reliable CVs of 13.76% for Douala and 9.89% for Ndu. From 2007-2016, the CV for Doula was unreliable (25.42%), while that of Ndu was reliable (16.5%).

3.3 Mean Decadal Rainfall and Interannual Standardized Precipitation Index

Another source of disparity in rainfall characteristics in Douala and Ndu is in the amounts received (Figure 4).

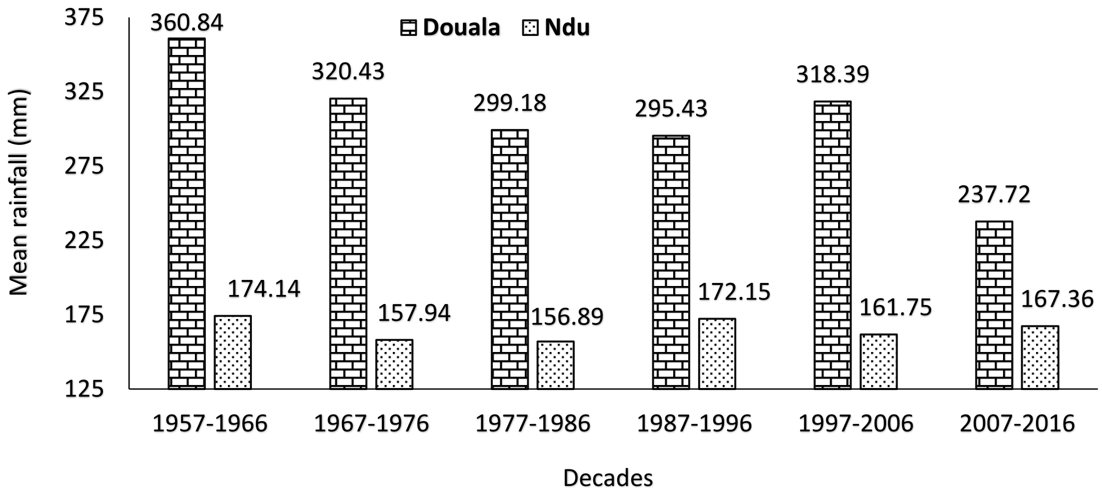

Figure 4: Mean decadal rainfall for Douala and Ndu

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The interannual SPI pattern is the same as the average annual rainfall pattern (Figure 5).

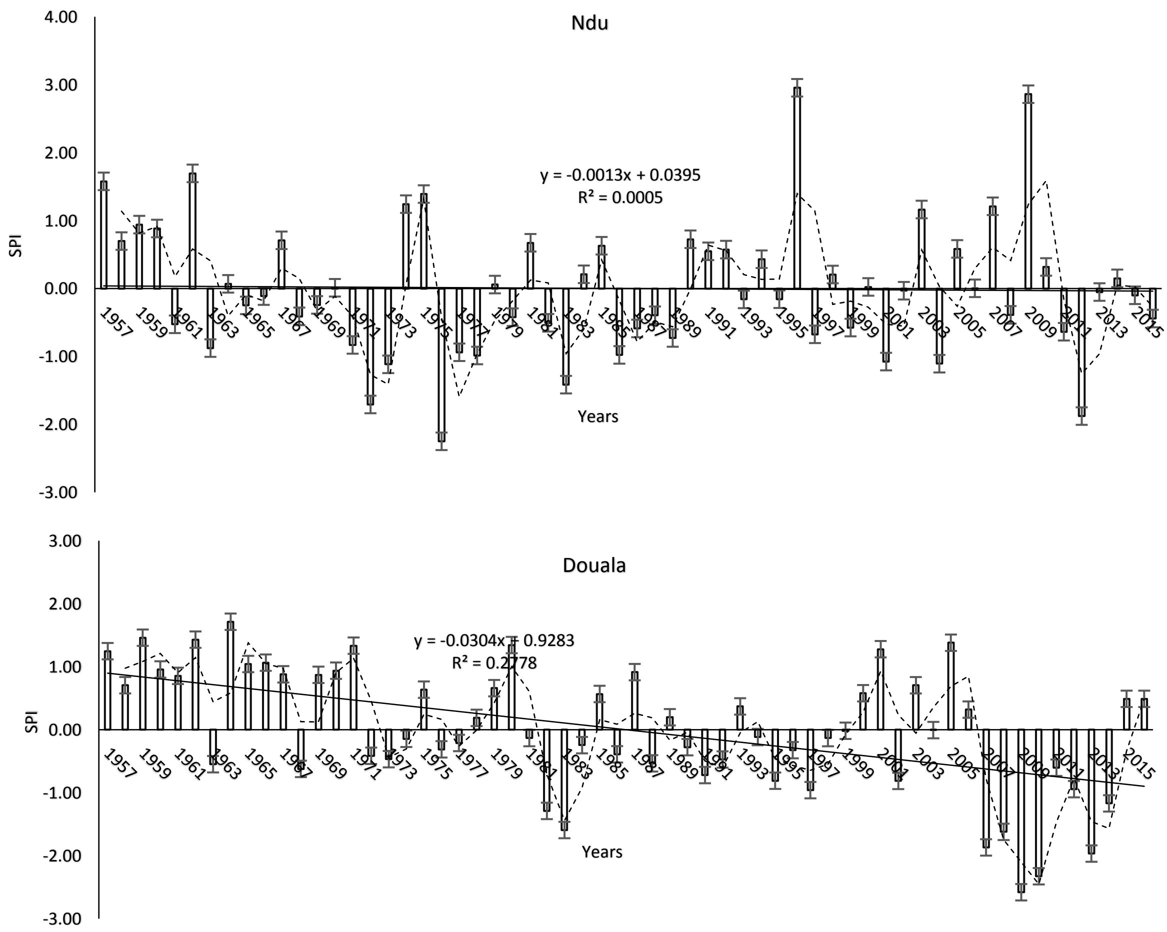

Figure 5: Interannual Standardized Precipitation Index for Ndu and Douala (1957-2016)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The interannual SPI pattern for Ndu is near stable, while that of Douala is decreasing. For all the decades in this study, Douala received more than double the amount of rainfall in Ndu. Again, rainfall reliability is supported by decadal SPI values. Decadal SPI variations show a clearer picture of rainfall variability.

3.4 Decadal Standardized Precipitation Index

Not all the SPI categories can occur in a weather station within 10 years. From 1957-1966, rainfall was near stable in Douala but witnessed a decrease in Ndu (Figure 6).

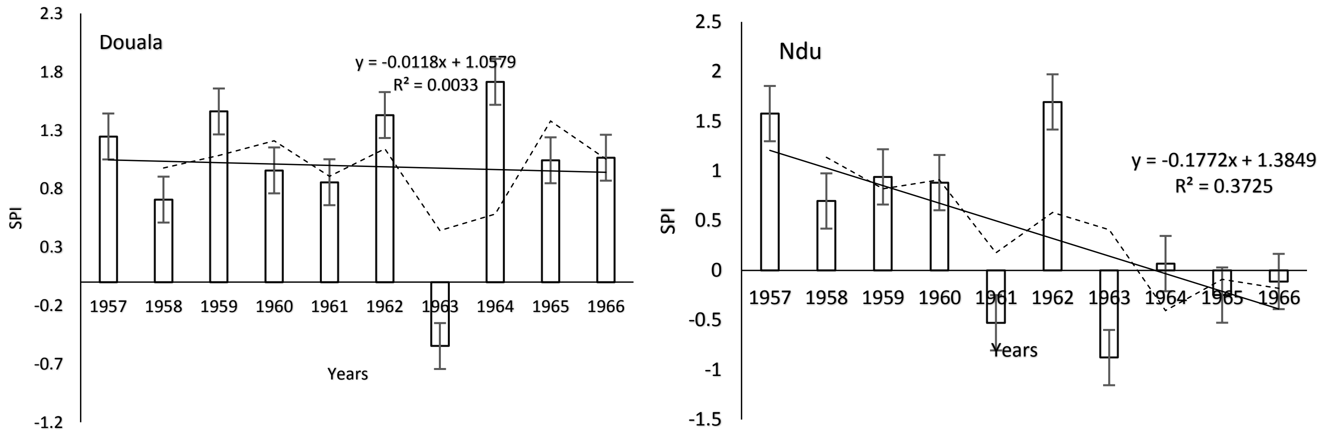

Figure 6: Standardized Precipitation Index for Douala and Ndu (1957-1966)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The SPI characteristics were as follows: 1 incident of severely wet conditions in Douala (1964) and two in Ndu (1957, 1962). There were 5 episodes of moderately wet in Douala (1957, 1959, 1962, 1965, 1966) and none for Ndu. Douala also had 3 incidents of mildly wet conditions (1958, 1960, 161), while Ndu had 5 (1958, 1959, 1960, 1962, 1964). Only one year of mild dryness was recorded in Douala (1963), but Ndu had three (1963, 1965, 1966). Ndu recorded more years of dry weather conditions (3-1963, 1965, 1966) than Douala (1-1963) during the 1957-1966 decade.

The 1967-1976 decade marked a decrease in rainfall trend for both stations, but the decrease in Douala was above the average, while that in Ndu was below average (Figure 7). The SPI conditions were as follows: moderately wet (Douala, 1-1971), (Ndu, 2-1974, 1975), mildly wet (Douala, 4-1967, 1969, 1970, 1975), (Ndu, 2-1967, 1970), mild dryness (Douala, 5- 1968, 1972, 1973, 1974, 1976), (Ndu, 3-1968, 1969, 1971), moderate dryness with 2 episodes in Ndu (1972, 1973), and 1 extreme dryness in Ndu (1976).

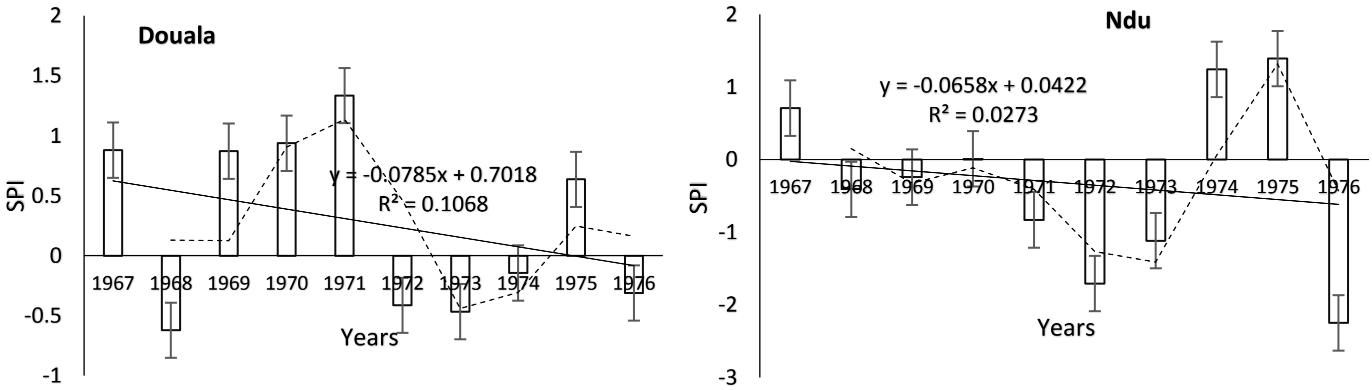

Figure 7: Standardized Precipitation Index for Douala and Ndu (1967-1976)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

In summary, Ndu had more severe dry weather conditions from 1967 to 1976 than Douala. While Douala had 5 mild dryness events, Ndu had 3 mild dryness, 2 moderate dryness and 1 extreme dryness.

From 1977-1986, there was a decreasing trend in rainfall in Douala, while Ndu experienced an increasing trend below the average (Figure 8). The SPI incidents were as follows: moderately wet (Douala, 1-1980; Ndu, 1-1979), mildly wet (Douala, 3-1978, 1979, 1985, Ndu, 3-1981, 1984, 1985), mild dryness (Douala, 4-1977, 1981, 1984, 1986, Ndu, 4-1977, 1978, 1982, 1986) and moderate dryness (Doula, 2-1982, 1983; Ndu, 2-1980, 1983).

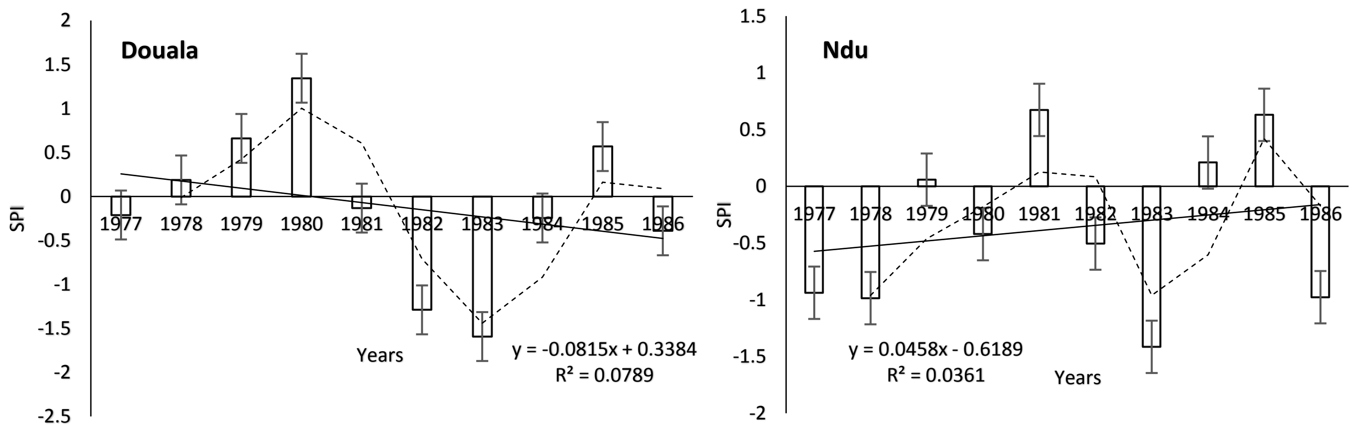

Figure 8: Standardized Precipitation Index for Douala and Ndu (1977-1986)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The distribution of wet and dry years was equal, but there were slight variations in the years that these episodes occurred. However, there was mild dryness (1977 and 1986) at both stations, as well as moderate in Douala and Ndu (Dryness, 1983). The 1987-1996 decade witnessed decreased rainfall in Douala, while rainfall in Ndu increased (Figure 9).

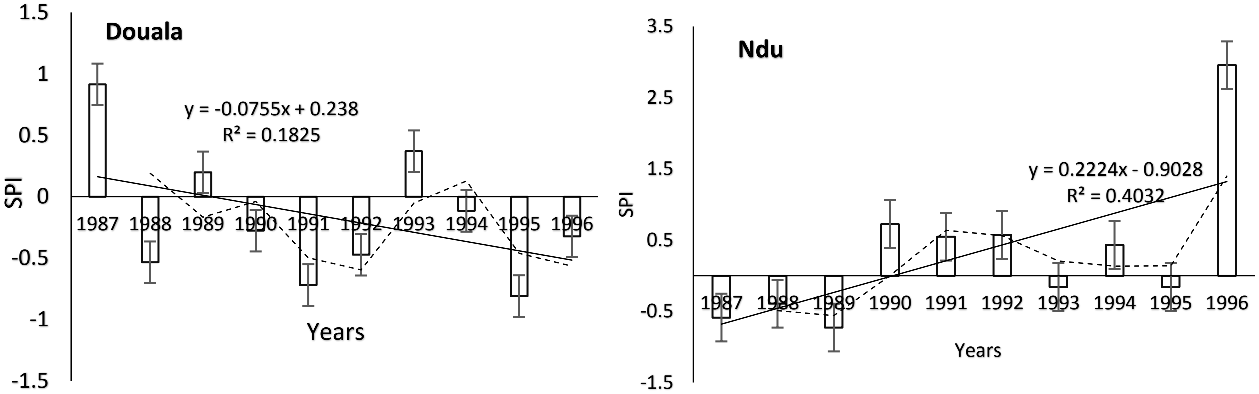

Figure 9: Standardized Precipitation Index for Douala and Ndu (1987-1996) Source: Generated from rainfall data for Ndu and Douala (1957-2016)

The SPI events were distributed as follows: extreme wet (1 incident in Ndu, 1996), mildly wet (Douala, 3-1987, 1989, 1993; Ndu, 4-1990, 1991, 1992, 1994), mild dryness (Douala, 7- 1988, 1990, 1991, 1992, 1994, 1995, 1996; Ndu, 5- 1987, 1988, 1989,1993, 1995). Douala had more dry years than Ndu. The 1997-2006 period was marked by increasing rainfall at both stations, though the increase in Ndu was more below the average (Figure 10).

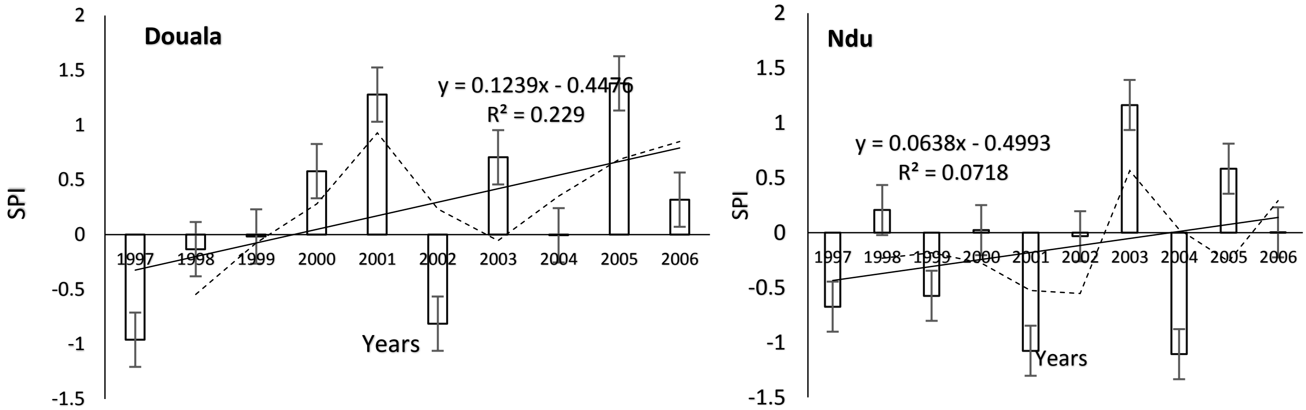

Figure 10: Standardized Precipitation Index for Douala and Ndu (1997-2006)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

During this decade, the SPI episodes were as follows: moderately wet (Douala, 2-2001, 2005; Ndu, 1-2003), mildly wet (Douala, 3-2000, 2003, 2006; Ndu, 4-1998, 2000, 2005, 2006), mild dryness (Douala, 5-1997, 1998, 1999, 2002, 2004; Ndu, 3-1997,1999, 2002), moderate dryness (Ndu, 2-2001, 2004). It can be seen that both stations had five incidents of dry weather conditions, but Ndu had 3 years of mild dryness (1997, 1999, 2002) and two years of moderate dryness (2001, 2004), while Douala had five years of mild dryness (1997, 1998,1999, 2002, 2004).

From 2007-2016, the rainfall trend in Douala was marked by an increase below the average, while Ndu witnessed a decrease in rainfall (Figure 11). This decade was the wettest in Ndu, with 2009 and 2007 recording extreme and severe wet conditions respectively. Conversely, this was the driest decade in Douala, with 3 years of severe dryness (2007, 2008, 2013) and 2 years of extreme dryness (2009, 2010). The other SPI incidents were as follows: mildly wet (Douala, 2-2015, 2016, Ndu, 2-2010, 2014), mild dryness (Douala-2, 2011, 2012; Ndu, 5-2008, 2011, 2013, 2015, 2016), moderate dryness (Douala, 1-2014; Ndu, 1-2012).

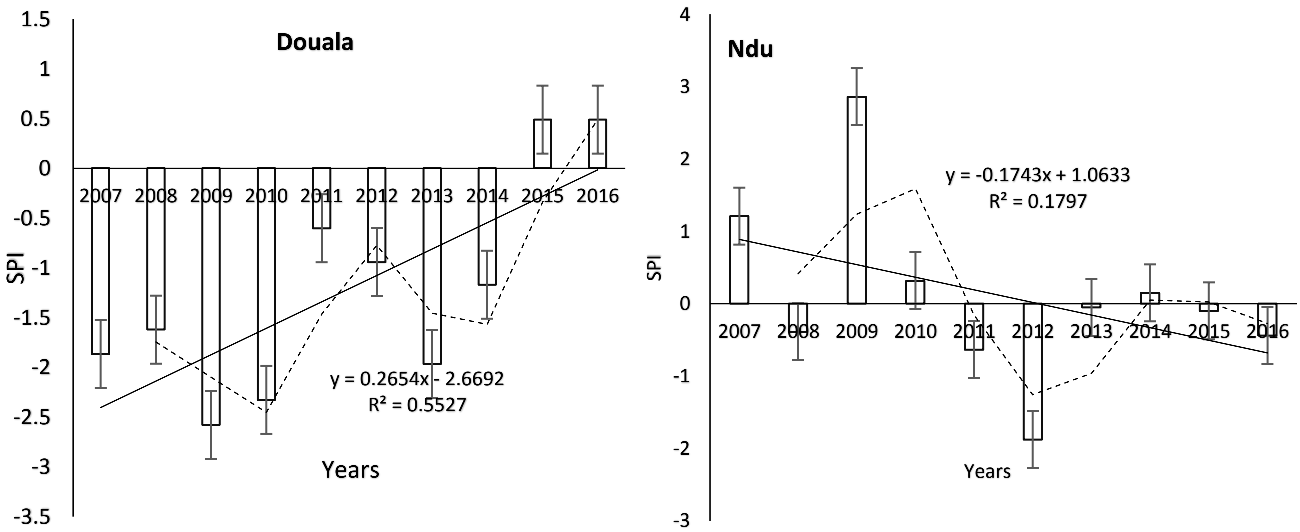

Figure 11: Standardized Precipitation Index for Douala and Ndu (2007-2016)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

In summary, there were 2 episodes of extreme wetness in Ndu, one severely wet in Douala, and 3 in Ndu (Table 2, Figure 12).

Table 2: Summary of SPI episodes for Douala and Ndu (1957-2016)					
SPI Value	SPI Class	Douala		Ndu	
		Episodes	%	Episodes	%
>2.00	Extreme wet	0	0.00	2	3.33
1.5 to 1.99	Severely wet	1	1.67	3	5.00
1.00 to 1.49	Moderately wet	9	15.00	4	6.67
0 to 0.99	Mildly Wet	18	30.00	20	33.33
-0.1 to -0.99	Mild dryness	24	40.00	23	38.33
-1.00 to -1.49	Moderate dryness	3	5.00	7	11.67
-1.50 to -1.99	Severe dryness	3	5.00	0	0.00
<-2	Extreme dryness	2	3.33	1	1.67
Total		60	100	60	100.00

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

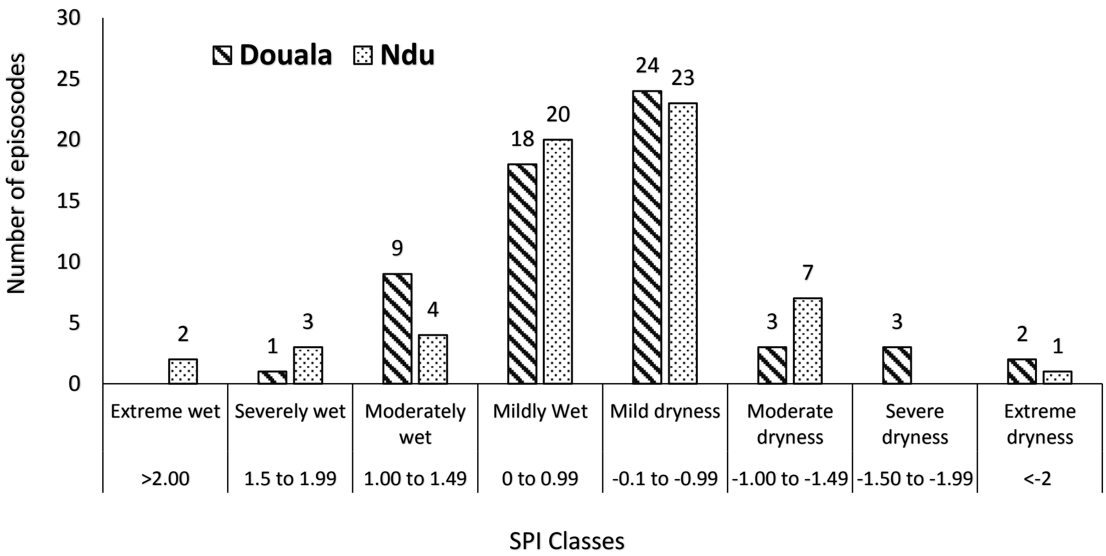

Figure 12: SPI episodes for Douala and Ndu (1957-2016)

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

A detailed summary of SPI episodes for Douala and Ndu is shown (Table 3).

Table 3: Standardized Precipitation Index Episodes for Douala and Ndu (1957-2016)					
Decades	SPI Classes	Douala (Years)	Episodes	Ndu (Years)	Episodes
1957-1966	Extreme wet	0	0	0	0
	Severely wet	1964	1	1957, 1962	2
	Moderately wet	1957, 1959, 1962, 1965, 1966	5	0	0
	Mildly Wet	1958, 1960, 1961	3	1958, 1959, 1960, 1962, 1964	5
	Mild dryness	1963	1	1963, 1965, 1966	3
	Moderate dryness	0	0	0	0
	Severe dryness	0	0	0	0
	Extreme dryness	0	0	0	0
1997-1976	Extreme wet	0	0	0	0
	Severely wet	0	0	0	0
	Moderately wet	1971	1	1974, 1975	2
	Mildly Wet	1967, 1969, 1970, 1975	4	1967, 1970	2
	Mild dryness	1968, 1972, 1973, 1974, 1976	5	1968, 1969, 1971	3
	Moderate dryness	0	0	1972, 1973	2
	Severe dryness	0	0	0	0
	Extreme dryness	0	0	1976	1

Table 3: Standardized Precipitation Index Episodes for Douala and Ndu (1957-2016)

1977-1986	Extreme wet	0	0	0	0
	Severely wet	0	0	0	0
	Moderately wet	1980	1	1979	1
	Mildly Wet	1978, 1979, 1985	3	1981, 1984, 1985	3
	Mild dryness	1977, 1981, 1984, 1986	4	1977, 1978, 1982, 1986	4
	Moderate dryness	1982, 1983	2	1980, 1983	2
	Severe dryness	0	0	0	0
	Extreme dryness	0	0	0	0
1987-1996	Extreme wet	0	0	1996	1
	Severely wet	0	0	0	0
	Moderately wet	0	0	0	0
	Mildly Wet	1987, 1989, 1993	3	1990, 1991, 1992, 1994	4
	Mild dryness	1988, 1990, 1991, 1992, 1994, 1995, 1996	7	1987, 1988, 1989,1993, 1995	5
	Moderate dryness	0	0	0	0
	Severe dryness	0	0	0	0
1997-2006	Extreme dryness	0	0	0	0
	Extreme wet	0	0	0	0
	Severely wet	0	0	0	0
	Moderately wet	2001, 2005	2	2003	1
	Mildly Wet	2000, 2003, 2006	3	1998, 2000, 2005, 2006	4
	Mild dryness	1997, 1998, 1999, 2002, 2004	5	1997, 1999, 2002	3
	Moderate dryness	0	0	2001, 2004	2
	Severe dryness	0	0	0	0
	Extreme dryness	0	0	0	0
2007-2016	Extreme wet	0	0	2009	1
	Severely wet	0	0	2007	1
	Moderately wet	0	0	0	0
	Mildly Wet	2015, 2016	2	2010, 2014	2
	Mild dryness	2011, 2012	2	2008, 2011, 2013, 2015, 2016	5
	Moderate dryness	2014	1	2012	1
	Severe dryness	2007, 2008, 2013	3	0	0
	Extreme dryness	2009, 2010	2	0	0

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

In summary, moderately wet conditions were 9 in Douala and 4 in Ndu. 18 mildly wet conditions were recorded in Douala and 20 in Ndu. There were 24 and 23 mild dryness episodes in Douala and Ndu respectively. Moderate dryness conditions were 3 in Douala and 7 in Ndu, 3 severe dryness in Douala, 2 extreme dryness in Douala and 1 extreme dryness in Ndu. Again, a decadal summary of the mean rainfall, standard deviation, mean SPI, CV, rainfall reliability, SPI class and trend is presented (Table 4).

Table 4: Summary of rainfall characteristics for Douala and Ndu

Decades	MRF (mm)	SD	Mean SPI	CV (%)	Reliability	SPI Class	Trend
				Douala			
1957-1966	360.84	34.75	0.99	9.63	Reliable	Mildly wet	Decrease
1967-1976	320.43	40.67	0.27	12.69	Reliable	Mildly wet	Decrease
1977-1986	299.18	49.12	-0.11	16.42	Reliable	Mild dryness	Decrease
1987-1996	295.43	29.91	-0.18	10.12	Reliable	Mild dryness	Decrease
1997-2006	318.39	43.81	0.23	13.76	Reliable	Mildly wet	Increase
2007-2016	237.72	60.43	-1.21	25.42	Unreliable	Moderate dryness	Increase
Mean	305.33	43.12		14.67	Reliable		
				Ndu			
1957-1966	174.14	19.5	0.41	11.2	Reliable	Mildly wet	Decrease
1967-1976	157.94	26.75	-0.32	16.94	Reliable	Mild dryness	Decrease
1977-1986	156.89	16.18	-0.37	10.32	Reliable	Mild dryness	Increase
1987-1996	172.15	23.53	0.32	13.67	Reliable	Mildly wet	Increase
1997-2006	161.75	16	-0.15	9.89	Reliable	Mild dryness	Increase
2007-2016	167.36	27.62	0.1	16.5	Reliable	Mildly wet	Decrease
Mean	165.04	21.60		13.09	Reliable		

Source: Generated from rainfall data for Ndu and Douala (1957-2016)

From 1957-2016, rainfall has been more reliable in Douala and Ndu, though interspaced with relatively dry decades (1977-1986, mild dryness; 1987-1996, mild dryness and 2007-2016, moderate dryness in Douala) and 1967-1976 (mild dryness); 1977-1986 (mild dryness) and 1997-2006 (mild dryness) in Ndu.

4. Discussion

Climatic indices have been developed from simple ones such as the percentage of normal precipitation and precipitation percentiles, to more complicated indices, such as the Palmer Drought Severity Index (PDSI) (World Meteorological Organization, 2012). Precipitation is the only required input parameter for the SPI. It is effective in analyzing wet and dry cycles with changes in latitude. It is more likely that datasets would only have 90% or only 85% complete records for meaningful analyses to be carried out. Users of SPI do not have this luxury and might have to settle for less (75–85% complete datasets) unless they look for estimation techniques to fill in the gaps in the records. Long and pristine data records (60 years for this study) are neither practical nor typical in many cases, especially in a developing country like Cameroon. Thus, the user needs to be aware of the statistical shortcomings of extreme events when dealing with shorter periods of records for various locations (Guttman, 1999).

Depending on the confidence and method of calculation, the use of estimated data is acceptable to show climate variability and change (Tume, 2022 a,b). Naturally, the fewer the estimated data used, the more reliable the results are (World Meteorological Organization, 2012). SPI is a good indicator of the change in precipitation over time. Its flexibility permits the precipitation change to be calculated over different time scales such as 3, 6, 12, 24, and 48 months. Rainfall deficit assessments using SPI are recorded within a threshold of zero because a drought sets in when the SPI values fall below the zero threshold. In this study, Douala was observed to record more rainfall deficits than Ndu, counteracting the norm that aridity increases with an increase in latitude. Such dry episodes are in the form of meteorological, agricultural and hydrological droughts that are recorded in all climatic regions across the globe. The climates of Ndu and Douala broadly fall under tropical climates as per the Köppen classification *(A-climates)*. Douala has a mixture of *Am*/*Af* (tropical monsoon/tropical rain forest) climates, whereas Ndu has an *Aw* (tropical savanna) climate. Tropical locations show seasonal precipitation changes (Strahler, 2013; Rohli and Vega, 2018). These differences are, in part, due to the influence of the various climatic controls (distance to large water bodies/continentality) (Rohli and Vega, 2018) (in the case of Ndu and Douala). Large water bodies are capable of storing huge quantities of energy during high-energy periods (the Atlantic Ocean that washes the coast of Douala, during the rainy season) and releasing this energy slowly to the atmosphere during low-energy times (dry season) (Barry and Chorley, 2003). These energy fluxes can have a significant effect on the climate of a location adjacent to the water body. The recurrence of more dry episodes in Douala can be attributed to the anthropogenic factors of dense settlement and economic activity (industrial and auto-mobile emissions that send hydrophobic nuclei into the atmosphere, leading to rainfall deficits).

Assuming that all other factors are equal, near oceans (Douala) are not as warm as they are in the interiors of continents (Ndu). Likewise, dry seasons in coastal locations are generally not as severe as they are in inland locations (Tume, 2022 a,b; Rohli and Vega, 2018). In addition, the onset of seasons is delayed significantly over and near oceans because of the oceanic absorption of energy during the rainy season and its slow release to the atmosphere from the onset of the wet season till the beginning of the dry season (Ahrens and Henson, 2019). Conversely, this study has revealed that the coastal city of Douala has more extreme weather events in terms of rainfall deficits than Ndu. Periods of rainfall deficits in Douala are often characterised by very dry weather and very high temperatures that cause human discomfort.

The *Am/Af* and *Aw* climatic regimes are directly influenced by the inter-tropical convergence zone (ITCZ). The dominant prevailing winds during the wet season are the warm-moist southeast (SE) winds from the Atlantic Ocean that push the ITCZ northward with the onset of the wet season. As a zone of convergence of the SE and northeast (NE) trade winds, tropical rainfall is largely influenced by the position of the ITCZ. From late October to November, the NE trade winds have a dominating influence, and the ITCZ is pushed to the south so that dry weather conditions prevail because of harmattan. From March to April, the SE trade winds have an urge over the NE trade winds, such that the ITCZ gradually moves northward, indicating the start of the wet season (Barry and Chorley, 2003). The SE trade winds are moisture-laden and favourable for higher relative humidity, condensation, and the development of towering clouds (Strahler, 2013; Barry and Chorley, 2003). Consequently, the position of the ITCZ shifts northward, and rainy conditions prevail (Patt and Winkler, 2007). The ITCZ is a band of varying width between the wind circulation of the northern and southern hemispheres (Ahrens and Henson, 2019; Dashew and Dashew, 1999). It is typically an area with lots of convective activity (thunderstorms), variable wind direction, and fluctuating wind strength.

5. Conclusion

The mean monthly rainfall increases from January to a maximum in July, August, and September and gradually declines from October to December in Ndu and Douala. The interannual rainfall is near stable in Ndu (continentality), but decreasing in Douala as a result of the hydrophobic nuclei from industrial emissions and automobiles. Interannual rainfall is not always a good measure of rainfall variability because decreasing rainfall can still be reliable, whereas increasing rainfall can be unreliable. Hence, the interannual CV for Ndu is 13.09% (reliable), whereas that of Douala is 14.69% (reliable). These characteristics show that Douala is wetter (higher amounts of mean monthly and annual rainfall) than Ndu, although rainfall is more reliable in Ndu. Nearness to the ocean does not always depict rainfall reliability as anthropogenic activities may always offset local atmospheric conditions as depicted by more dry rainfall episodes in Douala. This calls for more research on rainfall characteristics in different ecological zones of Cameroon to establish more intriguing local realities. These results are useful in planning for water resources management in the face of future climatic uncertainties. Douala is the largest urban agglomeration in Cameroon and faces many challenges, among which is water. Ndu on the other suffers from water scarcity as most of the watersheds are covered by eucalyptus. The climate crisis is setting in silently to aggravate the water crises. This calls for more reflections on how to harness the already dwindling water resource base to meet the needs of the growing population.

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