Research

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Assessment of the Spatial Variation in Rainfall Seasonality in Benue State

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1. Abstract

This study utilized the seasonality index to investigate rainfall trends and seasonal regimes in Makurdi, Otukpo, Gboko, Zaki-Biam, Igumale, Vandeikya, Katsina-Ala and Bopo stations in Benue state. The results revealed at least mean seasonality index of 0.68 in southern Vandeikya station and 0.77 in Makurdi northern station. Seasonality rainfall regimes varied across the state with a shorter, drier season (RSWSDS) observed in Vandeikya and Igumale stations, a dominant Seasonal Regime (SR) in Otukpo, Gboko, Bopo and Katsina-ala stations, and a long drier season (MSWLDS) experienced in the Makurdi and Zaki-biam stations. These variations in rainfall regimes were observed in 1987, 1999, 1993, 1996, 1998, 2000, 2012, 2015 and 2017 years showing the marked seasonal years with a long drier season (MSWLDS) of 5 to 6 months of rainfall while the other years are seasonal regimes. The Mann-Kendall trend test revealed an insignificant upward trend for Makurdi, Oturpo, Gboko, Zaki-biam, Igumale and Vandeikya stations. In contrast, the Bopo and Katsina-Ala stations revealed insignificant downward trends meaning that there is no significant trend in the rainfall seasonality index across all stations in Benue state.

2. Keywords:
Seasonality Index, Mann-Kendal Test, Rainfall Regimes, Rainfall etc

3. Introduction

Greenhouse emission levels are a precursor for earth temperature rise, changes in precipitation, shifting of seasons, extreme floods and droughts (Manyeruke et al., 2013)[13] which threatens farmers livelihood and wellbeing (Mkuhlani et al. 2019) [14]. Rainfall is characterized by seasonal and interannual spatial variabilities (Alhamshry, et al. 2019)[14] caused by the position and movement of the ITCZ which determines the dominant air masses prevailing during the seasons. The tropical maritime air masses bring moisture and move northeastwards for 4 months from the south-west coast with moisture to support large scale convection, form massive cummulo-nimbus clouds and rainfall. While the south-west push from the Sahara Desert of the ITCZ by the tropical continental air masses supplies dry light moisture in a rapid push back to the coast bringing dry season and the harmattan in negative feedback (Obarein and Amanambu 2019)[17].

Ninety-seven per cent of cropland agriculture in sub-Saharan Africa is dependents on seasonal rainfall (Oyinbo et al., 2014)[23]. For example, seasonal variation within a decade in rainfall in the Worobong Ecological Area of Fanteakwa District, Ghana revealed a decline in the major season from 1449.94mm between 1985 to 1994 to 1278.58mm and 1098.94mm between 1995-2004 and 2005 to 2014 (Kyei-Mensah et al. 2019)[10]. In Ethiopia, the monomodal summer rainfall cycle between June to September and peaks in July and August is observed in Northern and Central Ethiopia while bimodal spring rainfall cycles experienced in March to May with peaks in April to May and a rapid cycle in October to November is observed in the South (Alhamshry, et al. 2019) [4]. In Botswana rainfall is erratic such that areas with a high coefficient of variation (CV) of 50% e.g., Tsabong is observed with low rainfall and areas with high rainfall such as Kasana records a low CV of 29% (Byakatonda et al, 2018)[6].

In Nigeria, rainfall decreases with increasing latitude from 400mm per year in the northeast to 2710mm per year around the Port Harcourt and Calabar regions of the south etc. Since Nigeria's atmosphere is characterized by a plethora of variations in relative humidity, temperature and rainfall due to its tropical position (Oguntoyinbo, 1983; Nieuwolt, 1977) [20, 16], there is a need to investigate the seasonal variation in rainfall amongst the states where rainfed agriculture is the dominant occupation of the people to aid agricultural planning and maximization of the agricultural cultivability of the state.

4. Materials and Methods

4.1. Study Area

Benue State is straddled between the Savannah Belt North and the Rain Forest South of Nigeria with a blend of climate, pedology and vegetation. It is situated on Latitudes 6° 25'N` and 8° 8' N and longitudes 7° 47'E and 10° 0' E with a landmass of approximately 34,059km2, a projected population of 7,097,863 in 2020 from 2006 (NPC; 2006) and politically

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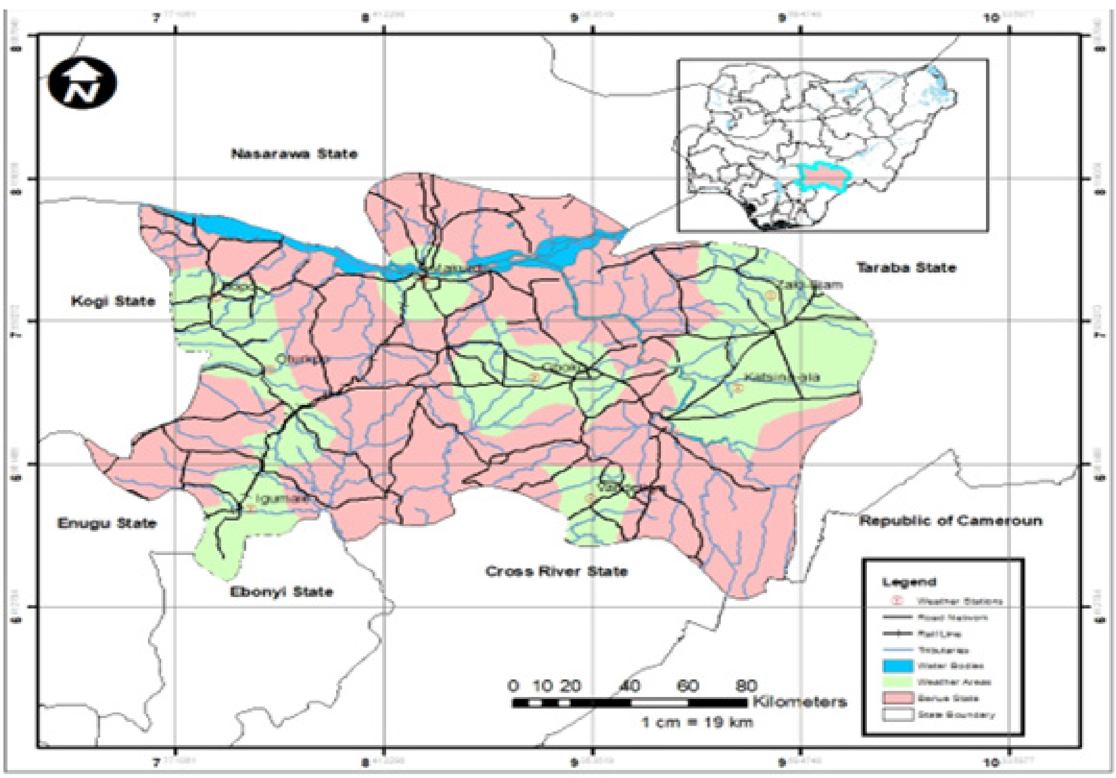
bifurcated into 23 local council areas including the capital in Makurdi. It is bordered to the North by Nasarawa State, Taraba State to the East, Cross River State and the Republic of Cameroun to the South and South East, and Kogi and Enugu States to the West and South West of Nigeria with an ethnically homogeneous Tiv, diverse Idoma, Igede, Etulo, Jukun and immigrant's Ibo, Hausa, Yoruba and other Nigerians.

Benue state experiences both the dry and wet seasons; the dry season starts with a harmattan from November to January and ends in March with heat while the wet season commences in April with high humidity and precipitation and ceases in October. Light showers are also common in January, February and March due to the East-West line squalls to signal the preparation of the planting season. The area has recorded annual rainfall of between 1200mm to 1500mm, average maximum and minimum diurnal temperatures of 35°C and 21 °C during the wet season and 37°C and 16°C during the dry season, relative humidity of 74.88% and diurnal sunshine of 6.2hrs.

The landscape is defined by oxisols and ultisols tropical ferruginous soil in the North, lateritic and forest vegetation cover in Oju, Obi, Ogbadibo, Oturpo and Vandekiya areas in the South, entisols, inceptisols with young soils on hill slopes and recent alluvium and Euthropic Brown earths and volcanic parent materials in Gbajimba, deep gullies in Ogbadibo an extension of the eastern Nigerian, meta sedimentary deep gully system and other gully sites in Makurdi North Bank area, Tse Mker and Gbem in Vandeikya, and Gbajimba town. Stream bank erosion in Gboko town and incised streams on sloppy ground coterminous to Anwase, Kyogen, Abande ranges in Kwande LGA are peculiar environmental landscape and problems. The State is Drained by the Benue River and tributaries from the Cameroonian mountains which makes a confluence with the Niger River in Lokoja (Tyubee, 2006; Adamgbe and Ujo, 2012) (Figure 1).

Figure 1: Study Area



4.2. Methods

4.2.1. Mann-Kendall Trend Test

The Mann-Kendall test is a non-parametric statistical test used to test for presence of an increasing or a decreasing trend in the considered time series (Mann, 1945, Kendall, 1975)[12, 9]. Mann-Kendalll test statistic was done using R Language. Studies that have employed the Mann–Kendall test for the detection of trends in hydrological time series data are (Wilks, 1995; Serrano et al., 1999; Brunetti et al., 2000a; 2000b; Onoz and Bayazit, 2003; Patra et al., 2012)[28, 25, 20, 22, 24] and it has proven to be more efficient for detecting trend in a skewed data distribution (Lonobardi and Villani, 2009).

The computations assume that the data are independent and are identically distributed.

The mathematical equation for calculating Mann-Kendall statistics is

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

Where n is the number of data, x is the data point at times j and k (k>j),

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

and the sign function is given as

Where S = Mann-Kendall test statistic, Sgn = an indication function, xj and xk are the annual values in years j and k, j > k, respectively. A positive S value indicates an increasing trend while a negative S indicates a decreasing trend in the data series.

In a situation where there are ties (i.e., equal values in the x values), the variance of S is estimated and given by:

Var (S) = [n (n-1) (2n+5)]-∑mi=1 ti(ti-1) (2ti+5)]
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Where m = number of tied groups in the data set and ti is the number of data points in the ith tied group.

For a time, series such as this with n longer than 10 (n > 10), S approximates a standard normal distribution, ZMK. ZMK is computed to test the presence of a statistically significant trend. The Z test statistics is given as;

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

A positive value of Z indicates an increasing trend while a negative value indicates a decreasing trend.

The Julian days defined as the particular day of the year in which a date falls was used. For example, the 28th day of February marks the 59th day of the year from January 1st.

4.2.2. Theil-Sen's Slope

Theil-Sen's Slope was used to estimate the slope of an existing trend that is, the change in rainfall (mm) per year. It is used where the trend is assumed to be linear. It is insensitive to outliers and has been called the most popular nonparametric techniques for estimating a linear trend. The trend magnitude is computed;

(Xj-Xi)
B = Median ______________
Tj-Ti

Where xj and xi = values at times tj and ti respectively.

4.2.3. Rainfall Seasonality Index

The rainfall seasonality index was estimated for each year over the period of study for all the stations using the method of Walsh and Lawler (1981). The seasonality index is computed as follows:

$$SIi = \frac{1}{Ri}\sum_{n=1}^{n=12}\left|Xin - \frac{Ri}{12}\right|$$

Where Ri is the total annual precipitation for the particular year under study and Xin is the actual monthly precipitation for month. This method has been employed by several scholars in estimating the seasonality of rainfall across a zone (Adebayor, 1997; Adejuwon, 2012).

The various categories of climate based on rainfall seasonality can be assessed or interpreted by using the following values of the SI index as provided by Walsh and Lawler (Table 1).

Table 1: Seasonality Index (SI) Class Values and the Associated Rainfall Regimes (after Walsh and Lawler, 1981)

SI Class Limit	Rainfall Regime
≤ 0.19	Very equable
0.20-0.39	Equable but with a definite wetter season
0.40-0.59	Rather seasonal with a shorter, drier season
0.60-0.79	Seasonal
0.80-0.99	Markedly seasonal with a long drier season
1.00-1.19	Most rain in three months or less
≥1.20	Extreme, almost all rain in 1-2 months

4.2.4. Exponential Population Projections

Nt = P0 ert

Where; Nt = number of people at a future time, P = number of people at the beginning time

E = base of the natural logarithms at 2.71828, r = rate of increase divided by 100 and

t = time period involved.

5. Result and Discussion

5.1. Rainfall Seasonality in Benue State

The rainfall seasonality index in Table 1 and 2 and figures 2, 3 and 4 which classifies the type of climate in relation to water availability was calculated using the Walsh and Lawler's method. Higher values of the seasonality index indicate greater water resource variability and scarcity in time or the occurrence of rain in few months of the year. It therefore measures the spread and steadiness of rainfall during the wet season (Walsh and Lawler, 1981).

The result of the individual seasonality index revealed that the mean seasonality index over the study period range from 0.68 in the southern part of the state to 0.77 in the northern part of the state. Thus, based on the interpretation as given by Walsh and Lawler, (1981) seasonality index class values, only one major regime (the markedly seasonal regime could be observed. However, considering the lowest seasonality index to the

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highest seasonality index, three major regimes could be observed; The Rather Seasonal with a Shorter, Drier Season (RSWSDS), the Seasonal Regime (SR) and the Markedly Seasonal with a Long Drier Season (MSWLDS) (Table 2).

Table 2: Descriptive Summary of Rainfall Seasonality in Benue State

Station	Mean Seasonality Index	Highest Seasonality Index	Lowest Seasonality Index	Standard Deviation	CV (%)
Makurdi	0.77	0.88	0.64	0.06	7.49
Otukpo	0.71	0.84	0.58	0.06	8.9
Gboko	0.71	0.83	0.58	0.06	8.05
Zakibiam	0.77	0.88	0.69	0.05	6.65
Igumale	0.71	0.83	0.57	0.06	8.39
Vandeikya	0.68	0.82	0.53	0.07	10.59
Bopo	0.73	0.87	0.59	0.06	8.59
Katsina-Ala	0.72	0.94	0.59	0.07	9.34

5.2. Rainfall Seasonality Index

The Vandeikya station in the southern part of the state recorded the lowest value of the mean seasonality index of 0.68 while the Makurdi station (in the north) recorded the highest value of the mean seasonality index (0.77). The latter is very close to the next regime of Walsh and Lawler classification which indicates that the northern region of the state easily experience the markedly seasonal regime with 5-6 months of rains as against the former (in the southern region) with at least value of 0.68 which is closer to the previous regime; the purely seasonal regime with 7-8 months of rains (Figure 2).

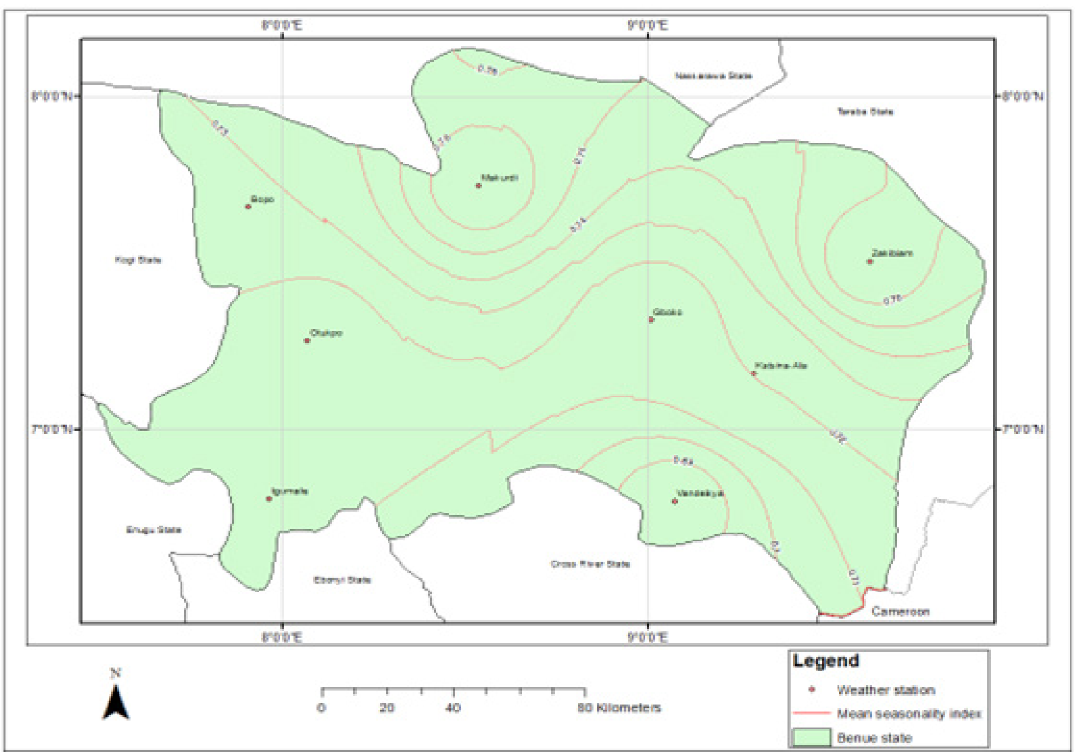

Figure 2: Spatial Variation in the Mean Seasonality index of Rainfall in Benue State
Source: Author's Analysis (2019)

The Katsina-Ala station in the northern region recorded the highest value (0.94) as opposed to the Vandeikya station in the Southern region with lower values (0.82). Also, the Southern region of the state recorded the least value of the lowest seasonality index as expected when compared to northern

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stations with higher values. The coefficient of variation (CV) of the seasonality index revealed the Zakibiam and Makurdi station (Benue north) recording the least CV of 6.65 and 7.49 respectively while the highest value was 10.59% in Vandeikya, Benue South. Larger values of the CV indicate that the rain is more spread or distributed over the year (i.e., occurs in most months of each year) while lower values indicate that the precipitation months is homogenously distributed (i.e., occurs in few months of the year)(Figure 3, 4).

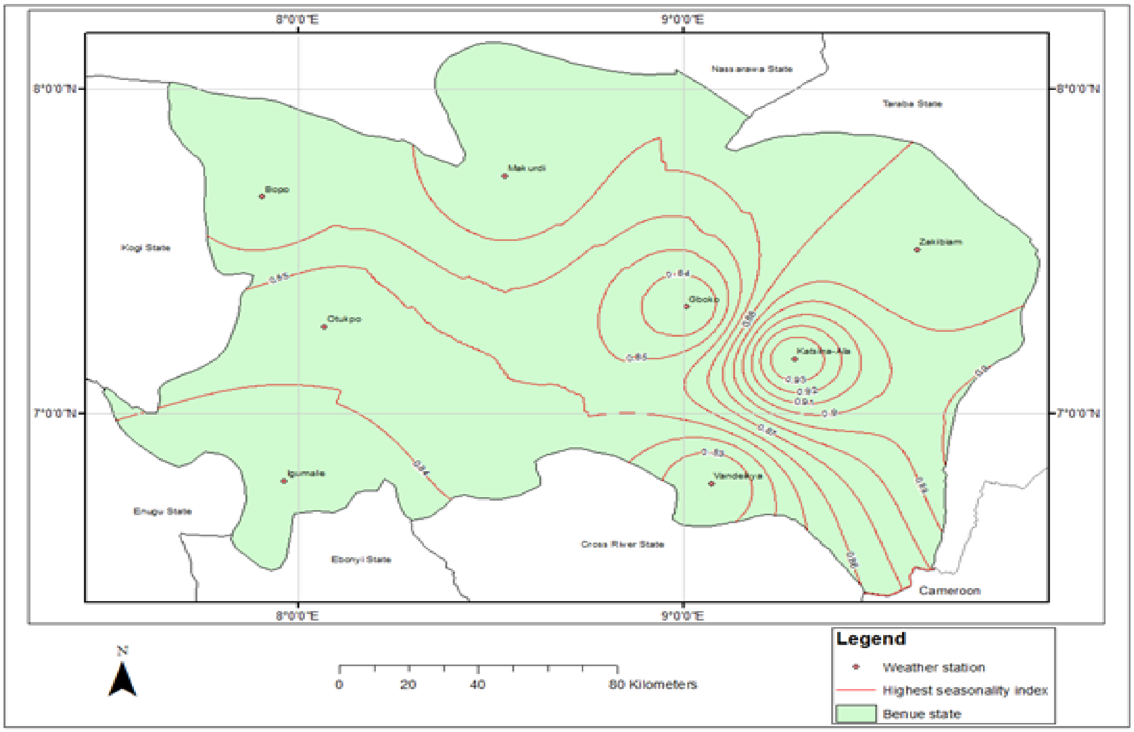

Figure 3: Spatial Variation in the Highest Seasonality index of Rainfall in Benue State
Source: Author's Analysis (2019)

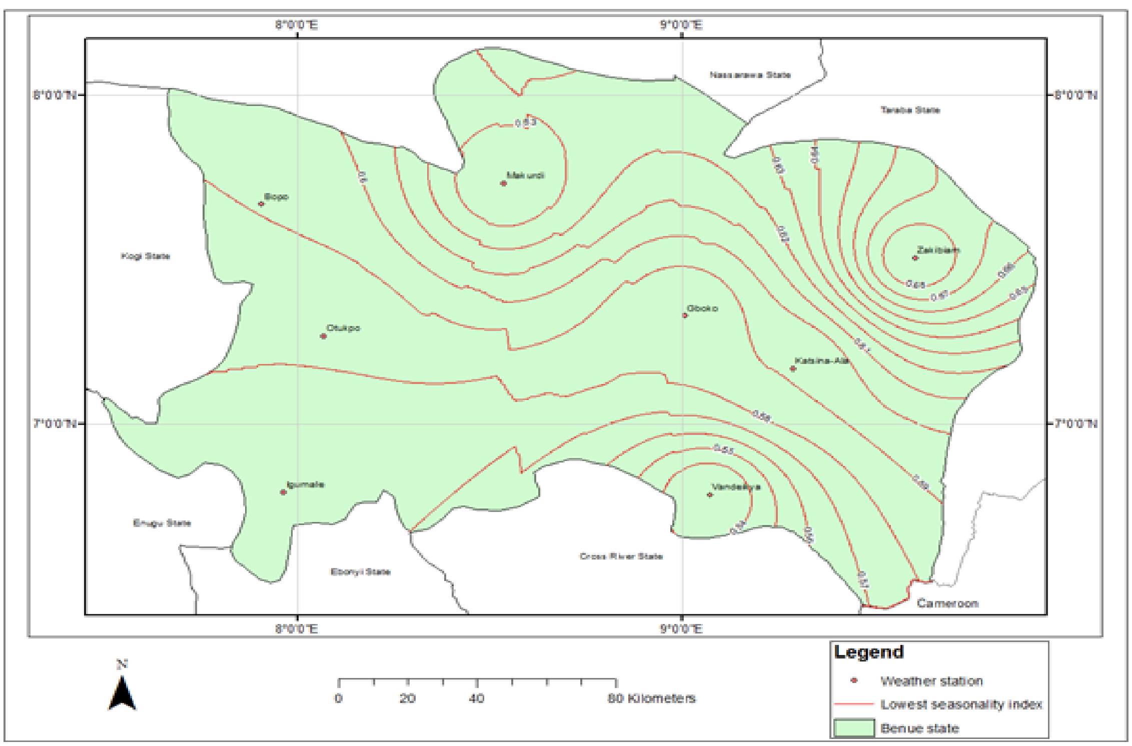

Figure 4: Spatial Variation in the Lowest Seasonality index of Rainfall in Benue State
Source: Author's Analysis (2019)

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Thus, from the foregoing interpretation of the seasonality index, the selected locations of the study area can be classified into three rainfall regimes shown in Figure 5 identified based on the Walsh and Lawler's (1981) method. The Rather Seasonal with a Shorter, Drier Season (RSWSDS): This regime is dominant in the extreme south and south western eastern part of the state at the Vandeikya and Igumale station. The Seasonal Regime (SR): this exists at some years in all of the stations and stands as the dominant regime throughout the study period but more pronounced at the Otukpo, Gboko, Bopo and Katsina-Ala station.

The Markedly Seasonal with a Long Drier Season (MSWLDS): This is more dominant in the most northern region of the state (Makurdi) and the northeastern part (Zakibiam). In summary, the study reveals that there is an increase in the degree of rainfall seasonality in a south-north direction. The implication of the above regime is that only the extreme southern part of the state could conveniently support double cropping without irrigation. In addition, crops requiring a long-wet season particularly trees and root crops can conveniently be cultivated in the same part of the state. This observation of the south north increase in the seasonality index is also related to previous studies index in some part of Nigeria. For example, Adebayo, (1997, 2001) observed three regimes in Adamawa state; the Rather Seasonal with a Shorter Drier Season, the Seasonal Regime and the Markedly Seasonal with a Long Drier Season and two major regimes in Taraba; the markedly seasonal and the purely seasonal regime with 7 to eight months (Figure 5).

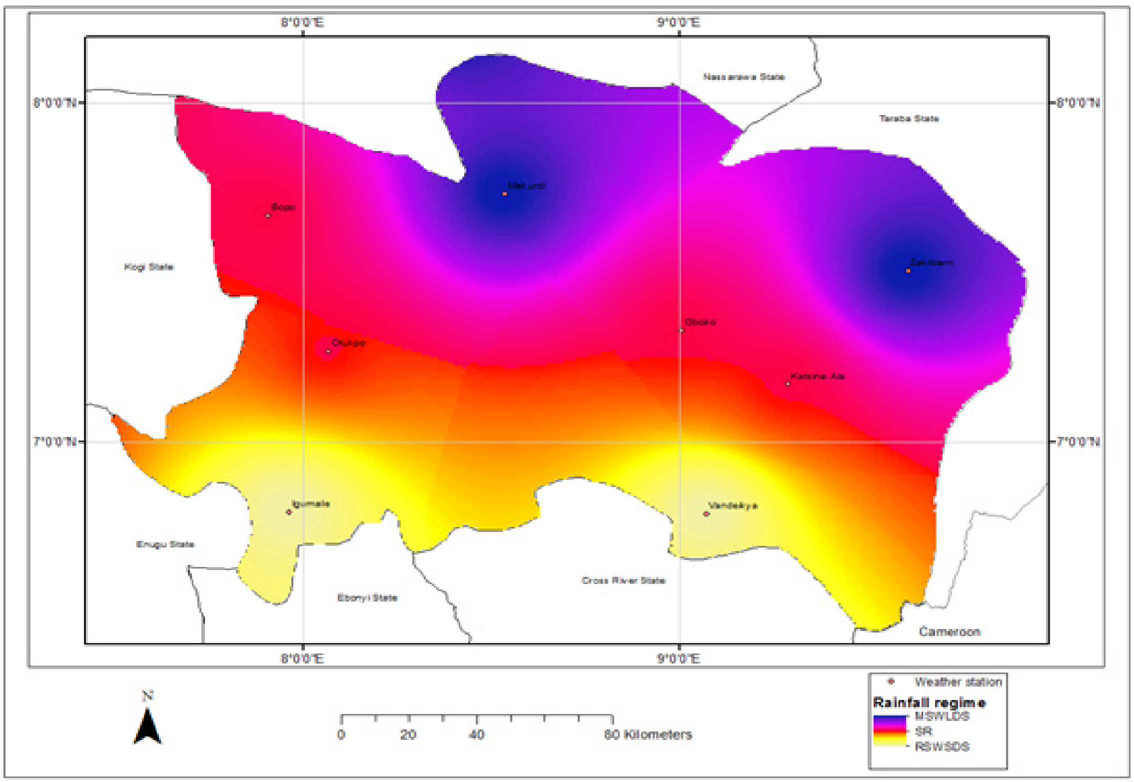

Figure 5: Zonal Classification of Rainfall Regime in Benue State (1984-2017) According to Walsh and Law's (1981) Method

RSWSDS: Rather Seasonal with Short Drier Season

SR: Seasonal Regime

MSWLDS: Markedly Seasonal with Short Drier Season

Source: Author's Analysis (2019)

5.3. Trend Analysis of Rainfall Seasonality

The seasonality index for all stations as stated earlier is presented in Table 3, Time series graphs plotted out of this result revealed in figures 6 to 13 show the trend of the rainfall seasonality over the study period for each station. From this, it could be observed that several fluctuations exist in the rainfall seasonality index from 1984 to 2017. For Makurdi station, the seasonality index ranges from 0.64 in 2001 to 0.88 in 1990. Two rainfall regimes could be observed. The years 1987, 1999, 1993, 1996, 1998, 2000, 2012, 2015 and 2017 are markedly seasonal years with a long drier season i.e., with 5-6 months of rains while the rest of the period (with values ranging from 0.64 to 0.78) are seasonal. For Otukpo station, two major regimes can be identified for all the years with an exception of the year 2009 when a different regime of rather seasonal with a shorter drier season was observed. Of the two major regimes identified, only the years; 1989, 1998, and 2000 are markedly seasonal with a long drier season while the rest of the years witnessed a seasonal

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regime. Thus, the Otukpo station witnessed a seasonal regime all through the thirty-four years with just five years left out (Table 3).

Table 3: Rainfall Seasonality for all the Stations from 1984 To 2017

Year	Makurdi	Otukpo	Gboko	Zakibiam	Igumale	Vandeikya	Bopo	Katsina-Ala
1984	0.71	0.65	0.69	0.7	0.68	0.66	0.67	0.69
1985	0.71	0.66	0.65	0.69	0.65	0.6	0.73	0.94
1986	0.7	0.65	0.65	0.7	0.65	0.57	0.71	0.65
1987	0.8	0.74	0.72	0.72	0.73	0.68	0.82	0.72
1988	0.76	0.73	0.73	0.76	0.73	0.71	0.75	0.73
1989	0.86	0.84	0.83	0.86	0.83	0.81	0.85	0.83
1990	0.72	0.62	0.64	0.74	0.63	0.59	0.69	0.64
1991	0.77	0.68	0.69	0.76	0.69	0.65	0.77	0.69
1992	0.79	0.72	0.72	0.76	0.72	0.69	0.74	0.72
1993	0.8	0.73	0.73	0.79	0.73	0.68	0.79	0.73
1994	0.79	0.75	0.76	0.81	0.76	0.71	0.75	0.76
1995	0.78	0.73	0.73	0.76	0.73	0.68	0.75	0.73
1996	0.8	0.74	0.73	0.78	0.74	0.68	0.78	0.73
1997	0.72	0.65	0.67	0.73	0.66	0.62	0.68	0.67
1998	0.88	0.82	0.81	0.85	0.82	0.81	0.87	0.81
1999	0.76	0.67	0.69	0.78	0.68	0.64	0.76	0.69
2000	0.84	0.81	0.82	0.82	0.82	0.82	0.85	0.82
2001	0.64	0.65	0.68	0.7	0.66	0.67	0.69	0.68
2002	0.8	0.78	0.8	0.81	0.79	0.81	0.77	0.8
2003	0.7	0.63	0.68	0.71	0.67	0.65	0.66	0.68
2004	0.77	0.69	0.71	0.74	0.7	0.71	0.71	0.71
2005	0.76	0.69	0.68	0.77	0.69	0.66	0.68	0.68
2006	0.85	0.76	0.76	0.83	0.77	0.73	0.76	0.76
2007	0.83	0.77	0.73	0.81	0.75	0.67	0.73	0.73
2008	0.77	0.7	0.7	0.78	0.7	0.66	0.7	0.7
2009	0.69	0.58	0.58	0.71	0.57	0.53	0.59	0.59
2010	0.75	0.64	0.63	0.74	0.63	0.57	0.63	0.63
2011	0.87	0.78	0.78	0.88	0.77	0.74	0.78	0.78
2012	0.83	0.71	0.71	0.82	0.71	0.64	0.71	0.71
2013	0.69	0.61	0.65	0.73	0.63	0.59	0.65	0.65
2014	0.74	0.67	0.68	0.75	0.68	0.64	0.68	0.68
2015	0.8	0.73	0.76	0.82	0.75	0.73	0.76	0.76
2016	0.73	0.73	0.73	0.74	0.73	0.72	0.73	0.73
2017	0.8	0.76	0.78	0.84	0.73	0.76	0.78	0.78

For Gboko station, similar trend pattern as observed in the Otukpo station is also replicated here as the year 2009 still witness the rather seasonal with short drier season. Also, the rest of the years as observed in Otukpo station (seasonal regime) with an exception of the year 2002 when a long drier season could also be observed. For Zakibiam station, only two major regimes could be strictly observed. It is characterized with more years of markedly seasonal regime with 5-6 months of rains or a long drier season in the years; 1989, 1994, 1998, 2000, 2002, 2006-2007, 2011-2012, 2015 and 2017 while the rest of the years are seasonal. The Zakibiam station thus witnessed more years of a long drier seasonal regime than the rest of the stations.

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In Igumale station, a dominant seasonal regime is observed almost all through the period of study with few exceptional years. Apart from the year, 2009 that witnessed a rather seasonal with shorter, drier season over the period of study and the years; 1989, 1998 and 2000 experienced a markedly seasonal with a long drier seasonal regime, the rest of the 30 years out of the 34 years' period of study experienced a seasonal regime. Thus, the Igumale station can be classified as a zone of seasonal rainfall regime. The Vandeikya station is marked with a more pronounced three regimes than the rest of the stations where two major regimes were marked with an exception of the year, 2009. Here, the rather seasonal with a shorter, drier season could be observed for a greater number of years (1986, 1990, 2009-2010 and 2013) compared to the rest of the stations where only one year of this category were observed. Only three years (1989, 1998, and 2000) are markedly seasonal with a long drier season (5 to 6 months of rainfall) while the rest of the period are markedly seasonal.

Going through the trend in Bopo station, only two regimes were observed. The years 1987, 1989, 1998 and the year, 2000 are markedly seasonal while the rest of the period are seasonal. However, the station is not left out of the exceptional case as observed in the rest of the stations as it is also markedly seasonal with a shorter, drier season in the year, 2009. Finally, for Katsina-Ala, the seasonality index is still observed to be; seasonal and markedly seasonal with a long drier season. Only the years, 2009 as observed in other stations deviates from the general regime that exist here over the study period apart from the five years (1985, 1987, 1998, and 2000) that experienced a markedly seasonal with a long drier season, the rest of the periods are markedly seasonal (Figure 6-13).

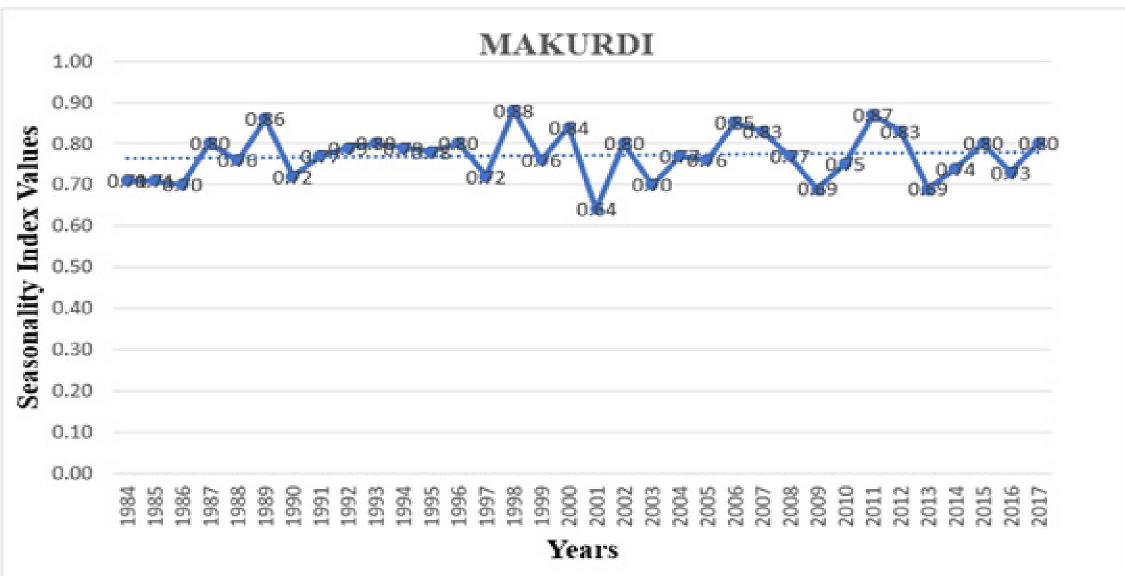

Figure 6: Trend in Rainfall Seasonality Index for Makurdi Station (1984-2017)
Source: Author's Computation (2019)

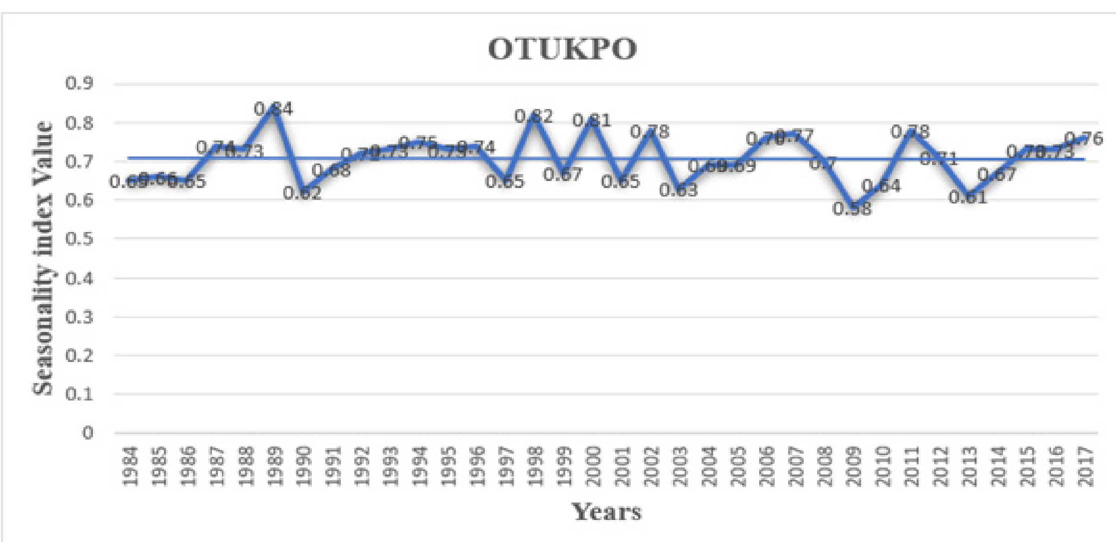

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Figure 7: Trend in Rainfall Seasonality Index for Otukpo Station (1984-2017)
Source: Author's Computation (2019)

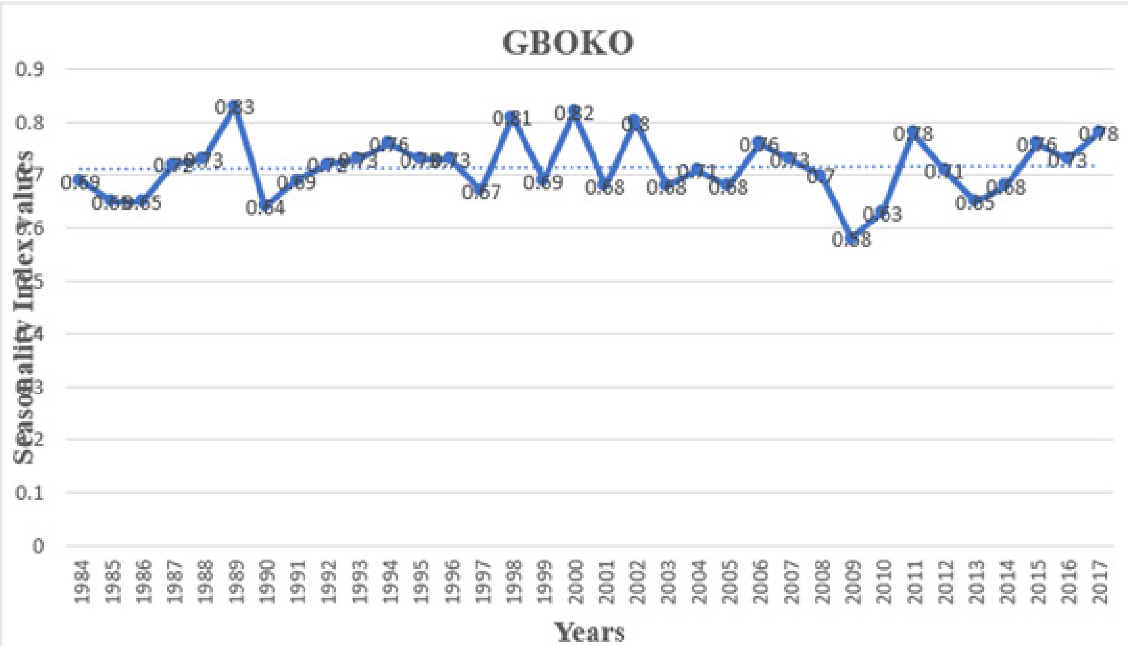

Figure 8: Trend in Rainfall Seasonality Index for Gboko Station (1984-2017) Source: Author's Computation (2019)

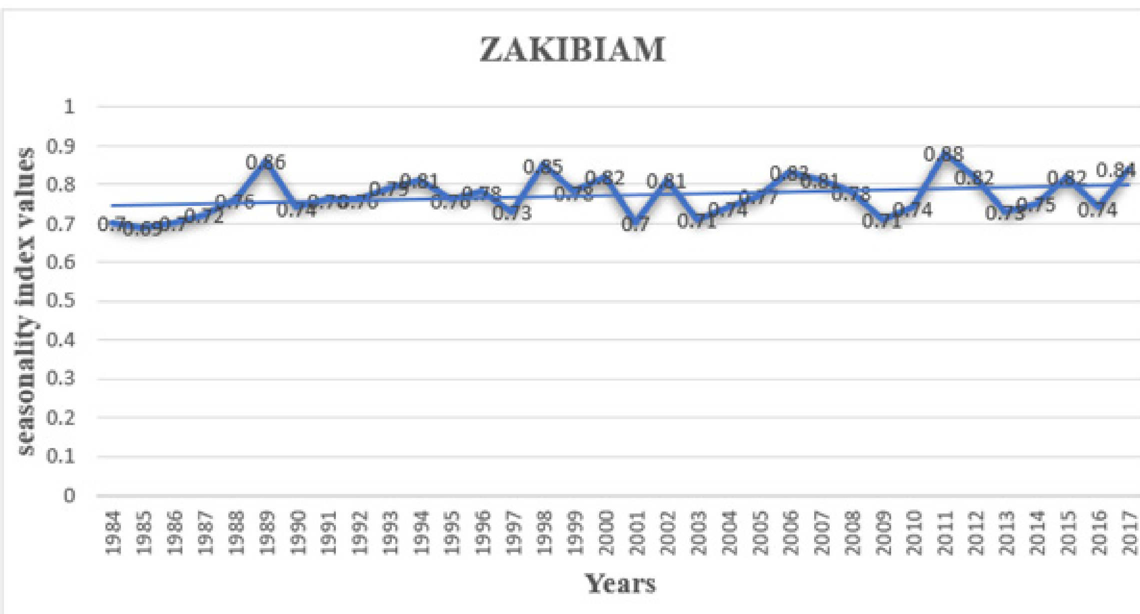

Figure 9: Trend in Rainfall Seasonality Index for Zakibiam Station (1984-2017) Source: Author's Computation (2019)

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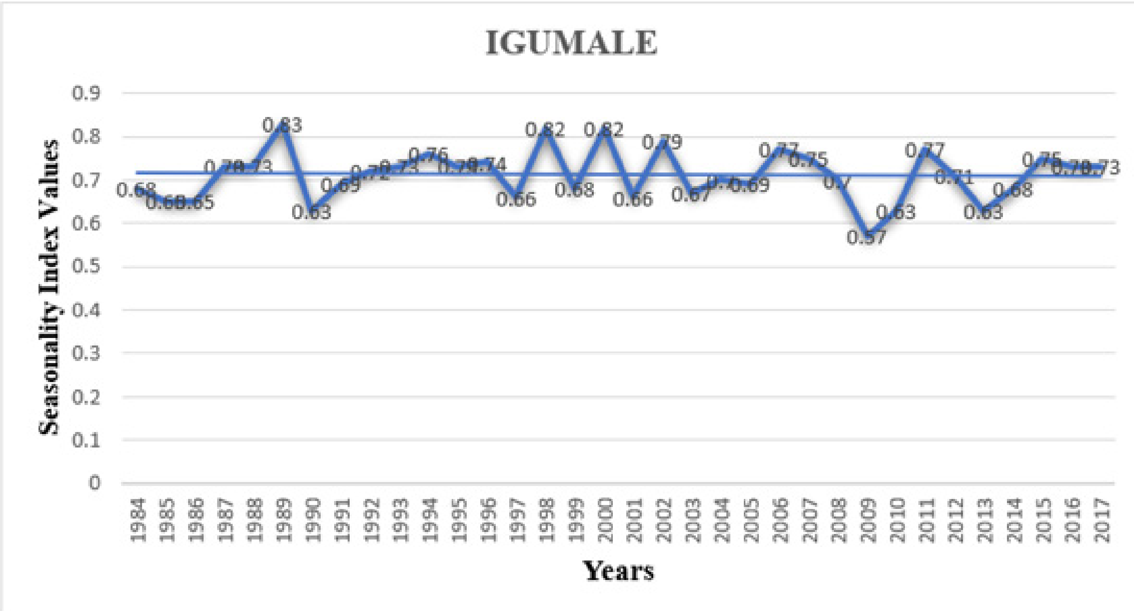

Figure 10: Trend in Rainfall Seasonality Index for Igumale Station (1984-2017) Source: Author’s Computation (2019)

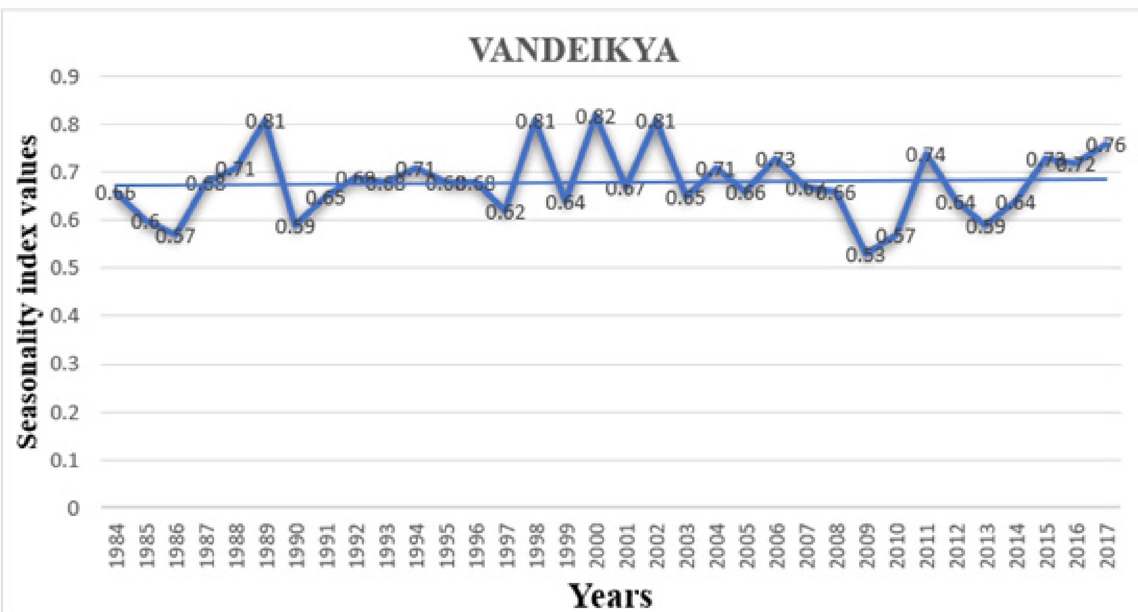

Figure 11: Trend in Rainfall Seasonality Index for Vandeikya Station (1984-2017)
Source: Author’s Computation (2019)

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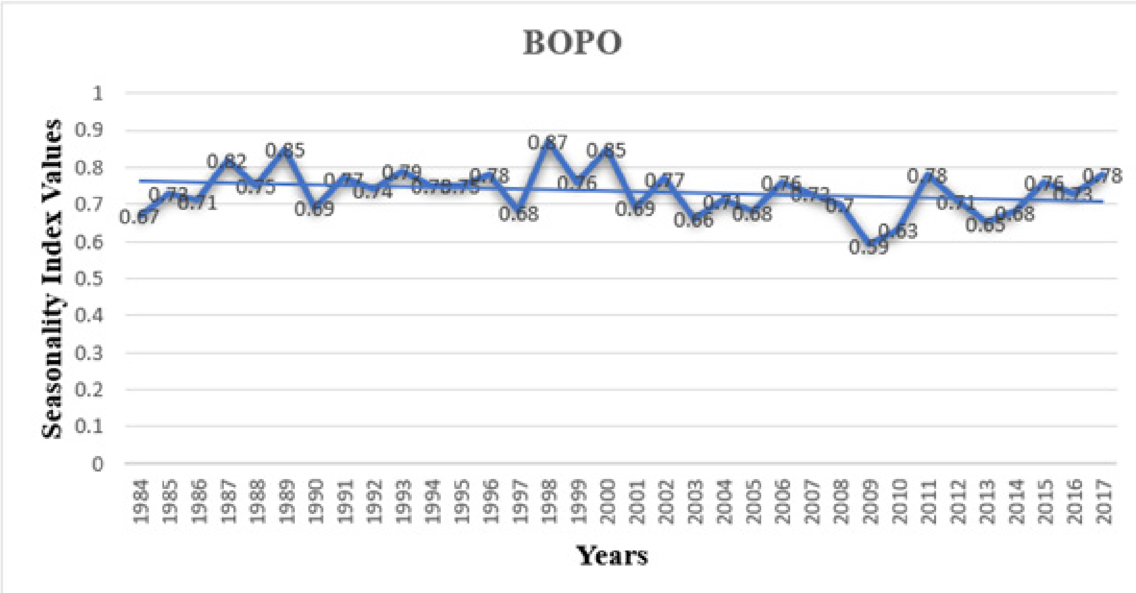

Figure 12: Trend in Rainfall Seasonality Index for Bopo Station (1984-2017)
Source: Author's Computation (2019)

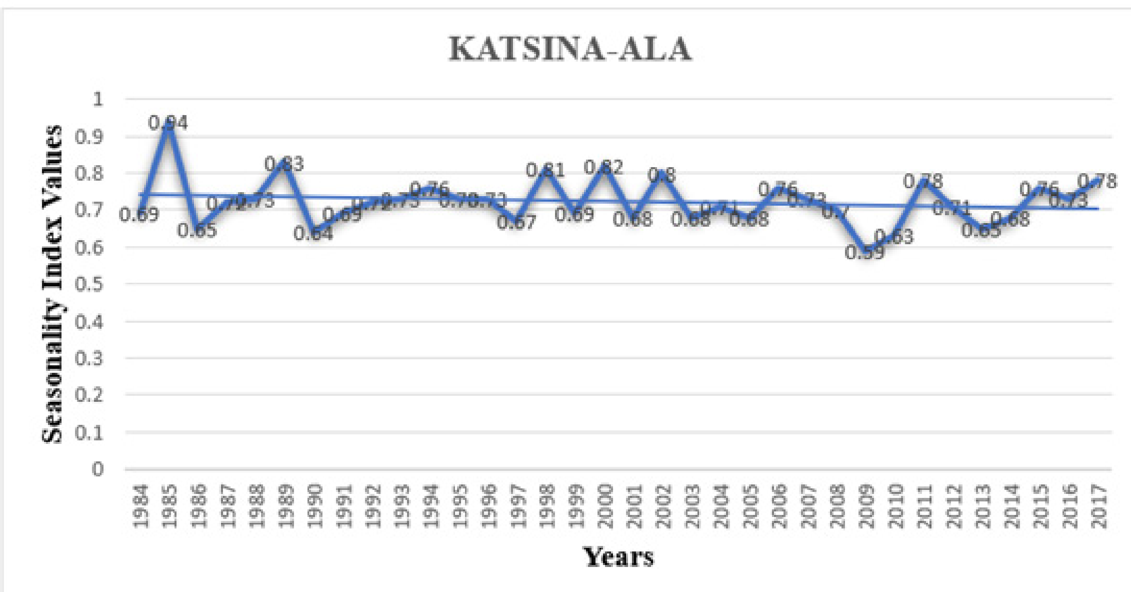

Figure 13: Trend in Rainfall Seasonality Index for Katsina-Ala Station (1984-2017) Source: Author's Computation (2019)

5.4. Mann-Kendall Trend Statistics and Sen's Slope Estimator of Rainfall Seasonality Index across Stations

Based on the Mann-Kendall trend test and Sens Slope on Table 4 and 5, the seasonality index shows an upward insignificant trends for Makurdi, Oturpo, Gboko, Zaki-biam, Igumale and Vandeikya stations except for Bopo and Katsina-Ala stations where insignificant downward trends were observed. Estimating the magnitude of the trend using the Sen's slope estimator, 50% of the stations revealed no trend while the remaining 50% were confirmed in line with the Mann-Kendall trend test result. Hence, there has been no significant trend in the rainfall seasonality index over the period of study in Benue state (Table 4,5).

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Table 4: Mann-Kendall Result of Rainfall Seasonality Index Across the Stations

Station	Z	P-Value	Mann-Kendall	Nature of trend		
Makurdi	0.49146	0.6231		31		Upward
Otukpo	0.28261	0.7775		34		Upward
Gboko	0.43234	0.6655		32		Upward
Zakibiam	1.9642	0.04951		133		Upward
Igumale	0.2681	0.7886		19		Upward
Vandeikya	0.37177	0.7101		21		Upward
Bopo	-1.1149	0.2649		-76		Downward
Katsina-Ala	-0.3428	0.7318		-24		Downward

Source: Author's Analysis (2019)

Table 5: Sen's Slope Estimator of Rainfall Seasonality Index

Sen's Slope (Seasonality) **Station**	**Sen's Slope**	**Nature of trend**
Makurdi	0.000434783	Upward trend
Otukpo	0	No trend
Gboko	0	No trend
Zakibiam	0	No trend
Igumale	0.001818182	Upward
Vandeikya	0.000434783	Upward
Bopo	-0.001428571 Downward	
Katsina-Ala	0	No trend

Source: Author's Analysis (2019)

6. Conclusion

The result of the seasonality index according to Walsh and Lawler's table of index revealed a single rainfall regime (Seasonal Regime) for all the stations based on the mean value of seasonality index over the period of study. But in general, three regimes were observed over the period of the study; the Rather Seasonal with shorter drier season, the seasonal regime and the markedly seasonal with a longer drier season. An upward insignificant trend in the seasonality index was observed for all the stations except for Bopo and Kastina-Ala with downward trends. However, the trend is insignificant for 90% of the stations except for Bopo station.

The south-north variation in the various rainfall parameters as observed in this study is in line with the movement of the ITCZ as observed by Oguntoyinbo, (1983); Laux et al., (2007) [20, 18, 11], while the decreasing trends in the annual rainfall pattern is also consistent with the findings of Adejuwon, (2012); Odjugo (2010); Ismail and Oke (2012); and Itiowe et al (2019) [3, 19, 7, 8] on rainfall seasonality in Nigeria.

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AIE conceptualized the paper and wrote the introduction and data analysis while PNG, CPO and AOA wrote the review of the literature, conclusion and reedited the entire manuscripts. All authors approved and agreed on the final draft.

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