ABUAD Journal of Engineering and Applied Sciences (AJEAS)

ISSN: 2992-5584

Volume 1, Issue 2, 78-87

Spatial and Temporal Features of Meteorological Drought Utilizing Non-Stationary Standardized Precipitation Index (SnsPI) for Designated Stations in the North-Western Region of Nigeria

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Date Submitted: 15/10/2023
Date Revised: 06/11/2023
Date Accepted: 12/11/2023
Date Published: 26/12/2023

Abstract: *Global warming, which manifests through variability or change in climate, often attracts or intensifies extreme hydrological events such as drought. The adverse effects of this event on water resources, agriculture, ecosystems, and all facets of human endeavors have been felt across the globe. In light of this, this study evaluated the spatio-temporal characteristics of meteorological drought over selected stations in the north-western zone of Nigeria with the objectives of characterizing the drought field and establishing a homogenous drought field for effective regionalization. To achieve this, a non-stationary rainfall-based meteorological index (SnsPI) was employed to assess and characterize the meteorological drought field at different timescales of 3, 6, and 12 months for each station. At SnsPI_3, the percentage of drought severity recorded for Gusau, Kaduna, Kano, Katsina, Sokoto, Yelwa and Zaria were 6.11, 5.93, 8.45, 2.16, 8.89%, 15 and 10.5%, respectively. At the 6-month timescale, the percentages of severe conditions are 11.5% (Gusau), 10.64% (Kaduna), 8.45% (Kano), 4.23% (Katsina), 12.76% (Sokoto), 15% (Yelwa), and 16.67% (Zaria), and finally, at 12_timescale, the values are 16.26% (Gusau), 10.63% (Kaduna), 3.62% (Kano), 4.22% (Katsina), 9.09% (Sokoto), 9.09% (Yelwa) and 14.69% (Zaria). The study indicated that all the stations had experienced droughts of different severities and established that the 6-month timescale is the best for time-tuning the resolution of drought in the north-western region of Nigeria. In view of the observed shortcomings of the SnsPI and its derivatives, other indexes that take into consideration the implications of global warming by incorporating potential evapotranspiration should be considered for drought studies in the north-western region of Nigeria..*

Keywords: Drought, SnsPI, characterisation, PCA, cluster analysis.

1. INTRODUCTION

Drought is the second most prevalent natural catastrophe worldwide, particularly in the arid and semi-arid regions [1]. It is referred to as a "period of insufficient rainfall either in time or in space" that is caused by low rainfall, usually related with high rates of evaporation. It results into crop failure, enough to cause a severe shortage of food in a nation [2]. The main causes of most droughts can be traced to changing weather patterns which resulted from the excessive accumulation of heat on the earth's surface, meteorological changes which result in a reduction of rainfall, and reduced cloud cover, all of which results in increased evaporation rates [3]. Generally, the effects of drought include mass starvation, famine and cessation of economic activity particularly in areas where rain fed agriculture is the main goal of the rural economy [4]. Drought has been classified as meteorological, agricultural, hydrological and socio-economic drought.

Several drought metrics have been developed to evaluate the water supply shortage in accordance to the time duration of precipitation deficit [5]. Drought indices are mathematical instruments used to quantify drought to aid decision makers in taking proper measures for mitigating its effects [6]. Most of the popular indices used in drought assessment and evaluation include the Standardised Precipitation Index (SPI), the Standardised Precipitation Anomaly Index (SPAI), and Standardised non-stationary Precipitation Index (SnsPI). These metrics have recorded different performance depending on their features (i.e., robustness, transparency, sophistication, extendibility and dimensionality) [7]. Different researchers have proposed different drought indices best suited for a particular area based on their respective excellent recognition. From the study of [8], it was revealed that Standardised Precipitation Index (SPI) is more achievable than other types of indices because of its unique and flexibility for different timescales. The use of standardised drought indices, such as the SPI, as an operational basis of drought monitoring systems has been gaining recognition in many parts of the world. Recommendations for the use of the SPI, and those metrics that possess its properties, do not take into consideration, the shortcomings that this type of metrics can exhibit under the influence of multi-decadal climate variability [9].

Russo also developed a non-stationary Gamma distribution with its scale parameter varying linearly with time and then estimated a Standardised non-stationary Precipitation Index (SnsPI) to describe precipitation changes in Europe [10]. In validating its reliability, the SnsPI was compared with the traditional SPI concerning temporal and spatial assessment of historical droughts [11]. From a social repercussion point of view in drought assessment, the SPI may not reflect the social consequences caused by deficit/surplus rainfall across both the high and low rainfall months. For instance, a rainfall deficit of 8.4mm in January (traditionally dry month) and 68.73mm in August (wet season) may result in more or less similar values of SPI [12]. However, the consequences attributable to the rainfall deficit corresponding to a SPI value of (-2) in a traditionally dry period (January) are very different from the same corresponding to a similar SPI value in a climatologically wet period (August). The two events may be statistically equally frequent but have vastly contrasting socioeconomic impacts. Such issues may lead to practical difficulties while planning drought response activities [13]. The choice of these metrics is predicated on the need to ascertain the robustness of using only rainfall-based indexes for drought quantification taking cognisance of drought state transition and the spatiotemporal variability in rainfall patterns across the region with implications for relevant stakeholders; majorly, agricultural and hydropower generation (i.e., reservoir management concerning inflow for resolving demand and supply requirements).

Despite the avalanche of available studies in this regard, the majority of these works, their studies have been documented that establish homogenous meteorological drought areas for effective regionalisation. Thus, this study aims to assess spatio-temporal characteristics of meteorological drought over selected stations in the North-Western region of Nigeria.

2. METHODOLOGY

2.1 Study Location and Hydrometeorology/Data

Northwest part of Nigeria which consists of the selected stations (Gusau, Kaduna, Kano, Sokoto, Katsina, Yelwa and Zaria) is located between Latitudes 9^{o} 021N and 13^{o} 581N and Longitudes 3^{o} 081E and 10^{o} 151E (Figure 1). The area so defined covers a land area approximately 91, 633.75 squared miles (Table 1). Northwest region of Nigeria shares borders with Niger Republic in the northern part, Benin and Niger Republic in the Western part, Niger State and FCT to the south, and Yobe, Bauchi and Plateau States to the East. The climate of Northwest region of Nigeria is the tropical wet-and-dry type (Koppen's Aw climate). The wet season lasts from April through October with a peak in August, while the dry season prolongs from November of one calendar-year to April of the next [14]. The annual average rainfall varies from about 1733 mm at the extreme southern part of the zone to about 600 mm at the extreme northern part [15].

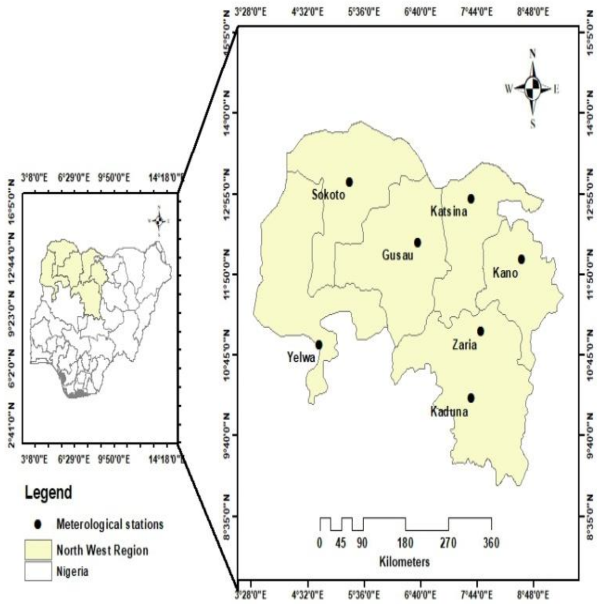

Figure 1: Map of the North-Western region of Nigeria showing the study of meteorological stations
Source: (Saliu *et al.*, 2023)

Table 1: Land area of North-western zone by states

States	Latitude (°)	Longitude (°)	Acres	Square miles
Kaduna	10.50774	7.44101	10,450,326	16,594.14
Kano	12.00136	8.51475	4,988,880	7,921.88
Katsina	12.97245	7.58434	5,796,006	9,203.52
Yelwa	10.883	4.75000	9,098,310	14,447.27
Sokoto	13.06137	5.24632	6,844,950	10,869.14
Gusau	12.1459	6.71333	9,331,026	14,816.80
Zaria	11.08554	7.71995	139, 100	17, 781
Total			**46,648, 598**	**91, 633.75**

Source: Abaje *et al.* (2012)

2.1.1 Data source/mobilisation and data processing

In employing the SnsPI for this study, Daily rainfall time data for varying stations across the North-Western part of Nigeria was obtained from Nigerian Meteorological Agency (NiMet). The data period span through the year 2006 to 2020 with varying time base. However, for this period the entire data, precisely the daily time sequence for each station was screened for continuity and consistency. Based on this, data sequence with substantial length of missing values were discountenanced (i.e., the year removed or ignored) while those found to exhibit discernible inconsistency/coherence were also removed; this explained the varying length of data for the stations.

2.2 Method

2.2.1 Non-stationary standardised precipitation index (SnsPI)

It is worthwhile to present here a brief explanation of the method of computation of the Standardised non-stationary Precipitation Index (SnsPI), as it was developed to incorporate the variability of long precipitation datasets which cannot be appropriately handled by the SPI [13]. The SnsPI is obtained by fitting the precipitation data to a non-stationary gamma distribution with a fixed shape parameter but a time varying scale parameter. This is implemented by expressing the mean of the rainfall series in terms of a time-dependent linear equation. The SnsPI may be computed at different temporal scales. Hence, if X_t represents the monthly rainfall series for a particular month, say January, and μ_t represents the nonstationary mean rainfall for that month, then

$$E(X_t) = \mu_t = b_1 + b_2 t \quad (1)$$

Where b_1 and $b_2$are constants; and t is time step. Thus, the mean rainfall for the month of January is not a constant; rather it is a function of time. The next step is to express this non-stationary monthly rainfall series as a gamma distribution, which is also used in the case of SPI. Thus$X_t \sim \text{Gamma}(\alpha, \beta_t)$, where α and β_t are the shape and scale parameters, respectively. The scale parameter β_t maybe expressed as

$$\beta_t = \frac{\mu_t}{\alpha} \quad (2)$$

If there zero rainfall values at the monthly scale, then a mixed distribution, consisting of a concentrated probability and a gamma distribution, maybe considered, as in the case of SPI. Subsequently, for each of the 12 monthly rainfall series, the cumulative distribution is transformed to standard normal variates (Z) to obtain the month-wise SnsPI series, which are then recognized into a chronological series. The different timescales of 3, 6 and 12 were employed due to length of data and linkage between meteorological and other drought types. The drought field was characterised based on Table.

Table 2: Drought intensities classification table resulting from SnsPI computation

SnsPI Values	Class
>2	Extremely Wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0.99 to −0.99	Near normal
-1 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
<-2	Extremely dry

Source: Chanda and Maity, 2015

3. RESULTS AND DISCUSSION

3.1 Temporal Distribution of Drought Characteristics

The results (Figures 2-8) of the analysis show many years of wet period as well as drought period as categorized into near normal (NN)with SnsPI between 0.99 and -0.99, moderate wet (MW)with SnsPI between 1 and 1.49, very wet (VW) with SnsPI between 1.5 and 1.99, extremely wet (EW)with SnsPI from 2 and above. Drought period as categorized as follows, moderate drought (MD)with SnsPI between -1 and -1.49, severe drought (SD) with SnsPI between -1.5 and -1.99, extreme drought (ED)with SnsPI from -2 and below, below average rainfall with SPI index between 0 and below, and above normal drought (AN) with SnsPI index below -0.99. The 3_month SnsPI analysis indicate short- and medium-term moisture condition while the 6_month SnsPI could be associated with unusual stream-flows and reservoir levels which depends on the region and time of year [16]. More so, there is shortage in short- and medium-term moisture condition which signifies the prevalence of meteorological drought years during the period of study. The stations generally experienced about 11 years of above average rainfall between 2009 and 2019.

From 2006 to 2009, series of drought years were prevalent with few wet years. The prevalence of unusual stream-flows and reservoir levels as the SnsPI (6 months) revealed that the entire study area experienced about 4 years of 6-month below average rainfall condition during the years under investigation as earlier reported by [17].

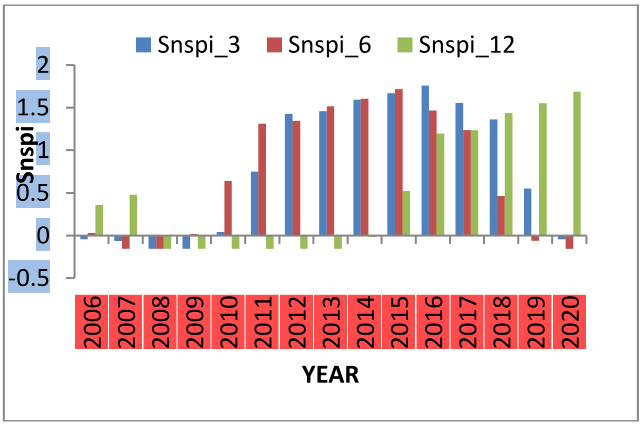

Figure 2: Mean annual SnsPI chart (Gusau)

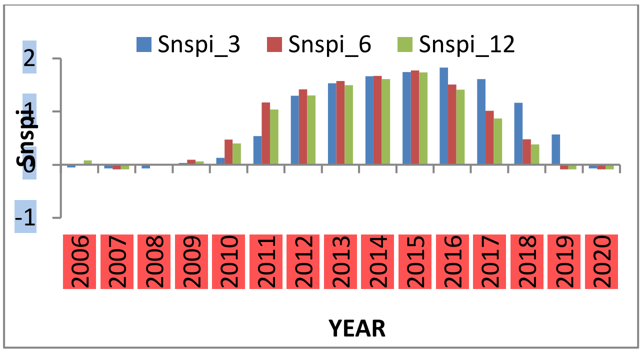

Figure 3: Mean annual SnsPI chart (Kano)

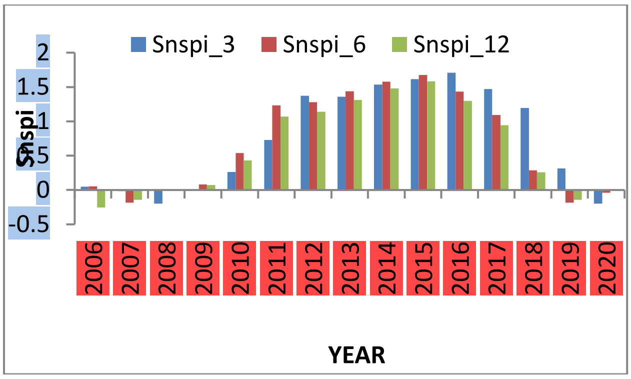

Figure 4: Mean annual SnsPI chart (Sokoto)

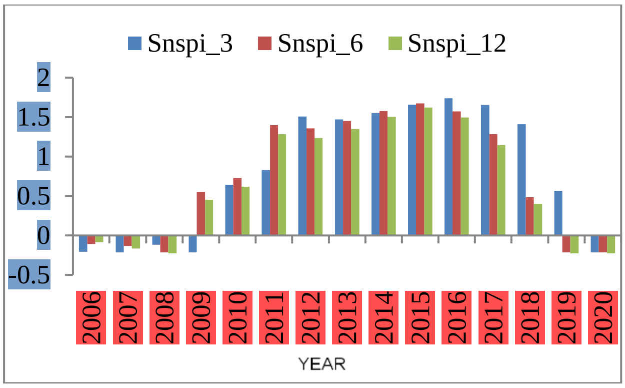

Figure 5: Mean annual SnsPI chart (Kaduna)

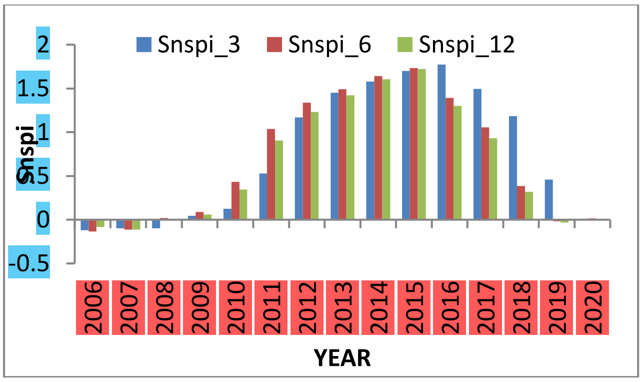

Figure 6: Mean annual SnsPI chart (Katsina)

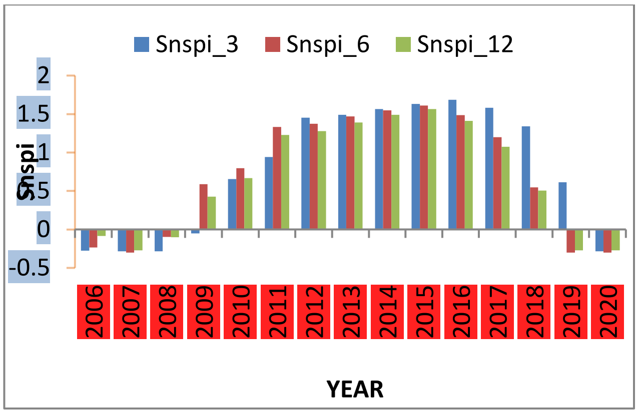

Figure 7: Mean annual SnsPI chart (Yelwa)

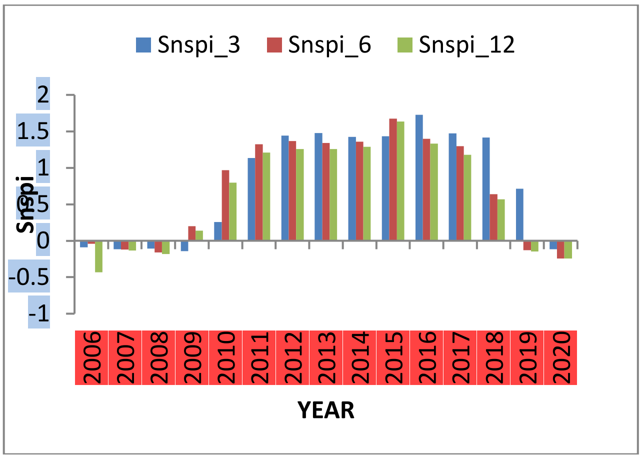

Figure 8: Mean annual SnsPI chart (Zaria)

3.1.1 Categorisation of droughts using standardised non-stationary precipitation index (snspi)

Tables 3-9 clearly showed the summary of drought intensity in all stations at 3, 6 and 12_month timescale using Standardised Non-stationary Precipitation Index (SnsPI). The categorization was done on the basis of extremely wet, very wet, moderately wet, near normal, moderately dry, severely dry, extremely dry. Across all the stations, there was uniformly occurrence of near normal condition, moderately wet and extremely dry conditions. For instance, Gusau recorded 101 numbers of near moderately wet condition, 22 and 8 numbers of near normal and extremely dry conditions respectively for the past 15 years under a 3_month timescale as shown in Table 4. The same conditions with little variation in the frequency of occurrence were recorded under the timescale of 6 and 12 for the past 15 years. Generally, all the stations recorded the same drought conditions but with little variation in the frequencies of occurrence.

Table 3: Summary of Kano drought intensity

Drought Intensity	**Index Threshold**	**SnsPI_3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	**Freq**	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	103	72.53	103	72.54	103	74.64
Near Normal	-0.99 to 0.99	27	19.01	27	19.01	30	21.74
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	12	8.45	12	8.45	5	3.62
Total		**142**	**100**	**142**	**100**	**138**	**100**

Table 4: Summary of Gusau drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	**Freq**	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	101	77.10	101	73.19	70	56.91
Near Normal	-0.99 to 0.99	22	16.79	21	15.22	33	26.83
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	8	6.11	16	11.59	20	16.26
Total		**131**	**100**	**138**	**100**	**123**	**100**

Table 5: Summary of Kaduna drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	**Freq**	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	106	78.52	105	74.47	105	74.47
Near Normal	-0.99 to 0.99	21	15.56	21	14.89	21	14.89
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	8	5.93	15	10.64	15	10.63
Total		**135**	**100**	**141**	**100**	**141**	**100**

Table 6: Summary of Katsina drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	**%**	**Freq**	**%**	**Freq**	**%**
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	97	69.78	98	69.01	98	69.01
Near Normal	-0.99 to 0.99	39	28.06	38	26.76	38	26.76
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	3	2.16	6	4.23	6	4.22
Total		**139**	**100**	**142**	**100**	**142**	**100**

Table 7: Summary of Sokoto drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	Freq	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	102	75.56	101	71.63	101	70.63
Near Normal	-0.99 to 0.99	21	15.56	22	15.60	29	20.28

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	Freq	%
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	12	8.89	18	12.76	13	9.09
Total		**135**	**100**	**141**	**100**	**143**	**100**

Table 8: Summary of Yelwa drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	**Freq**	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	106	75.71	106	75.71	107	81.06
Near Normal	-0.99 to 0.99	13	9.29	13	9.29	13	9.85
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	21	15	21	15	12	9.09
Total		**140**	**100**	**140**	**100**	**132**	**100**

Table 9: Summary of Zaria drought intensity

Drought Intensity	**Index Threshold**	**SnsPI _3**		**SnsPI _6**		**SnsPI _12**	
		Freq	%	**Freq**	%	**Freq**	%
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	110	82.71	111	77.08	110	76.92
Near Normal	-0.99 to 0.99	9	6.77	9	6.25	12	8.39
Moderately dry	-1 to -1.49	0	0	0	0	0	0
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	14	10.53	24	16.67	21	14.69
Total		**133**	**100**	**144**	**100**	**143**	**100**

3.2 Spatial Variations in the SnsPI

3.2.1 Spatial distribution of drought characteristics

Figures 9-11 showed the spatio-temporal maps of all stations at timescales of 3, 6 and 12 months respectively. The patterns showed the most affected areas with drought conditions as well as stations with average rainfall conditions as in the study of [18] in China. In Figure 9, all stations recorded near normal conditions (SnsPI ranging between -0.99 and 0.99) with Zaria, Yelwa and Kaduna recording close values to moderately dry conditions while Gusau, Kano, Sokoto and Katsina recorded values close to moderately wet conditions. All stations in Figure 10 recorded near normal conditions (SnsPI ranging between -0.99 and 0.99 according to the stated standardised values in Table 1) with close values to moderately dry conditions in Yelwa, Kaduna, Zaria and Sokoto while close conditions to moderately wet situations experienced in Katsina, Gusau and Kano meteorological stations at 6-_month timescale. In Figure 11, Yelwa and Kaduna recorded moderately dry conditions with extreme condition in Yelwa. Sokoto, Zaria, Katsina, Gusau and Kano experienced moderately wet conditions (SnsPI ranging between 1.0 and 1.49 for the past 15 years).

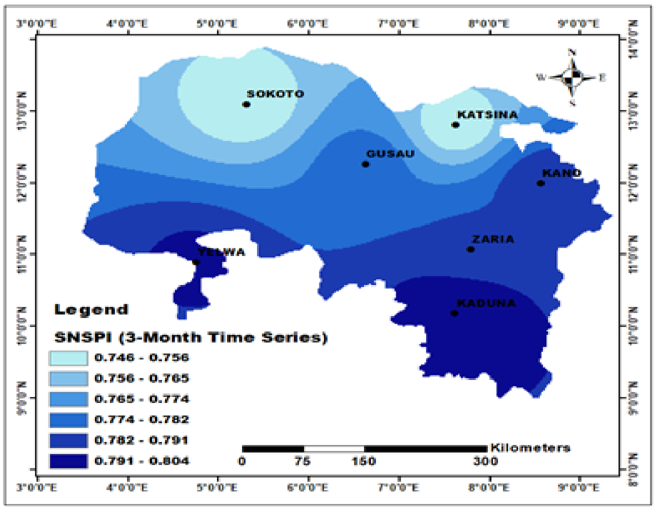

Figure 9: 3_month mean annual SnsPI spatial map for all station

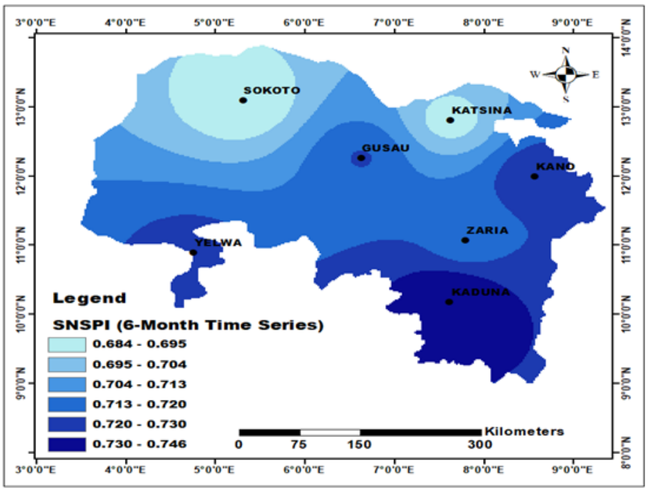

Figure 10: 6_month mean annual SnsPI spatial map for all station

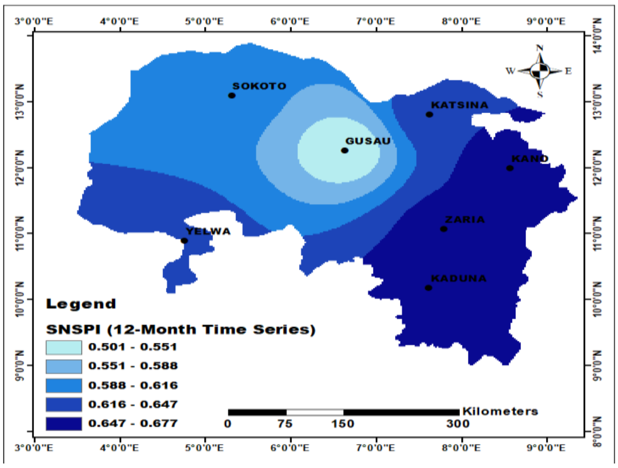

Figure 11: 12_month mean annual SnsPI spatial map for all station

3.3 Regionalisation of Drought into Coherent Zones

Figure 12 shows the Scree plot diagram of the three components of the PCA and their respective contributions. PCA of the SnsPI fields revealed that the first principal components (PC1) have not only the largest, but also the most dominant contributions to the total variance after the orthogonal linear transformation SnsPI_6 drought estimates. The principal components PC1, PC2 and PC3 explained 69.18%, 52.29% and 27.22% of the total cumulative variance respectively with the first principal component contributing largely to the entire zones. The first result of the principal components function, contain the coefficients of the linear combination of the original values that generate the principal components. The coefficients are known as factor loadings. The first three PCs revealed the contributions of the PC as Table 10.

According to PCA, the first Empirical Orthogonal Function (EOF) explained of the total variance. The first principal component (PC1) showed variation (Table 10) affecting the region as a whole, with maximum loading distributed across the stations, hence represents rainfall i.e., all places wet or all places dry. All factor exhibited both positive and negative correlation with the principal component. The correlation coefficient between the drought at any point and the principal component was obtained from the product of the factor loading and square root of the eigenvalue.

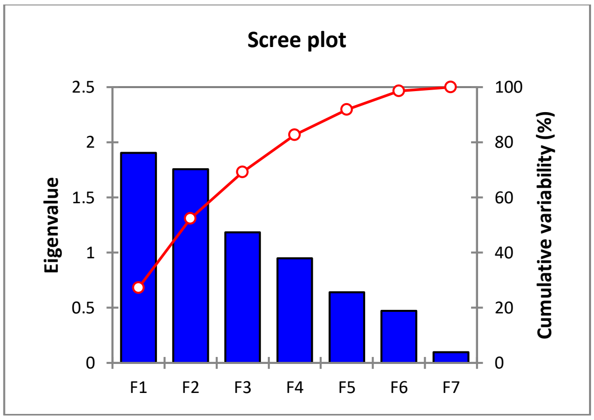

Figure 12: Scree plot diagram

Table 10: Principal components coefficients of the drought estimates

Station	PC1	PC2	PC3
Gusau	0.028	0.476	0.014
Kano	0.116	-0.445	0.117
Kaduna	-0.364	-0.145	0.367
Sokoto	-0.354	0.048	0.067
Katsina	0.639	0.008	0.167
Yelwa	0.026	0.399	0.299
Zaria	0.094	0.044	0.567
Cumulative Variance %	**69.18**	**52.29**	**27.22**

The geographical distribution pattern of loading of the first three principal component (PC1, PC2 and PC3) computed for monthly drought total series of the seven stations within the stations are shown in Figures 13-15 respectively. It is seen in Figure 13 that Sokoto, Gusau and Kano recorded the highest drought severity (dry spell condition) while Kaduna and Zaria recorded wet spell condition. In Figure 14, Kano had the highest drought severity condition while Gusau recorded the least drought condition corresponding to extremely wet conditions. Other stations recorded between mild drought and near normal conditions as shown in the map.

Finally in Figure 15, Sokoto recorded the highest severity condition corresponding to extremely dry condition and Katsina with the least wet condition among the stations under consideration.

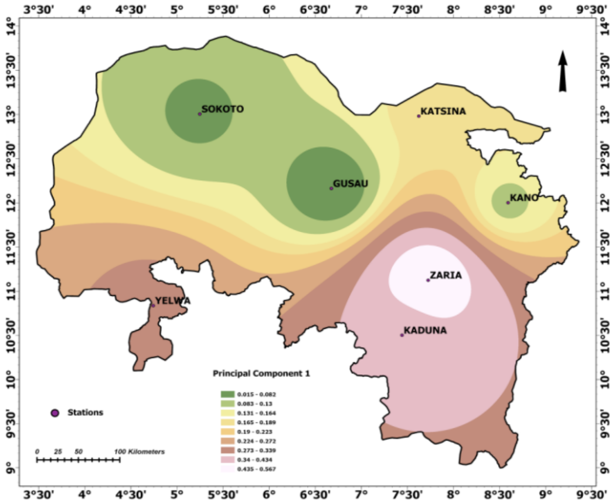

Figure 13: Principal component 1

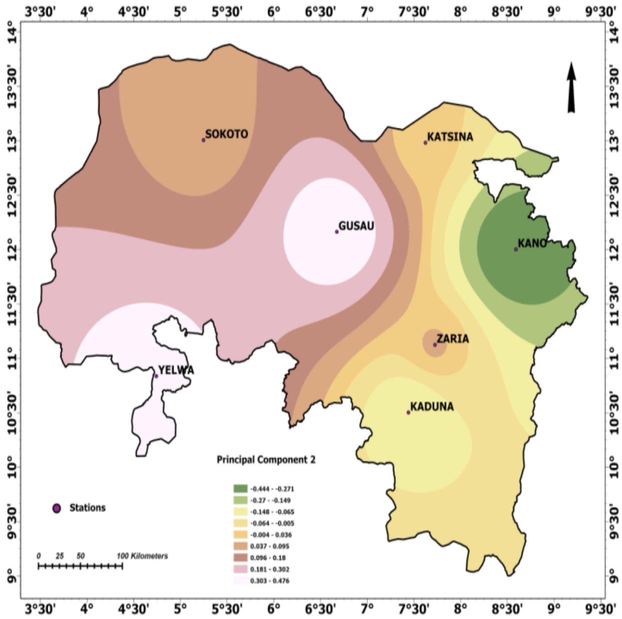

Figure 14: Principal component 2

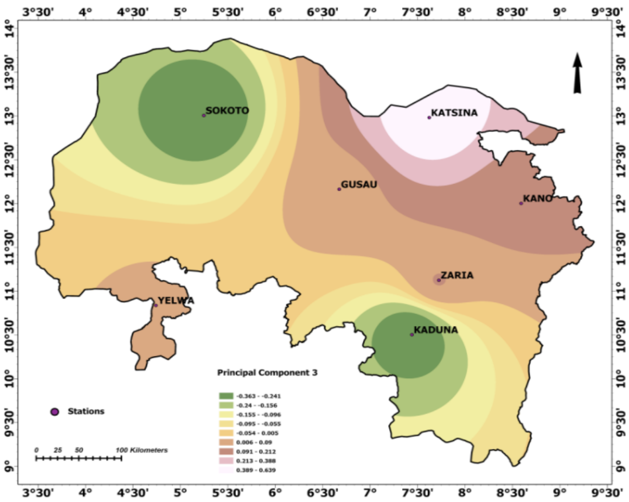

Figure 15: Principal component 3

In order to investigate the relationship among variables, each variable (station) can be represented by the factor loadings for two principal components (dimensions). All variables are plotted with respect to the PC1 and PC2 and shows both negative and positive correlation with the PC1 and PC2.

Table 11: Factor loadings

Station	F1	F2	F3
Gusau	-0.4874	-0.5118	0.3426
Kano	0.6089	0.5667	-0.1060
Kaduna	0.8129	-0.4296	-0.1906
Sokoto	0.1550	-0.4781	-0.2517
Katsina	0.0531	0.6055	0.7026
Yelwa	0.0235	-0.5770	0.4762
Zaria	0.7803	-0.2431	0.4832

The factor loading map F1, F2 and F3 showed the relationship among variables. The loading map after varimax rotation are shown in Figure 16-18, respectively.

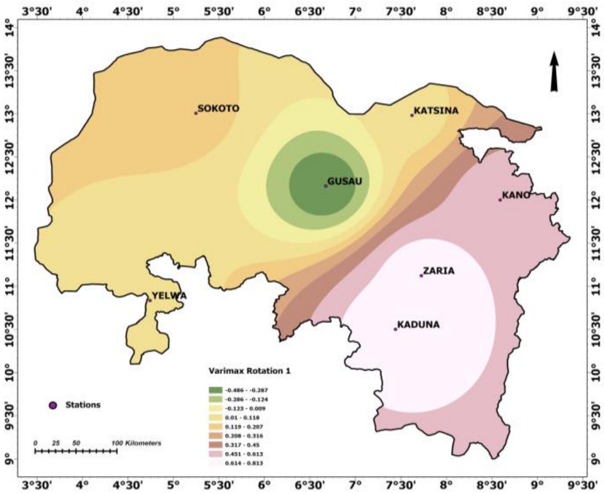

Figure 16: Factor loading D1

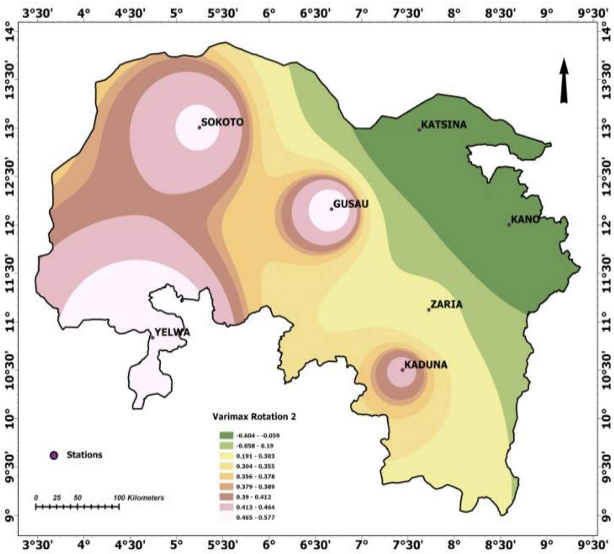

Figure 17: Factor loading F2

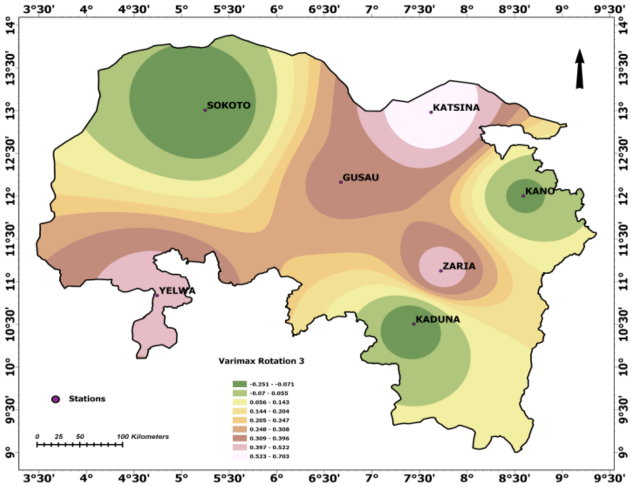

Figure 18: Factor loading F3

3.3.1 Regionalisation of coherent drought estimates

The characteristics of rotated PCs were used to delineate coherent homogeneous zones of rainfall variation over the study area. By selecting a loading magnitude for which sharp gradient on different rotated PC, a loading Magnitude of 0.4 was used for delineation of homogeneous zones.

The factor loading F1 and F2 was analysed using the K-means Cluster analysis. F3 was not considered because it has less than 0.4000 in magnitude. K-means cluster analysis showed 2 clusters; cluster 1 has three stations or observations while cluster 2 has four observations as shown in Table 12 and cluster centroid of F1 and F2 in Table 12-14.

Table 12: Cluster Analysis

Variables	No of Stations	Cluster sum of Squares	Average distance from centroid	Maximum distance from centroid
F1	3	0.235	0.261	0.385
F2	4	1.241	0.545	0.701

Table 13: Cluster Centroid

Variable	Cluster 1	Cluster 2	Grand Centroid
F1	-0.1030	0.5638	0.2780
F2	-0.5223	0.1249	-0.1525

Table 14: Distance between cluster centroids

Cluster 1	0.0000	0.9292
Cluster 2	0.9292	0.0000

4. CONCLUSIONS

This study examined the spatio-temporal characteristics of meteorological drought over selected stations in North-Western region of Nigeria for the purpose of characterising and establishing meteorological drought field (to show spatial extent of drought) and also establish homogenous meteorological drought areas for effective regionalisation. In the meteorological drought characterisation, the typology of the meteorological drought was analysed in terms of its characteristics such as mild, moderate, severe and extreme and this was done using SnsPI drought index. Based on the analysis, it is apparent that despite the fact that annual timescale maybe long, it can be employed to obtain information on the temporal evolution of drought most importantly, regional behaviour. Monthly timescale can be more appropriate if emphasis is on evaluating the effects of drought in situations relating to water supply, agriculture and water abstractions.

On the basis of the spatio-temporal patterns drawn, drought incidents such as mild, moderate, severe and extreme were recorded in Sokoto, Yelwa, Gusau and Kano with minimal record of extreme conditions in other stations. The results of the Principal Component Analysis (PCA) and the Cluster Analysis reveal the SnsPI_6 to be is the best timescale for this study for time tuning resolution. The implications of the severity of drought in the stations reported (Sokoto, Yelwa, Gusau and Kano). The identified spatial patterns across the stations highlighted the challenging nature of drought event in the North-western region of Nigeria and the need for a well-coordinated water resources planning and drought preparedness; as well as effective and efficient emergence responses during drought events. The PCA and Cluster Analyses results show that the North-Western region can only regarded as a unit entity. In light of the findings, the lack of an adoptable threshold for drought quantification is a critical limitation hence there is need to establish a regional threshold vis-a-vis the employment of an only rainfall-based metrics for drought study may not be a veritable option but consideration should be given to other indexes that use variables that impact on regional water balance (SPEI).

CONTRIBUTION TO KNOWLEDGE

Based on the conclusion drawn, the study established that for meteorological drought analysis for North-western region of Nigeria, 6-month time tuning resolution is the best.

ACKNOWLEDGEMENT

I wish to thank members of TETFUND Sponsored DEWS Team for the opportunity extended to me as one of their scholars.

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