



Comparative Assessment of Standard Precipitation Index and Standard Precipitation Evapotranspiration Index as Drought Evaluation Tools in Coastal Winneba-Ghana

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

In coastal Winneba-Ghana, drought occurrence negatively affects the ecosystems and agriculture and threatens food security and socio-economic livelihoods. Nevertheless, there exist dearth of information on a detailed statistical evaluation of drought indices over this area. This study made a comparative assessment of Standard Precipitation Index (SPI) and Standard Precipitation Evapotranspiration Index (SPEI) over coastal-Winneba. A daily temperature and rainfall data from 1980-2019 acquired from the Ghana Meteorological Agency was used to perform SPI and SPEI. Pearson correlation coefficient and cross-correlation, and Bland and Altman plot were used to test for the strength and direction and the degree of agreement, respectively between SPI and SPEI. Results showed a strong and positive association between SPI and SPEI (0.90, 0.91, 0.84, and 0.93) at 1-, 3-, 6-, and 12-month timescales, respectively. Results again, showed a good degree of agreement between SPI and SPEI (-0.06138, -0.00736, -0.05211, and -0.01810) at 1-, 3-, 6-, and 12-month timescales, respectively. Results further, showed that while both SPI and SPEI correlated strongly with each other, SPEI performed better in the detection of severe and extreme droughts at

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all timescales than SPI. Additionally, results showed that in the absence of temperature data to perform SPEI, the SPI can be used since the study found an acceptable degree of agreement scores between SPI and SPEI at all timescales in the study area. The study, therefore, recommends the utilization of numerous drought indices in drought performance assessment at a particular region or locality to arrive at a strong decision.

Keywords: Climate change; coastal; drought; SPEI; SPI; Winneba.

1. INTRODUCTION

Drought, which is an intrinsic characteristic of a changing climate, is a naturally reoccurring event described by several climatological and hydrological variables [1]. Drought, thus, indicates a reduction in precipitation over extended time duration, which may range from several months to years [2]. Depending on the frequency, duration, magnitude and severity, drought can be considered as a meteorological, agricultural, or hydrological, and socioeconomic [3] and these classifications are often connected to each other. For example, a meteorological drought can lead to agricultural drought, hydrological drought, and socioeconomic drought [4].

Over the years, there have been several improvements in the measurement of drought extreme and severity, and these have led to the creation of different drought indices: The Palmer Drought Severity Index (PDSI) developed in 1965 [5], the Standard Precipitation Index (SPI) in 1993 [6], and the Standard Precipitation Evapotranspiration Index (SPEI) in 2010 [7]. As confirmed by [7], the PDSI was a significant development of drought indices as it enables the determination of both positive (wetness) and negative (dryness) values. These determinations were based on the quantity and need hypothesis of the water balance equation [7], and therefore, requires precipitation, temperature, moisture supply, runoff, and surface evaporation [7,8]. However, the PDSI has some weaknesses such as the inability to assess multi-scale drought characteristics [9] and the strong effect of the calibration period [10].

The above-mentioned weaknesses caused the development of the SPI [6], which addresses the issue of multi-scalar type of drought. While many, including the World Meteorological Agency (GMA) identify the SPI as the principal reference drought index [11], it has been deficient by its ability to use only precipitation data and ignore other important climatic variables such as temperature and evapotranspiration [7,12]. The

SPI thus emphasises the variations in precipitation as the major determinant of drought. [13] have stressed against the exclusion of temperature. [13] in their study on the role of temperature and precipitation in the PDSI, found equal responses in both variables. Precipitation variability was stronger only at the point where temperature variability was lesser [13]. The SPEI provides a simple evaluation and presents detailed drought data by considering monthly water changes [8]. It thus can determine the differences between precipitation and potential evapotranspiration [8]. The SPI and the SPEI indices have been employed in this study.

Several pieces of studies on drought indices and occurrences have been performed worldwide [14,15,16,17,18]. [14] employed different drought indices to assess climate change impacts. [15] also, utilized different drought indices to assess the evolution of drought impacts on corn yield in Moldova. [16] have also used different drought indices for ecological, agricultural, hydrological performances. Besides, [17] applied different drought indices in China. [18] has further examined the performance of SPI, SPEI, and PDSI indices for agricultural drought in North China Plain.

The occurrence of drought has remained one of the greatest challenges in many parts of the world especially, in the water scarcity zones [19,20]. [4] in their study on drought modelling, considered drought as a severe and expensive event worldwide because of climate change and other extreme natural occurrences. Findings from the study of [21] confirmed a major increase in the frequency, severity, and duration of drought in Africa, Southern Australia, and eastern Asia. Findings from a study by [22] further emphasized the increases in intensity of future drought occurrences a result of global warming.

Drought has a regional trajectory, and its occurrence differs from one climatic region to the other [23]. According to the data from the Emergency Events Database (EM-DAT),

between 1900 to 2020, drought affected over 2 billion people worldwide, and caused damages over 182 million United States Dollars with over 11 million deaths [24]. On continental level, Asia is the most affected by drought (78.4%) of the world's total followed by Africa (16.6%), the Americas (4.0%), Europe (0.6%) and the Oceania (0.4%) [24]. While Asia is considered the most affected continent, Africa has the highest number of drought occurrences with Ethiopia and Somalia recording the highest drought occurrences in Africa between 1900 and 2020 [24,25]. Ghana has experienced many severe and extreme drought in the 1970's, 1980's, and 2000-2013 [24,26].

There exist several pieces of evidence on drought occurrences in Ghana [27,28,29,30,31,32,33]. Many of these studies have either analysed drought occurrences for the whole Ghana or for the Volta basin zones [27,30,31,33]. However, data for these studies are either analysed for the whole country or whole agro-ecological zone. While such analyses are essential to filling the information gap on drought in the country, they tend to limit details of specific places especially, looking at the variability in rainfall from the local to regional and to the global level. These studies have also employed only the Standard Precipitation Index (SPI) in their analyses and while this is important for drought indices assessment, a comparison of drought indices provides a comprehensive assessment of drought occurrences [8]. [31] made the effort to compare both SPI and SPEI to assess drought indices over the entire Volta basin of Ghana. Consequently, there is no single study that has employed both the SPI and SPEI in assessing drought indices over specific place in Ghana. A specific site assessment for drought is, thus needed. Such study will not only bridge the information gap on drought on specific site in Ghana but will enrich the literature on drought occurrences in Ghana.

This study, therefore, seeks to assess the performance of SPI and SPEI over Winneba-Ghana. The study specifically, compared SPI and SPEI indices, performed correlation analysis between SPI and SPEI, and examined the degree of agreement between SPI and SPEI. The study is organized as follows: section 2 provides a brief description of the study area and highlight the data and methods, section 3 shows the results and discussion, and section 4 provides conclusion.

2. MATERIAL AND METHODS

2.1 Study Area

Winneba, the capital of the Effutu municipality is geographically located between latitude 5° 20' N and longitude 0° 37' W (Fig. 1). It is a coastal town, and its climatological features fall into the coastal savannah agroecological zones of Ghana. Annual mean temperatures range from 22°C to 28°C. The main rainfall season starts from April to July and drops in August while the minor season begins in September and ends in November [34]. Annual rainfall in Winneba ranges between 400 millimetres to 500 millimetres [34] and have June and January are the wettest and driest months, respectively. Winneba has coastal savannah grassland vegetation which is suitable for vegetable farming. Soils in this area are mostly clayey with high salinity [34]. Two major rivers drain the area: the Ayensu and the Gyahadze rivers. Winneba had a total population of 68,597 as of 2012 with 32,795 and 35,802 males and females, respectively [34]. Fishing and farming are the major economic activities followed by services.

2.2 Data and Quality Control

The study used daily temperature (maximum and minimum) and rainfall data of Winneba synoptic station of the Ghana Meteorological Agency (GMet). The GMet has provided meteorological data in Ghana for many years. In 1937, the Meteorological Department was established right after the Second World War. The department was however, handed over to Ghana's Ministry of Communications in 1957 where Ghana officially became independent. 14 synoptic stations, fully equipped with meteorological equipment were established in 1957 and were supported by about 350 stations measuring precipitation, temperature, humidity, wind, clouds, among others. More expansions were made during the 1960s but the economics crises which occurred in Ghana in the 1970s and 1980s caused a declined in the operations of the meteorological stations. Upgrades were made in the late 1990s and currently GMet has 22 synoptic stations and about 310 meteorological stations operating every 24 hours a day [35].

Quality control check was performed on the temperature (maximum and minimum) and rainfall datasets to see the percentage of missing values and any outliers within the data. From this analysis, the total percentage of missing values

in the dataset were less than 1%. Missing data were given a value of -99.9 in the R statistical package. The period of data employed in the analysis ranged from 1980-2019 (40 years). Outliers (values greater or less than 3σ from the long-term average value for a particular month) were noticed in the monthly daily maximum and minimum data and rainfall.

2.3 Methods

The Standard Precipitation Evapotranspiration Index (SPEI), Standard Precipitation Index (SPI), Pearson correlation coefficient, cross-correlation, and the Bland and Altman plot were the methods utilized in this study.

2.3.1 Standard Precipitation Evapotranspiration Index (SPEI)

The SPEI [7] was computed using the SPEI package in the R statistical package [36]. The SPEI package requires long term temperature (maximum and minimum) and rainfall data. The SPEI has been employed in many drought studies and has been found suitable [8,37,38,39,40]. To estimate the value of SPEI, the variation in water balance is normalized as log-logistic probability distribution. The probability density function as used by [41] is expressed in the equation below.

$$f(x) = \frac{\beta}{\alpha} \left(\frac{x-\gamma}{\alpha}\right) + \left[1 + \left(\frac{x-\gamma}{\alpha}\right)\right]^{-2} \quad (1)$$

Where α , β , and γ are scale, shape, and origin, respectively [41]. The probability distribution function can, therefore, be expressed as:

$$f(x) = \left[1 + \left(\frac{\alpha}{x-\gamma}\right)^\beta\right]^{-1} \quad (2)$$

The calculation of the SPEI by [7] is shown below.

$$SPEI = W - \frac{C_0 + C_1W + C_2W}{1 + d_1W + d_2W^2 + d_3W^3} \quad (3)$$

When $P \leq 0.5$, $W = \sqrt{-2\ln(P)}$, and $P > 0.5$, $W = \sqrt{-2\ln(1-P)}$, $C_0 = 2.5155$, $C_1 = 0.8028$, $C_2 = 0.0203$, $d_1 = 1.4327$, $d_2 = 0.1892$, $d_3 = 0.0013$.

2.3.2 Standard Precipitation Index (SPI)

The SPI [6] was also computed from the SPEI package in the R statistical package [36]. The

SPI has also been widely employed in assessing drought [26,41,42,43,44,45,46]. The SPI is calculated by applying long-term precipitation data. An incomplete gamma distribution is then mounted and changed to normal distribution. The gamma is shown as the probability density function [47,48]. The SPI is mathematically expressed as:

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}, x > 0 \quad (4)$$

Where, α and β are shape and scale, respectively. x is precipitation amount and $\Gamma(a)$ is the gamma function. The $\Gamma(a)$ is expressed as:

$$\Gamma(a) = \int_0^\infty x^{a-1} e^{-\frac{x}{\beta}} dx \quad (5)$$

The greatest values of α and β are assessed by the likelihood method as shown below.

$$\alpha = \frac{1}{4A} \left[1 + \sqrt{1 + \frac{4A}{3}}\right] \quad (6)$$

$\beta = \frac{\bar{x}}{\alpha}$, where, $A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$, where n is the number of precipitation sequence.

The aggregate probability of a particular month is expressed in the equation below.

$$G(x) = \int_0^x g(x) dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \quad (7)$$

The SPI can, therefore, be computed as:

$$SPI = S \frac{t - (ct2 + c10) + c0}{[(d3t + d2)t + d1] t + 1.0} \quad (8)$$

$$t = \sqrt{\ln \frac{1}{G(x)^2}}$$

Where X is the precipitation amount, $G(X)$ is the gamma function of precipitation probability distribution, S is the positive and negative coefficient of the aggregate probability distribution, when $G(X) > 0.5$, $S = 1$, and when $G(X) \leq 0.5$, $S = -1$, $C_0 = 2.5155$, $C_1 = 0.8028$, $C_2 = 0.0103$, $d_1 = 1.4327$, $d_2 = 0.1892$, $d_3 = 0.0013$.

2.2.3 Pearson correlation coefficient and cross-correlation

To establish a relationship between SPI and SPEI, statistical technique such as the Pearson correlation and cross- correlation was used. The

Pearson correlation and cross-correlation have been used by [8,49,50,51,52] to establish statistical relationships for drought indices. The Pearson correlation coefficient is considered by [53] and [54] as the most common statistical method to detect the relationship between two variables. The Pearson correlation coefficient ranges from a perfect positive linear relationship with value of +1 to a perfect negative linear relationship with value of -1. Cross-correlation on the other hand assess the similarity between two different variables at different time lags [55]. Cross-correlation value also ranges -1 to +1. The closer the value is to +1, the more positive and stronger the variables are correlated.

2.3.4 Bland and Altman Plot

The Bland and Altman plot was used to examine the degree of agreement between SPI and SPEI. The Bland and Altman's plot, which is a graphical representation has been used in several studies (e.g., [56,57,58]) to examine the degree of agreement between methods. [59] established the Bland and Altman plot for comparing the

difference and mean between two methods. The results of the difference are plotted on the y-axis against the mean on the x-axis. The difference in mean and the standard deviation are used to design the limits of agreement, which quantifies the agreement between two methods. [60] has established that the high dispersion of points on the Bland and Altman plot indicates an uneven bias between the two methods. Therefore, based on the rules established by [59], the differences and mean of every single set of SPI and SPEI values were calculated separately. In this study however, the mean difference (Bias) and the standard deviation (SD) were calculated from the difference of every single set of SPI and SPEI values. The lower (Bias -1.96) and the upper (Bias +1.96) limits of agreement were computed at 95% confidence interval.

The study employed 1-, 3-, 6-, 9-, and 12-months' SPI and SPEI for analysis. This was done to reveal drought occurrences, severity and extreme in short, medium, and long terms. Drought categorization of SPI and SPEI values (Table 1) based on [61] is adopted in this study.

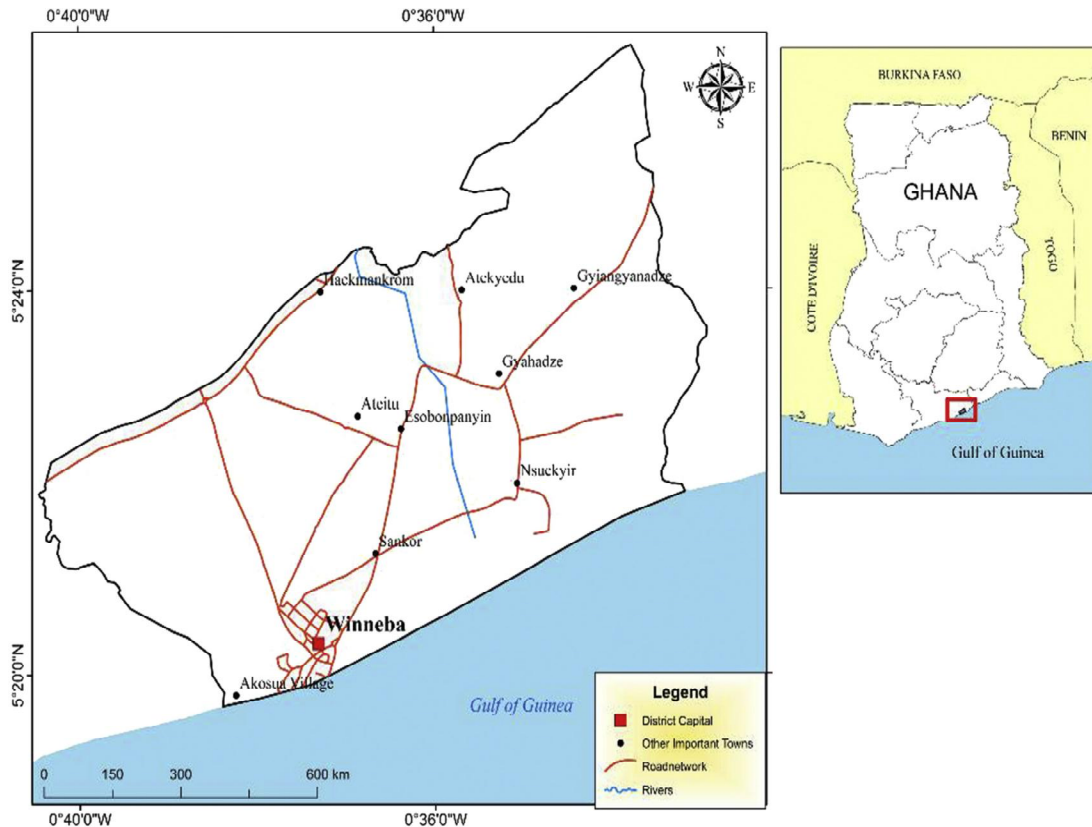


Fig. 1. Geographical map of the Effutu municipality showing Winneba (Cartography, GIS, and remote sensing laboratory of the university of education, Winneba)

Table 1. Drought categorization based on SPEI and SPI values [61]

SPI and SPEI values	Category
2.00 and above	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
-0.99 to 0.99	Mild drought
-1.00 to -1.49	Moderate drought
-1.50 to – 1.99	Severe drought
≤-2.00	Extreme drought

Table 2. Drought characteristics over Winneba

	SPI-1	SPEI-1	SPI-3	SPEI-3	SPI-6	SPEI-6	SPI-12	SPEI-12
Mild drought	427	401	391	402	387	389	373	381
Moderate drought	33	51	54	33	62	34	66	34
Severe drought	18	20	29	34	21	31	27	30
Extreme drought	2	8	4	9	5	21	3	24

3. RESULTS AND DISCUSSION

3.1 Comparison between SPI and SPEI

Fig. 2a, b, c, and d report SPI and SPEI values at 1-, 3-, 6-, and 12-month timescales over Winneba respectively from 1980-2019. It is obvious that both SPI and SPEI have identified more of mild type of drought in the short-term (1- and 3-month), medium-term (6-month) and the long-term (12-month) (Table 2). However, there exist great disparities in SPI and SPEI in terms of drought severity and extreme at all timescales.

Based on the short-term, the 1-month SPI detected extreme (severe) droughts in 1990 and 2015 (1980-1982, 1984, 1987, 1988, 1990, 1998, and 2011) while SPEI detected extreme (severe) drought in 1980, 1982, 1984-1986, and 1990 (1980-1982, 1984, 1985, 1990, 1992, 2007, and 2008). The 3-month SPI also identified extreme (severe) droughts in 1980 and 1990 (1980-1982, 1984-1986, 1990, 1998, and 2009) while that of SPEI detected extreme (severe) droughts in 1980, 1982-1984, 1989, and 1990 (1980-1984, 1986, 1990, 1992, 1995, 1998, 2001, and 2009).

On the medium-term, the 6-month SPI identified extreme (severe) in 1980, and 1981 (1980-1984, and 1986) and that of the SPEI identified extreme (severe) droughts in 1980, 1981-1984, and 1990 (1980-1984, 1986, 1988, and 1990). On the long-term, the 12-month SPI identified extreme (severe) in 1981 (1980, 1981, 1983-1986) while that of the SPEI identified extreme (severe) droughts in 1980, 1981, 1983, 1984,

and 1986 (1981, 1982, 1984-1986, 1990, and 1991).

In summary, both SPI and SPEI are better indices to be employed in drought severity and extreme assessment as has been confirmed in studies such as [8,18,30,31,62,63,64]. In this study, SPEI was able to identify clearer extreme and severe droughts over Winneba than SPI. It thus, can be said that SPEI is better suited for extreme and severe drought assessment in the short, medium, and long terms. The SPEI's clearer performance in this study conforms to studies such as [8,62,65].

[65] employed SPI and SPEI in drought analysis at different timescales in Inner Mongolia and their findings suggested a more utilization of the SPEI than the SPI in drought assessment. A similar finding showing the SPEI robustness has again been established by [62] who compared the suitability of the SPI and SPEI for drought probability distributions in Europe. Also, findings by [8] who compared SPI and SPEI indices on drought severity and extreme in Bangladesh, indicated the better performance of SPEI than SPI. As reported by [65], climate dynamics and variations in climatic conditions in different regions and localities will always result in variations between the SPI and SPEI. There is no doubt that SPI is a better index for detecting drought variations. However, its neglect of the effect of evaporation on drought makes it deficient and may not be appropriate for drought monitoring in arid and semi-arid regions or localities [66,67,68]. The SPI in this study only considered precipitation over Winneba as the

main index and this probably resulted to less detection of the drought values. It must be noted that, the SPI was able to identify extreme drought

in the August 2015 while the SPEI identified mild drought.

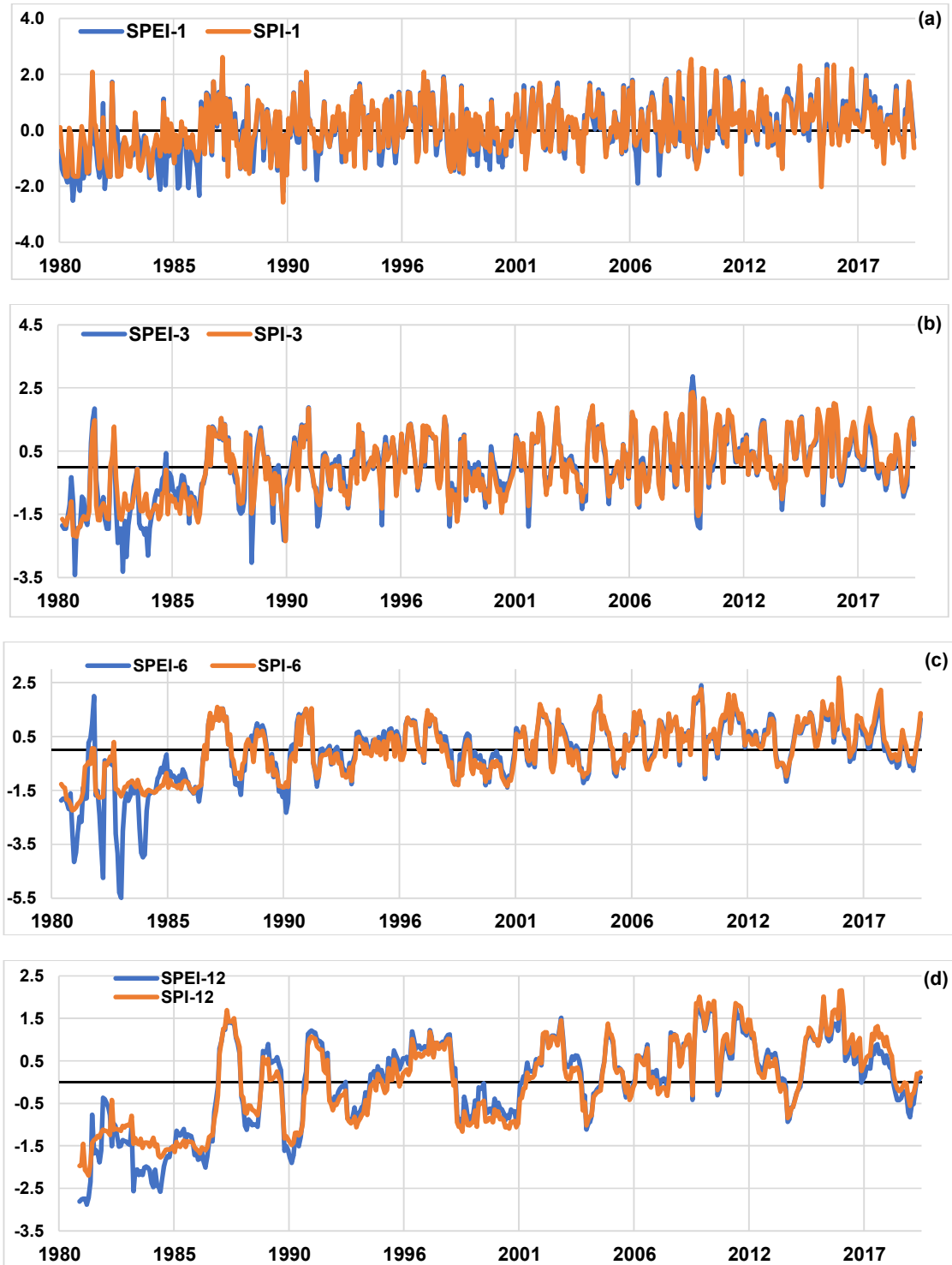


Fig. 2. SPI and SPEI values for Winneba. (a) 1-, (b) 3-, (c) 6-, and (d) 12-month timescales

As established by [69], temperature in Winneba has been increasing and the inclusion of temperature in the SPEI index resulted in its better performance at all timescales (Fig. 3) making the performance of the SPI deficient in this study. Findings by [8] stressed the better performance of the SPEI due to its utilization of the potential evapotranspiration (PET) parameter as an additional input. This finding is again supported by [70] who reported a greater reliability in the utilization of PET with the hydrological drought index. Findings in the study [71] also emphasised that the SPEI detects actual drought situations since increasing temperature and decreasing rainfall causes higher evaporation. This study thus supports the statement by [8] that precipitation and PET propagate unique climatic changeability of drought extreme and severity.

Fig. 3 illustrates the number of severe and extreme drought occurrences at different timescales over Winneba. SPEI clearly identified more extreme and severe drought occurrences over Winneba than SPI. For the 1-month timescale, SPEI recorded 8 and 20 months of extreme and severe droughts, respectively while that of the SPI recorded 18 and 2 months of severe and extreme droughts, respectively. For the 3-month timescale, a similar pattern was identified for extreme (9 months) and severe (34 months) for SPEI and extreme (4 months) and severe (29 months) for SPI. The 6-month timescale also recorded extreme of (21 months) and severe of (31 months) while that of the SPI recorded extreme of (5 months) and severe (21 months).

For the 12-month timescale, SPEI recorded extreme of (24 months) and severe of (30 months) while that of the SPI recorded extreme of (3 months) and severe of (27 months). This study has detected decadal extreme and severe droughts occurrence in the 1980s, 1990s, 2000s and 2010s over Winneba. This result can be compared with other drought studies in Ghana (e.g., [26,27,30]. [26] has utilized the SPI index to mild to extreme drought in coastal Ghana. [27] has also employed the SPI index to identify drought in the Volta Basin of Ghana. [30] further utilized the SPI index to detect drought in the Volta Region of Ghana.

3.2 Correlation Analysis of SPI and SPEI

The Pearson correlation coefficient was employed to determine the linear correlation

between SPI and SPEI at different timescales (Fig. 4). Strong and significant linear correlation was found between SPI and SPEI at all timescales: 1-month ($r=0.90$ at $P = .05$), 3-month ($r=0.91$ at $P = .05$), 6-month ($r=0.84$ at $P = .05$), and 12-month ($r=0.93$ at $P = .05$) and both indices show increasing trend. This finding is in consistent with SPI and SPEI comparison study done by [8] in Bangladesh, [58] in Tigray Region, Northern Ethiopia, [72] in Pakistan, and [73] in the Upper Blue Nile Basin, Ethiopia. In disagreement with the finding of this study is that of [74] who compared SPI and SPEI indices in the Chi River basin, Thailand and reported a decreasing trend. Other inconsistent studies including [75] in Bangladesh and [76] in Iran compared the SPI to other indices such as Effective Drought Index (EDI) and found better performance in the EDI than the SPI.

The cross-correlation method was again used to examine the relationship between lagged SPI and SPEI. At 1-month time lag, strong and positive correlations were established for both the short-term (0.92 and 0.95), medium-term (0.92), and long-term (0.96) droughts. In this study, all trends in SPI and SPEI indices have been identified to be strong and positive and drought occurrences are frequent. This finding, therefore, reinforces [77] and [78] assertion that global warming has increased drought occurrences in this century in many regions and localities of the world.

[79] do not accept the use of the Pearson correlation as a method of examining the degree of agreement between two variables. [79] are of the view that two variables can be positively (negatively) correlated however, with no agreement between them. [80] and [54] have also advised against the use of correlation for comparing variables. Therefore, the correlation analysis in this study shows the strength and direction of the linear association between the SPI and the SPEI and not the level of agreement or differences.

3.3 Degree of Agreement between SPI and SPEI

To detect the degree of agreement or difference between SPI and SPEI, the Bland and Altman plot was employed (Fig. 5). As has been reported by [60], the Bland and Altman plot provide a graphical illustration of the agreement between two assessments. To detect a better degree of agreement in the Bland and Altman's plot, the

differences in the average of the two methods or variables should be close to zero [54]. In this study, SPI and SPEI detected mean difference values close to zero (-0.06138, -0.00736, -0.05211, and -0.01810) for 1-, 3-, 6-, and 12-month timescales, respectively. Thus, a good agreement exists between SPI and SPEI at all timescales. This finding is conformity with the finding of [58] who employed the Bland and Altman’s plot to detect the degree of agreement between SPI and SPEI as drought assessment

tools in Tigray Region of Northern Ethiopia. The finding also conforms to [80] who asserted that a good agreement is achieved if point dispersion is reduced, and points get closer to the mean (bias) line. Fig. 5 thus, shows a good degree of agreement since majority of the points are closer to the bias line and with majority of the dispersion confined within the upper (+1.96SD) and lower (-1.96SD) limits of each timescale.

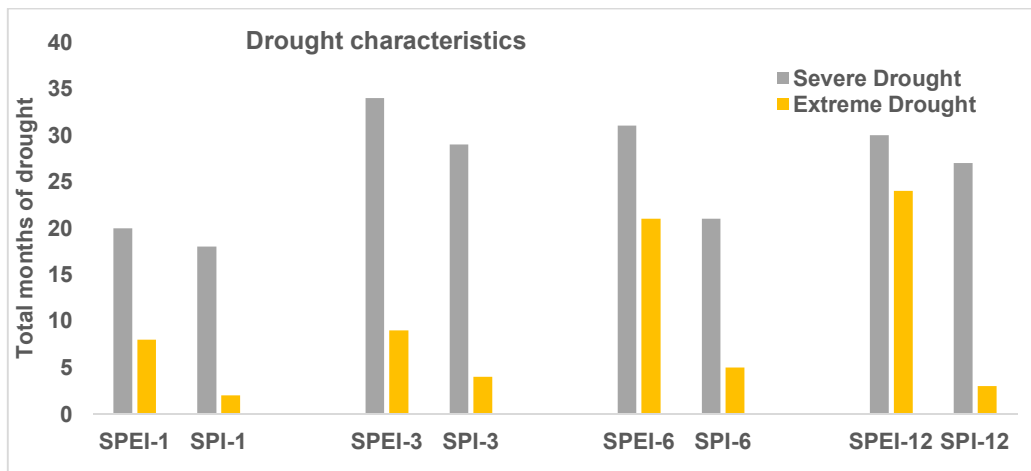


Fig. 3. Frequency of severe and extreme drought events in Winneba (1980-2019) based on SPI and SPEI

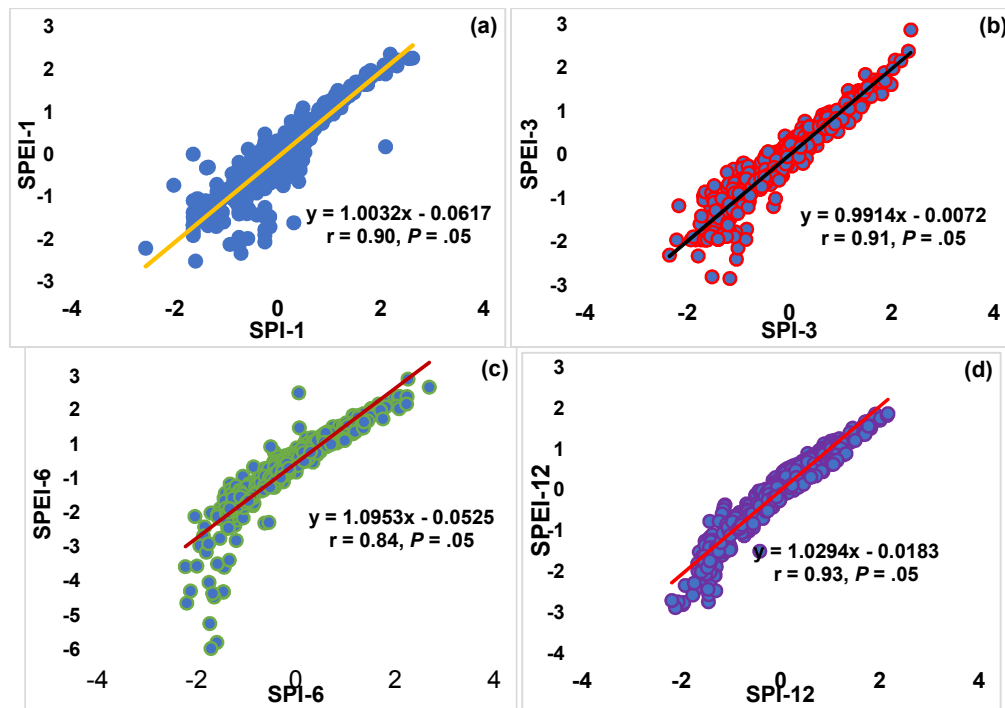


Fig. 4. Correlation between SPI and SPEI at (a) 1-, (b) 3-, (c) 6-, and (d) 12-month timescales

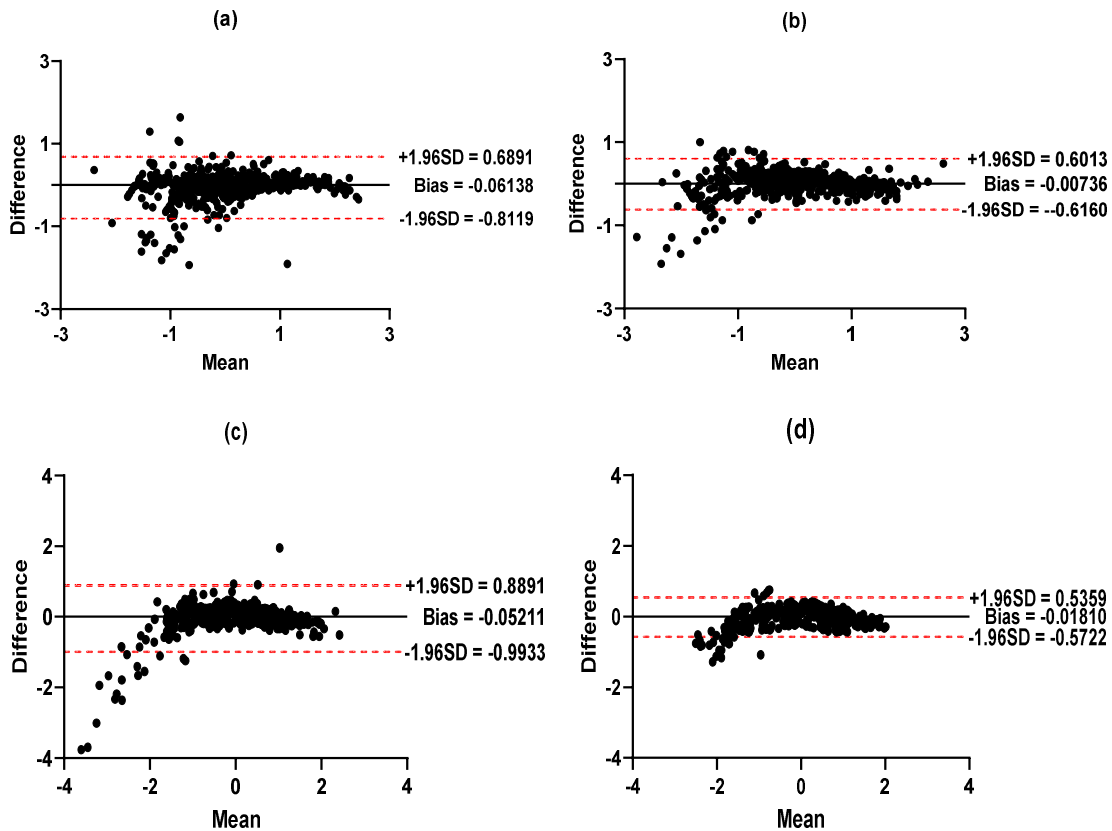


Fig. 5. Bland and Altman plot showing SPI and SPEI at (a) 1-, (b) 3-, (c) 6-, and (d) 12-month timescales

4. CONCLUSION

The study compared the performances of SPI and SPEI drought indices over Winneba-Ghana. The SPI and SPEI featured drought occurrences, severity and, extreme from 1980-2019. The association and the degree of agreement between SPI and SPEI were established using Pearson correlation coefficient and cross-correlation, and the Bland and Altman plot, respectively.

Results show that between 1980-2019, the mild drought type has occurred many times in Winneba under both SPI and SPEI. SPI and SPEI performances with respect to drought severity and extreme were the focus of the study. The results again, show a strong and positive association between SPI and SPEI (0.90, 0.91, 0.84, and 0.93) at 1-, 3-, 6-, and 12-month timescales, respectively. Also, a good degree of agreement was found between SPI and SPEI (-

0.06138, -0.00736, -0.05211, and -0.01810) at 1-, 3-, 6-, and 12-month timescales, respectively.

The study further, established that while both the SPI and SPEI correlate very well with each other, the SPEI performed better than the SPI in drought occurrences, severity, and extreme detections in Winneba at all timescales. The SPEI's great performance was due to the inclusion of PET in the analysis. Variations in PET affect the water balance system such as surface runoff and natural water need. Increases in PET will, therefore, have a negative effect on crop yield in Winneba whose agricultural activity is rain-fed. This thus, makes evaporative requirement an essential element in defining drought conditions in Winneba.

The results of the study have shown strength in SPEI than SPI as drought assessment tools in Winneba. Nevertheless, the significance of SPI cannot be overlooked. This is because the SPI

showed a good agreement with SPEI in the agreement analysis. Also, the SPI was able to detect decadal extreme drought in the 2010s in the periods analysed while the SPEI failed. The SPI can, therefore, be used when there exists unavailability of temperature data to perform SPEI. This study, therefore, recommends the utilization of numerous drought indices when assessing the duration, extreme, and severity of drought at a particular region or locality to arrive at a strong decision.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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