Appraisal of Dry Spell and its Associated Implication on Rain-Fed Crop Production: A Case Study of Soil Moisture Requirement for Plant Growth in Jos-Plateau

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ABSTRACT

With an emphasis on the soil moisture needs for optimum plant growth, this study evaluated the effects of dry periods on rain-fed agricultural output in Jos-Plateau, Nigeria. In Nigeria's highlands with cooler temperatures than surrounding lowlands, where agricultural communities rely significantly on seasonal precipitation, the study fills important knowledge gaps about drought patterns. We examined dry spell trends in six Local Government Areas (LGAs): Barkin Ladi, Bassa, Bokkos, Jos South, Mangu, and Riyom, using satellite data from Google earth engine and precipitation data from the CHRS portal covering the years 2014–2023. In light of crop water requirements, dry periods were defined as five days in a row with rainfall of less than 5 mm. Vegetation Condition Index (VCI), Temperature Condition Index (TCI), Precipitation Condition Index (PCI), and Soil Condition Index (SCI) were among the climatic indices used to calculate the Advanced Drought Response Index (ADRI). Google Earth Engine, Python, and ArcGIS 10.8 were used for temporal and geographical analysis. The findings showed notable differences in the frequency of dry spells over time and space, with October being a consistently troublesome month in all LGAs and falling around crucial late-season crop maturity times. While Bassa showed more endurance with few early-season disruptions, Jos South and Mangu had the worst circumstances, with up to 10 dry period episodes every year. The ADRI study showed a concerning trend from largely favourable circumstances in 2014 to ongoing, severe drought stress by 2020–2023, with a large area of red–orange coverage signifying widespread vulnerability in agriculture. The study has important ramifications for agricultural planning, emphasizing the urgent need for adaptive farming practices, such as improved water conservation methods, location-specific management tactics, and early maturing crop types, to guarantee regional food security.

Keywords: Dry spell, rain-fed agriculture, soil moisture, drought monitoring, Jos-Plateau

INTRODUCTION

Precipitation is undeniably a major factor for supporting crop production, making the global rain-fed agricultural system crucial for food security. A significant portion of the world's freshwater and food production relies on seasonal precipitation. Rain-fed cropping systems may face poor productivity if the variabilities in weather parameters, including rainfall are below the optimum requirement. Fluctuation in rain greatly impacts the seasonal agricultural production output for any country that depends substantially on wet-season farming. This phenomenon is termed a dry spell, and it has drawn more attention since it can militate with planting plans, impede crop development, and reduce overall agricultural output. Dry spells are a sequence of days without a substantial amount of precipitation (Sanchi *et al.*, 2021). The number of days without adequate rainfall during the wet season is satisfied as a dry spell range from three days (3) or more; five days of dryness in the wet season is called a pentad dry spell (Sawa and Adebayo,2018; Sanchi *et al.*, 2021). Examples of regions that are vulnerable to wet-season dry spells—often termed drought due to altered natural vegetation—include the Mediterranean (which encompasses several countries), Central Asia, Titicaca basing and West Bengal in India (Tremblay *et al.*, 2020; Nurgul *et al*, 2020; Ricardo *et al.*, 2021; and Sabita *et al.*, 2020). Tremblay *et al.* 2020 highlighted four types of droughts (i.e., Meteorological, agricultural,

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socioeconomic and hydrological) within Mediterranean countries potentially resulting from changes in wind circulation patterns or disturbances to the natural ecosystem.

Nigeria’s instances of dry spell and drought was recorded in some regions of the country; parts affected include most of the state found in the Sudan and Sahel savannah belt, and some southern part of the country (Mansur, 2020; Chibuike *al et*, 2023). The central region of Nigeria also had some forms of rainfall anomaly. Most of these meteorological anomalous events are attributed to the unabated impact of climate change: global warming has also negatively affected arable land and small and medium agro-allied enterprises (Afolabi *et al*., 2019; IPCC, 2023; Kazi, 2016). These anomalies may cause brief but significant periods of insufficient precipitation, resulting in dry spells at some points in the wet season that may have a significant impact on the growth of crops that rely on rainfall. Understanding the dynamics of wet-season dry periods and their impact on agricultural systems is therefore crucial, especially in situations where vulnerable communities mainly rely on subsistence farming. With a specific focus on the temperate-like climate found in some parts of Nigeria, this study undertakes a thorough assessment of the wet-season dry spell and its effects on rain-fed agricultural output which comes through sufficient moisture availability. The aim of the research is to investigate how wet-season dry spells impact crop growth and yield by examining soil moisture availability for farming and their spatial and temporal distribution within the years and region of the study. An in-depth analysis of the patterns and fluctuations of rainfall spanning a ten-year period was carried out to examine its impact on soil moisture. The availability of water for root uptake is greatly influenced by soil moisture, which also plays a crucial role in total agricultural production.

The study is believed to offer valuable insights into potential solutions for adjusting rain-fed cropping systems to these climatic uncertainties. The study will also provide farmers, decision-makers, and stakeholders with vital information for making educated decisions on crop selection, planting techniques, and water management by examining the soil moisture requirements for optimal plant growth during such difficult times. The study's results can also help advance the conversation on climate resilience in agriculture by providing a model for boosting food security and sustainability in rain-fed areas that are dealing with the complex effects of shifting climatic patterns.

The Study Area

Jos plateau is found within the Plateau State; located in the North-central of Nigeria. It consists of six local government areas (LGAs) out of seventeen. The LGAs include Barkin Ladi, Basa, Bokos, Jos-south, Mangu, and Riyom. These LGAs are located at latitude 9º1˙12” N to 10º22’43” N 1and longitude 8º38’24” E to 9º41’44” E. The total land area is 10086.8395 KM^2; and an approximated population of 2.5 million people. The state is called after the beautiful Jos Plateau, a mountainous area in the state's north with fascinating rock formations. The grasslands that blanket the plateau are littered with bare rocks. The Shere Hills range in Jos has a height range of roughly 1,250 meters to a high of 1,829 meters above sea level. Years of tin mining have also formed deep ponds and wells in the area.

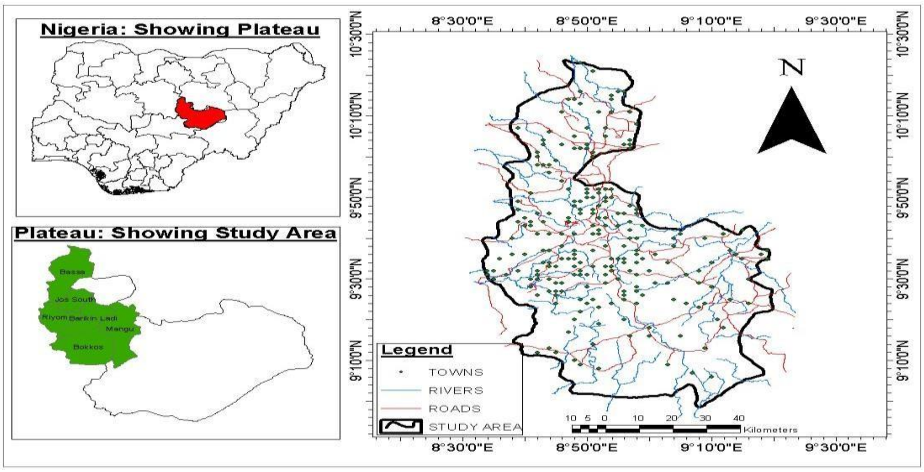

Figure 1. Map of the study area

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Source: Authors

Despite being in the tropical zone, Plateau State has a near-temperate climate, with an average temperature ranging between 18ºC and 22°C. Between December and February, the coldest weather is caused by Harmattan winds. The warmest months are typically March and April during the dry season with the range between 26ºC and 30ºC. The average annual precipitation ranges from 131.75 cm (52 in) in the south to 146 cm (57 in) on the Jos-Plateau. During the wet season months of July and August, the most rainfall is reported (https://www.plateaustate.gov.ng/plateau/at-a-glance, date of acquisition was 25 September, 2023).

The region's natural vegetation was most likely a mix of savanna, open woodland, and forest. Human activities have destroyed the plateau's tree cover, and open grassland now covers the majority of the plateau. Small patches of woodland and forest persist on high and inhospitable terrain, such as the southern and western escarpments, rivers, and rock outcrops.

MATERIALS AND METHODS

Audu et al (2013) and Mansur et al (2020) studied the drought in Nigeria but those studies that were taken to investigate drought or dry spells, didn't account for the temperate-like climate found on the Jos-Plateau, Obudu, Mambila plateau and Madara hill which share almost similar climatic variables.

Dataset

Data for this research were acquired from Google Earth Engine (GEE) using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data. MODIS data utilized consisted of Terra (MOD) and Aqua (MYD) satellites' products, specifically focusing on surface reflectance and vegetation indices collections provided in the Earth Engine Data Catalog. MODIS sensors capture 250m to 1km spatial resolution varying with spectral bands and a revisit period of 1-2 days considering the combined Terra and Aqua satellite pair. Precipitation data was collected from the CHRS portal (https://chrsdata.eng.uci.edu/, accessed on 26 Oct., 2023), and it has a spatial resolution of 0.04 × 0.04 degrees (approx. 4km) and a temporal resolution of 1 hour. Rainfall data sets and MODIS satellite imagery were downloaded and preprocessed for a ten-year period of analysis, leveraging the cloud-computing capabilities of Google Earth Engine for efficient large-scale geospatial data processing and analysis.

Tools

The tool used for this analysis includes ArcGIS, MS Excel, Python, and Google Earth engine.

Methods

The sequence of days defined as a dry spell in this context was a sequence of five days with less than five millimeters (<5mm) of rainfall. Audu et al (2013) and Mansur et al (2020) considered days with rainfall less than 2mm and 1mm respectively, as drought; But considering the soil moisture availability for plant development, these thresholds are insufficient to support crop growth and good yield, most especially for soil characterized by 70% sandy. crops' moisture need of 10mm/day, requires 20mm of rainfall or other sources of water on average, this water needs of crops vary, and is dependent on temperature, wind, and stages of growth (shttps://www.fao.org/3/s2022e/s2022e02.htm, access on 20 Oct.., 2023); the table 1 below show twenty (20) essential crops water need approximation throughout their growing seasons:

Table 1: Water Needs Approximation throughout Plant Life

S/N	Crop	Crop Water Need (mm/total growing period)
1	Maize	500-800
2	Potato	500-700

3	Rice (paddy)	450-700
4	Bean	300-500
5	Tomato	400-800
6	Pepper	600-900
7	Cabbage	350-500
8	Peanut	500-700
9	Onion	350-550
10	Soybean	450-700
11	Sorghum/Millet	450-650
12	Sugarcane	1500-2500
13	Pea	350-500
14	Melon	400-600
15	Cotton	700-1300
16	Sunflower	600-1000
17	Barley/Oats/Wheat	450-650
18	Banana	1200-2200
19	Citrus	900-1200
20	Sugarbeet	550-750

Source: FAO (https://www.fao.org/3/s2022e/s2022e02.htm)

Hence, dry spell days were enumerated using Python, and spatial variability was assessed to understand their temporal and geographic extent. The study area's farmland distribution was evaluated by classifying various land use and land cover types after necessary data preprocesses into two group, i.e., arable land and non-arable land using support vector machine (SVM) algorithm in google earth engine.

In this paper, we used the Advance Drought Response Index (ADRI), which is measured in percentage that ranges from 0 to 100. It is calculated in google earth engine (Javascript API) using various indices such as the Vegetation Index (VCI), Temperature Condition Index (TCI), Precipitation Condition Index, Soil Condition Index (SCI). These indices are key indicators for dry spells or drought monitoring.

The Vegetation Condition Index is to assess the drought events in vegetation cover (Liu and Kogan, 1996). The researchers optimized VCI by replacing NDVI with MSAVI, which showed better performance in determination of vegetation sensitivity and soil noise to the index (Qi *et al*., 1994) than NDVI. The VCI was calculated using the Modified Soil Adjusted Vegetation Index (MSAVI) in Google earth engine (Javasript API) since it is the factor for VCI. The formula was given below:

$$MSAVI = (1 + L) * (Bnir - Bred) / (Bnir + Bred + L) \qquad \text{Eq. 1}$$

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Where: L is a correction factor which ranges from 0 for very high vegetation cover to1 for very low vegetation cover- 0.5 was used as the value of L, Bnir is near infrared band, and Bred is red band

$$VCI = \frac{SAVI - SAVImin}{SAVImax - SAVImin} \times 100 \qquad \text{Eq 2}$$

Where VCI is the Vegetation Condition Index, *SAVI* is the Soil Adjusted Vegetation Index, *SAVImin* is the Soil Adjusted Vegetation Index minimum value, and *SAVImax* is the Soil Adjusted Vegetation Index maximum value.

Temperature Condition Index was evaluated using two (2) meters above the ground temperature data sourced from the above link. the equation for the computation of TCI is as follows:

$$TCI = \frac{LST - LSTMmin}{LSTmax - LSTmin} \times 100 \qquad \text{Eq 3}$$

Where: TCI is Temperature Condition Index, *Tmax* is the maximum temperature, *Ti* is temperature initial, and *Tmin* is minimum temperature.

Precipitation Condition Index was analyzed as follows:

$$PCI = \frac{Pi - Pmin}{Pmax - Pmin} \times 100 \qquad \text{Eq. 4}$$

Where *Pi* is precipitation initial, *Pmin* is precipitation minimum and *Pmax* is precipitation maximum.

Land surface temperature values were calculated to get insight into the soil condition of the various farms distributed in the study. The equation for calculating the Soil Moisture Index (SMI) is:

$$SCI = \frac{SMI - SMImin}{SMImax - SMImin} \times 100 \qquad \text{Eq. 5}$$

Where: *SMImax* is the soil moisture index maximum, *SMI* is soil moisture index, *SMImin* is the minimum value of soil moisture index.

The Advanced Drought Response Index (ADRI) was used to assess the drought conditions, which is a comprehensive analytical tool that considers variables such as meteorological, agricultural, and hydrological dryness. The ADRI equation used was:

$$ADRI = [L * VCI * \{C + \frac{1}{L * (VCI + TCI + PCI + SCI)} * (PCI + TCI + SCI)\}] \qquad \text{Eq 1}$$

and a normalization factor, L. A constant, c, is also used to avoid a null denominator. Each index has its own formula for computing its values. The values of L and c used in this paper are 0.25 and 0.01, respectively. If the ADRI value is close to 0, it indicates drought-like conditions, while values near 100 indicate healthy conditions.

RESULTS AND DISCUSSION

The rainfall data provides a detailed examination of consecutive dry spell patterns in six Local Government Areas (LGAs) of Plateau State, Nigeria, over ten years from 2014 to 2023. The data closely follows events at each station where five or more consecutive days were recorded with rainfall less than 5mm during the critical months of May to October, which encompasses onset into the wet season and the peak of the rainy season. The next section presents data for each of the Local Government Areas (LGAs):

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Table 2: Total count of consecutive five days without rainfall in each local government (LGA)

Barkin Ladi							**Bassa**					
	May	June	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Sept.	Oct.
2014	0	1	1	0	1	4	0	0	0	0	0	2
2015	0	0	0	0	0	4	0	0	0	0	1	2
2016	1	0	0	0	1	5	1	1	0	0	0	4
2017	0	0	0	0	0	6	1	0	0	0	0	6
2018	0	0	0	0	0	3	0	0	0	0	0	1
2019	1	0	0	0	0	3	0	2	0	1	0	3
2020	2	0	0	1	1	5	1	0	0	1	1	5
2021	0	0	0	0	0	2	0	1	0	0	0	3
2022	0	0	1	1	0	3	0	0	0	2	1	2
2023	0	1	0	1	0	3	0	3	0	0	0	2
Bokkos							**Jos South**					
	May	June	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Sept.	Oct.
2014	0	1	0	0	1	4	0	0	0	0	1	4
2015	0	1	0	0	0	2	0	0	1	0	1	4
2016	0	1	1	0	1	3	0	0	0	0	1	5
2017	1	0	1	0	0	4	1	0	0	0	0	6
2018	0	0	1	0	0	0	0	0	0	0	0	1
2019	1	2	0	0	0	2	0	2	0	0	0	4
2020	1	0	0	2	1	3	0	0	0	0	0	6
2021	0	0	0	0	0	1	0	0	0	0	0	3
2022	1	0	0	1	0	2	0	0	0	1	1	3
2023	0	0	0	0	0	2	0	1	0	0	0	2
Mangu							**Riyom**					
	May	June	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Sept.	Oct.
2014	2	1	0	0	0	5	0	1	0	0	0	4
2015	1	1	0	0	0	4	0	0	0	0	0	2
2016	1	0	0	0	2	3	1	0	0	0	1	5

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2017	4	0	1	0	0	5	0	0	0	0	0	5
2018	0	1	0	0	0	2	0	0	0	0	0	1
2019	1	2	0	0	0	1	1	3	0	0	0	3
2020	1	1	0	1	0	5	0	0	0	1	0	4
2021	1	0	0	0	0	1	0	2	0	0	0	2
2022	1	0	0	2	0	3	0	0	0	1	0	2
2023	0	0	0	0	0	4	0	2	1	1	0	2

BarkinLadi exhibits a relatively modest dry spell frequency, with October consistently being the most vulnerable to long dry spells. The area had its worst years in 2016, 2017, and 2020, with 7-8 total dry spell events each. October itself accounts for the majority of these events, with 2017 being particularly severe with 6 consecutive dry spells happening that month. The initial three months of the wet season (May-July) record low occurrences of dry spell, meaning that once the rains are established, they become quite consistent during thepeak.

Bassa exhibits a divergent trend with comparatively lower incidences of dry spells compared to other areas. The region shows high stability during the conventional wet season months (June-August) with all but one year recording zero dry spells in these months. October seems to be the principal concern month, particularly in 2016 and 2017 when the area recorded 4 and 6 consecutive dry spells respectively. The overall pattern shows Bassa enjoys more uniform rainfall distribution, yet it still faces challenges during the latter part of the wet season transition.

Bokkos experiences moderate dry spell risk with an unusual pattern of the month of June being surprisingly problematic for some years. Unlike other locations, Bokkos recorded a number of dry spells in June 2019 (2 incidents) and June 2023, which is unusual because June would typically be the time of onset of regular wet season rains. The area has normal October difficulty, with 2014, 2016, and 2020 recording 3-4 dry spell incidents in this transitional month.

Jos South exhibits one of the most concerning dry spell trends out of the six stations. The area experienced particularly severe conditions in 2017 and 2020, with 7 and 6 cumulative dry spell events respectively. October is particularly challenging, with 2016, 2017, and 2020 all experiencing 5-6 consecutive dry spells. The recurrence of October problems over multiple years suggests a systematic problem with the wet-to-dry season transition for this area.

Mangu presents the most varying dry spell pattern, with some years experiencing relatively high frequencies and others experiencing minimal issue. The area experienced its most active dry spell year in 2017 with 10 events, including an unprecedented 4 back-to-back dry spells in May, representing a significant lag in wet season onset. Mangu also presents concerning trends in October across multiple years, with 2014, 2016, 2017, and 2020 each experiencing 3-5 dry spell events.

Riyom traces a pattern similar to other highland areas, with October consistently being the problem over the decade. The station experienced its worst in 2016 and 2017, recording 7 and 5 total dry spell events respectively. Like Mangu, Riyom occasionally experiences early season problems, though not as common as the consistent late-season problems.

The temporal analysis reveals several important trends in all the locations. The year 2017 emerges as a particularly challenging one with all the regions recording above-average frequencies of dry spells. This suggests regional climatic processes may have influenced precipitation patterns in Plateau State during this year. Conversely, years 2018 and 2021 are revealed to be relatively good ones with lower incidences of dry spell occurrences in all the regions. The seasonal distribution of frequency singles out October as consistently troublesome across all six locations, pointing to systematic issues with the wet-to-dry season transition. This has significant implications for farm planning, as October coincides with late-season crop maturation periods. The period May-July, which corresponds to early wet season, typically shows reduced frequencies of dry spells, though isolated early- season disruptions can have disastrous implications for planting timetables.

From a farming point of view, these dry spell trends point to the necessity of adaptive farming practices. The regular October difficulties imply that farmers ought to focus on early maturing varieties of crops and incorporate water saving measures for late-season crop needs.

The location to location variability also points to the possibility of diversified regional measures to agricultural planning, with regions such as Bassa having more favorable prospects for longer growing seasons than more sensitive ones such as Jos South and Mangu.

The data brings to the fore the complex microclimatic variations within Plateau State despite the comparatively small geographical distances between the LGAs. The variations are likely manifestations of the impacts of differences in topography, relief, and local geographical conditions on rainfall patterns. Understanding these localized trends is necessary for informing location-specific adaptation measures to climate and strengthening agricultural resilience within the area.

This detailed examination of land use provides a multifaceted image of the spread of agricultural and non-agricultural lands throughout the study area shown in Figure 2. The area of investigation encompasses a total surface area of 7,364.117775 square kilometers, which is a large geographical region that encapsulates the intricate relationship between productive agricultural land and various non-agricultural land features. The cultivable land portion, shown in a radiating green color in figure 2, covers an area of 3,072.399816 square kilometers and accounts for about 41.7% of the total area. This vast percentage of cultivable land suggests a landscape with high agricultural potential to support cultivation of crops. The distribution pattern of arable land appears quite well distributed throughout the area, yet with high concentrations in certain locations and apparent fragmentation in others, reflecting the natural topographic differences and human settlement patterns that dictate land use decisions.

Alternatively, the non-arable components occupy a considerably larger extent of 4,291.717959 square kilometers that forms about 58.3% of the entire defined area. The category includes a range of varied land units that are unproductive or not available for the growth of crops, such as major rock outcrops which most probably reflect geochemical units with resistance to weathering and soil development. The occurrence of rocky terrain is commonly associated with more elevated land or topography where the bedrock is near the surface, forming natural impediments to agricultural development and the fragmented pattern of arable land shown in the map. The built-up areas included in this category of non-arable suggest human settlements, infrastructure development, and urbanization that have been transformed from their natural form to serve residential, commercial, industrial, and transport requirements.

Aquatic ecosystems, including rivers and reservoirs, are a fundamental component of the category of non-arable land, playing significant roles in regional ecological processes and water resource management. Native rivers create essential drainage networks, maintain biodiversity, and often form fertile floodplains that, in spite of periodic inundation, have the potential to increase the agricultural productivity of adjacent arable land via the mechanisms of nutrient deposition and groundwater recharge. Man-made dams are human landscape modifications, which were built for reasons such as reservoirs of water, flood control, hydroelectric power generation, and facilitation of irrigation, but they irreversibly submerge land areas that once were in existence.

The spatial pattern of distribution established in this study points towards a nature- and human-influenced landscape in which cultivatable land is located within the context of limiting factors that define agricultural potentiality. The relatively high rate of non-cultivatable land suggests that agricultural expansion in the region is subject to considerable geographic and environmental limitations, rendering effective use of the available cultivatable land of crucial significance to the food security and economic growth of the region.

This pattern of land use has profound regional planning, agricultural development planning, and environmental ramifications. The extensive non-agricultural land, while limiting agricultural expansion, may provide important ecosystem services like biodiversity conservation, watershed protection, mineral resources, and recreational values. The representation of the fragmented distribution of arable land on the map may indicate several challenges and opportunities for the governance of agriculture. Such a situation may call for careful consideration of farming practices, land consolidation initiatives, and sustainable intensification strategies to maximize productivity while maintaining ecological integrity.

These measurements of land use categories provide essential baseline data, facilitating decision-making in agricultural policy, land use planning, and sustainable development planning that must balance the competing demands for agricultural production, urbanization, infrastructure development, and environmental conservation within the constraints presented by the natural terrain features of the region

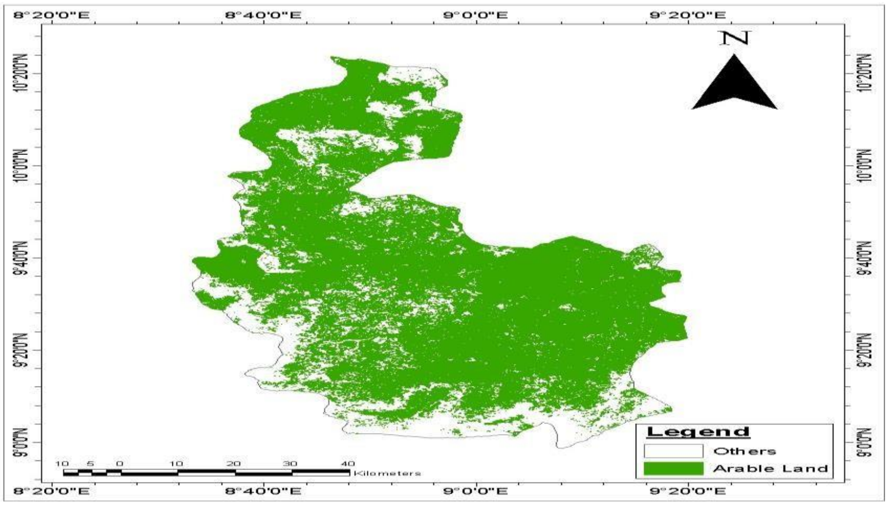

Figure 2: Spatial spread of arable farmlands in the study area

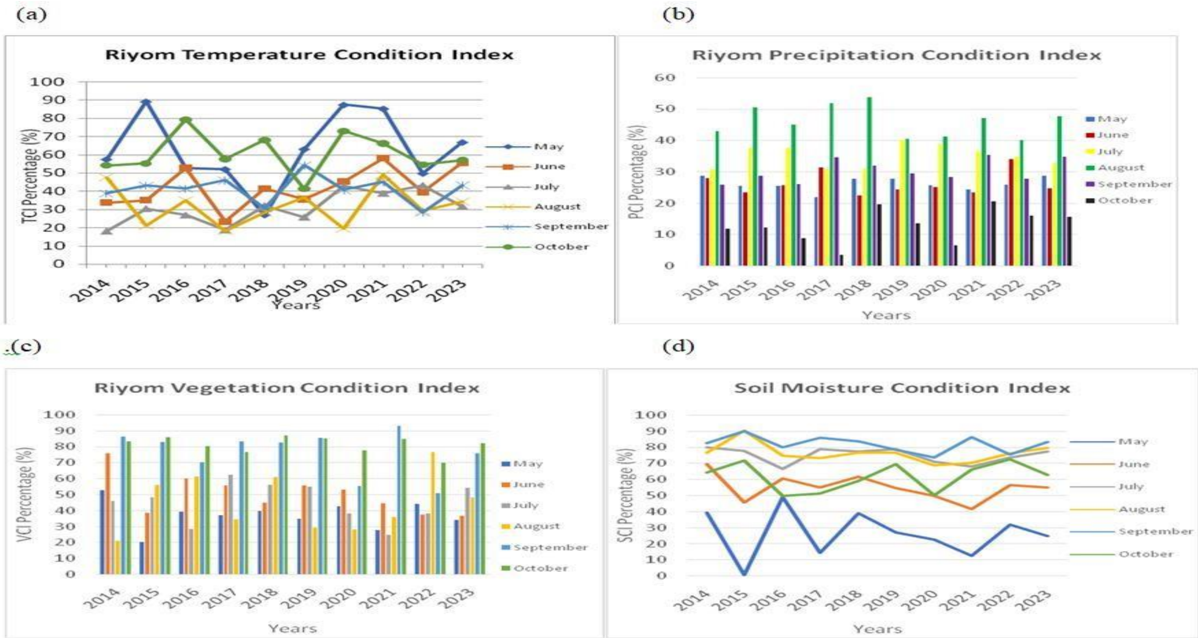

Figure 3: Riyom Geographic Mean Monthly Distribution of TCI, PCI, VCI, and SMCI

Figure 3 illustrates the monthly average percent of Riyom Local Government, which includes Temperature Condition Index (TCI), Precipitation Condition Index (PCI), Vegetation Condition Index (VCI), and Soil-moisture Condition Index (SCI). May is highly variable, with maximum TCI, PCI, VCI, and SMCI values in 2015, 2023, 2014, and 2016, at levels of 89%, 29%, 48%, and 50% (see Figures 1a, 1b, 1c, and 1d). May normally marks the start of the farming season in Plateau State. Season variation of TCI show decline as the

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progress until month of August where the low TCI lowest ebb is evident in August, then the value will start rising. Conversely, 2014 and 2019 August show higher values than June and July. June shows moderate variation of TCI, PCI, and SMCI. There is, nevertheless, an extreme drop in the mean value in June in the majority of the years in the study period for the June PCI. The maximum values of TCI, PCI, VCI and SMCI are 60%, 31%, 34%, 78% and 70%, corresponding to the years 2016, 2022, 2014 and 2014 respectively. The oscillation in July is moderate with the maximum percentages are 43%, 40%, 62% and 80% for TCI, PCI, VCI and SMCI which correspond with the year 2022, 2019, 2017 and 2014. The month of August experience variability of TCI between 49% in year 2021 as the upper limit and 18% in 2014 as the lower limit, PCI is at its maximum across the years of study. PCI upper bound is 54% for the year 2018 and lower bound is 40% for the year 2022. August Month VCI is found to be higher than July, but the values for 2014, 2017, 2019 and 2020 deviate from the norms. Seasonal trend of VCI is found to be irregular for most of the years except 2015, and 2018 where it indicates successive rise during the year. VCI upper limit is 77% in 2022 and the lower limit is 21% in 2014. August is also associated with higher SMCI is peak at 90% in 2015 and the lowest is at 69% in 2020. September monthly variability across the years shows that maximum temperature condition is at 54% and the minimum is 28% in 2019 and 2022 respectively; there is a noticeable decrease in the precipitation in the month of September when compared with month of August, the maximum precipitation is 34% in 2017 and lowest is 26% in 2014. On the contrary, vegetation is blooming when the precipitation is recessing; the maximum and minimum VCI is 50% and 92% in 2020 and 2021, respectively. Furthermore, soil moisture also registered an extreme increase in September at 90% and 73% during the years 2015 and 2020, respectively, based on multiple years of data. Months of October have proven to be very variable similar to the month of May; the highest and lowest TCI values are 79 and 41 which correspond to the years 2016 and 2019. Precipitation is lowest here with 3% in the year 2017and 20% in the year 2021. Vegetation at this time, is very high with low variability, the highest values are 85% in the year 2018 and 70% in the year 2022. Soil moisture demonstrates a decrease in values with high variation throughout the years; the highest value is 72% in the year 2022 and 49% in the year 2016.

The implications of Riyom's monthly climatic indices are the high variability in temperature, rainfall, vegetation, and soil moisture, which all have a direct impact on agricultural operations. May marks the onset of the farming season and is accompanied by weather-induced hardships brought about by variations in all the indices. Cooler temperatures with moderate variations in rainfall and soil moisture characterize the period from June to August, although anomalies are noted in certain years. September and October show contrasting trends, with September having more vegetation and soil moisture but more variability in October. Unpredictable vegetation trends and extreme climatic events point to the need for adaptive agriculture practices like crop selection, pest management, and planting and harvesting timing adjustments. The study also highlights the importance of climate modeling in deciphering long-term trends and informing climate adaptation in agriculture.

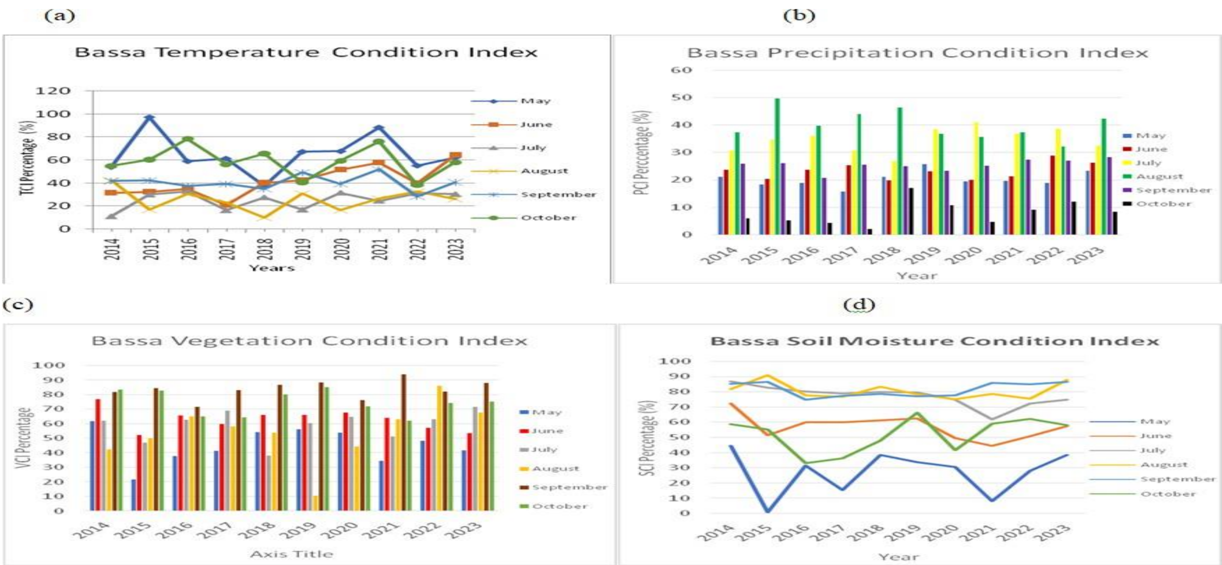

Figure 4: Bassa Geographic Mean Monthly Distribution of TCI, PCI, VCI, and SMCI

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The above figure 4 shows Bassa Local Government TCI, PCI, VCI and SCI monthly distributions over the ten years period. The TCI indicated its year-wise decreasing trend with its minimum value occurring in August month followed by the rise in the temperature since September month. The temperature of the surface of the soil changes considerably online and in comparison as we move over the years. The highest, which is 91%, was recorded in 2015 but the lowest, which is 10%, was recorded in the month of August in 2018. May displays a big variance during the period of study. The pattern of seasonal performance in the PCI indicates that the value will keep on rising until the month it reaches the peak, which will either be August or July and then it will begin to fall. The trend of PCI as is shown in figure 2b increases after May and peaks in August (2014, 2015, 2016, 2017, 2018, 2021 and 2023) or July (2019, 2020 and 2022). It is 2015 and 2017 with the greatest percentage of 50 and the least of 2 in PCI. The seasonal tendency and the year to year variation of VCI is irregular. Similarly, in August 20219, a strange decrease in VCI value was witnessed where the VCI value stood 10 percent lower than the VCI value of May in the season and also in the period of years under analysis. The year showing gradual increase till it reached maximum in August and start decreasing in value towards the close of the season is 2022 (see figure 3c) but the remaining period in the year shows unstable trend within the growing season. The highest is of 94 percent in September 2021. It is noticed that the level of soil moisture is increasing throughout the growing season of every year until attaining the highest point in July in 2014, 2016, 2017, 2019; August in 2015, 2018 and 2023 and September in 20202, 2021 and 2022.The variability over years as shown on figure 2d reflect higher change of alternation of high and low oscillation against 1% in 2015 to 44 in 2014 in month of May. In 2021 and 2014, June minimum and maximum values are 44 and 72 percent respectively. DLWR index of soil moisture is high during July, August and September, and the variations are fair throughout the month. In Bassa LGA, SCI tends to fall in values at the beginning of September. There are low values in October and they are exceptionally perturbing over the years.

When the analysis of climate indices of the Bassa Local Government is considered there is a major implication in the field of agriculture as the temperature, precipitation, vegetation and soil moisture are highly variable. The changes of temperatures with a minimum in August and maximum in May and extreme temperatures may impact crop growing and livestock. The amount of precipitation is the highest in July or August that affects the supply of water, and the unstable vegetation patterns indicate that crop yields are not always optimal. The pattern of soil moisture is increasing during the growing period but has high variability thus making it difficult to control crop water supply. These trends place importance on adaptation approaches to the agriculture sector such as thoughtful crop choices, irrigation facility design, and pest control. Consequently, enhancing productivity in the area requires coping with climate change by using resilient farming techniques.

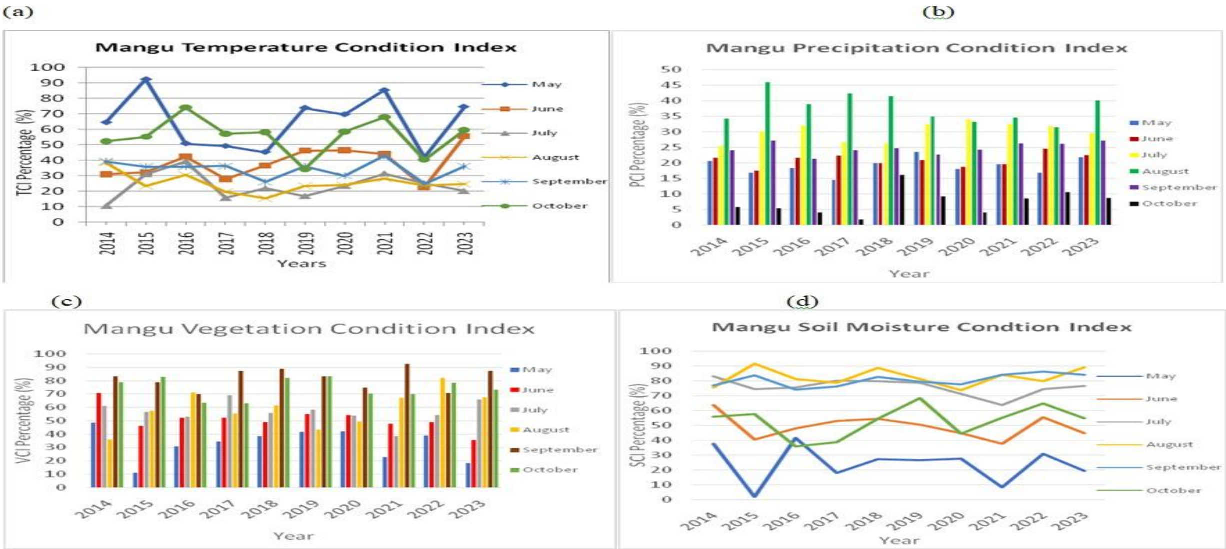

Figure 5: Mangu Geographic Mean Monthly Distribution of TCI, PCI, VCI, and SMCI

The monthly mean percentages of Mangu Local Government of figure 5 were indicated; the monthly mean distributions contained Temperature Condition Index (TCI), Precipitation Condition Index (PCI), Vegetation Condition Index (VCI) and Soil-moisture Condition Index (SCI) can have a significant variation as is characteristic of other areas with a high of TCI value at 92 percent in 2015 and lower at 42 percent in 2022.

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With the incidence of the month of May, there exists a wide range of variance with alternating increase and decreasing average value (see figure 3a). May PCI vary by 15 percentage of low in 2017 and 24 percentage of high in 2019 (Plot figure 1b). The distribution of VCI between the months of May varied between 11 per cent in 2015 and 42 per cent in 2022, which made us aware of the difference that has been experienced (see figure 1c). Usually, months of lowest SCI are May and October and in 2016, the highest low and in 2015, the lowest low of SCI are observed (see figure 1d). TCI, PCI and SMCI variability is high in the month of June but this value experiences a decline in its VCI in June. The highest figures stand at 46%, 24%, 71%, and 63% and this is concurrent to the year 2019, 2022, 2014 and 2014 correspondingly annually. TCI is low in July the oscillation is fair. Nonetheless, it is moderate VCI, with an exception of 2021 that is 38%. The range of variations of TCI is between 39 percent in 2014 and 15 percent in 2018, PC variability is maximum 46 percent in 2018 and minimum 31 percent in 2022, VCI variability is maximum 77 percent in 2022 and minimum 21 percent in 2014, and SMCI variability reaches to a maximum of 91 percent in 2015 and minimum is 77 percent in 2020.Monthly variability of season in the months of September of the last five years revealed that the maximum temperature condition is 86 and 73 in 2022 and 2016 respectively; and the precipitation will not show any appreciable increase in the month of September as compared to the month of August with maximum condition being 27 in 2015 and 2023 and the minimum condition being 21 in 2016. Quite on the opposite, vegetation is flowering at the same time when the precipitation is in recess, the maximal and minimal VCI is 50 percent and 92 percent in 2020 and 2021 respectively. Also, the moisture content of the soil augmented extremely higher in the month of September in which the maximum value was sufficient to be 93 percent in the year 2021 among the years. October months have also proved to be very volatile like the month of May; with the highest and lowest values of TCI being 79 and 41 corresponding respectively with 2016 and 2019. The low precipitation is experienced here with 3 percent in 2017 and 20 percent in the year 2021. Vegetation as at this moment is both high and variability extremely low with the highest of 85 percent in 2018 and 74 percent in 2016. Soil moisture exhibits a decrease in the values with a high range of variable over the years with the highest value being 68 % in 2019 and the lowest at 36 % in 2016.

This discussion demonstrates that the climate indices of Mangu Local Government have major implication to agriculture in terms of climate variability. May have fluctuation of every index, and have a potential of weather difficulties. It is found that in June to August high precipitation and soil moisture is recorded whereas September and October witness fluctuating trends, as there is variability in vegetation and precipitation. Such extreme events as excessive soil moisture in 2015 and 2021 or low temperature and precipitation in 2016 and 2018 also make planning of agriculture more challenging. These trends have an effect on the planting, the taking in, and the choice of a crop, where in times of low precipitation years there may be a need to use drought-resistant varieties. The farmers also need to observe the pests and diseases and long term trends of the climate indices provide information on the changes that could adapt to climate change.

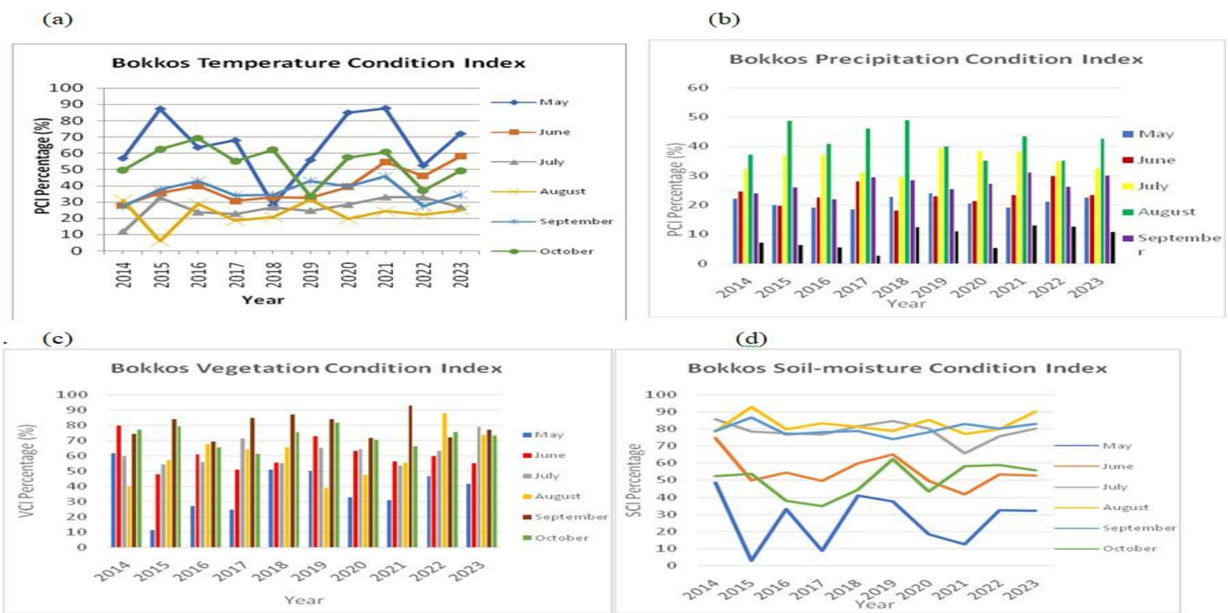

Figure 6: Bokkos Geographic Mean Monthly Distribution of TCI, PCI, VCI, and SMCI

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Figure 6 above is the distribution of Bokkos Local Government TCI, PCI, VCI and SCI by month for period years under study. The TCI had a yearly declining trend with lowest value in August, and then followed by the increase in the temperature from September. The soil surface temperature has varying values compared across the years. The peak value of 87% is in the month of 2021, and the low value of 6% was in August 2015. May is highly unstable throughout the study period. The Pattern of PCI, as described by figure 5b, rose in May and reached its peak in August. The peak of 49% in 2015and 2017, and minimum of 3% PCI is noticed in 2017. The VCI distribution pattern is not irregular during the year. Successive rise is noticed in the VCI in 2015 and 2018, but the rest of the year shows erratic pattern during the growth period. The highest is 93% in September 2021, but the lowest is 11% in May 2015. The soil moisture is observed to be rising throughout each year's growing season until it reaches its highest in August (with 2019 being in September), then PCI readings will begin to fall. Monthly fluctuation over the years as is evident in figure 4d depict greater change of high and low oscillation from 3% in 2015 to 48% in May of 2014. June also depicts trend increase and decrease in the values; it continued to alternate until 2023: June minimum and maximum values are 41% in 2021 and 75% in 2014. July, August and September are characterized by higher soil moisture index with modest fluctuations over the month and early introduction of SCI value decline in September. October values are low and high perturb throughout the years.

The climatic indices analysis of Bokkos Local Government indicates notable climate variability and consequential implications for agriculture. There are seasonal variations in temperatures, with the lowest being in August and highest in May, which may impact crop development. Extreme temperature occurrences, like in August 2015, are dangerous to crops and animals. Rainfall is maximum in August, and drought years like 2017 have an effect on productivity. Plant growth is unstable, and sudden declines, like that experienced in May 2015, can be detrimental to ecosystems. Soil water reaches its peak in August but is highly variable among years. Such temperature, rainfall, vegetation, and soil water variability necessitate planning for plant choice, irrigation, pest control, and climate change adaptation to maintain sustainable agriculture.

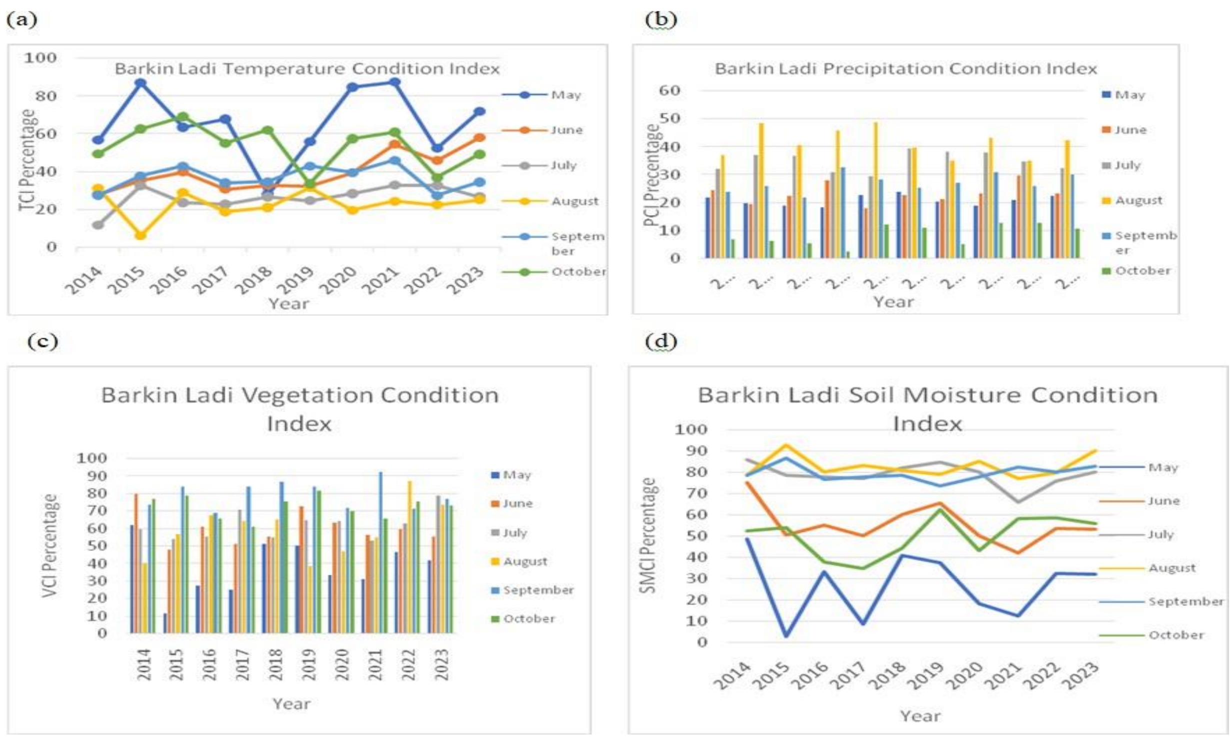

Figure7: BarkinLadi Geographic Mean Monthly Distribution of TCI, PCI, VCI, and SMCI

The agroclimatic surveillance of BarkinLadi (figure 7) shows complex Precipitation-vegetation-soil interactions with typical seasonality and increasing temporal variability. May is the most peaked month in the Temperature Condition Index (80% plus) with a record of extreme pre-monsoon warming, whereas July-August are low (20-40%) with overcast conditions of the rainy season in spite of adequate moistness. The Precipitation Condition Index confirms August to be the maximum rainy month (40-50%), but experiences alarming interannual variation in important planting months of June and July, signaling potential shifts in rainy

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season timing that hinder some crop agricultural planning. The Vegetation Condition Index indicates complex biological responses with best conditions typically occurring in August-September rather than early season months, indicating a 1-2 month lag between precipitation peaks and vegetation response, while indicating pronounced stress periods in 2015, 2018, and 2016.

The Soil Moisture Condition Index indicates the most alarming trends, demonstrating innate hydrological efficiencies in which heavy August rainfall ironically is associated with maximum soil moisture retention. Such apparent pairing suggests graded hydrological performance perhaps due to more intense rainfall, cloud cover, low evapotranspiration, or sufficient infiltration capacity. Low early-season soil wetness values (0-60% in May-July) are followed by rapid increase through August-September, which implies recharged efficiency of the recharge, since September values range from near 79% to over 89% in different years. Soil water fluctuations affect plant survival and crop yields, particularly during months critical for hydrological functioning.

In a broader agroclimatic context, these trends capture a typical climate variability signature over Plateau State, Nigeria, emphasizing the adaptive capacity of the region to inter-seasonal moisture variability. The cross-index analysis suggests that the coupling between rainfall and soil moisture during the peak months is an efficient hydrology system supporting persistent vegetation growth and agricultural productivity. The coincidence of maximum rainfalls with maximum soil water retention under August-September conditions favors crop development and favors crop development and supports healthy vegetation growth. This autogenic positive feedback process, combined with the uniform temperature regimes and vegetation response cycles, indicates that despite inter-annual variability, the region possesses sufficient environmental resilience to support natural ecosystems as well as agricultural systems and thus qualifies as a climatically stable location in Nigeria's Middle Belt area for sustainable land use management. ecosystems and agricultural systems, highlighting the compelling imperative for integrated land and water management measures.

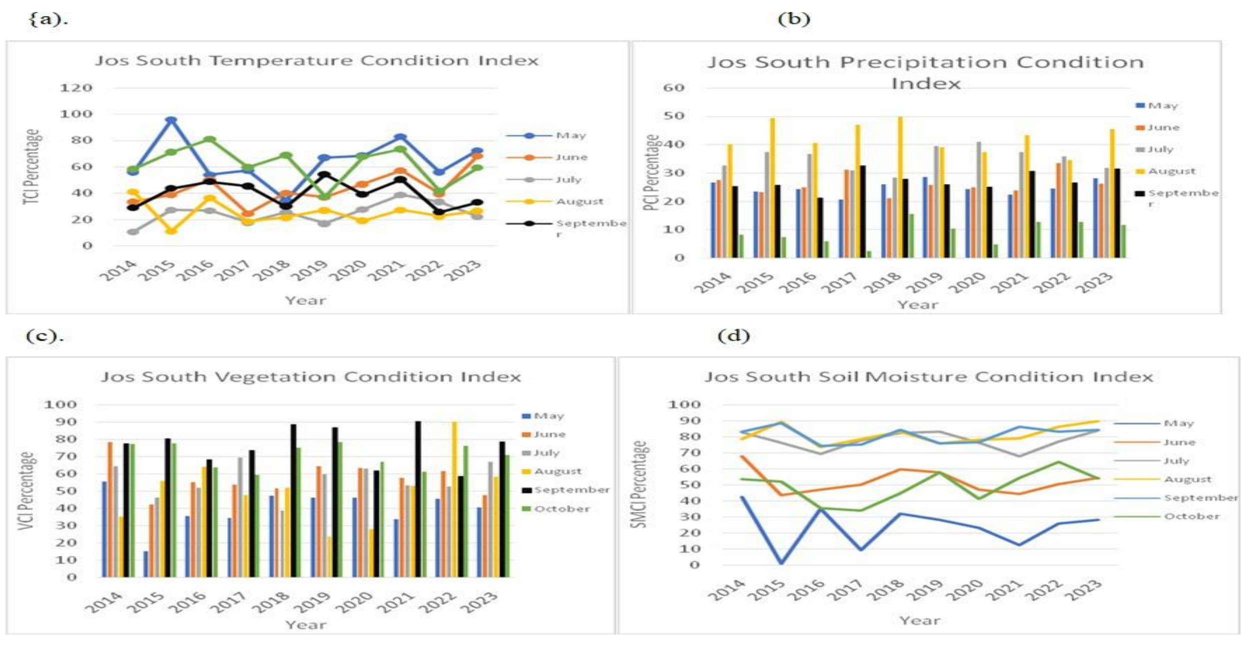

Figure 8: Jos South Geographic mean Monthly distribution of TCI, PCI, VCI, SMCI

The Jos South climate condition indices for the period 2014-2023 reveal a complex environmental system with great seasonal and interannual variability in all the parameters observed. The Vegetation Condition Index illustrates the greatest seasonal trends with September consistently recording the highest values (80-90% in almost all years), particularly exceptional in 2018, 2021, and 2022 when the values ranged between 90% or higher. May vegetation Condition was highly variable with well below-average performance in 2015 and 2016 (below 40%), and August shows high levels in 2014, 2015, and 2019. October vegetation levels are relatively consistent across years (60-75%), showing sustained plant vigour well into the early stages of the dry season, though 2020 presents a pronounced anomaly with reduced performance across multiple months.

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The Precipitation Condition Index indicates continuing moisture deficits during the study period, with the majority of monthly values ranging from 10% to 50%, which is far below historical means. The most fluctuating month of precipitation is August, ranging from approximately 20% in bad years to approximately 50% in good years (2015, 2018). The start of the wet season exhibits uneven performance, with May values typically ranging from 25-40% for most years, and June following a similar pattern, with notable spikes in 2017 and 2022, reaching around 30-35%. Rainfall in September is generally 20-35% with outstanding performance in 2017 and 2021, whereas July is moderate in consistency at 15-35% with very poor deficits in 2016 and highs in 2015. October consistently has the lowest figures, usually 10-15% in every year, to mark the termination of the wet season.

The Soil Moisture Condition Index has a typical bimodal character that effectively buffers rainfall variability through the Jos Plateau's unique hydrological characteristics. Late wet season months record consistently high values with August showing excellent stability (75-90% in every year) and September also recording similar figures (75-85%), while offering the best vegetation growth conditions in spite of rain shortfall. Conversely, May soil moisture has high variability, dipping to near zero in 2015 and remaining critically low (10-15%) in 2016 and 2021, with other years having moderate values (25-45%). June values range from 40-70%, reflective of transition recovery from dry season deficits, although 2014, 2015, and 2016 show a lagged recovery trend. October soil wetness has relatively strong levels (45-65%) in most years, with specifically improved performance in 2018, 2022, and 2023, reflecting the ability of the area to hold plant-available water well into post-monsoon times and accounting for the sustained vegetation productivity despite unfavourable precipitation conditions.

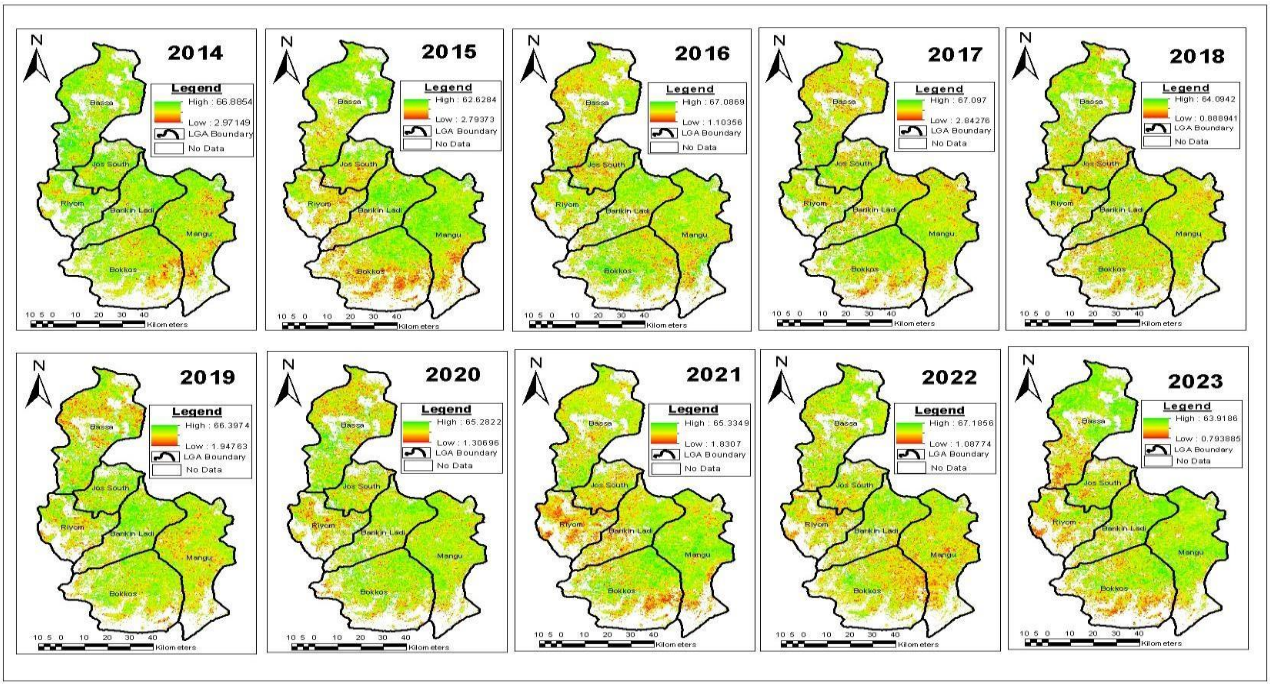

Figure 8: Mean Annual Spread of Advance Drought Response Index

This map series represents the Advanced Drought Response Index (ADRI) across some six local government of Plateau state, Nigerian between 2014 and 2023 that signifies spatial and temporal evolution of drought in a period of ten years. The researchers applied color-coded categorization system in which green represents high ADRI values (better moisture or less drought stress), yellow represents moderate values, and red/orange represents low ADRI values (severe drought condition). The geographical area shown in the maps includes Bassa, BarkinLadi, Ryom, Jos South, and Mangu, all with clearly demarcated administrative boundaries indicated across the maps. The map of each year shows the range of ADRI values. The highest values always appear high, ranging from around 63% to 67%, and the lowest values appear to decrease over time. This is indicative of the overall increase in the severity of the droughts. Looking at the temporal trend, 2014 shows a lot of green coloration across most of the regions, indicating relatively good moisture conditions with little or minimal drought stress. Starting in 2015, there is noticeable appearance of yellow and orange characteristics,

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particularly in the southern regions of the mapped region, indicating the onset of moderate drought conditions. This pattern intensifies tremendously in 2016, where large areas of the land, especially in the central and southern parts, show orange and red hues, indicating severe drought stress.

The 2017 to 2019 period shows some improvement as more green is restored to parts of the region, while there are still big sections of yellow and orange, particularly in the south and east. 2020 appears to be a watershed, with extensive red and orange coverage of most of the mapped area to show extensive severe drought across most of LGAs. The 2021-2023 photos indicate a disconcerting pattern of continued drought stress, with large areas appearing orange and red, which is evidence of extended severe drought. While there are certain northern regions that remain greenish throughout most of the years, and this would suggest that these may have different hydrological characteristics or undergo different patterns of precipitation, overall the trend is one of clear movement away from the relatively favourable conditions of 2014 towards mountingly severe drought conditions towards the end of the decade.

CONCLUSION

This thorough examination of dry spell trends and how they affect Jos-Plateau's rain-fed crop output provides important new information about the agricultural vulnerability of the area. October is typically the most difficult month for all locales, according to the study, which shows notable geographic variation in drought conditions among the six LGAs under investigation. According to the Advanced Drought Response Index (ADRI) evolution, the temporal study reveals a troubling trajectory from comparatively favourable conditions in 2014 to more severe and ongoing drought stress by 2020–2023.

The research revealed that dry spells are not evenly spaced over the plateau, with Jos South and Mangu going through the worst of them and Bassa being more resilient to temperature fluctuations. The intricate microclimatic elements affecting regional weather patterns, such as topography, elevation, and geographical characteristics, is highlighted by this spatial variance, even if the geographical distances are relatively modest.

The persistent October dry spell issues in all LGAs have a significant impact on agricultural systems, especially on the maturity times of late-season crops. The unpredictable trends shown in the main climate indices (TCI, PCI, VCI, and SCI) make agricultural planning even more difficult and emphasize how urgently climate-adaptive measures are needed.

The study's conclusions greatly advance our knowledge of how climate and agriculture interact in Nigeria's temperate-like highlands by offering crucial baseline information for creating focused adaptation plans and enhancing rain-fed systems' agricultural resilience.

RECOMMENDATIONS

Immediate Agricultural Adaptations

Crop Management Strategies: Farmers should prioritize early maturing crop varieties to avoid the consistently problematic October dry spells. Implement diversified cropping systems that include drought-tolerant varieties, particularly in high-risk areas like Jos South and Mangu. Develop location-specific planting calendars based on the identified dry spell patterns for each LGA.

Water Conservation Techniques: Establish rainwater harvesting systems and improve soil water retention through mulching and conservation tillage practices. Implement micro-irrigation systems where feasible to optimize water use efficiency during critical growth periods.

Policy and Planning Interventions

Early Warning Systems: Develop and implement drought early warning systems using the ADRI methodology established in this study. Create location-specific alert mechanisms for farmers based on real-time monitoring of climate indices.

Agricultural Extension Services: Strengthen extension services to disseminate climate-smart agricultural practices, focusing on areas with high drought vulnerability. Provide training on adaptive farming techniques and drought-resilient crop varieties.

Research and Development Priorities

Continued Monitoring: Establish long-term monitoring networks to track climate indices and refine drought prediction models. Expand the study to include additional LGAs and extend the temporal scope for better trend analysis.

Crop Breeding Programs: Invest in developing and promoting climate-resilient crop varieties suited to the plateau's unique temperate-like conditions and increasing drought stress.

Infrastructure Development: Improve water storage and distribution infrastructure, particularly in highly vulnerable areas identified in this study, to support irrigation during dry spell periods.

REFERENCE

1. Afolabi, M. S., Adeleye, B. N., & Oni, O. A. (2019). Climate change and agricultural productivity in Nigeria: A panel data analysis. Journal of Environmental Management, 245, 496-505.
2. Ahmed, K. F. (2016). Climate change impacts on agricultural productivity: Evidence from Nigeria. Agricultural Systems, 142, 98-108.
3. Audu, E. B., Isikwue, B. C., &Eweh, J. J. (2013). Spatial and temporal variations of rainfall in Nigeria. Journal of Environmental and Earth Science, 3(9), 50-59.
4. Ibebuchi, C. C., & Abu, I. O. (2023). Drought characterization over Nigeria: A comprehensive analysis of precipitation patterns. Atmospheric Research, 281, 106-118.
5. IPCC. (2023). Climate Change 2023: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
6. Liu, W. T., & Kogan, F. N. (1996). Monitoring regional drought using the Vegetation Condition Index. International Journal of Remote Sensing, 17(14), 2761-2782.
7. Mansur, M. B. (2020). Drought assessment and monitoring in Nigeria using remote sensing techniques. Environmental Monitoring and Assessment, 192(8), 1-15.
8. Nurgul, A., Xiaolei, Y., &Gulnur, S. (2020). Drought patterns in Central Asia: A comprehensive analysis. Water Resources Research, 56(4), e2019WR026855.
9. Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H., &Sorooshian, S. (1994). A modified soil adjusted vegetation index. Remote Sensing of Environment, 48(2), 119-126.
10. Ricardo, M., Silva, J. P., & Santos, A. (2021). Drought impacts on Mediterranean agriculture: A regional assessment. Agricultural Water Management, 248, 106-115.
11. Sabita, D., Kumar, R., & Sharma, P. (2020). Drought vulnerability assessment in West Bengal, India. Natural Hazards, 103(2), 1547-1568.
12. Sanchi, I. D., Iguisi, E. O., Sha'Aba, N. A., &Garba, S. (2021). Dry spell analysis and agricultural implications in the Nigerian Guinea Savanna. Weather and Climate Extremes, 33, 100-112.
13. Sawa, B. A., & Adebayo, A. A. (2018). Pentad dry spell analysis in the northern Guinea savanna of Nigeria. Journal of Climatology, 38(9), 3654-3668.
14. Tremblay, L., Larocque, M., Anctil, F., & Rivard, C. (2020). Drought characteristics in Mediterranean countries: A comprehensive review. Water Resources Management, 34(12), 3895-3915.
15. FAO. (n.d.). Crop water information. Retrieved October 20, 2023, from https://www.fao.org/3/s2022e/s2022e02.htm
16. Plateau State Government. (n.d.). Plateau at a glance. Retrieved September 25, 2023, from https://www.plateaustate.gov.ng/plateau/at-a-glance