ASSESSMENT OF REMOTE SENSING ON DEFORESTATION OF ECONOMIC TREE SPECIES IN WUDIL, KANO STATE, NIGERIA

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Abstract. A remote sensing strategy was investigated to evaluate how temperature and rainfall affect the deforestation of economically important tree species in Wudil, Kano Nigeria. The research was carried out in Wudil. To assess the vulnerability of the study area to desertification and the abundance of economic tree species. Landsat satellite products (Landsat 5, 7, 8. were used as the sources of remote sensing imageries. These products were sourced for intervals of ten years, from 1986 to 1999, 2006 to 2016, and 2020 Standardized temperature anomaly and precipitation index from 1986 to 2020 were analyzed using primary and secondary data obtained for information on temperature and rainfall, a hundred questionnaires were used to analyze how much anthropogenic activity has contributed to desertification in the area by looking at their socioeconomic activities, roads, and infrastructural development. To determine the quantity, distribution, growth, and yield of all the species, a transect of one square kilometer was surveyed using regional techniques in each of the four cardinal directions. Principal component analysis revealed that the activity variables and activity observations for 1999, 2006, 2016, and 2016 were all negative, while the years 1986 and 2020 were positive. Increased trends in temperature and decreasing trends in rainfall are evident using the Mann-Kendall analysis, with P-values of 0.0 and 0.003, respectively, which are smaller than the alpha value of 0.05. The main causes of drought and desertification vulnerability according to the findings include variations in the characteristics of rainfall, human activities, and overgrazing. More tree-planting initiatives should be encouraged, ideally making them an annual event in the study region.
Keywords: *drought, desertification, temperature, rainfall, over-grazing, human activities*

Introduction

Desertification is a form of land degradation that occurs when biological productivity in fertile parts of dry lands decreases as a result of natural or human-induced processes (Rossi, 2020). It is the expansion of dry regions brought on by several factors, such as soil over-exploitation. Deforestation and climate change were consequences of the

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expansion of urban and other related infrastructural activities (Ortiz et al., 2022). More than 2 billion people live in dry lands (Nichols et al., 2007) which make up around 40 to 41 percent of the planet's surface area (UNCCD, 2007). According to estimates, between 6 and 12 million square kilometers of drylands have been affected by desertification, between 10 and 20 percent of those areas are already degraded, 1 to 6 percent of dryland residents reside in deserted areas, and a billion people are at risk from further desertification (Davies, 2017). According to certain research, during the past 50 years, Africa has lost around 650,000 km^2 of its fertile agricultural land. This indicates that this region's desertification process has advanced significantly (Nicholson et al., 1998).

Trees are valuable to human beings not only economically, environmentally, and industrially, but also spiritually, historically, and aesthetically because they maintain human life through direct and indirect benefits by providing a diverse range of items for survival and success (Seth, 2003). Many small creatures need trees as shelters to protect them from predators, and forests provide a habitat for the diverse range of organisms that inhabit the planet (Wakawa, 2016). Some well-known shrub and tree species can be found in Nigeria's northern region, and they do quite well there. These species' availability is influenced by various edaphic, geomorphic, anthropogenic, and climatic influences. Additionally, this region is distinguished by its high temperatures, scant precipitation, low humidity, and loose sandy soil. When the weather is dry, high temperatures are common (Salami and Lawal, 2018). Trees Demand Investment----Although trees offer numerous environmental, social, and economic advantages, they also have expenses, just like any other living thing or piece of infrastructure. Trees gain value and advantages as they get larger. When a tree is young, investing in periodic maintenance will help to reduce future expenditures, enhance benefits, and lengthen its functional lifespan (Thelma, 2015; Audu and Adie, 2018). Unfortunately, this investment is under threat in the majority of Nigeria's northern states (Abdulrashid and Yaro, 2014) and while this study focuses on one of the most agriculturally practiced towns in Kano state (Wudil), that is to say, the study area incorporates almost all aspects of agriculture, including farming, fishing, and livestock production. The frontline desert-threatened states of Nigeria make up 40% of the total land area in the country. The worst affected states include Kano, Jigawa, Borno, Sokoto, and Katsina which share a common border with the northern Niger Republic, with most of the areas covered by the Sahara Desert. It is becoming more and more challenging to achieve sustainability in the management of vulnerable lands. Rising pressure from desertification has been aggravated by a period of continuous drought for nearly 20 years (Gadzama and Ayuba, 2016). Due to dunes and insufficient water, most sources have decreased in volume, leading to poor economic conditions, and farmers losing their access to farmlands (Thelma, 2015). Remote sensing with a high-resolution spatiotemporal imageries system was used to detect the changes in biophysical parameters using land use land classification together with survey techniques in analyzing economically important tree species in Wudil. Furthermore, the study aims to achieve spatial-temporal land use classification in Wudil from 1986 to 2020 by gaining access to desertification drivers as well as the frequency, distribution, density, and relative density of economic tree species.

Materials and Methods

Study area

The study was conducted in Wudil Local Government Area, latitude 11° 47' N and longitude 8° 50' E, Kano state, Nigeria with an estimated land area of 362 km^2 (Dambatta

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et al., 2021) and an approximated human population of 314,520 (Gwaison, 2019) (*Figure 1*). The town is located on the outskirts of the Kano metropolis and is among the most populous local governments of the state's 44 local government councils Census, 2006 (Muhammad, 2011).

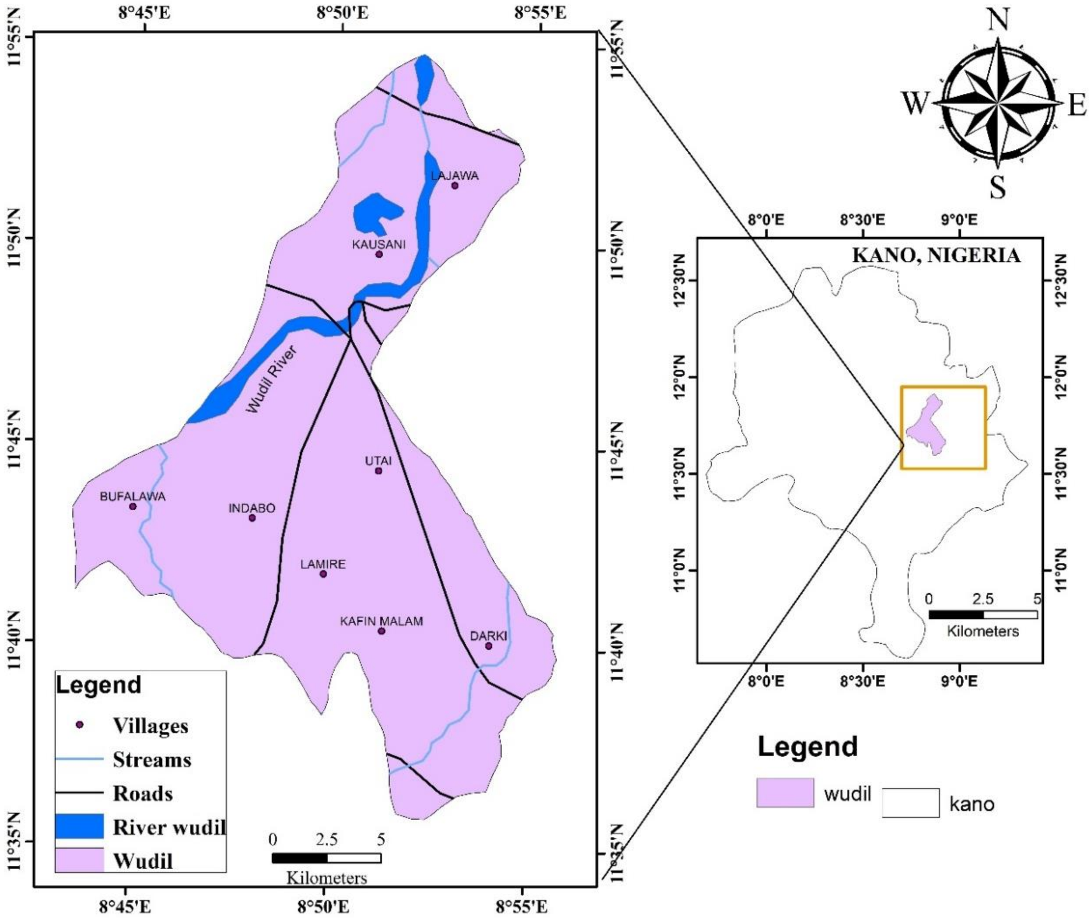

Figure 1. *Map of the study area*

Data sources

Landsat Thematic Mapper (TM) Landsat 5 and Landsat Enhanced Thematic Mapper (ETM+) systems Landsat 7 & 8 sourced from the United States Geological Survey (USGS) for the periods 1986, 1999, 2006, 2016, and 2020 were used in the mapping of Land Use Land Cover (LULC). Supervised classification was conducted to track the pattern of changes in the LULC using Environmental Visualizing Imaging (ENVI). Annual mean temperatures were obtained from the Nigerian Meteorological Station (NIMET) and the National Aeronautics and Space Administration (NASA). Frequency distributions were generated using standardized precipitation index (SPI), standardized temperature anomaly (STA) combined graph analysis (CCA), with descriptive and inferential statistical methods. Principal component analysis (PCA) was conducted between variables using (XlSTAT) to see the relationship between variables and observe the association or correlation between active variables and active observations.

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Principal component analysis

The following mathematical equation or algorithm was used to perform (PCA):

In PCA, given the mean-centered X with n Samples and P variables, the first Principal component $\mathbf{PC_1}$ is given by the linear combination of the original variables $\mathbf{X_1, X_2 \ldots . Xp}$ $\mathbf{PC_1 = w_{11}X_1 = w_{11}X_1 + w_{12}X_2 + \ldots \ldots + w_{1p}x_p}$. The first principal component $\mathbf{PC_1}$ represents the component that retains the maximum variance of the data $\mathbf{w_1}$ corresponds to an eigenvector to the covariance matrix.

$$\Sigma = \frac{1}{n-1} XTX \quad \text{(Eq.1)}$$

Loadings Matrix

$$\Sigma = \frac{1}{n-1} \mathrm{XTX} = v\frac{s2}{N} - 1vt = VEVT \quad \text{(Eq.2)}$$

This means that the principal axes V are eigenvectors to the covariance matrix and

$$E = \frac{s2}{N} - 1 \ldots \ldots \ldots \ldots 3 \quad \text{(Eq.3)}$$

are its eigenvalues.

The standard context for PCA as an exploratory data analysis tool involves a data set with observations on p numerical variables, for each of n entities or individuals. These data values define p n-dimensional vectors x1... Xp or, equivalently (Jollife and Cadima, 2016). Primary and secondary data were sourced on temperature and rainfall. A hundred questionnaires were distributed to measure the human activities' influence on desertification and major economic tree species. A transect of one square kilometer was measured using local methods to determine the number, distribution, growth, and yields of the key economic tree species.

Mann-Kendall test

The Mann-Kendall (MK) statistical test (Mann, 1945; Kendall, 1975) was used for spotting trends in hydro-meteorological time series like groundwater. According to Wang et al. (2020), the tool is a rank-based non-parametric technique and is frequently used in statistical analyses. The Mann–Kendall trend test is based on the correlation between the ranks and sequences of a time series. For a given time series $\{Xi,\ i = 1, 2 \ldots,\ n\}$, the null hypothesis H0 assumes it is independently distributed, and the alternative hypothesis H1 is a monotonic trend. The test statistic S is given by:

$$S = \sum \mathrm{n} - 1\mathrm{i} = 1\sum \mathrm{nj} = \mathrm{i} + 1\mathrm{sgn}\ (\mathrm{Xj} - \mathrm{Xi}) \quad (1)\ S = \sum \mathrm{i} = 1\mathrm{n} - 1\sum \mathrm{j} = \mathrm{i} + 1\mathrm{nsgn}\ (\mathrm{Xj} - \mathrm{Xi}) \ \ldots \ldots \ldots \ldots \quad \text{(Eq.4)}$$

where X_i and X_j are the values of sequence i, j; n is the length of the time series.

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Decadal mean (% change from normal), frequency of rainfall, and temperature over Wudil from 1986 to 2020

From 1986 to 2020, the cumulative decadal temperature and rainfall change was computed using the following equation. As utilized by Patra et al. (2012), in Detecting rainfall trends in twentieth century from (1871–2006) over Orissa State, India. The decadal metrological change is generally used to detect an increase or decrease in climatic data during a 10-year or longer timeframe.

$$A - \frac{B}{A} * 100 \quad \text{(Eq.5)}$$

where A= Current Value, B= Starting point.

Supervised classification

The remote sensing image data were preprocessed with the envi5.0 program, and the specific approach used is shown in *Figures 2 and 3*. The first training images were mostly divided into flora, waterbodies, built-up areas, and bare fields. We got five remotely sensed images of multiple settings from the USGS website (http://glovis.usgs.gov/) on seasonally similar days of April 19, 1986, April 30, 1999, April 12, 2006, April 24, 2016, and April 20, 2020. Image quality is frequently higher in cloudless and dry-season photographs (*Table 1*).

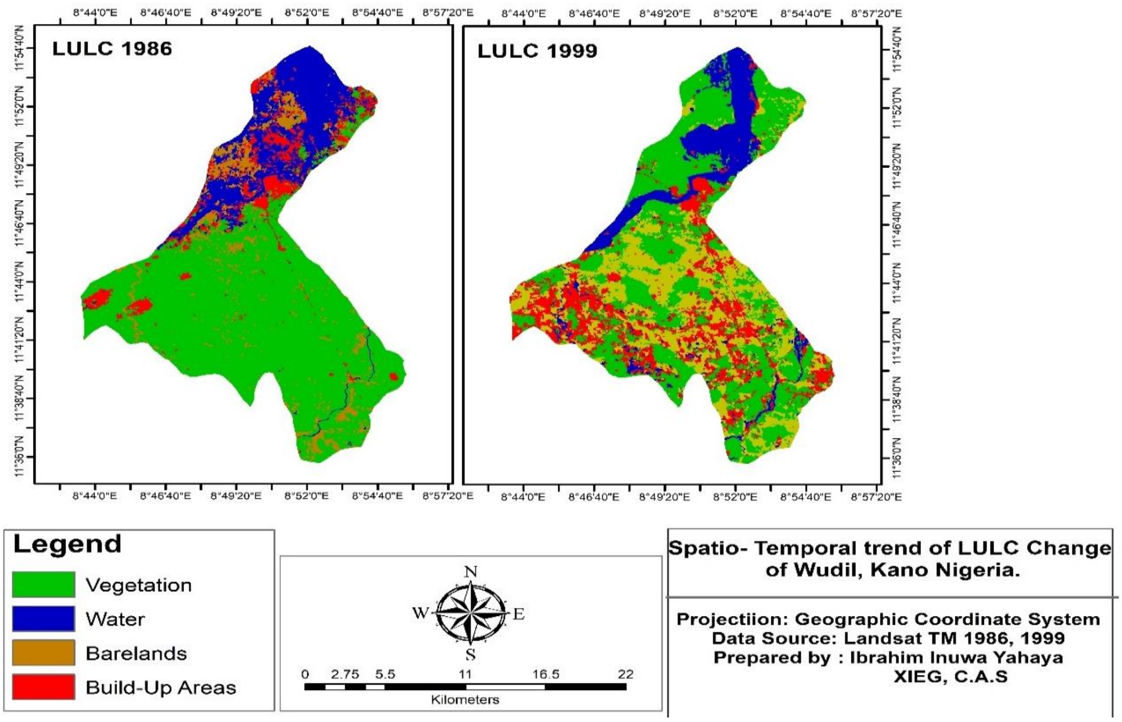

Figure 2. *(LULC) of Wudil 1986 & 1999*

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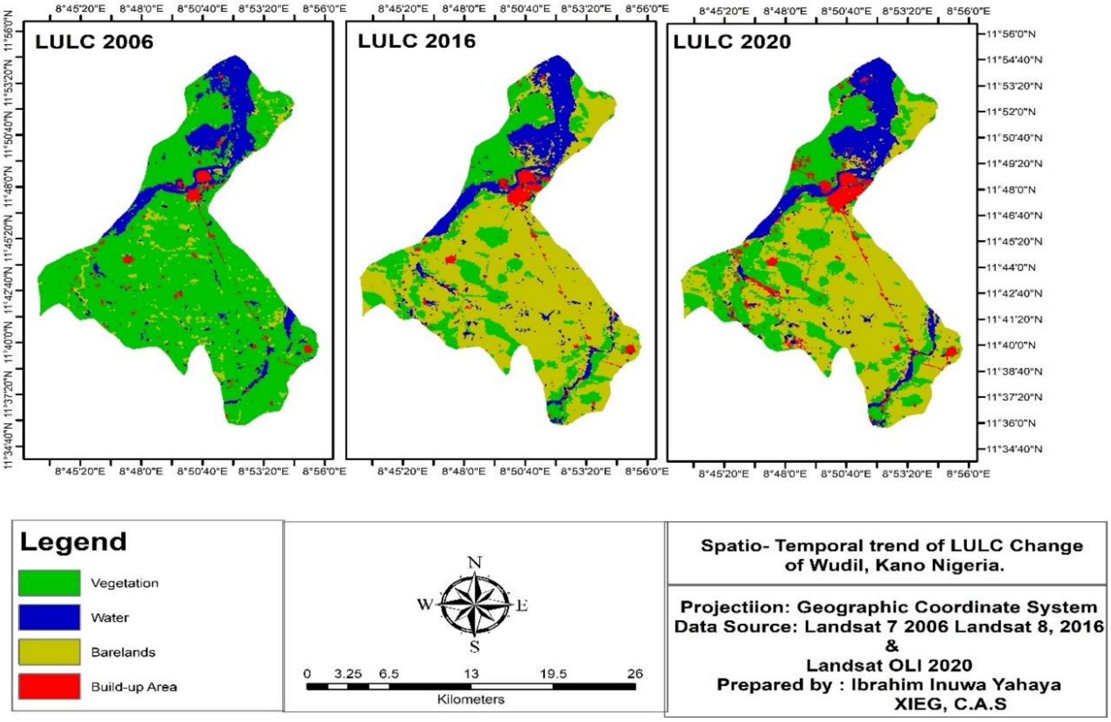

Figure 3. *(LULC) of Wudil 2006, 2016 & 2020*

Table 1. *The study's data for remote sensing images*

Year	1986	1999	2006	2016	2020
Sensor	Landsat5 TM	Landsat 7 ETM+	Landsat 7 ETM+	Landsat OLI 8	Landsat OLI 8
Path/ Row	188/052, 188/053	188/052, 188/053	188/052, 188/053	188/052, 188/053	188/052, 188/053
Date	1986/4/19	1990/4/30	2006/4/12	2016/4/24	2020/4/20
Cloud cover	0	0	0	0	0

Surveying of economic tree species in four cardinal directions of the study area

Wudil Local Government Region in Kano State was comprehensively surveyed for the existence of economic tree species along the research region's four cardinal directions—north, west, east, and south. Using the transect mapping technique, the number of each species of economic tree identified at each of the four cardinal points was counted across a one-kilometer-square area. The following formulae were used to calculate the frequency, relative frequency, distribution, abundance, and relative abundance of the economic tree species:

$$\text{Frequency (relative dispersion)} = \frac{\text{No.of line transect in which spp occurred}}{\text{Total no.of line transect studied}} * 100 \quad \text{(Eq.6)}$$

$$\text{Relative frequency} = \frac{\text{Freq.of spp}}{\text{Total freq.of all spp}} * 100 \quad \text{(Eq.7)}$$

$$\text{Density} = \frac{\text{Total no.of individuals of a spp in all Line transects}}{\text{Total no.of all line transects studied}} \quad \text{(Eq.8)}$$

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$$\text{Relative Density} = \frac{\text{Density of the spp}}{\text{Total Density of all species}} * 100 \quad \text{(Eq.9)}$$

$$\text{Abundance} = \frac{\text{Total no.of individuals of a spp in all line transects}}{\text{Total no.of line transects in which spp occurred}} \quad \text{(Eq.10)}$$

$$\text{Relative Abundance} = \frac{\text{Abundance of spp}}{\text{Total Abundance of all the spp}} * 100 \quad \text{(Eq.11)}$$

Results and Discussion

Spatio-temporal change of Wudil

The assessment of land cover change in this study was done over a forty-year period (Symeonakis and Drake, 2004; Nwilo et al., 2020) analyses gradual desertification and land degradation using time series data. Land cover data for Wudil was extracted from Landsat satellite images in 1986, 1999, 2006, 2016, and 2020. From 1986 to 1999 band pictures, the ten-year interval distributions were not fully met. The band pictures of Wudil were not detected in 1996 and 1998, primarily due to Landsat problems in some years. To detect changes in vegetation, bare fields, built-up areas, and waterbodies, 5 band images were used (*Table 1*). Due to the low spatial resolution of the long-term spam period, categorizing the various sets of vegetation, such as farmlands, forestland, cultivated land, grassland, and shrubs, is difficult. We do our best to maximize the land use land cover analysis in order to map out the changes in the research region (Ismail and Abubakar, 2015) utilized a supervised classification algorithm to detect changes in land use and land cover from 2000 to 2014 in Kano, Mukhtar (2016) employed supervised classification to detect land use and land cover change using a remote sensing approach. Koko et al. (2022) and Surajo et al. (2023) employed supervised classification to detect changes in land use and land cover and found the strategy compelling and reliable in change detection. Past and existing trends of the vegetation of the study area to access desertification vulnerability are presented in *Figures 2 and 3*. Based on the LULC maps in *Figure 2*, in 1986, the vegetation cover of the study area was 88.47%, waterbodies were 2.44%, bare land was 0.85% and the built-up area was 8.24%. This particular year in the study area was characterized by high rainfall, and low temperature, with a precipitation index and temperature anomaly figure of 0.5 and -1 respectively. Which can be interpreted as adequate soil moisture and cool temperature (*Figures 4-7*). In 1999, the LULC classification of the area of study had 88.43% vegetation cover, water bodies decreased slightly to 1.09%, barren lands increased to 27.62%, and the built-up area decreased slightly by 5.31%. *Figure 3*, LULC 2006 categorization in the research region recorded a large vegetation reduction of 62.15%, which may be attributed to an increase in temperature and a drop in rainfall with figures of 27.36 °C and 458 mm (*Figures 4 and 6*), respectively, it can further be interpreted in *Figures 5, 7, 8, and 9* all of which indicate the rise of temperature and reduction of rainfall in the study area, moreover, the population of Kano increases to 9,401,288 according to the 2006 census (National, Bureau of Statistics, 2013). In essence, this year is marked by drought characteristics such as minimal rainfall, high temperatures, and a rise in population. Water bodies had a percentage of 0.77%, barren lands had a percentage of 27.62%, and built-up areas had a percentage of 11.84%. In 2016, the percentages of vegetation, waterbodies, barren lands, and built-up areas were 86.67%, 0.96%, 0.53%, and 11.84%, respectively. *Figure 3*

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depicts the last band image of the research region in the year 2020, with vegetation accounting for 84.17%, waterbodies accounting for 3.08%, barren lands accounting for 1.00%, and built-up area accounting for 11.75%. Wudil's vegetation and bare plains have been decreasing and escalating respectively in recent years (Isma'il and Abubakar, 2015). *Table 2* depicts the changes in land use and land cover categorization in Wudil from 1986 to 2020, as well as the changes in each of the aforementioned characteristics after conversion to kilometer square km^2.

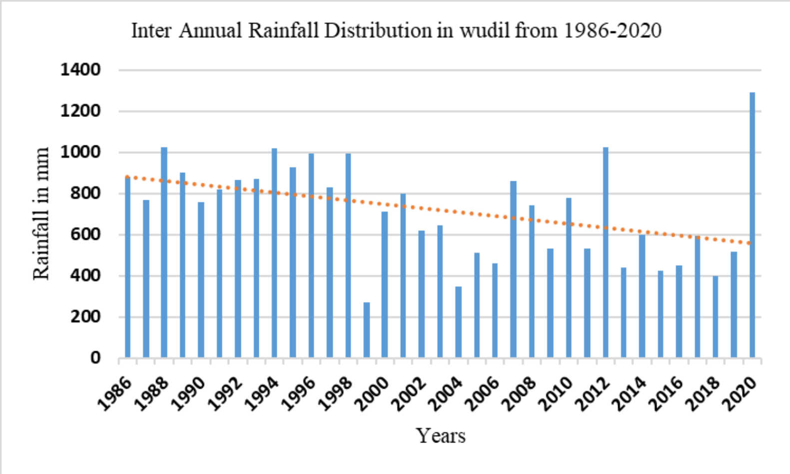

Figure 4. *Inter-annual rainfall distribution Wudil from 1986-2020*

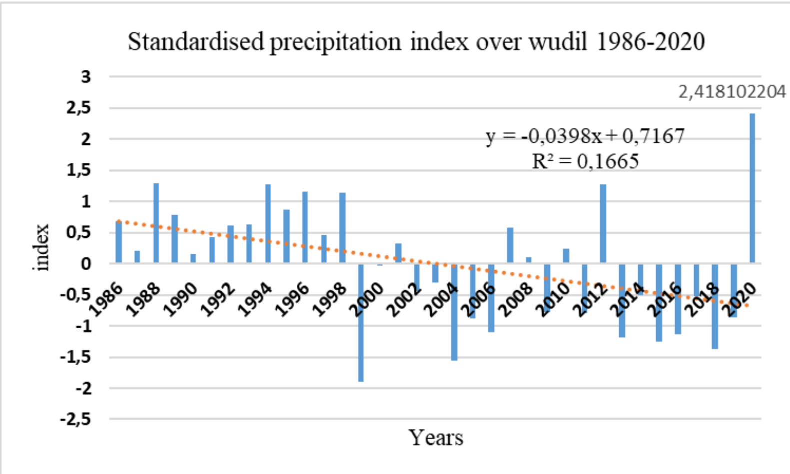

Figure 5. *Standard precipitation index (SPI) over Wudil from1986-2020*

Discussion

Driving factors of desertification

Rainfall and temperature

The current study used 34 years of precipitation and temperature data from 1986 to 2020 to conduct a trend analysis of the Wudil local government region. The Mann-Kendall trend test was employed to determine the trend. *Figures 8, 9* show the yearly

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rainfall and temperature over 34 years, with the maximum rainfall coming in 2020 with a total precipitation of about 1291.78 mm and the minimum rainfall occurring in 1999 with a total of roughly 269.78 mm. The average rainfall in Wudil Kano Nigeria over the 34-year period is 719.826 mm, while the average temperature is 26.1789 °C. Climatic Time series analysis has been widely used by various academics all over the world; most scholars find this analysis useful in accessing or studying changes in the variability of rainfall and temperature. Time series and man-Kendall trend analysis were employed by researchers such as Mondal et al. (2012) to determine the trend and slope magnitude using monthly precipitation trend for forty years span. Sa et al. (2017) used the Mann– Kendall (MK) test along with modified Mann–Kendall (m-MK) test to assesses the spatial pattern of changes in rainfall extremes of Sarawak in recent years (1980–2014). Achugbu and Anugwo (2016) used standard precipitation index (SPI) in` Drought Trend Analysis in Kano Using Standardized Precipitation Index from (1911-2010), Variations and Trends in Annual Rainfall Amounts and the Onset of the Rainy Season for Kano for 87 Years (1916-2002) was conducted by Ati et al. (2008). Mustapha (2014); Sawa et al. (2014); and Umar et al. (2019) all used dynamics of hydrological analysis and climate variability from rainfall and temperature in the semi-arid region of Kano.

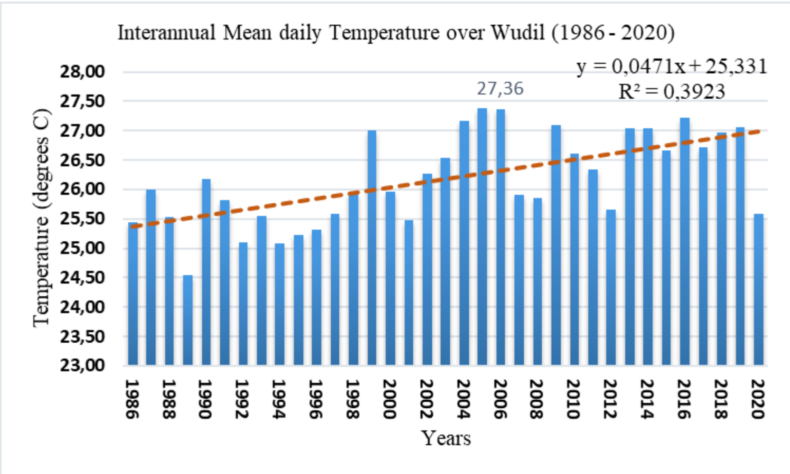

Figure 6. *Inter-annual mean daily temperature over Wudil from 1986-2020*

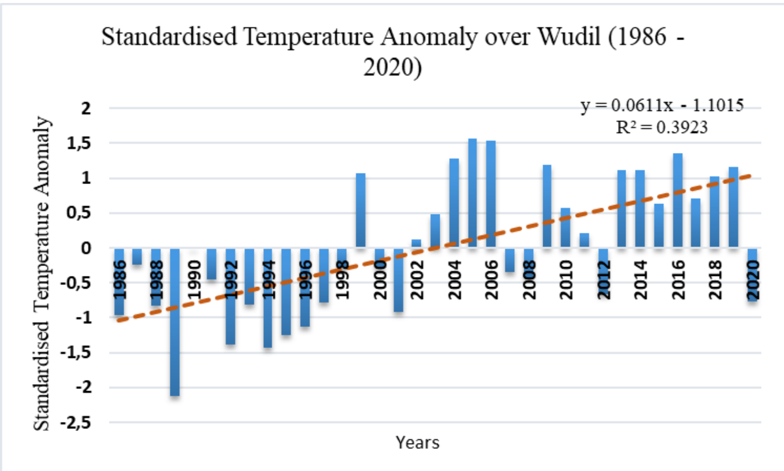

Figure 7. *Trends of Temperature anomaly over Wudil from1986-2020*

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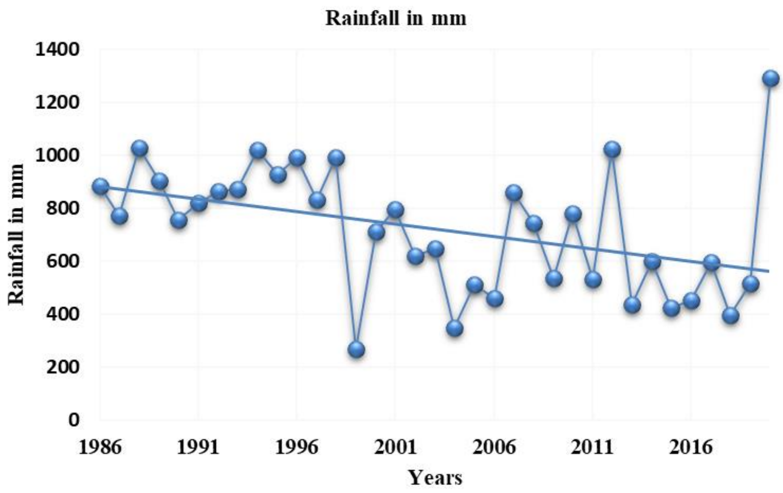

Figure 8. *Mann- Kendall trend test of Annual Rainfall of Wudil 1986-2020*

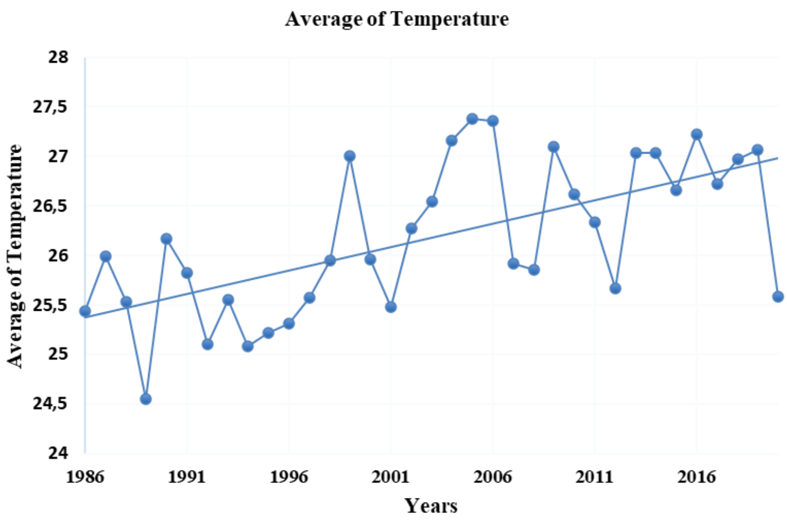

Figure 9. *Mann- Kendall trend test of the average temperature of Wudil 1986-2020*

Table 2. *Spatiotemporal Land Use and Land Cover Distribution for Wudil 1986–2020 In km²*

LULC	1986KM²	1999KM²	2006KM²	2016KM²	2020KM²	CHANGES
Vegetation	320.2614	320.1166	224.983	313.7454	304.6954	-15.566
Waterbodies	8.8328	3.9458	2.7874	3.4752	11.1496	2.3168
Bare lands	3.077	18.7154	99.9844	1.9186	3.62	0.543
Built-up Area	29.8288	19.2222	34.209	42.8608	42.535	12.7062
Total	362	362	361.9638	362	362	0

Source: Author Analysis 2020

The study area's total annual rainfall intercept (mm) for the years 1986 to 2020 was calculated as shown in *Figure 4*, with years 1988, 1994, 1996, 1998, 2002, and 2020 recording annual rainfall totals exceeding 1000 mm, which is higher than Wudil's annual

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mean rainfall. While the year 1999 2000, 2005, 2005, 2006, 2014, 2015, 2016, 2018, and 2019 had the lowest Rainfall distribution.

This can be interpreted as changes in rainfall variability as the millennia set in unlike in the ’90s, possibly because of the introduction of anthropogenic activities (*Table 3*) and population increase.

Table 3. *Economic Activities of Respondents*

Sources of income	Frequency	Percentage
Farm	49	49
Firewood selling	09	09
Off-farm	28	28
Tree selling	14	14
Total	**100**	**100**

This analysis of inter-rainfall distribution coincides with the reduction of the vegetation in land use land cover classification in the year 2006 (*Figure 3*). The standardized precipitation index in Wudil L.G.A. (*Figure 5*) indicates that the research area has an absolute wet climate from 1986 to 1998, but has negative values in 2000, 2002, 2004, 2005, 2006, 2010, 2012, 2014, 2016, and 2019. The year 2020 had the highest recorded rainfall, with a standardized precipitation index exceeding 2.0 values in an extraordinarily rainy season, which confirms the LULC 2020 analysis, as shown in *Figure 2* (vegetation recovery from 2006 to 2020, 62.15% to 84.17%).

As indicated by the average temperature analysis in, the Mann-Kendall test demonstrates an increasing trend in temperature (*Figure 9*) from 1986 to 2020 in Wudil Kano, Nigeria. This is because the p-value (two-tailed) is lower than the alpha value (0.05) (*Table 4*). In this scenario, we accept Ha instead of Ho. Wudil Kano, Nigeria, in particular, experienced an increase in average temperature between 1999 and 2019.

Table 4. *Mann-Kendall trend test / Two-tailed test (Average of Temperatures)*

Kendall's tau	0.439	
S	261	
Var(S)	4958.333	
p-value (Two-tailed)	**0.000**	***
alpha	0.05	

An approximation has been used to compute the p-value, Signification codes: 0 < "***" < 0.001 < "**" < 0.01 < "*" < 0.05 < "." < 0.1 < " " < 1, Test interpretation: H0: There is no trend in the series, Ha: There is a trend in the series. As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis is H0, and accept the alternative hypothesis Ha

The yearly rainfall research in Wudil Kano, Nigeria, reveals a decreasing tendency from 1986 to 2020 according to the Mann-Kendall test. This is because the p-value (two-tailed) of 0.003 is lower than the alpha value of 0.05. (*Table 5*). We accept Ha while rejecting Ho in this regard. Wudil Kano, Nigeria's annual rainfall is falling, particularly between 1999 and 2019.

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Table 5. *Mann-Kendall trend test / Two-tailed test (Rainfall in mm)*

Kendall's tau	-0.358	
S	-213	
Var(S)	4958.333	
p-value (Two-tailed)	**0.003**	**
alpha	0.05	

An approximation has been used to compute the p-value, Signification codes: 0 < "***" < 0.001 < "**" < 0.01 < "*" < 0.05 < "." < 0.1 < " " < 1, Test interpretation: H0: There is no trend in the series, Ha: There is a trend in the series. As the computed p-value is lower than the significance level alpha=0.05, one should reject the Null hypothesis H0, and accept the alternative hypothesis Ha

From 1986 to 1999, the location's annual mean daily temperature was below 25°C (*Figure 6*). This suggests that the high rate of precipitation seen in these years justified the brief time of low temperatures. From 1999 to 2019, the temperature began to shift, rising from 25°C to above 27°C in the years 1999, 2004, 2005, 2006, 2014, 2015, 2016, and 2019. The annual mean daily temperature decreases to 25°C in the year 2020, which has the highest rainfall intercept and precipitation index (*Figures 4 and 5*), although these are the years with the lowest rainfall intercept and precipitation index.

Figure 7 indicates the yearly temperature variance from the mean in the study area shows a negative anomaly for the 1980s and 1990s, while it shows a positive anomaly for the 2000s and 2010s. This suggests that the decades with positive anomalies have a mean annual daily temperature that is greater than the research location's baseline temperature and is generally warmer. General, it demonstrates the reality that after millennia, activities that weren't there in the 1980s and 1990s finally caused dryness and drought, perhaps another factor that contributed to the decline in the number and yields of some economic trees. After observing the climatic parameters of Wudil from 1986 to 2020 and calculating the decadal changes, it was discovered that the temperature of Wudil increased by 0.39% over the four decades (*Figure 9*). As for Rainfall decadal change, the analysis was conducted in two ways from 1986 to 2019 & from 1986- 2020 this is because the year 2020 comes with a special case in the study area it has an annual minimum Rainfall of 1291.78 mm and a precipitation index of 2.418. *Figures 4, 5* possibly because of the El Niño and La Niña events which occur every two to seven years, on average, as said by Timmermann et al. (2018) El Nino occurrences, which occur every few years, are characterized by surface warming of the tropical Pacific Ocean and a weakening of the equatorial trade winds. These conditions are accompanied by changes in atmospheric and oceanic circulation, which affect global climate, marine and terrestrial ecosystems, fisheries, and human activities; nevertheless, they do not occur on a regular basis. El Nino occurs more frequently than La Nina. With this, the decadal precipitation change in Wudil in the first trench reduces by -70.62 mm (*Table 6*) while increasing by 31.57 mm in the second trench.

Table 6. *Decadal precipitation change over Wudil from 1986-2019 and 1986-2020 (Rainfall in mm)*

1ST (trench)	**2ND (trench)**
1986- 1996 A	1986- 1996 A
1996- 2006 B	1996- 2006 B
2006-2016 C	2006-2016 C
2016- 2019 D	2016- 2020 D

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Human activities

Growth of population

The population of Wudil increased by almost double when compared to the population in 2006, according to the National population commission (NPC). Moreover, according to Mohammed and Bawa (2023) the majority of the population of Kano rejects the family planning program due to their faith and the effects that come with it. A man is entitled to marry from one to four wives, among them each wife is expected to have at least 5 children. The field assessment of rapid urbanization that was conducted between Ibadan and Kano shows the rapid increase in urbanization between these two cities (Ifeoma et al., 2023). The establishment of Kano State University of Science and Technology Wudil (K.U.S.T) in the year 2001 leads to the coming together of various people across the country (Isma'il and Abubakar, 2015), as a lot of deforestation was observed for land clearing which leads to the destruction of many economic trees across the city. Also, the 540 km dualization of the road from Kano to Maiduguri, which goes through the research area, results in the extinction of numerous tree species.

A structured questionnaire is a document that consists of a set of standardized questions with a fixed scheme, which specifies the exact wording and order of the questions, for gathering information from respondents (Cheung, 2014). This research uses the structural questionnaire in the study area in the four cardinal locations of the town, North, west, south, and east. 100 respondent were selected and 99 percent of the respondents are male due to the fact that women in the study area are mostly housewives (Aderounmu and Falana, 2020) and have no experience in agricultural and climatic considerations. The questionnaire is divided into four sections, a) Demographic information, b) economic activities, c) crop production, most of the respondents engage in Agricultural activities d) 80% of respondents received no benefits from non-governmental organizations, while 20% heard about empowerment but did not receive i.e.) 80% of respondents received no benefits from non-governmental organizations, while 20% heard about empowerment but did not receive it. e) Respondents are asked if they have planted or logged trees such as mango (Mangifera indica), baobab (Adansonia digitata), African locust bean (Parkia biglobosa), and date palm (Phoenix dactylifera) in the past 5 to 10 years. According to them, economic trees take several years to mature and are becoming increasingly scarce in the research region. According to respondents, the majority of economic trees were discovered naturally prior to deforestation, and the only economic trees they were able to plant were mango and some date palm, the latter of which takes 50 years to mature and bear fruit except for the improved variety, which is very expensive to obtain.

The majority of Wudil's residents work in agriculture, and they firmly think that permitting trees to grow on farmland reduces the productivity of that area. Rarely do local farmers let the tree grow on their farms; rather, they either cut it down to supply fuel or to create more space (*Table 3*), which produces food and cash crops both during the wet and dry seasons using irrigation (Nababa, 2017).

Livestock

Although there isn't much data on the number of livestock in Wudil, it is one of Kano State's major cattle markets and is well-known for it. The market, which is located about 39 kilometers outside Kano City, has been said to exist for decades. It is considered that in West Africa, the market is a place where the best breeds can be purchased. Every

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market day, 60 truckloads of cattle enter and leave the town, according to Alhaji Nasiru Muhammed Wudil, Chairman of the Association of Amalgamated Livestock Traders, Wudil branch. The acting Sarkin Karan Wudil, Alhaji Rabi'u Garko, said the market was the largest in Nigeria and probably West Africa, adding that commercial activities usually start on Wednesday night and continue till Friday (Giginyu, 2021). Based on Abdu and Danbatta (2016), the frequency of cattle products is shown in his Structural Analysis of Cattle Market in Kano State, Nigeria. He subsequently evaluated the number of cattle traded as follows (1-7) 80, 8-15 (25) 16-20 (5) 21-25 (5) 26-30 (1) 31- above (4) in respondents of 120 traders: White Fulani (39) Red Bororo (64) Barahaje (2) Gudali (4) Bakoloji (11). This conforms to the findings of this study's survey of 100 cattle producers. According to the respondents, the majority of livestock in the study area was cattle (43%), followed by sheep (26%). Goats, chickens, and donkeys have a percentage of (12%), (8%), and (11%), respectively. Overgrazing by cattle has a big impact, even though it may not necessarily be the main cause of the drought. The livestock market in Wudil, however, is among the oldest in all of Africa, not just Nigeria, according to past research (Bello, 2020). Grazing cattle can alter the soil's composition by causing erosion, land degradation, and the washing away of topsoil by wind and water. According to Hiernaux et al. (1999), the area of crusted soils decreased and fragmented as a result of grazing. The domestic energy source that is used by households the most is fuel wood. Considering that the vast majority of respondents (78%) said that wood is their main source of energy, Also, it was demonstrated that there is no connection between per capita income and per capita use of fuel wood (Tukur, 2009) According to some researchers, the Kano Close-Settled Zone's trees may eventually vanish due to the area's expanding population and proximity to the Kano Metropolitan Area (Falola et al., 1988). A 40 km radius around Kano's metropolis has seen the removal of the majority of trees from farms. The heavily forested reality of this area is completely at odds with these dreams. Instead, increased motor traffic, improved transportation infrastructure, and decreased fuel prices have led to the expansion of Kano's petroleum hinterland. As lower- and middle-income households switch from commercial petroleum-based energy sources to more affordable and accessible biomass alternatives, Kano's surrounding rural ecosystem and woodland resources may be under additional stress due to the nation's high inflation rate and economic conditions (Maconachie et al., 2009).

Principal component analysis

Table 7 displays the principal component analysis eigenvalues from F1 to F4. It's interesting to note that only the values in F1 and F2 satisfy the Kaiser requirement as the most significant components, while the other components have eigenvalues lower than 1. Given that the variable explains a unit of variance, an eigenvalue greater than 1 indicates that the relevant component explains more variance than the variable alone (Sheytanova, 2015). The selection criterion didn't fit eigenvalues 3 and 4 at all. To put it another way, the F1 and F2 components were picked because, as shown by the highest eigenvalues, they have the most variables. F2 and F4, on the other hand, were discarded since they were unimportant components with the lowest values and scant data to explain the cumulative variability. *Figure 10* shows the scree plot from F1 to F4 with the values of each component plotted on the y-axis and the cumulative variability in percentage shown on the x-axis. The overall values of variability have 100% and it validates the scree plot and eigenvalues.

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Table 7. *Eigenvalues*

	F1	F2	F3	F4
Eigenvalue	3.610	1.555	0.800	0.035
Variability (%)	60.162	25.920	13.335	0.583
Cumulative %	60.162	86.082	99.417	100.000

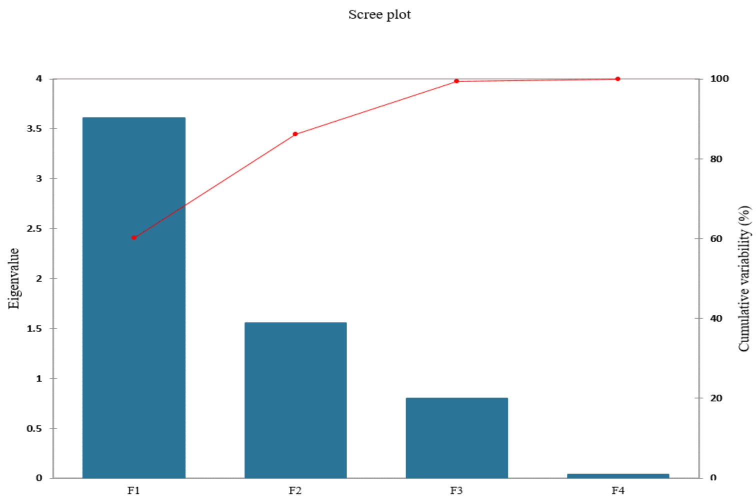

Figure 10. *Scree plot showing cumulative variability*

The initial principal components have a strong correlation with four of the original variables, according to the aforementioned data (*Figure 11*). The initial essential elements rise as precipitation, water, vegetation, and built-up area do (B.U.A). In the F1 components, the build-up area and the vegetation are orthogonal, indicating that they are not correlated (R is close to zero), the rainfall and water are correlated; as rainfall increases (0.8644), water tends to increase as well (0.94647), the bare land and vegetation are negatively correlated (R is-1) and the temperature and water are on the outside of the center, indicating a negative correlation between the variables. These elements might be seen as indicating that the Wudil local government region of Kano would have an increase in vegetation and water bodies as a result of an increase in rainfall.

Although there are a lot of building activities in the study area most especially due to the creation of federal government organizations such as the University, police academy, and roads construction that leads to Maiduguri state, although the building activities are going at a steady condition it cannot be compared to the previous decades (*Figure 2*) and building activities will increase significantly in the coming decades. The second principal components analysis shows decreasing value in the variables of bare lands and temperature with a figure of -0.769227 and -0.9275 respectively. Temperature and bare lands show a sign of correlation as Temperature increases, bare lands increase as well. Bare lands and temperature show negative values in the study area, which is not a good sign of climatic conditions, these can be a sign of anthropogenic influence or activities by humans in the study area.

According to the land use land classification (LULC) discussed earlier, the values for the corresponding years are shown in *Figure 12* observation charts. The values for the years 1986 and 2020 on the first principal components are positive (1.0727) and (2.55005),

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respectively, while the values for the years 1999, 2016, and 2006 are negative (-1.06894), (-0.48839), and (-2.69544) respectively. According to the findings, the observation plots show positive signs in F1 in the study area, which can be viewed as high vegetation, high rainfall, low temperature, and high water bodies, while in F2 negative signs can be viewed as low rainfall, reduction in water bodies, increase in bare lands, and high temperature in Wudil Kano Nigeria.

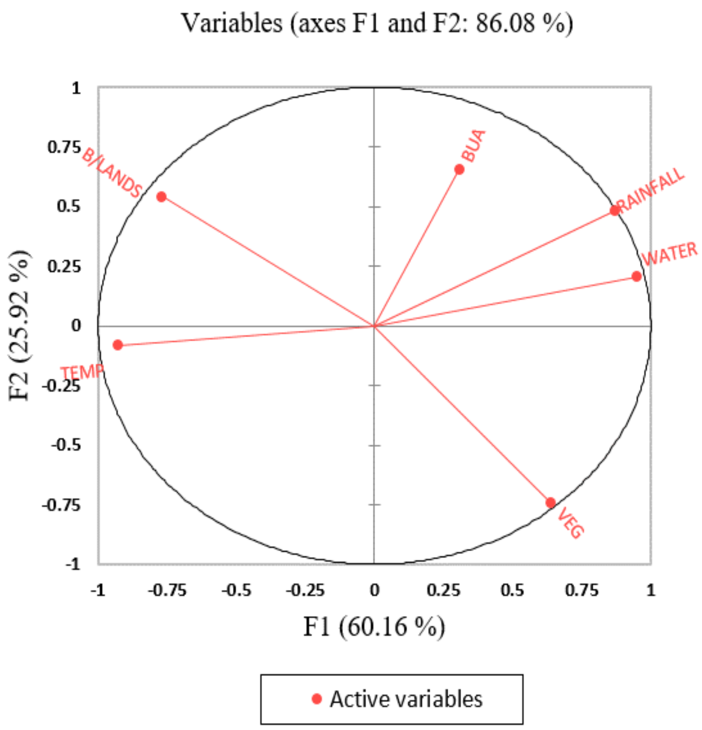

Figure 11. *Correlation circle of variables projection*

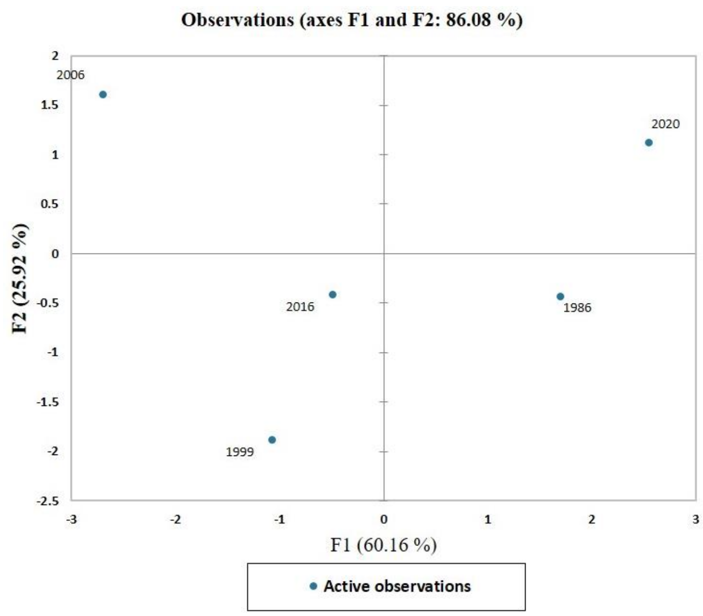

Figure 12. *Observation charts of corresponding years*

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The biplots of axes F1 and F2 for the active variables and active observations are shown in *Figure 13*. There is no correlation between rainfall and build-up Area, but it can be interpreted as an increase in building activities in Wudil in 2020. In the year 2020, rainfall and water are correlated as water increases and water bodies increase as well, with figures of (1.97190) and (1.665819), respectively. According to the vegetation index for the year 1986, which is 1.4502, Wudil's climate is in better shape than it was in 1999. There are many woodlots and valuable trees in the city, which is in its natural state. On the other hand, barren lands (-1.74663) and temperature are where the second major component's negative values are found (-2.1061). All three of the years 1999, 2006, and 2016, which are all connected with drought-related characteristics, come under the second principal component (F2), particularly the year 2006, which has an increase in bare lands that is evident with a figure of (-2.69544). The number, growth, yield, and distribution of certain important economic trees in the research region were found to be impacted by deforestation.

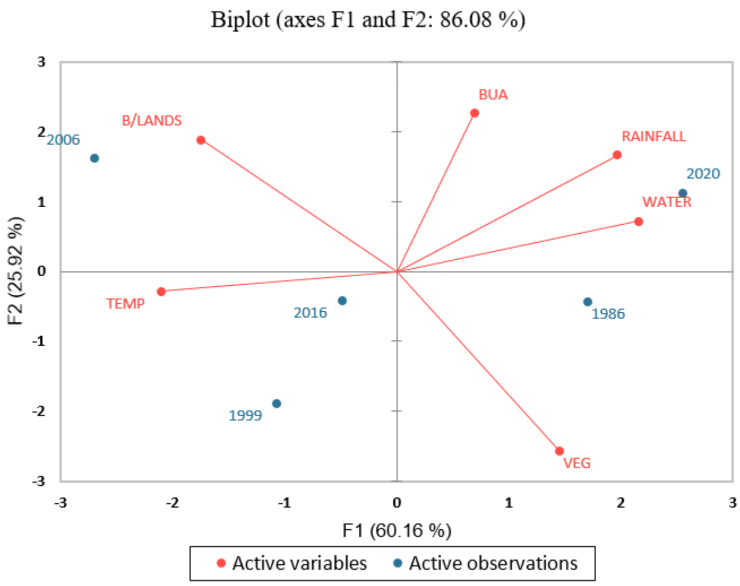

Figure 13. *Biplots chats of the variables*

Economic trees

Nigeria's rich northern border is where the majority of agricultural activities, including farming, fish farming, raising cattle, and poultry, are carried out (Food and Agriculture Organization of the United Nations, 2019). Nigeria's productive land is currently undergoing some changes as a result of anthropogenic activity and global climatic issues (Ani et al., 2022). Although it will be very difficult to combat land degradation, deforestation, and desertification among a rapidly expanding population of 200 million Nigerians, primarily due to the extreme poverty that the country's residents are experiencing. The Northern region of the country has several economically significant trees, some of which have been discovered to provide health, financial, and economic benefits (Kumar and Navaratnam, 2013; Ebifa-Othieno et al., 2017; Aderounmu and Falana, 2020; Khan et al., 2020). Due to urbanization and the consequences of urban heat island, Kano metropolis is currently largely or entirely without economic trees (Tanko et al., 2017). Wudil local government area is one of Kano’s forty-four local government

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areas, several kilometers from the metropolis. Due to increased population and deforestation rates, these economic trees can only be found outside of major cities. Despite this, the economic trees in Wudil, Kano State, Nigeria, were surveyed using transect sampling method techniques. The approach of sampling tree composition analysis is not new in tree composition, having been used by Fayolle et al. (2014) in their analysis of 1175 tree species' patterns of species composition in tropical African forests. Sagar et al. (2003) also used tree species composition in India on tree composition, dispersion, and diversity along a disturbance gradient in a dry tropical forest region of India. The approach was also used by Wittmann et al. (2006) in the Amazon forest. Tree species composition was also adopted by Wakawa et al. (2016) at Kano State University of Science and Technology Wudil. With neem tree recording the highest frequency, Contrary to his study the tree species composition survey was conducted at the four end cardinal directions of the entire study area.

Some economically significant trees in the research area displayed poor growth, yield, abundance, and distribution, while Parkia biglobosa, Jujube, Baobab, Mango, and Eucalyptus trees showed 100% frequency. Date palm and Mahogany both show 75% frequency. Regarding the abundance, 14%, 4%, 66%, 11%, 5%, 3%, 3.5%, and 9% were observed for the species Parkia biglobosa, Date palm, Baobab, Mango, Eucalyptus, and Mahogany, respectively. While the relative densities of 4.111%, 74.15%, 1.0279%, 0.88%, 3.377%, 1.0279%, and 1.9823% for Parkia biglobosa, Date palm, Baobab, Mango, Eucalyptus, and Mahogany were obtained respectively. Azadirachta indica (Neem tree), according to Wakawa (2016), has the greatest frequency of 3959 and a percentage of 47.89% (Wakawa, 2016) which coincides with this study as neem is the specie with the highest frequency in the study area (*Figure 14*).

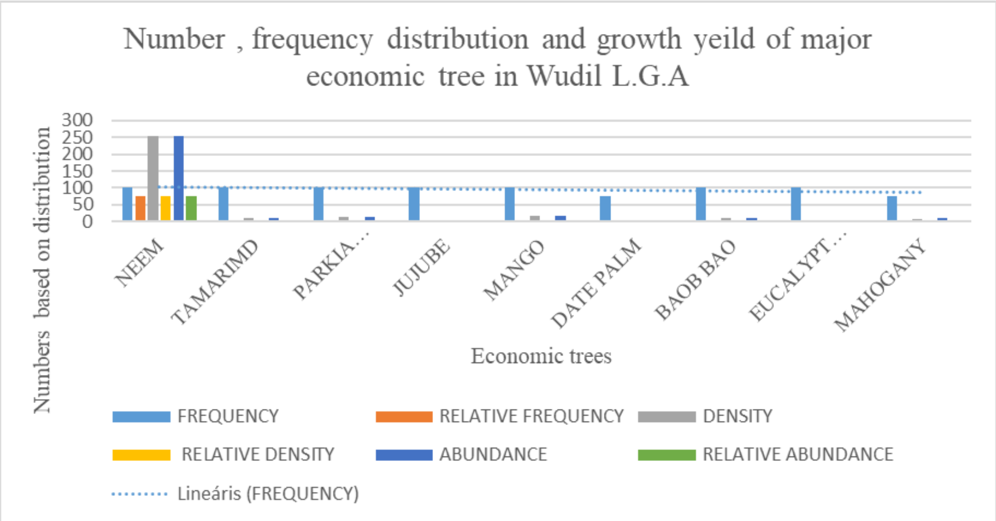

Figure 14. *Distribution of economic trees*

The aforementioned makes it clear that the factors considered (climate, human effect) have contributed differently to deforestation and desertification in the study area. The high rate of tree cutting by the indigenous population, who use firewood for cooking, baking, and as a common fuel source, is one indicator of how much of an impact the climate has had due to its influences (high temperatures, changes in rainfall characteristics).

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Conclusions

As seen in this study, remote sensing offers the capacity to evaluate how temperature and precipitation affect the deforestation of particular economic tree species. In the 1980s and 1990s, the research region had more trees due to the limitation of anthropogenic activities and climate change mitigation challenges, the millennium decades of the 2000s and 2010s featured higher temperatures and reduced rainfall intercepts. Temperature and rainfall both exhibit dynamic trends, in accordance with Mann-Kendall analysis, which leads to the rejection of Ho and acceptance of Ha. The main causes of drought and desertification vulnerability according to these findings include variations in rainfall patterns, human influence, and overgrazing. However, deforestation, road construction, and city growth brought on by population growth are all key contributors to the decline of important economic trees in the study area. If precautions are not taken, the effects of drought and desertification, which are occurring in the study at an imperceptible rate, could have devastating consequences, just as vegetation cover decreased from 88% in 1999 to 64% in 2006. It is clear that the research area's key economic trees are diminishing, which has a detrimental impact on climate change as well as other environmental and economic problems.

Recommendations

- The government needs to strengthen compliance with the land-use act in the study area to seriously reduce falling trees and monitor other anthropogenic activities such as road and urban expansions that seem to be occurring at a high and faster rate in the study area.
- Cities should be redesigned by urban managers and planners to incorporate a lot of parks, gardens, orchards, and open spaces into their physical plans. These measures will allow for the free movement of air and the supply of shades that will help with city cooling.
- To educate the population about the value of economic trees in environmental conservation, extensive radio, television, and other mass media campaigns must be conducted.
- More tree-planting initiatives should be supported, ideally making them an annual event in the study region.

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Conflicts of Interests. The authors affirm that they have no known opposing interests or subjective relationships that could have acted to affect the work reported in this paper.

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APPENDIX

Table A1. *Tree Species Composition in Wudil Local Government Area Kano State across North, West, East, and Southern Parts*

S/NO	LOCAL NAME	SCIENTIFIC NAME	COMMON NAME	WE	WW	WS	WN	TOTAL
1.	Darbejiya	Azadirachta indica	Neem	500	190	200	120	1010
2.	Tsamiya	Tamarindus indica	Tamarind	15	8	14	3	40
3.	Dorawa	Parkia biglobosa	Locust bean Tree	20	6	14	16	56
4.	Magarya	Ziziphus Mauritania	Jujube	8	2	1	1	12
5.	Mangwaro	Mangiifera indica	Mango	30	12	9	22	73
6.	Dabino	Phoenix dactylifera	Date palm	6	5	0	3	14
7.	Gamji	Ficus platyphylla	Gutta-percha	1	0	2	0	3
8.	Bishiyar Kuka	Adansonia digitata	Baobab	20	18	3	5	46
9.	Giginya	Borassus aethopium	Deleb or Fan palm	3	1	1	2	7
10.	Kurna	Ziziphus spinachristi	Christ’s thorn	6	2	0	3	11
11.	Baure	Ficus sychomoros	Fig	3	3	1	6	13
12.	Bishiyar turare	Eucalyptus camaldulnensis	Eucalypt tree	3	2	3	6	14
13.	Kalgo	Piliostigma reticulatum	Indian red head	2	1	1	0	4
14.	Chediya	Ficus thoningi	Chinese banyan	5	2	1	3	11
15.	Madaci	Khaya senegalensis	Mahogany	2	2	23	0	27
16.	Kaiwa	Diospyros mespliformis	African Ebony tree	3	1	3	3	10
17.	Marke	Anogeisis leiocarpus	African birch	3	1	5	2	11

Source: Field Work, 2020. Key: WE: Wudil East, WW: Wudil West, WS: Wudil South, WN: Wudil North

Table A2. *Satellite Imagery used in the study*

S/N	Data type	Obtaining year	Resolution	Source
1.	Landsat 5 (TM)	1986	30m	USGS
2.	Landsat 7(ETM+)	1999	15m	USGS
3.	Landsat 7(ETM+)	2006	15m	USGS
4.	Landsat 8 (OLI)	2016	30x30	USGS
5.	Landsat 8 (TIRS)	2020	30x30	USGS

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Figure A1. *An example of a local mango tree from the study area. Source: Field survey 2020*

Figure A2. *An example of a local Neem tree (Azadirachta indica) from the study area. Source: Field survey 2020*

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Figure A3. *An example of a local Eucalyptus tree (Eucalyptus camaldulnensis) from the study area. Source: Field survey 2020*

Figure A4. *An example of a local Tamarind tree (Tamarindus indica) from the study area. Source: Field survey 2020*

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Figure A5. *An example of a local Date palm (Phoenix dactylifera) from the study area. Source: Field survey 2020*

Figure A6. *An example of a local Baobao (Adansonia digitata) from the study area. Source: Field survey 2022*

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Figure A7. *An example of a local Tree Deleb or Fan palm from the study area (Borassus aethopium). Source: Field survey 2022*

Figure A8. *An example of a local Jujube Tree (Ziziphus mauritania) from the study area. Source: Field survey 2020*

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Figure A9. *An overview of the cattle market in Wudil Kano, Nigeria. Source: Teajay, 2019. Wudil Friday Market*

Figure A10. *An overview of the cattle market in Wudil Kano, Nigeria (Ram section). Source: Teajay, 2019. Wudil Friday Market*

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Figure A11. *An overview of the cattle market in Wudil Kano, Nigeria. Source: Teajay, 2019. Wudil Friday Market*

Figure A12. *An overview of the cattle market in Wudil Kano, Nigeria (goat section). Source: Teajay, 2019. Wudil Friday Market*

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