An Assessment of the Trend of Deforestation and its Impact on the Changing Climate in North Central Nigeria

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Abstract

Deforestation has become a major environmental issue in the world today especially in Sub-Saharan Africa where forest wood is worth more to people than their wellbeing in the long run. Thus, the forest cover is constantly depleted due to its use as fuel and in the manufacture of paper and charcoal. Nigeria has the world's highest deforestation rate of primary forests according to revised deforestation figures from the Global Forest Resources Assessment of the Food and Agriculture Organization of the United Nations (FAO, 2015). Between 2000 and 2005 the country has lost 55.7% of its primary forests and is currently estimated to having only 6% of its entire land area covered by forests. Logging, subsistence agriculture, and the collection of fuelwood are cited as leading causes for the forest clearing in the West African country. Deforestation is considered to be one of the major contributing factors to global climate change. This research aims at assessing the trends in deforestation in North Central Nigeria with respect to changes in climatic parameters while also seeking to educate locals on how their actions like deforestation and bush burning are constantly modifying the climate. Changes in the extent of the forest cover were studied over 32 years with a 10-year time step using satellite images obtained from the United States geological survey archive and the Idrisi image analyst software, while climatic parameters for the study area (rainfall and temperature) were obtained from the archive of the Nigerian Meteorological Agency, Oshodi, Nigeria. The data was analyzed using the trend line equation for the same period. The results of the forest cover change were mapped and overlaid to determine the extent of forest cover change and its implication on changes in climate. The results reveal a decline in rainfall and a rise in

Annual temperature averages. The rate of forest depletion was 17.38% between 1987 and 2018 with an additional 30.1% decline in the light vegetation over the same period. Changes in built up areas and densely vegetated forest areas have a highly statistically significant influence of R^2 above 90% and P-value <0.05 on maximum temperature.

Keywords: Deforestation, Environmental Management, Climate Change, Nigeria Forest

Introduction

Forests are of great importance to the environment; they furnish us with the basic necessities of life, providing habitats for a variety of species, helping to control and moderate the climate, and prevent soil erosion and flooding. Despite all these benefits obtained from forest ecosystems, the clearing of forests has remained a consistent feature of man's development contributing immensely to the continuous depletion of forests. Deforestation is clearing Earth's forests on a massive scale often resulting in damage to the quality of the land. Glenn et al. (2011) reporting Dove (1993) indicates that poverty draws people to exploit tropical forests for immediate gains. Dolisca et al. (2007) and Ehrhardt-Martinez (1998) explain that pressures brought about by the land tenure system and population growth are some of the identifiable causal factors of deforestation. According to Geist and Lambin (2002), demographic, institutional, cultural, economic and technological factors and policies all contribute to the underlying driving forces of deforestation.

According to the Seventy years of FAO's Global Forest Resources Assessment (FAO, 2018) on the state of the forests, the global forest cover has been found to have decreased from 31.6% to 30.6% between 1990 and 2015 albeit a slower pace of encroachment reported in recent years. Forests produce vital oxygen and provide homes for people and wildlife; the world's most threatened and endangered animals live in forests, and 1.6 billion people rely on benefits that forests offer, including food, fresh water, clothing, traditional medicine and shelter. But the fact remains that forests around the world are under threat from deforestation, jeopardizing these benefits. Forests are cut down for many reasons, but most of them are related to money or to people's need to provide for their families. Deforestation comes in many forms, including man-made fires and clear-cutting for agriculture which is the by far the biggest driver of deforestation (Nepstad et al., 2008). This corroborates the findings of the Global Forest Fund (2002) that deforestation comes as a direct consequence of the following; shifting cultivation, logging, grazing, fuelwood use, and urbanization. The World Resources Institute (2005) reports that over 11 million hectares of tropical forests are cleared annually, and that approximately 225 million hectares of tropical forests have been cleared in the year 2000 based on the current rate of use. Shifting cultivation is by far the most significant cause and it accounts for close to 70% of the total deforestation in the Africa region. Farmers cut forests to provide more room for planting crops or grazing livestock, ranching and development and for unsustainable logging for timber. These and the forest degradation due to climate change have come to impact people's livelihoods and the survival of a wide range of plant and animal species as 46-58 million square miles of forest equivalent to 36 football fields are lost each year (WWF Living Planet Report, 2013).

The importance of forests in climate control cannot be overemphasized because it plays a critical role in moderating climate change (UN, 2016). Forests act as a carbon sink soaking up carbon dioxide that would otherwise be free in the atmosphere and contribute to the ongoing positive changes in climate patterns. Deforestation undermines this important carbon sink function. According to WWF Living Planet Report (2013), it is estimated that 15% of all greenhouse gas emissions are the result of deforestation which is a concern, particularly, in tropical rainforests since they are home to much of the world's biodiversity. For example, in the Amazon around 17% of forest has been lost in the last 50 years due mostly to forest conversion for cattle ranching.

Although deforestation appears to be on the decline in some countries, it remains disturbingly high in others including Brazil, Sri-Lanka and

Nigeria and has become a grave threat to the world's most valuable forests (WWF Living Planet Report, 2012). Analysis of the FAO (2008) report shows that developing countries in the tropics have suffered the worst rates of forest loss between 2000 and 2005, and that 10 countries with the highest deforestation rates during that period were all considered "developing" with 9 been tropical countries. Among these countries, Nigeria has the world's highest deforestation rate of primary forests. According to the revised deforestation figures the country has lost 55.7% of its primary forests between 2000 and 2005 largely attributed to logging, subsistence agriculture, and collection of fuel wood (FAO; FAOSTATS, 2008; Oriola et al. 2017; Tilakasiri et al., 2016; Olanrewaju et al. 2018). In Nigeria, as in other tropical countries, the rate of deforestation has accelerated in recent years. In 2016, the FAO confirmed that Nigeria has lost about 350,000 to 400,000 hectares of forest cover per year to deforestation, with the total estimated percentage cover of forests in Nigeria standing at less than 6%.

The high rates of changes witnessed in the study area in terms of land use/ land cover from forested land to the built environment is alarming and call for caution. According to WWF Living Planet Report (2013), trees play a critical role in absorbing the greenhouse gases that fuel global warming. Therefore, fewer forests mean larger amounts of greenhouse gases entering the atmosphere and increased speed and severity of global warming, hence the need for this study. The aim of this research is to assess the rate/trend of deforestation in North Central Nigeria and its implication on the changing climate.

The Study Area

North Central Nigeria consists of the seven states situated geographically in the middle belt region of the country, spanning from the West, around the confluence of the River Niger and the River Benue (Figure 1). The region itself is rich in natural land feature, and boasts some of Nigeria's most exciting scenery. The region is also home to many historical and colonial relics.

Figure 1: Map of North Central Nigeria

Source: Adapted from GADM (2017)

North Central Nigeria experiences the humid tropical climate characterized by wet and dry seasons (North Central Nigeria Atlas, 1981). The wet season commences towards the end of March and spans to October. The dry season that starts in November spans to February which in North Central Nigeria is characterized by the dusty wind from the Northern part of Nigeria referred to as the Harmattan, and the hot temperature which extends from November to March (Olaniran, 2002). The wet season is characterized by high humidity which begins in April spanning through October while extremely high temperatures often exceeding 30^{o}C is usually experienced between February and April. North Central Nigeria is located in the transition zone between the deciduous rainforest of the Southwest and the savannah grassland of the North. The vegetation in North Central Nigeria is composed of species of trees such as locust bean, shear butter, acacia, baobab, and elephant grasses, shrubs and plants among others. Areas under the effective cover of vegetation in North Central Nigeria are protected from the impact of raindrops while bare surfaces such as football fields, unpaved roads, ploughed land among others encourage runoff, sheet and gully erosion.

The soil in North Central Nigeria is formed under the grassland savannah cover and belongs to the soil group called Ferruginous soil. This is an ideal soil for the growing of crops such as yam, cassava, and maize, among others. This type of soil yields readily to the agents of denudation when exposed to elements unprotected by the vegetation cover (Jimoh, 1999 and 2000).

Material and Methods

Multi-temporal satellite images (Landsat TM 1987 and 1999 of 30m spatial resolution respectively; Spot 5 multispectral 2005 of 10m spatial resolution, and Landsat OLI/TIRS 2018 of 15m resolution) were obtained and analyzed using ArcGIS 10.6 and Erdas Imagine 2016.

Table 1: Images Path, Row and Date of Acquisition

Path	Row	1987	1999	2005	2018
		Landsat TM	Landsat ETM	Spot 5	Landsat Oli/Tits
187	052			3/5/2005	3/20/2018
	053	7/7/1987	2/15/1999	3/5/2005	3/20/2018
	054	7/8/1987	2/15/1999	3/5/2005	3/20/2018
	055	7/9/1987	2/15/1999	3/5/2005	2/3/2018
188	052			3/18/2005	3/30/2018
	053			3/18/2005	3/30/2018
	054	8/4/1987	11/18/1999	3/18/2005	3/30/2018
	055	8/4/1987	11/18/1999	3/18/2005	3/30/2018
189	052	2/7/1987	11/18/1999	3/5/2005	3/18/2018
	053	2/7/1987	11/18/1999	3/5/2005	3/18/2018
	054	2/7/1987	1/28/1999	3/5/2005	3/18/2018
	055	2/7/1987	1/28/1999	3/5/2005	3/18/2018

190	052	3/4/1987	11/16/1999	3/22/2005	3/25/2018
	053	3/4/1987	11/16/1999	3/22/2005	3/25/2018
	054				3/25/2018
191	052	7/3/1987	2/11/1999	3/25/2005	3/16/2018
	053	7/3/1987	2/11/1999	3/25/2005	3/16/2018
	054	7/3/1987	2/11/1999	3/25/2005	3/16/2018

Source: Authors' Analysis (2018).

The images were acquired from the Global land cover facility and the data available crossed seasons. However, a careful assessment of the data reflects minimal influence of seasonal variations on the objectives of this study. This is because the forest covers, unlike shrubs and grasslands, are usually subject to human interference and is unlikely to have diminished or increased within the span of a season. Image preprocessing was carried out on the images to ensure that the data was geometrically and radio metrically corrected for analysis. The pre-processing stage usually involves image rectification and image sub-setting. This is with a view to correcting whatever distortion that might have occurred during acquisition from the satellite (Paul, 1992; Ogunleye, 2010). For this analysis the Histogram Equalization technique was employed to balance the color of the images while image sub setting was used to extract the study area. Band combinations were also carried out to highlight features of interest.

The image was initially classified using the ISODATA algorithm to perform an unsupervised classification. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either the means of arbitrary cluster or the means of an existing signature set, and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration.

This process helps in separating the images into unique spectral classes. The ISODATA method repeats the clustering of the image until either:

1. a maximum number of iterations has been performed, or
2. a maximum percentage of unchanged pixels has been reached between two iterations.

The image generated 36 classes through 10 iterations at 0.97 convergence threshold. The convergence threshold is the maximum percentage of pixels that has cluster assignments that can go unchanged between iterations. This threshold prevents the ISODATA utility from running indefinitely. By specifying a convergence threshold of 0.95 it specifies that as soon as 95% or more of the pixels stay in the same cluster between one iteration and the next, the utility should stop processing. In other words, as soon as 5% or fewer of the pixels change clusters between iterations, the utility stops processing). The classes were then grouped using trained eye assessments and Google earth pro. The generated classification was then converted to shape files and introduced into the ArcGIS image classification window as training samples.

Leo Breiman's Random Forest Supervised Classification Algorithm, which is a supervised machine learning model, was utilized for the supervised classification of the data sets. The random forest algorithm makes use of decision trees, usually many decision trees, called an ensemble or a forest, that is then used for prediction. Each tree generates its own prediction and is used as part of a voting scheme to make final predictions. The final predictions are not based on any single tree but rather on the entire forest. The use of the entire forest rather than an individual tree helps avoid overfitting the model to the training data set as does the use of both a random subsets of training data and explanatory variables in each tree that comprises the forest. For this research, 20% of the training samples were trained by the random forest classifier. The model output was adjusted and reviewed until it suited the expected model behavior of the data sets. The model was then applied to the image to generate a supervised classification of the study area.

Time Series Analysis

For the time series analysis, the time series modeler in SPSS version 20 and Excel trend line analysis was used to analyze the trend and time series analysis of rainfall and temperature for the study area. Average annual maximum and minimum temperatures and rainfall data were subjected to time series analysis using a series of models (ARIMA, Holt and TS).

The curve estimation regression method was used to analyze the relationship between land use and the climatic variables due to the nature of the variables, and linear, cubic and exponential algorithms were employed to determine the relationship between these variables.

Results and Discussion

The land use and land cover classification of the entire North Central Nigeria covering an area extent of 232,344.76 km^2 shows a steady decline in vegetal resources over the study period with built-up areas and bare surfaces as the biggest gainers in the study period (Figures 2-5).

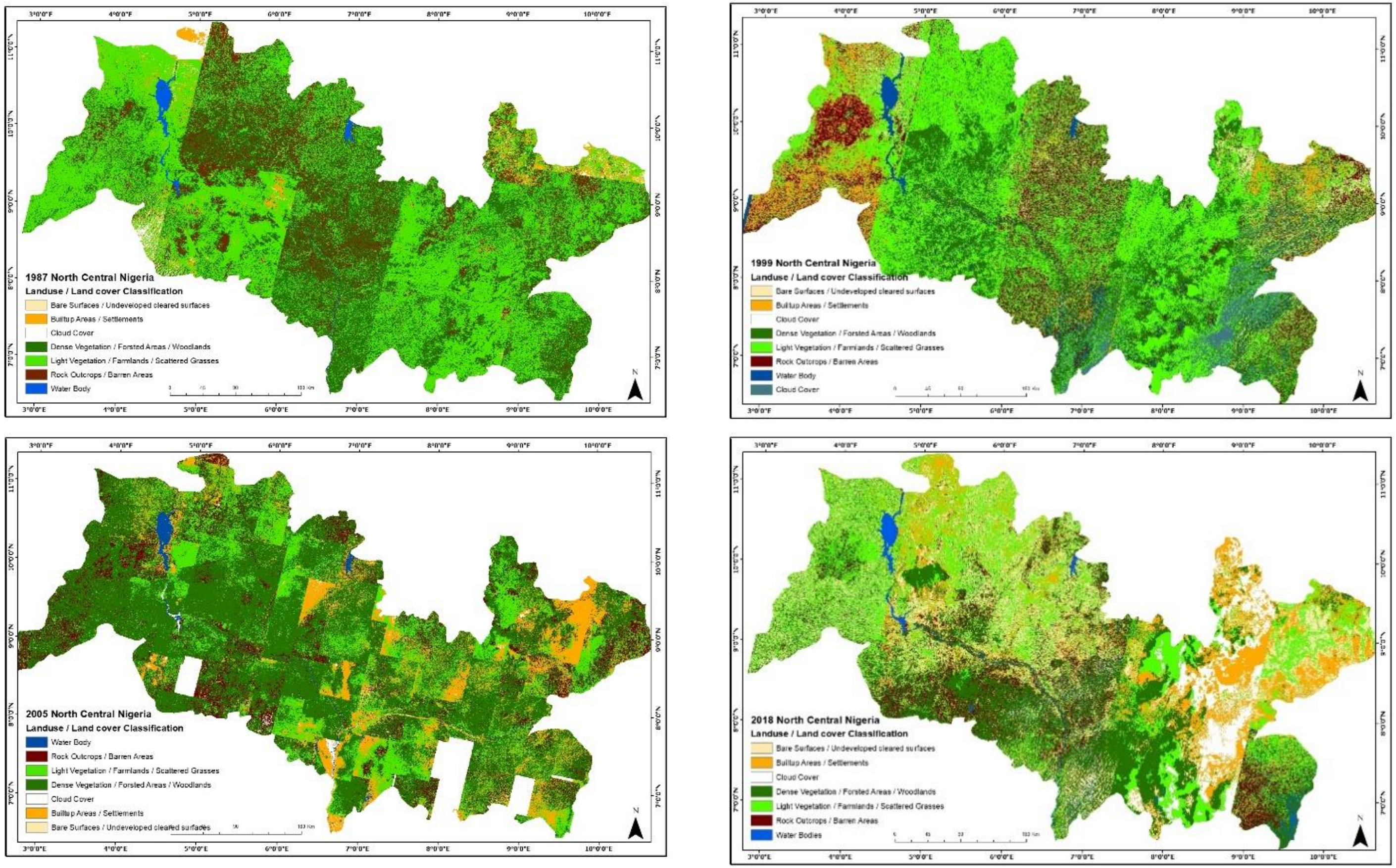


Figure 2-5: Land Use Land Cover Classification for North Central Nigeria (1987-2018), Top-bottom (1987, 1999, 2005 and 2018). **Source: GLCF, Analyzed by Author** (2018)

The built-up areas that accounted for 2.81% of the area in 1987, 14.15% in 1999, 26.06% in 2005 and 29.76% in 2018 depict a steady rise in extent over the period while bare surfaces increased from 0.55% in 1987 to 17.34% in 2018 (Table 2).

Table 2: Land Use Land Cover Change (1987 – 2018)

Landuse / Land cover	**1987**		**1999**		**2005**		**2018**	
	Area Km^2	**%**	**Area Km^2**	**%**	**Area Km^2**	**%**	**Area Km^2**	**%**
Bare Surfaces / Undeveloped cleared surfaces	1271.77	0.55	17067.73	7.35	35007.51	15.07	40295.21	17.34
Built-up Areas / Settlements	6519.78	2.81	32878.22	14.15	60549.13	26.06	69156.12	29.76
Cloud Cover	1555.45	0.67	9547.99	4.11	1156.70	0.50	7586.77	3.27
Dense Vegetation / Forested Areas / Woodlands	76283.07	32.83	69199.01	29.78	47643.93	20.51	35938.36	15.47
Light Vegetation / Farmlands / Scattered Grasses	112214.69	48.30	61937.28	26.66	50091.42	21.56	42314.74	18.21
Rock Outcrops / Barren Areas	32705.28	14.08	35590.77	15.32	35192.97	15.15	32697.20	14.07
Water Body	1794.71	0.77	6123.77	2.64	2703.10	1.16	4356.37	1.87
Grand Total	**232344.76**	**100**	**232344.76**	**100**	**232344.76**	**100**	**232344.76**	**100**

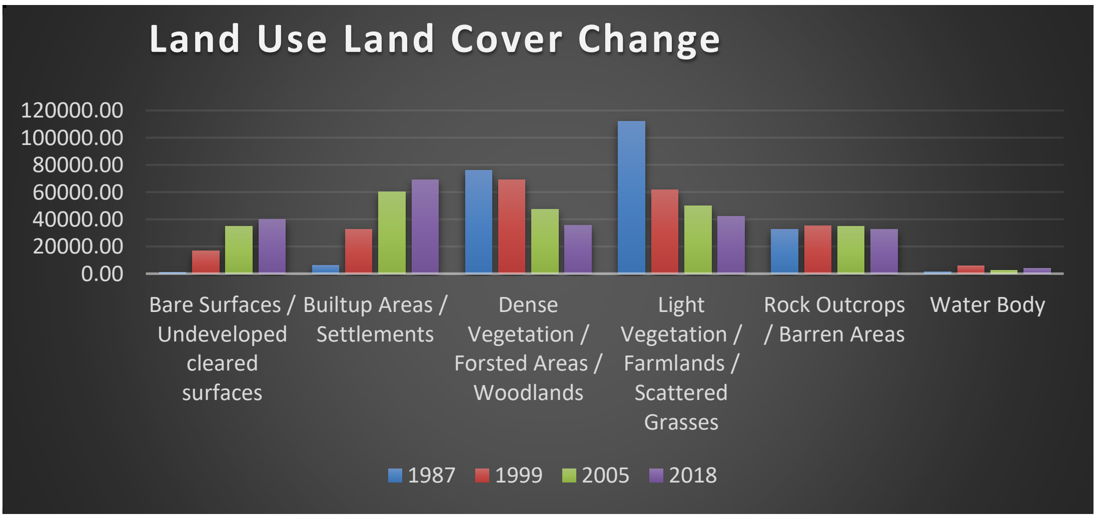
Source: Authors' Analysis (2018)

The forested areas declined from 32.83% in 1987 to 15.47% in 2018 while light vegetation (grasslands, shrubs etc.) declined hugely from 48.30% to 18.21% in 2018.

The rock outcrops and Water bodies remained fairly constant through the study period with changes occasioned by vegetation growing over rock outcrops and on the banks of water bodies thus reducing visible areas of the classes.

The cloud cover remained a constant through the images covering 0.67% of the image in 1987, 4.11% in 1999, 0.5% in 2005 and 3.27% in 2018. Figure 6 depicts the land use extent of all classes during the study period.

Figure 6: Land Use and Land Cover Change (1987-2018)



Source: Authors' Analysis (2018)

The results of the forest cover analysis show a 17.36% decline between 1987 and 2018, while lightly vegetated surfaces inclusive of grasslands, farmlands, shrubs and patches of scattered grasses had a 30.10% decline within the same period.

This is due in part to the geometric urbanization as witnessed in this region during the period under study. Cities such as Ilorin, Minna, Jos and the FCT (Federal Capital Territory) have all had varying degrees of encroachment on forest cover and vegetal resources in a bid to develop land for residences and expand industries (Table 3).

The built up areas gained by +26.96% while Bare surfaces gained by +16.80%. The cloud cover retained a 2.60% cover while rock outcrops and water bodies remained fairly constant.

Table 3: Percentage Change in Land Use/Land Cover (1987-2018)

	Changes 1987 – 2018	
Land use / Land cover	**Area**	**%**
Bare Surfaces / Undeveloped cleared surfaces	+39023.44	+16.80
Built-up Areas / Settlements	+62636.34	+26.96
Cloud Cover	6031.32	2.60
Dense Vegetation / Forested Areas / Woodlands	-40344.72	-17.36
Light Vegetation / Farmlands / Scattered Grasses	-69899.96	-30.08
Rock Outcrops / Barren Areas	-8.08	0.00
Water Body	+2561.66	+1.10

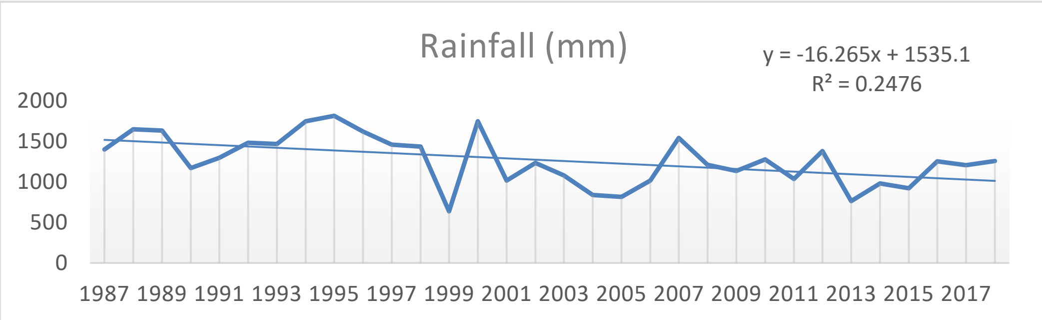
Source: Authors' Analysis (2018)

The overall accuracy of the land use maps using Kappa indices for 1987, 1999, 2005 and 2018 was determined to be 86.01%, 88.45%, 87.53%, and 82.31%, respectively.

Climatic Analysis

The Mean annual rainfall for the entire North central Nigeria was analyzed using linear trend line analysis for 32 years and results show a decline in the amount of average annual rainfall over the period (Figure 7). The average total amount of rainfall is expected to decrease by -16.265 mm for every annual total rainfall of about 1535 mm recorded.

Figure 7: Trend Line Chart for Mean Annual Rainfall



Source: Nigeria Meteorological Agency (2018)

The model statistics for the time series shows 87.50% goodness of fit with a Maximum predicted error of 22.86 and a P value of 0.75 as shown in Table 4.

Table 4: Model Statistics for Time Series (Holt Model)

Model	Number of Predictors	Model Fit statistics		Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	MaxAPE	Statistics	DF	Sig.	
Rainfall NC-Model_1	0	.875	22.858	11.935	16	.748	0

Source: Authors' Statistical Analysis (2018)

For temperature, the trend analysis for the states in the North Central Region was carried out using the multivariate time series model (ARIMA, Holt and simple TSL). The time series utilized the ARIMA model for the analysis and shows an 85.3% goodness of fit and a p value of 0.201(Table 5, Figures 8 and 9).

The results of the analysis show an expected rise of +0.05^{0}C for every 29.94^{0}C recorded maximum temperature and an expected rise of

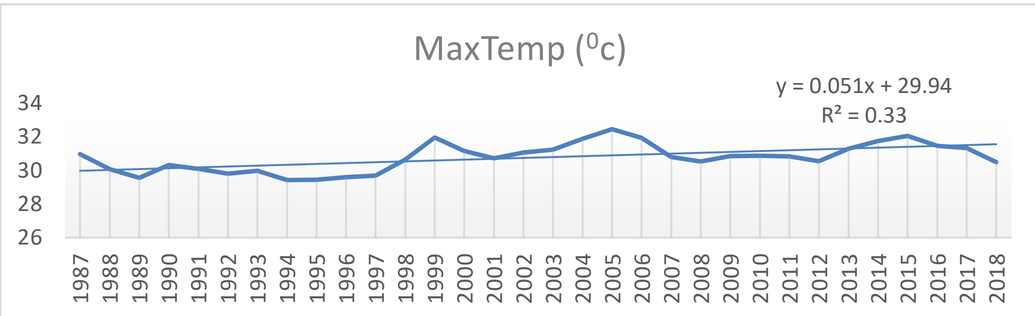
+0.038^{0}C for every 20.06^{0}C recorded minimum temperature in the study area.

Table 5: Model Statistics Time Series (ARIMA)

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Temperature-Model_1	0	.853	20.442	16	.201	0

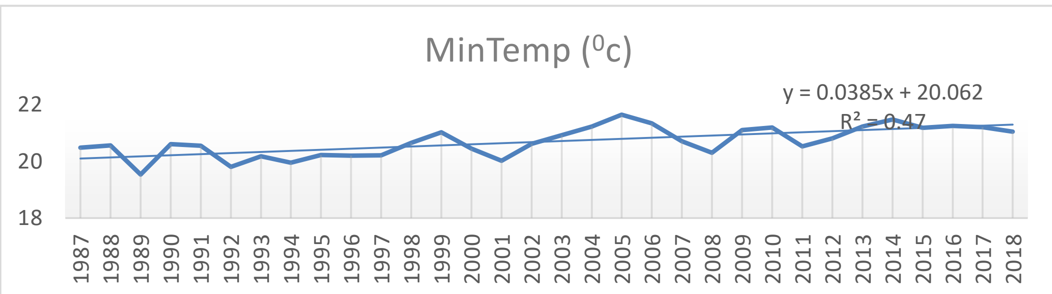
Source: Authors' Analysis (2018)

Figure 8: Trend Line Chart for Maximum Temperature



Source: Authors' Analysis (2018)

Figure 9: Trend Line Chart for Minimum Temperature



Source: Authors' Analysis (2018)

To explore the relationship between land use classes and climatic variables, the variables were standardized using the mean and standard deviation of the variables. The result was then analyzed using the curve estimation regression method.

The results (as shown in green) indicate that changes in built up areas and densely vegetated, forested areas have a highly statistically significant influence (R^2 *above 90% and P value < 0.05*) on maximum temperature (^{0}c) with (.939 [*0.031*]), (.932 [*0.034*]) while lightly vegetated, grassland areas also influence maximum temperature albeit no statistical significance is shown with (.711 [0.157]).

The assessment of the influence of the land use types on rainfall (mm) showed built-up areas (.591 [*0.362*]), densely vegetated, forested areas (.594 [*0.230*]) and lightly vegetated, grassland areas (.622 [*0.211]*) exhibiting some form of influence with no statistical significance as P >0.05(Table 6).

Minimum temperature was seen to only have been influenced by changes in bare surfaces (.698 [*0.164]*) and rock outcrops (.849 [*0.079]*).

Table 6: Linear Regression Summary Estimating Relationship between Land Use and Climatic Variables (1987 – 2018)

LULC	Min Temp				Max Temp				Rainfall			
	R^2	Sig	F	t	R^2	Sig	F	t	R^2	Sig	F	t
Bare Surfaces	0.698	.164	4.632	-2.152	0.000	.978	0.001	-0.031	0.407	.362	1.372	-1.171
Built-up Areas	0.003	.945	.006	.077	0.939	.031	30.718	-5.542	0.591	.231	2.896	1.702
Dense Vegetation	0.004	.940	.007	.085	0.932	.034	27.516	-5.246	0.594	.230	2.921	1.709
Light Vegetation	0.041	.797	.086	-.293	0.711	.157	4.916	2.217	0.622	.211	3.292	-1.814
Rock Outcrops	0.849	.079	11.251	3.354	0.015	.878	0.030	0.173	0.400	.368	1.333	1.154
Water Body	0.010	.900	.020	.142	0.012	.891	.024	-.156	0.022	.850	.046	.214

Source: Authors' Analysis (2018)

Summarily, increase in temperature and the subsequent declining amount of rainfall has been shown to have impact on the vegetal resources of the study area. The maximum temperature has a 93% impact on forested areas and a 71% impact on grasslands and shrubs while rainfall is also shown to have a R^2 value of 59%, 59.4% and 62.2% on built up, forested areas and grasslands respectively.

Conclusion

Urbanization and industrialization are the world's highest excuse for the rate of deforestation globally experienced and North Central Nigeria is no exception. This research has shown the rate of changes in land use in North Central Nigeria between 1987 and 2018 while assessing the rate of forest depletion in the study area and results show that forests have given way to built-up areas, and to grassland in most areas. This is substantiated by the time series analysis carried out on the climatic variables in North Central Nigeria also showing an increase in temperature (maximum temperature) as well as a corresponding decline in rainfall amount in the study area thus lending credence to the fact that over exploitation of forest resources in the study area without recourse to reforesting is leading to an all-round change in the climate pattern as evidenced by the strong relationship between maximum temperature, rainfall and forest cover.

It is therefore recommended that for this region that is yet to be on the hotspot of forest depletion, it is imperative that laws and legislations be urgently put in place to combat the trend of deforestation and arrest it while embarking on afforestation in areas where massive urbanization has overtaken forest growth and vegetation especially in city capitals and other major towns.

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