Scientific Research Publishing

American Journal of Climate Change, 2023, 12, 489-503
https://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Modeled Implications of Global Warming Conditions on Precipitation Totals in Valley and Highland Areas of Nigeria

Johnson Orfega Mage[1], Rhoda Mojisola Olanrewaju[2], Ifeanyi Chris Onwuadiochi[3]*

[1]Department of Geography, Benue State University, Makurdi, Nigeria
[2]Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria
[3]Department of Geography and Meteorology, Nnamdi Azikiwe University, Awka, Nigeria
Email: mage.orfega@gmail.com, rodamoji@gmail.com, *ci.onwuadiochi@unizik.edu.ng

How to cite this paper: Mage, J. O., Olanrewaju, R. M., & Onwuadiochi, I. C. (2023). Modeled Implications of Global Warming Conditions on Precipitation Totals in Valley and Highland Areas of Nigeria. *American Journal of Climate Change, 12,* 489-503.
https://doi.org/10.4236/ajcc.2023.123022

Received: May 29, 2023
Accepted: September 25, 2023
Published: September 28, 2023

Abstract

Global temperature has been increasing causing differences in precipitation response in different physiographic regions as feedback mechanism. The aim of this work is to model the implications of the global warming conditions on precipitation occurrences in the valley and highland areas of Nigeria. Harmonic analysis on the average monthly rainfall observations was performed for 56 years (1961-2016) using the Turbo Pascal for windows programming language in order to implement the computation. This was carried out by fitting a periodic function of sinusoidal character to enhance the determination of the contribution of each harmonic, the amplitude of each harmonic and the time at which each harmonic is maximum. The result of harmonic plots of the grand average monthly rainfall for the valley area of Makurdi and highland area of Jos shows that there exists a similarity in the trend of variations of harmonic series plots of the data as either plots exhibit single rainfall maxima or peak, meaning that rainfall patterns are mono-modal in nature. Modeled result of average monthly rainfall for the valley area of Makurdi shows an increase in rainfall occurrences from the month of January to August but a decrease from September to December, meaning an expectation of more rains immediately after onsets and lesser rains before cessations. The modeled result for the highland area of Jos however shows a decrease in the occurrence of rainfall in the months of January and February but an increase from the month of March to December. The implication is that there will be water deficiency for late crops and aquifer recharge in the valley areas while highland areas will experience delayed onset of agricultural calendar. The study recommends timely release and adherence to weather/climate forecasts.

Keywords

Physiographic, Regions, Harmonics, Rainfall, Patterns

1. Introduction

The study on rainfall response to global warming in low and highland areas of Nigeria is significant because these marginal areas are important agricultural zones of the country; hence an understanding of the variation in rainfall behaviour is vital for agricultural development of the physiographic regions. Agricultural practices in Nigeria are predominantly rain-fed and rainfall characteristics determine the agricultural calendar (Olayide et al., 2016). Changing rainfall totals as a response to global warming will affect agricultural activities and production. The valley areas are flood plains which are used for the cultivation of rice, sugar cane and vegetables while on the highlands crops like Irish potatoes and many varieties of fruits that thrive in cooler environments are cultivated. This is because the low lying valleys used for flood plain cultivation can be inundated reducing the usage of these marginal lands for agriculture. Similarly, erosion on slopes of the highland areas may be aggravated thus destroying farmlands or reducing productivity through fertility loss by erosion.

Many settlements are situated in the low lying valleys of rivers Niger and Benue. Response by increasing rainfall total will worsen the occurrences of flooding which is already prone in these settlements (Ikusemoran et al., 2013). Also, other environmental disasters like erosion and landslides may be intensified especially in the highlands (Aliba et al., 2015). Decreasing response of rains will lead to reduction in fishing activities and hydro-electric power generation which will adversely affect standard of living in the study area. Changing precipitation will worsen issues of migration and conflict in the region. Clashes between cattle herders and farmers have become pronounced due to competition for climate based resources and the situation will get worse if conditions become drier (Chukwuma, 2020). Modeled projection of the implications of the global warming conditions on precipitation totals in the valley and highland areas will avail information on the anticipated future rainfall occurrence in the study area. This will help to plan ahead the expected vulnerability and climate risk, thus embarking on timely adaptation measures.

Topography can affect precipitation in at least three important ways. Firstly, it can intensify the solar heating over land by providing an elevated heat source. This magnifies the regional-scale land-sea temperature contrast and facilitates the onset and maintenance of monsoon regimes that produce convective rainfall and latent heating. Variations of this heating can affect weather and climate in other tropical areas, as well as in the extra tropics via atmospheric teleconnections. Secondly, topography can contribute to orographic rainfall and additional latent heating. That is, as moist air is forced up a slope, the air cools, moisture condenses and rainfall and latent heating occur with consequences similar to those associated with convective heating. Thirdly, topographic barriers in the tropics obstruct the large-scale air flow and force some air to go around rather than over topography. This mechanical effect disturbs the flow downstream and sets up large-scale circulation patterns that extend into the extra tropics via planetary long waves (Meehl, 1992).

Topography also has specially marked effects on weather elements such as air humidity, temperature and rainfall. These effects result in concomitant changes in soil and vegetation distribution over hilly or mountainous areas (Korner, 2004: Viviroli & Weingartner, 2004). The mountain ecosystems help in stabilizing atmospheric circulation by creating barriers to free movement of winds.

The temperature trend in Nigeria since 1901 (**Figure 1**) shows increasing pattern, the mean air temperature in Nigeria between 1901 and 2005 was 26.6˚C while the temperature increase for the 105 years was 1.1˚C (Odjugo, 2010). This is obviously higher than the global mean temperature increase of 0.74˚C recorded since 1860 when actual scientific temperature measurement started (Spore, 2008; IPCC, 2007). Similarly, according to the Federal Ministry of Environment (2014), temperature has been on the increase in Nigeria in the last five decades and has been very significant since 1980s. An increase in global precipitation is anticipated but this increase will be uneven across different regions, these calls for regional analysis of precipitation characteristics. Rainfall has however shown a general decreasing trend in Nigeria since 1901 (**Figure 2**) but with regional differences. This study therefore aims at modeling the response of precipitation to global warming conditions on different physiographic areas of lowland and highland in the Middle Belt Region of Nigeria. The specific objectives are to determine grand average of monthly rainfall and harmonics curves for the

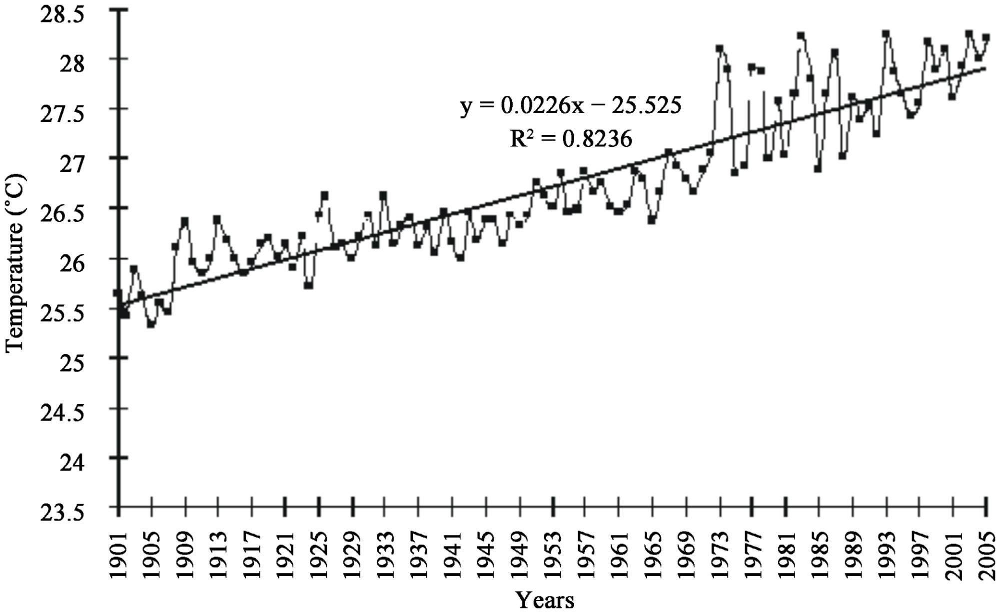


Figure 1. Air temperature distribution in Nigeria between 1901 and 2005 (Odjugo, 2010).

selected stations in lowland and the highland from 1961 to 2016 and model the implications of the global warming conditions on rainfall occurrences in the lowland and highland areas.

This study is limited to the valley area of Makurdi and the highland of the Jos Plateau which are located in the Middle Belt Region of the country within latitudes 6˚24'N to 11˚42'N and longitude 2˚42'E to 13˚6'E covering a total area of 320,000 km^2, about 35% of the total land area of Nigeria (**Figure 3**). The choice

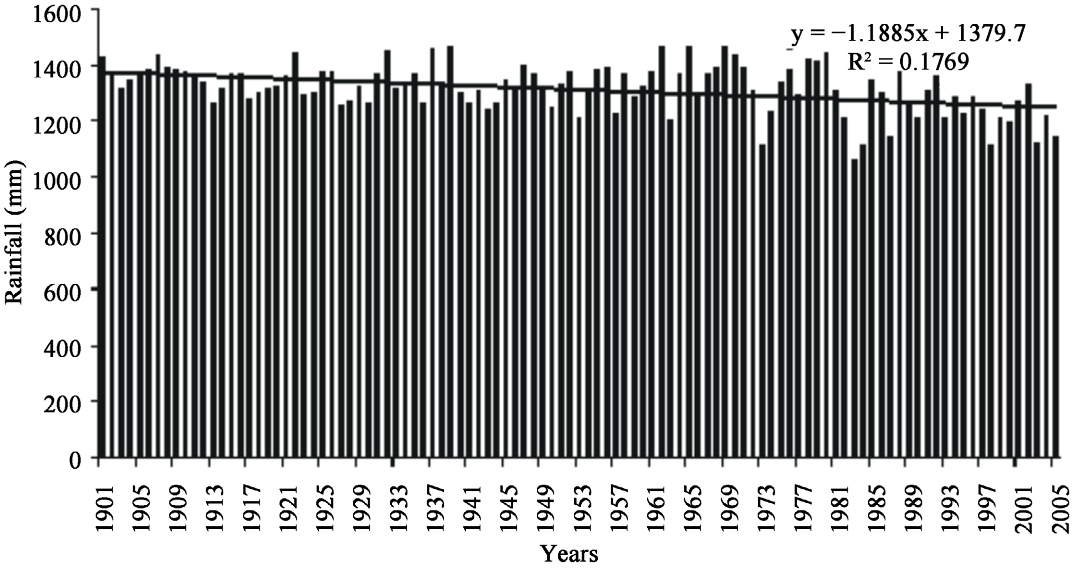


Figure 2. Rainfall distribution in Nigeria between 1901 and 2005 (Odjugo, 2010).

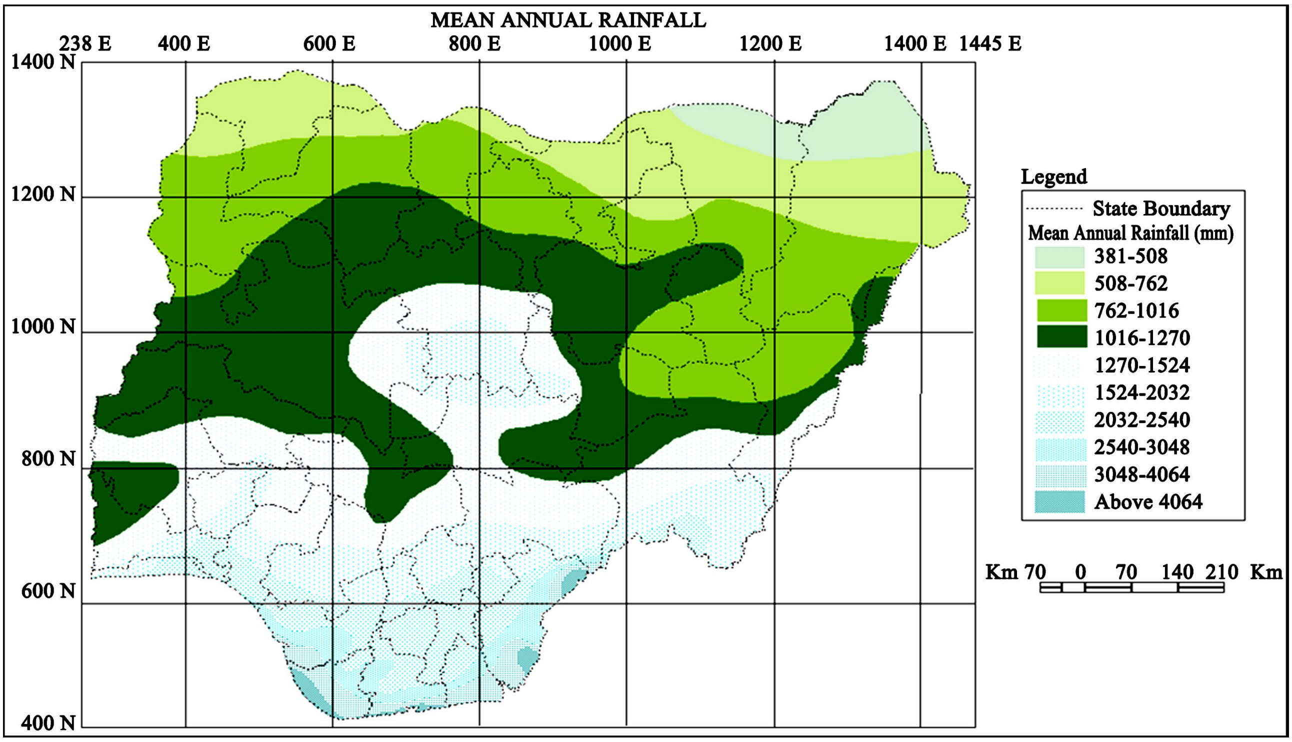


Figure 3. Nigeria showing mean annual rainfall spatial patterns (Ishaku & Majid, 2010).

of Makurdi and Jos is because the two stations are the ones with the required recorded data with highest difference in elevation; Makurdi (92 m) and Jos (1286 m) and both stations experience rainfall abnormality in the country by recording rainfall amount that does not coincide with their latitudinal values. The period of study (1961-2016) 56 years is chosen to cover the recent five decades with reported cases of intense global warming and extreme rainfall events worldwide. The base year of 1961 is decided because of data availability in both stations of Makurdi and Jos.

2. Research Methodology

To model the implications of the global warming conditions on rainfall totals in the valley and highland areas, the Harmonic analysis technique was used. Harmonic analysis of a time series uses a Fourier series to analyze periodic fluctuations. It is a particularly useful tool in studying annual precipitation patterns as it reveals the spatial variation of various precipitation characteristics (Isikwue et al., 2013). Harmonic Analysis, which is commonly applied to study periodic variations, decomposes a time series into its constituent parts if the time series represents a periodic phenomenon. It transforms a complex time series to a sum of many sinusoidal functions or harmonics (Park, 2008). The Harmonic analysis is based on a mathematical principle that a curve, viewed as a function, may be represented by a series of trigonometric functions. This is as given by Isikwue et al. (2013):

$$X_t = \bar{X} + \sum_{t=1}^{N/2}\left[A_i \sin\left(\frac{360}{i^2}\right)it + B_i \cos\left(\frac{360}{i^2}\right)it\right] \tag{1}$$

where;

$$A_i = \frac{2}{N}\sum_{t=1}^{N/2}\left[\bar{X}\sin\left(\frac{360}{p}it\right)\right];\quad B_i = \frac{2}{N}\sum_{t=1}^{N/2}\left[\bar{X}\cos\left(\frac{360}{p}it\right)\right] \tag{2}$$

X_t is the observed value at time, t, $\bar{X}$ is the arithmetic mean, number of observations, i is the number of harmonics and P is the period of observation. In other words, the time series equals the mean plus the sum of all $N/2$ harmonics. The Equation (1) above can be rewritten as;

$$X_t = \bar{X} + \sum_{t=1}^{N/2} C_i \cos\left[\left(\frac{360}{p}\right)i\left(t - t_i\right)\right] \tag{3}$$

The type of variation dominating the curve is revealed by a comparison of the sizes of the amplitudes C_i, where; $C_i = \sqrt{A_i^2 + B_i^2}$ is the amplitude of the i^{th} harmonic and $t_i = P/360$, arc sin (A_i/C_i) is the time at which the i harmonic has a maximum. It can also be expressed in percentage. A harmonic with overwhelming contribution would definitely account for most of the periodic variation in the data, while the contributions of the other harmonics would be considered negligible. Large first harmonic amplitude suggests strong annual variation, while comparatively large second harmonic amplitude points to strong semiannual variation.

Autocorrelation plots of the data were made in order to determine whether significant relationship in the data. Paired sample T-test will be used to determine whether there is a significant relationship between the estimated rainfall values of the years 1961 and 2016 and their corresponding observed values. This serves as a test for the efficiency of the harmonic analysis model in estimating the rainfall amount for 20 and 50 years ahead in Makurdi and Jos representing two different altitudes.

Harmonic analysis on the average monthly rainfall observations was performed for the 56 years under study using the Turbo Pascal for windows programming language in order to implement the computation. This was carried out by fitting a periodic function of sinusoidal character to enhance the determination of the contribution of each harmonic (expressed as a percentage of total variation in the rainfall measurements it accounts for), the amplitude of each harmonic and the time at which each harmonic is maximum. The rainfall data was partitioned into monthly totals and each year was considered on the basis of the twelve months that make up the year. The 12 months coding is shown in Table 1.

3. Results and Discussion

The harmonic plots of both the valley and highland stations of Makurdi and Jos respectively show that the observed multiple peaks of the total rainfall in the time series plot are now reduced to bimodal patterns, by the amplitudes of the oscillations of the troughs and valleys of the harmonics. Hence, the harmonic analysis could have filtered or smoothened out some noise or spikes in the data. The harmonics plot of average monthly rainfall (mm) for the interval of 12 months for Makurdi and Jos is given in Figure 4 and Figure 5 respectively.

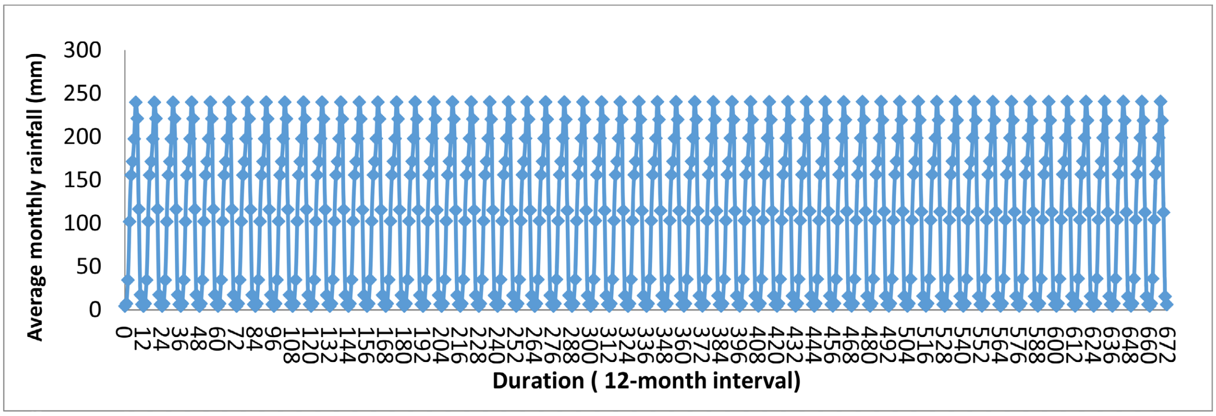
The result of harmonic plots of the grand or net average monthly rainfall (mm) for the interval of 12 months for the valley area of Makurdi and highland area of Jos show that there exists a similarity in the trend of variations of harmonic series plots of the data. Both plots exhibit single rainfall maxima or peak as shown in Figure 6 and Figure 7 respectively. That is, rainfall patterns are mono-modal in nature. This indicates that in a particular year, the rainfall peaks are observed in one single month of August for the valley of Makurdi and either July or August for the highland area of Jos. This implies that rainfall peak is attained earlier in the highland areas of Jos than the valley areas of Makurdi. This result partially agrees with the findings of Ogungbenro & Morakinyo (2014) in their work on rainfall distribution and change detection across climatic zones in Nigeria which revealed that rainfall peaks in July for areas within the Guinea Savanna Zone; but the result refutes their conclusion on the occurrence of August break and a double rainfall maximum within the belt. This difference could be attributed to the unique physiographic attributes of the valley and highland and their influence on rainfall behaviour as opposed to the other regions within the Savanna vegetation belt.

Results extract from the run of harmonic analysis on average monthly rainfall (mm) for the interval of 12 months for Makurdi and Jos are summarized in Table 2 and Table 3 respectively. Table 2 shows that the first harmonic dominates

Table 1. Code for the month axis along with the year

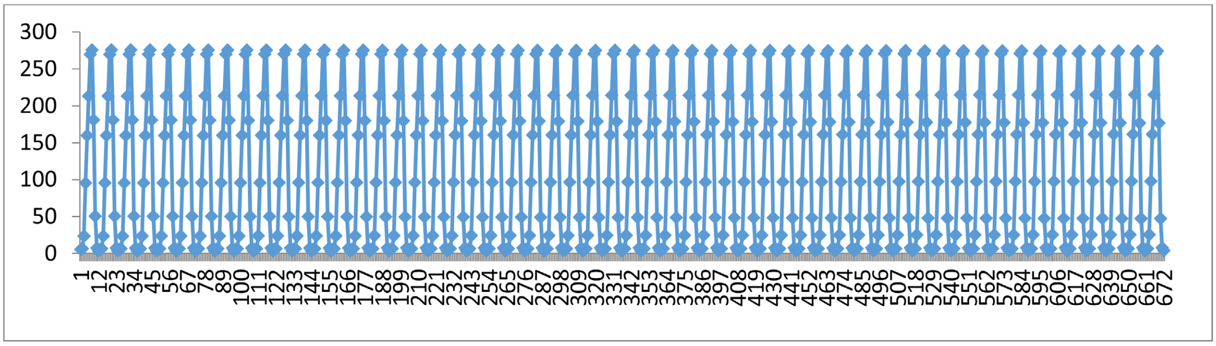
Month	Year	Month	Year
0 - 12	1961	348 - 360	1990
12 - 24	1962	360 - 372	1991
24 - 36	1963	372 - 384	1992
36 - 48	1964	384 - 396	1993
48 - 60	1965	396 - 408	1994
60 - 72	1966	408 - 420	1995
72 - 84	1967	420 - 432	1996
84 - 92	1968	432 - 444	1997
92 - 108	1969	444 - 456	1998
108 - 120	1970	456 - 468	1999
120 - 132	1971	468 - 480	2000
132 - 144	1972	480 - 492	2001
144 - 156	1973	492 - 504	2002
156 - 168	1974	504 - 516	2003
168 - 180	1975	516 - 528	2004
180 - 192	1976	528 - 540	2005
192 - 204	1977	540 - 552	2006
204 - 216	1978	552 - 564	2007
216 - 228	1979	564 - 576	2008
228 - 240	1980	576 - 588	2009
240 - 252	1981	588 - 600	2010
252 - 264	1982	600 - 612	2011
264 - 276	1983	612 - 624	2012
276 - 288	1984	624 - 636	2013
288 - 300	1985	636 - 648	2014
300 - 312	1986	648 - 660	2015
312 - 324	1987	660 - 672	2016
324 - 336	1988		
336 - 348	1989		

Source: Authors' fieldwork, 2018.



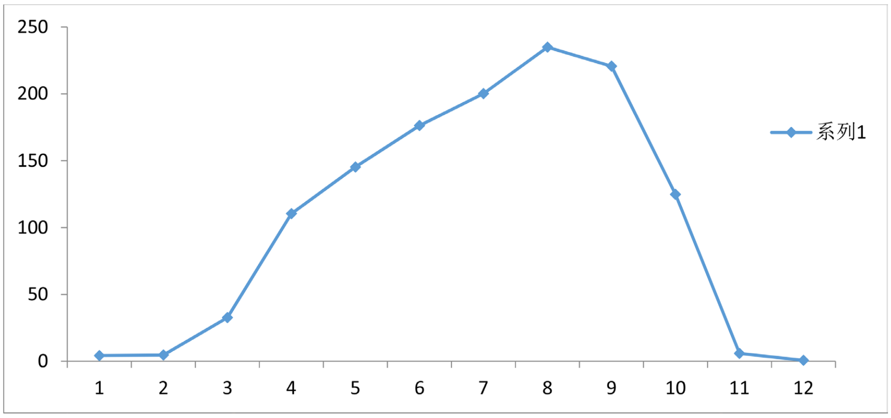
Source: Authors' fieldwork, 2018.

Figure 4. Harmonic plots of average monthly rainfall for Makurdi.



Source: Authors' fieldwork, 2018.

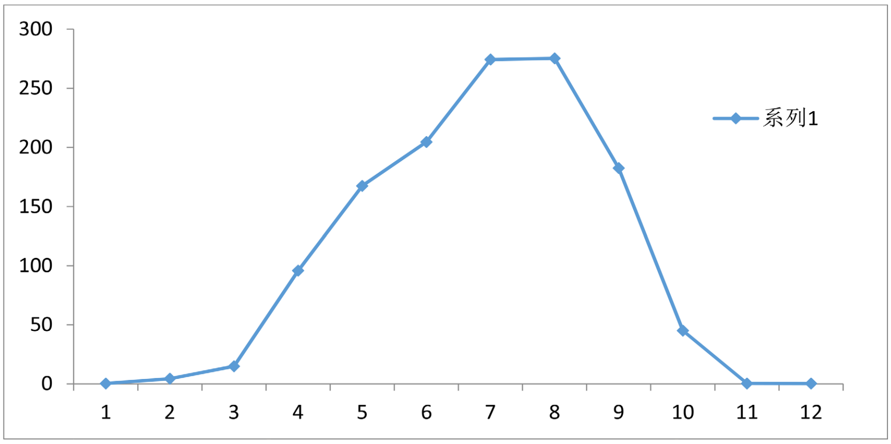
Figure 5. Harmonic plots for average monthly rainfall for Jos.



Source: Authors' fieldwork, 2018.

Figure 6. Grand average of monthly rainfall and harmonics curves for Makurdi.

the periodic components in the monthly average rainfall of Makurdi as it has the highest percentage contribution of 92.27%, indicating that the monthly rainfall in the station actually fluctuates. The large amplitude of the first harmonic indicates strong annual variation of rainfall in the station as in the works of Wong et al. (2009) and Kirkyla & Hammed (1989). Results from **Table 3** shows that the



Source: Authors' fieldwork, 2018.

Figure 7. Grand average of monthly rainfall and harmonics curves for Jos.

first harmonics also dominates the periodic components in the monthly average rainfall of Jos as it has the highest percentage contribution of 91.67, indicating fluctuation or periodicity of the monthly rainfall in the station. The periodic fluctuation is dominated by halve a cycle as is evident in the grand average monthly plots in Figure 6.

Using the grand average monthly rainfall obtained as 105.08 and 105.41 mm for Makurdi and Jos respectively as model estimates from the harmonic analysis, the period of 12 months, and the sine and cosine coefficients in Table 2 and Table 3, the periodic function X_t for the monthly average rainfall of Makurdi and Jos were obtained using extracts from equations

$X_t = 105.08 + \sum_{i-1}^{\alpha}\left[A_t \sin(30it) + B_t \cos(30it)\right]$ and

$X_t = 105.41 + \sum_{i-1}^{\alpha}\left[A_t \sin(30it) + B_t \cos(30it)\right]$. Where A_i and B_i are coefficients of sine and cosine respectively and i's are integers ranging from 1 to 3 as given in Table 2 and Table 3. The equations were then implemented in the harmonic analysis program to make a short consecutive five year and long five years interval forecasts of monthly average rainfall measurements for Makurdi and Jos. The result of short consecutive five year and long five years interval forecasts of monthly average rainfall is presented in Table 4 and Table 5 for Makurdi and Table 6 and Table 7 for Jos respectively.

Modeled result of the short consecutive five years and long five years interval forecast of average monthly rainfall for the low land area of Makurdi is presented in Table 4 and Table 5 respectively. The result shows an increase in rainfall occurrences from the month of January to August. The forecast however, shows a decrease in rainfall from the month of September to December. The implication of the result is that there will be more rainfall earlier in the season in the lowland areas and lesser of the rainfall towards the end of the season. In other words, more rains should be expected immediately after onsets and lesser rains should be anticipated before cessations. The effect of this rainfall pattern on agriculture is that the second phase of crops that mature towards the end of

Table 2. Result extract from the run of harmonic analysis program on average monthly rainfall for Makurdi, Nigeria.

Harmonics	Sine Coefficient (A_i)			Cosine Coefficient (B_i)			Amplitude	Percentage Contribution
	A_1	A_2	A_3	B_1	B_2	B_3	e	%
1st	−71.3732	0	0	−95.6051	0	0	119.31	92.27
2nd	0	8.2930	0	0	−22.6645		24.13	3.78
3rd		0	21.9057	0	0	6.6775	22.90	3.40

Source: Authors' computation, 2018.

Table 3. Result extract from the run of harmonic analysis program on average monthly rainfallfor Jos, Nigeria.

Harmonics	Sine Coefficient (A_i)			Cosine Coefficient (B_i)			Amplitude	Percentage Contribution
	A_1	A_2	A_3	B_1	B_2	B_3	e	%
1st	−68.6401	0	0	−124.5191	0	0	142.18	91.67
2nd	0	35.4786	0	0	3.0423	0	35.61	5.75
3rd	0	0	10.1121	0	0	19.5849	22.04	2.20

Source: Authors' computation, 2018.

Table 4. A display of five (5) years forecasts of average monthly rainfall for Makurdi.

Month	Actual value	Model estimate	Prediction	For	five	years	2023
	mm	mm	2019	2020	2021	2022	
January	4.371121	4.37169456	4.592643	4.596435	4.600221	4.604001	4.607776
February	7.322132	7.32318281	7.547414	7.551703	7.556002	7.56031	7.564627
March	34.4915	34.50412808	36.20828	36.2394	36.27054	36.30169	36.33286
April	101.9317	101.95488772	104.2546	104.2959	104.3372	104.3785	104.4198
May	155.6073	155.61971678	156.5829	156.5999	156.6168	156.6338	156.6507
June	171.3649	171.37058608	171.7531	171.7602	171.7673	171.7744	171.7816
July	197.5399	197.56417362	198.9465	198.9718	198.9972	199.0226	199.048
August	239.9136	239.93046752	240.7229	240.7367	240.7504	240.7642	240.7779
September	221.0115	220.96086625	218.701	218.6588	218.6166	218.5743	218.532
October	116.5207	116.42223539	112.5699	112.4995	112.429	112.3586	112.2882
November	17.53493	17.47866512	15.52517	15.49012	15.45511	15.42012	15.38517
December	6.490347	6.48473775	6.285245	6.281267	6.277278	6.273278	6.269267

Source: Authors' computation, 2018.

the rainy season will experience moisture deficiency. Also, decrease in rainfall towards the end of the rainy season will reduce the recharge of underground aquifers and worsen the perennial problem dry season water scarcity in the area.

The occurrence of more rainfall earlier in the season in the low land area may

Table 5. A display of five (5) years interval forecasts of average monthly rainfall for Makurdi.

Month	Actual value mm	Model estimate mm	Prediction 2023	For 2028	Five year 2033	Interval 2038
January	4.371121	4.37169456	4.607776	4.626563	4.645207	4.663707
February	7.322132	7.32318281	7.564627	7.58636	7.608334	7.630551
March	34.4915	34.50412808	36.33286	36.48895	36.64545	36.80234
April	101.9317	101.95488772	104.4198	104.6261	104.8322	105.0382
May	155.6073	155.61971678	156.6507	156.7351	156.8192	156.9028
June	171.3649	171.37058608	171.7816	171.8172	171.853	171.8889
July	197.5399	197.56417362	199.048	199.175	199.3022	199.4297
August	239.9136	239.93046752	240.7779	240.8461	240.9137	240.9807
September	221.0115	220.96086625	218.532	218.32	218.1072	217.8936
October	116.5207	116.42223539	112.2882	111.9361	111.5841	111.2322
November	17.53493	17.47866512	15.38517	15.21084	15.03724	14.86439
December	6.490347	6.48473775	6.269267	6.249054	6.228575	6.207832

Source: Authors' computation, 2018.

be explained by the fact that since air descent is more pronounced in the low land (a condition that inhibits rainfall formation), most of the rainfall in the low land region are formed outside of the region but drifted into the area by regional wind movement most especially the squall line movement earlier in the season during the northward movement of the Inter Tropical Discontinuity Zone (ITDZ).

The modeled result of the short consecutive five years and long five years interval forecast of average monthly rainfall for the high land area of Jos presented in Table 6 and Table 7 respectively shows a decrease in the occurrence of rainfall in the months of January and February (Out of season rains). Meanwhile, the forecast shows an increase in rainfall occurrences from the months of March to December. Since the rainy season normally begins in Jos area in April, the implication of the result is that the high land area increasingly becomes drier during the dry season and wetter during the wet season. Also, the increasing rainfall during the wet season will aggravate the ability of running water to detach, erode and transport soil down slope on the steep slopes of the plateau; this in the long run will impoverish the soils, destroy buildings and other structures.

A validation of the forecast results was done. Observations show that the equations exhibit a good fit to the average monthly rainfall as they produced very close estimates of the actual monthly average rainfall. They yielded the same means (average monthly rainfall) as that of the actual data; and very close standard deviations of the actual and that of the model estimates as shown in Table 8, which also display the results of the forecasts with the corresponding actual and estimates of monthly average rainfall measurements. These estimates are

Table 6. A display of five (5) years forecasts of average monthly rainfall for Jos.

Month	Actual value mm	Model estimate mm	Prediction 2019	For 2020	five 2021	years 2022	2023
January	5.623487	5.62239385	5.173242	5.165008	5.156768	5.148521	5.140268
February	6.661881	6.66167306	6.593512	6.591801	6.590072	6.588326	6.586562
March	23.63638	23.65069491	25.57857	25.61369	25.64884	25.68399	25.71916
April	95.59064	95.61481835	98.0062	98.0549	98.09798	98.14107	98.18415
May	159.86	159.88205114	161.5743	161.6547	161.686	161.7174	161.7487
June	213.4155	213.44332591	215.3005	215.3199	215.3534	215.3869	215.4204
July	269.7288	269.75439859	271.0043	271.1973	271.2225	271.2478	271.273
August	275.898	275.86938433	274.2867	274.3756	274.3478	274.3199	274.292
September	181.0741	180.97681663	176.5892	176.6348	176.5566	176.4783	176.4001
October	50.72391	50.63784280	47.2003	47.25032	47.19023	47.13016	47.07013
November	7.416882	7.42719075	7.754023	7.759316	7.764584	7.769827	7.775045
December	3.540324	3.55695430	4.087653	4.097243	4.106826	4.116402	4.125971

Source: Authors' computation, 2018.

Table 7. A display of five (5) years interval forecasts of average monthly rainfall for Jos.

Month	Actual value mm	Model estimate mm	Prediction 2023	for 2028	Five year 2033	interval 2038
January	5.623487	5.62239385	5.140268	5.098904	5.057378	5.015692
February	6.661881	6.66167306	6.586562	6.577482	6.567965	6.55801
March	23.63638	23.65069491	25.71916	25.89525	26.07172	26.24857
April	95.59064	95.61481835	98.18415	98.39946	98.61464	98.8297
May	159.86	159.88205114	161.7487	161.9055	162.0621	162.2186
June	213.4155	213.44332591	215.4204	215.5881	215.7558	215.9237
July	269.7288	269.75439859	271.273	271.3988	271.5242	271.6492
August	275.898	275.86938433	274.292	274.1519	274.0109	273.8688
September	181.0741	180.97681663	176.4001	176.0085	175.6167	175.2245
October	50.72391	50.63784280	47.07013	46.7704	46.47141	46.17317
November	7.416882	7.42719075	7.775045	7.800757	7.825844	7.850306
December	3.540324	3.55695430	4.125971	4.173717	4.221291	4.268694

Source: Authors' computation, 2018.

known as model estimates. Table 8 displays both the measured and the estimated rainfall values in Makurdi and Jos respectively. The level of deviation measured from the estimated rainfall values were determined using Paired sample T-test analysis. The results show that there are no significant differences at

Table 8. Validation results for Makurdi and Jos stations.

Month	Makurdi Actual value mm	Station Model estimate mm	Jos Actual value mm	Station Model estimate mm
January	4.371121	4.37169456	5.623487	5.62239385
February	7.322132	7.32318281	6.661881	6.66167306
March	34.4915	34.50412808	23.63638	23.65069491
April	101.9317	101.95488772	95.59064	95.61481835
May	155.6073	155.61971678	159.86	159.88205114
June	171.3649	171.37058608	213.4155	213.44332591
July	197.5399	197.56417362	269.7288	269.75439859
August	239.9136	239.93046752	275.898	275.86938433
September	221.0115	220.96086625	181.0741	180.97681663
October	116.5207	116.42223539	50.72391	50.63784280
November	17.53493	17.47866512	7.416882	−7.42719075
December	6.490347	6.48473775	3.540324	3.55695430
Monthly Average	105.10	105.08	105.42	105.41
Standard Deviation	87.83	87.59	105.01	104.81
T - Value	4.082		3.491	
P - Value	4.081		3.490	
Remark	No Significant	Difference	No	Significant Difference

Source: Authors' computation, 2018.

95% confidence level between the measured and the estimated rainfall in both years as can be seen from the T and P values. Hence, the predictions for the other years ahead are valid as far as rainfall variations in these stations are concerned.

4. Conclusion and Recommendation

Climate change and global warming are topical issues that have come to occupy environmental studies worldwide. The effect of global warming impinges on all facets of life including precipitation. Precipitation is one of the most important elements of weather and climate and in the tropics where agriculture is predominantly rain fed, water supply is majorly from natural sources, an understanding of the direction of response of precipitation to warming global conditions becomes paramount. This study shows the direction of response of precipitation to global warming on the unique marginal physiographic regions of the Benue valley and Jos plateau. The study recommends that refined modeling techniques that bring high quality term forecasts should be developed and used in immediate regions as well as diffusing of information to help interpret forecasts in terms of their agronomic and economic implications to users in local environments.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aliba, N. V., Lekwot, V. E., Yakubu, A. A., Eziashi, A. C., & Kwesaba, D. A. (2015). Perception and Responds to Gully Erosion in Jos South Local Government Area of Plateau State, Nigeria. *Journal of Multidisciplinary Scientific Research,* 3, 14-18.

Chukwuma, K. H. (2020). Constructing the Herder-Farmer Conflict as (In)Security in Nigeria. *Journal of African Security, 13,* 54-76. https://doi.org/10.1080/19392206.2020.1732703

Federal Ministry of Environment (2014). *Nigeria's Second National Communication under the United Nations Framework Convention on Climate Change*. Federal Ministry of Environment.

Ikusemoran, M., Dami, A., & Maryah, U. M. (2013). GIS Based Assessment of Flood Risk and Vulnerability of Communities in the Benue Flood Plains, Adamawa State, Nigeria. *Journal of Geography and Geology, 5,* 148-160. https://doi.org/10.5539/jgg.v5n4p148

Intergovernmental Panel on Climate (IPCC) (2007). *Climate Change 2007: Synthesis Report. Summary for Policymakers.* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Ishaku, H. T., & Majid, M. R. (2010) X-Raying Rainfall Pattern and Variability in Northeastern Nigeria: Impacts on Access to Water Supply. *Journal of Water Resource and Protection, 2,* 952-959. https://doi.org/10.4236/jwarp.2010.211113

Isikwue, B. C., Ameh, M. E., & Utah, E. Y. (2013). Analysis of Rainfall Variability over Some Cities in Nigeria Using Harmonic Analysis Technique. *Nigerian Journal of Physics, 24,* 16-24.

Kirkyla, K. I., & Hammed, S. (1989). Harmonic Analysis of the Seasonal Cycle in Precipitation over the United States: A Comparison between Observations and General Circulation Model. *Journal of Climate, 12,* 1463-1475. https://doi.org/10.1175/1520-0442(1989)002<1463:HAOTSC>2.0.CO;2

Korner, C. (2004). Mountain Biodiversity, Its Causes and Function. *AMBIO: A Journal of the Human Environment, 13,* 11-17. https://doi.org/10.1007/0044-7447-33.sp13.11

Meehl, G. A. (1992). Effect of Tropical Topography on Global Climate. *Annual Review of Earth Planet Science, 20,* 85-112. https://doi.org/10.1146/annurev.ea.20.050192.000505

Odjugo, P. A. (2010). General Overview of Climate Change Impacts in Nigeria. *Journal of Human Ecology, 29,* 47-55. https://doi.org/10.1080/09709274.2010.11906248

Ogungbenro, S. B., & Morakinyo, T. E. (2014). Rainfall Distribution and Change Detection across Climatic Zones in Nigeria. *Weather and Climate Extremes, 5,* 1-6. https://doi.org/10.1016/j.wace.2014.10.002

Olayide, E. O., Tetteh, I. K., & Popoola, L. (2016). Differential Impacts of Rainfall and Irrigation on Agricultural Production in Nigeria: Any Lessons for Climate-Smart Agriculture? *Journal of Agricultural Water Management, 178,* 30-36. https://doi.org/10.1016/j.agwat.2016.08.034

Park, S. (2008). Harmonic Analysis of Long Term Modis Time Series Data for Vegetation Dynamics in Hawaii. In *ASPRS 2008 Annual Conference*.

Spore (2008). *Special Issue August 2008: Climate Change* (p. 23). Technical Centre for Agricultural and Rural Cooperation (CTA).

Viviroli, D., & Weingartner, R. (2004). Hydrological Significance of Mountains: From Regional to Global Scale. *Hydrological Earth Systems Science, 8,* 1016-1029. https://doi.org/10.5194/hess-8-1017-2004

Wong, C. L., Venneker, R., Uhlenbrook, S., Jamil, A. B. M., & Zhou, Y. (2009). Variability of Rainfall in Peninsula, Malaysia. *Journal of Hydrology and Earth System Science Discussion, 6,* 5471-5503. https://doi.org/10.5194/hessd-6-5471-2009