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ASSESSMENT OF CLIMATE CHANGE SCENARIOS IN NORTH CENTRAL NIGERIA USING RAINFALL AS AN INDEX

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ABSTRACT

Climate change is the most significant challenge to achieving sustainable development, and it threatens to drag millions of people into grinding poverty (World Bank, 2014). While many across Africa are dependent on rain fed agriculture for sustenance, a changing climate could be devastating. Assessment of the climate change scenario in the North central Nigeria was carried out using rainfall as an index. Results showed increasing trends of 0.22mm, 3.38mm per annum for Lokoja and Abuja stations respectively while Ilorin, Jos and Kaduna stations each exhibited a decline of 0.18mm, 0.23mm and 0.44mm per annum respectively. However for the whole North central region of Nigeria, a positively significant trend in rainfall with a predicted increase of 0.58mm of rainfall per annum was observed. Based on the prediction, rainfall increase of 14.49% from what was observed in 2013 (the base year) is expected by 2042. Various adaptation strategies that can be put in place to safeguard the region from extreme weather events that can emanate from such climatic scenario were suggested.

Keywords: Climate Change, Drought, Flood, Rainfall, Crop, Adaptation Strategies.

BACKGROUND

Climatic variability is a term used to explain the variations in climatic conditions on various spatio-temporal scales and it include fluctuations, trends and cycles which constitutes a 'noise' in the climatic series as man could easily adapt to such minor differentials (Ayoade 2003). However when these fluctuations and changes in climate becomes persistent such that significant changes in the climate scenario are overwhelmingly obvious a new climate is said to have emerged (Olaniran, 2002). Similarly IPCC, (2007) defined Climate change as a significant change in the state of the climate of a place that can be identified by changes in the mean and/or in the variability of its properties that persist over a long period of time. Thus it can be said that climate change connotes any form of long-term climatic inconsistency.

One thing that should be the utmost concern of any nation of the world is knowing the vulnerability level of its socio-economic activities to climate change and measures that can be adopted in either coping or mitigating such impacts. Nigeria is an agrarian country and the most populous in African with an estimated population of 173 billion people. It is thus imperative for a country such as Nigeria to have a sustainable agriculture in order to meet the need of her ever growing population. This has been a mirage because economic downturn between population growth and food requirement exists in Nigeria due to unpredictable climate changes (Adefolalu, 2006).

Climate change's effects are becoming more evident every day. From changing weather patterns and reduced water availability, to deforestation and melting icecaps -- the examples are all around us. Resource scarcity is fast becoming a priority on both the political and business agenda as 2.7bn (40% of the world's population) live in areas which experience severe water shortages for at least one month of the year (Waterwise, 2015. Climate change has become the most significant challenge to achieving sustainable development, and it threatens to drag millions of people into grinding poverty. Climate change increases the costs of development in the poorest countries by between 25 and 30 percent. For developing countries, the annual cost of infrastructure that is resilient to climate change is around $1.2 trillion to $1.5 trillion, resulting in a yearly $700 billion gap in financing and it will take combining efforts of development banks, financial institutions, export credit agencies, institutional investors, and public budgets to meet the climate and development challenge *(World Bank, 2014)*.

Rainfall the major index of climate change in the tropics (Ayoade 2004) is a vital climatic factor that determines vulnerability level of crop production in Nigeria (Oguntoyinbo, 1981, Olaniran, 2002 and Ayoade, 2004). Extreme of it often results in flooding or drought. The country though bless with an impressive size of arable land has poor agricultural production that results in food shortage. Climate affects crop yield directly by irregularity in rainfall pattern. The four components of food security as highlighted by FAO (2008) are food availability, food access, food utilization and food stabilization. All these are climate determined in Nigeria.

The North Central Nigeria which is the food basket of the nation has suffered flood episodes of diverse magnitudes of recent. These includes the Lokoja flood of 2012 as reported by the National Emergency Management Agency (NEMA, 2013), the Ilorin flood of 2014 (Jimoh, 2014) and the Kaduna flood of 2014 (Alabelewe, 2014). These have resulted in the loss of lives, farm lands and other properties worth of several amount of money. Thus to safeguard future losses mentioned above assessment of the climate change scenario of North Central Nigeria is attempted in this study.

THE STUDY AREA

The study area is the North Central Nigeria. It covers latitude 7^0 00’-11^0 30’ North of the equator and longitude $4^0$00’-$11^0$00’ East of the Greenwich meridian (see figures 1 and 2). It enjoys the tropical continental climate characterized by wet and dry seasons. Wet season is synonymous to planting season since agriculture in the area is rain-fed. Mean annual rainfall ranges between 1,200mm and 1500mm while temperature is high almost throughout the year except during Harmattan period which begins in November and lasts until February. The weather is cold and dry during the period coupled with hazy atmosphere and dust particles flowing around. The vegetation of the North Central Nigeria cut across the three savannah belts (Guinea, Sudan and Sahel) and this is one of the reasons why both roots and cereals cropping are very popular in these ecological zones.

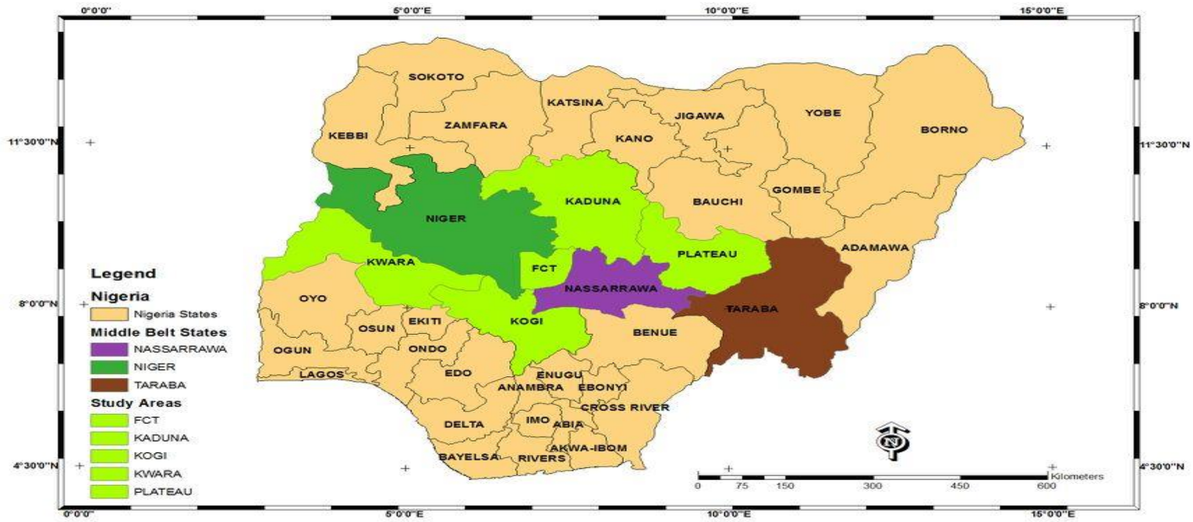

Figure 1: Map of Nigeria showing the North-Central Zone of Nigeria.

Source: **National Space Research Development Agency**, (**NASRDA, 2013**).

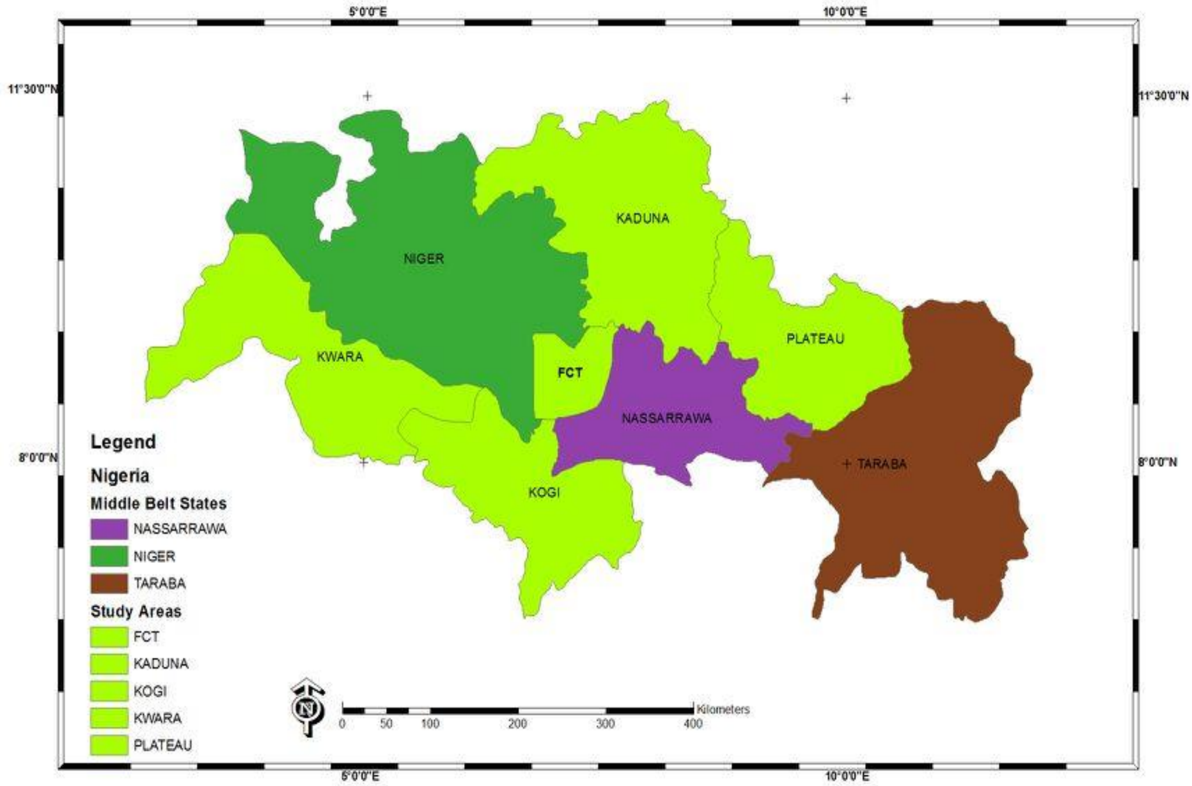

Figure 2: Map of North-Central Nigeria showing the study area.

Source: **National Space Research Development Agency**, (**NASRDA, 2013**).

METHOD OF STUDY

North Central of Nigeria consists of eight (8) states of which five (5) namely Kogi, Kwara, Kaduna, Plateau and Abuja were randomly sampled for the study (See Figure 2 above). Monthly rainfall data was collected for a period of fifty one (51) years which spanned between 1962 and 2012. However for Abuja the data covered thirty one (31) years period for which data was available. The data collected on monthly basis was later partitioned on annual basis.

In order to assess the climate change scenario of the study area, time series analysis was used to model the trend(s) in the rainfall data for the selected stations of the North Central Region of Nigeria. It was also used to derive the trend line equation that helped to predict future rainfall amount in the study area and hence the vulnerability level. Correlation analysis was carried out to study the strength in relationship between rainfall and time (years).

RESULTS AND DISCUSSION.

Figures 3-6 reflect the normal mean distribution of rainfall over the fifty (50) years for Kwara (Ilorin), Jos Plateau, Kaduna and Kogi States (Lokoja).

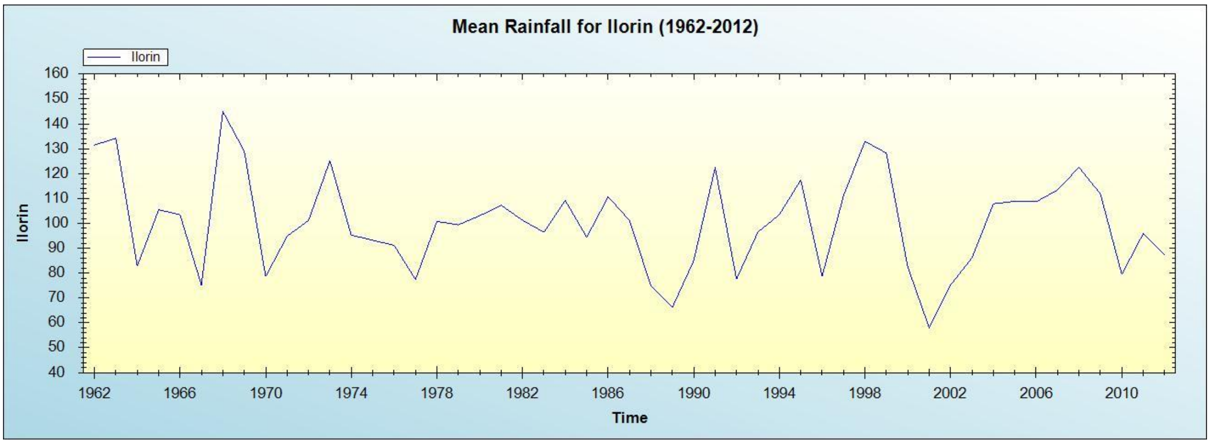

Figure 3: Normal Mean Distribution of Rainfall in Ilorin Kwara State (1962-2012).

Source: Author's Computation 2014.

Figure 3 above reflects the normal mean distribution of rainfall in Kwara State. Rainfall distribution is highly variable. The highest rainfall amount was observed in 1967 while the least was reported during year 2001.

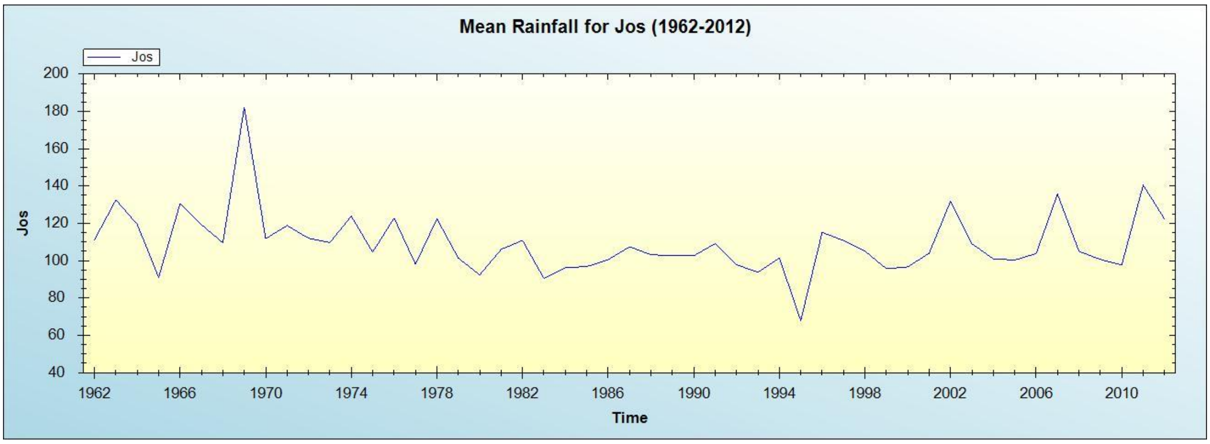

Figure 4: Normal Mean Distribution of Rainfall for Jos (1962-2012).

Source: Author's Computation 2014

Normal mean rainfall distribution for Jos Plateau is variable as well however, the degree of its variability is not as high as that of Kwara State. The peak rainfall similarly occurred in 1967 as in Kwara State but the least rainfall was observed during the year1995 (see figure 4).

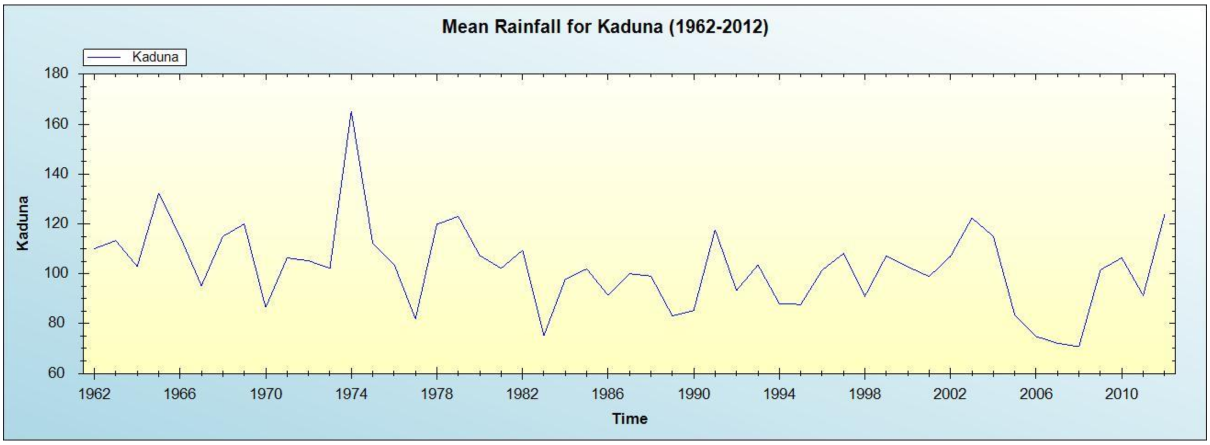

Figure 5: Normal Mean Distribution of Rainfall for Kaduna (1962-2012).
Source: Author's Computation 2014

Figure 5 reflects the normal mean rainfall distribution for Kaduna State during the period between 1962 and 2012. Rainfall fluctuated as in other states discussed above. The highest rainfall amount occurred in 1974 and year 2008 observed the lowest amount.

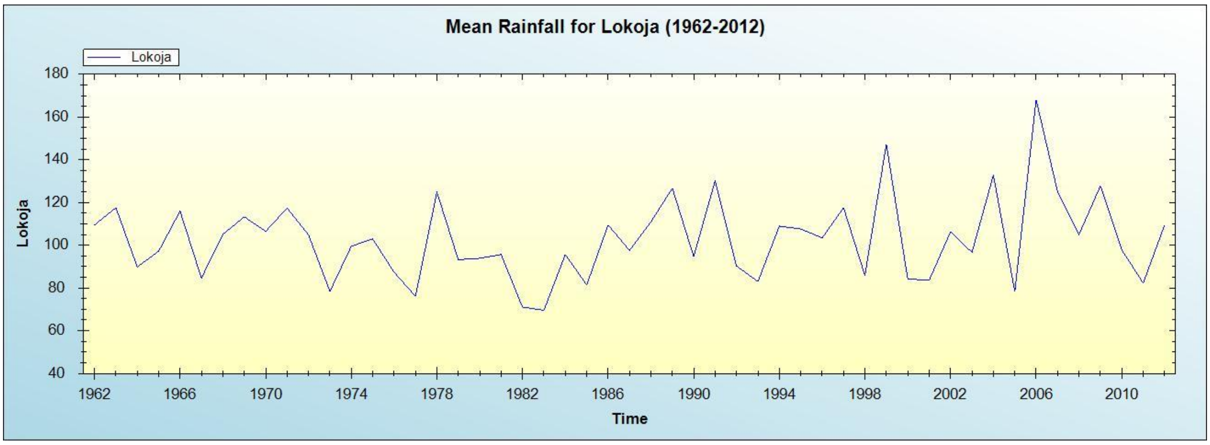

Figure 6: Normal Mean Distribution of Rainfall for Lokoja, Kogi State (1962-2012).
Source: Author's Computation 2014

Kogi State was also witnessed fluctuation in rainfall during the period of study. The peak period of coincided with the year 2008 while the lowest occurred in 1983.

Generally fluctuations characterised rainfall distribution throughout the study period over all states considered. Similarly each station reflects different periods of peak and least rainfall throughout the period of study. The exception of this is Kwara State and Jos Plateau State that recorded similar period of peak rainfall.

RESULTS OF TREND ANALYSES FOR THE STUDTY AREA.

Table I: Result of Trend Analyses for Ilorin Station.

Variable	Ilorin
Included Observation	51
Linear Trend Equation	Yt = 105.23 -0.18661*t
R	0.144811
R-Squared	0.020970
R-Square Adjusted	0.992696
Sum Square Error (SSE)	17964.390479
Mean Squared Error (MSE)	366.620214

Source: Author's Computation 2014

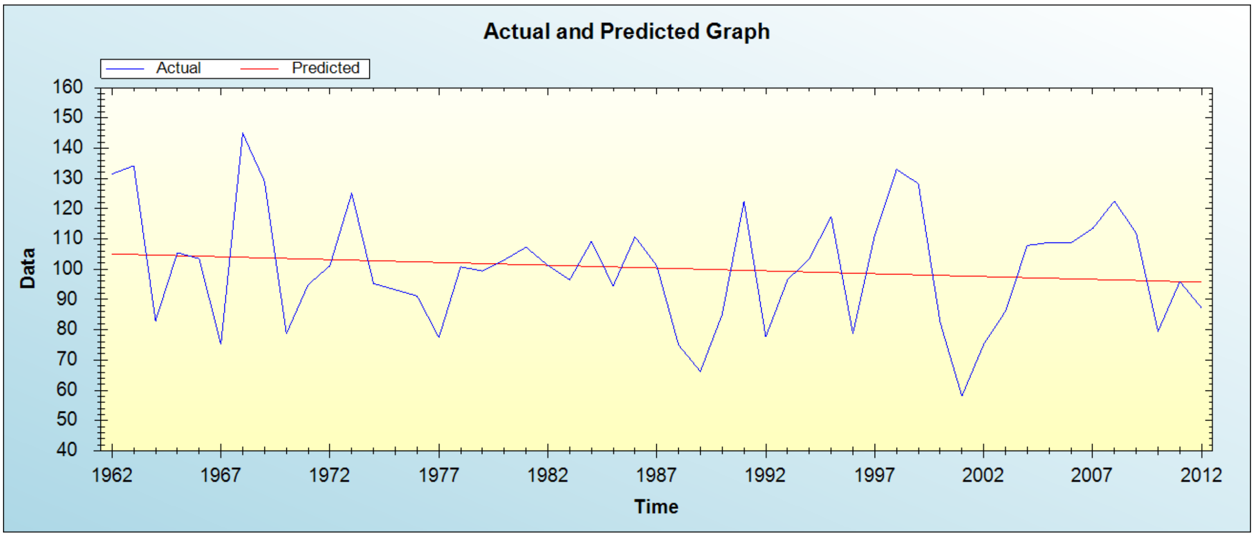

Figure 7: Linear Trend of Annual Rainfall at Ilorin Kwara State

Source: Author's Computation 2014

Figure 7 above indicates that rainfall in Ilorin is characterized by a slight downward trend and the rate is about 0.2mm per annum as shown in the trend equation (table 1).

Table II: Result of Trend Analyses for Jos Station.

Variable	Jos
Included Observation	51
Linear Trend Equation	Yt = 115.37 -0.23237*t
R	0.204436
R-Squared	0.041794
R-Square Adjusted	0.991807
Sum Square Error (SSE)	13679.078433
Mean Squared Error (MSE)	279.164866

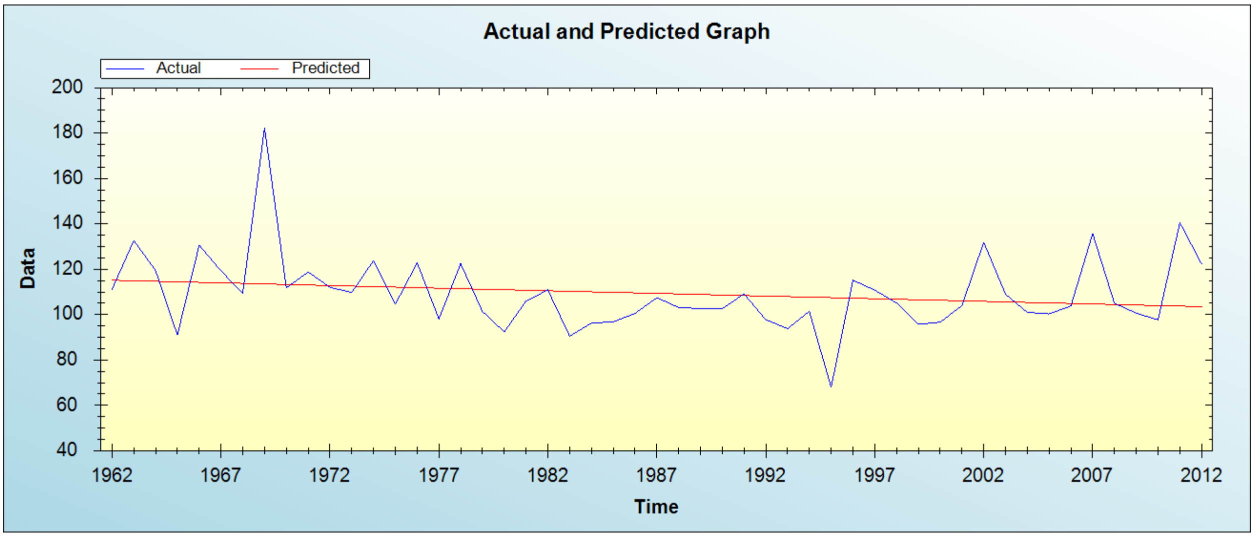

Figure 8: Linear Trend of Annual Rainfall at Jos

Source: Author's Computation 2014

Rainfall trend in Jos is towards a decline as well and the rate is not significant. Just like Ilorin station the rate is about 0.2mm per annum. However a weak positive relationship of 0.2 exists between rainfall and year (table II). For instance years 2011 and 2012 received more than normal rainfall. Again fluctuation around the mean is not as pronounced as what was observed in Kwara State and about twenty seven (27) years out of fifty years considered received above average rainfall and the tendency is towards more than normal rainfall in the area (figure 8). This is not surprising because the terrain of the area is characterized by plateau that gives it orographic rainfall.

Table III: Result of Trend Analyses for Kaduna Station.

Variable	Kaduna
Included Observation	51
Linear Trend Equation	Yt = 112.37 -0.37809*t
R	0.335732
R-Squared	0.112716
R-Square Adjusted	0.992043
Sum Square Error (SSE)	12434.665817
Mean Squared Error (MSE)	253.768690

Source: Author's Computation 2014

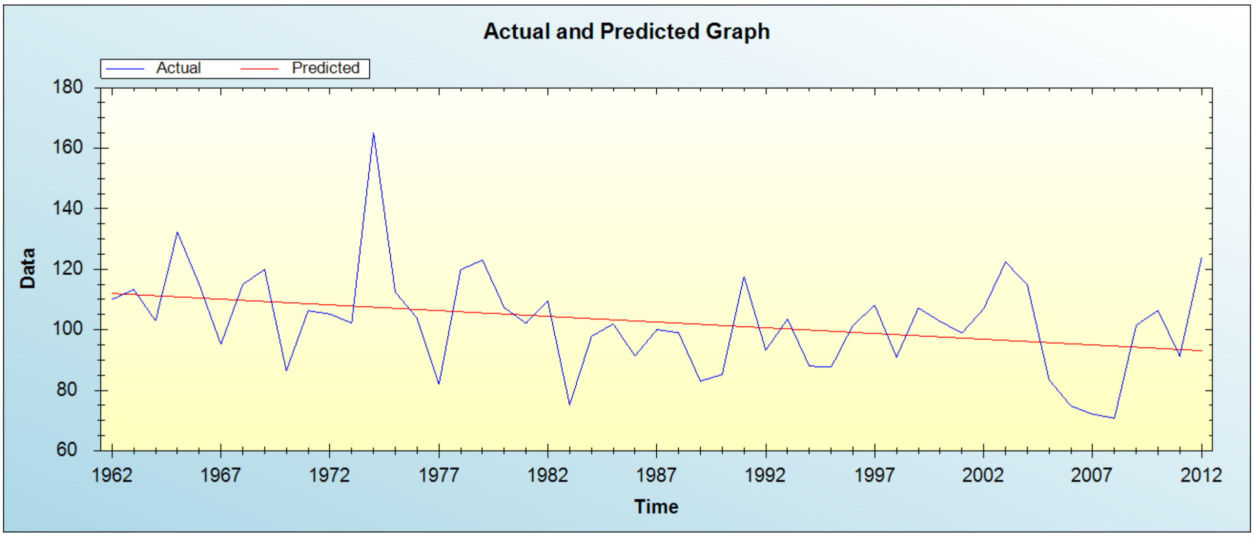

Figure 9: Linear Trend of Annual Rainfall at Kaduna

Source: Author's Computation 2014

Fluctuation of mean annual rainfall in Kaduna as revealed in figure 9 above showed a downward trend and the rate of decline is about 0.4mm of rain per annum (tale III). Rainfall is below normal for most years under consideration. The reason might not be unconnected with the fact that Kaduna State is closer to the southern fringe of Sahara desert than any other stations in the study area..

Table IV: Result of Trend Analyses for Lokoja Station.

Variable	Lokoja
Included Observation	51
Linear Trend Equation	Yt = 96.965 +0.224*t
R	0.170989
R-Squared	0.029237
R-Square Adjusted	0.992845
Sum Square Error (SSE)	18409.099578
Mean Squared Error (MSE)	375.695910

Source: Author's Computation 2014

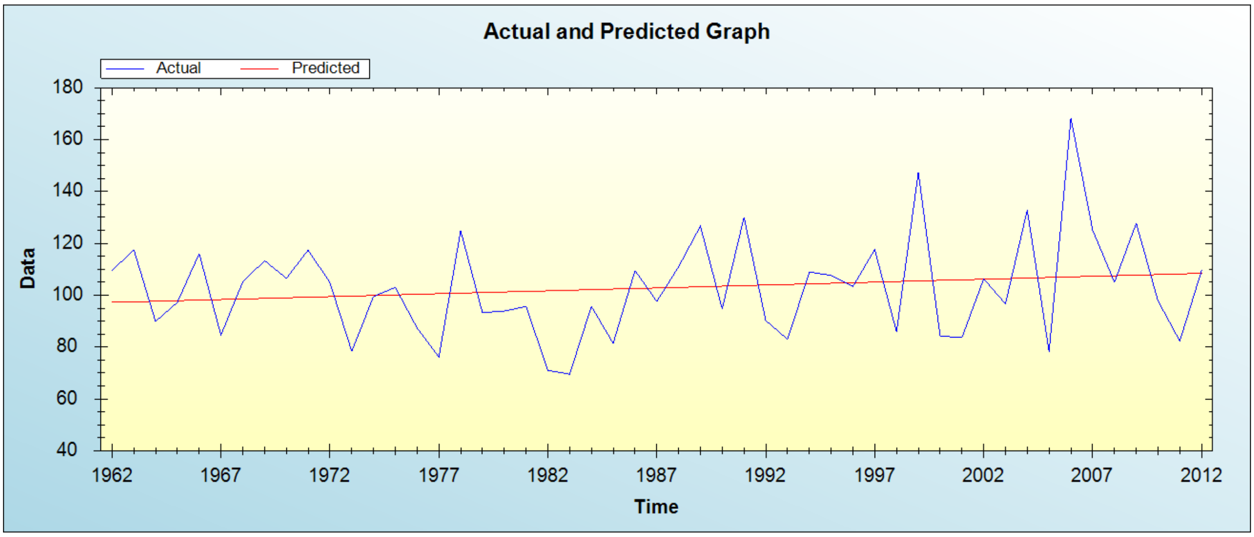

Figure 10: Linear Trend of Annual Rainfall at Lokoja

Source: Author's Computation 2014

Fluctuation of rainfall also occurred in Lokoja, Kogi State but it was above normal. The trend as depicted in table IV and by figure 10 above showed a rise of 0.22mm of rainfall per annum. Increase in rainfall observed might be linked with the fact that Lokoja being a confluence station is surrounded by water.

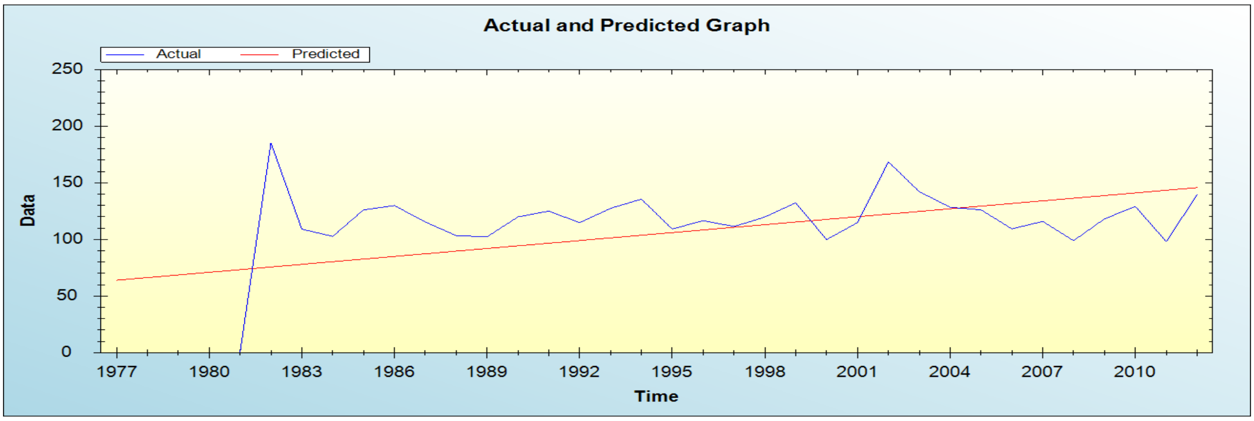

Figure 11: Linear Trend of Annual Rainfall at Abuja

Source: Author's Computation 2014

Table V: Result of Trend Analyses for Abuja Station.

Variable	Abuja
Included Observation	31
Linear Trend Equation	Yt = -13.945 +3.3823*t
R	0.813358
R-Squared	0.661551
R-Square Adjusted	0.998669
Sum Square Error (SSE)	64671.276952
Mean Squared Error (MSE)	1319.821979

Source: Author's Computation 2014

Abuja, the Federal Capital Territory

Similarly, Abuja station has an increasing trend in rainfall during the thirty one years under consideration (figure 11). The rate of increase is very significant with a positive rise of about 3.38mm per annum. Most years under consideration received rainfall that is well above normal. There is a high positive correlation of 0.81mm between rainfall and time in this station (table V). The reasons for such increase may be explained under two factors. First, Abuja rainfall pattern might have been influenced by the groups of inselberg which surround the city resulting in orographic rainfall. Secondly is the fact that city is used to be warmer than the periphery hence its air more buoyant and this enhances the formation of rainfall producing cumulonimbus cloud faster than its surrounding areas.

Results of Trend Analyses for North Central Nigeria.

Table VI and figure 12 below showed the result of the trend analysis of the annual mean rainfall for the entire North Central Nigeria. It appears the negative trends in mean annual rainfall observed in some stations is subsumed because the decline is not significant and has resulted in positive linear trend for the entire area.

Table VI: Summary of the Results of Trend Analyses of North Central Nigeria.

Variable	Mean
Included Observation	51
Linear Trend Equation	Yt = 83.199 +0.56184*t
R	0.636306
R-Squared	0.404885
R-Square Adjusted	0.991689
Sum Square Error (SSE)	5126.969262
Mean Squared Error (MSE)	104.632026

Source: Author's Computation 2014

There is a positive relationship between rainfall and time (r = 0.63) and a sharp increase of 0.56mm rainfall per annum during the period of study in the area.

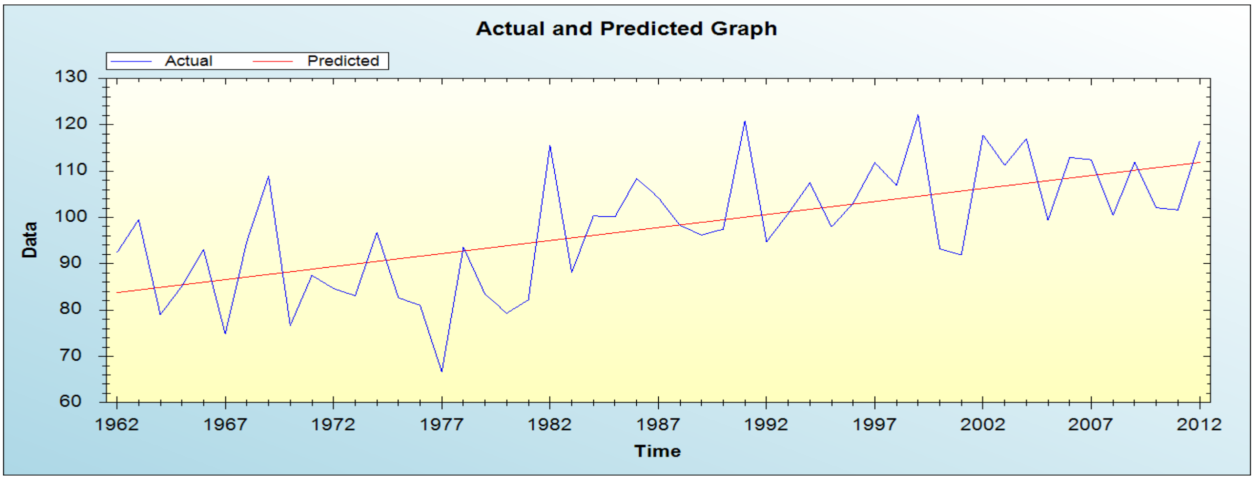

Figure 12: Linear Trend of Annual Rainfall in the North Central Nigeria.

Source: Author's Computation 2014

PREDICTION OF FUTURE CLIMATE GHANGE SCENARIO USING RAINFALL

Table VII below reflects the predicted future climate change scenario of the study area using rainfall trends of the selected stations. The period of prediction spanned between years 2013 – 2042.

Table VII: Predicted Rainfall Increase For North Central Nigeria

YEAR	MEAN ANNUAL RAINFALL (MM)	INCREASE FROM BASE (%)
2013	112.41	-
2018	115.22	2.5
2024	118.60	5.49
2030	121.97	8.49
2036	125.34	11.5
2042	128.71	14.49

Source: Author's Computation 2014

The forecast as shown in table VII above indicates a progressive increase in the percentage mean annual rainfall of 2.5%, 5.49%, 8.49%, 11.5% and 14.49% by the year 2018, 2024, 2030, 2036, and 2042 respectively. This steady increase is reflected in figure 13 below.

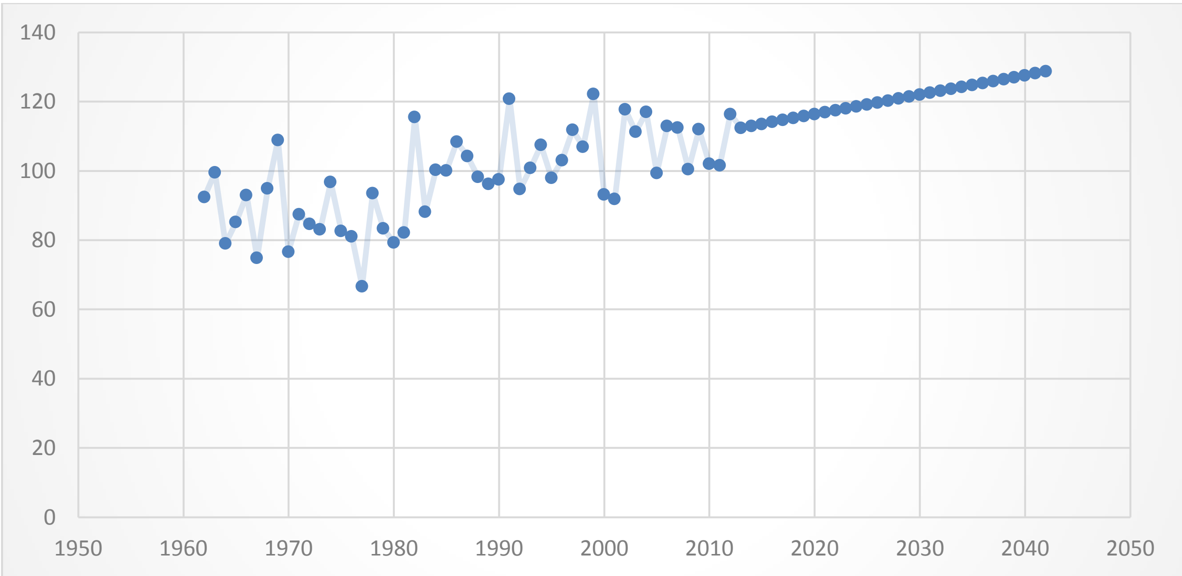

Figure 13: Linear Trend of Mean Annual Rainfall During (1962-2012) and After (Predicted 2013-2042) the Study Period in the North Central Nigeria.

Source: Author's Computation 2014

The prediction of future rainfall pattern up to year 2042 was also made for each selected stations in the study area (see Figure 14 below). The result shows a future increase in rainfall in all the selected stations with an exemption of Kaduna. The magnitude of increase will vary among stations. The rate of rainfall increase will be highest at Abuja followed by Lokoja, Jos while Ilorin will experience a mild increase in rainfall during this period.

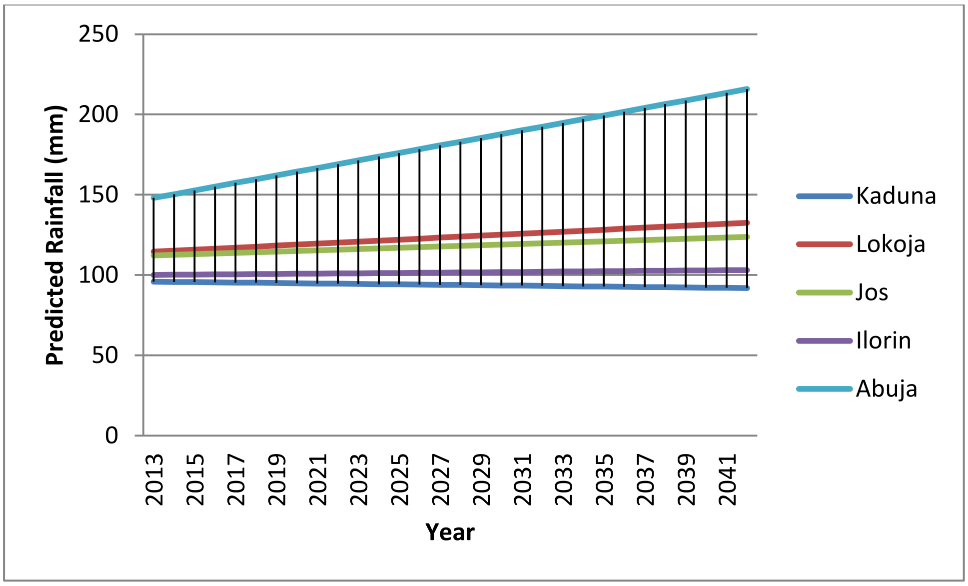

Figure 14: Prediction of Rainfall Trend in North Central Nigeria (2013-2042)

Source: Author's Computation 2014

IMPLICATION OF FINDINGS ON SUSTAINABLE DEVELOPMENT

The 2007 Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report warned of changing weather patterns and rising sea levels due to accelerating GHG emissions from human activities. For many, a warming climatic system is expected to impact the availability of basic necessities like freshwater, food security, and energy, while efforts to redress climate change, both through adaptation and mitigation, will similarly inform and shape the global development agenda. The links between climate change and sustainable development are strong. While climate change will know no boundaries, poor and developing countries, particularly the Least Developing Countries, will be among those most adversely affected and least able to cope with the anticipated shocks to their social, economic and natural systems (IPCC, 2007). There is a dual relationship between sustainable development and climate change. On the one hand, climate change influences key natural and human living conditions and thereby also the basis for social and economic development, while on the other hand, society's priorities on sustainable development influence both the GHG emissions that are causing climate change and the vulnerability (IPCC, 2007).

The implication of the above findings for the North Central Region of Nigeria is surmised thus;

1. Future occurrences of flood episodes of diverse magnitudes is expected to increase in frequency. What makes this region more vulnerable is the fact that the major Nigerian Rivers (Niger, Benue and Kaduna Rivers) cut across these areas. The incidence of flood will also impose harder hardships on the poor in those communities, as lives and properties which are major points in achieving sustainable development are bound to be lost.
2. The dependence of most of the residents of these communities on rain fed agriculture is also expected to impact on the productivity of the crops. This is because, the changes in rainfall regime is bound to influence the growing calendar of farmers thus exacerbating the poverty level.
3. The changing weather patterns as a result of climate change also might increase the risk of respiratory diseases and thus reduce the productivity of certain parts per million persons of the population.

SUGGESTED ADAPTATION STRATEGIES

- In area where increase in rainfall is envisaged farmers are encouraged not to engage in the cultivation of flood plain area but limit their farming activities to upland areas.
- Where flood plain agriculture farming practice is going to be adopted, farmers should concentrate more on the cultivation of water loving crop such as swamp rice and at the same time put every effort in place to combat flood.
- The State Government of where surplus rain is envisaged should put all measures in place towards harvesting and storing excess rain water for future use.
- However in area where drought is envisaged such as Kaduna State, farmers are advised to focus on the planting of drought resistant crops such as cassava and guinea corn and at the same time get all arrangements ready for irrigation farming practices.
- More dams could be constructed on the major rivers to accommodate excess water during its peak discharge and this could be put to use in various forms e.g. Hydro Electric Power generation, irrigation, domestic uses etc.

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APPENDICES

Appendix I: Rainfall Prediction for the North Central Nigeria (2013 – 2042)

Year	Forecasted
2013	112.4146
2014	112.9765
2015	113.5383
2016	114.1002
2017	114.6620
2018	115.2238
2019	115.7857
2020	116.3475
2021	116.9094
2022	117.4712
2023	118.0331
2024	118.5949
2025	119.1567
2026	119.7186
2027	120.2804
2028	120.8423
2029	121.4041
2030	121.9660
2031	122.5278
2032	123.0896
2033	123.6515
2034	124.2133
2035	124.7752
2036	125.3370
2037	125.8989
2038	126.4607
2039	127.0225
2040	127.5844
2041	128.1462
2042	128.7081

Source: Author's Computation 2014

Appendix II: Forecast of Annual Rainfall in Selected Stations of North Central Nigeria (2013-2042).

Year	Kaduna	Lokoja	Jos	Ilorin	Abuja
2013	95.8933	114.5965	112.2645	100.0811	148.0224
2014	95.7548	115.2171	112.6628	100.1852	150.3573
2015	95.6163	115.8378	113.061	100.2893	152.6923
2016	95.4777	116.4584	113.4593	100.3935	155.0273
2017	95.3392	117.079	113.8576	100.4976	157.3623
2018	95.2006	117.6997	114.2558	100.6017	159.6972
2019	95.0621	118.3203	114.6541	100.7058	162.0322
2020	94.9235	118.9409	115.0524	100.8099	164.3672
2021	94.785	119.5615	115.4506	100.914	166.7022
2022	94.6464	120.1822	115.8489	101.0181	169.0371
2023	94.5079	120.8028	116.2472	101.1222	171.3721
2024	94.3693	121.4234	116.6454	101.2263	173.7071
2025	94.2308	122.0441	117.0437	101.3304	176.0421
2026	94.0922	122.6647	117.442	101.4346	178.377
2027	93.9537	123.2853	117.8402	101.5387	180.712
2028	93.8151	123.9059	118.2385	101.6428	183.047
2029	93.6766	124.5266	118.6368	101.7469	185.382
2030	93.538	125.1472	119.035	101.851	187.7169
2031	93.3995	125.7678	119.4333	101.9551	190.0519
2032	93.2609	126.3885	119.8316	102.0592	192.3869
2033	93.1224	127.0091	120.2298	102.1633	194.7219
2034	92.9838	127.6297	120.6281	102.2674	197.0568
2035	92.8453	128.2504	121.0264	102.3715	199.3918
2036	92.7067	128.871	121.4246	102.4757	201.7268
2037	92.5682	129.4916	121.8229	102.5798	204.0617
2038	92.4297	130.1122	122.2212	102.6839	206.3967
2039	92.2911	130.7329	122.6194	102.788	208.7317
2040	92.1526	131.3535	123.0177	102.8921	211.0667
2041	92.014	131.9741	123.416	102.9962	213.4016
2042	91.8755	132.5948	123.8143	103.1003	215.7366

Source: Author's Computation 2014