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Performance Evaluation of Small Scale Irrigation Schemes By Using Process and Comparative Indicators: Case Study on Golina and Kokono Small Scale Irrigation Schemes, North Wollo Zone, Amhara Region, Ethiopia

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Abstract

Meteorological factors that mostly influence food production of any Nation are rainfall and temperature. Their extremes are significant and observable indices of evidences of negative climate change scenarios and adequate knowledge of extreme events will help in policy making to save the nation of future losses due to their extremes. With the advent of climate change, rainfall and temperature patterns are potential threats to achieving the SDG's of zero hunger and poverty eradication, coupled with the ever growing world population and development.

This paper x-rays rainfall and temperature regimes of Northern Nigeria over a 47 years period and its trend within 13 states as it has affected farming activities and caused massive migration of herders to more favourable and conducive areas that usually lead to incessant herder- farmer's crisis in Nigeria.

Keywords: Climate change extreme events, Rainfall and temperature.

1. Introduction

Climate change impact on flora is receiving increasing attention around the world (Fuhrer, 2003). Climate change projections may result in reductions of average annual discharge (productivity) of up to 50%, which poses a great challenge to the whole socio-economic model that is based largely on water demanding activities: recreation, tourism and food production (Iglesias and Garrote, 2015). Rainfall and temperature are two very important climatic variables that determine the nature of any environment whether for crop production or human habitation and these are the defining variables for classifying any area as either temperate or tropical. They are also the two most important climatic variables directly affecting the growth and yield of plant and crop for both man and animal consumption and their high variability is a great threat to food security of any nation and the world in general.

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The world around us is changing; there is growing awareness of the state of the environment, and concern due to the over-exploitation of natural resources by mankind. Reduction of water and food resources combined with population growth can lead to hunger and poverty.

The expected changes in temperature over the next 30−50 years are predicted to be in the range of 2−3 °C (IPCC) (2007). Heat waves or extreme temperature conditions are projected to become more intense, more frequent, and would last longer than what has been currently observed in recent years (Meehl *et al*., 2007). Extreme temperature conditions may have short-term durations of a few days with temperature increases of over 5 °C above the normal temperatures. Extreme events occurring during the dry season would have the most dramatic impact on plant productivity; however, there has been little research conducted to document these effects as found by (Kumudini *et al*. 2014). Rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. These values were summarized by Hatfield *et al*., 2008, Hatfield *et al*., (2011) for a number of crop species typically for grain and fruit production. A recent review by Barlow *et al.* (2015) on the effect of temperature extremes, frost and heat, in wheat (*Triticum aestivum* L.) production revealed that frost caused sterility and abortion of formed grains while excessive heat caused reduction in grain number and duration of the grain-filling period.

While Rainfall is usually seen as beneficial to crops and fields, but there is an “ideal” amount of rainfall in any given growing season for most crops. If the average rainfall is much lower or higher than the ideal, it can lead to significant problems, from drowned crops to lower yields which would militate against the actualisation of the SDG of zero hunger in 2030. (sigfox.com, 2018). Rainfall seasonal variability greatly affects soil water availability to crops, and thus poses crop production and food security risks.

Increase in one of these two variables causes the other to decrease and they are all much needed for optimum growth and yield of food crops. Their extremes are detrimental to growth of plant for food production. While very low temperatures would prevent seed germination, excessively high temperature will also scorch young plants and prolonged high temperatures causes’ rapid loss of soil moisture which poses threat of soil aridity and desert encroachment resulting to immigration of herders to areas with lower temperatures and higher rainfall that can sustain the growth of grasses and plants for their animals all year round hence leading to continuous herders-farmers clashes during such periods and conditions and hence threatening food production in this areas .

Meehl *et al.* (2007) in their analysis revealed that daily minimum temperatures will increase more rapidly than daily maximum temperatures leading to the increase in the daily mean temperatures and a greater likelihood of extreme events and these changes could have detrimental effects on food production. If these changes in temperature and rainfall are expected to occur over the next 30 years then understanding their trends will help in planning and developing adaptation strategies to offset the impacts that may be caused by their variability and changes anticipated. Hence the objective of this paper is to x-ray rainfall and temperature regimes of Northern Nigeria over a period of 40 years.

2. Methods/Techniques

2.1 Geo-Informatics

A geographic information system (GIS) is a methodology for handling all geographic and geo-referenced data. Its application allows for large scale analyses of the Earth's surface and at the same time, provides increasingly detailed knowledge on many planetary variables and improved understanding of its functioning (CREAF, 2016).

The mean rainfall result obtained from the assessment were interpolated in a GIS environment (QGIS 2.18.24) to delineate, classify and produce the rainfall and temperature maps of Northern Nigeria (Fig. 1).

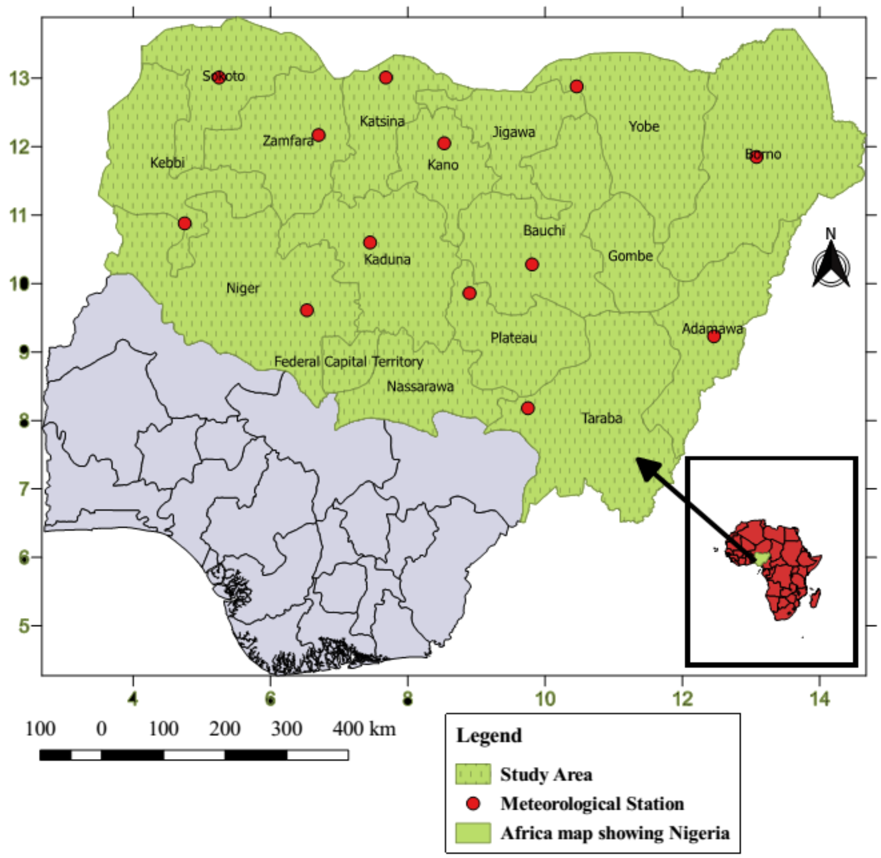

Figure 1.0 Map of Nigeria showing location of study area and climatic stations

2.2 Interpolation

The analysed results of decadal maximum temperature and mean rainfall interpolated in a QGIS 2.18.24 environment showed their spatial distribution within Northern Nigeria and this would help in policy formation.

2.2.1 Interpolation method

The Inverse Distance Weighting (IDW) interpolation method was used for all the map plotting. The results of the interpolated raster were the clipped to the masked layer of northern Nigeria to produce maps of all the different variables.

2.3 Contouring

Contours were extracted from the raster file for maximum temperature at 10mm intervals and rainfall at 50mm joining points of equal maximum temperature and rainfall respectively in the QGIS 2.18.24 environment. (Fig 2)

2.4 Studied Materials

Rainfall and Temperature:

Rainfall and Maximum temperatures of the study area were obtained from Nigerian meteorological stations for over 47 years (1972 to 2018) and examined decadally to show their pattern of changes in Northern Nigeria (Fig 3)

Rainfall for each station was analysed using a three years moving average to show its trend and the mean rainfall was determined for the 47 years rainfall data and plotted in a QGIS environment to show the spatial distribution and variability of rainfall of Northern Nigeria.

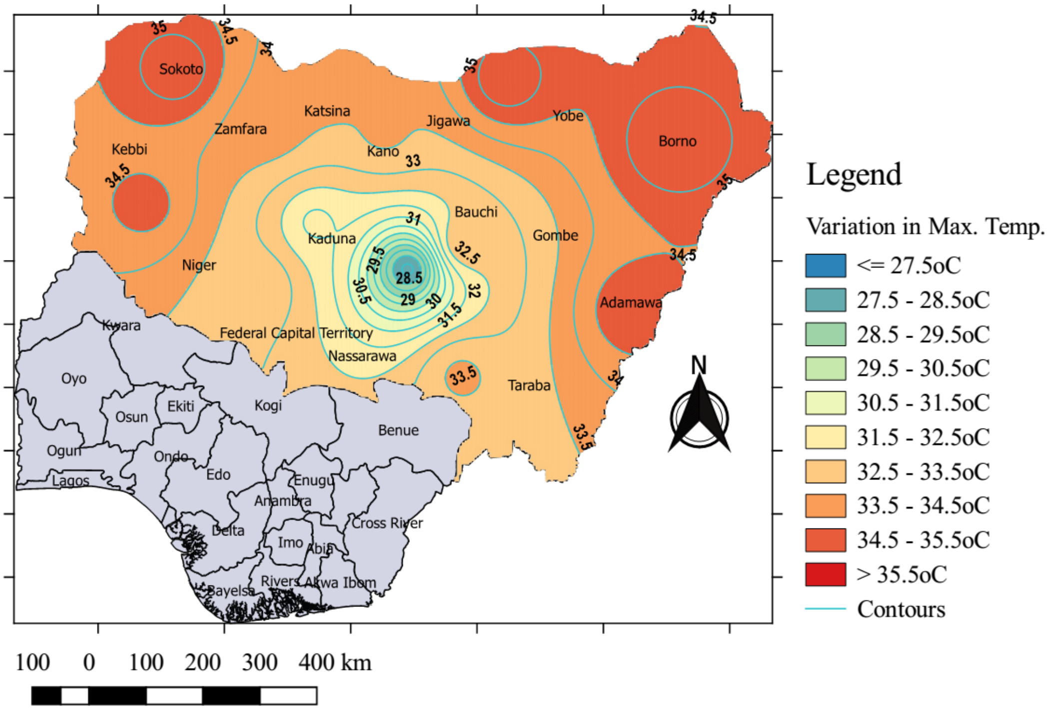

Figure 2: Map of Nigeria showing the spatial pattern of maximum temperatures of Northern Nigeria.

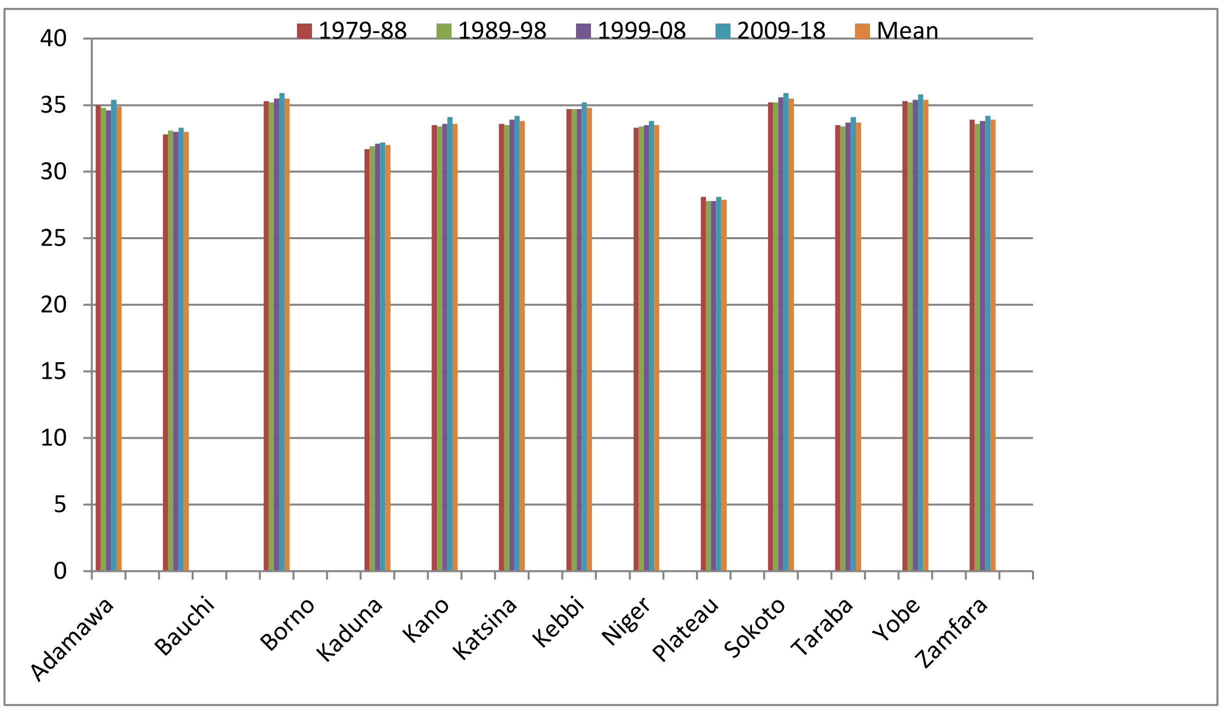

Figure 3: Showing changes in decadal maximum temperature of Northern Nigeria.

Table 1: Showing decadal variability in maximum temperature in Degree Celsius of the study area.

Decade	Adamawa	Bauchi	Borno	Kaduna	Kano	Katsina	Kebbi	Niger	Plateau	Sokoto	Taraba	Yobe	Zamfara
	Long. **12.46** Lat. **9.23**	Long. **9.81** Lat. **10.28**	Long. **13.08** Lat. **11.85**	Long. **7.45** Lat. **10.6**	Long. **8.53** Lat. **12.05**	Long. **7.68** Lat. **13.01**	Long. **4.75** Lat. **10.88**	Long. **6.53** Lat. **9.61**	Long. **8.9** Lat. **9.86**	Long. **5.25** Lat. **13.01**	Long. **9.75** Lat. **8.18**	Long. **10.46** Lat. **12.88**	Long. **6.7** Lat. **12.17**
1979-88	35.0	32.8	35.3	31.7	33.5	33.6	34.7	33.3	28.1	35.2	33.5	35.3	33.9
1989-98	34.8	33.1	35.2	31.9	33.4	33.5	34.7	33.4	27.8	35.2	33.4	35.2	33.6
1999-08	34.6	33.0	35.5	32.1	33.6	33.9	34.7	33.5	27.8	35.6	33.7	35.4	33.8
2009-18	35.4	33.3	35.9	32.2	34.1	34.2	35.2	33.8	28.1	35.9	34.1	35.8	34.2
Mean	**34.9**	**33.0**	**35.5**	**32.0**	**33.6**	**33.8**	**34.8**	**33.5**	**27.9**	**35.5**	**33.7**	**35.4**	**33.9**
SD	**0.34**	**0.24**	**0.30**	**0.21**	**0.29**	**0.32**	**0.24**	**0.19**	**0.18**	**0.33**	**0.29**	**0.28**	**0.27**

2.5 Area Description

The study area covers states within Northern Nigeria, which falls within Latitude 13°81N to 6.72°S and Longitude 14.65°E to 2.69° W (Global weather Data for SWAT) and the area cuts across the Sahel, Sudan and Guinea Savannah and covers a total land area of approximately 643,813.999 Km^2 (QGIS 2.18.) as shown in figure 1

3. Results

3.1 Maximum Temperature

Result for maximum temperature as seen in Table 1 revealed a gradual decadal increase in temperature over the Northern Nigeria. Temperature values varied with standard deviation values of 0.34, 0.33, 0.32, 0.30, 0.29, 0.28, 0.27, 0.24, 0.21, 0.19, and 0.18 for Adamawa, Sokoto, Katsina, Borno, Taraba-Kano, Yobe, Zamfara, Bauchi-Kebbi, Kaduna, Niger and Plateau States respectively. Results of maximum temperature showed a constant increase with the highest maximum temperatures recorded in the last decade 2009-2018 agreeing with (IPPC, 2007, and Meehl*et al.*, 2007) projections of an increase in temperature.

3.2 Rainfall Patterns

3.2.1 Adamawa State Rainfall

Results of Adamawa State rainfall as seen in figure 4 showed a mean annual rainfall of 878.6mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall showed that between 1971-73, 1981-86, 1989-90, 2001 and 2007-2015 rainfall were below the mean annual rainfall with the lowest rainfall of 664.4mm per annum recorded in 2008 while from 1973-1981, 1986-89, 1991-99, 2001-2006 and 2006 the 3 years moving average rainfall were above mean annual rainfall with the highest rainfall of 1026.2mm per annum recorded in 2015.

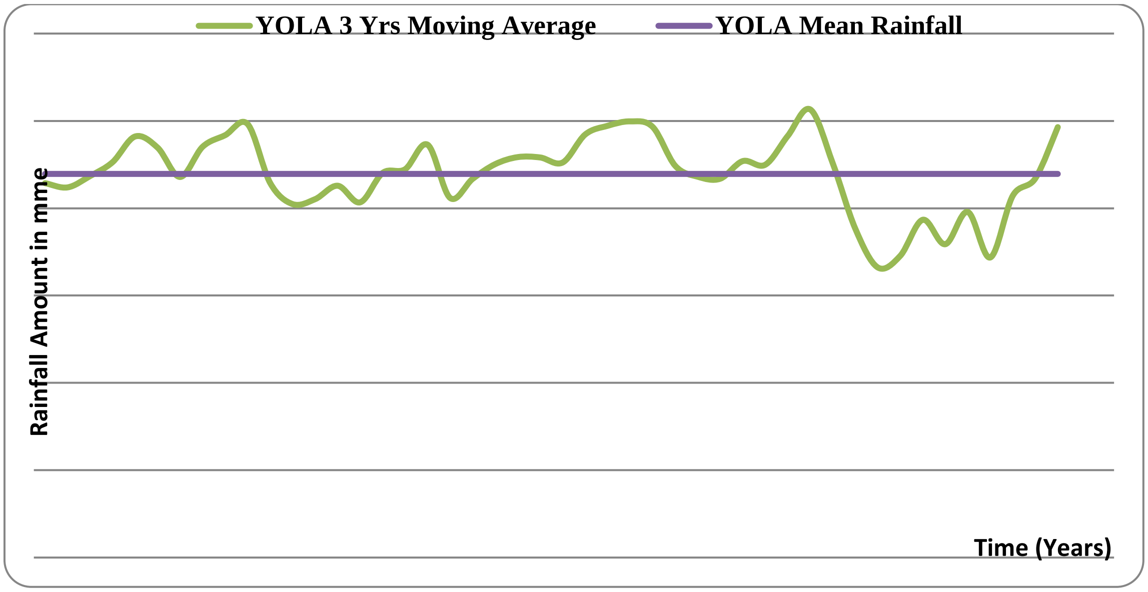

Figure 4: A representation of Rainfall in (mm) against Time (years) showing rainfall trend of Adamawa State from 1971 to 2018.

3.2.2. Bauchi State Rainfall

Results of Bauchi rainfall as seen in figure 5 showed a mean annual rainfall of 1102.5mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall showed that between

1971-1991, 1993-1998 and 2000-2006 rainfall was below the mean annual rainfall with the lowest rainfall of 799.4mm per annum recorded in 1983 while from 1991-92, 1998-2000 and 2007-2016 the 3 years moving average rainfall were higher than the mean annual rainfall with the highest rainfall of 1713.5mm per annum was recorded in 2013.

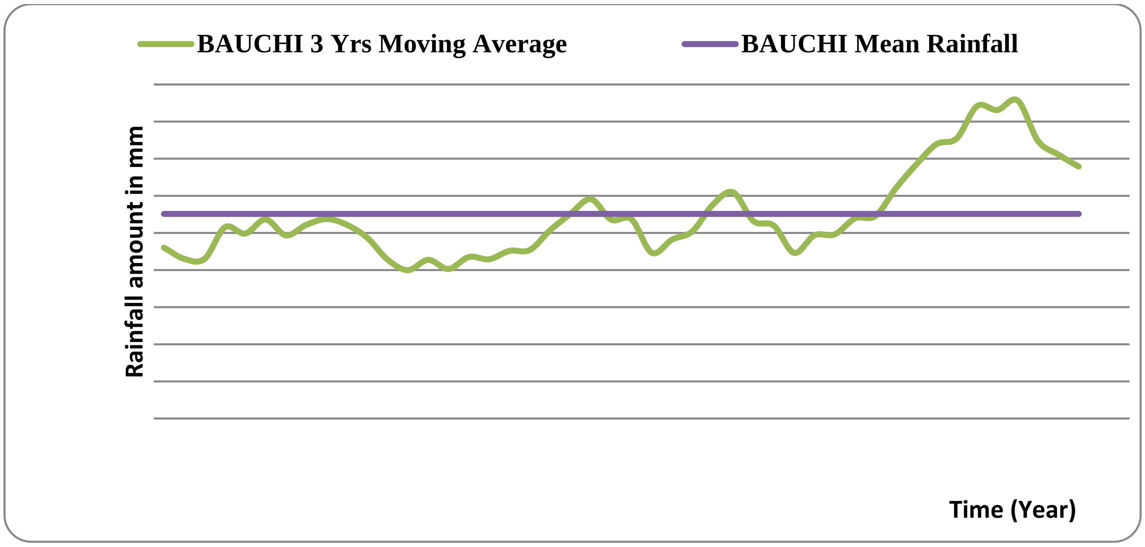

Figure 5: Rainfall in (mm) against Time (years) showing rainfall trend of Bauchi State from 1971 to 2018.

3.2.3 Borno State Rainfall

Rainfall results of Borno State as seen in figure 6 showed a mean annual rainfall of 590.1mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall depicts that rainfall from 1971-73, 1975 and 1979-1994 were below the mean annual rainfall with the lowest rainfall of 242.7mm per annum recorded in 1981 while between 1974, 1976-78 and 1995-2016 the 3 years moving average rainfall were above the mean annual rainfall with the highest 3 years moving average rainfall of 856.5mm per annum recorded in 2016.

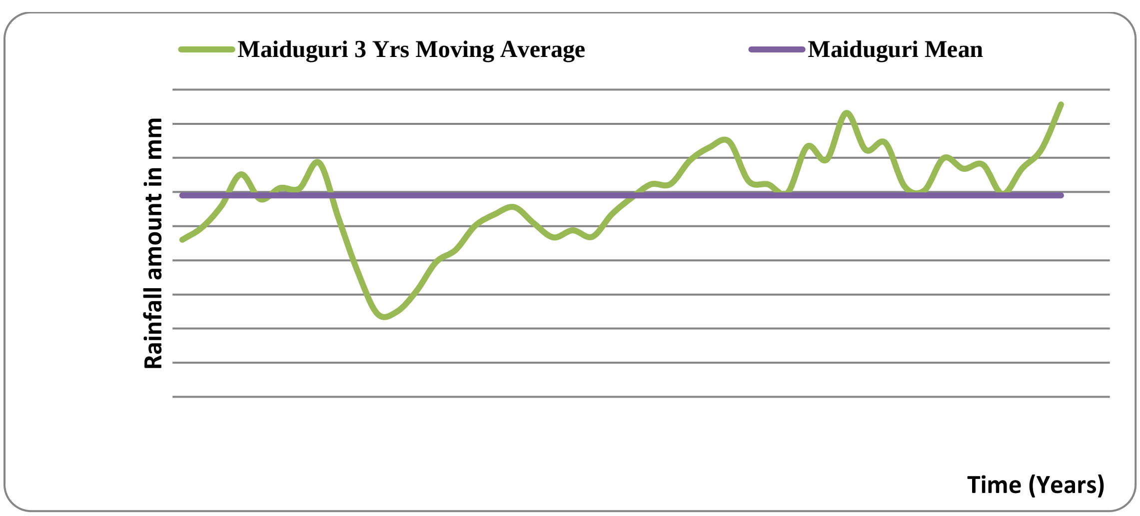

Figure 6: Rainfall in (mm) against Time (years) showing rainfall trend of Borno State from 1971 to 2018.

3.2.4 Kaduna State Rainfall

Results of Kaduna rainfall as seen in figure 7 showed a mean annual rainfall of 1259.9mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall revealed that from 1975-76, 1981-1996 and 2004-2009 rainfall were below mean annual rainfall with the lowest rainfall of 855.1mm per annum recorded in 2006. While from 1972-74, 1977-80, 1996-98, 2001-2004 and 2010-2016 the 3 years moving average rainfall were above mean annual rainfall with the highest rainfall of 1627.2mm per annum recorded in 2016.

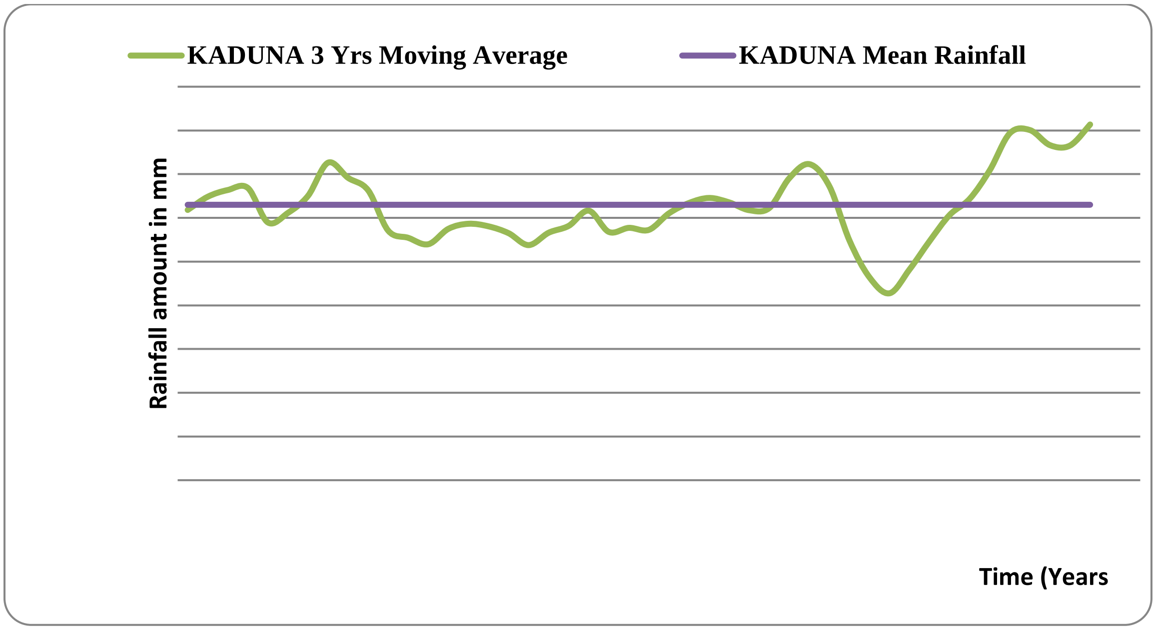

Figure 7: Rainfall in (mm) against Time (years) showing rainfall trend of Kaduna State from 1971 to 2018.

3.2.5 Kano State Rainfall

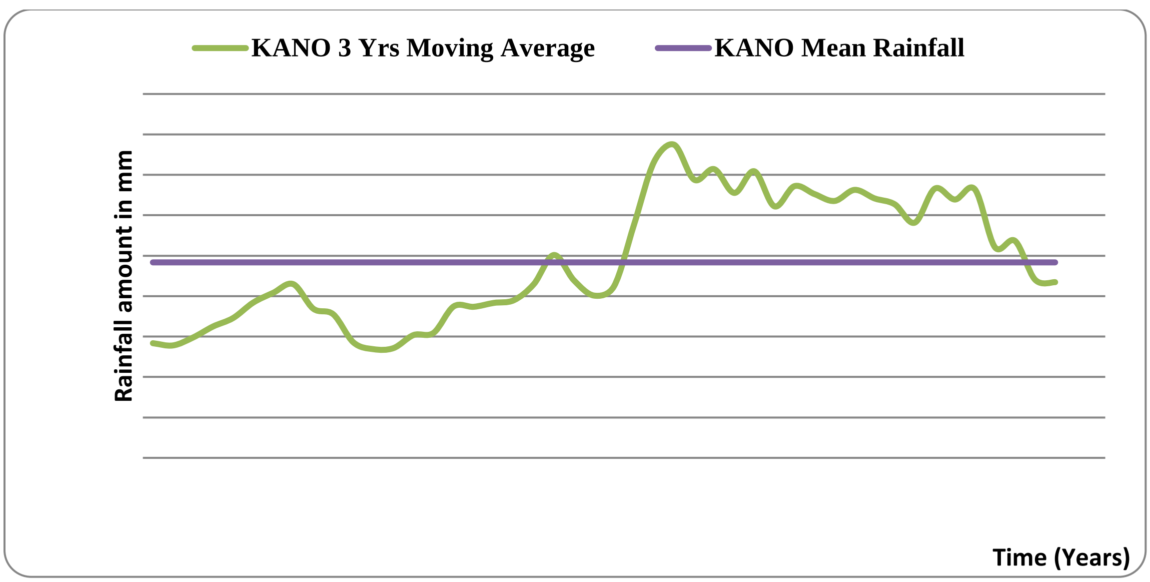

Figure 8: Rainfall in (mm) against Time (years) showing rainfall trend of Kano State from 1971 to 2018.

Rainfall results for Kano State as seen in figure 8 showed an annual mean rainfall of 967.0 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall results revealed that from 1971-1991, 1993-1995 and 2015-2016 rainfall were below mean annual rainfall with lowest rainfall result of 537.6mm per annum recorded in 1982 while from 1991 and 1995-2014 the 3 years moving average rainfall were higher than the mean annual rainfall with the highest rainfall of 1549.0 mm per annum recorded in 1997.

3.2.6 Katsina State Rainfall

Rainfall results of Katsina State as seen in figure 9 showed a mean annual rainfall of 589.5 mm per annum over a period of 47 year from 1971 to 2018. The 3 years moving average rainfall revealed that from 1971-76, 1980-87, 1992-99 and 2013-2015 rainfall were below mean annual rainfall per annum with the lowest rainfall of 356.1 mm recorded in 1992 while in 1977-1980, 1988-92, 1998-2012 and 2016 the 3 years moving average rainfall were fairly above the mean annual rainfall with the highest rainfall of 968.1 mm per annum recorded in 2005.

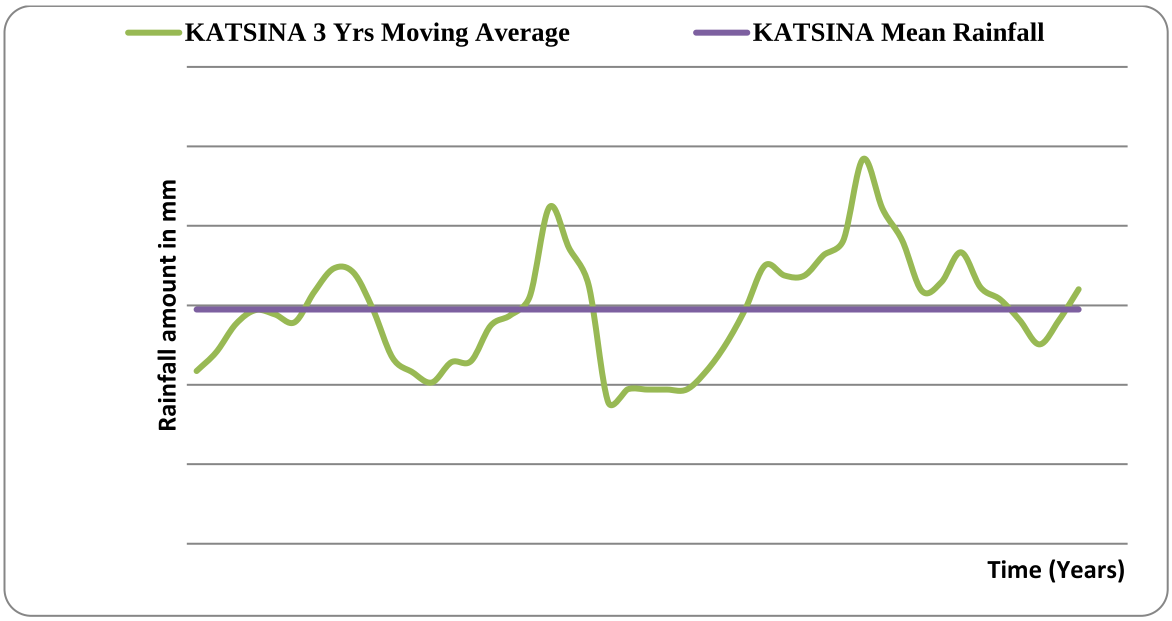

Figure 9: Rainfall in (mm) against Time (years) showing rainfall trend of Katsina State from 1971 to 2018.

3.2.7 Kebbi State Rainfall

Rainfall results of Kebbi State as seen in figure 10 showed a mean annual rainfall of 979.1 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average showed that from 1971-73, 1975-1990, 1996, 2002-2005 and 2011-2013 rainfall were below mean annual rainfall with the lowest rainfall of 632.4 mm per annum recorded in 1987 while from 1991-1995, 1997-2001 and 2014-2016 the 3 years moving average rainfall were above mean annual rainfall with the highest rainfall of 1250.9 mm per annum recorded in 1999.

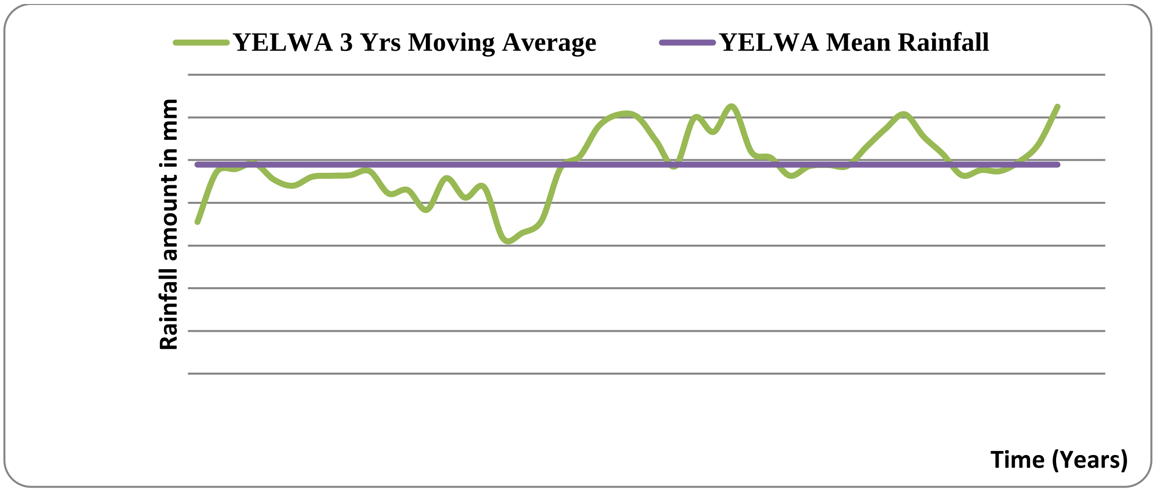

Figure 10: Rainfall in (mm) against Time (years) showing rainfall trend of Kebbi State from 1971 to 2018.

3.2.8 Niger State Rainfall

Rainfall results of Niger State as seen in figure 11 showed a mean annual rainfall of 1201.5 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall revealed that from 1971-73, 1979-1988, 2001-2003, 2009 and 2013 rainfall were below mean annual rainfall with the lowest rainfall of 913.4 mm per annum recorded in 1982 while from 1975-78, 1989-2000, 2004-2008, 2010-2012 and 2014-2016 rainfall results revealed that rainfall were above mean annual rainfall with the highest rainfall amount of 1392.4 mm per annum recorded in 1977.

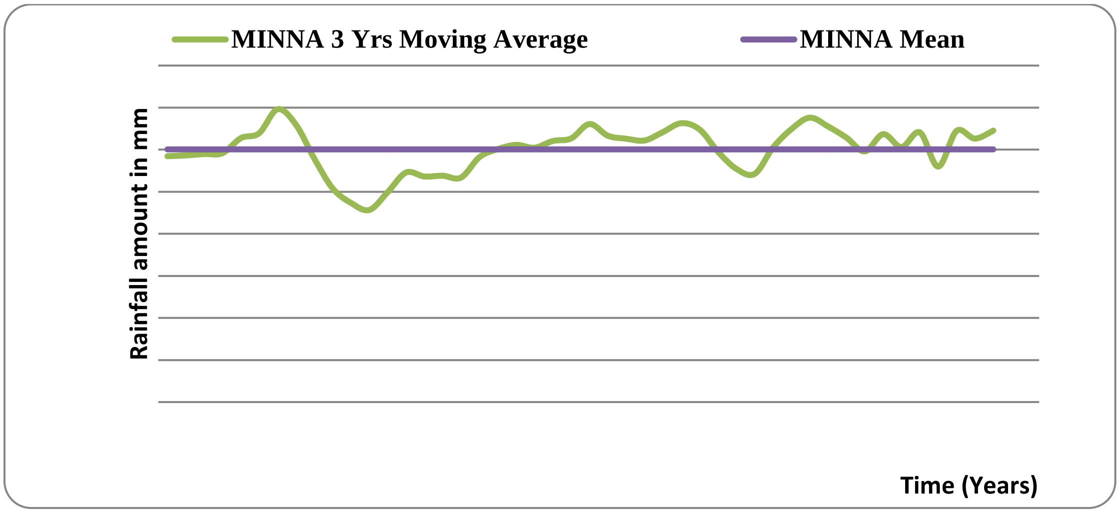

Figure 11: Rainfall in (mm) against Time (years) showing rainfall trend of Niger State from 1971 to 2018.

3.2.9 Plateau State Rainfall

Rainfall results of Plateau State as seen in figure 12 showed a mean annual rainfall of 1254.4 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall showed that rainfall from 1979, 1981-1995, 1997-99, 2003-2004, 2007 and 2013-2016 rainfall were below mean annual rainfall per annum with the lowest rainfall of 1052.5 mm per annum recorded in 1993 while from 1971-78, 1996, and 2000-2009 the 3 years moving average rainfall were above the mean annual rainfall per annum with the highest rainfall of 1394.2mm recorded in 1974.

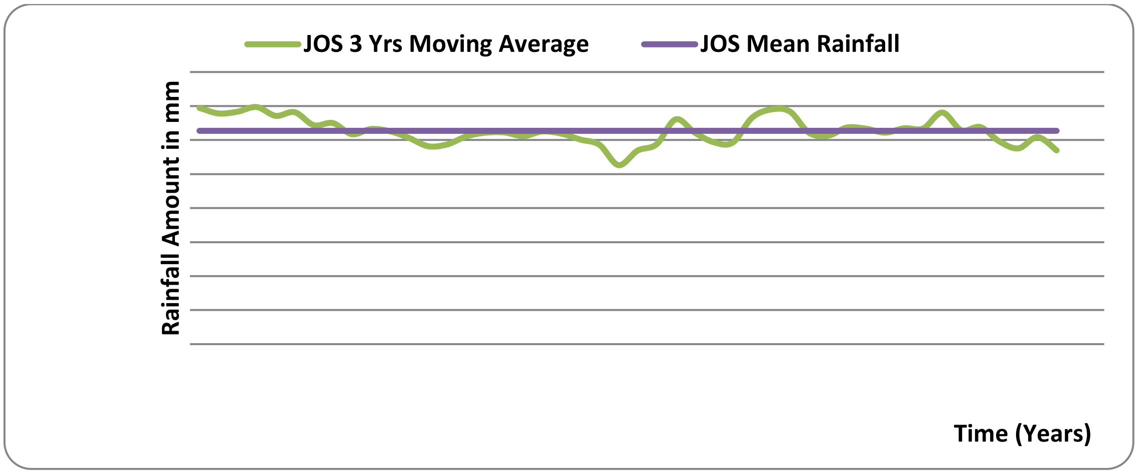

Figure 12: Rainfall in (mm) against Time (years) showing rainfall trend of Plateau State from 1971 to 2018.

3.2.10 Sokoto State Rainfall

Results of rainfall for Sokoto State as seen in figure 13 showed a mean annual rainfall of 627.1 mm per annum over a period of 47 years from 1971 to 2018. The 3 years average rainfall results points out that rainfall from 1971-1974, 1979-1988, 2005-2007 and 2015-2015 were below mean annual rainfall per annum with the lowest rainfall amounts of 425.1 mm recorded in 1986 while from 1973-78, 1992, 1996-98 and 2010-2016 the 3 years moving average rainfall amount were above the mean annual rainfall per annum with the highest rainfall amount of 719.9 mm per annum recorded in 1976.

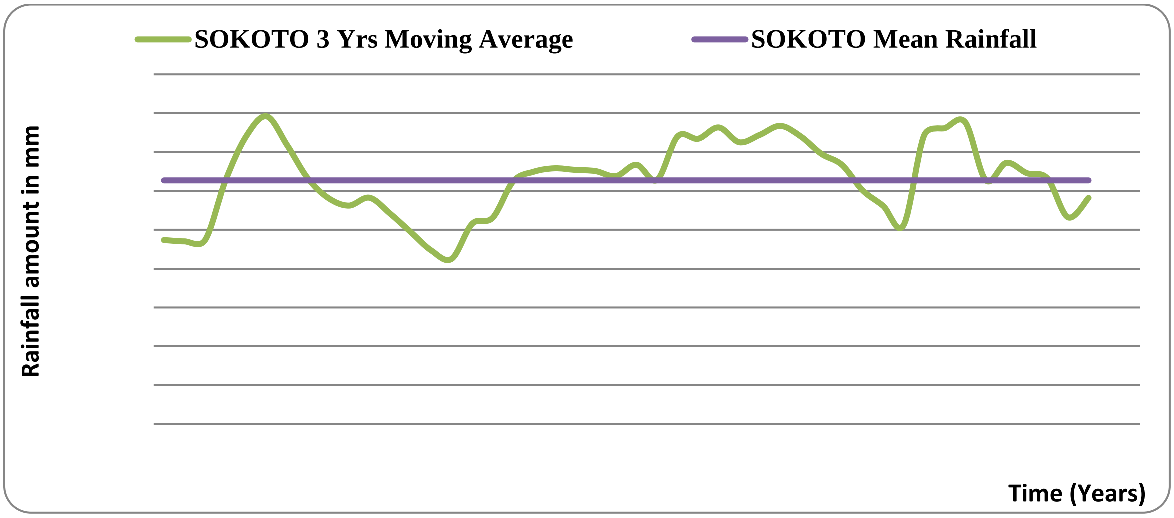

Figure 13: Rainfall in (mm) against Time (years) showing rainfall trend of Sokoto State from 1971 to 2018.

3.2.11 Taraba State Rainfall

Results for Taraba rainfall in figure 14 showed a mean annual rainfall of 1088.4 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall revealed that from 1971-73, 19977-79, 1981-83, 1985-87, 1989-91, 1996-2000, 2002-2007 and 2010-2013 rainfall were below the mean annual rainfall per annum with the lowest rainfall amount of 801.6 mm per annum recorded in 2003 while rainfall from 1974-1976, 1980, 1983-84, 1988-89, 1992-95, 2007-2010 and 2014-2016 rainfall were above the mean annual rainfall per annum with the highest rainfall amount of 1445.2 mm per annum recorded in 2016.

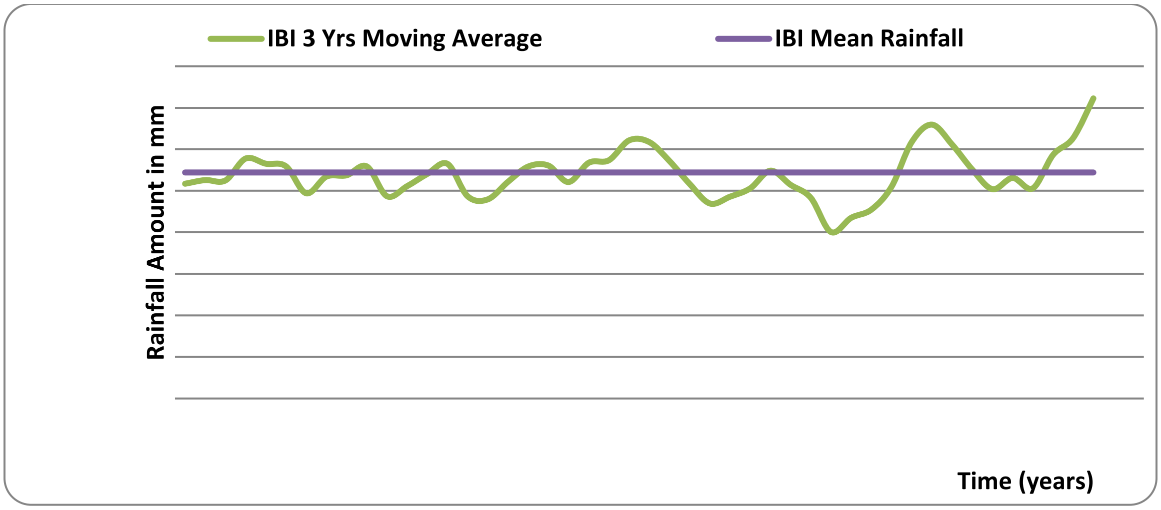

Figure 14: Rainfall (mm) against Time (years) showing rainfall trend of Taraba State from 1971 to 2018.

3.2.12 Yobe State Rainfall

Rainfall results of Yobe State as can be seen in figure 15 showed a mean annual rainfall of 458.5 mm per annum over a period of 47 years from 1971 to 2018. The 3 years moving average rainfall results revealed that rainfall from 1971-72, 1979-1991, 1993-95 and 1999-2009 were below the mean annual rainfall per annum with the lowest rainfall amount of 270.5 mm per annum recorded in 1986 while from 1992, 1996-98 and 2010-2016 rainfall were above the mean annual rainfall per annum with the highest rainfall amount of 969.9 mm per annum recorded in 2016.

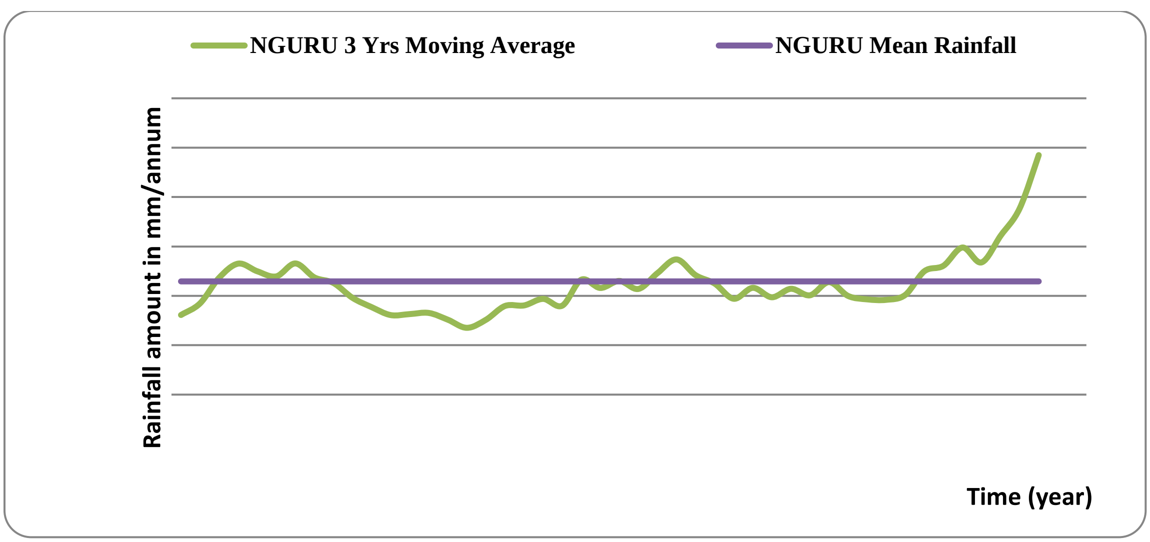

Figure 15: Rainfall in (mm) against Time (years) showing rainfall trend of Yobe State from 1971 to 2018.

3.2.13 Zamfara State Rainfall

Results of rainfall for Zamfara State as can be seen in figure16 showed a mean annual rainfall amount of 907.2 mm per annum over a 47 year period from1971-2018. The 3 years moving average rainfall revealed that from 1971-76, 1980-1990, 1995, 1999-2000, 2004-2007 and 2009-201 rainfall were below the mean annual rainfall with the lowest rainfall amount of 746.7 mm per annum recorded in 2011 while from 1976-79, 1990-1994, 1996-99, 2001-2004, 2008-2009 and 2014-2016 rainfall were above mean

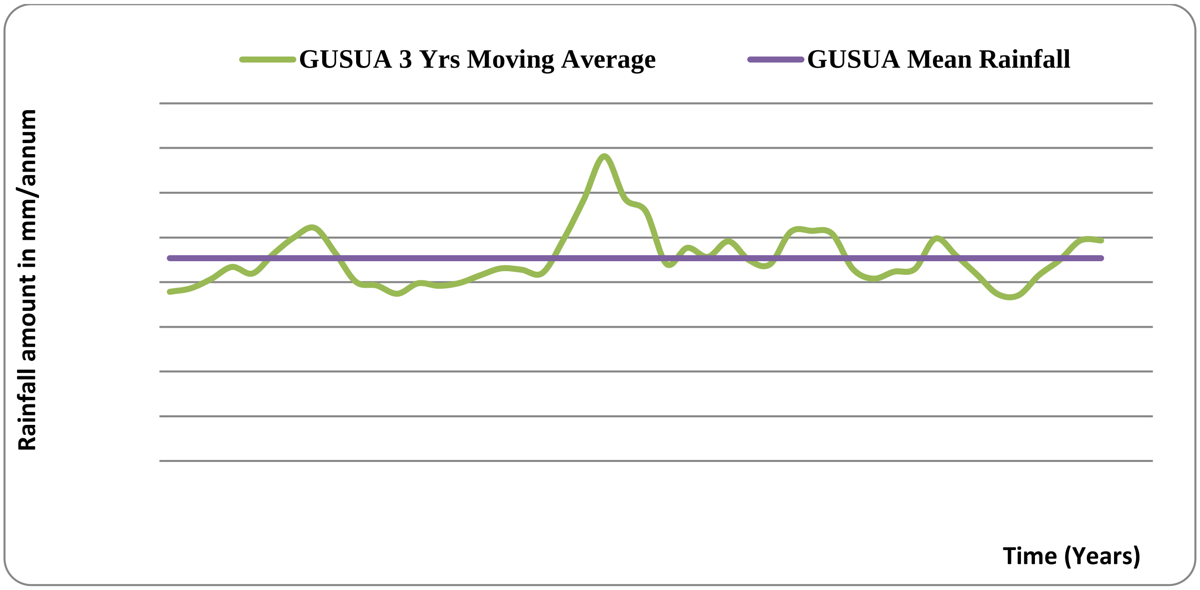

Figure 16: Rainfall in (mm) against Time (years) showing rainfall trend of Zamfara State from 1971 to 2018.

annual rainfall per annum with the highest rainfall amount of 1363.5 mm per annum recorded in 1992.

4. Discussion

The expected changes in temperature over the next 30−50 years are predicted to be in the range of 2−3 °C Intergovernmental Panel Climate Change (IPCC) (2007).

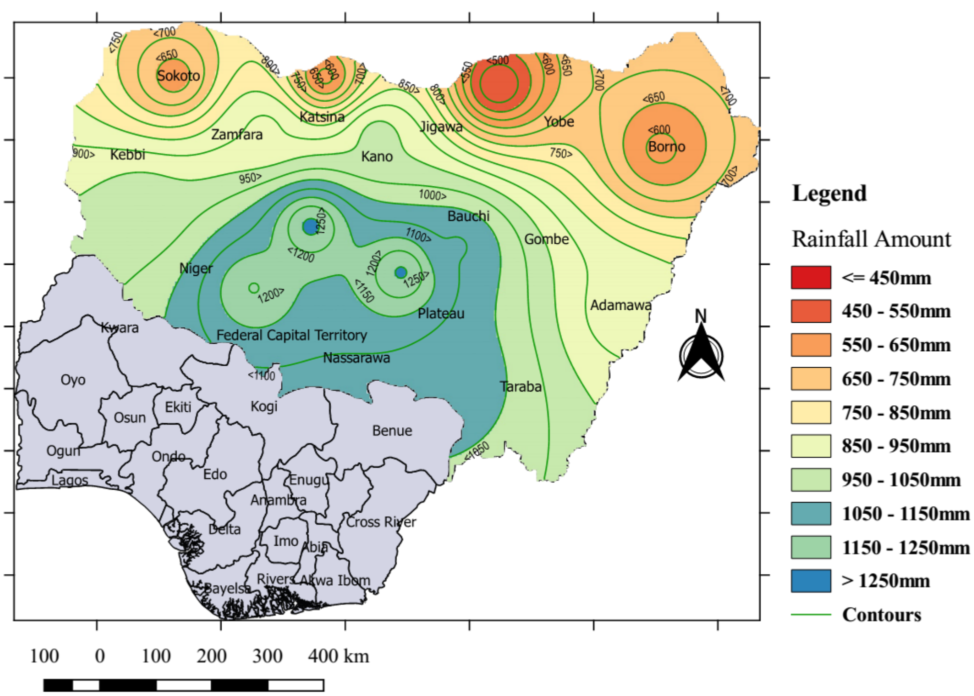

Figure 17: Map of Nigeria showing spatial mean rainfall pattern of Northern Nigeria.

Heat waves or extreme temperature events are projected to become more intense, more frequent, and last longer than what has been currently observed in recent years (Meehl *et al*., 2007) While temperature showed a whopping 0.8, 0.7, 0.6, 0.5, and 0.3 increasing difference for Adamawa, Taraba-Borno-Kano-Katsina-Sokoto, Yobe-Zamfara, Bauchi-Kaduna-Kebbi-Niger and Plateau state respectively agreeing totally with (IPCC, 2007 and Meehl *et al.*, 2007) projections. Rainfall in with its unpredicted nature which is determined by a lot of factors had been increased in the last decade in most states of Northern Nigeria as seen in figures 4 to figure 16. Its spatial variability can also be seen in figure 17.

5. Conclusion

As seen from the results while rainfall amount was highly variable and unpredictable in Northern Nigeria from one location to another (figure. 17), maximum temperatures kept rising on a gradual note yet crop and plant requirements for optimum growth and yield remain constant. This had contributed to the incessant records of failure in food production and optimum crop yields over the years which remained the highest threat to food security in the world and Nigeria in particular.
Adequate knowledge of rainfall and temperature patterns is required for the fight against the imminent creeping danger of food insecurity since they are the basic climatic variable that will militate against the attainment of the SDGs if not given adequate consideration.

6. Acknowledgement

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