Rainfall trends and its implications on water resources management: a case study of Ogbomoso city in Nigeria

Abstract

A 37-year annual rainfall was collected from NIMET to study the trend of rainfall parameter and its implications on water resources management in the tropical city of Ogbomoso, Oyo State, Nigeria. The data was co-tested by both parametric and non-parametric statistical methods to determine the trend. The linear regression statistic and M-K, both, showed that rainfall trend in the study area is positive over the period with R2 of 0.001 while M-K showed positive trend at 0.05 significance level. The results of the analysis implied that more rainwater was received in the city during the period under consideration. Thus, there was sustainable natural replenishment of both surface and subsurface water sources. The study further noted the possible negative effects of this finding including contamination of surface sources, destruction of life and properties through flooding including farmlands, human infrastructure and prevalence of diseases, among others. Thus, efforts should be made to ensure comprehensive water resource management. However, further research into the optimal utilization of the excess rainwater received in the area should be investigated.

Keywords: hydro-climatology, mann-kendall, climate change, water resources, rainfall trend

Introduction

The global awareness of climate change scenarios has invariably influenced the emphasis and persistent hydro-climatological research among scholars at different scales, most especially, rainfall studies. In the first place, the ultimate source of water to mankind is precipitation. According to Bowen University, Nigeria, the excess rainwater received in the area should be investigated. Water resource management implies the activity of planning, distributing and managing the optimum use of water resources. Water management is aimed at achieving one or more of the following: domestic water supply, industrial water use, irrigation farming, flood control, water quality control, among others. Ifabiyi & Ojoye observed that the trends of rainfall have a great impact on the hydrologic cycle and therefore affect both the quality and quantity of water resources. They further stated that the concentration of greenhouse in the atmosphere has increased over the past few decades and this increase, according to them, is expected to increase rainfall characteristics such as the rainfall amounts, intensity, duration and frequency, which is also expected to alter the pattern of rainfall. Frederick & Major and Ojoye in buttressing this finding, also noted that climate change studies have revealed that droughts will become more rampant and extreme rainfall events more frequent if the trend is not controlled. It has been noted that such a study at local scale is preferable than at a larger scale because such a trend will have different implications at local scale than generalized observations which may not be applicable at local level. In addition to these observations, it is already noted that there is less certainty associated with the trends in precipitation. Thus, Houghton et al. concluded that precipitation amounts have increased over much of the globe, with a decrease over subtropical areas, but that the detection of these trends is problematic because they are neither temporally nor spatially uniform as noted by Folland et al. In view of these observations, consistent study of various characteristics of rainfall at different scales is important. To this end
this research work has been embarked upon to examine the trends in rainfall in Ogbomoso, a city in Nigeria. The study will further reveal the implications of such trend on water resource management in the study area and probable remedial measures will be suggested to ensure sustainable management of this resource.

**Methodology**

**Study area**

Ogbomoso is located within the tropical region with distinctive wet (April –October) and dry seasons (November-March). Average temperature in the region is 31°C while total annual is about 1800mm. The temperature is persistently high with an annual range of about 5°C. According to Adeboyejo and Abolade, Ogbomoso is a pre-colonial urban center and the second largest city, both in terms of population and spatial extent in Oyo State, Nigeria (Figure 1).

Ogbomoso, formerly the seat of Ogbomoso Local Government Area, is currently made up of five LGAs namely Ogbomoso North, Ogbomoso South, Orire, Ogo-Oluwa and Surulere LGAs with their headquarters in Kimira-Ogbomoso, Arowomole, Ikoyi, Ajaawa and Irekun respectively. The city is located approximately 100km north of Ibadan, the Oyo State capital, and roughly 80km from both Kwara and Osun State capitals, Ilorin and Osogbo, respectively. Ogbomoso is dominated by both tropical rainforest to the southern part and derived guinea savanna to the northern part.

Ogbomoso, in the last few decades, has witnessed a tremendous urban expansion, the process which has led to the removal of natural vegetation for infrastructural development like roads, schools, residential buildings among others. Thus, urbanisation process has inflicted much on the environment that urban heat has increased abruptly. Even though, Ogbomoso is located in the tropics where the temperature is perpetually high all the year round, the urban heat island could have aggravated the rate at which water is vapourised in the city.

**Data collection and analysis**

A 37-year rainfall data (1970-2006) collected from the Office of Nigeria Meteorological Agency in Ilorin was used in this study. Monthly rainfall totals were summed up to give annual rainfall total for each of the years studied. This is presented in Table 1.

**Method of analysis**

Regression analysis was applied to determine the linear trend of rainfall over the period. Linear regression analysis is one of the simplest methods of determining trends of an incidence in time series. The equation is given by:

\[ Y = a + bX \]  \hspace{1cm} (1)

Value of \( Y \) when \( X = 0 \)

Where \( X \) is the explanatory variable (year) and \( Y \) is the independent variable (rainfall data). The slope line is \( b \) and \( a \) is the intercept. Several authors have applied this parametric statistical method in water resources studies among which are Koutsouris et al.19

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**Figure 1** Oyo State Map showing the location of Ogbomoso (the study area).

(Inset: Map of Nigeria showing Oyo State)

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Results and discussion

As shown in Figure 2, the results of regression analysis revealed that there is positive trend in the pattern of rainfall over the period under study. The $R^2$ of 0.001 indicates that the trend is positive. The range of rainfall incidence over the period shows that the least rainfall was in 2001 with 697.1 mm while the highest rainfall was recorded in 1998 with 1594.5 mm total rainfall. However, the years with rainfall totals less than 1000mm were recorded in nine years of the entire period namely 1970, 1977, 1988, 1989, 1992, 1996, 2000, 2001 and 2002. However, over the period, cases of water associated deaths and other environmental hazards such as flooding, farm and other infrastructural destructions were recorded.

Table 1: Annual total rainfall in Ogbomoso from 1970 to 2006

| S/N | Year | Annual total rainfall(mm) | S/N | Year | Annual total rainfall(mm) |
|-----|------|---------------------------|-----|------|---------------------------|
| 1   | 1970 | 938.3                     | 20  | 1989 | 794                       |
| 2   | 1971 | 1106.8                    | 21  | 1990 | 1020.1                    |
| 3   | 1972 | 1197.3                    | 22  | 1991 | 1468.4                    |
| 4   | 1973 | 1460.8                    | 23  | 1992 | 931.6                     |
| 5   | 1974 | 1256.5                    | 24  | 1993 | 1157.9                    |
| 6   | 1975 | 1090.5                    | 25  | 1994 | 1242                      |
| 7   | 1976 | 1078                      | 26  | 1995 | 1409.2                    |
| 8   | 1977 | 928.9                     | 27  | 1996 | 945.3                     |
| 9   | 1978 | 1209.4                    | 28  | 1997 | 1334.4                    |
| 10  | 1979 | 1193.1                    | 29  | 1998 | 1595.5                    |
| 11  | 1980 | 1237.1                    | 30  | 1999 | 1539.3                    |
| 12  | 1981 | 1286.9                    | 31  | 2000 | 990.3                     |
| 13  | 1982 | 1215.1                    | 32  | 2001 | 697.1                     |
| 14  | 1983 | 1157.2                    | 33  | 2002 | 902.3                     |
| 15  | 1984 | 1310.5                    | 34  | 2003 | 1033.5                    |
| 16  | 1985 | 1133.3                    | 35  | 2004 | 1294                      |
| 17  | 1986 | 1328.4                    | 36  | 2005 | 1305.9                    |
| 18  | 1987 | 1213.7                    | 37  | 2006 | 1303.8                    |
| 19  | 1988 | 898.9                     |     |      |                            |

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Summary of Mann-Kendall statistic

The M-K analysis showed that

The number of positive differences = 391.0
The number of negative differences = 312.0
S = 312.0 - 391.0 = 79

Since Variance is determined by \( \frac{(n-1)(2n+5)}{18} \),

Thus 79\( \sqrt{12107} \)

\( Z_s = 110.03 \)

\( Z_{crit,0.05} = 126 \) (by two-tailed test)

Thus, the result could be interpreted to indicate increasing (positive) trend since \( Z_{crit,0.05} \) is greater than \( Z_s \).

The trend of rainfall in Ogbomoso, a city in the south western Nigeria of 37 years was studied. The result of Mann-Kendall, non-parametric test, showed that there was an increasing trend in rainfall over the period studied. This result was also similar to the outcome of linear regression test which shows a slope with a positive trend, \( R^2 = 0.0014 \) over the period. These findings corroborated the report of Egbinola and Amobichukwu and that of Igwenagu for Enugu which discovered increasing trend in rainfall in their respective areas of study. However, the scenario of increasing trend in rainfall events is expected in view of the climate change. It has been discovered that more rainfall will be experienced in the tropics as a result of change in temperature. In buttressing this fact, Trenberth and Tollefson observed that there is a direct influence of global warming on precipitation. Trenberth further revealed that increased heating leads to greater evaporation and thus surface drying, thereby increasing the intensity and duration of drought. In view of this scenario, Trenberth showed that the water holding capacity of air increases by about 7% per 1℃ warming, which leads to increased water vapour in the atmosphere. The finding implies that the manifestation of the evidence global warming is already being experienced in Ogbomoso. This finding is also in agreement with the observation of Ren et al. which noted that there has been an increasing trend over both land and ocean from 1900 to 2008. In fact, it was discovered that the trends along latitude averaged over the oceans show very strong positive trends in the equatorial regions between 5°N and 15°N which are likely to be dominated by the Inter-Tropical Convergence Zone (ITCZ). However, the results of the analysis which showed an increasing rainwater supply in the area imply that efforts need to be put in place for a comprehensive environmental management, especially as it affects water resources. It is expected that water resource management would involve such measures that will ensure availability and accessibility of quality water for domestic use in the light of increased surface runoff that introduces pollutants into water sources, sustainable agricultural practice, especially irrigation farming, flood control through channelization of water passages. It is important that water resource managers rise up to the challenge imposed by water contamination that could arise so that the inhabitants of the city will have good access to potable water. Ifabiyi and Ogunbode had already revealed that accessibility to potable water in Oyo State, of which Ogbomoso is inclusive, had poor access to good quality water despite the availability of the resource, the finding attributed to poor water quality among others. More downpour would make the surface water sources more susceptible to pollution in view of the increased surface runoff. In buttressing this observation, cases of contamination of underground water in Ogbomoso has been reported. In view of this conclusion, Ojoowo and Kolade concluded that water supply in Ogbomoso is not fully supportive to human health. Thus strategies, such as public enlightenment and education, and direct involvement of

**Figure 2** Mean annual rainfall pattern in Ogbomoso (1970-2006).
(Source: Author’s fieldwork, 2012)
stakeholders should be in place to enhance in improving the integrity of water. In another way, the advantage of more water from rainfall should be exploited by channeling it to domestic and industrial uses. Thus other water sources could be preserved for future.

Secondly, water resource/environmental managers need to ensure channelization of water passages to avert flooding especially at the downstream through the enlargement of river channels and streams. In the work of Aderogba, Ogbomoso is one of the southwestern Nigerian cities observed to be prone to flooding. It was noted that flooding frequency of an average of 11 days annually was noted in Ogbomoso and loss of properties worth of about 18 million naira was often involved. In addition, Adetunji and Oyeleye had revealed that one of the problems of urbanization in Nigeria is flooding which they attributed to heavy rainfall induced by climate change. Also, in conjunction with the channelization is that effort should be put in place to protect wetlands from being excessively rendered damaged by water logging. This is necessary to protect farmlands that valuable for irrigation. The increasing trend in rainfall should be exploited to develop and boost rain-fed agriculture to enhance food and cash crop production.

Conclusion

Climate change scenario has impacted on man and his environment globally. In view of this, an investigation into the trends of rainfall and its implication on water resources management in the tropical city of Ogbomoso, Nigeria was carried out. A 37-year annual rainfall total was subjected to both linear regression and Mann-Kendall statistics. The results of these analyses showed that there was a positive trend indicating increasing water supply over the period studied in the area. Thus, both surface and sub-surface water resources did not suffer natural replenishment. This means that strategic and comprehensive measures should be put in place to checkmate the negative implications of the increased rainwater supply through rainfall such as water pollution, flooding, wetland underutilization and destruction of farmlands among others. Suggested measures to control these menace include public enlightenment and education on controlling water pollution, channelization and dredging of river courses, development of rain-fed agriculture among others. The study suggested that further investigation be conducted on optimal utilization of excess rainwater received.

Acknowledgments

None.

Conflicts of interest

The author declares that there is no conflict of interest.

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