DE G DE GRUYTER OPEN
Slovak Journal of Civil Engineering Vol. 26, 2018, No. 1, 40 – 46
DOI: 10.2478/sjce-2018-0006

THE IMPACT OF GLOBAL WARMING ON PRECIPITATION PATTERNS IN ILORIN AND THE HYDROLOGICAL BALANCE OF THE AWUN BASIN

Ayanniyi AYANSHOLA[1], Oluwatosin OLOFINTOYE[1*], Ebenezer OBADOFIN[1]

Abstract

This study presents the impact of global warming on precipitation patterns in Ilorin, Nigeria, and its implications on the hydrological balance of the Awun basin under the prevailing climate conditions. The study analyzes 39 years of rainfall and temperature data of relevant stations within the study areas. Simulated data from the Coupled Global Climate model for historical and future datasets were investigated under the A2 emission scenario. Statistical regression and a Mann-Kendall analysis were performed to determine the nature of the trends in the hydrological variables and their significance levels, while a Soil and Water Assessment Tool (SWAT) was used to estimate the water balance and derive the stream flow and yield of the Awun basin. The study revealed that while minimum and maximum temperatures in Ilorin are increasing, rainfall is generally decreasing. The assessment of the trends in the water balance parameters in the basin indicates that there is no improvement in the water yield as the population increases. This may result in major stresses to the water supply in the near future.

Address

[1] Department of Water Resources and Environmental Engineering, University of Ilorin, Ilorin, Nigeria

* ***Corresponding author:*** olofintoye.oo@unilorin.edu.ng, olofintoye.oo@gmail.com

Key words

- Global warming,
- Coupled global climate model,
- Soil and water assessment tool (SWAT),
- Hydrological balance,
- Awun basin.

1 INTRODUCTION

Global warming is a sustained increase in the average temperature of the earth, which is enough to cause changes in the global climate (Venkataramanan and Smitha, 2011). Global warming can occur due to a variety of causes, which may be natural or human (anthropogenic) induced. Anthropogenic activities, such as the combustion of fossil fuels, the burning of wood and wood products, the decomposition of organic waste in solid waste landfills, the raising of livestock, bush burning, deforestation and some other agricultural activities, increase the concentration of certain greenhouse gases (GHGs) in the atmosphere. This results in an alteration of the equilibrium between the natural GHGs (water vapor, carbon dioxide, methane and nitrous oxide) and man-made GHGs such as sulfur hexane fluoride, hydro-fluorocarbons and perfluorocarbons in the Earth's atmosphere, thus promoting the warming of both the atmosphere and the oceans since they are heat-trapping gases.

There is growing concern about global warming and the impact it will have on people and the ecosystems on which they depend. Since the early 20th century, the average surface temperature of the earth has increased by roughly 0.8 °C (1.4 °F), with about two thirds of the increase occurring since 1980 (Idowu et al., 2015). Temperatures will likely rise at least another 2°F and possibly more than 11°F over the next 100 years (Olofintoye and Sule, 2010; Olofintoye and Adeyemo, 2011; Salami et al., 2011). The Intergovernmental Panel on Climate Change (IPCC, 2007) reported that the current estimate of the chemical composition of the atmosphere clearly indicates that concentrations of principal greenhouse gases are increasing rapidly and already appear to significantly exceed the peak concentrations of past centuries. It is inferred that global climate change induced by increases in temperature may change precipitation patterns and

Vol. 26, 2018, No. 1, 40 – 46

probably raise the frequency of extreme events such as floods and droughts. These changes may have serious impacts on society, especially in river basins (Olofintoye et al., 2012). Such impacts may include rises in sea levels and increases in the occurrence of flooding events. The developing nations of Africa, Asia, and South America are bound to be seriously affected in the event of climate change and therefore ought to be interested in the subject (Madueme, 1999). The IPCC (2001) described Africa as one of the continents most vulnerable to climate change and variability, and Nigeria is one of the countries within Africa expected to be affected the worst as reported by Environmental Resources Management (ERM, 2009).

Current observations and climate projections suggest that one of the most significant impacts of climate change is likely to be on the hydrological system and hence on river flows and regional water resources (Bates et al., 2008). Principal climate variables affecting water availability are precipitation, the temperature and potential evapotranspiration. Precipitation is any form of water (either liquid or solid), such as rain, snow, or hail, that falls from the atmosphere and reaches the ground. It is the main source of all freshwater resources and determines the level of soil moisture, which is essential in the formation of runoff and hence river flow. Soil moisture is determined not only by the volume and timing of precipitation, but also by a complex interaction and feedbacks with evaporation and temperature (IPCC, 2001).

In Nigeria the major form of precipitation is rainfall. Due to her location in a low pressure zone of the Earth and her proximity to the Atlantic Ocean in the South, Nigeria experiences heavy rainfalls, especially in the southern part of the country as compared to the north. Studies on the impact of global warming on precipitation patterns are therefore pertinent in facilitating the sustainable management of freshwater resources in the various river basins in the country. This study presents the impact of global warming on the precipitation patterns of Ilorin, Nigeria, and its implications on the hydrological balance of the Awun drainage basin under the prevailing climate conditions.

1.1 The Study Areas

1.1.1 Ilorin

The metropolis of Ilorin constitutes a major part of the Awun drainage basin in Nigeria. The city, which is the capital of the state of Kwara, Nigeria, is situated above the equator between the latitudes 8º30′ and 8º50′N and longitudes 4º20′ and 4º35′E (Fig. 1). The city of Ilorin occupies an area of about 468 sq. km. in a transition zone between the forest and guinea savannah regions of Nigeria. The city is about 300 kilometers away from Lagos in the south and 500 kilometers from Abuja, the federal capital of Nigeria, in the north. The climate is tropical and under the influence of two prevailing trade winds. The metropolis of Ilorin experiences two climatic seasons, i.e., rainy and dry seasons. The rainy season often occurs between March and November. The annual rainfall varies from 1000 mm to 1500 mm with a peak around September to early October. The mean monthly temperature is generally high throughout the year (Ajibade, 2002).

The average daily temperatures vary from 25 ºC in January to 27.5 ºC in May and 22.5 ºC in September. The type of vegetation found there is derived savannah with a riparian forest along the river banks. The drainage system is dendritic. The general elevation of the land on the western part varies from 273 m to 364 m (i.e. 900 to 1/200 ft.) above sea level. In the northwestern part of Ilorin lies an isolated hill known as Sobi hill, which is about 394 m above sea level. Large portions of the land surface of Ilorin are as high as 100 m above sea level, with the highest point having an elevation roughly 394 m above sea level. The geology of the study area consists of Precambrian basement complex rock. The population of the city as of the year 2006 is 766,000 according to the census report of the Nigerian Population Commission (NPC, 2006).

1.1.2 Awun Basin

The Awun basin is a small watershed in the state of Kwara, Nigeria. Viessman et al. (1989) defined a watershed as a land area that contributes surface runoff to any point of interest. The entire basin is located between the latitudes 8°28′N and 9°00′N and longitudes 4°30′E and 4°45′E with a total area of 954 km^2. The length of the main river channel is 80.23 km (Sule and Alabi, 2013). Sule (2003) described a river basin to be the most appropriate scale for the management of water resources. Based on the stream order concept, the Awun River can be classified as the highest order stream of the basin as it is a mainstream channel that carries the flow from the entire tributary area upstream of the River Niger. Fig.1 shows the proximate location of the Awun drainage basin.

2. MATERIALS AND METHODS

2.1 Data

This study includes an analysis of historical station data as well as downscaled data from Global Climate Model (GCM) simulations. The meteorological data include the minimum temperature, maximum temperature, and rainfall. These were obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos, Nigeria. The nature of the data collected was the rainfall depth (mm) and maximum and minimum temperatures (ºC) recorded for every month of the year. The data analyzed in this study spanned 39 years from 1977 to 2015. The minimum required period for any climatic study is thirty-five (35) years (Ifabiyi, 2013). Therefore, the average monthly data for 35 years and above were collected for each of the parameters. The hydrological data analyzed were the runoff and water levels. Other data used included soil and land use data for the study area.

2.2 Data Analysis

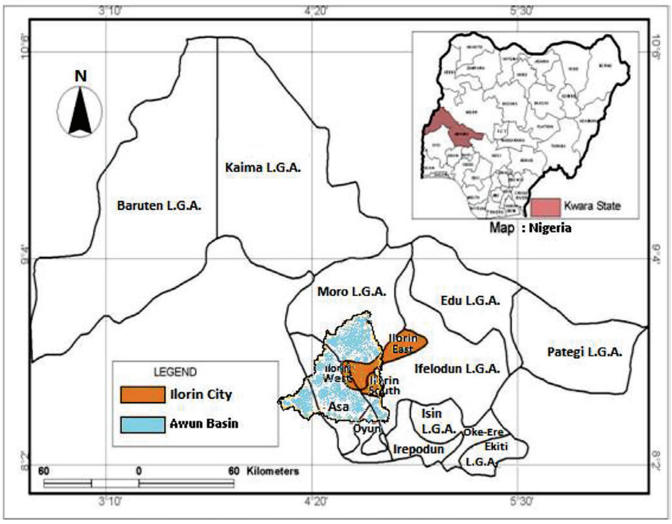

Fig. 1 *Map of the State of Kwara showing Ilorin and the Awun Drainage Basin*
Source: Adapted *from Tunde et al, (2013)*

2.2.1 Statistical Analysis

The meteorological data were subjected to various forms of statistical analysis to determine the mean, median, mode, maximum and minimum values, variance, standard deviation, coefficient of variation, and skewness. Excel software was employed in the computation of the various statistics.

2.2.2 Trend Analysis for Climate Data

A linear regression and determination coefficient analysis were employed to establish the relationship between the meteorological parameters and time, while a Mann Kendall test statistic (Salmi et.al., 2002) was used to determine the significance of trends exhibited by the parameters. Zaitun time series software and Excel were used to perform the trend analysis for the climatic variables.

2.2.3 Global Climate change model analysis

The Coupled Global Climate model (CGCM 3.1-TR47) developed by the Canadian Center for Global Climate Modeling was used to analyze the historical and future projections of the data. Climate data obtained from the IPCC and CGCM were downscaled to the local study area using the Climate Wizard web application. The climate model was adopted due to its regional resolution of 2.8º x 2.8º, which makes it compatible for climate projections within the study area. Climate variations were investigated under an A2 emission scenario, which exhibits a semblance of the activities in the basin. Through the application of the climate model, the historical and future averages of the minimum, maximum, and mean temperatures as well as the hottest days, the total rainfall amounts and the number of dry days were determined for the study area.

2.2.4 Stream Flow and Water Balance Analysis

A Soil and Water Assessment Tool (SWAT model) was used to estimate the water balance and derive the stream flow and yield in the study area. The inputs to the model were the weather data, soil and land use data, and digital land elevation models. Outputs from the model included water yield, surface and lateral flows, deep aquifer recharge, and stream flow.

3. RESULTS AND DISCUSSIONS

3.1 Statistical analysis

Over the period studied, the temperature in Ilorin is observed to have had fluctuating values that were not too broad. The broadest range of the minimum temperature was 7.6 ºC, while the range of the maximum temperature was 8.8 ºC. Yearly averages of minimum and maximum temperatures for each year were computed over the months (January –December) within the particular year. The minimum of the yearly averages of minimum temperatures (21 ºC) occurred in the year 1990, while the maximum of the yearly averages of maximum temperatures (33.3 ºC) occurred in the year 2000. Ilorin was coolest in January, 1990, with an average temperature of 16.0 ºC and hottest in February of 2008 with an average temperature of 37.7 ºC. On the basis of the average monthly temperatures, December is the coolest (19.28 ºC), while March is the hottest month (35.83 ºC). The maximum annual average rainfall in Ilorin is 1736.50 mm, while the minimum is 697.10 mm. The highest monthly rainfall is 382.50 mm, while some months had no rainfall during the period under review. On average, September is the month with the highest average monthly rainfall (222.64 mm), while January has the lowest average rainfall (7.36 mm).

3.2 Trend analysis

3.2.1 Maximum Temperature

The regression model developed showed that the maximum temperature (computed from monthly averages from the daily maximum) is significantly increasing in the study area over time. This indicates that there is a positive linear relationship between the maximum temperature (T_{Max}) and time (t). The trend line equation suggests a yearly increase of about 0.08 ^{0}C in the maximum temperature, while the coefficient of determination R^2, indicates that about 42.3% of the variation in the maximum temperature may be explained by variations over time. A forecast using the regression model developed suggests a continual rise in the maximum temperature, which is expected to rise above 40 ^{0}C in the next 50 years. Fig. 2 presents the maximum temperature regression model developed.

3.2.2 Minimum Temperature

The trend analysis of the minimum temperature (computed from monthly averages from the daily minimum) shows a significantly increasing minimum temperature in the study area, which indicates that there is a positive linear relationship between the minimum temperature (T_{Min}) and time (t). The trend line equation suggests that for every minimum temperature of 20.98 ^{0}C, there is an expected rise of 0.02 ^{0}C annually with a 13% likelihood of an increase. The minimum temperature model developed is presented in Fig. 3.

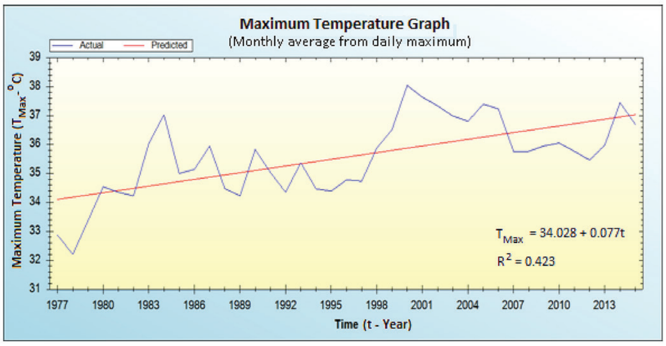

Fig. 2 *Regression model developed for the maximum temperature*

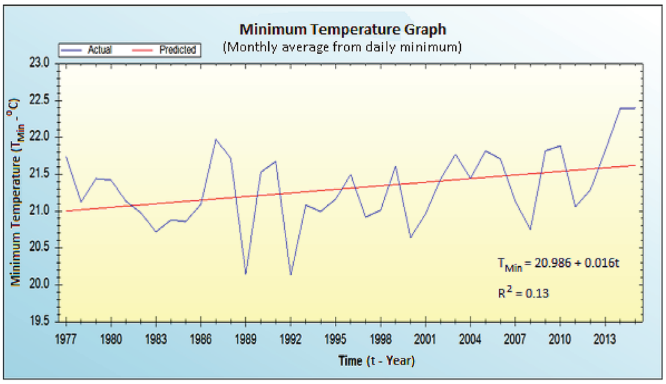

Fig. 3 *Developed regression model for minimum temperature*

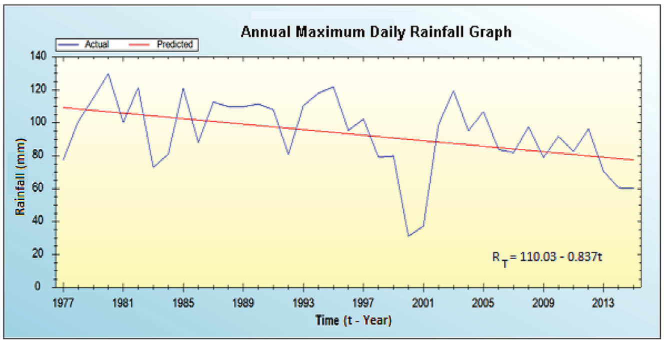

Fig. 4 *Regression model developed for the Annual Maximum Daily Rainfall*

3.2.3 Rainfall

While the maximum and minimum temperatures show a rising trend, rainfall, on the other hand, depicts a declining trend over the years in the study area. The annual maximum daily rainfall (R_t) exhibits a decline in the trend with the trend line equation suggesting a reduction in the amount of rainfall by about 0.84 mm per annum. The amount of rainfall is expected to continuously decline in the study area. These results are consistent with analyses by Odjugo (2011). The model developed for the annual rainfall is shown in Fig. 4.

3.3 Mann-Kendall test statistics

The results of the non-parametric Mann-Kendall (Salmi et al., 2002) test for maximum and minimum temperatures as well as annual rainfall are presented in (Tab.1). A detailed discussion on the application of the non-parametric Mann-Kendall test for determining the significance of monotonic trends in a dataset is available in Olofintoye and Sule (2010).

The results in Table 1 indicate that the normalized Kendall statistics (Z_S) for maximum and minimum temperatures are greater than the critical value ($Z_{0.025}$ = 1.96) at the 5% level of significance. This implies that the positive trends observed in the values of the meteorological variables over time are statistically significant. However, the negative trend in annual rainfall is not significant as observed from the results in the table.

3.4 Assessment of global warming in Ilorin downscaled from global climate model

The Climate Wizard web application was applied to downscale the future climate simulations using an A2 emission scenario. The analysis was done for historical (1961 – 1990) and future periods of 2046 – 2065 in Ilorin.

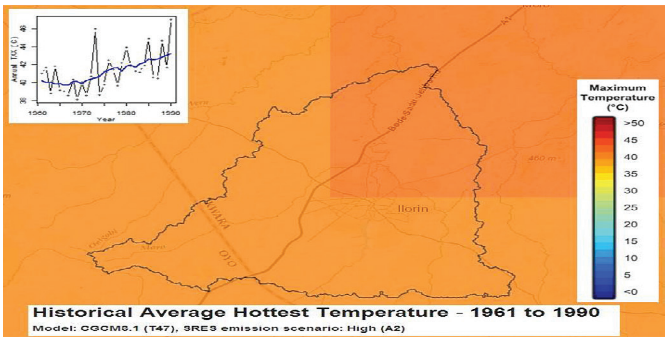

Fig. 5 *Historical Average Hottest Temperature (1961-1990)*

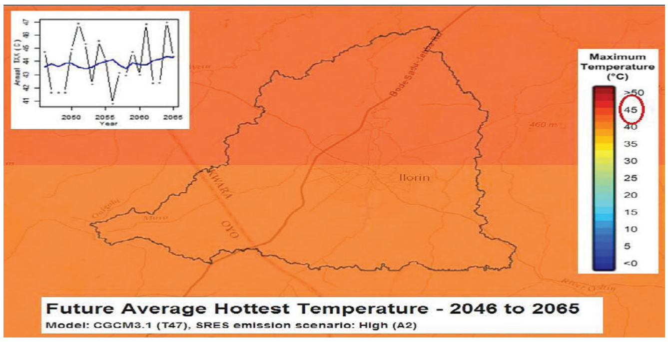

Fig. 6 *Future Average Hottest Temperature (2046-2065)*

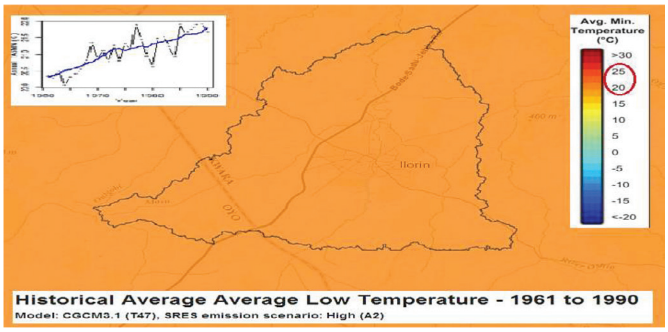

Fig. 7 *Historical Average Minimum Temperature (1961-1990)*

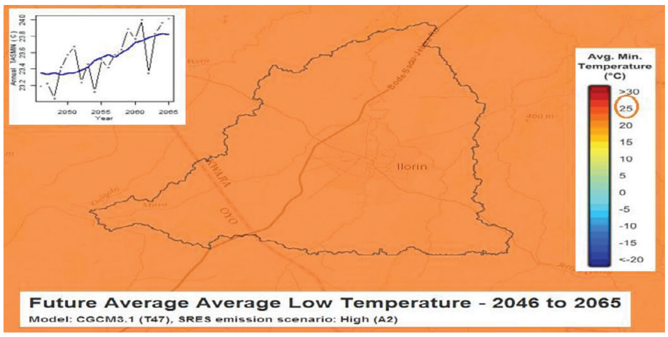

Fig. 8 *Future Average Minimum Temperature (2046-2065)*

Tab. 1 *Results of the Mann-Kendall Test for Trends in Meteorological Variables*

Data	*Autocorrelation Factor*	*Kendall's S*	*Normalized Z_S*	*Trend*	*Significance Status*
Maximum Temperature	-0.382	213	2.7250	Positive	Significant
Minimum Temperature	-0.006	553	4.4915	Positive	Significant
Annual Rainfall	0.090	-54	0.4550	Negative	Not Significant

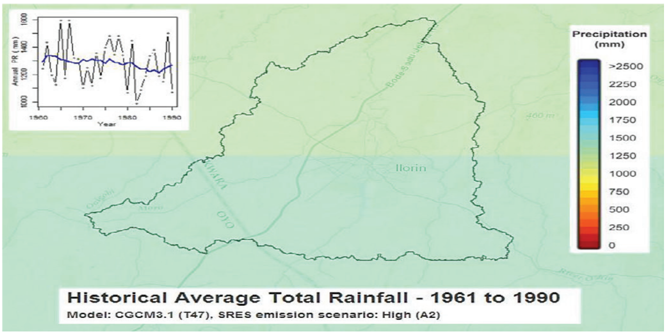

Fig. 9 *Historical Average Total Rainfall (1961-1990)*

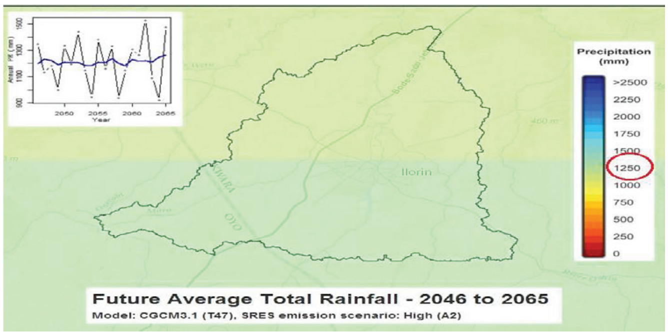

Fig. 10 *Future Average Total Rainfall (2046-2065)*

3.4.1 Analysis of the Maximum Temperature

The analysis of the downscaled average maximum temperature for the study area for the historical period (1961-1990) and future period (2046 – 2065) indicates that the maximum temperature in the past period was around 32 ^{0}C and 36 ^{0}C with a consistent average of about 34^{0}C. It was observed (Fig. 5) that areas north of the basin (the Awun subbasin and most parts of the Moro subbasin) recorded the highest temperature in the historical climate data, whereas areas in the Ilorin environs as well as southward of the basin experienced cooler temperatures. The future averages, however, indicate an expected drastic rise in maximum temperatures to ranges between 35 ^{0}C and 42 ^{0}C (Fig. 6). The positive trend is consistent with the earlier results from the trend analysis and the findings of Matthews et al. (2014). This rising trend is expected to portend negative implications for the hydrologic at balance in the study area.

3.4.2 Analysis of the Minimum Temperature

Fig. 7 below depicts the average minimum temperature for the study area for the historical period (1961 – 1990), while Fig. 8 shows the future averages (2046 – 2065) under the A2 emission scenario. The results show that the minimum temperature between 1961 and 1990 rose between 18 ^{0}C and 24 ^{0}C with the trend showing an increase throughout the period. The results are consistent with the trend of the minimum temperature from the data analyzed (1977 – 2015). The minimum temperature for the future period (2046 – 2065) indicates that the minimum temperature is expected to rise above 25 ^{0}C towards 27 ^{0}C. The trend also shows a continuous increase, albeit a buckle in the trend around 2055, before a spike in the trend till 2065.

In general, the mean annual temperature is projected to increase by 1.1 ^{0}C to 2.5 ^{0}C in the 2060s and by 1.4 ^{0}C to 4.6 ^{0}C by the 2090s. The range of projections by the 2090s under any one emission scenario is around 1 ^{0}C - 2 ^{0}C. The projected rate of warming is similar throughout the years, but the warming is higher in the northern part of the basin when compared to its southern part.

3.4.3 Analysis of the Annual Rainfall

An assessment of the averages in the amount of rainfall in the study area shows that the total amount of rainfall in the past ranged between 1300 mm and 1600 mm per annum. The trend shows a downward trend in the amount of rainfall to the tune of about 3 mm per month with areas northward experiencing more rainfall than areas in Ilorin and southward in the basin (Fig. 9).

The future total average rainfall (Fig. 10), however, shows a drop in the amount of rainfall with expected total average rainfall between 1200 mm and 1250 mm. The trend in the rainfall shows a fairly stable rainfall distribution during the period, with an expected increase towards the end of the period. Projections of the mean annual rainfall from different models in the ensemble are broadly consistent in indicating a small increase in rainfall for the study area. The projected changes in precipitation, however, show variations across the study area. Seasonal median projections indicate the rainy season months in Ilorin to be in March, April, May, June, July, August, September, and October, while December, January, and February will generally be dry.

3.5 Water balance analysis of and implications for the water resources of the basin

A SWAT model was used to estimate the water balance in the basin and hence derive the stream flow and water yields. The annual averages for the various hydrologic parameters for the Awun Basin over a period of 37 years (1979-2015) are depicted in the model's output (Fig. 11). The annual streamflows and water yields were derived from the annual application of the model over the study period. These results are presented in Fig. 12.

The model's output (Fig. 11) shows that while the average total amount of rainfall received in the basin per annum is estimated at 1134.4 mm, 625.4 mm is lost to evapo-transpiration; 195.98 mm appeared as surface runoff; while only 15.48 mm of the rainfall percolates into the aquifer as a deep aquifer recharge. The high rates of evapo-transpiration, which are probably due to high temperatures, result in lower streamflows, which ultimately affect the yield of the basin.

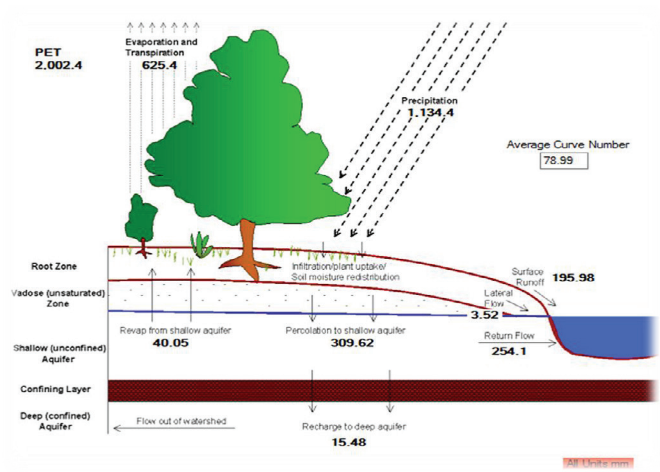

Fig. 11 *Output from the SWAT model showing the water balance of the Awun basin.*

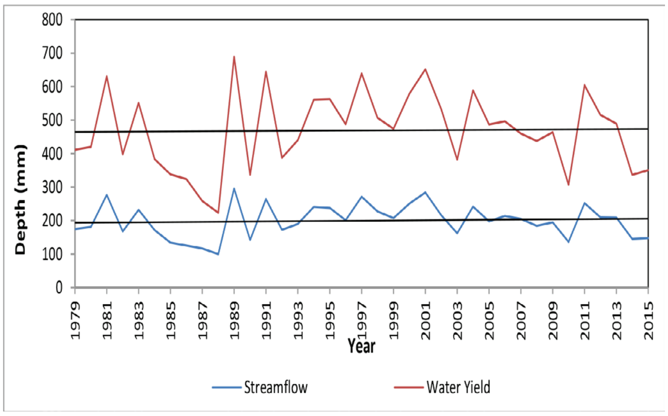

Fig. 12 *Plot of the Yearly Streamflow and Water Yields for the Awun Basin (1979-2015)*

Fig. 12 shows that the streamflow and water yields in the basin follow a similar pattern. This indicates a close relationship between these hydrological parameters. These hydrological variables also have a direct relationship with precipitation. It has also been observed that the trends in these parameters have remained more or less constant over 37 years. This is consistent with findings from the trend analysis of the rainfall that there are no significant trends in the rainfall values in the basin. This may, however, portend dire consequences as water shortages may be experienced in the near future as the population in the basin increases. It should, however, be noted that the yearly streamflow and water yield for Awun Basin depend not only on precipitation totals, but also on the evapotranspiration, air temperature and temporal regime of the meteorological and hydrological conditions. Attempts to relate the yearly streamflow and water yield for the basin to these other parameters are hereby left for further studies.

4. CONCLUSION

A study on the impact of global warming on the precipitation patterns in Ilorin and its implications on the hydrological balance of the Awun River basin was conducted. It can be inferred from the research conducted that the global climate is undergoing drastic changes and highly variable distributions. Our nation and indeed the study area is no exception to the wave of climate change.

Global warming is indicative of rising temperatures and declining rainfall amounts (IPCC, 2007; NEST, 2003). Its impact on the hydrological cycle has also been carefully analyzed, and the results have shown that the water yield is dwindling; thus the availability of subsurface water and even surface water is expected to take a downward tilt in future projections. What this portends for the study area is increased stress to the water, which may be of concern to farmers, and a possible drop in crop yields as well as increases in physiological (heat) stress.

The study herein revealed that while the minimum and maximum temperatures in Ilorin are increasing, the rainfall is generally decreasing. The assessment of the trends in the water balance parameters of the Awun basin indicates that the water yield has remained more or less constant over an historical period of 39 years. This may result in a decline in the water supply in the near future. This decline in light of increasing temperatures and diminishing rainfall observed from the study of historical, current and future climate projections may result in a significant depletion of freshwater resources with inimical effects on the environment, regional development and socio-economic growth as the population increases in the study area.

REFERENCES

Ajibade, L. T. (2002) *Indigenous Systems of Land Evaluation in the Yoruba Speaking Area of Kwara State.* Unpublished Ph.D Thesis. Obafemi Awolowo University (OAU), Ile-Ife, Osun State, Nigeria.

Bates, B. C. – Kundzewicz, Z. W. - Wu, S. - Palutikof, J. P. (2008) *Climate change and water.* Technical Paper of the Intergovernmental Panel on Climate Change, Geneva; Available at http www.ipcc.ch/ipccreports/ tp-climate-change-water.htm. Accessed 7th Nov 2016.

Environmental resources management final report –ERM- (2009) *Impact of Climate Change on Nigeria's Economy*.

Idowu, S. O. – Capaldi, N. – Fifka, M. – Zu, L. – Schmidpeter, R. (2015) *Dictionary of Corporate Social Responsibility: CSR, Sustainability, Ethics and Governance*. Vienna, New York: Springer Publishing International, 603pp. ISBN 3319105361

Ifabiyi, I.P. (2013) *Impact of Climate Change on Water Resources: Causes and Adaptation.* In: Proceedings of the 1st Regional Workshop of the National Water Capacity Building Network, North Central Regional Centre (NWRCBNet-NC), University of Ilorin. pp 68-83.

IPCC (2001) *Climate change: The scientific basis.* Technical summary of the working group 1 report (Houghton, J.T., Ding Y., Griggs D, J., Moguer M., Van Der Linden, P.J., Dai X., Maskell K., and Johnson C.A.). Cambridge University Press, Cambridge, UK and NY, NY, USA, 94 pp. Online at www.ipcc.ch

Intergovernmental Panel on Climate (IPCC) (2007). *Climate change 2007*. The Fourth Assessment Report (AR4). Synthesis report for policymakers http: // www.ipcc.ch/pdf/assessmentreport/ar4/syr/ar4_ syr_spm.pdf. (Accessed 7th Nov. 2016).

Madueme, T. C. (1999) *The need for long term studies on regional climate change to ensure adequate electric power production.* In Global Climate Change - Impact on Energy Development, Publisher: Damtech Nigeria Ltd, Eds. J. C. Umolu, pp. 220 - 222.

Matthews, H. D. – Graham, T. L. – Keverian S. – Lamontagne, C. – Seto D. - Smith T.J. (2014) *National Contributions to Observed Global Warming.* Environmental Research Letters 9(2014).

National Population Commission – NPC- (2006). *Population Census of the Federal Republic of Nigeria: Analytical Report of the National level*, NPC, Abuja.

Nigerian Environmental Study/Action Team (NEST) (2003). *Climate Change in Nigeria. A Communication Guide for Reporters and Educators.* Ibadan: NEST pp. 5-16.

Odjugo, P. A. (2011).*Climate Change and Global Warming: The Nigerian Perspective.* Journal of Sustainable Development and Environmental Protection. 1(1): 6-17.

Olofintoye, O. – Adeyemo, J. (2011) *The role of global warming in the reservoir storage drop at Kainji Dam in Nigeria.* International Journal of Physical Sciences. 6(19); 4614–4620. Published by Academic Journals.

Olofintoye, O. O. – Sule, B. F. (2010) *Impact of Global Warming on the Rainfall and Temperature in the Niger Delta of Nigeria.* USEP: Journal of Research Information in Civil Engineering, Vol. 7, No. 2, 2010.

Olofintoye, O. – Adeyemo, J. – Otieno, F. (2012) *Impact of Regional Climate Change on Freshwater Resources and Operation of the Vanderkloof Dam System in South Africa.* In Global Warming – Impacts and Future Perspective. Bharat Raj Singh (ed.)165-184. Croatia: Published by InTech – Open Access Company.

Salami, A. W. – Olofintoye, O. O. – Sule, B. F. (2011) *Modeling Global Warming Impact on the Rainfall of Some Selected Cities in the Niger Delta of Nigeria.* Journal of Engineering Research.16(4); 1-12, Published by the Faculty of Engineering, University of Lagos, Nigeria.

Salmi, T. – Määttä, A. – Anttila, P. – Ruoho-Airola, T. – Amnell, T. (2002) *Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates: The Excel Template Application Makesens*. Finnish Meteorological Institute Publications on Air Quality, No. 31, Helsinki, Finland.

Sule, B. F (2003) *Water Security: Now and the Future*. Sixty-fifth Inaugural Lecture of the University of Ilorin, Ilorin, Nigeria.

Sule, B. F. – Alabi, S. A. (2013) *Application of synthetic unit hydrograph methods to construct storm hydrographs.* International Journal of Water Resources and Environmental Engineering. Vol. 5(11), pp. 639-647, Nov., 2013.

Tunde, A. M. – Adeleke, E. A. – Adeniyi, E. E. (2013) *Impact of Climate Variability on Human Health in Ilorin, Nigeria.* Environment and Natural Resources Research; Vol. 3, No. 1; 2013. doi:10.5539/enrr.v3n1p127

Venkataramanan, M. – Smitha (2011) *Causes and effects of global warming.* Indian Journal of Science and Technology, Vol. 4, No. 3 (March 2011) ISSN: 0974- 6846.

Viessman, W. – Knapp, J. W. – Lewis, G. L. (1989) *Introduction to Hydrology*. Harper and Row Publishers, New York.