Modeling Trends of Temperature Effects on Water Level of Rivers in N/E Nigeria

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Abstract
This study investigates temperature variabilities in N/E Nigeria using observations of temperature (^{0}C) from 6 stations from 1981-2010 (30years). Trends in annual and seasonal temperature series were modeled using Mann-Kendall test. The analysis revealed significantly higher ($P<0.01$) in April compare to all the other months with overall mean temperature ranged between 20.2 - 31.8^{0}C among all the locations over months and years. There was significant increase of 0.38^{0}C (positive trend) in temperature in all studied area except Taraba. Each degree rise of temperature of 0.74^{0}C (Gombe), 0.12^{0}C (Adamawa), 0.38^{0}C (Yobe), 0.53^{0}C (Borno) and 0,69^{0}C (Bauchi) and decrease 2.05^{0}C (Taraba) lead to a reduction and increase in water level by 78.77, 19,10, 74.26, 79.62, 20.65 and 209.29 mm respectively. Analyses of decadal trends in the time series further suggest a sequence of alternately decreasing and increasing trends in mean annual temperature in Nigeria during the study period.
Keywords: Modeling, Temperature, Water Level, Rivers, N/E Nigeria.

1. Introduction

Rising temperatures are likely to lower water quality in lakes through increase stability resulting in reduced oxygen concentrations and increase the release of phosphorus from sediments. Sometimes, rising temperature can also improve water quality during winter (Nicholls, 1999). Temperature affects evaporation and availability of water (Glantz, 1992), and regulates physiological processes in humans (Parsons, 2003), animals and crops (Collins, 2011), so rises in temperatures are likely to have wide-ranging impacts. Increasing temperature and changing patterns of precipitation, are among the many consequences, which are attributed to climate change. Regional variations can be much wider, and considerable spatial and temporal variations may exist between climatically different regions (Dammo et al., 2015).The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) revealed an increasing trend in global average temperature since 1850 and recognised (Christensen et al., 2007; Jones et al., 2007; Pachauri, 2007; Trenberth et al., 2007). Global mean temperature was recognized to have increased by 0.76 °C within the period of 1850 to 2005. Depending on global action to reduce greenhouse gas emissions, a predicted further rise in temperature of 1–5 °C within and beyond this century is envisaged (Jones et al., 2007). The IPCC noted that the predicted increase in average global temperature was highly likely due to emissions of anthropogenic greenhouse gases (Hegerl et al., 2007). In most parts of the world, both minimum and maximum temperatures have increased with significant positive trends beyond that predicted to be caused by natural variability (Brown et al., 2008). Many researchers analyzed the temperature time series from various climate change perspectives across a wide range of temporal and spatial scales. However, the analysis of trends in the temperature time series is a challenging aspect of climatological studies and a number of studies examined trends of temperature in different parts of the world, indicating statistically significant warming (Thomas et al, 2013)**.** Temperature increase will cause ecological stress that could impair the functioning of ecological systems particularly in terms of plant growth and development. Settlements will similarly be affected as difficult condition forces people to move to marginal lands (Onyenechere, 2010). Diseases that luxuriate under high temperature may in all probability be amplified under changing climate driven by increased temperature.

2.0. Materials and Methods

2.1. The study area

The study site cover an area of aproximately 157,000 sq km located between latitude 10^0 03′ 00′′ – 13^{0}50′ 00′′E and longitude 7^0 43′ 00′′ – 12^0 45′ 00′′ N.

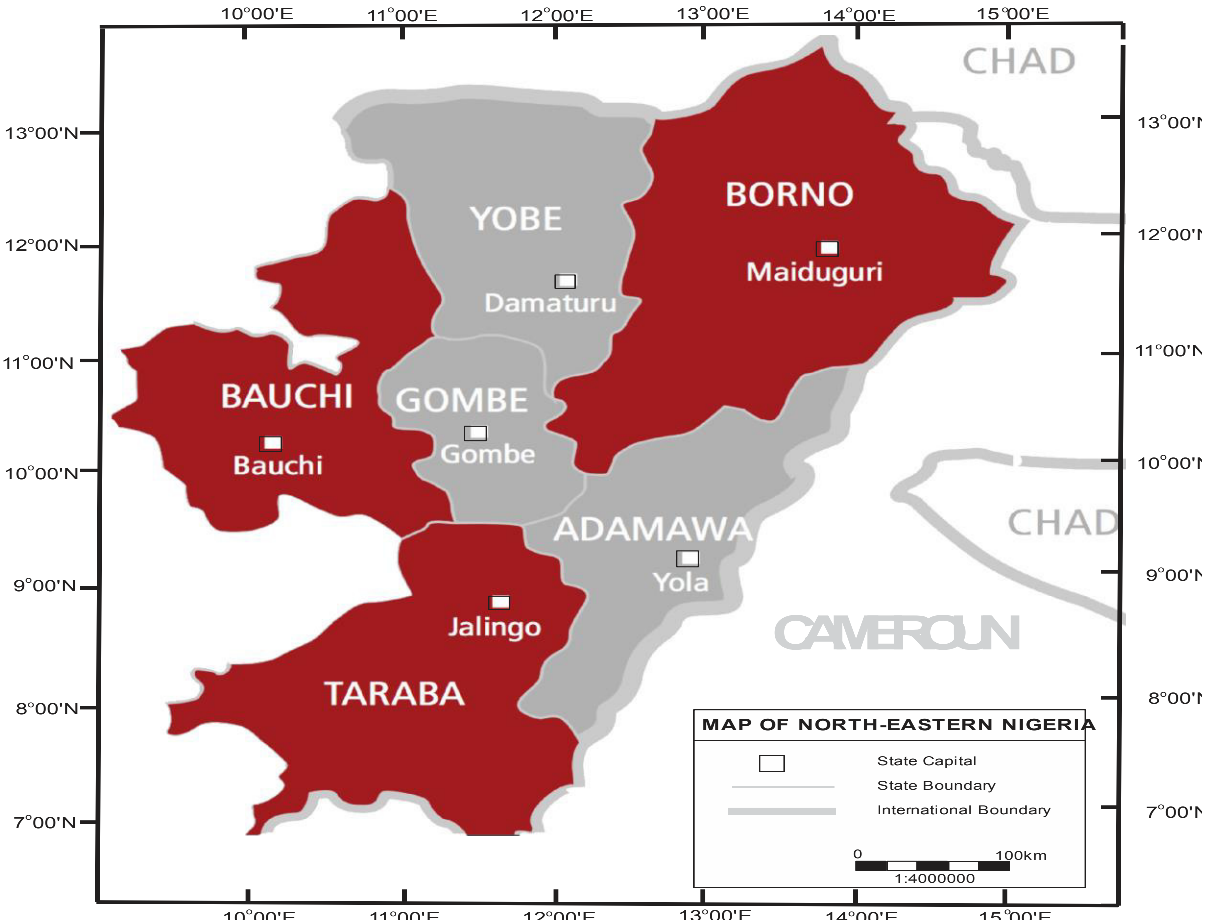

Fig. 1: Map of North Eastern Nigeria
Source: Lands and Survey Maiduguri, 2011

2.1.1. Methodology

Data were collected on temperature for a period of 30 years, (1981 – 2010). Existing gaps were generated using the model of Monte Carlos (1994). Analysis of variance were carried out to test whether the mean monthly temperature observed in the region are the same for the year 1981-2010 or vary significantly. Regression was used to quantitatively sort out multiple effects of climatic parameter on water level (multiple regressions) in order to generate model showing relative contribution. Mathematical models were developed using the coefficients obtained from the actual regression, to predict water rainfall as described by Mann-Kendall and Spearman rank statistics given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sign}\,(x_j - x_k)$$

$$\text{Sign}\,(x_j - x_k) = 1 \text{ if } x_j - x_k >|0$$
$$= \text{if } x_j - x_k = 0$$
$$= -1 \text{ if } x_j - x_k < 0$$

Where,
x_J represents the data point at time j.
x_k represents the data point at time k

3.0. Results and Discussion

Pattern for monthly temperature for the 6 locations are shown in Fig. 4.6d. The trend is of 4th order polynomial. There was a monthly rise in temperature of between 3.71 and 16.33^{0}C between January and April. This subsequently decreased to between 1.10 - 4.32^{0}C between May and December (Fig. 1). Temperature impacted negatively on water level at Gombe, Adamawa, Taraba and Yobe. Each rise in temperature of 0.03, 0.04, 0.01 and 0.07^{0}C (Table 1) led to a reduction in water level by 78.77, 19.10, 209.29 and 74.26 mm in the respective sites (Table 2.) The highest adverse effect of temperature on water level was observed at Taraba, followed by

Gombe, Yobe and Adamawa. Conversely, temperature did not result in water level reduction in Borno and Bauchi, rather contributed positively. Positive and negative contribution may be attributed to the changes in climate variables in those locations. However, the positive rise in temperature is an evidence of climate change resulting from population increase and excessive emission of CO_2 and greenhouse gases into the atmosphere (IPCC, 2007). The increased global warming has the capacity to trigger large-scale climatic disturbances which ultimately may have significant impact on rainfall, evaporation and relative humidity (Igweze et al., 2014).

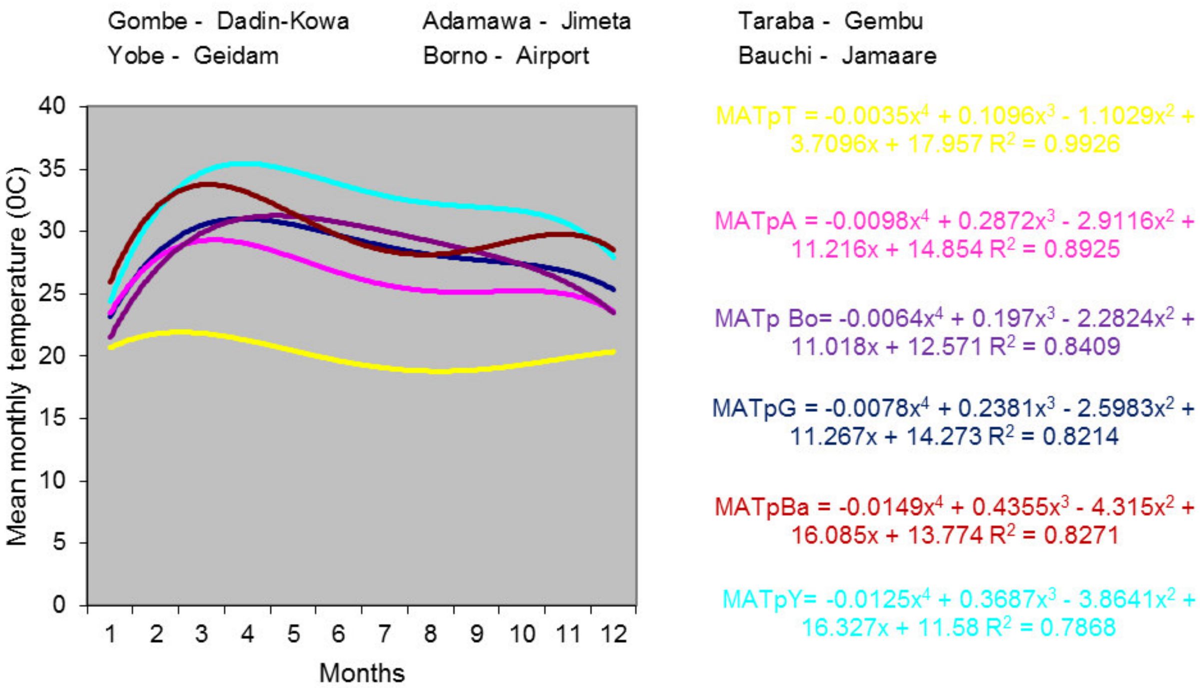

Fig 1: Mean monthly pattern of rainfall across 6 locations in N/E Nigeria
MATp= Mean annual temperature (^{0}C)
T-Taraba, A-Adamawa, Bo- Borno, G-Gombe, Ba-Bauchi and Y-Yobe

Table 1: Mean annual temperature for 3 decades in 6 Gauge Rivers in N/E Nigeria (^{0}C)

	Average Temperature (^{0}C)			
Gauge Rivers	1981 – 1990	1991 – 2000	2001 – 2010	Station
Dadin-kowa	27.66	27.96	28.70	Dadin – kowa
Jimeta	26.76	25.75	25.87	Jimeta
Donga	20.71	20.81	18.76	Gembu
Geidam	31.73	31.68	32.06	Geidam
Alau	29.29	27.78	28.31	Airport
Jamaare	29.57	29.71	30.4	Jamaare
Range	20.71 – 31.73	20.81 – 31.68	18.76 – 32.06	

Table 2: Model effects of temperature on water level in 6 locations of N/E Nigeria

Locations	Effects
Gombe	$\hat{y}_G = -0.07877tp$
Adamawa	$\hat{y}_A = -0.01910tp$
Taraba	$\hat{y}_T = -0.20929tp$
Yobe	$\hat{y}_Y = -0.07426tp$
Borno	$\hat{y}_{Bo} = +0.07962tp$
Bauchi	$\hat{y}_{Ba} = +0.02065tp$

Model equation of effect of temperature on water level N/E Nigeria

WL = 3.49 - 0.0415 MATEMP

Model equation of mean annual temperature commonly distinguishes the effects of temperature on the amount of water received in rivers in the 6 locations. The temperature in these specific sites contributed to decrease in water level of rivers, in which each degree rise in temperature resulted in decrease in water level. The model was validated by subjecting data obtained to obtain predicted water level. Fig 2 show a comparison between predicted and observed water levels obtained from the effect of temperature in all the locations. A good linear relationship ($r^2 = 0.985$) was obtained between predicted and observed water levels with most of the data points uniformly scattered on a straight line with high coefficient of determination. This implies that the relationship between the observed and predicted values of water levels exhibit a tendency towards a clear model that tracked well the observed data.

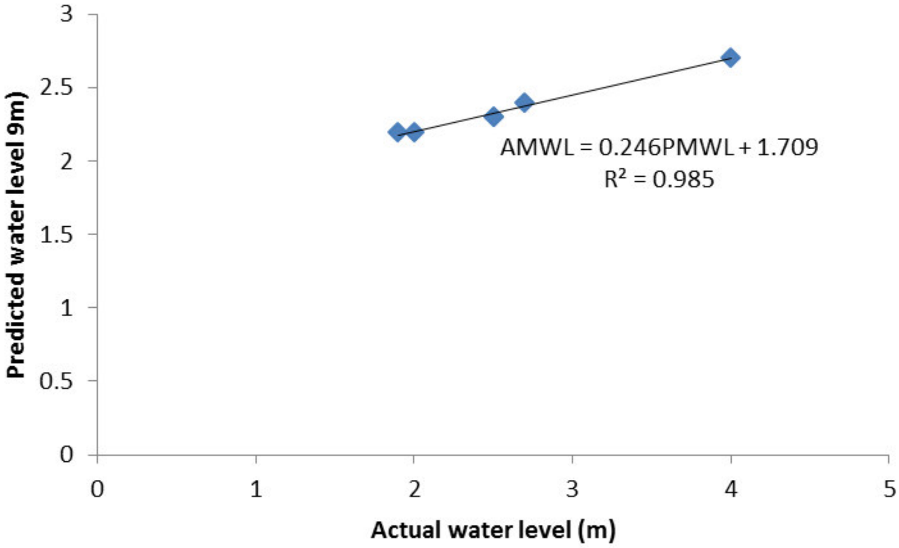

Fig 2: Predicted versus Actual water level

4.0. Conclusion

There was significant variability on the effects of temperature on water level. Temperature had larger profound effect on the water level within the study area. Developed model could be used in predicting water level of rivers in North – east Nigeria with 98.5% certainty.

5.0. Recommendation

- The study on effect of temperature on water level need to be carried out from time to time in order to validate the model developed in this study.
- Research needs to be conducted to investigate whether effect of temperature will respond the same way to water levels in other regions of the country.

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