Empirical Estimation of the Effects of Climate Change on Drainage Sections

Ibeje, A.O.

Department of Civil Engineering, Imo State University, Owerri, Nigeria,
engineeribeje@gmail.com

Abstract

Variability in climate change has compromised the design capacity of drains. Proper estimation of climate impacts on runoff is therefore necessary for the design of efficient and effective hydrologic sections. In this study, drainage sections were designed by incorporating climate-induced changes in runoff after quantifying the changes in annual runoff due to climate variability. The variability in each meteorological variable was used to estimate the climate-induced changes in the annual runoff. This approach was applied in some river basins in Southeast Nigeria and the highest change of 1.68 m^3/s, in annual runoff, was observed in the River Adada in Enugu State, and 0.04 m^3/sin Otamiri River, Imo State. It was also observed that climate change did not significantly affect the drainage sections in Abakiliki and Umuahia although only the drainage width increased by 0.1% in Awka. There was a very significant change of 7% in the dimensions of the drain located in Adada watershed, Enugu while in the Otamiri river basin, Owerri, 0.2%change in the drainage capacity was estimated. It is evident that this study highlights the need for incorporating the excess climate-induced runoff volumes caused by climate change, in the design of efficient and safe hydrologic structures.

Keywords: climate, design, drains, hydrology, meteorology

1. INTRODUCTION

CLIMATE which is the regular pattern of weather conditions of a place, is reported to be stable if there is insignificant variation in weather elements over a long period of time (Akamigbo and Ninja, 2011).Olusina and Odumade (2012) defined climate change as the change in the statistical properties of climate when considered over long periods of time, regardless of cause. Climate fluctuations over periods shorter than few decades do not represent climate change. As global temperature increased by $0.6 \pm 0.2^{\circ}$over 100years (Folland et al., 2001), the concentration of greenhouse gas (GHG) such as CO_2 increased from 282ppm to 365ppm between 1800 to 2000 (Rosegrant et al., 2002), confirming that GHG is responsible for global warming. These gases, which are either volcanic or anthropogenic in origin, absorb terrestrial radiations from the earth and eradiate the heat back to the earth, thereby leading to earth surface temperature increase called global watering (Ozor, 2009)

Climate change is a global phenomenon that is experienced in many countries in different forms. According to UCS (2010), rain that should have fallen in different days of a month fell within a day or two causing massive floods in parts of India, Pakistan, USA, UK and Japan in 2014. Climate change also manifests as trends in various meteorological records, particularly temperature (Nwaiwu et al., 2014). In Nigeria, increasing temperatures and decreasing rainfall in the semi-arid region of Sokoto, Kastina, Kano, Nguru and Maiduguri have induced increased evaporation, drought and desertification with consequent drying up of some water bodies like Lake Chad (Ayuba, 2005). Like other parts of the globe, Nigeria is highly vulnerable to the impacts of climate change. Climate change was also reported to have increased the number of dry spells during the rainy season from May to September in some areas of Sudan-Sahelian region of northern Nigeria (Sawa, 2010). In high grounds of Jos, Yelwa and Ilorin, Abiodun et al. (2011) asserted that the temperatures have increased from 0.20 to 0.50 while in the southwest areas like Shaki, Isoyin and Ondo, 0.9 to 1.90 increase in temperature was observed. According to another study by Abiodun et al. (2011), there was 0.014 per year rise in minimum temperature in Nigeria while the incidence of heat wave has increased by more than 20 days between 1971 and 2000. Ojo (2008) suggested that climate change in Nigeria was in the form of trend in rainfall and temperature. Oladipo (2008) therefore projected a decrease in rainfall and consequently drier conditions in the Guinea, Sudan and Sahel Savannah while Ojo (2008) expected that precipitation would probably increase by 5-20% in the humid areas of the Savannah areas of Nigeria.

Nigeria is not left out in the occurrence of extreme floods as a manifestation of climate change. Extreme floods are recently prevalently in the southern and the Middle belt region of Nigeria. Ibekwe (2012) also reported that farmlands were submerged and destroyed in 2012 and people were displaced in the States of Benue, Niger, Kogi, Edo and Rivers surrounding the Rivers Niger, Benue and Cross-river. Between 2010 and 2013, massive flooding has led to collapse of earth dams, contamination of water supply and sanitation facilitation (IFRC, 2003).

The significance of extreme flooding events in southeast Nigeria in general prompts the consideration of the contribution of climate change to runoff generation in the region. In southeast Nigeria, extreme flooding events contribute to the shaping of landscapes through an erosion process and hence determine the type, location and dimensions of hydrologic infrastructure (Okonkwo and Mbajiorgu, 2010). Excess runoff from sustained rainfall has even seriously damaged the riverbeds (Frei et al., 2001). With the impact of extreme precipitation and sea level rise on flood risks, the current design capacity of flood infrastructures are not robust enough to cope with the climate-related flooding. There is a need to incorporate information about the present and future climate variability into the planning and management of water channels.

The format followed is to sequentially access the variability in each of the meteorological variable, thereafter quantifying the changes in annual runoff due to climate variability, then the design of drainage sections while incorporating climate-induced changes in runoff, and finally assessment of the percentage in drainage section due to climate change is implemented. To demonstrate this approach, flood data of six selected gauged catchments in Anambra-Imo River basin located in the southeast region of Nigeria, were used to estimate effects of climate change on drainage sections.

2. METHODOLOGY

2.1 STUDYAREA

Rivers Adada, Ajali, Imo Ivo and Otamiri are all located in the Anambra-Imo River basin of Southeast Nigeria. The southeast Nigeria is located within the tropical rainforest belt of Nigeria. About 60-70% of the inhabitants of this region are engaged in the cultivation of cash crops due to the favorable weather provided by the tropical rainforest (Okoye et al., 2010). Figure 1 shows that Adada River basin in Enugu State, Nigeria is situated between latitude: $6^0 25'$-$6^0 45'$ N and longitude: $7^0 00'$ E-$7\ ^0 23'$E (Nweke, 2015). In Table 1, Obasi et al. (2017) reported that Ajali River watershed gauged at Aguobu Umumba in Ezeagu North Local Government Area (L.G.A.) of Enugu State, Nigeria is located at latitude: $6^0 28'0''$N to $6^0 16'0''$N and longitude: $7^0 6'0''$E to $7^0 24'0''$E at an elevation of 52m. The Otamiri River catchment area measures about 100 square km^2 in Imo state, Nigeria. The source of the Otamiri River is located on latitude $05^0 26'$N and on longitude $07^0 02'$E (Ibe et al., 2003). Unlike Rivers Otamiri, Adada and Ajali which are located in Anambra-Imo river basin of southeast Nigeria, the Ivo River Basin is a sub-basin of the Cross River basin of south-south Nigeria. Figure 1C show that it is geographically located within latitudes $5^0 51'$N to $5^0 59'$N and longitudes $7^0 24'$E to $7^0 40'$E. It covers an area of over $450Km^2$ (Ezekwe et al., 2012).

The tributaries of River Ivo pass through Abia, Ebonyi and Enugu States (Ezekwe et al., 2019). The catchment area of River Ivo lies at the southern end of the Lower Benue trough of Nigeria.

On the other hand, Amangabara (2015) asserted that Imo River drains three States, namely Imo State, Abia State and Rivers State. The total area drained by this river in Imo, Abia and Rivers State is about 7,770 km^2 (Amangabara, 2015). The gauging stations of these rivers considered in the study are given in Table 1.

Table 1. *Geographical Location of the Rivers*

STATE	RIVER	STATION	LAT.	LONG.	CATCHMENT AREA (Km^2)	ZERO LEVEL OF GAUGE (m)	GBM LOCAL(m)
IMO	Otamiri	Nekede	05°26'N	07°02'E	100	97.71	100
Abia	Abia	Umuopara	05°33'N	07°25'E	1450	86.50	100
Anambra	Adada	Umulokpa	06°38'N	07°11'E	890	NA	NA
Enugu	Ajali	Aguobu-umumba	07°19'N	07°13'E	900	NA	NA
Ebonyi	Ivo	Imezi-Olo	06°28'N	06°11'E	125	NA	NA

NA* = Not Available

Source: AIRBDA, 2010

2.2 METHOD OF DATA COLLECTION

Monthly discharge records that were used cover over 10 years for the selected Rivers Ajali and Adada in Enugu State, Otamiri in Imo State, Ivo in Ebonyi State and Imo in Abia State (Table 1). The discharge data were obtained from the Anambra-Imo River Basin Development Authority (AIRBDA).Records of monthly climatic data were rainfall depth, maximum and minimum air temperatures, sunshine hours, evaporation, humidity, wind speed, soil temperature, cloud cover, solar radiation, and atmospheric pressure for the cities of Umuahia in Abia, Awka in Anambra, Abakaliki in Ebonyi, Enugu in Enugu and Owerri in Imo states were obtained from the Nigerian Meteorological Agency. The data spanned variedly between 1922 and 2008 (86 years) for all stations, but the length of data varied among the different climatic variables. By adopting the approach used by Adepitan *et al.* (2017), SPSS statistical software was used to estimate the statistical parameters of the climate variables.

2.3 QUANTIFICATION OF CLIMATE CHANGE

The climatic change was calculated as the percentage difference of the mean annual climate for rainfall, evaporation and humidity. However, for sunshine hour, temperature and wind speed, the climatic change was calculated as the mean of the annual mean change increment according to the approach by Sankarasubramaniam *et al.* (2001) which are expressed in Eqs. (1) – (6).

$$\Delta I\% = \frac{\bar{I}_{20th}-\bar{I}_{19th}}{\bar{I}_{19th}} * 100\% \text{ ---------------- } (1)$$

$$\Delta E\% = \frac{\bar{E}_{20th}-\bar{E}_{19th}}{\bar{E}_{19th}} * 100\% \text{ ---------------- } (2)$$

$$\Delta H\% = \frac{\bar{H}_{20th}-H_{19th}}{\bar{H}_{19th}} * 100\% \text{ ---------------- } (3)$$

$$\Delta S = \bar{S}_{20th} - \bar{S}_{19th} \text{ --------------------- } (4)$$

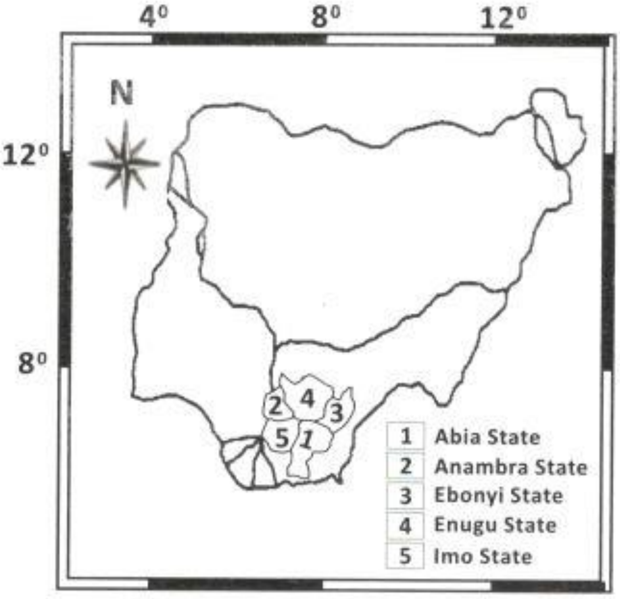

Fig: 1a

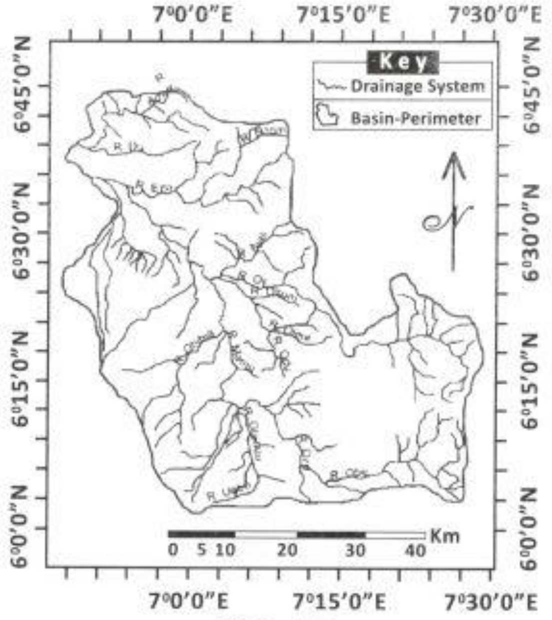

Fig: 1b

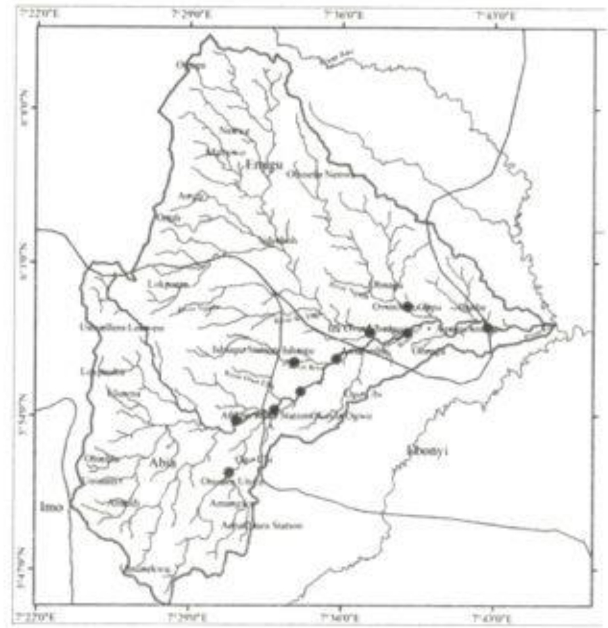

Fig: 1c

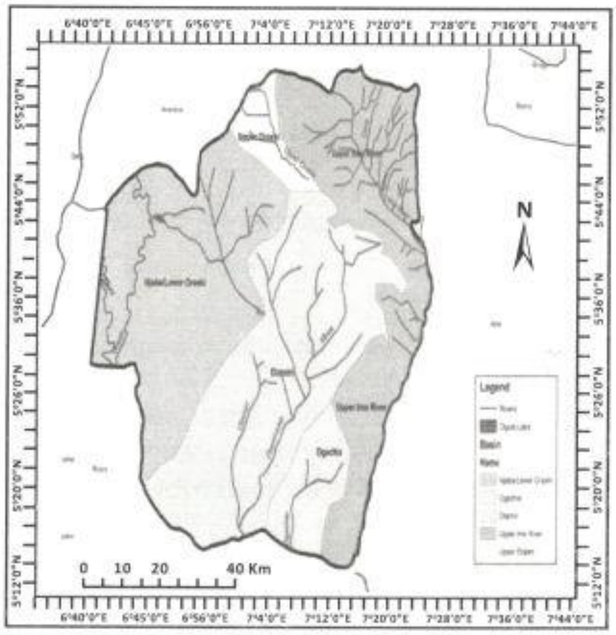

Fig: 1d

Figure 1: Fig. 1A Map of Nigeria showing the location of the states of the southeast region, Fig. 1B Map of Enugu state showing Rivers Adada and Ajali, Fig. 1C Map of Ebonyi state showing River Ivo, Fig. 1D Map of Imo State showing Rivers Otamiri and Imo.

$$\Delta W = \overline{W}_{20th} - \overline{W}_{19th} \quad \text{--------------} \quad (5)$$

$$\Delta T = \overline{T}_{20th} - \overline{T}_{19th} \quad \text{---------------} \quad (6)$$

Where ΔI = climatic change in Rainfall Intensity, ΔS = climatic change in Sunshine Hours, ΔT= climatic change in Air Temperature, ΔTs = climatic change in Soil Temperature, ΔE = climatic change for Evaporation, ΔH = climatic change for Humidity, ΔW = climatic change in wind velocity, ΔR = climatic change in Solar Radiation

The effect of climatic change on annual runoff was deduced by factoring the climate change scenario, i.e. the sum of climate change and the climatic variables and yielded the expression in Eq. (7):

$$\Delta Q + Q = 10^{\alpha_0} * I\left(\frac{\Delta I\%}{100}+1\right)^{\alpha_1} * (S+\Delta S)^{\alpha_2} * (T+\Delta T)^{\alpha_3} * E\left(\frac{\Delta E\%}{100}+1\right)^{\alpha_4} * H\left(\frac{\Delta H\%}{100}+1\right)^{\alpha_5} * (R+\Delta R)^{\alpha_7} * (T_s+\Delta T_s)^{\alpha_8} * (W+\Delta W)^{\alpha_9} \text{ ---}(7)$$

The Climate-Flood Model was formulated with runoff at the gauging station as a function of climate variables as in Eq. (8);

$$Q = \alpha_0 * I^{\alpha_1} * S^{\alpha_2} * T^{\alpha_3} * E^{\alpha_4} * H^{\alpha_5} * W^{\alpha_6} * R^{\alpha_7} * T_s^{\ \alpha_8} \text{ ------------------ } (8)$$

But to quantify changes in annual runoff due to climate change, ΔQ, runoff predictions made from Eq. (8) were subtracted from those made from Eq. (7) which implied that Eq. (9) is:

$$\Delta Q = (\Delta Q + Q) - Q = \text{Equation 7} - \text{Equation 8} \text{ ------------------------- } (9)$$

2.4 HYDRAULIC DESIGN OF THE DRAINS

The nature of the pavement surface was assumed to be flat, while the Manning Constant, n = 0.013. According to the Nigerian Highway Manual Part I for flat pavement, the runoff coefficient, c= 0.9,100m length of the drains was fed by 0.85 catchment area *A* at a Return period of 10 years at a time of concentration, T_c of 15mins. The slope of drain, S was obtained using the relation according to Agunwamba (2001) in Eq. (10):

$$S = \left(\frac{0.0194L^{0.77}}{Tc}\right)^2 \text{ -------------------------- } (10)$$

The design discharge was computed using the rational formula according to Agunwamba (2001)to obtain Eq. (11):

$$Q = 0.278CiA \text{ ------------------------------ } (11)$$

Where Q is discharge (m^3/s); C is runoff coefficient, defined as the ratio of runoff from an area to the rainfall in that area; I = the rainfall intensity (mm/hr) and A = area of the drainage basin (km^2), discharging into the outlet under consideration.

For the time of concentration, T_c= 15mins and Return period, T of 10years, the corresponding rainfall intensities, i for the respective River basins of Otamiri, Adada, Ajali, Ivo and Imo (Umuopara) were obtained using the rainfall intensity-frequency-duration curves of Owerri, Enugu, Awka, Abakiliki and Umuahia prepared by Okonkwo and Mbajiorgu (2010).

3.0 RESULTS AND DISCUSSION

The amount of change in climate variables in the study areas was computed using Eqs (1) to (6). The results of the computations are presented in Table 2. From Table 2a, it can be observed that Owerri had the highest positive change in evaporation of 0.11% and the lowest positive change in evaporation of 0.06% occurred in Abakaliki. This is consistent with the highest trend rate of evaporation that was observed in Owerri (Ekwueme, 2000).The other cities had a negative change in evaporation. From Table 2b, it can be observed that Awka had the highest positive change in rainfall of 0.41% and the lowest change in rainfall of 0.13% occurred in Abakaliki. This is consistent with the lower trend rate of rainfall that occurred in Awka (Ekwueme, 2000). Owerri, Enugu and Umuahia all had negative changes in rainfall. Table 2c shows that Awka had the highest positive change in relative humidity of 0.08%. This is consistent with the result of trend analysis of relative humidity by Ekwueme (2000) in which Awka had the highest trend rate in the southeastern region of Nigeria. The lowest change in relative humidity of -0.09 occurred in Abakaliki and Owerri. From Table 2e, it can be observed that Awka has the highest change in sunshine hours of 0.03. The lowest change in sunshine hours occurred in Owerri and Umuahia. Table 2f shows that Enugu had the highest change in wind speed of -0.08. This is consistent with the result of trend analysis for wind speed by

Ekwueme (2000) in which Enugu had the most significant trend in the southeastern region of Nigeria. The lowest change in wind speed occurred in Abakaliki, Owerri and Awka. From Table 2g it can be observed that Umuahia has the highest change in solar radiation of 0.08, the lowest change in radiation of -0.01 occurred in Abakaliki. This did not follow from the result of previous study by Ekwueme (2000) in which the highest trend rate of solar radiation occurred in Awka. From Table 2h, it can be observed that Enugu has the highest change in air temperature of 0.12. This follows from the result of previous study by Ekwueme (2000), in which Enugu had the most significant trend as well as the highest rate of decrease in air temperature (0.04698°C/year) in the southeastern region of Nigeria. The no change in air temperature of was observed in Awka. From Table 2d, it can be observed that Umuahia has the highest change in soil temperature of 0.12 while the lowest change in soil temperature of 0.1 occurred in Awka and Abakaliki. This is inconsistent with the result of trend analysis of soil temperature by Ekwueme (2000) in the southeast, Nigeria in which the highest rate of increase in soil temperature occurred in Enugu (0.2381°C/year).

The quantity of change in runoff in the study areas was computed using Eq. (9). The effect of climatic change on runoff was deduced by substituting the sum of climate change and respective annual records of climatic variables to yield values of $Q + \Delta Q$. To quantify changes in annual runoff due to climate change, ΔQ, runoff predictions, Q, made from climate-flood models using only the respective annual records of climatic variables were subtracted from those made for the values of $Q + \Delta Q$ and mean change in runoff due to climate change was evaluated for all the rivers under study as shown in Table 3. The highest mean change of 1.68 m^3/s in the annual runoff in the southeastern Nigeria due to climate change was observed in Adada River in Enugu State.

The mean change of 0.04 m^3/s observed in Otamiri River was entirely due to climate change. Otamiri River has huge variations arising mainly due to non-climatic factors has the ever increasing population of Owerri relies on the River for water supply (Ekwueme, 2000). River Imo (Umuokpara) has insignificant change of 10^{-27} m^3/s in annual runoff due to climate change because evaporation, solar radiation and air temperature are significant predictors of runoff in this river (Ekwueme, 2000). These significant climatic represent sources, losses in the river countering the significant increasing trend of rainfall, thus producing a net zero change in the runoff of the river.

Table 2. Quantified Change in Climate in Southeast Nigeria

Table 2a: *Quantified Change in Evaporation in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ	Δ%
Owerri	4.31	4.31	0	0.11
Umuahia	4.59	4.59	−0.01	−0.21
Enugu	3.38	3.39	0	−0.1
Abakiliki	3.86	3.85	0	0.06
Awka	3.26	3.26	0	−0.09

Table 2b: *Quantified Change in Rainfall in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ	Δ%
Owerri	202.31	205.76	−3.45	−1.68
Umuahia	177.91	178.45	−0.55	−0.31
Enugu	142.32	142.59	−0.27	−0.19
Abakiliki	166.15	165.92	0.22	0.13
Awka	153.86	153.23	0	0.41

Table 2c: *Quantified Change in Relative humidity in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ	Δ%
Owerri	78.17	78.23	−0.07	−0.09
Umuahia	79.05	79.16	−0.11	−0.14
Enugu	72.61	72.79	−0.18	−0.25
Abakiliki	73.2	73.26	−0.06	−0.09
Awka	69.76	69.71	0.05	0.08

Table 2d: *Quantified Change in Soil temperature in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ
Owerri	24.94	205.76	−3.45
Umuahia	24.97	178.45	−0.55
Enugu	26.82	142.59	−0.27
Abakiliki	25.63	165.92	0.22

Table 2e: *Quantified Change in Sunshine hours in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ
Owerri	4.32	4.31	0
Umuahia	4.41	4.4	0
Enugu	5.42	5.43	−0.01
Abakiliki	5.51	5.52	−0.01
Awka	4.78	4.77	0.03

Table 2f: *Quantified Change in Wind speed in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ
Owerri	4.21	3.21	0
Umuahia	4.47	4.47	−0.01
Enugu	5.5	5.64	−0.08
Abakiliki	3.62	3.62	0
Awka	4.05	4.05	0

Table 2g: *Quantified Change in Radiation in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ
Owerri	12.91	12.93	−0.02
Umuahia	11.1	11.02	0.08
Enugu	12.73	12.74	−0.02
Abakiliki	12.74	12.75	−0.01
Awka	18.11	18.13	−0.03

Table 2h: *Quantified Change in Air temperature in Southeast Nigeria*

STATES	$\overline{x}_{20}$	$\overline{x}_{19}$	Δ
Owerri	27.44	27.39	0.05
Umuahia	26.55	26.52	0.02
Enugu	29.35	29.23	0.12
Abakiliki	26.42	26.41	0.01

Table 3. Quantified Changes in Annual Runoff in South Eastern Nigeria due to climate change

River	Otamiri Owerri	Adada, Enugu	Ajali, Awka / Onitsha	Ivo, Abakalili	Imo, (Umuokpara Umuahia)
ΔQ m^3/s	0.04	1.68	0.012	0.001	10^{-27}

3.2 ESTIMATE OF THE SLOPE OF DRAIN

The slope of the drain *S* was obtained using Eq. (10) as 0.01712 and from Eq. (11) the expression for the design runoff for drainage channel was evaluated as in Eq. (12):

$$Q = 0.21267i \quad \text{------------------ (12)}$$

However, design runoff impacted by climate change was calculated by adding the change in runoff due to climate change ΔQ, thus Eq. (13):

$$Q + \Delta Q = 0.21267i + \Delta Q \quad \text{----------- (13)}$$

For the time of concentration, T_c= 15mins and Return period, T of 10years, the respective rainfall intensities, i, of Owerri, Enugu, Awka, Abakiliki and Umuahia, as given by Okonkwo and Mbajiorgu (2010), were used to estimate the corresponding design runoff and climate-impacted design runoff for drainages located in the respective River basins of Otamiri, Adada, Ajali, Ivo and Imo (Umuopara) using Eqs. (12) and (13). The results are presented in Tables 4 and 5.

Table 4. Estimated Design Runoff for the Capital Cities of Southeast Nigeria

City	Owerri	Enugu	Awka / Onitsha	Abakalili	Umuahia
ΔQ m^3/s	7.975	6.891	7.039	7.146	7.273

Table 5: Climate-impacted Design Runoff for Southeast Nigeria

City	Owerri	Enugu	Awka / Onitsha	Abakalili	Umuahia
ΔQ m^3/s	7.975	6.891	7.039	7.146	7.273
ΔQ (m^3/s)	0.04	1.68	0.012	0.001	–
$Q+\Delta Q$ (m^3/s)	8.015	8.571	7.051	7.146	7.273

3.3 ESTIMATED DESIGN SECTION

Substituting the values of the slope of drain = 0.01712 and n = 0.013 in the Manning's expression for optimal capacity of rectangular drain and equating it to the design runoff, Q (Eq. (12)), we have: Eq. (14).

$$Q_c = \frac{3.17496y^{\frac{8}{3}}(0.01712)^{\frac{1}{2}}}{0.013} = 31.95475y^{\frac{8}{3}} = Q = 0.21267i \quad (14)$$

Hence, the design section of the rectangular drain is given by the following expressions in Eqs. (15) and (16):

$$y = (0.00665535i)^{\frac{3}{8}} \quad (15)$$

$$b = 2y = 2(0.00665535i)^{\frac{3}{8}} \quad (16)$$

To obtain the rectangular section $y + \Delta y$ and $b+\Delta b$ impacted by climate change, equating the Manning's expression for optimal capacity of rectangular drain and Eq. (12), Eq. (17) is derived:

$$Q_c = \frac{3.17496y^{\frac{8}{3}}(0.01712)^{\frac{1}{2}}}{0.013} = 31.95475y^{\frac{8}{3}} = Q + \Delta Q = 0.21267i + \Delta Q \quad (17)$$

Hence, the design section of the rectangular drain impacted by climate change is given by the following expressions in Eqs. (18) and (19):

$$y = \left(0.00665535i + \frac{\Delta Q}{31.95475}\right)^{\frac{3}{8}} \quad (18)$$

$$b = 2y = 2\left(0.00665535i + \frac{\Delta Q}{31.95475}\right)^{\frac{3}{8}} \quad (19)$$

Eqs (18) and (19) were used to obtain sections of the drains and the results are recorded in Table 7. It can be observed that climate change did not significantly affect the sections of drains in Abakiliki and Umuahia whereas only the width of the drain was affected by 0.1% in Awka. There was a very significant change of 7% in the dimensions of the drain located in Enugu due to climate change. This has notably serious engineering implications in the design of hydraulic structures in Adada river basin because failure to account for these differentials occasioned by climate change could result in economic and hydrologic damages. This is a very important finding of this study and is evidently supported by the highly significant trend in climate variables in Enugu suggested possible increase design sections of hydraulic structures in Enugu. The climate-flood model of Adada River, Enugu was the most significant regression model in southeast Nigeria for prediction of annual runoff. The change in design sections in the Otamiri river basin, Owerri was 0.2% in the dimensions of the drain.

Table 6. Design Rectangular Section of Drain in Southeast Nigeria

City	Owerri	Enugu	Awka / Onitsha	Abakalili	Umuahia
y (m)	0.594	0.569	0.567	0.57	0.574
b (m)	1.188	1.138	1.134	1.14	1.148

Table 7: Climate-impacted Rectangular Section of Drains in Southeast Nigeria

City	Owerri	Enugu	Awka / Onitsha	Abakalili	Umuahia
$y + \Delta y$ (m)	0.595	0.61	0.567	0.57	0.574
$b + \Delta y$ (m)	1.191	1.221	1.135	1.141	1.148
Δy %	0.168	7.206	0	0	0
Δb %	0.253	7.293	0.088	0	0

4. CONCLUSIONS

Changes in climate variables caused by climate change were quantified. Climate-flood models were used to ascertain the climate change impact on annual runoffs in the selected catchment areas. The highest change of 1.68 m^3/s in the annual runoff was observed in Adada River in Enugu State. The change of 0.04 m^3/s observed in Otamiri River was entirely due to climate change. It is not conclusive, however, why global warming is specifically highly sensitive to changes in rainfall and water availability. Continuous direct measurements of runoff and its measures could illustrate the relationship between the increase in annual runoff and global warming.

The predicted and climate-impacted runoffs were comparatively used in the hydraulic design of drains in southeastern Nigeria. It can be observed that climate change did not significantly affect the sections of drains in Abakiliki and Umuahia whereas only the width of the drain was affected by 0.1% in Awka. There was a very significant change of 7% in the dimensions of the drain located in Enugu due to climate change. This highly significant trend in climate variables in Enugu suggested possible increase design sections of hydraulic structures in Enugu. The change in design sections in the Otamiri river basin, Owerri was 0.2%.

REFERENCES

Abiodun, B.J., Salami, A.T. and Tadross, M. (2011). Climate Change Scenarios for Nigeria: Understanding Biophysical Impacts. South Africa: Building Nigeria's Response to Climate Change (BNRCC) Project.

Akamigbo, F.O.R. and Nnaji, G.U. (2011). **Climate change and Nigerian soils: vulnerability, impact and adaptation.** ***Agro-Science*** *Journal of Tropical Agriculture, Food, Environment and Extension*.10 (1), 80-90.

Amangabara, G.T. (2015). Drainage morphology of Imo Basin in the Anambra-Imo River basin area, of Imo state, southern Nigeria. *JGEESI* 3(1),1–11. https://doi.org/10.9734/JGEESI/2015/17114

Anambra-Imo River Basin Development Authority (AIRBDA) (2010). *Hydrological Year Book*

Ayuba, H.K.(2005). *Environmental Science: An Introductory Text*. Kaduna. Apani Publications.

Frei, C., Davies, H.C., Gurtz, J. and Schär, C. (2001). Climate dynamics and extreme precipitation and flood events in Central Europe. *Integrated Assessment*, **1**, 281–299.

Ekwueme, B. (2020). *Analysis and Prediction of the Effect of Climate Change on Flood in Southeastern Nigeria*. Unpublished Ph.D. Thesis. Faculty of Engineering, University of Nigeria, Nsukka.

Ezekwe, I.C., Aisubeogun, A. O., Chima, G.N., Odubo, E. (2012). TDS-Eh graph analysis: a new water quality index and rural water supply implications of a river affected by mining in southeastern Nigeria. *Frontiers of Earth Science.* 6(1), 66-74. https://doi.org/10.1007/s11707-011-0201-2

Ezekwe, I.C., Clinton, I., Oyediran, A.G. and Asiegbu, O.V. (2019). Preliminary Investigation of the Distribution and Relative Abundance of Plankton and Fish Species in Ivo River Basin Southeastern Nigeria. *Acta Scientific Microbiology*. https://www.actascientific.com/ ASMI/pdf/ASMI-02-0182.pdf.

Folland, C.K., Karl, T.R., Christy, J.R., Clark, R.A., Gruza, G.V., Jouzel, J., and Wang, S.W. (2001). Observed Climate Variability and Change 2001: The Scientific Basis. In: Ding Y, Griggs DJ, Noguer M, van de Linden PJ, Dai X, Maskell K, Johnson CA (eds).*Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. (pp. 99-181). Cambridge. Houghton GT. Cambridge University Press.

Ibe K.M., Nwankwor G.I. and Onyekuru S.O. (2003).*Groundwater pollution vulnerability and groundwater protection strategy for the Owerri Area, Southeastern Nigeria*, In: Water resources systems-water availability and global change. Proceedings of Symposium IIS02a Sapporo, IAHS 280:184-194.

Ibekwe, N. (2012). Floods: sad Tale from affected States ERAQ/FOEN. https://www.premiumtimesng.com/news/103083-floods-sad-tale-from-affected-states erafoen.html

International Federation of Red Cross (IFRC) (2013). *Information Bullet in Nigeria: Floods* www.ifrc.org/nigeria-floods

Nnaji, G.U., Asadu, C.L.A. and Mbagwu, J.C. (2002). Evaluation of the physicochemical properties of soils under selected agricultural land utilization types. *Agro-Science*. 3, 27-33.

Nwaiwu, I.U.O., Ohajianya, D.O., Orebiyi, J.S., Ibekwe, U.C., Lemchi, J.I., Onyeagocha, S.U.O., Odoemena, B., Utazi, C.O., Osuagwu, C.O. and Tasie, C.M.***(2014).*Climate change trend and appropriate mitigation and adaptation strategies in southeast Nigeria. *G.J.B.A.H.S., 3(1),120-125.***

Nweke, E. (2015).*Design and supervision of hydraulic structures for Enugu State NEWMAP.* Consultancy Assignment between Nest Engineering and NEWMAP, Enugu.

Obasi, A.A., Ogbu, K.N., Ndulue, E.L., Ogwo, V.N. and Mbajiorgu, C.C. (2017). Prediction of the impacts of climate changes on the stream flow of Ajali river watershed using SWAT Model. *Nigerian Journal of Technology*. 36 (4), 1286-1295. http://dx.doi.org/10.4314/njt.v36i4.39

Ojo, O. (2008). *State of Nigerian Environment*. A Paper presented at the First National Environmental Summit, Transcorp Hilton, Abuja, 20-21 October, 2008.

Okoye, B.C., Onyenweaku, C.E. and Ukoha, O.O. (2010). An Ordered Probit Analysis of Transaction Cost and Market Participation by Small-Holder Cassava Farmers in South-eastern Nigeria. *Nigerian Agricultural Journal*. 41 (2).

Oladipo, E.O. (2008).*Climate change and sustainable livelihood greening options for Nigeria*. A paper presented at the National Environment Summit, Transcorp Hilton Abuja

Olusina, J.O. and Odumade, O.M. (2012). *Modeling Climatic Variation Parameters of Nigeria using the statistical downscaling approach*. FIG Working Week, Rome, Italy

Ozor, N. (2009). Implications of Climate Change on National Development; The way forward. In: *Enugu Forum Policy Paper* 10. (AIAE) TS07F - Task Force on Surveyors and the Climate Change II, 6099 1/17

Rosegrant, M.W., Cai. X. and Cline, S.A. (2002). The role of rain-fed agriculture in the future of global food production. *Discussion Paper* No. 90, IFPRI, Environment and Production Technology Division

Sankarasubramaniam, A., Vogel, R.M. and Limburner, J.F.(2001). Climate elasticity of streamflow in the United States. *Water Resour. Res*. 37, 1771–1781. https://doi.org/10.1029/2000WR900330

Sawa, B.A.(2010).Climate Change and Spatio-Temporal Variability in the Occurrence of Dry Spells in Northern Nigeria. In: Ogidiolu, Musa S D, Ifatimehin O(eds) *Contemporary Issues in Infrastructural Development and Management in Nigeria*. JAS Ventures Anyingba, Nigeria.

Union of Concerned Scientists (UCS)(2010). Heavy Flooding and Global Warming: Is there a Connection?/heavy-flooding-and-global-warming.html#.VEUwDiLF9Q0