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The Effects of Global Warming and Climate Variability on Water Resources Development: A Case Study of Otamiri-Njaba River Basin of Imo State, Nigeria

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ABSTRACT

The relationship existing between water resources, temperature and other climate elements is very clear and indisputable. This research worked on the effects of global warming and climate variability on the water resources in the catchment area of Otamiri – Njaba river basin. In the work meteorological and hydrological data were collected and analyzed. The method of time series and multivariate regression and linear correlation were employed. In the research, it was observed that the climate variability and global warming created extreme conditions in the precipitation style resulting to very high intensities of rainfall which had resulted to the flooding of the area and very low/no rainfall which had given rise to prolonged drought. This scenario on its own had adversely affected economic and agricultural activities in the river basin.

Keywords: *Climate, Global Warming, Water, Temperature*

INTRODUCTION

Climate variability is a key factor in water resources development and its role in energy and food security is undeniable. Climate variability and global warming are related and had direct links in the factors that produce them. Global warming and climate variability affect the quantity of water available for human life sustainability on planet-earth and by extension affect human habitat, clothes, food, energy and power availability. The implication of the variability and over-bearing heat signifies uncontrability of human activities and also a proven factor that militate against short and long term planning. The current increasing variability of climate elements such as temperature and rainfall pose a threat to water resources and constitute grave consequences on every national socio-economy. The climate variability had introduced greater challenges to human resilience thereby making the human race more vulnerable.

It is an axiom to say that the climate of an area dictates the direction of many weather elements which invariably affect the water cycle of the area concerned. The climate of Nigeria is controlled by the dynamics of the South Western winds emanating from the Atlantic ocean that moves from the south to the North and North East lies moving down to the South. These two major winds are responsible for the two main seasons in Nigeria including the Anambra-Imo River Basin, where the prevailing seasons are rainy, dry and harmattan seasons. The study area is the Otamiri- Njaba river basin which cuts across many local government areas of Imo State and it is a subset of the Anambra-Imo River basin

The establishment of the eleven (11) River Basin development Authorities (RBDA) in the early 70's marks the commencement of surface and groundwater development in Nigeria and has provided a leap for agricultural development. The effects of climate variability scenario have led to increase of environmental temperatures and lower rainfalls.

This research has become needful due to the persisting climate variability and notable rise in temperature and the adverse change being noticed on the water resources system in Otamiri- Njaba River basin.

Global Warming

Global warming occurs when carbon dioxide (CO_2) and other air pollutants and greenhouse gases collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the earth's surface. Normally, this radiation would escape into space but these pollutants, which can last for years to centuries in the atmosphere, trap the heat and cause the planet to get hotter. This is known as greenhouse effect.

The minimization of climate change requires high reduction in emissions and resorting to renewable energy sources. Researchers agree that the earth's rising temperatures are fuelling longer and hotter heat waves, more frequent droughts, heavier rainfall and more powerful hurricanes. It has been established by researchers in 2015 that the persisting drought in California which created the worst water shortage in the recent one thousand and two hundred years has continued to increase by 15-20% due to global warning. Also in 2016, the National Academic of Service, Engineering and Medicine announced that it is now possible to confidently attribute certain weather events like some heat waves directly to climate change.

It had alreadybe established that human influence has been the dominant cause of the observed global warming. The highest human influence has been the emission of greenhouse gases such as carbon dioxide, methane, and nitrous oxide.

Effects of Global Warming

Global warming has adverse consequence on the environmental, economical and health conditions of the world's population. In a summarized form, global warming can cause such consequences as; severe droughts which can dominate into water shortage and enhance the risk of wildfires, aquatic life reduction due to disruption of habitants and high level of air pollution resulting to allergies, asthma and setting up conditions favourable for the throwing of pathogens and mosquitoes.

Future global warming has such impacts as rising global temperature, rising sea levels, changing precipitation and the expansion of desert. Other effects are extreme weather events such as heat waves, droughts, heavy rainfall, flooding, ocean acidification and species extinctions. Possible societal responses to global warming include mitigation by emissions reduction, adaptation to its effects, building systems resilient to its effects, and future climate engineering.

Global Warming

Glaciers are melting, sea levels are rising, cloud forests are dying and wild life is scrambing to keep pace. It has become clear that humans have caused must century's warming by releasing heat trapping gases called greenhouse gases, as we power our modern lives. The "greenhouse effect" is the warming that happens when certain gases in the earth's atmosphere trap heat. These let in light but keep heat from escaping like the glass walls of a greenhouse.

First, sunlight shines onto the earth's surface, where it is absorbed and then radiates back into the atmosphere as heat. In the atmosphere the greenhouse gases trap some of this heat and the rest escapes into space. The more greenhouse gases are in the atmosphere the more heat gets trapped. In 1824, Joseph Fourier calculated that the earth would be much cooler if it had no atmosphere. This greenhouse effect is what keeps the earth's climate livable. Without it, the earth's surface would be an average of about 60^{o}F cooler.

Water Resources Development

Water resources development of a region requires the conception, planning, design, construction and operation of various facilities, to utilize and control water and to maintain water quality. Due to the fact that every water development project is unique and has inherent factors surrounding it, it is not possible to proffer a direct solution. The special conditions of each project should be handled through an integrated application of the fundamental knowledge of many disciplines. Even though, it is basically the function of civil engineers, the services of other specialists from other fields are needed. The services of economists, geologists, chemists, biologists, electrical engineers, mechanical engineers, and political scientists.

Water resources development involves strategies that could be channeled into the sustainability of the water resources and their quality. Water resources planning is the orderly consideration of various aspects of water resources engineering from the original statement of purpose to the final decision on a course of action. Various alternatives are evaluated before taking the final decision. Planning forms the basis for the decision to proceed with a proposed water-resources project. Planning is a very critical aspect and perhaps the most important aspect of engineering for the project. Planning involves all works associated with the decision of a project and the implementation procedures of the project including the bill of engineering measurement and evaluation. Experience and professional judgement are needed in water resources project planning. However, quantitative analysis is the basis of applying experience and professional judgement in water resources project planning.

Water resources engineering is an area of Civil Engineering which is concerned with the preservation of water sources, utilization of water control and water quality management. The purposes of water utilization include irrigation, water supply, hydropower and navigation. Water control involves the regulation of water for variety of purposes such as flood control, land drainage, sewerage and bridges so that water does not cause damage to the project, inconvenience to the public or loss of life. Water quality management or pollution control is also an important phase of water resources engineering to maintain the required quality for municipal and irrigation uses and for environmental and ecological preservation and balance**.**

Climate Variability

It has been established that climate has been changing in a manner that impacts negatively on the sustainability of live on earth. Climate which is described as the average weather over a period of time has elements and these include temperature, precipitation, humidity etc. Climate variability extends beyond the average and includes the changes and their extremes as these can have great impacts. Climate is usually described for different seasons, months and their average over a period of thirty years. Long time series of observation are important in detecting the changes in our climate.

Climate variability is very much involved with energy and most commonly in the form of heat energy. Radiation comes from the sun in the form of solar radiation at short waves lengths and people radiate proportionally to the fourth power of absolute temperature and this makes the inhabitants of earth surface and atmosphere to radiate infrared wavelengths. Weather and climate on earth are determined by the amount and distribution of incoming tradition from the sun. Incoming radiant energy may be scattered and reflected by clouds or aerosols (dust or pollution) or absorbed in the atmosphere. The transmitted radiation is then absorbed or reflected at the earth's surface. Radiant solar (short wave) energy is transformed into sensible heat (related to temperature), latent energy (involving different water bodies), potential energy (gravity and height), and kinetic energy (involving motion), before being emitted as long-wave infrared radiant energy. Energy may be stored, transported in various forms and converted into different types, giving rise to a rich variety of weather or turbulent phenomena in the atmosphere and ocean. Climate variability has been a source of concern not necessarily because of its inherent fascination but because of its huge and adverse effects on the planet earth which may even lead to its extinction.

Temperature

Anambra-Imo River Basin is a water catchment area which is made up of the five south eastern states of Anambra, Abia, Ebonyi, Imo and Enugu. In this region, rainy season brings in cooler weather as a result of increased cloud cover, which acts as blockage to the intense sunshine by shielding much of the sun rays during the rainy season. The ground remains cool thereby making for cooler temperatures during the rainy season. But afternoons during the rainy season can be hot and humid-a feature of tropical climates. During the rainy season, it is damp and the rainfalls are much.

There is light temperature during the dry season as there is little or no rain at this time. There is little cloud in the Anambra-Imo River Basin during the dry season. The sun shines through the atmosphere with little obstructions from the clear skies making the dry season a period of warm weather conditions. There is haze in the atmosphere during the December period because the sun is partially obscured from shining. The activities of the wind lower temperatures considerably thereby saving the inhabitants from the scorching heat of the sun. The temperatures run up to 44^oC (111.2^oF) within the basin.

Rainfall

Rainfal is the condensation of water vapour from the atmosphere and its falling to the earth's surface. This occurs mostly as rainfall, but also snowball and hail are all forms of precipitation. Precipitation is the basic source of water that evaporates or else moves to the streams and rivers or else seeps into the ground and emerges into groundwater. The understanding of these processes is vital for the management of surface water and groundwater resources.

The boundaries of hydrometeorology are not clear cut and the problems of the hydrometeorologist overlaps with those of the climatologist, hydrologist, cloud physicist and the weather forecaster. It deals with measurement, analysis and modeling of atmospheric and land surface processes tied to the hydrologic cycle. These analyses often serve as the bases for the design of flood – control and water usage structures primarily dams and reservoirs. The hydrometeorologist concerns himself further with determination rainfall probabilities, the space and time distribution of rainfall and evaporation, the recurrence interval of major storms, now melt and runoff and probable wind tides and waves in reservoirs.

MATERIALS AND METHODS

The hydrometeorological data were obtained from the Nigerian Meteorological Unit Sam Mbakwe International Cargo Airport Owerri and the Anambr-Imo River Development Authority, Owerri. The hydrological and meteorological data were collected on a daily and summarized into annual discrete data. The hydrological data collected include rainfall and river discharges while the meteorological data include temperature, wind speed and solar radiation.

Data Analysis

In the analysis, temperature, rainfall, sunshine hours, relative humidity and river discharges were processed on the temporal basis of monthly, annually and seasonal time series using statistical methods. Multivariate regression techniques and linear correlation were applied to dictate the strength and the parameters. Descriptive statistics were used to analyze the rainfall, temperature and river discharges on the instrumentality of time series analysis. With these, the effects of global warming and climate variability on water resources were investigated.

RESULT PRESENTATION AND ANALYSIS

The results of rainfall, river discharge, and meteorological data were presented on tables 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6 as shown below:

Table3.1. *Rainfall Results From 2000-2016*

	Amount of Rainfall (mm).													
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Max Rainfall**	**Average Rainfall**
2000	39.1	0.0	53.2	354.2	47.3	391.8	382.7	356.4	344.0	246.5	116.5	5.5	391.8	194.8
2001	5.5	62.0	206.4	172.2	140.8	385.4	301.7	348.7	430.8	213.4	22.6	14.8	430.8	132.0
2002	0.2	27.9	90.4	241.7	265.6	345.6	391.5	294.2	261.9	225.8	91.0	1.7	391.5	186.5
2003	42.3	92.6	136.9	73.3	278.1	277.4	439.5	379.2	476.4	123.8	50.6	0.2	476.4	137.5
2004	6.1	32.4	67.4	258.8	268.9	298.2	327.0	384.4	305.1	260.3	56.7	0.2	384.4	188.8
2005	35.5	58.4	102.6	194.3	359.8	367.0	380.6	302.4	232.9	199.8	13.9	0.2	380.6	187.3
2006	78.5	48.4	108.1	104.1	157.3	349.9	397.6	232.1	537.6	303.3	33.3	0.0	537.6	195.9
2007	0.2	7.4	57.7	62.1	260.9	397.3	485.4	509.0	303.0	180.2	42.7	9.6	509.0	193.0
2008	13.6	0.0	117.5	215.4	209.7	473.9	630.2	289.6	449.8	382.9	9.2	26.2	630.2	234.8
2009	38.6	71.4	71.2	242.8	441.5	239.0	497.9	539.2	485.3	236.8	115.4	0.0	539.2	248.3
2010	0.0	62.5	34.1	164.2	297.5	255.2	252.0	453.8	258.4	306.6	18.4	1.6	453.8	175.4
2011	0.0	133.7	84.4	114.8	528.3	189.3	305.2	506.7	366.0	241.2	49.7	24.8	528.3	212.0
2012	0.2	74.1	22.1	158.0	249.2	284.2	430.2	316.0	483.1	175.9	113.2	0.0	483.1	192.2
2013	0.0	40.0	130.9	190.5	253.2	188.7	254.1	409.1	279.0	101.1	48.6	132.4	409.1	169.0
2014	0.0	21.4	100.2	157.0	289.4	236.2	139.3	336.3	355.6	220.7	91.3	30.0	355.6	164.8
2015	12.4	72.2	61.0	61.4	236.6	364.7	325.8	359.2	352.9	324.3	78.1	0.0	364.7	187.4
2016	0.0	29.4	192.5	143.9	157.4	272.6	378.1	409.4	423.8	144.7	12.2	0.2	423.9	180.4

Source: *NIMET, Imo Airport, 2017.*

Table3.2. *Discharge Data Results for Otamiri River for 2007/2008 Hydrological Year*

DAYS	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1	7.70	7.10	7.10	7.34	8.12	9.24	8.96	8.54	7.98	7.84	7.70	7.58
2	7.70	7.34	6.98	7.22	8.26	9.10	8.96	8.54	7.98	7.84	7.70	7.58
3	7.46	7.34	7.70	7.70	8.32	9.24	9.10	8.54	7.98	7.84	7.70	7.58
4	7.34	7.22	7.10	7.58	8.54	9.24	9.38	8.40	7.98	7.84	7.70	7.58
5	7.46	.22	7.10	7.22	8.26	9.24	9.10	8.12	7.98	7.84	7.70	7.58
6	7.46	7.10	7.22	7.46	8.82	9.24	9.24	8.12	7.98	7.98	7.70	7.58
7	N.R	7.22	7.10	7.34	9.24	9.24	9.24	8.12	7.98	7.98	7.70	7.58

8	N.R	7.22	7.10	7.10	8.40	10.98	9.24	8.26	7.98	8.26	7.70	7.58
9	7.70	7.10	7.10	7.46	8.40	11.78	9.56	8.26	7.98	7.98	7.70	7.58
10	7.98	7.10	7.10	7.34	8.68	9.24	10.08	8.40	8.12	7.84	7.84	7.58
11	7.58	7.22	7.10	8.54	9.38	9.10	9.56	8.40	7.98	7.84	7.84	7.58
12	7.46	7.22	6.98	7.70	9.10	9.38	9.10	8.40	7.98	7.98	7.84	7.84
13	7.46	7.10	7.70	7.70	9.10	9.24	9.10	8.26	7.98	7.98	7.84	7.98
14	7.46	7.10	7.10	7.70	9.10	9.24	9.24	8.26	7.98	8.40	7.84	7.84
15	7.46	7.10	7.22	9.10	8.54	9.24	9.56	8.12	7.26	8.26	7.70	7.84
16	7.34	7.10	7.22	8.12	8.68	9.10	8.96	8.12	8.12	8.26	7.70	7.70
17	7.34	7.10	6.98	7.84	9.10	9.10	8.82	8.12	7.98	7.98	7.70	7.70
18	7.34	7.10	7.10	7.84	9.10	9.10	8.68	7.98	7.98	7.98	7.70	7.70
19	7.46	7.10	7.10	7.84	9.10	9.24	8.68	7.98	7.84	7.98	7.70	7.70
20	7.46	7.10	6.98	7.84	8.68	9.96	8.68	7.98	7.84	8.12	7.70	7.84
21	7.34	7.10	6.98	7.84	8.96	8.96	9.56	7.98	7.84	7.84	7.70	7.70
22	7.34	7.10	8.40	7.70	8.82	9.10	9.56	7.98	7.98	7.84	7.70	7.70
23	7.34	7.10	8.12	7.98	8.82	8.96	9.56	7.98	7.84	7.84	7.70	7.70
24	7.34	7.10	7.22	7.84	9.10	8.96	9.24	7.98	7.84	7.84	7.70	7.84
25	7.46	7.10	7.10	8.12	9.10	9.10	9.10	7.98	7.98	7.84	7.70	7.84
26	7.34	7.10	7.10	7.98	9.10	8.96	9.10	7.98	7.84	7.70	7.58	7.98
27	7.22	7.10	7.10	7.84	9.24	8.96	9.10	7.98	7.84	7.70	7.58	7.98
28	7.22	7.10	7.22	8.12	9.10	8.82	9.38	7.98	7.84	7.84	7.58	7.98
29	7.10	7.10	7.34	7.98	9.10	8.68	9.24	7.98	7.84	7.84	N.R	7.98
30	7.10	7.10	7.46	8.12	9.24	8.82	9.10	7.98	7.84	7.70	N.R	7.98
31	N.R	7.22	N.R	8.68	9.24	N.R	8.68	N.R	7.98	7.70	N.R	7.98
Max	7.98	7.34	8.40	9.10	9.38	11.78	10.08	8.54	8.26	8.40	7.84	7.98
Mean	7.43	7.13	7.24	7.79	8.88	9.25	9.20	8.16	7.95	7.91	7.66	7.73
Min	7.10	6.98	6.98	7.10	8.12	7.94	8.68	7.98	7.84	7.0	7.70	7.58

Source: *Anambra Imo River Basin Development Authority*

Table3.3. *Discharge Data Results for Njaba River for 2007/2008 Hydrological Year,*

DAYS	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB
1	0.98	1.93	2.17	3.11	3.32	3.13	2.17	4.21	2.93	4.21	2.93	0.98
2	1.15	1.85	2.61	3.19	3.43	4.02	2.17	4.11	3.05	4.21	2.93	0.98
3	1.09	1.91	2.61	3.17	3.74	4.13	2.17	3.91	3.19	4.21	2.93	0.98
4	1.09	1.93	2.45	3.19	4.02	4.21	2.17	3.91	3.37	3.00	2.93	0.98
5	1.13	1.95	2.50	3.19	4.30	4.21	2.17	4.02	4.21	3.26	2.93	0.98
6	0.98	1.93	2.61	3.19	4.30	4.21	2.17	4.02	4.21	2.93	2.93	0.98
7	0.85	1.93	2.61	3.21	4.30	4.21	2.17	4.02	4.21	4.21	2.93	0.98
8	0.85	1.93	2.67	3.30	3.78	4.21	2.17	4.02	4.21	4.21	2.93	0.98
9	0.85	1.98	2.69	3.37	3.24	4.21	2.17	4.02	4.02	4.21	2.93	0.98
10	0.98	1.95	2.74	3.34	2.93	4.21	4.21	2.93	3.08	4.21	2.93	0.98
11	0.98	1.95	2.76	3.37	2.93	4.28	4.21	2.93	3.50	2.93	2.93	0.98
12	0.98	1.98	2.65	3.39	2.82	4.28	4.21	3.17	2.93	2.93	2.93	0.98
13	1.19	1.93	2.69	3.24	2.85	4.21	4.21	3.69	2.65	2.93	2.93	0.98
14	1.32	2.02	2.67	2.93	2.91	4.21	4.21	4.21	2.85	2.93	2.93	0.98
15	1.46	2.04	2.69	2.93	3.02	4.21	4.21	3.91	2.93	2.93	2.93	0.98
16	1.09	2.04	3.04	2.82	3.30	4.21	4.21	3.08	2.93	2.93	2.93	0.98
17	1.00	2.09	3.08	2.82	4.21	4.21	4.21	2.93	2.93	2.93	2.93	0.98
18	0.98	2.00	3.15	2.91	4.21	4.21	2.17	2.92	2.93	2.93	2.93	0.98
19	0.98	2.09	3.11	3.02	4.21	4.21	2.17	2.93	2.93	2.93	2.93	0.98
20	1.15	2.09	3.19	3.30	4.13	4.21	2.17	3.00	2.93	2.93	2.93	0.98
21	1.09	2.04	3.17	4.21	4.00	4.21	4.21	3.11	2.93	2.93	2.93	0.98
22	1.13	2.06	3.19	4.21	4.28	4.21	4.21	3.11	2.93	2.93	2.93	0.98
23	1.15	2.09	3.19	4.21	2.17	2.17	4.21	2.98	2.93	2.93	2.93	0.98
24	1.41	0.15	3.19	3.24	2.17	2.17	4.21	2.91	4.21	2.93	2.93	0.98
25	1.41	2.17	3.21	2.93	2.17	4.21	4.21	2.93	4.21	2.93	2.93	0.98
26	1.48	2.17	3.30	2.93	2.17	4.21	4.21	2.93	4.21	2.93	2.93	0.98
27	1.41	2.17	3.37	2.82	4.28	4.21	4.21	2.93	4.21	2.93	2.93	0.98
28	1.37	2.13	3.34	2.85	4.21	2.17	4.21	2.93	4.21	2.93	2.93	0.98
29	1.37	22.15	3.37	2.91	3.19	2.17	4.21	2.93	4.21	2.93	2.93	0.98

30	1.37	2.17	3.39	3.02	3.15	2.17	4.21	2.93	4.21	2.93	0.98	
31	1.48		3.37	3.41	3.13	4.17		2.93		2.93	0.98	
Max	**1.48**	**2.17**	**3.39**	**4.21**	**4.20**	**4.21**	**4.21**	**4.21**	**4.21**	**4.21**	**2.93**	**0.98**
Mea	**1.15**	**2.03**	**3.10**	**3.33**	**3.45**	**3.90**	**3.39**	**3.37**	**3.20**	**3.23**	**2.77**	**0.98**
Min	**0.85**	**1.85**	**2.17**	**2.82**	**2.17**	**2.17**	**2.17**	**2.91**	**2.65**	**2.93**	**0.98**	**0.98**

Source: *Anambra-Imo River Basin Development Authority*

Table3.4. *Meteorological Data of Study Area, For October, 2011*

Day	**Temperature (^{0}c)**			**Relative Humidity (%)**	**Price Evaporation (Ml)**	**Sunshine Hours (Hrs)**	**Wind Speed (Knots)**
	Max	**Mix**	**Mean**				
1	33.50	25.00	29.25	72.50	0.80	3.00	6.38
2	33.50	23.00	28.25	78.00	0.90	2.00	6.76
3	28.00	23.00	25.50	76.00	1.10	4.00	6.83
4	33.50	24.00	28.75	80.50	1.00	5.00	16.66
5	33.50	24.00	28.75	85.00	1.40	4.00	15.89
6	33.50	23.00	28.25	85.50	0.10	0.00	10.90
7	33.50	22.00	27.75	79.00	0.60	4.30	2.32
8	30.60	22.00	26.30	81.00	1.60	3.00	6.28
9	33.50	23.00	28.25	75.00	1.00	4.00	5.32
10	35.50	23.00	29.25	79,00	0.30	3.00	1.55
11	37.00	26.00	31.50	82.00	0.40	4.00	4.63
12	36.00	25.00	30.50	84.50	0.40	2.40	4.35
13	36.00	23.00	29.50	68.00	0.40	7.20	4.60
14	36.00	23.00	29.50	72.00	1.10	6.00	3.82
15	35.00	21.00	28.50	7S.50	0.10	0.00	5.14
16	37.00	28.00	32.75	67.50	0.90	7.00	4.32
17	34.50	25.00	29.75	75.00	1.00	6.00	4.40
18	34.50	25.00	29.75	80.50	1.90	3.00	10.00
19	34.50	23.00	28.75	79.00	1.10	5.50	0.00
20	34.50	23.00	28.75	82.00	0.50	0.00	1.47
21	34.50	24.00	29.25	68.50	0.50	3.45	0.00
22	34.70	22.00	28.10	81.00	0.30	2,00	0.00
23	34.00	22.00	28.10	69.50	0.60	6.00	1.77
24	32.00	23 00	27.50	77.00	0.20	2.45	2.68
25	32.00	21.00	26.50	79.00	1.00	0.00	0 00
26	32.00	25.00	28.50	82.00	0.80	3 30	0 00
27	32.00	22.00	27.00	85.00	3.00	7.30	0.03
28	32.00	24.00	28.00	80.00	3.00	6 30	2.93
29	32.00	22.00	27.00	84.50	1.30	8.50	0.00
30	32.00	23.00	27.50	87.00	0.90	2.30	0.00
31	31.00	24.00	27.50	85.00	1.10	3.45	0.00
Mean	**33.66**	**23.42**	**28.53**	**78.68**	**0.95**	**3.82**	**4.16**
Max	**37.50**	**28.00**	**32.75**	**87.00**	**3.00**	**8.50**	**16.66**
Min	**28.00**	**21.00**	**25.50**	**67.50**	**0.10**	**0.00**	**0.00**
Sum							
NR NO RAINFALL							

Table3.5. *Meteorological Data of Study Area for November, 2011*

Days	**Temperature (0c)**			**Relative Humidity (%)**	**Piche Evaporation (Ml)**	**Sunshine Hours (Hrs)**	**Wind Speed (Knots)**
	Max	**Min**	**Mean**				
1	31.00	23.00	27.00	85.00	0.90	6.00	0.00
2	31.00	22.50	26.75	80.00	1.00	0.10	0.00
3	31.00	23.00	27.00	80.50	1.00	5.00	0.00
4	31.00	23.00	27.00	82.00	030	6.00	0.00
5	31.00	23.00	27.00	64.50	0.20	5.00	0.00

6	28.00	22.00	25.00	87.00	0.10	5.30	0.00
7	32.00	24.00	28.00	90.00	1.00	6.00	0.60
8	30.00	22.00	26.00	87.00	0.80	4.35	1.20
9	28.00	19.00	23.50	66.50	0.70	5.20	0.90
10	29.00	21.00	25.00	84.00	1.20	600	0.10
11	28.00	22.00	25.00	87.00	1.00	500	0.00
12	29.00	18.50	23.75	87.50	1.40	7.00	0.00
13	30.00	21.00	25.50	82.50	0.90	4.00	0.50
14	34.00	24.50	29.25	80.00	1.00	5.00	0.06
15	10.00	24.00	27.00	87.50	1.00	4,00	0.14
16	33.00	25.00	26.00	87 0.0	0.40	5.00	0.05
17	33 00	22.00	27.50	82.00	1.70	7.00	0.01
18	29.00	23.00	26.00	84.50	1.10	6.00	0.09
19	30.00	25 00	27.50	92.50	1.00	5.30	0.01
20	31.50	23.00	27.25	86.50	0,60	6.00	0.02
21	30.00	24.00	27.00	84.00	0.20	7.00	0.70
22	34.00	24.00	29.00	81.00	U.70	6.00	0.50
23	30.00	23. 00	26.50	85.00	1.60	6.00	0.11
24	29.00	25.00	27.00	79.50	1.42	5.45	0 12
25	39.00	26.00	32.50	75.00	2.30	5.30	0.13
26	37. 00	28.00	32.50	77.00	2.40	8.00	0.00
27	35.00	27.00	33.00	76.50	1.10	7.30	0.02
28	40.50	13.00	26.75	77.S3	1.50	5.00RIVER	0.08
29	40.50	13.00	25.75	77.50	140	6.30	0.02
30	41. 00	13.50	27.25	78.50	2.00	5.40	0.31
31							
Mean	**32.32**	**22.17**	**27.24**	**83.13**	**1.07**	**5.60**	**0.31**
Max	**41.00**	**28.00**	**33.00**	**92.50**	**2.40**	**8.30**	**1.58**
Min	**28.00**	**13.00**	**23.50**	**75.00**	**0.10**	**0.10**	**0.00**
Sum							
NR NO RAINFALL							

Table3.6. *Meteorological Data of Study Area for December, 2011*

Day	**Temperature (0c)**			**Relative Humidity (%)**	**Piche Evaporation (Ml)**	**Sunshine Hours (Hrs)**	**Wind Speed (Knots)**
	Max	**Min**	**Mean**				
1	40.50	12.00	26.25	73.00	3.50	8.45	2.44
2	37.60	8.50	23.15	65.00	4.70	7.50	4.64
3	41.00	21.50	31.50	61.00	2.20	7.40	1.50
4	35.00	9.00	22.00	60.00	2.40	8.30	1.39
5	30.00	19.00	24.50	6050	1.50	5.00	0.29
6	31.00	18.00	24.50	72.50	1.70	6.00	1.90
7	33.00	21.00	27.00	76.00	2.00	6.30	3.00
8	31.00	11.00	21.00	69.00	4.20	8.00	2.30
9	37.00	22.00	29.50	60.00	3.50	5.30	2.20
10	32.00	18.00	25.00	61.50	2.40	7.45	1.90
11	34.00	19.00	26.50	69.50	4.00	6.30	5.00
12	39.00	18.50	28.75	65.00	0.61	6.00	4.13
13	32.50	17.50	27.50	61.57	4.50	3.00	7.81
14	37.00	9.50	23.25	65.00	7.34	8.00	0.75
15	40.00	11.00	25.50	72.00	2.50	5.30	10.87
16	39.00	11.00	25.00	70. 00	3.75	7.00	8.39
17	28.00	13.00	20.50	69.00	3.20	7.45	3.50
18	31.00	18.50	24.75	67.00	0.80	6.00	6.20
19	39.00	15.00	27.00	60.00	0.60	6.50	0.05
20	31.00	21.00	27.50	61.50	0.90	6.45	7.30
21	37.50	13.00	25.35	69.50	1.80	7.00	0.21
22	38.50	17.00	27.75	75,00	2.30	6.00	7.70

23	37.00	12.00	24.50	09.00	2.20	6.30	0.87
24	41.00	19.00	30.00	60.50	0.50	6.00	6.03
25	39.00	14.00	26.50	6500	4.90	8.00	10.60
26	30.00	27.00	28.50	61.50	0.70	7.00	1.18
27	28.00	25.00	26.50	71.00	2.90	6.00	2.59
28	28.00	26,00	27.00	69.00	0.50	7.45	1.00
29	30.00	19.00	24.50	65.50	2.00	8.00	0.86
30	33.00	23.00	28.00	65.00	3.00	6.00	1.97
31	36.00	31.00	33.50	69.00	3.00	7.00	0.41
Mean	**35.01**	**17.42**	**26.21**	**66.47**	**2.58**	**6.65**	**3.54**
Max	**41.50**	**31.00**	**33.50**	**76.00**	**7.34**	**8.45**	**10.87**
Min	**28.00**	**8.50**	**20.50**	**60.00**	**0.50**	**3.00**	**0.05**
Sum							
NR NO RAINFALL							

The data of rainfall, river discharges and meteorology data were used to development time series graphs as shown on figures 3.1, 3.2, 3.3, 3.4 and 3.5.

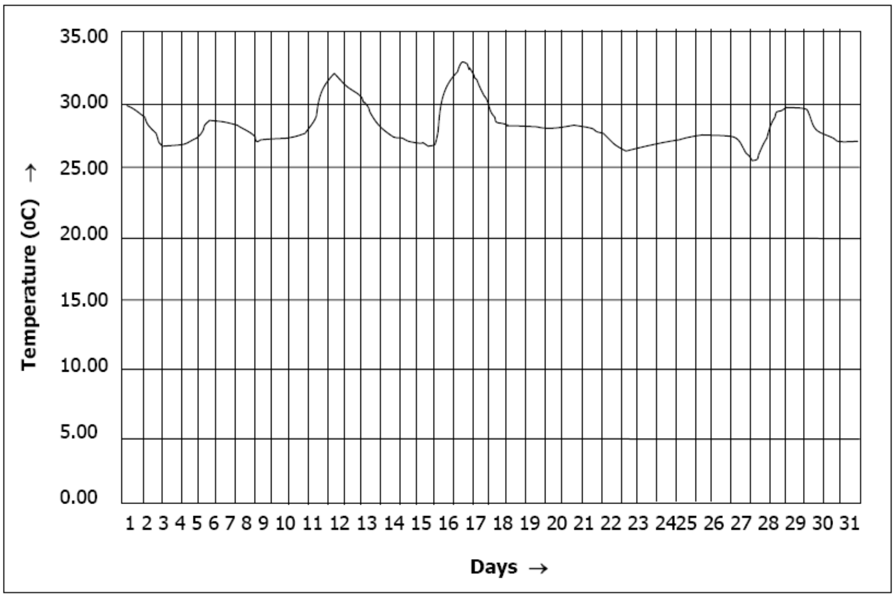

Fig3.1. *Variation of Mean Temperature for October, 2011*

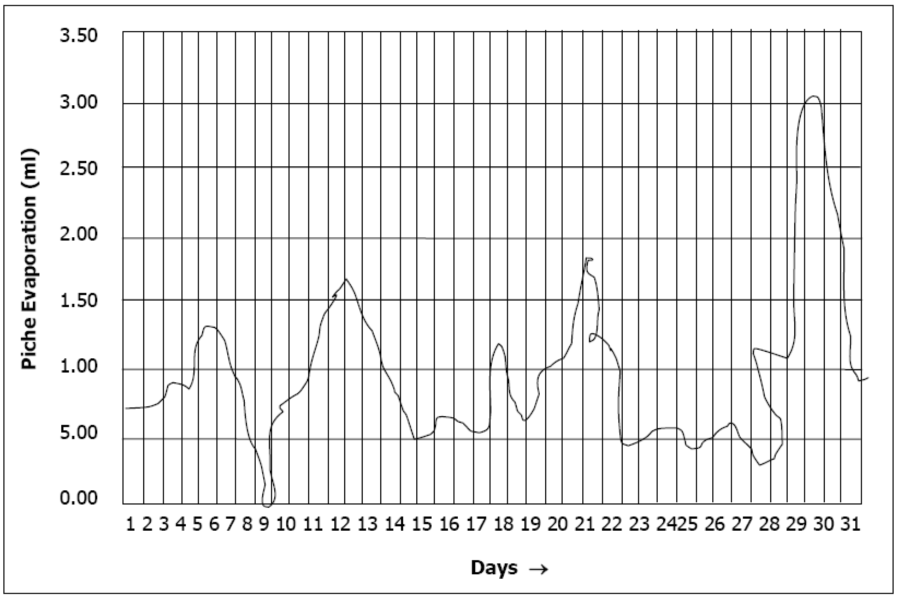

Fig3.2. *Variation of Evaporation for October, 2011*

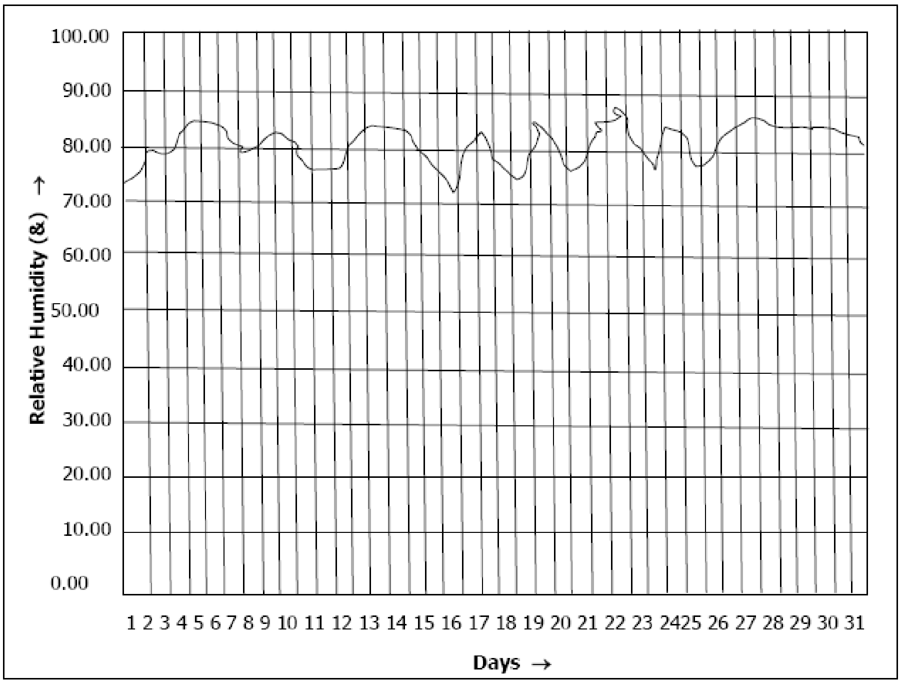

Fig3.3. *Variation of Relative Humidity for October, 2011*

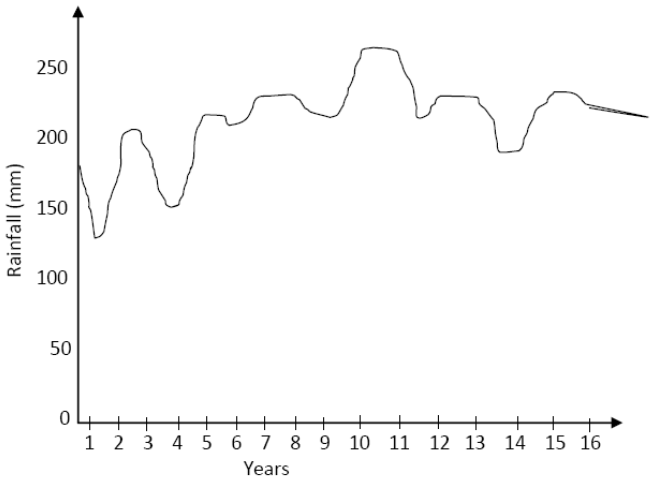

Fig3.4. *Time Series for Rainfall Data (2000 –2016 22016).*

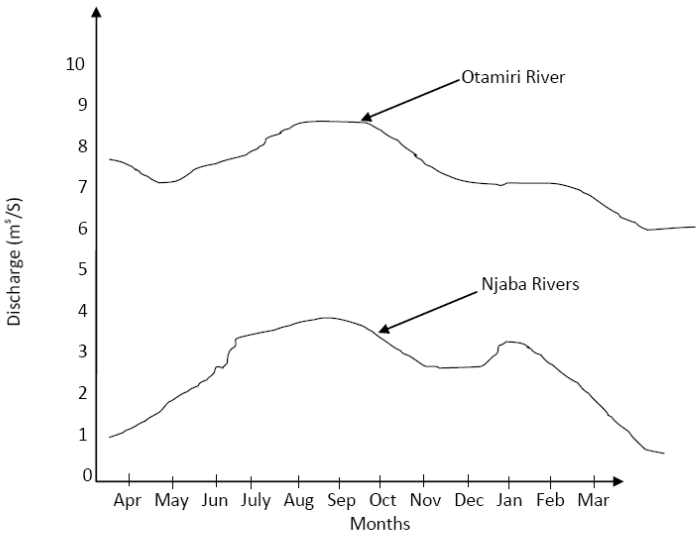

Fig3.5. *Time Series for discharge in Otamiri and Njaba River River Rivers*

Result Analysis

The tables 3.1 to 3.6 were used to show the various hydrological and meteorological data collected in the river basin while time series and variation graphs were employed to illustrate the variabilities of the elements. Rainfall is the most important element of climate as it is the major source of recharging the surface and ground water. It also has immeasurable effects on the development of vegetation in ay catchment area. From the analysis, it can be observed the amount of rain increases from the month of April and reduces drastically towards the month of November. It was observed from figure 3.5 that the two rivers Otamiri and Njaba were fully recharged during the period of June to October. This was due to the low/non-availability of rain during the period of December, March and April. This scenario is peculiar to the two rivers and this situation occurs in repetitive pattern due to seasonality. Slight changes were noticed here due to climate change arising from global warming. The raw data were subjected to long term forecasting model in time series module. From the model the two rivers followed similar trends from the available modeled data. The two rivers possess great potential for the development of the catchment area. From forecasted values, the two rivers can meet the water needs of the catchment areas even during the extreme condition of dry/no precipitation. As observed from the analysis, it is necessary to put in place hydraulic structures in the form of diversion, storage and flood control measures to arrest situations arising from high amount of rainfalls which can precipitate flooding and its attendant environmental hazards. The analysis of the results showed that the effects of climate variability and global warming on the water resources wee highly minimal. However, with the nonchalant attitudes noticed among the populace n the river basin and the continued changes expected from the climate elements of temperature, evaporation and humidity, it becomes obvious that monitoring programmes should be mounted on the climate factors and ever increasing global warming.

Conclusion And Recommendations

Conclusion

Actually, there exists obvious changes in the rainfall pattern in the South East which had resulted into the regime of very high intensity rainfall and very low rainfall. The periods of the unprecedented high rainfall culminate into flooding while the low/no rainfall result to heat and abnormal drought. This affects the water resources adversely as massive evapo transpiration is encouraged. There is no gainsaying in the fact that appropriate methods/approaches need to be adopted as a response to the climate variability and global warming.

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