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Impacts of Climate Variables on Water Yield in Ujama Okpauku River, Yala Lga, Cross River State, Nigeria

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ABSTRACT

An assessment of the impacts of climate variables on water yield in Ujama Okpauku River, Yala LGA, Cross River State, Nigeria was carried out. The interplay of climatic variables particularly rainfall (its intensity, duration, area distribution and frequency of occurrence temperature, human activities (deforestation, irrigation, farming, urbanization), and catchment characteristics (basin size, shape, slope and elevation) determines the quality of water yield in a river. The rotated component matrix and regression coefficient method was used to analyze the climate variables. The model summary explained (R=83.4%), (R^2=69.5%) and (Adjusted R^2= 55.4%) respectively. The component matrix loads strongly on the following components rainfall 0.86, sunlight 0.88 and temperature 0.76 respectively. Components matrix i have positive regression coefficient on the following factors rainfall 0.002, temperature 0.30, and sunlight 1.68. This suggest that, water level is expected to be higher in every unite increase in the rainfall, temperature and sunlight. Similarly the component matrix loads strongly on the following components, year 0.95, wind speed 0.88 and evaporation 0.61 respectively. Components matrix ii have negative regression coefficient on the following factors year -0.92, wind speed -0.12 and evaporation -0.16 respectively. This implies that water yield is expected to be low in every unite increase in the years, wind speed and evaporation. The wind speed, evaporation and length of years were contributing factors for the low water yield in Ujama Okpauku River, Yala LGA, Cross River State, Nigeria. The study recommends a massive afforestation around Ujama Okpauku River course and restriction of farming activities along and around the river course to reduce evapo-transpiration, erosion, flood rates and boast water yield in the catchment area.

Introduction

Climate change is the result of high concentration of green house (heat trapping) gases. Most carbon (iv) oxide causing the atmosphere to retain more heat than usual, this results in altering climatic variables over a period of time (IPCC, 2014). These greenhouse gases could be caused by natural factors or caused by human factors (UNFCCC, 2007; Egor et. al. 2016; Osang et. al. 2013, 2014,& 2015). However, studies have shown that human factors (anthropogenic factors) are the major causatic factors of climate variability, thereby reducing the ability of the natural environment to achieve successful carbon sink/sequestration such as deforestation, poor land use planning and management, drying and pollution of water bodies (Cooper etal., 2008; WHO, 2013; Ayoade, 2008; Adefolaru, 2000; Ewona et. al. 2013, 2014, 2016).

Reports indicate that the Country already faces serious impacts of climate change such as change in rainfall pattern, changes in average mean temperatures, changes in natural flora and fauna, flooding and drought (Odjugo, 2010; Tyndall, 2003; WHO, 2013; Obi et. al. 2013, 2016, 2017; Okunola and Ikuomola, 2010).

This poses short to long-term disturbances of the hydrological cycle reducing the availability and accessibility of water (Eneti and Ezenwayi, 2011; Smith, 2006; Khon, 2007; Gleick, 2000). In like terms, Bello et. al., (2012) reported that within the period of 105years, temperature increased by 1.1^0C, while rainfall decreased by 81 mm in Nigeria.

Several studies has shown that climate variability has effects on water resources (Ranjan etal., 2006; Rosenberg etal., 1999; Singh and Kumar, 2010; Vaccaro, 1992; Richardson and Wright 1984) and have demonstrated that elevation carbon (iv) oxide concentrations. Changes in temperature and precipitation are associated with increased evapo-transpiration and lower water yield (Nyenje and Batelaan, 2009; Toews and Michael, 2007; Schmidhuber and Tubiellot, 2007). It is the inability of rainfall to equate the fast rate of evapo-transpiration that leads to deteriorating water yield in water bodies. The intergovernmental panel on climate change has made it undisputable that the earth is warming and estimate that the global mean surface temperatures has increased by 0.6 ± 0.2^0C and predicts an increase of $2\text{-}4^0$C in the next 100 years.

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These changes will exert influence in altering evapo-transpiration and precipitation rates in timing and intensity, which will have serious implications on the volume and discharge rates on Okpauku river. Ekpoh and Nsa, (2011), Odjugo, (2009), Ayoade (2008), these authors also argued that the interplay of climatic variables particularly rainfall (its intensity, duration, area distribution and frequency of occurrence temperature, human activities (deforestation, irrigation, farming, urbanization), and catchment characteristics (basin size, shape, slope and elevation) determines the quality of water yield in a river, (Ojar et. al. 2014; Pekene 2015; Osang et. al. 2013; Udoimuk et. al. 2014).

Even though the magnitude of the impact of climate change on water yield has remained uncertain, IPCC (2014) maintained that the World water bodies is one of the most vulnerable after agricultural sector as numerous actors are susceptible and interlinked especially in the face of the declining precipitation rates and frequent episodes of water scarcity (Ati etal., 2002; Ekpo and Agu, 2014) sea level rising causing marsive floods in most areas of Niger Delta. Okpauku River has been known to overflow its banks during periods of high floods and the water level can be as high as 40-55m deep with an estimated discharge of 6,200m^3/s in September and about 64.6 m^3/s between February and March prior to the onset of the rains (Osang et. al. 2013). This low flow regime in the dry season provides an important source of water for many settlements along the catchment area. A further reduction in the natural river flow occasioned by climate variability will have severe negative impacts on the downstream users. There is a concern among the people of Yala LGA that the Ugama Okpauku river may not be able to meet their primary need for water due to seasonal declining fluctuation of the river. The river has continued to dwindle in volume with serious threat to water supply. Unfortunately, no study has attempted to examine the nature of water yield fluctuation in Okpauku river, yet the effects are far reaching and need to be investigated. Thus, this study investigates the impacts of climate variability on water yield in Okpauku River (Ushie et. al 2014; Osang et. al. 2013, 2016).

Materials and Methods

Study Area

Yala LGA is located between latitudes 8^0 14' and 9^0 01' East and longitudes 6^0 15' and 6^0 56' North. Yala is bounded from the south by Obubra and Ikom LGAs of Cross River State. In the South West by Izzi in Eboyi State on the East by Ogoja, North-East by Bekwarra and to the North by Konshisha LGA in Benue State. Yala LGA has a landmass of 14,378 SqKm approximately. The topography of the place is imdulating with sandy soil. Three major rivers transvers the area, namely, Aya River which passes through Ugaga, Oloko; Ujama Okpauku River which rises from Ijegu-Yala area through Itekpa to Udenyuma to Onwu River to Cross River in Obubra LGA; Mfuma River which passes through Alebo, Okpodom Northwards of the LGA. Yala has savannah vegetation characterized by closely packed trees with eucalyptus trees, mean temperatures ranges between 26-36^{0}C, mean rainfall 1966.36mm and mean annual evaporation 46mm.

Physics of the Climatic Variables

Temperature (^{0}C) and Sunlight

The ozone layer is warm because it absorbs ultraviolet (UV) rays from the sun. The mesosphere is the layer above the stratosphere. The temperature decreases with height here just like it does in the troposphere. Heat transfer coefficient or film coefficient, in thermodynamics and in mechanics is the proportionality constant between the heat flux and the thermodynamic driving force for the flow of heat (i.e., the temperature difference, ΔT):

$$h = \frac{q}{\Delta T} \qquad (1)$$

where:

q = Amount of heat transferred (heat flux), W/m^2 (thermal power per unit area

h = Heat transfer coefficient, W/(m^2•K)

ΔT = Difference in temperature between the solid surface and surrounding fluid area, K.

It is used in calculating the heat transfer, typically by convection or phase transition between a fluid and a solid. The heat transfer coefficient has SI units in watts per square meter Kelvin: W/(m^{2}K).

Wind speed

The total inherent energy of the wind is determined by the following equation, Uquetan et. al. (2016)

$$P_{TOTAL} = ½ \rho A\mu^3 \qquad (2)$$

Where:-

P_{TOTAL}: Total power (watts)

ρ: air density (1.225kg/m3)

A: Rotor Swept Area (m^2)

μ: wind speed (m/s)

Rainfall

Rain is liquid water in the form of droplets that have condensed from atmospheric water vapor and then precipitated—that is, become heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. The intensity and duration of rainfall are usually inversely related (high intensity storms are likely to be of short duration and low intensity storms are likely to have long duration), (Udo, *et al*., 2002), (Ryan, 2005). In view with (Afangideh *et al*., 2013; Udoimuk et. al. 2014),

$$\text{rainfall intensity (mm/year)} = \frac{\text{Annual rainfall amount}}{\text{Annual rainfall duration}}$$

Methodology

Climatic data were obtained from Nigeria Meteorological Agency (NIMET). While data on water yield were obtained from Cross River Basin Development Authority. Climatic variability was expressed using average, variance and standard deviation. Linear regression and principle component analysis was also used to establish the influence of rainfall, temperature, sunlight, wind speed, evaporation and water yield.

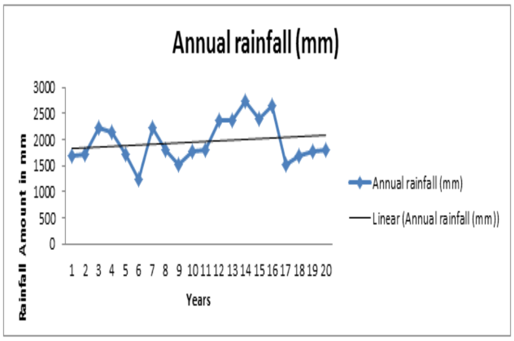
Results and Discussion

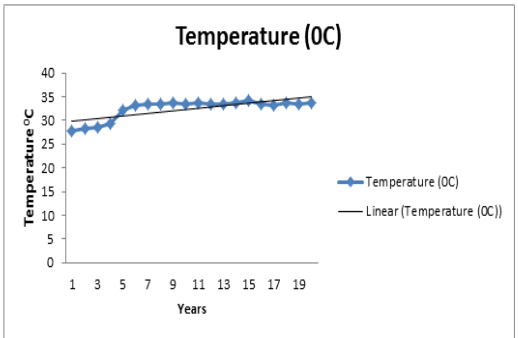
The results of climatic variability on water yield in Ujama Okpauka River for the period 1993-2012 is presented in table 1. The average rainfall was 1961mm with a variation of 160175.4 and standard deviation of 400.21 respectively. The average temperature was 32.47^{0}C with a variance 4.44 and standard deviation of 2.10. The average sunlight was 9.310mm with a variance of 0.98 and standard deviation of 0.99 respectively. The average wind speed was 43.01 with a variance of 58.89 and standard deviation of 7.67 respectively. Average evaporation was 49.08 with a variance of 48.06 and standard deviation of 6.93 respectively. The water level was 48.42 with a variance of 27.40 and standard deviation of 5.23 respectively.

TABLE 1. Annual mean climatic variables in Yala for the period of 1996-2015.

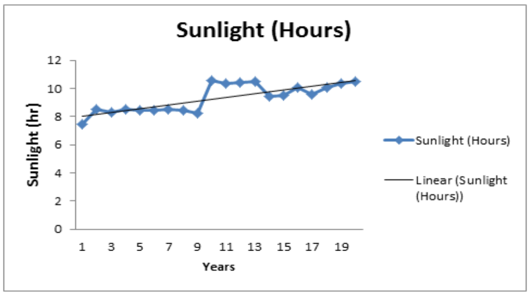
S/n	YEAR	Annual rainfall (mm)	Temperature (^{0}C)	Sunlight (Hours)	Wind speed (nus)	Evaporation (mm)	Water Level (m)
1	1996	1696.4	27.7	7.43	20.74	36.3	54.3
2	1997	1706.2	28.2	8.53	42	39.7	48.1
3	1998	2239.8	28.6	8.28	43.18	48.4	51.2
4	1999	2150.4	29.4	8.54	42.52	44.8	48.8
5	2000	1712.7	32.1	8.46	30.84	50.1	52.3
6	2001	1251.4	33.2	8.42	37.6	59.2	53
7	2002	2220.7	33.4	8.5	35.4	47.6	47.5
8	2003	1815.8	33.5	8.48	38.8	45.3	50.2
9	2004	1523.9	33.7	8.26	44.2	45.5	49.1
10	2005	1781.6	33.5	10.56	42.84	48.4	53.6
11	2006	1816.3	33.8	10.34	43	45.8	52.2
12	2007	2373.1	33.4	10.4	45.5	45.6	47
13	2008	2354.7	33.5	10.48	47.32	46.5	55
14	2009	2737.9	33.7	9.45	47.74	46.4	53.9
15	2010	2398.7	34.2	9.5	44.9	44	49.2
16	2011	2640.2	33.4	10.1	48.8	49.6	43.1
17	2012	1532.5	33.3	9.6	51.2	58.4	41.6
18	2013	1698.6	33.6	10.04	52.6	59.6	39.3
19	2014	1762.9	33.5	10.36	48.2	60.1	38.2
20	2015	1806.4	33.8	10.48	52.86	60.4	40.8
	AVERAGE	1961.01	32.475	9.3105	43.012	49.085	48.42
	VARIANCE	160175.4	4.443026	0.984594	58.89202	48.06345	27.40168
	STDEV	400.2192	2.107849	0.992267	7.674113	6.932781	5.234662

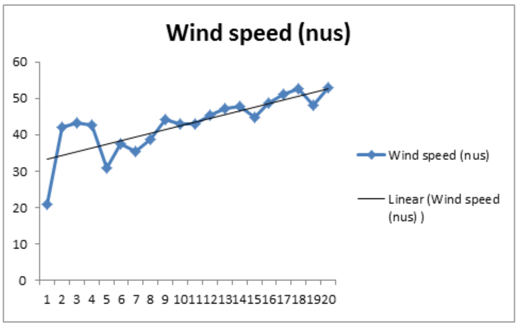
The model summary explained (R=83.4%), (R^2=69.5%) and Adjusted (R^2= 55.4%) respectively. The rotated component matrix and regression coefficient was used to analyze the variables and converged in three iterations. The component matrix loads strongly on the following components rainfall 0.86, sunlight 0.88 and temperature 0.76 respectively. These components matrix have positive regression coefficient on the following factors rainfall 0.002, temperature 0.30, and sunlight 1.68. This suggest that, water level is expected to be higher in every unite increase in the rainfall, temperature and sunlight.





Similarly the component matrix loads strongly on the following components, year 0.95, wind speed 0.88 and evaporation 0.61 respectively. These components matrix have negative regression coefficient on the following factors year -0.92, wind speed -0.12 and evaporation -0.16 respectively. This implies that, water yield is expected to be low in every unite increase in the years, wind speed and evaporation. The wind speed, evaporation and length of years were responsible for the low Water Yield in Ujama Okpauku River, Yala LGA, Cross River State, Nigeria.





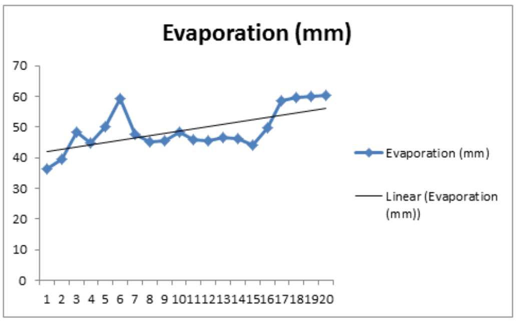


TABLE 2.Coefficients[a] of the climate variables.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	1862.176	671.904		2.771	.016			
	Year	-.928	.346	-1.049	-2.681	.019	-.655	-.597	-.411
	Rainfall	.002	.003	.134	.666	.517	.110	.182	.102
	Temperature	1.303	.595	.525	2.189	.047	-.251	.519	.335
	Sunlight	1.682	1.467	.319	1.147	.272	-.383	.303	.176
	Windspeed	-.121	.189	-.177	-.639	.534	-.593	-.174	-.098
	Evaporation	-.167	.195	-.221	-.857	.407	-.639	-.231	-.131
a. Dependent Variable: Wateryield									

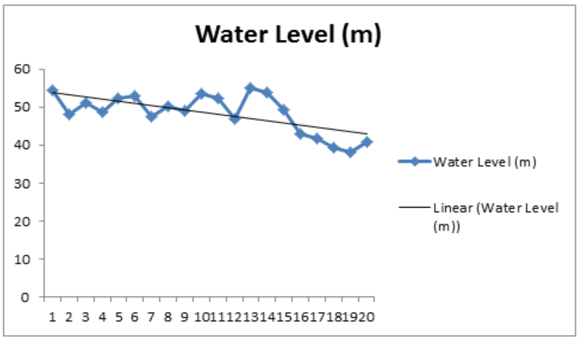


TABLE 3. Rotated Component Matrix[a] of the climate variables.

	Component	
	1	2
Year	.957	-.120
Rainfall	.304	.865
Temperature	.764	-.022
Sunlight	.882	.126
Wind speed	.880	-.048
Evaporation	.618	-.678
Water Level	-.608	.522

TABLE 4. Model Summary of the climate variables.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.834[a]	.695	.554	3.4953
a. Predictors: (Constant), Evaporation, Rainfall, Temperature, Sunlight, Wind speed, Year				
b. Dependent Variable: Water yield				

Conclusion

An assessment of the Impacts of climate variables on water yield In Ujama Okpauku River, Yala LGA, Cross River State, Nigeria was carried out. The interplay of climatic variables particularly rainfall (its intensity, duration, area distribution and frequency of occurrence temperature, human activities (deforestation, irrigation, farming, urbanization), which determines the quality of water yield in a river. The rotated component matrix and regression coefficient method was used to analyze the climate variables. The model summary explained (R=83.4%), (R^2=69.5%) and (Adjusted R^2= 55.4%) respectively. The component matrix loads strongly on the following components, rainfall 0.86, sunlight 0.88 and temperature 0.76 respectively. These components matrix have positive regression coefficient on the following factors rainfall 0.002, temperature 0.30, and sunlight 1.68. These suggest that, water level is expected to be higher in every unit increase in the rainfall, temperature and sunlight. Similarly the component matrix i loads strongly on the following components, year 0.95, wind speed 0.88 and evaporation 0.61 respectively. Components matrix ii have negative regression coefficient on the following factors year -0.92, wind speed -0.12 and evaporation -0.16 respectively. This implies that water yield is expected to be low in every unit increase in the years, wind speed and evaporation. The wind speed, evaporation and length of years were contributing factors for the low water yield in Ujama Okpauku River, Yala LGA, Cross River State, Nigeria. The study recommends a massive afforestation around Ujama Okpauku River course and restriction of farming activities along and around the river course to reduce evapo-transpiration, erosion, flood rates and boast water yield in the catchment area.

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