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Potential Impacts of Climate Change and Population Growth on Water Resources in Guinea Savanna Ecological Zone of Nigeria

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Abstract:
The variability and uncertainty of water resources associated with climate change are critical issues in so many regions of the world as projected climate change portend increase in water scarcity risks at a peak level. Hence, this study attempted to examine potential impacts of climate change along with population growth dynamics on the water resources of the Guinea Savanna Ecological Zone (GSEZ) of Nigeria. To this end, three catchments (Kainji lake catchment (KLC), Asejiri lake catchment (ALC), and Shiroro lake catchment (SLC)) spanning the ecological zone were used; the choice of these catchments was informed by the availability of long and continuous hydrometeorological data. To achieve the aim of the study, water availability analysis was done through the instrumentality of the web-based Royal Netherland Meteorological Institute (KNMI) Climate Explorer. For effective analysis, annual water yield scenarios (short-term, medium-term, and long-term) were generated for future periods using the multi-model ensemble mean of coupled model intercomparison project 5 (CMIP 5 GCMs). These were under three Co_2emission trajectories based on Representative Concentration Pathways (RCP); here, RCP 2.6, 4.5, and 8.5 were adopted. Results obtained based on regional trend analysis revealed absolute water scarcity in the GSEZ. on the other hand, using climate change-population growth scenarios for the respective RCPs, the results indicated variable water stress conditions across the sub-basins or catchments. Under changing climate with stagnant population growth, the cumulative decrease in per capita water stood at 26847 cumec, and 8906 cumec, respectively for KLC and ALC; i.e., between the baseline period (2007-2008) and long-term projection, Similarly, for varying population growth dynamics with constant climate regime, the per capita water was found to be 70678 cumec/year for KLC while both SLC and ALC had a total water availability of 7.0 BCM/year with per capita water reduced to 21853 cumec/year and 18902 cumec/year for KLC. However, for combined climate change-population growth scenario, the results revealed varying spatial trend for the projected future periods under different RCPs in terms of per capita water situations; this connotes variable impact pattern across the GSEZ. It suffices to note that though the CMIP 5 ensemble model is robust, the disparity in its ability to reproduce annual rainfall regime as well as the distribution of variability in processes like evapotranspiration perhaps might have contributed to the nature of the overall results. Therefore, it is imperative to surmise that projected water scarcity on the long-term could largely be attributable to climate change and passively to population growth dynamics.

Keywords: *Trend, per capita water, population growth, representative concentration pathway, climate change*

1. Introduction

Global population growth and its respective demand, as well as climate change, put the water resources under pressure. It is estimated that by 2050, about 4.8 to 5.7 billion individuals will be living under conceivably water-scant regions. Climate change is speeding up every now and then over the Earth's surface because of the increment in human exercises. As per the Intergovernmental Panel on Climate Change in contrast with prior many years, radiative driving on the regular framework has expanded a complex from the 1970s. In like manner, the complete radiative driving is accounted for to be 43% higher in IPCC Assessment Report 5 (AR5) than AR4. The change in neighborhood and worldwide climate, size, and example of temperature and rainfall, influences the rate and event of hydrologic cycles, for example, water cycle and water resources. Water is a basic and fundamental resource for both human uses and environment administrations. Nigeria's surface water resources are assessed at to be around 267 billion m3/annum while its groundwater resource is assessed around 52 billion m3of groundwater potential (A. Babagana 2017). Notwithstanding the gigantic water resources, water resources improvement has not had the option to stay up with the remarkable populace development. With rising populace, water resources address a significant essential and driver of financial turn of events. It likewise assumes a conspicuous part in force and energy age: hydroelectric force a lot of absolute force creation has diminished from more than 70 % in 2004 to the current extent of about 40%. (Babatolu et al., 2014) Yet, simultaneously, populace and financial development have prompted perpetually requests on the resources. The amount and nature of Nigeria's water resources are influenced by the coupling of the human variables and climate change. The projected climate change predicts expansion in water shortage chances at a pinnacle level. Climate change adjusts hydrological measures that keep up with water supply and biological system capacity, and its effect is felt through changing examples of water resources. The changeability and vulnerability of water resources related with climate change are basic issues in bone-dry and semi-dry areas of the world, and tropical waterway catchments face the difficulties of the water resource as the populace develops dramatically. The effects of climate change on hydrological factors and its cycles have been concentrated broadly, especially on surface spillover, groundwater stream, stream, and evapotranspiration, and soil dampness, by examining anticipated and downscaled climatic information and utilizing diverse hydrological models. This is especially noticeable in semi-parched and dry areas on the grounds that in these locales, water resources, fundamentally stream and surface overflow, are exceptionally touchy to climate change; a little change in climate factors might bring about huge varieties of hydrological cycles and aftereffect changes of local water resources. The investigation of the potential reasons for climate change and the reenactment of past and future climate elements help to work on our agreement and consistency of climate conduct on occasional, yearly, decadal, and centennial time scales. In such manner, models and downscaling measures are generally utilized; fundamentally for objectivity of examination, representative concentration pathways (RCP) are considered for situation improvement. Consequently, the main point of this examination spin around the utilization of a holistic investigation of the ramifications of climate change and populace development elements on the water resources of the Guinea Savanna Ecological zone of Nigeria; this depends on situation improvement taking insight of drivers and striking pressing factors that may trigger change sway.

2. Methodology

The study area lies between Longitudes 3°E to 15°E of the Greenwich meridian and Latitudes 8°N to 14°N of the equator Figure 1. The area covers the Guinea savanna Ecological Zones of Nigeria. It is bordered to the north by Niger Republic, to the east by Republic of Cameroun, to the south by the tropical rainforest and to the west by Benin Republic. The two predominant air masses that influence the weather and climate of this zone are Tropical Continental (cT) air mass and Tropical Maritime air mass (mT). The former is dry and dusty which originates from Sahara Desert, while the latter is dense and moist which originates from Atlantic Ocean. The rainfall distribution has a mean of 1120 mm but attain 1500 mm around the plateau while temperature has a mean annual of 24°C to 30°C.

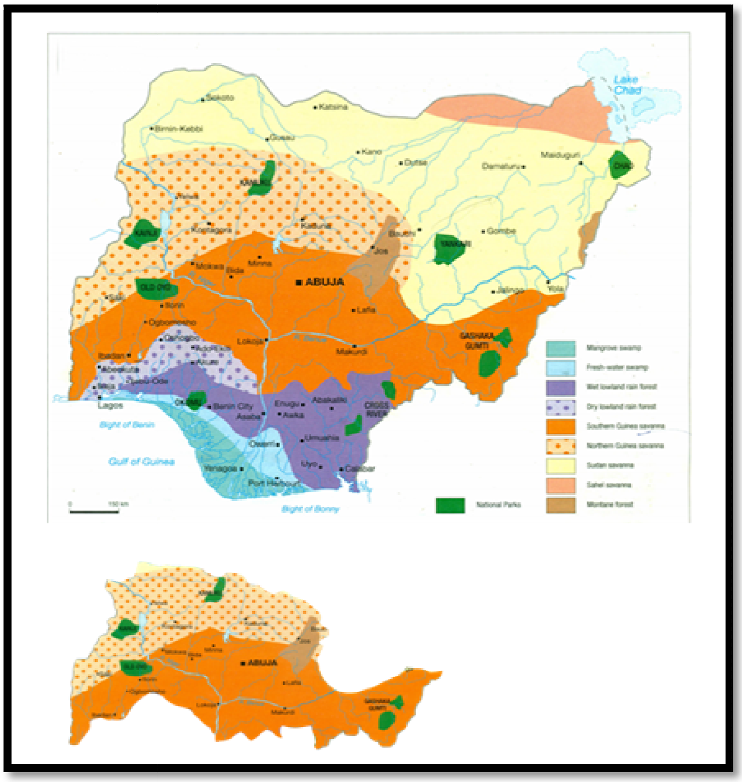

Figure 1

(a) Political map of Nigeria Showing the catchment boundary and (b) Extract detailing the Guinea Savanna Ecological Zone

For this study, three (3) catchments were selected taking cognizance of data availability and hydrologic evolution dynamics of the ecological zone; these were:

- Kainji Lake
- Asejire Lake
- Shiroro Lake

Notwithstanding, examination of water accessibility was completed in three stages. Initially, yearly water yield (yearly contrasts among rainfall and evapotranspiration) was created utilizing an online use of Royal Netherland Meteorological Institute Known as KNMI Climate Explorer (https://climexp.knmi.nl). Numerous climate change examines have been attempted utilizing information from this source (Nurmohamed and Donk 2017; Jacquelyn et al., 2018; Mitchell et al., 2019 and Salihu et al., 2020). The directions of every one of the three catchments to be specific (Kainji lake Catchment, Asejire Lake Catchment and Shiroro Lake Catchment) were utilized to determine the normal yearly water yield. The water yield situation projections were produced for three future periods in particular present moment (2019-2048), medium-term (2049-2078) and long haul (2079-2100) utilizing the multi-model troupe mean of (Coupled Model Inter examination Project 5) CMIP5 GCMs under three Co2 outflow directions (RCPs 2.6, 4.5 and 8.5) concerning the 1981–2010-gauge condition. In the subsequent advance, populace of every one of the catchment was anticipated for three future periods specifically present moment (2019-2048), medium term (2049-2078) and long haul (2079-2100) utilizing the Nigeria's normal populace development pace of 2.6% as announced in 2006 populace census.(JICA Team).In the third step, the data created from stage one and two above were utilized to assess the per capita water in every one of the three catchment dependent on the most regularly utilized marker of water pressure known as the Falkenmark pointer' or 'water pressure file' dependent on Table 1. It is the most regularly utilized proportions of water pressure (Scheweet *al*., 2013; Mohammed et al., 2014; and Singh and Kumar, 2015; Umesh and Pouyan, 2016; and Salihu et al., 2020). This strategy characterizes water shortage as far as the absolute water resources that are accessible to the number of inhabitants in a space; estimating shortage as the measure of inexhaustible freshwater that is accessible for every individual every year.This was done in three ways namely (1) water availability under climate change at constant population growth, (2) water availability under population growth with stable climate, and (3) water availability condition under the combined influence of climate change and population growth. This was computed as:

$$WSI = \frac{AWY \times TLA}{TP} \quad 3.1$$

where,

WSI: Water Stress Index,AWY: Annual water yield, TLA: Total land area, TP: Total population

WSI (CM/Capita/Year)	Stress Level
> 1,700	No Stress
1,000 - 1,700	Stress
500 - 1,000	Scarcity
< 500	Absolute Scarcity

Table 1: Classification of Water Stress Level
Source: Falkenmark (1989) as in Taikan and Quiocho (2020)

However, population projection was computed according to equation (1):

$$P_T = P_O e^{k\Delta t} \quad (1)$$

where:

P_T: Population at time T
P_O: Population at time zero or initial population
k : Growth rate
Δt: Elapsed time in years from time zero

For objectivity, Mann-Kendall test (Mann, 1945; Kendall, 1975) was applied to detect the monotonic trends in projected water stress time series. The Mann-Kendall statistical test has been frequently used to quantify the significance of trends in hydro-meteorological time series (Pervez and Henebry, 2015; Abdussalam, 2017;Nahlah*et al.,* 2019). This was calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n} \text{sign}\left(x_j - x_k\right) \quad (2)$$

$$\text{VAR}(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_{i(t_i-1)(2t_i+5)}}{18} \quad (3)$$

where:

n = the number of data points
t_i = the number of ties for the i value and
m = the number of tied values (a tied group is a set of sample data having the same value)

$$Z_s = \begin{Bmatrix} \frac{S-1}{\sqrt{VAR(S)}} if S > 0 \\ 0 \qquad if S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} if S < 0 \end{Bmatrix} \quad (4)$$

A positive value of Z_s indicates increasing trends while negative $Z_s$value reflects decreasing trends, while 0 value indicates trend was detected at specific significant levels (α). When $|Z_s|$ >Z_1-$^{\alpha}/_2$, the null hypothesis is rejected and a significant trend exists in the time series.Z_1-$^{\alpha}/_2$was obtained from the standard normal distribution Table. In this study, significance levels of α=0.05 was used. According to Nahlah*et al.* (2019), at the 5% significance level, the null hypothesis of no trend is rejected if $|Z_s|$ > 1.96; that is, connoting significant trend in the series.

In order to assess trends at a regional scale, the regional MK test was employed as used by (Mohammed *et al.,* 2014; Michael *et al.,* 2017 and Salihu *et al.,* 2020), to quantitatively combine results of the MK test for individual locations and to evaluate the regional trends. In the regional MK test, the S_r of regional data employed is as in equation (5):

$$S_r = \sum_{i=1}^{n} S_i \quad (5)$$

where

$S_r$is Kendall's S for the "ith" location in a region with m locations within the region. If S_r is estimated using independent identically distributed data, $S_r$is approximately normally distributed for large m with mean equal to 0 and the variance as noted below.

$$Var(S_r) = \sum_{i=1}^{n} Var = \sigma^2 \quad (6)$$

$$Z_r = \begin{Bmatrix} \frac{S_r - 1}{\sigma} if S_r > 0 \\ 0 \quad if S_r = 0 \\ \frac{S_r + 1}{\sigma} if S_r < 0 \end{Bmatrix} \quad (7)$$

To determine whether to reject the null hypothesis of no trend or otherwise, the test statistics Z_r was assessed against the critical value Zcritical corresponding to the specific significance level α of the test. For the two-tailed test, the critical value is defined as $\Phi^{-1}(1 - \alpha/2)$, where Φ is cumulative distribution function of standard normal distribution (Helsel and Hirsch 2002; as in Michael *et al.,* 2017). The null hypothesis is rejected and the trend is considered significant statistically if the value of $|Z_r|$ ≥ Zcritical

3. Discussion

3.1. Evaluation of CMIP5 Model Performance for Rainfall and Evapotranspiration

The authenticity of the CMIP5 multi-model ensemble mean simulation compared with observed evapotranspiration and rainfall in the Guinea savanna ecological zone of Nigeria was assessed using statistical metrics. Table2 shows the statistical details

Climatic Variable	**Kainji Lake Catchment (Klc)**			**Asejire Lakecatchment (Alc)**			**Shiroro Lakecatchment (Slc)**		
	RMSE	MAE	NSE	RMSE	MAE	NSE	RMSE	MAE	NSE
Annual Evapotranspiration	0.86	0.70	0.91	0.67	0.62	0.93	0.75	0.58	0.97
Annual Rainfall	0.49	0.35	0.99	0.53	0.43	0.96	0.60	0.58	0.78

Table 2: Evaluation between Observed and Simulated Rainfall and Evapotranspiration

The result demonstrates that Kainji Lake Catchment (KLC) has the highest error between the simulated and observed annual evapotranspiration given as RMSE (0.86) and MAE (0.70) while the Asejire Lake Catchment (ALC) has the least error given as RMSE (0.67) and MAE (0.62). As for NSE, Shiroro Lake Catchment (SLC) has the highest value (0.97) followed by ALC (0.93) and then KLC (0.91). As noted here,these error values do not in any statistical way connote the inadequacy of the model since they are global statistics and do not reflect the distribution of the variability of the process like evapotranspiration, there is also disparity in the ability of the CMIP5 multi-model ensemble mean to reproduce the annual rainfall across the three catchments. SLC has the highest error between the simulated and observed annual rainfall given as RMSE (0.60)and MAE (0.58) while KLC has the least error given as RMSE (0.49) and MAE (0.35). As for NSE, KLC has the highest error with a value of 0.99 and the least is SLC (0.78). This implies that the CMIP5 multi-model ensemble mean is more robust in its capability to replicate the annual rainfall in KLC than in SLC and ALC.

Furthermore, regardless of the variations in the capability of the CMIP5 multi-model ensemble mean to replicate annual evapotranspiration and rainfall across the three catchments or catchment of Guinea savanna, the errors between the observed and simulated are within the tolerable threshold. The error mergins for evapotranspiration (0.58 - 0.97) and rainfall (0.35 - 0.99) are in tandem with (0.18 - 1.78) reported by Vera and Diaz (2015) for the South America and also consistent with the work of Salihu*et al.,* 2020 in the Guinea and Sudano-Sahelian ecological zones of Nigeria . NSE of (0.8) threshold is in the range of 'very good values' as recommended by Moriasi *et al.* (2007) cited in (Miguel *et al.,* 2018) for general performance ratings. Consequently, it can be deduced that the CMIP5 multi-model ensemble mean is good at simulating the rainfall and evapotranspiration in the Nigeria's Guinea savanna ecological zone.

3.2. Water Availability under Climate Change with Stagnant Population Growth

Water availability under changing climate with stagnated population growth for Guinea savanna ecological zone of Nigeria is presented in Table3 within the Guinea savanna ecological zone, the study concentrated on three hydrological catchments namely: Kainji Lake Catchment (KLC), Asejire Lake Catchment (ALC) and Shiroro Lake Catchment (SLC).

Catchment	Year	Population (Millions)	TWA (BCM/year)	Per Capita WA(Cumec/year)	Falkenmark Index rcp2.6	rcp4.5	rcp8.5
KLC	2006	172835	150	86788	No Stress	No Stress	No Stress
	2007-2018	172835	14250	82449	No Stress	No Stress	No Stress
	2019-2048	172835	12500	72323	No Stress	No Stress	No Stress
	2049-2078	172835	10850	62776	No Stress	No Stress	No Stress
	2079-2100	172835	9610	55602	No Stress	No Stress	No Stress
ALC	2006	2559,853	7403	2892	No Stress	No Stress	No Stress
	2007-2018	255853	7252	2833	No Stress	No Stress	No Stress
	2019-2048	255985	36623	2587	No Stress	No Stress	No Stress
	2049-2078	255985	35323	2079	No Stress	No Stress	Stress
	2079-2100	255985	34293	1677	Stress	Scarcity	Absolute Scarcity
SLC	2006	235404	70	29736	No Stress	No Stress	No Stress
	2007-2018	235404	6745	28673	No Stress	No Stress	No Stress
	2019-2048	235404	5983	25416	No Stress	No Stress	No Stress
	2049-2078	235404	5164	21937	No Stress	No Stress	No Stress
	2079-2100	235404	4652	19767	No Stress	No Stress	No Stress

Table 3: Water Availability (WA) Under Climate Change with Stagnant Population Growth for Guinea Savanna Ecological Zone Of Nigeria
Total Water Availability (TWA), Per Capita Water Availability (PCWA), Billion Cubic Metre(BCM)

Climate projection for short term (2019-2048), medium (2049-2078) as well as long- term (2079-2100) in KLC, indicate absence of water stress across the projected periods for RCP2.6, RCP4.5 and RCP8.5 (Table3), respectively. In addition, results of trend analysis are in mild agreement; though there is discernible evidence of significant trend but statistically, it does not translate to significant water stress. That there are significant trends at the 0.05 significance level (Table 4). Despite this, there is evidence of decrease in water availability such that between the baseline period of (2007-2018) and short-term projection (2019-2048), a decrease of 1,0126 Cumec is visible, between 2019-2048 and 2049-2078 the decrease stands at 9547 Cumec while for 2048-2078 and 2079-2100, the decrease is 7174 Cumec. The cumulative decrease in per capita water between the baseline period (2007-2018) and long- term projection (2079-2100) stands at 26,847 Cumec (Table3). This portrays an adverse effect of climate change on water availability in the catchment (KLC).

In ALC, climate projection for short (2019-2048), medium (2049-2078) as well as long term (2079-2100) exhibits absence of water stress for two projection periods at the 0.05 significance level under lower emission trajectory of RCP2.6, while (2079-2100) projection at the same emission pathway illustrates presence of water stress though not significant at the 0.05 significance level (Table3).

Climatic Period	Water Stress: Climate Change			Population Growth			Combined Impacts			Regional Trend		
RCP8.5												
	KLC	ALC	SLC	KLC	ALC	SLC	KLC	ALC	SLC	CC	PG	CI
2019-2048	+2.57*	+1.62	+1.95*	+2.24*	-1.51	+1.98*	+2.02*	-2.32*	+2.01*	+2.07*	+2.26*	+1.56
2049-2078	+2.08*	-1.31	+2.67*	+2.09*	-2.47*	+2.04*	+1.98*	-2.46*	+2.17*	+1.15	+2.19*	+1.71
2079-2100	+1.92*	-2.61*	+2.08*	+1.95*	-2.62*	+2.39*	+1.93*	-2.51*	-2.41*	-1.48	+1.44	-2.42*
RCP4.5												
	KLC	ALC	SLC	KLC	ALC	SLC	KLC	ALC	SLC	CC	PG	CI
2019-2048	+1.97*	+2.62*	+1.96*	+2.24*	-1.51	+1.98*	+2.42*	-1.63	+1.96*	+2.02*	+2.26*	+2.39*
2049-2078	+2.06*	+1.13	+2.17*	+2.09*	-2.47*	+2.04*	+2.39*	-2.25*	+2.03*	+2.18*	+2.19*	+2.15*
2079-2100	+2.28*	-2.21*	+2.33*	+1.95*	-2.62*	+2.39*	+2.23*	-2.17*	-1.19	+1.94*	+1.44	-2.37*
RCP2.6												
	KLC	ALC	SLC	KLC	ALC	SLC	KLC	ALC	SLC	CC	PG	CI
2019-2048	+2.17*	+2.41*	+2.60*	+2.24*	-1.51	+1.98*	+2.58*	-0.98	+2.41*	+1.97*	+2.26*	+2.06*
2049-2078	+2.06*	+2.31*	+2.03*	+2.09*	-2.47*	+2.04*	+2.51*	-2.48*	+2.37*	+2.26*	+2.19*	+2.01*
2079-2100	+2.18*	-0.61	+1.98*	+1.95*	-2.62*	+2.39*	+2.46*	-2.31*	+2.24*	+2.43*	+1.44	-1.79

Table 4: Mann–Kendall Trend Analysis of Projected Water Availability for Guinea Savanna Ecological Zone Of NigeriaNote: CC =, PG =, AndCI =
**= Statistically Significant Trends at The 0.05 Significance Level.*
(+) = Absence of Water Stress (-) = Presence of Water Stress

Under RCP4.5, climate projection for 2019-2048 reveals absence of water stress that is significant at 0.05 significant levels but not for 2049-2078 while presence of water stress that is statistically significant is evident in 2079-2100 projection period. As for the highest Co_2 emission concentration (RCP8.5), climate change projection shows that there is absence of water stress though not significant at the 0.05 significance level for short term (2019-2048) projection, while for the medium projection, there is presence of water stress although not significant but become significant at long term projection (Table3). Similarly, at SLC just like in KLC, there is absence of water stress that is statistically significant at 0.05 significant levels across the projected periods for RCP2.6, RCP4.5 and RCP8.5 (Table3). The decrease in per capita water between the baseline period of (2007-2018) and short-term projection (2019-2048) of 3,257 Cumec is visible, between 2019-2048 and 2049-2078 the decrease stands at 3,479 Cumec, for 2048-2078 and 2079-2100, the decrease is 2,170 Cumec, while the cumulative decrease between the baseline period (2007-2018) and long-term projection (2079-2100) stands at 8,906 Cumec (Table3).

However, at a regional level, there is evidence of absence of water stress in the Guinea savanna ecological zone. This assertion is strengthened by the result of Regional Mann-Kendall (RMK) test at the 0.05 significance level which revealed that under low and medium high Co_2 concentration, there is absence of water stress for all the three projected periods. on the contrary, the statistical analysis under the higher emission trajectory illustrates presence of water stress for 2019-2048 and 2049-2078 projection periods. The former was significant at the 0.05 significance level, while the later was not (Table 3). As for the 2079-2100 projection periods, the analysis shows the presence of water stress though not significant at the 0.05 significance level. Despite this mixed and contrasting results as reported by Liu *et al.* (2019), climate change has significant impacts on hydrological, biological, and ecological systems which are all closely related to water resources, causing sustainability concerns around the world. These facts indicate that understanding the evolution mechanism of climate change has thus become a priority area, both for research and for water management strategies.

3.3. Water Availability under Population Growth with constant Climate

Table5 shows water availability status under population growth at stable climate in Guinea ecological zone of Nigeria. Based on 2006 population census (JICA project team), which stood at 172.8 thousand for

Catchmen	Year	Population (Millions)	TWA (BCM/year)	Per Capita WA(Cumec/year)	Falkenmark Index
KLC	2006	172,835	15.0	86788	No Stress
	2007 – 2018	212,231	15.0	70678	No Stress
	2019 – 2048	446,768	15.0	33574	No Stress
	2049 – 2078	940,492	15.0	15949	No Stress
	2079 – 2100	1,571,456	15.0	9545	No Stress
ALC	2006	2,559,853	7,403	2892	No Stress
	2007 – 2018	3483240	7,403	2125	No Stress
	2019 – 2048	7332581	7,403	1019	Stress
	2049 – 2078	15435842	7,403	489	Absolute Scarcity
	2079 – 2100	25,791,556	7,403	287	Absolute Scarcity
SLC	2006	235,404	7.0	29736	No Stress
	2007 – 2018	320319	7.0	21853	No Stress
	2019 – 2048	674305	7.0	10381	No Stress
	2049 – 2078	1,419,482	7.0	4931	No Stress
	2079 – 2100	2371795	7.0	2951	No Stress

Table 5: Water Availability under Population Growth with Stagnant Climate for Guinea Savanna Ecological Zone of Nigeria
Total Water Availability (TWA), Per Capita Water Availability (PCWA), Billion Cubic Metre(BCM)

KLC, the total available water was 15.0 BCM/year and the per capita water was 86,788 CM/year; this reveals that there was no water stress in the catchment at this time. Conversely, ALC population under the same period stood at 2.55 million with total available water of 7.4 BCM/year and the per capita water of 2892Cumec/year. Based on Falkenmark Index, this indicates that there is no water stress in this catchment (Table5). As for the SLC, it has a population of 235.4 thousand under the same time with total water availability of 7.0 BCM/year and per capita water of 29,736Cumec/year. At 2018, the population projection based on 2.6% growth rate of 2006 national census, the total population of KLC is projected to be 212.2 thousand with total water availability assumed to remain 15 BCM/year under stable climate condition. The per capita water was found to be 70678 CM/year which means there is no water stress in the catchment (Table5). However, the situation at ALC during the same time shows a total water availability to remain at 7.4 BCM and per capita water decreasing to 2125 Cumec/year indicating that there is absence of water stress in the catchment. The condition over SLC at the same period shows that total water availability remain at 7.0 BCM/year and per capita water decreased to 21853Cumec/year. This also points out that there is absence of water stress condition in the catchment.

In KLC, population projection for short (2019-2048), medium (2049-2078) as well as long- term (2079-2100) exhibits absence of water stress with statistically significant trend for the three projected periods at the 0.05 significance level (Table 3). But, the variation between the per capita water of the baseline period (2007-2018) and short-term projection (2019-2048) stands at 37,104 Cumec/year, the disparity between 2019-2048 and 2049-2078 stand at 17,625 Cumec/year, between 2049-2078 and 2079-2100 there is a decrease of 6,404 Cumec/year, while the cumulative decrease between the baseline period (2007-2018) and long- term projection (2079-2100) stands at 61,133 Cumec/year (Table 4.). The quantity of water available in the KLC is two-fold that of the ALC with small population which accounted for the absence of water stress in the catchment. As for the ALC, the three population projection periods all demonstrate presence of water stress in the catchment. This may not be unconnected with the large population within this catchment with corresponding relative low water availability. The trend of water stress was tested at the 0.05 significance level and the analysis showed that for the short term, it is not significant but for the medium and long- term projections, there is significant trend in the presence of water stress (Table4). This result agrees with Schewe*et al.,* (2014) which established that a common prediction to the next few decades is that population growth, not climate change, will be the dominant factor determining number of people living under water scarcity condition. Similarly, the condition at SLC illustrates the absence of water stress for the baseline as well as the three projected periods. The trend analysis confirms a significant trend in the absence of water stress at the 0.05 significance level for the projection periods under consideration (Table 4.). Notwithstanding, there is evidence of decrease in per capita water such that between the baseline period (2007-2018) and short-term projection (2019-2048), there is a visible decrease of 11,472 Cumec, between 2019-2048 and 2049-2078 the decrease stands at 5,450 CM, between 2048-2078 and 2079-2100 the decrease is 1,980 Cumec, while the cumulative decrease between the baseline period and long-term projection stands at 18,902 Cumec (Table5).

In addition, at a regional scale there is confirmation of absence of water stress in the Guinea savanna ecological zone. This is reinforced by the result of the regional trend analysis tested at the 0.05 significance level. The statistical test indicates significant trend in the absence of water stress for 2019-2048 and 2049-2078 projection period, but not significant for the 2079-2100 period. When the regional analysis of Guinea savanna ecological zone under stable climate with population growth is compared with the findings under stagnated population growth and climate change, there are variations across the projected periods (Table3). This is a clear indication that the impact of climate change and population growth on water availability in Guinea savanna ecological zone is not the same but rather of different magnitude. This finding is in agreement with that of Gao *et al. (*2016) that demographic changes are very likely to outpace the impact of climate change on water availability and should therefore be the priority for local policy making.

3.4. Water Availability under Combined Climate Change and Population Growth

The water availability under the collective impact of climate change and population growth for Guinea savanna ecological zone is as shown in Table6. At the KLC, there is evidence of absence of water stress for both the baseline and the three projected periods. i.e., for the RCP2.6, RCP4.5 and RCP8.5. The results of trend analysis revealed significant trend in the absence of water stress at the 0.05 significance level for the three projected periods, as well as under the three representative concentration pathways (Table 3). However, in spite of the absence of water stress in the catchment, there is a continuous decrease in per capita water across the projected periods. A closer look at Table6shows that per capita water decreases from 67,144 Cumec in the baseline period (2007-2018) to 27,979 Cumec during the short-term projection (2019-2048) with a difference of 39,165 Cumec, between 2019-2048 and 2049-2078, the decrease stands at 16,442 Cumec, between 2048-2078 while for 2079-2100, the decrease is 5,422 Cumec. The cumulative decrease between the baseline period (2007-2018) and long-term projection (2079-2100) stands at 61,029 Cumec (Table6). But for ALC, there is presence of water stress even at the baseline period for high emission trajectory but not for low and medium high Co_2 concentration. Water availability during the projected term periods have worsened to the level of water scarcity under RCP2.6 and RCP4.5 with absolute scarcity under RCP8.5 for the 2019-2048 projection. Although, the trend analysis demonstrates that there is no significant trend at the 0.05 significance level for RCP2.6 and RCP4.5 however it is significant under RCP8.5. Conversely, the per capita water condition under the 2049-2078 and 2079-2100 projection periods indicates absolute scarcity with a statistically significant trend under the three representative concentration pathways (Table 3). The implication of this finding is that there is foreseeable water crisis in this catchment, capable of disrupting the normal socio-economic activities in the area. As reported in Hanasaki*et al.* (2018), climate change leads to decreases in water quantity and will worsen as population increases, this will lead to increases in the demand in regions of scarcity which can force the use of poor or unsuitable water with drastic repercussions for industry, human health and the associated costs of health care.

Catchment	Year	Population (Millions)	TWA (BCM/year)	Per Capita WA(CM/year)	Falkenmark Index rcp2.6	rcp4.5	rcp8.5
KLC	2006	172,83515.0		86788	No Stress	No Stress	No Stress
	2007-2018	212,23114,250		67144	No Stress	No Stress	No Stress
	2019-2048	446,76812,500		27979	No Stress	No Stress	No Stress
	2049-2078	940,49210,850		11537	No Stress	No Stress	No Stress
	2079-2100	1,571,456 9,610		6115	No Stress	No Stress	No Stress
ALC	2006	2,559,8537,403		2892	No Stress	No Stress	No Stress
	2007-2018	34832407,252		2082	No Stress	No Stress	Stress
	2019-2048	73325816,623		903	Scarcity	Scarcity	Absolute Scarcity
	2049-2078	154358425,323		345	Absolute Scarcity	Absolute Scarcity	Absolute Scarcity
	2079-2100	25,791,5564,293		166	Absolute Scarcity	Absolute Scarcity	Absolute Scarcity
SLC	2006	235,4047.0		29736	No Stress	No Stress	No Stress
	2007-2018	320319 6,745		21057	No Stress	No Stress	No Stress
	2019-2048	674305 5,983		8873	No Stress	No Stress	No Stress
	2049-2078	1,419,4825,164		3638	No Stress	No Stress	No Stress
	2079-2100	23717954,652		1961	No Stress	Stress	Scarcity

Table 6: Water Availability (WA) Under Climate Change and Population Growth for Guinea Savanna Ecological Zone Of Nigeria
Total Water Availability (TWA), Per Capita Water Availability (PCWA), Billion Cubic Metre(BCM)

However, in SLC unlike ALC, there is absence of water stress during the baseline as well as the short- and medium-term projections. The absence of water stress during the two projection periods was subjected to trend analysis at the 0.05 significance level, and the result indicates significant trend under the three emission pathways. The long- term projection shows presence of water stress under the RCP4.5 and RCP8.5 (Table6). In addition, the result of the regional trend for the whole ecological zone under the influence of climate change and population growth tested at the 0.05 significance level is as shown in Table 3. The 2019-2048 and 2049-2078 projections revealed absence of water stress with statistically significant trend under the low and medium high Co_2 concentration but not significant under the high emission trajectory. Based on the 2079-2100 projection, evidence abounds that there is presence of water stress, though not significant under RCP2.6 but significant under RCP4.5 and RCP8.5. This contrasting result is in accordance with the findings of Greve*et al.* (2018) who concluded that almost 80% of the world's population is exposed to significant fresh water security threats via multiple stressors, two of which are population and climate change. This is a clear indication that the envisaged condition in Guinea savanna ecological zone of Nigeria is a similitude of the 21st century global reality, where lack of water will be one of the key factors limiting development in many areas of the world.

4. Conclusions

Fluctuation in climate change and populace development recommend that provincial pattern of the relative multitude of three catchments, demonstrate that total water shortage is disturbing in the whole Guinea savanna environmental zones of Nigeria regarding all the three emanation situations just as across the projection time-frames. These vertical patterns tried at 0.05 critical levels were completely observed to be huge. Alternately, under populace development at steady climate, the populace was projected to be 172,835 thousand, 2.55 million, and 235.4 thousand for KLC, ALC and SLC individually. While per capita water for KLC remain at 86,788CM/year, for ALC is 2892 CM/year and SLC is 29,736CM/year. This means that shortfall of water worries about ALC and KLC there is worry about SLC. This suggests that future water shortage will by essentially brought about by climate change and just optionally by populace development in Guinea savanna environmental zone of Nigeria. The outcomes can go about as rules for vital anticipating versatile and alleviation measures to water pressure as imagined by the projection. This will likewise shape a pattern for future examination in Guinea savanna environmental zones and Nigeria overall.

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