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21ST CENTURY TREND OF WATER YIELD IN RIVER BASINS OF GUINEA AND SUDANO-SAHELIAN ECOLOGICAL ZONES, NIGERIA

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ABSTRACT

In Nigeria, the climate in recent years has witnessed significant variability across the various ecological zones due to climate change. Thus, the objective of this study was to analyse the 21st century trend of water yield in river basins of Guinea and Sudano-Sahelian ecological zones, Nigeria. The data and computation were done using KNMI Climate Explorer. The coordinates of the basins were used to derive the annual and seasonal water yield. Projections were produced for near-term (2019-2048), mid-term (2049-2078) and long-term (2079-2100) using ensemble mean of CMIP5 under RCP2.6, RCP4.5 and RCP8.5. Findings revealed that water yield during dry season demonstrates decreasing range of (-0.05 to -0.1 mm/day). It was observed that the decrease were only significant for RCP8.5 but not under middle and low emission trajectories. As for wet season, it reveals significant increasing trends at 0.05 significant levels with respect to RCP8.5 but not significant in low and middle emission scenarios. Regional trend analysis of average annual water yields reveals no significant positive trends for all the RCPs. This is to say that despite the projected increasing pattern of average annual water yield observed over Guinea and Sudano-Sahelian ecological zones, incidences of water crisis cannot be ruled out.

Contribution/Originality: This paper's primary contribution is finding that river basins of Guinea and Sudano-Sahelian ecological zones of Nigeria will be significantly affected by the anthropogenic climate change at highest emission trajectory. The result can act as guidelines for strategic planning against water crisis as envisaged by the projection.

1. INTRODUCTION

Climate projection is usually a statement about the likelihood that something will happen several decades to centuries in the future if certain influential conditions develop. Scenarios however, represent alternative possible ways in which the future may unfold [1]. Globally, it is estimated that by 2050 between 150 and 200 million people could be displaced as a consequence of phenomena, such as sea level rise and increased extreme weather events [2-5].

Furthermore, the Global Environmental Outlook's Baseline Scenario OECD, (2012) cited in Adefisan [6] projects increasing strains on water resources through 2050, with an additional 2.3 billion people expected to be living in areas with severe water stress, especially in North and South Africa and South and Central Asia. WWAP (United Nations World Water Assessment Programme) [7] predicts the world could face a 40% global water deficit by 2030 under a business-as-usual (BAU) scenario. Africa's rising population is driving demand for water under accelerated degradation of existing water resources. More so, about 66% of Africa is arid or semi-arid and more than 300 of the 800 million people in sub-Saharan Africa live in a water-scarce environment [8]. These statistics from global and continental trend are indeed mind-bogging which calls for a study of this nature at local scale to unravel the potential impact of climate change on water resources.

In Nigeria, the climate in recent years has witnessed significant variability across the various ecological zones due to climate change. According to Temidayo and Emmanuel [9] the Sahelian drought that started in 1969 which lingered on till 1973 to 1983-84 affected northern Nigeria and the calamity have had tremendous socio-economic impacts on the area where pressure on available resources result in hydrological imbalance such as inadequate water supply, reservoirs empty, wells dry up, and crop damage ensued. The severity of the drought was gauged by the degree of moisture deficiency, its duration, and the size of the area affected. This is also supported by Chukwuma [10] who contend that over the years, the Nigerian government had not given the much needed attention to issue of climate change, particularly in the arid northern Nigeria. The net effects were shrinking of the Lake Chad and insecurity occasioned by the farmer-herder clashes and population displacement.

However, understanding of climate change is continually improving, but the future climate remains uncertain [11]. For this reason, it is of vital importance to consider a range of possible future climate conditions across the Guinea and Sudano-Sahelian ecological zone of Nigeria if any meaningful development is to take place in the water resource management and agricultural sector which has been of utmost priority in recent times.

2. MATERIALS AND METHODS

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 Table 1. The area covers the Guinea and Sudano-Sahelian 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 these zones are Tropical Continental (cT) air mass and Tropical Maritime air mass (mT) [12]. 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 shows a mean of 1120mm but attain 1500mm around the plateau area. The temperature shows a mean annual of 24°C to 30°C. Figure 1 shows the study area.

Table-1. Location and size of the study area.

Ecological Zones	River Basin	Latitude (°N)	Longitude (°E)	Area (KM^{2})	Elevation (ma.s.l.)
Guinea savanna	Kainji Lake	9° 51' -	4° 34' -	1,300	142
	Basin (KLB)	10° 11'	4° 36'		
Sudan savanna	Sokoto - Rima	10° 12'	3° 44' -	135,000	300
	Basin (SRB)	12° 25'	8° 14'		
Sahel savanna	Komadugu - Yobe	12° 88' -	7° 90' -	84,138	294
	Basin (KYB)	13° 31'	11° 56'		

Source: Abdullahi, et al. [13].

The data and computation of water yield (differences between rainfall and potential evapotranspiration) were done using a web based application of Royal Netherland Meteorological Institute Known as KNMI Climate Explorer (https://climexp.knmi.nl)developed by Sillmann, et al. [14]. Many climate change studies have been undertaken using data from this source [15-17].

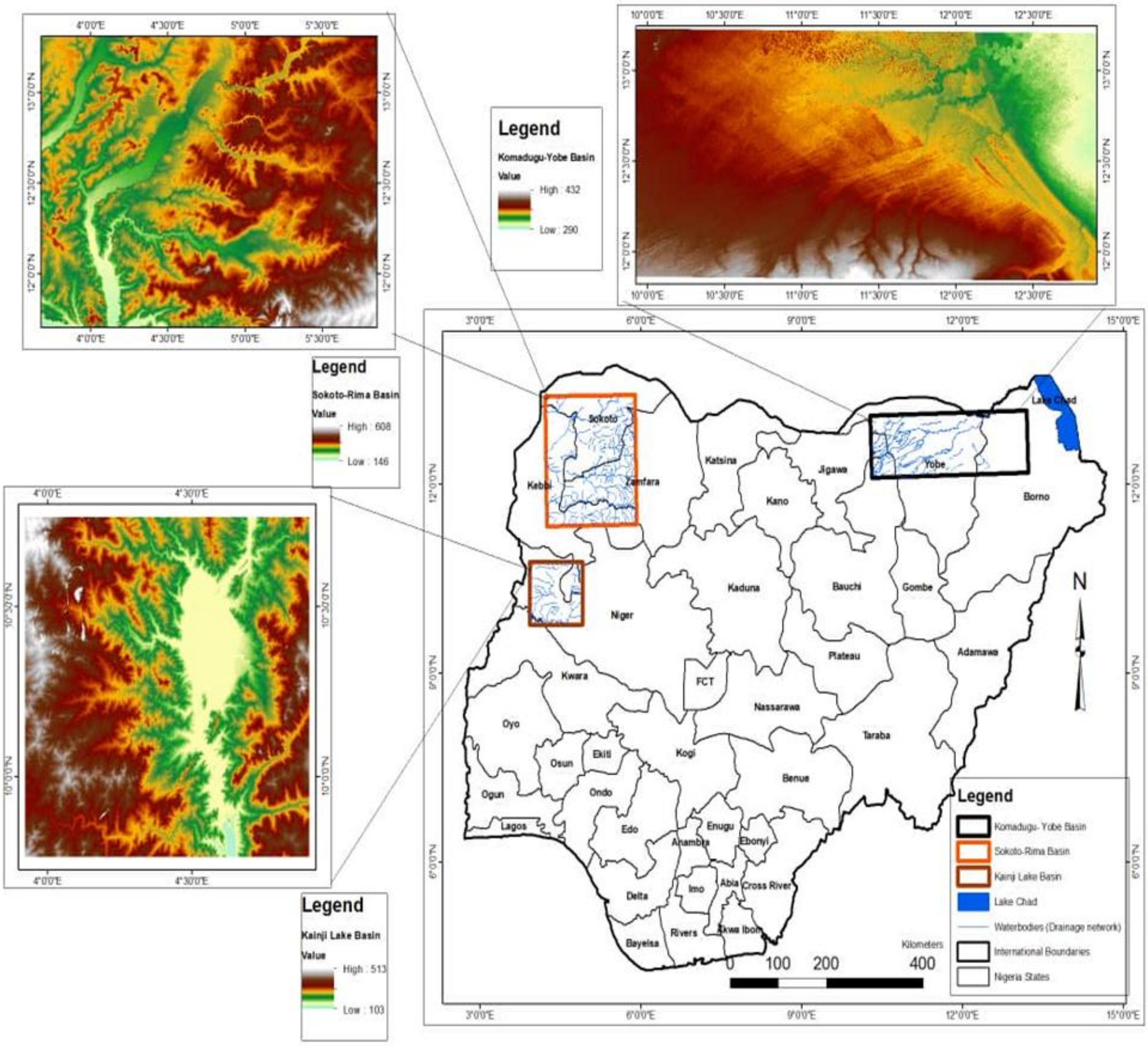


Figure-1. The Study area.

The coordinates of each of the three basins namely: Kainji Lake Basin (KLB), Sokoto-Rima Basin (SRB) and Komadugu-Yobe Basin (KYB) were used to derive the extreme rainfall indices considered herein Table 1. Projections were produced for three future periods namely: near-term (2019-2048), mid-term (2049-2078) and long-term (2079-2100) using the multi-model ensemble mean of CMIP5 GCMs under RCP2.6, RCP4.5 and RCP8.5 with references to the 1959-1988 and 1989-2018 baselines.

Furthermore, the whole process was done for annual (January-December), dry season (November-April) denotes as NDJFMA, and wet season (May-October) denotes as MJJASO. Berghuijs and Greve [18] computed these based on two balance equations: the water balance and the energy balance.

$$\frac{\Delta s}{dt} = P - E - Q \qquad (1)$$

$$R_{n} = p\lambda E + H + G \qquad (2)$$

Where S is the water storage, P the precipitation, E = actual evaporation,
Q the catchment runoff, Rn = the net radiation, λ = the latent heat of vaporization,
H = the sensible heat flux, G = the ground heat flux.

By dividing Equation 1 by Equation 2;

The runoff, Q, can be estimated as $(Q = P - E)$. (3)

Equation 3 was used to determine the water yield at seasonal and average annual basis.

To achieve part of objective, Mann-Kendall test [19, 20] was applied to detect the monotonic trends in projected water yield time series. The Mann-Kendall statistical test has been frequently used to quantify the significance of trends in hydro-meteorological time series [21-23]. This is calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n} \operatorname{sign}\left(x_j - x_k\right) \tag{4}$$

$$\mathrm{VAR}\,(S) = \frac{\left[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)\right]}{18} \tag{5}$$

Equations 4 and 5 were substituted to arrived at Equation 6

Where:

n = the number of data points.

t_i = the number of ties for the i value.

m = the number of tied values (a tied group is a set of sample data having the same value).

$$Z_s = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if S > 0 \\ 0 & if S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if S < 0 \end{cases} \tag{6}$$

Equation 6 was used to determine monotonic trend in the water yield at seasonal and average annual basis

A positive value of Z_s indicates increasing trends while negative $Z_s$value reflects decreasing trends, while 0 values indicate no trends. Testing trends was done at specific α significant level. When $|Z_s| > Z_{1-\alpha/2}$, the null hypothesis is rejected and a significant trend exists in the time series.$Z_{1-\alpha/2}$ is obtained from the standard normal distribution table. In this study, significance levels of α=0.05 was used. Nahlah, et al. [23] stated that at the 5% significance level, the null hypothesis of no trend is rejected if $|Z_s| > 1.96$ and conclude that there is significant trend in the time series.

In order to assess trends at a regional scale, the regional MK test was employed as used by Mohammed, et al. [24]; Michael, et al. [5] 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 is calculated as:

$$S_r = \sum_{i=1}^{n} S_i \tag{7}$$

Equation 7 is the regional Kendal test.

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.

$$Var(S_r) = \sum_{i=1}^{n} Var = \sigma^2 \tag{8}$$

$$Z_r = \begin{cases} \frac{S_r - 1}{\sigma} for S_r > 0 \\ 0 \quad for S_r = 0 \\ \frac{S_r + 1}{\sigma} for S_r < 0 \end{cases} \tag{9}$$

Equations 8 and 9 were used to determine the regional trend of the three locations as one.

To determine whether to reject or not the null hypothesis of no trend, the test statistics Z_r is assessed against the critical value Zcrit 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; cited in Michael, et al. [5]. The null hypothesis is rejected and the trend is considered significant statistically if the value of $|Z_r| \geq$ Zcrit.

3. RESULTS AND DISCUSSION

3.1. Projected Changes in Dry Season Water Yield

The near-term (2019-2048) projection shows that dry season water yield will decrease across the KLB, SRB and KYB with reference to the two baselines of 1959-1988 and 1989-2018 as well as under the RCPs 2.6, 4.5 and 8.5 Figure 2a-c. Condition observed in KLB indicate that water yield will decrease within the range of (-0.02 to -0.2 mm/day) for all the three RCPs under the two baseline periods of (1959-1988) and (1989-2018). RCP8.5 accounts for the highest decrease of (-0.2 mm/day) and lowest being RCP2.6 with (-0.02 mm/day) under the 1959-1988 baseline, while a contrasting pattern of increase is observed under 1989-2018 baseline for RCPs 2.6 and 4.5 which ranges from (+0.02 to +0.25 mm/day) but decreases by (-0.08 mm/day) for RCP8.5. Table 2 trend analysis of dry season water yield confirms no significant decreasing trend at 0.05 significant levels.

However, water yield during dry season over SRB reveals decreasing range of (-0.05 to -0.1 mm/day) with reference to the two baselines of 1959-1988 and 1989-2018 but not significant at 0.05 significant levels for low and highest emission trajectories Table 2. Similarly, KYB dry season water yield shows a decrease of (-0.07 to -0.3 mm/day) such that RCP4.5 and RCP8.5 responsible for the lowest and highest decreases respectively. Mann Kendal trend analysis at 0.05 significant levels reveal no significant decreasing trend for RCPs 2.6 and 4.5 but significant for RCP8.5 Table 2. At mid-term projection (2049-2078), KLB dry season water yield decreases with a lower magnitude compared to near-term projection. It ranges between (-0.09 to -0.15 mm/day) for all the three RCPs. Under 1959-1988 baseline, RCP4.5 accounts for the lowest decrease but highest decrease for RCP8.5 while under 1989-2018 baseline, RCP2.6 experience a slight increase of (+0.02 mm/day) but decreases within the range of (-0.07 to 0.1 mm/day) for RCPs 4.5 and 8.5 Figure 2a. Statistical trend analysis indicates neither non-significant increasing nor decreasing trend at 0.05 significant levels respectively. In SRB, there is existence of increase of dry season water yield to a magnitude of (+0.2 mm/day) for RCP2.6 under 1989-2018 baseline but decreases for other RCPs under both 1959-1988 and 1989-2018 baselines with a range of (-0.02 to 0.2 mm/day). The decreasing trends were tested at 0.05 alpha levels and were found only for RCP8.5 but not for lower emission pathways Table 2. Furthermore, KYB dry season water yield confirms similar pattern of decrease as observed over KLB and SRB with a range of (-0.04 to -0.5 mm/day) for all the three CO_2 emission trajectories.

1959 – 1988 Baseline **1989 – 2018 Baseline**

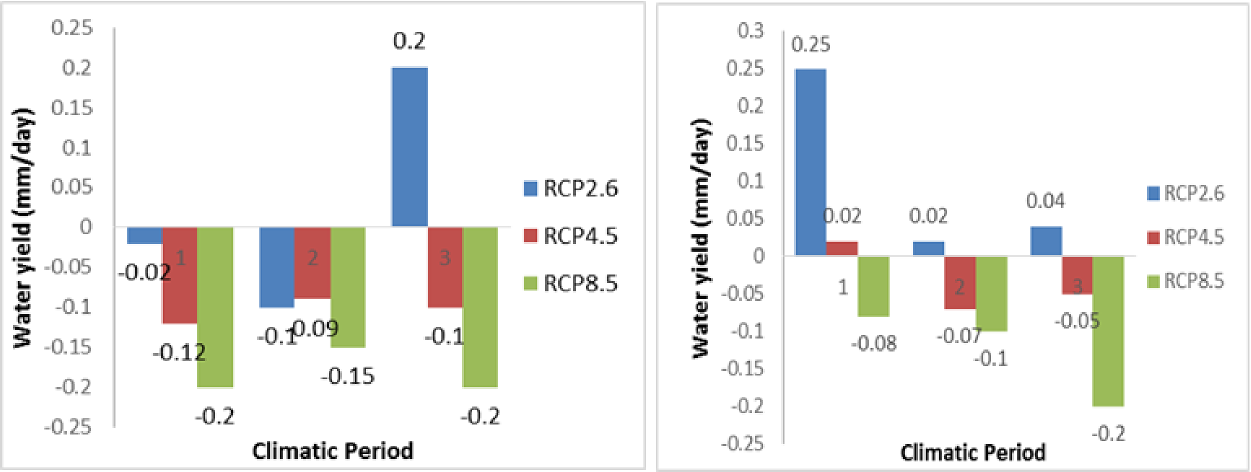


Figure-2a. Projected changes in dry season water yield for KLB.

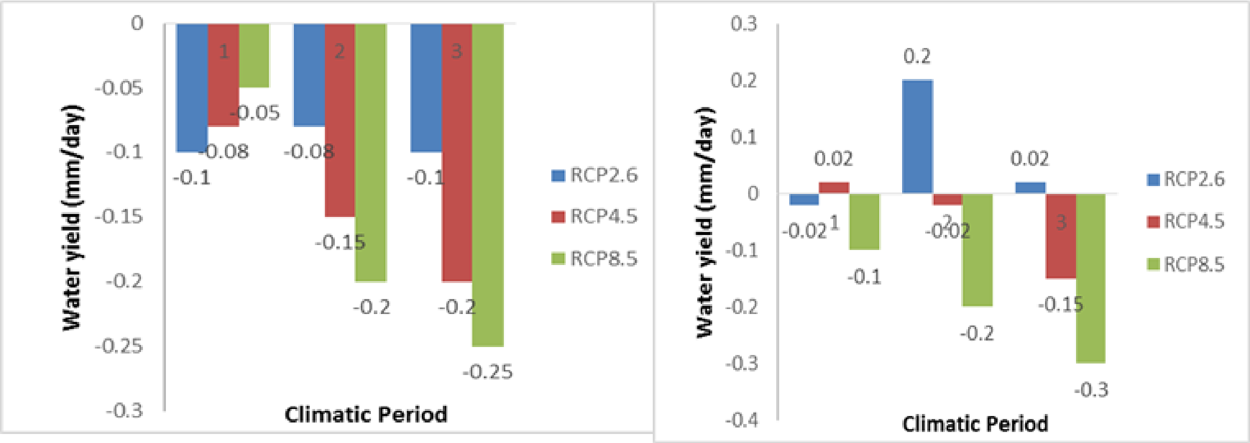


Figure-2b. Projected changes in dry season water yield for SRB.

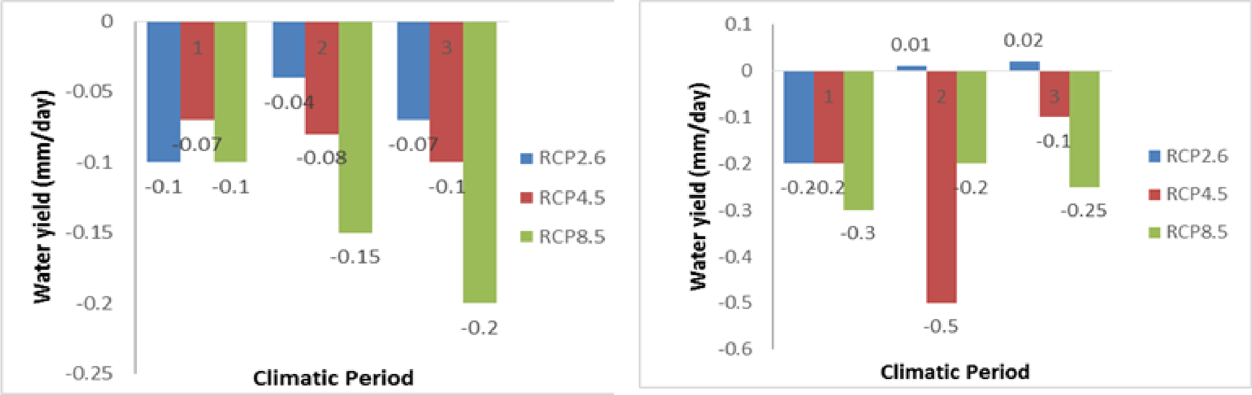


Figure-2c. Projected changes in dry season water yield for KYB.

Table-2. Mann–Kendall trend analysis of projected seasonal and average annual water yield for KLB, SRB and KYB.

Climatic Period	**Water Yield**											
	Dry			**Wet**			**Annual**			**Regional Trend**		
						RCP8.5						
	KLB	**SRB**	**KYB**	**KLB**	**SRB**	**KYB**	**KLB**	**SRB**	**KYB**	**Dry**	**Wet**	**Annual**
2019-2048	-1.18	-1.32	-2.86*	1.64	2.46*	0.38	0.18	1.73	1.09	-1.26	-2.08	1.48
2049-2078	-1.39	-2.86*	-1.06	2.92*	2.48*	2.60*	0.86	1.36	0.89	-2.06	2.73*	1.54
2079-2100	-2.64*	-2.31*	-2.80*	2.58*	2.82*	2.65*	1.36	1.86	1.93	-2.84*	2.36*	0.38
						RCP4.5						
	KLB	SRB	KYB	KLB	SRB	KYB	KLB	SRB	KYB	Dry	Wet	Annual
2019-2048	-0.67	-1.62	-1.36	1.30	1.48	1.35	1.82	1.39	0.31	-1.39	2.36*	1.86
2049-2078	-1.06	-1.31	-2.67*	0.89	2.39*	1.74	0.19	0.63	1.53	-0.05	1.75	0.31
2079-2100	-0.82	-2.61*	-1.88	2.56*	2.05*	1.64	0.33	1.24	1.51	-1.84	2.33*	1.38
						RCP2.6						
	KLB	SRB	KYB	KLB	SRB	KYB	KLB	SRB	KYB	Dry	Wet	Annual
2019-2048	-1.06	-1.62	-0.93	0.86	1.99*	2.03*	1.38	1.98	1.38	-1.69	2.36*	1.16
2049-2078	-0.69	-0.63	-1.54	0.69	0.88	0.62	0.86	1.36	1.38	-1.36	0.86	1.28
2079-2100	1.19	-0.40	-1.36	2.41*	2.77*	1.62	0.34	1.36	0.89	-0.28	2.56*	1.74

Note: (*) = Statistically significant trends at the 0.05 significance level.
(+) = positive trend in water yield (-) = negative trend in water yield.

Table-2. Mann–Kendall trend analysis of projected seasonal and average annual water yield for KLB, SRB and KYB.

Climatic Period	**Water Yield**											
	Dry			**Wet**			**Annual**			**Regional Trend**		
	RCP**8.5**											
	KLB	**SRB**	**KYB**	**KLB**	**SRB**	**KYB**	**KLB**	**SRB**	**KYB**	**Dry**	**Wet**	**Annual**
2019-2048	1.48	-1.18	-1.32	-2.86*	1.64	2.46*	0.38	0.18	1.73	1.09	-1.26	-2.08
2049-2078	-1.39	-2.86*	-1.06	2.92*	2.48*	2.60*	0.86	1.36	0.89	-2.06	2.73*	1.54
2079-2100	-2.64*	0.38	-2.31*	-2.80*	2.58*	2.82*	2.65*	1.36	1.86	1.93	-2.84*	2.36*
	RCP4.5											
	KLB	SRB	KYB	KLB	SRB	KYB	KLB	SRB	KYB	Dry	Wet	Annual
2019-2048	-0.67	-1.62	-1.36	1.30	1.48	1.35	1.82	1.39	0.31	-1.39	2.36*	1.86
2049-2078	-1.06	-1.31	-2.67*	0.89	2.39*	1.74	0.19	0.63	1.53	-0.05	1.75	0.31
2079-2100	-0.82	-2.61*	-1.88	2.56*	2.05*	1.64	0.33	1.24	1.51	-1.84	2.33*	1.38
	RCP2.6											
	KLB	SRB	KYB	KLB	SRB	KYB	KLB	SRB	KYB	Dry	Wet	Annual
2019-2048	1.16	-1.06	-1.62	-0.93	0.86	1.99*	2.03*	1.38	1.98	1.38	-1.69	2.36*
2049-2078	1.28	-0.69	-0.63	-1.54	0.69	0.88	0.62	0.86	1.36	1.38	-1.36	0.86
2079-2100	1.74	1.19	-0.40	-1.36	2.41*	2.77*	1.62	0.34	1.36	0.89	-0.28	2.56*

Note: (*) = Statistically significant trends at the 0.05 significance level.
(+) = positive trend in water yield (-) = negative trend in water yield.

RCP4.5 shows the highest magnitude of decrease specifically under 1989-2018 baseline period. This singular decrease is the highest for the whole three basins put together. Table 2 trend analysis of dry season water yield over KYB reveals significant decreasing trend at 0.05 significant levels for medium emission pathway but not for low and high emission trajectories.

During the long-term projections (2079-2100), dry season water yield over KLB experience increasing trend for RCP2.6 up to (+0.2 mm/day) but not significant. However, RCPs 4.5 and RCP8.5 continues with a decreasing trend under the two baselines with a range of (-0.05 to 0.2 mm/day) which were found significant for RCP8.5 but not for RCP4.5. In SRB the dry season water yield experiences decreasing pattern for all the three RCPs except RCP2.6 with slight increase of just (+0.02 mm/day). However, the range of decrease is within the range of (-0.1 to -0.3 mm/day) for RCPs 4.5 and 8.5. The (-0.3 mm/day) decreasing pattern is the highest observed for RCP8.5 in the whole basins such that Mann Kendal trend analysis confirms significant decreasing trend at 0.05 significant levels. As for KYB, decreasing trend is also noticed for the three RCPs but only significant for highest emission pathways. Regional trend analysis of the three basins as a whole confirms that Guinea and Sudano-Sahelian ecological zones of Nigeria will experience decreasing dry season water yield from the near-term (2019-2048), mid-term (2049-2078) and long-term (2079-2100) with reference to 1959-1988 and 1989-2018 baselines. In Table 2 it is observed that the decreasing dry season water yield were only significant for RCP8.5 but not under middle and low emission trajectories.

3.2. Projected Changes in Wet Season Water Yield

Wet season water yield over KLB, SRB and KYB that collectively refer to the Guinea and Sudano-Sahelian ecological zones are shown on Figure 3a-c. Wet season water yield were projected for near, mid and long-term with reference to 1959-1988 and 1989-2018 baselines.

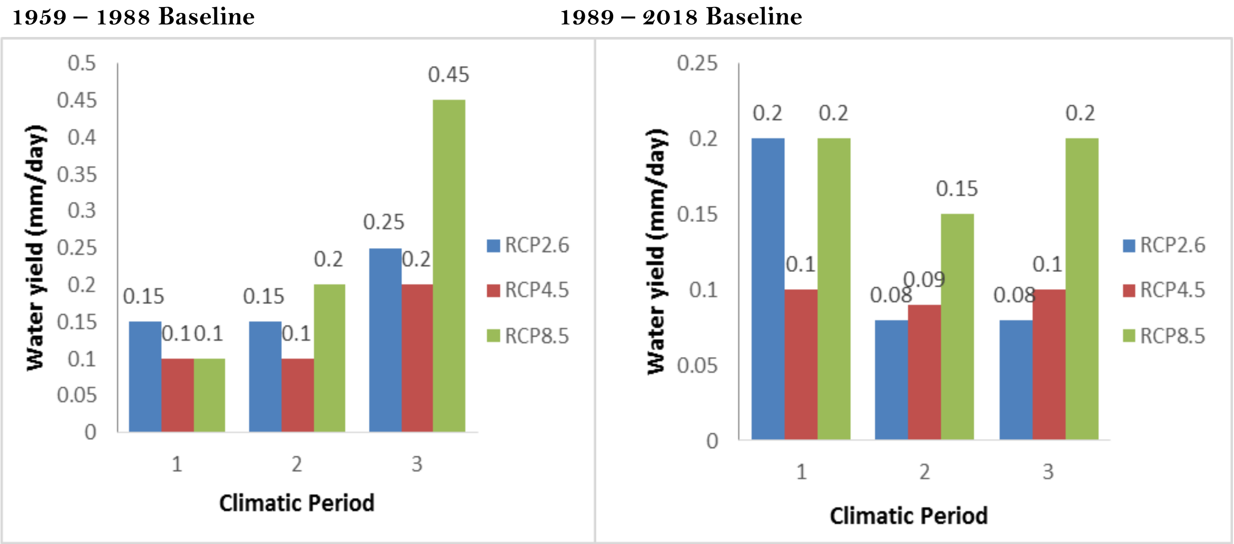


Figure-3a. Projected changes in wet season water yield for KLB.

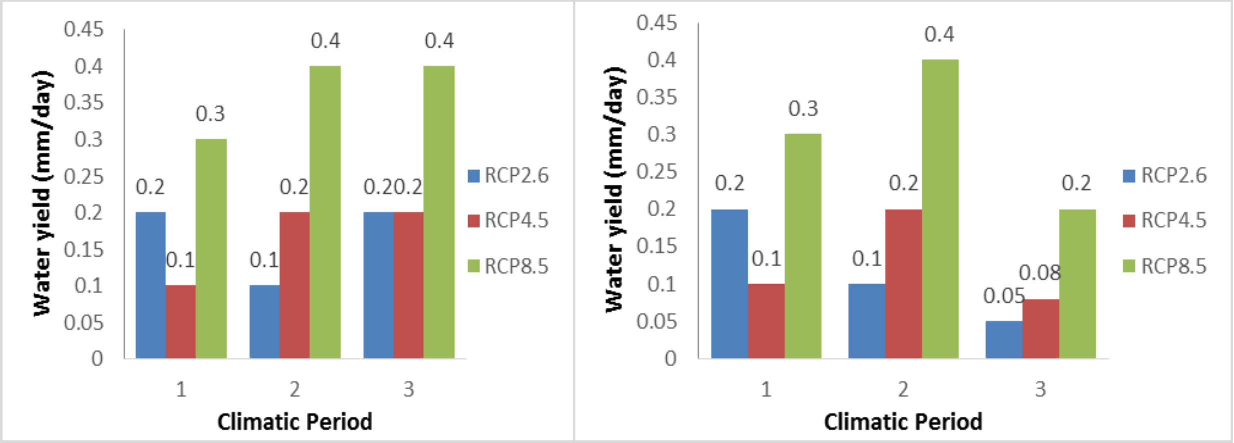


Figure-3b. Projected changes in wet season water yield for SRB.

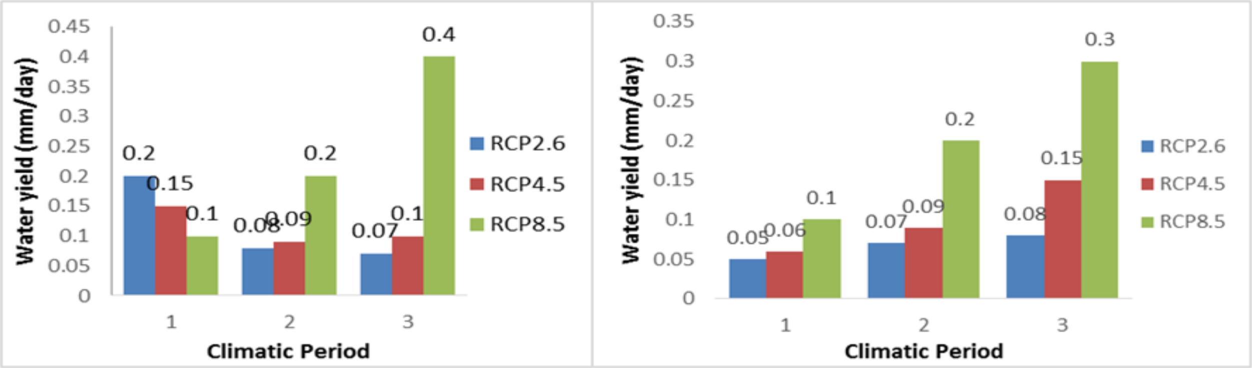


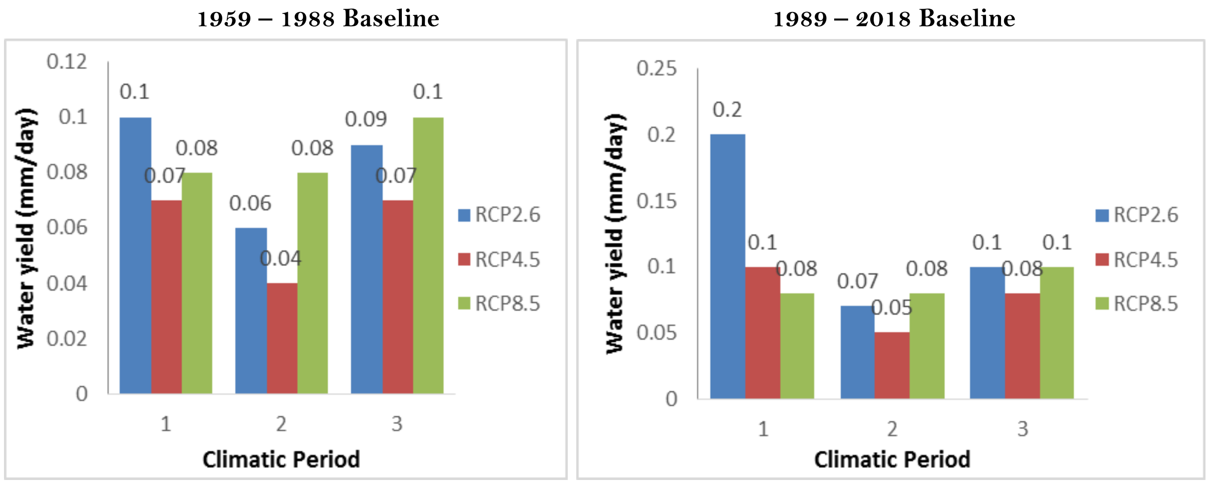
Figure-3c. Projected changes in wet season water yield for KYB.

Near-term projection (2019-2048) period at KLB, wet season water yield will increase within the range of (+0.1 to +0.2 mm/day) for all the three RCPs under the two baseline periods of (1959-1988) and (1989-2018). RCP2.6 accounts for the highest increase of (+0.15 mm/day) and lowest being RCP4.5 and RCP8.5 with (+0.1 mm/day) under the 1959-1988 baseline, while a contrasting pattern of increase is observed under 1989-2018 baseline where RCPs 2.6 and 8.5 account for the highest with (+0.2 mm/day) and lowest been RCP4.5 Figure 3a. Trend analysis of wet season water yield within the 2019-2048 periods over KLB indicates that it is not significant at 0.05 significant levels for all the three RCPs Table 2. SRB wet season water yield reveals that the range of increase is between (+0.1mm to +0.3 mm/day) for all the three RCPs under 1959-1988 and 1989-2018 baselines. RCP8.5 accounts for the highest under the two baselines with (+0.3 mm/day) each, while RCP4.5 accounts for the lowest Figure 3b. Trend analysis of wet season water yield in SRB under the 2019-2048 periods shows significant increasing trend at 0.05 significant levels for scenarios (RCP2.6 and RCP8.5) but non-significant for medium emission scenario (RCP4.5) see Table 2. Similarly, condition over KYB reveals lower magnitude of increase compared to SRB at this period. Figure 3c shows (+0.1 to +0.2 mm/day) range of increase under the 1959-1988 baseline for all the RCPs, but sharply decreases to the range of (+0.05 to +0.1 mm/day) under 1989-2018 baseline with RCP8.5 having the highest value and least being RCP2.6. It is important to point out that the range of increase under 1989-2018 baseline is the same for KLB and KYB but differ greatly with SRB. However, the trend analysis of wet season water yield over KYB under the (2019-2048) period shows that there is significant increasing trend for RCP2.6 under 1959-1988 baseline but not under 1989-2018 baseline as well as for other two RCPs.

By 2049-2078 projected period, wet season water yield in KLB will increase steadily to a range of (+0.1 to +0.2 mm/day) under 1959-1988 baseline such that RCP8.5 accounts for highest and lowest been RCP4.5. While under 1989-2018 baseline, it varies between (+0.08 to +0.15 mm/day) with RCP8.5 the highest and lowest will be RCP2.6. SRB projected wet season water yield indicates the same magnitude of increase under both baselines just between (+0.1 to 0.4 mm/day) for all the RCPs. RCP8.5 having highest value and lowest being RCP2.6 Figure 3b. At the same time for the KYB, projected wet season water yield ranges between (+0.08 to +0.2 mm/day) under 1959-1988 baseline with a wide margin between RCP8.5 and RCP2.6 but ranges between (+0.07 to 0.2 mm/day) under 1989-2018 baseline Figure 3c. The trend analysis Table 1 shows that there is significant increasing trend at 0.05 significant levels for highest emission of CO_2 but not for middle and low CO_2 emission pathways. Such a significant increase was also reported by Ajay, et al. [25] in Kaligandaki Basin of Nepal where water yield is the most affected water balance component in the basin. It was expected to increase throughout all the seasons with an increase of over 20% during the 2030s', 30% during the 2060s'and a maximum increase could be expected during the 2090s' of over 45%, under RCP8.5. In (2079-2100) period, anticipated condition in KLB mirror a similar pattern as obtained in the two preceding periods where there is a consistent increase in the wet season water yield. That is to say water yield increases from first projected period of 2019-2048 through 2049-2078 to third projected period of 2079-2100 in KLB Figure 3a. Trend analysis of (2079-2100) period in KLB reveals that there is significant increasing trend at 0.05 significant levels Table 2. SRB pattern of wet season water yield under (2079-2100) period is comparable with that observed over KLB such that the range of (+0.2 to 0.4 mm/day) in SRB is bit smaller Figure 3b. Thus, trend analysis of (2079-2100) period over SRB shows a significant increasing trend at 0.05 significant levels for all the three RCPs Table 2. The situation over KYB in this period reveals the projected pattern in the range of (+0.07 to 0.4 mm/day) for all the three RCPs such that RCP8.5 accounts for the highest and the lowest among the three been RCP2. Therefore, trend analysis of (2079-2100) period Table 2 over KYB reveals significant increasing trend at 0.05 significant levels for highest CO_2 emission pathways but not for the middle and low emission trajectories. Regional trend analysis of wet season water yields over KLB, SRB and KYB as a whole which constitute the Guinea and Sudano-Sahelian ecological zone of Nigeria reveals that under 2019-2048 period there is no significant increasing trends at 0.05 significant levels. This is with respect to high emission scenario (RCP8.5) but significant in low and middle emission scenarios (RCPs 2.6 and 4.5) Table 2. By (2049-2078) through (2079-2100) period, there is significant increasing trends in the whole Guinea and Sudano-Sahelian ecological zone as a region in wet season water yield for RCP8.5 except RCPs 2.6 and 4.5 under mid-term projection Table 2.

3.3. Projected Changes in Average Annual Water Yield

Average annual water yield over KLB, SRB and KYB as well as across the three scenarios between 2019 and 2100 are shown in Figure 4a-c. The (2019-2048) period shows that the average annual water yield will increase within the range of (+0.07 to 0.2 mm/day) for all the three RCPs under the two baseline of (1959-1988) and (1989-2018) respectively over the KLB. RCP2.6 accounts for the highest increase, while RCP4.5 responsible for the lowest under 1959-1988 baseline but RCP8.5 under 1989-2018 baseline Figure 4a. Trend analysis of average annual water yield within the 2019-2048 periods over KLB indicates that there are no significant increasing trends at 0.05 significant levels for RCP2.6 and RCP8.5 but significant forRCP4.5 Table 2. Situation over SRB reveals that the range of increase is between (+0.08 to 0.1 mm/day) for all the RCPs under 1959-1988 baseline but amplify to the range of (+0.15 to 0.2 mm/day) under the 1989-2018 baseline. RCP2.6 accounts for the highest under the two baselines while RCPs 4.5 and 8.5 responsible for the lowest Figure 4b.


1959 – 1988 Baseline

1989 – 2018 Baseline

Figure-4a. Projected changes in average annual water yield for KLB.

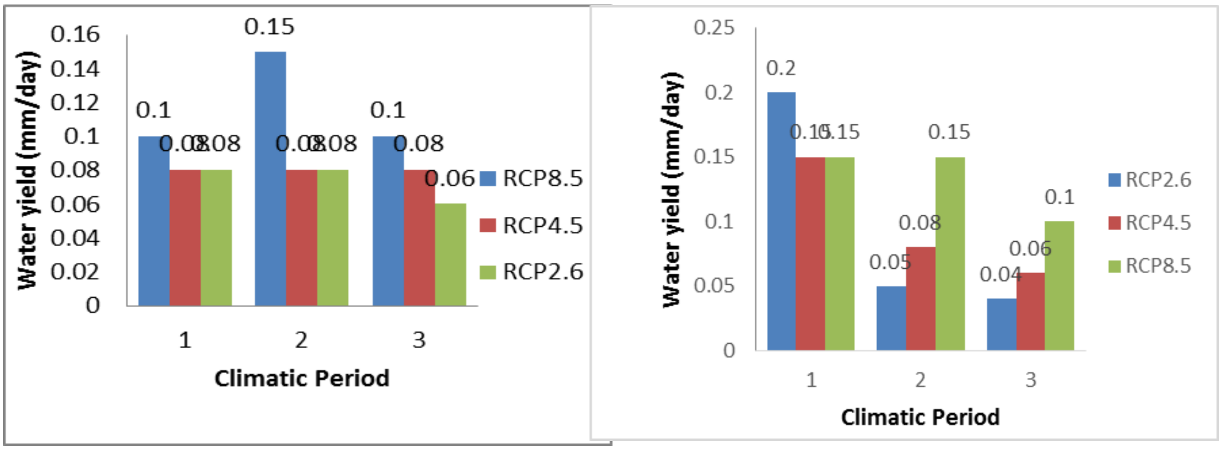


Figure-4b. Projected changes in average annual water yield for SRB.

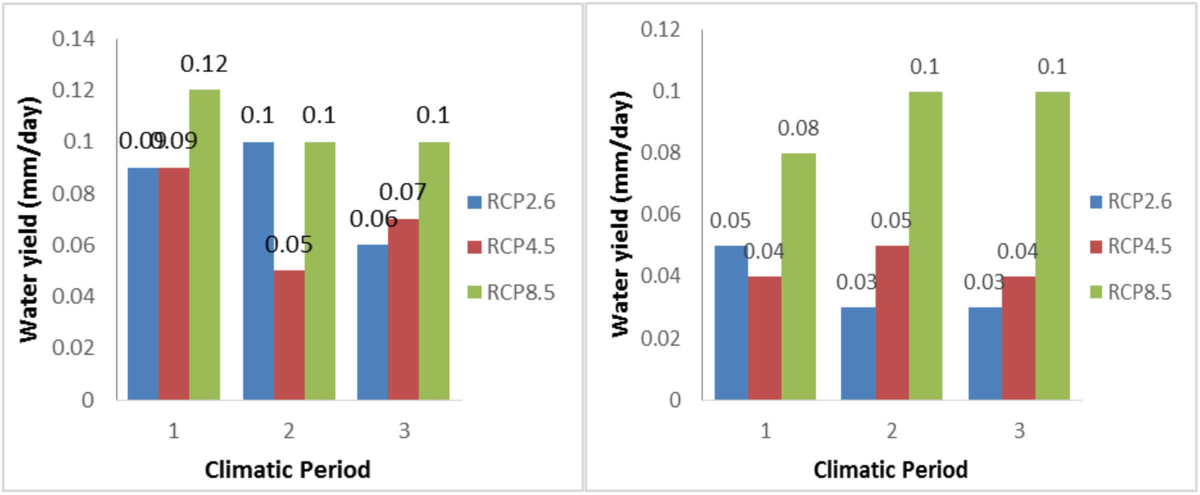


Figure-4c. Projected changes in average annual water yield for KYB.

Trend analysis in SRB under the 2019-2048 periods Table 2 shows no significant increasing trends at 0.05 significant levels for all the three emission trajectories. Likewise, in KYB average annual water yield reveals (+0.09 to 0.12 mm/day) range of increase under the 1959-1988 baseline for all the RCPs, but sharply decreases to the range of (+0.05 to +0.08 mm/day) under 1989-2018 baseline with RCP8.5 having the highest value and least being RCP2.6. However, the trend analysis over KYB under the (2019-2048) period shows that there are no significant increasing trends for all the three RCPs at 0.05 significant levels.

By (2049-2078) mid-term projected period, KLB average annual water yield increases within the range (+0.04 to +0.08 mm/day) this is slightly lower than that obtainable in near term projection. RCP8.5 sustains the lead under the two baselines while RCP4.5 is the lowest for the two baselines. Trend analysis result indicates no significant increasing trends exist under the low, middle and high emission pathways at 0.05 significant levels Table 2. SRB projected average annual water yield signify an increase of just between (+0.08 to +0.15 mm/day) s for all the three RCPs under the two baselines are visible. The projected increase is statistically not significant at 0.05 significant levels for all the three RCPs. On the other hand, the KYB projected average annual water yield ranges between (+0.05 to +0.1 mm/day) under 1959-1988 baseline with just a little margin between RCP8.5 and RCP2.6 but ranges between (+0.03 to +0.1 mm/day) under 1989-2018 baseline Figure 4c. The trend analysis shows that there is no significant increasing for all the three CO_2 emission pathways.

During (2079-2100) period, estimated provision in KLB reflects a consistent variability of increase in average annual water yield to the range (+0.07 to +0.1 mm/day) for all the three RCPs under the two baselines such that RCP8.5 accountable for the highest increases but lowest for RCP4.5 Figure 4a. Trend analysis of (2079-2100) period in KLB Table 2 discloses that there are no significant increasing trends at 0.05 significant levels for RCP2.6 and RCP4.5 and RCP8.5. Similar patterns of increasing trends are noticeable in SRB and KYB but Mann Kendal trend analysis at 0.05 degree of alpha confirms no significant trends for the two basins for low, middle and high emission trajectories.

Regional trend analysis of average annual water yields over KLB, SRB and KYB as a whole which constitute the Guinea and Sudano-Sahelian ecological zone of Nigeria reveals that there are no significant trends for RCPs 2.6, 4.5 and 8.5 with respect to the three projected periods under consideration. This is to say that despite the projected creasing pattern of average annual water yield observed over Guinea and Sudano-Sahelian ecological zones, incidences of water crisis cannot be ruled out because the anticipated increase not statistically significant 0.05 degree of alpha. This finding is in tandem with that reported by Ndhlovu and Woyessa [26] in Zambezi river basin where annual statistics under RCP8.5 show a significant increase of 40 % in water yield while under RCP4.5 there is an increase in water yield of 5 % but not significant. However, Anastasia, et al. [27] stated that climate change will alter the hydrological regimes of rivers in Europe. Further will create additional challenges for water resources and aquatic ecosystems which are already stressed due to extensive anthropogenic activities. Therefore, the impacts of the projected climate change have to be understood and incorporated into the regional water management strategies to ensure sustainable approach in governing the water systems [28].

4. CONCLUSIONS

In conclusion, water yield based on (P-E) projections were generated for three periods: the near-term (2019-2048), mid-term (2049-2078), and long-term (2079-2100). The results indicate that water yield can be expected to be characterized by higher variability under all climate change scenarios, such that dry season water yield will decreases across the entire Guinea and Sudano-Sahelian Ecological zones though not significant but significant with respect to wet season and annual water yield. Overall, this indicates increasing risk of both flooding during wet season and drought in dry season. Therefore, it is expected that this study will aid guidance to the understanding of the ongoing changes as well as possible changes in water yield in the study area, which in turn will help in adopting necessary adaptation measures to mitigate the negative impacts of climate change in the Guinea and Sudano-

Sahelian ecological zones of Nigeria. Therefore, these results are important for future planning of water resources management and agriculture been the sectors that will be adversely affected in Guinea and Sudano-Sahelian ecological zones of Nigeria.

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