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RESEARCH ARTICLE

Impacts of Climatic Variation on Water Balance and Yield of Watershed (Insights from The Kaduna Watershed, North Central Nigeria)

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Abstract. Many authors have identified climate variation impacts in Nigeria. However, the effects on water balance and water yield have not been thoroughly considered. Good knowledge of water balances is vital for sustainable water resource management in northern Nigeria due to high water stress and increased evapotranspiration compared to another part of the country. Hence, the study presents the first detailed climatic variation impacts on watershed water balance and water yield in north-central Nigeria. Soil and Water Assessment Tool (SWAT) was applied to predict the hydrological procedures. The Kaduna watershed (32,124 km2) calibrated and validated streamflow results were run independently using three land cover maps of 1975, 2000, and 2013. The model performance evaluation was statically attained using the coefficient of determination (r2), Nash-Sutcliffe (NS), besides the percentage of observed data (p-factor). The model evaluation result of r2 (0.80), NS (0.71), and p-factors of 0.86 indicated the model satisfactory performance evaluation of streamflow predictions. The streamflow estimation revealed Threshold depth of water (GWQMN.gw) as the most sensitive parameter. The findings discovered declined between 1975 and 2013 in precipitation, water yield, surface runoff (SURQ_mm), lateral flow (LAT_Qmm), deep aquifer (Deep_mm) by 4.2%, 37.3%, 56%, 15%, and 100% respectively, while shallow groundwater aquifer (GW_Qmm) experienced 10% decrease between 1975 and 2000 and appreciated by 6% between 2000 and 2013, evapotranspiration (ET_mm) increase by about 22.2% between 1975 and 2013. These results suggest considerable effects of climate variation in the watershed and call for further investigation to mitigate climate change influence.

1. Introduction

Hydrology has been recognized as an essential factor of water resources sustainability in a specified watershed (Chaves and Alipaz, 2007). Thus, the average amount of water generated by the watershed over a certain time from contributions of ground, lateral and surface water is referred to as Water yield (USDA, 2009). It is also considered as a residual amount of water (net) flowing through a location on a stream in a certain length of time (Tallis, 2011). Water yield in the ecosystem viewpoint signifies the probable facility of freshwater for hydropower generation, food production and drinking water (Lüke and Hack, 2018). Hence, its importance in the watershed is crucial to ecosystem survival. The major determinants of water yield in a watershed are land use and climate. A good understanding of the impacts of these factors remains vital for choice-making procedures in the watershed (Villamizar et al., 2019).

Waters resources, environmental and socio-economic sectors have been influenced by climate variability and climate change but among these factors; water resources are of utmost importance (Frederick and Major, 1997). Nigeria is among the country of the world considered to have been highly susceptible to the unfavorable influence of global warming and climate change even though the country contributes a lesser amount of the greenhouse effects (Safari, 2012). Largely, human anthropogenic activities, most especially land-use change, are responsible for climate variation in Nigeria (Sule and Odekunle, 2016; Bello et al., 2012; Fasona and Omojola, 2005; Idowu et al., 2011; Nicholson, 2013). Existing literature revealed the impacts of climate variation in different parts of Nigeria, including the decline in cultivated, savanna, and riparian areas Daramola et.al., 2022; Daramola et.al., 2020; Fasona and Omojola, 2005; Nzoiwu et al., 2017; Idowu et al., 2011), increased surface radiant temperature (Daramola et al., 2022; Bello et al., 2012; Nzoiwu et al., 2017; Ogilvie et al., 2010), unpredictable rainfall and rainfall decline, irregular runoff and sunshine hours (Daramola et.al., 2022) (Mahe et al., 2013) (Mohammed, 2014) (Nicholson, 2013) (Abaje et al., 2010) (Idowu et al., 2011) (Odjugo, 2005) (Mahé and Olivry, 1999), drought and flood (Douglas et al., 2008; Idowu et al., 2011; Odjugo, 2005; Odemerho, 2015), water shortages in reservoirs, rivers, irrigation for agriculture and industrial usage (Ishaku and Majid, 2010), and increase in air temperature (Bello et al., 2012).

Adams and Peck (2008) stated that climate change impacts on the hydrologic cycle are very important and have led to a decline in annual average runoff, reduction of available freshwater, surged evaporation rates and rainfall variability. The hydrologic cycle is modified by human anthropogenic activities and altered components such as infiltration, evapotranspiration, streamflow volume and rate (Ndulue and Mbajiorgu, 2018).

According to (Mahé and Olivry, 1999), West Africa witnessed up to a 60% decrease in the runoff. These changes are arguably associated with rainfall decrease in West Africa since 1970. These corroborate Conway et al (2009) that rainfall mainly impacts West Africa River regimes. Mahe et al (2013) confirmed a lasting decrease of baseflow, resulting in a striking downward slope of runoff in areas with annual rainfall above 750mm in west Africa. Although significant numbers of research focused on the impact of climate variation on hydrology have been executed in Nigeria (Bello et al., 2012; Ishaku and Majid, 2010; Mohammed, 2014) the aspect of climate variation that impacts water yield has not been rigorously explored. A relatively limited number of scholars' work has appraised climate variation's influences on hydrological regimes in West Africa (Roudier et al., 2014) and Nigeria in particular (Ndulue and Mbajiorgu, 2018). Hence to bridge this gap, the aim is to determine the water balance and water yield with physically based SWAT models and the likely impacts of their variation on the study area and proffer possible suggestions to the authority concern.

Geographically, the research area is situated in latitude 9.35°N and 11.28°N and Longitude 6.45°E and 8.55°E, having projected area of 3,212,462.87 ha. Kaduna watershed is traversed by rivers Kaduna, the longest with about 550km in length, followed by Gutalu 104.3km, Sarkinpawa 88.6km, and Dinya 16.7km (Fig. 1). The watershed relief ranges between 377m to 1544m, having 683m mean elevation above sea level. The watershed annual rainfall is about six months (April to September), while the average yearly rainfall gradually decreases from 1200mm (south) to about 1000mm (north), thus, making the southern part of the watershed wetter than the northern part (Areola et al., 2014).

The flora is largely guinea savannah, characterized by dispersed trees and high grasses. The southern part of the watershed is dominated by Guinea savanna or savanna woodland with trees growing as tall as 12 meters, while the northern fringe is Sudan savanna vegetation type due to its moderate rainfall regime (Areola et al., 2014). The watershed vegetation follows the rainfall prototype; thus, the southern part is denser than the northern part because the southern part receives more rainfall than the northern part. People's manner of life within the watershed includes weaving, hunting, trading, fishing, and farming. Popular among this activity is farming, focusing primarily on subsistence farming. The geology comprises rock developed more than a 1,500million years before now and viewed as the primary (Fig.2), and to the greatest extent, steady rock in Nigeria (Areola et al., 2014).

The watershed soil is largely Sandy loam soil, and constitute dabout 41.94% of the total soil, including loam, loamy sand, and sandy clay loam soil.

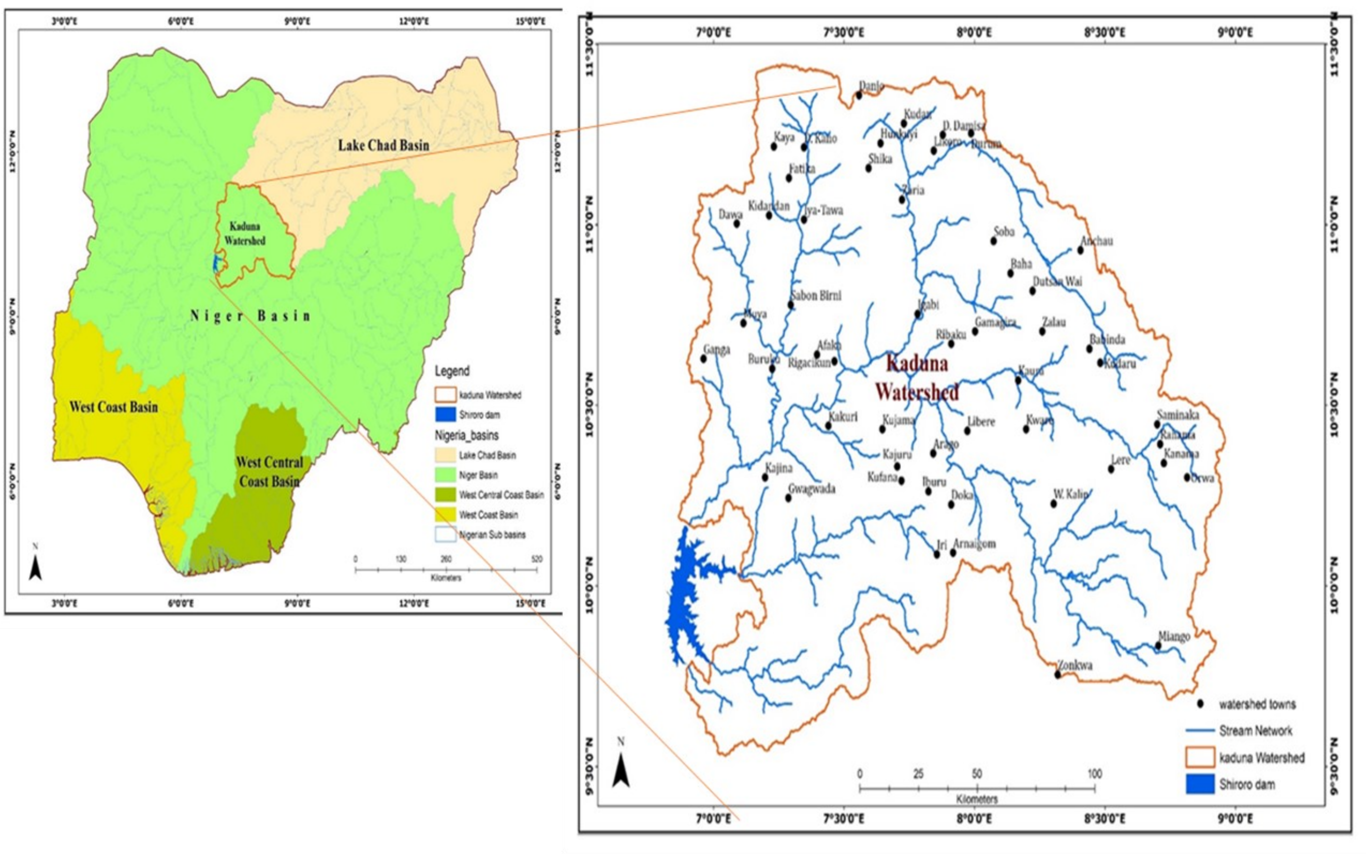

Figure 1. Map of Nigeria Presenting Kaduna Watershed

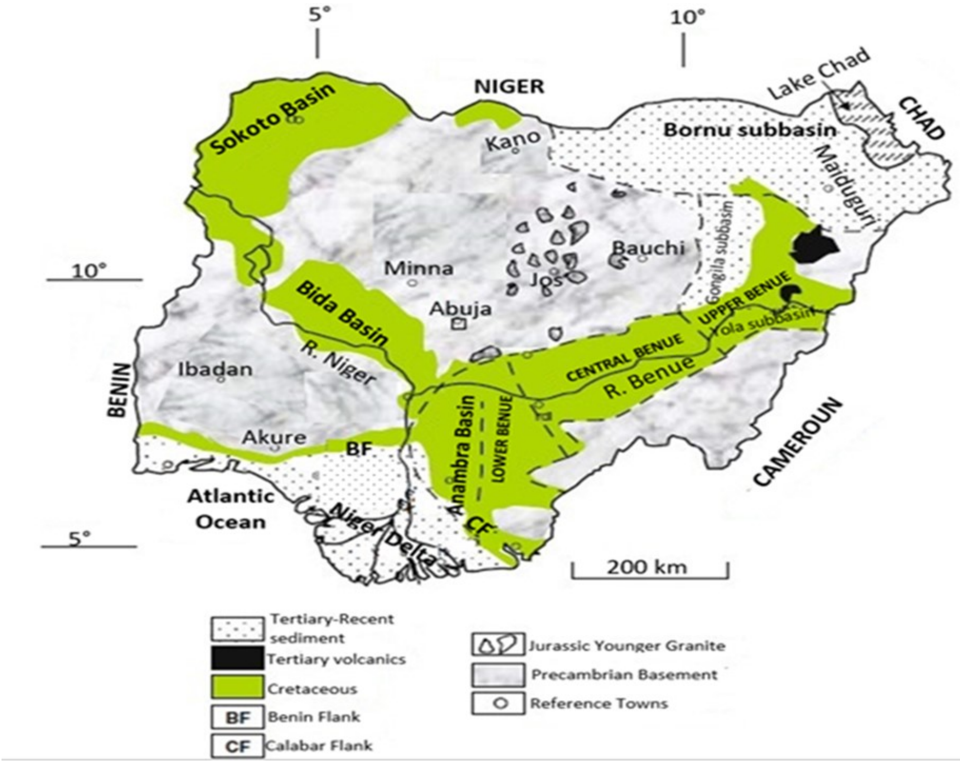

Figure 2. Geological Map of Nigeria
Source: Igwe and Adepehin (2017)

2. Methods

The SWAT model is a river basin or watershed scale model developed to quantify and predict the impacts of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods (Arnold et al., 2012b). According to Leon and George (2007), the model requires data about the terrain, land use, soil, and climate, like other modeling tools. It requires two components setup: a GIS system for storage and display of the maps, and terrain analysis to delineate watersheds and identify associated sub-basins and a component that can generate all the files needed by SWAT partly from the input maps and analyses, and partly by manual editing. Today's SWAT model simulation of the hydrologic cycle is centered on the water balance equation (Adeogun et al., 2018). SWAT is a physically-based model that requires specific information about weather, soil properties, vegetation, and land management practice in the watershed (Neitseh et al., 2009). According to Alemahayu et al (2014), the major input datasets include topography, soils, land-use/land cover data, management practices, weather, and hydrography. For further detail on SWAT see (Williams et al., 2008; Arnold et al., 2012a; Winchell et al., 2010).

The required information to run the SWAT model input was sourced from different sources (Table 1). These include a 30 m resolution of the study area Digital Elevation Model (DEM) from Shuttle Radar Topography Mission.

The watershed land use and land cover (LULC) data were obtained from West Africa: Land-use and Land Cover Dynamics of 1975, 2000, and 2013 produced by the U.S. the map was enhanced by the information established from the land use and land cover map reconnaissance survey of the study area and categorized to suit SWAT model LULC format (Table 2).

The watershed soil raster map consists of Nigeria's 1 km soil resolution map, acquired from the FAO Soil database 2009, improved upon with further evidence collected from the analyzed soil samples of two different layers (0-30 cm and 30-100 cm) in soil laboratory (Table 3).

SWAT model daily weather data input was collected from the Shiroro dam metrological station and Nigeria Metrological Station (NIMET). For further understanding of the SWAT model see (Winchell et al., 2010; Neitseh et al., 2009; Arnold et al., 2012a). The watershed streamflow data were extracted from the African Flood and Drought Monitor website. At the same time, the suspended sediment concentration (SSC) was measured for eight months from water samples collected from the four major reaches within the watershed.

The basic SWAT hydrological groups i.e. land use, soil texture, sub-basin number formulated by Abbaspour et al (2015) was used to parameterize the model via the following formula to define the parameter identifier of the study as follows v__SOL_ALB(..).sol, v__CH_N2.rte, v__ALPHA_BF.gw, v__SURLAG.bsn, v__GW_REVAP.gw, v__SPCON.bsn, v_CH_K2.rte, v__EPCO.hru, r__CN2.mgt, r__SOL_BD(..).sol, r__SOL_AWC(..).sol, r__OV_N.hru,

The parametrization result was used for sensitivity analysis; these formed the base for streamflow spatial calibration and validation. Calibration is used to reduce the difference between the observed and simulated values. It is a way to parameterize a model to a given local condition, minimizing the prediction uncertainty. In this study, the calibration was carried out by carefully selecting values for model input parameters and comparing model predictions (outputs) for a set of assumed conditions with the observed data of the same condition. Calibration and validation are usually done by splitting the observed data into two datasets for calibration and validation processes. The splitting must encompass (wet, moderate, and dry) data

Table 1. SWAT Input Data

S/N	Data	Narrative	Resolution	Sources
1.	Weather	Precipitation, Min. and Max. Temperature, Relative Humidity, Wind and Solar Radiation	Daily	Shiroro Dam Metrological station and NIMET Kaduna
2.	Topography	Digital Elevation Model	30m	Shuttle Radar Topography Mission
3.	Land Cover Map	Land cover classification	2km	U.S. Geological Survey Earth Resources Observation and Science (USGS EROS)
4.	Soil Map	Soil types and texture	1km	FAO Digital Soil database map of the World
5.	Streamflow	Streamflow	2012-2017	African Flood and Drought Monitor

Table 2. Study Area Land Cover Classification

Land-use Land cover Types	SWAT Code	Area [ha]	% Watershed Area
Range-Grasses	RNGE	1,066,467.2	32.73
Agricultural Land-Generic	AGRL	1,848,911.89	56.7
Barren	BARR	12,070.75	0.61
Residential	URBN	46,746.21	1.78
Wetlands-Mixed	WETL	22,091.75	1.01
Forest-Mixed	FRST	71,832.86	2.44
Wetlands-Forested	WETF	125,877.96	3.93
Water	WATR	18,464.22	0.81

Table 3. Soil Information of The Study Area Watershed

Soil Class	SWAT Code	Area [ha]	%Watershed Area
Sandy loam	Lf42-1a-1470	321,040.14	9.99
Sandy loam	Lf49-1a-1476	1,345,603.03	41.89
Sandy loam	Lf41-1-2a-1468	2,984.30	0.09
Sandy clay loam	Lg26-2a-1511	607,316.42	18.91
Sandy clay loam	Lf8-1493	808,879.95	25.18
Loam	I-60	25,565.48	0.8
Loam	I-c-99	18,572.64	0.58
Sandy clay loam	Af12-2b-1020	46,821.40	1.46
Loam	I-bc-1324	8,479.94	0.26
Loamy sand	Ao43-1b-1056	390.25	0.01
Sandy clay loam	I-Lf-1255	26,809.27	0.83

climate for the two processes; the user must make sure that the climatic data are not substantially different from each other and ensure that wet, moderate, and dry years occur in both periods (Gen et al. 1997). However, if this condition cannot be met, data may be split spatially, according to Arnold et al. (2012). The method uses the available data at a given monitoring location for the calibration phase. It performs the validation using another monitoring gauge within the watershed or calibration and validation using parameters from a watershed with approximately similar climatic, soils, and land-use conditions for calibration and validation in the study area watershed (Eckhardt and Arnold, 2001; Liew and Garbrecht, 2003; Cao et al., 2006; Parajuli et al., 2009; Arnold et al., 2012a. SWAT-CUPSUFI2 has been used to carried-out the spatial calibration and validation procedures, using the observed streamflow (2015 -2017) of reach Kaduna and Gutalu in Basins 62 and 79, respectively (Fig. 3). The result was validated via the observed streamflow (2015-2017) of reach Sarkinpawa and Dinya of basins 69 and 83 respectively due to climatic, land use, and soil data similarity (Cao et al., 2006; Parajuli et al., 2009; Liew and Garbrecht, 2003; Eckhardt and Arnold, 2001). For more information on calibration and validation see (K.C. Abbaspour et al., 2015). The model performance evaluation was conducted using the coefficient of determination (r2), Nash-Sutcliffe (NS), and Percentage of observed data (p-factor) (Arnold et al., 2012a). The three land cover maps (1975, 2000, and 2013) were run independently while keeping the other SWAT inputs constant, using Kaduna watershed, Nigeria's calibrated and validated result.

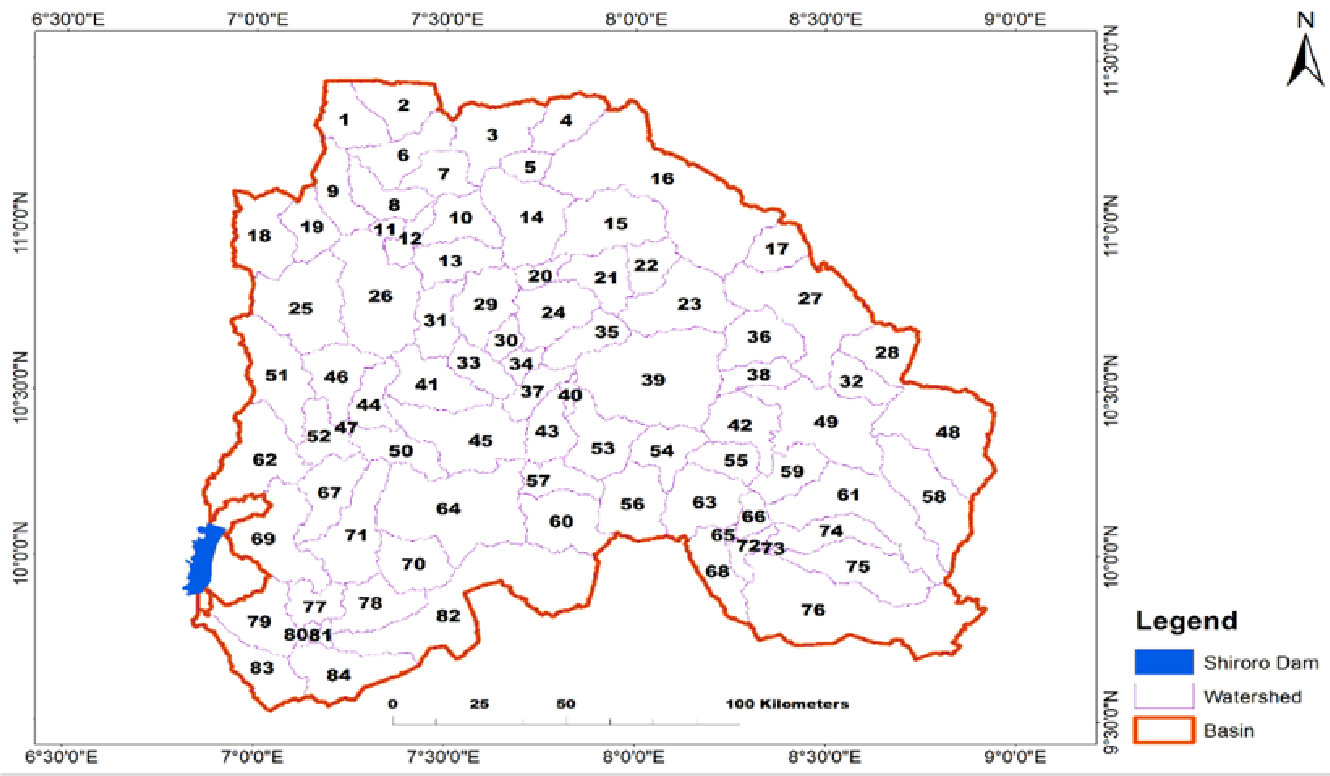

Figure 3. The Spatial Location of Kaduna Watershed Basins

3. Result and Discussion

Calibration and Validation

Spatial calibration and validation method was conducted to test the model performance evaluation (Liew and Garbrecht, 2003; Cao et al., 2006; Parajuli et al., 2009). Basin 69 streamflow in reach Sarkinpawa (Fig. 3) was well simulated with NS (0.71), r2 (0.80), p-factor 0.86, and r-factor (5.50) Daramola et al., 2019; Motovilov et al., 1999), according to (Arnold et al., 2012b; Moriasi et al., 2007) is considered satisfactory since the NS exceeded 0.5 (Table 4). The implication of this is that the hydrology will be well predicted. However, the r-factor of 5.50 indicates large uncertainty that the model cannot capture.

Basin 83 (reach Dinya), on the other hand, captures the river dynamics of flow with small NS (3.26), indicating mismatches mostly in timing (Abbaspour et al., 2015). However, the model result of r2 (0.43), p-factor (0.61), and r -factor (0.77) is considered modest. This result can be attributed to the diversity of water management and uses in basins with seventeen (17) different HRUs (K.C. Abbaspour et al., 2015). However, the result is good for hydrology predictions (Table 4 and Fig. 4).

The high r-factor of the flow validation in basin 69 is because of conceptual model uncertainties, which can be categorized into four: (i) uncertainties as a result of conceptual model simplification, e.g., assumption inflow velocity calculation, etc., (ii) uncertainties due to happening in the basin not captured by the model, e.g., erosion caused by landslides, mining, etc., (iii) is uncertainties due to development built-in the model, but their reality in the basin is unidentified to the model user, e.g., irrigation and water transfer, etc., and (iv) uncertainties caused by the developments that are not captured by the model and not identified by the model user, e.g., dumping of waste, chemicals in the river and road construction, etc.,

Table 4. Flow validation summary

Sampling points Basin	Flow Validation			
	NS	r2	p-factor	r-factor
Sarkinpawa (69)	0.71	0.80	0.86	5.50
Dinya (83)	-0.37	0.43	0.61	0.77

Abbaspour et al., 2015; 2007). Abbaspour et al., (2015) explained that these uncertainties are expected in a large watershed. Thus, a large watershed as large as the Kaduna watershed will experience all these uncertainties that may be largely responsible for the high r-factor prediction (Daramola et al., 2022). However, the general statistical evaluation performance of the model using Nash-Sutcliff, coefficient of determination, p-factor, and r-factor shows that the prediction is within the suitable standards (Moriasi et al., 2007; Krause et al., 2005; Motovilov et al., 1999).

Climate Variation and Impact on Water Balance and Water Yield

The quantification of the hydrological process in 1975, 2000, and 2013 except precipitation was carried out in the upstream Shiroro using the SWAT model (Table 5). The annual water yield results in 1975 (603.67 mm), 2000 (400.48 mm), and 2013 (387.27 mm) amounted to about a 37.3% reduction between the years 1975 and 2013. Evaporation and Transpiration (ET_mm) have the highest share of the water balance throughout the three years under consideration. Evapotranspiration increased progressively from the years 1975, 2000, and 2013 with 624.1 mm (50.9%), 785.4 mm (66%), and 796.3 mm (67%) of the water balance, respectively. Percentage water balance of lateral flow (Lat_Qmm) in the year 1975 was 1.81 (0.2%), 2000 was 1.63 (0.13%) and 2013 witnessed further

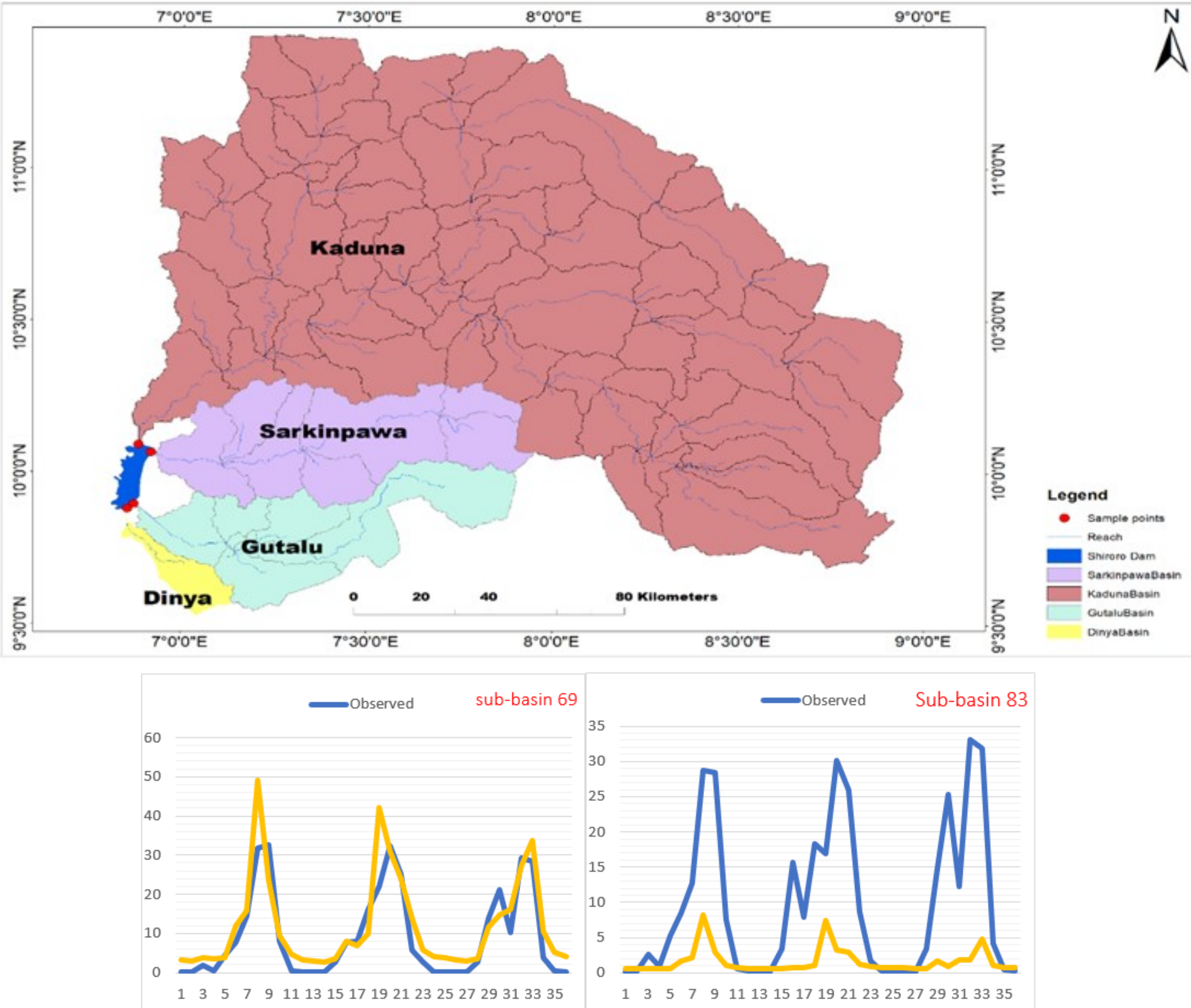

Figure 4. The Kaduna watershed shows the four major sub-basins observed and simulated streamflow of sub-basins 69 and 83. (The x-axis is the months (36), and the y-axis is discharge (m3/s))

reduction to 1.55 mm (0.1%). Groundwater shallow aquifer (GW_Qmm) declined from 489.86 mm (1975) to 338.79 mm (2000) slightly increased to 341.01mm (2013), having water balance percentages of about 40%, 27%, and 29%, respectively (Figure 4). The runoff (SUR_Qmm) in the years 1975 (86.21 mm), 2000 (60.31 mm), and 2013 (44.68) had water balance percentages of about 7%, 6%, and 4%, respectively. The model revealed that deep aquifer (Deep_mm) to be 25.79 mm, 16.82 mm, and 0 mm in 1975, 2000, and 2013 with a percentage water balance of about 2%, 1.5%, and 0%, respectively (Fig. 5).

Precipitation, evapotranspiration surface runoff, baseflow, and lateral flow have been considered important water balance components in a basin. The predictions of these elements except precipitation using appropriate modeling tools are vital because their quantification by measurement is tedious (Adeogun et al., 2014). The watershed hydrological processes were quantified using the SWAT model (Table 5); the analysis result revealed that precipitation has continued to decrease since 1975 to about 4.2% in 2013. The prediction agrees with Daramola et al., 2022; Bello et al., 2012; Mohammed, 2014; Odjugo, 2005; Ogilvie et al., 2010; Nicholson, 2013; Idowu et al., 2011; Fasona and Omojola, 2005; Mahé and Olivry, 1999; Abaje et al., 2010; Mahe et al., 2013). Similarly, Aigbe and Oluku (2012) connected the extinction of forest cover in Nigeria to a constant reduction in rainfall. More also, the study area evapotranspiration (ET_mm) continues to increase from 624.1 mm (1975) to 796.3 mm (2013); the result corroborates (studies Daramola et.al., 2022; Nzoiwu et al., 2017; Idowu et al., 2011; Bello et al., 2012). Adeogun et al (2014) predicted a similar increase in evapotranspiration rate from 34.85% (1998) to about 71.15% (2007) in the upstream catchment of Jebba Dam, Nigeria.

A decrease in rainfall of about 4.2% and about 22.4% increase in evapotranspiration between 1975 and 2013 in the watershed is a sign of climate variation (Mohammed, 2014; Abaje et al., 2010; Roudier et al., 2014). The results are in harmony with past studies that established that climate change could lead to falling in precipitation and a surge in temperature (Idowu et al., 2011; Zhang et al., 2018; Odjugo, 2005). Fall in precipitation and rise in temperature because of climate change could reduce water resources (Zhang et al., 2018; Odjugo, 2005; Idowu et al., 2011). Adams and Peck (2008) observed that increased evaporation rates reduce water supplies in many world regions.

The area under study has witnessed the impacts of

Table 5. The Watershed Hydrological Processes Quantification

Item	1975 Value	2000 Value	2013 Value	1975-2000 % < or >	2000-2013 % < or >	Total % < or >
Precipitation	1225.2mm	1198.1mm	1174.4mm	<2.2%	<2%	<4.2
Surface runoff q	86.21mm	60.31mm	44.68mm	<30%	<26%	<56%
Lateral soil q	1.81mm	1.63mm	1.55mm	<10%	<5%	<15%
Groundwater (shal aq) q	489.86mm	321.71mm	341.04mm	<34%	>6%	<30%
Groundwater (deep aq) q	25.79mm	16.82mm	0.00mm	<35%	<100%	<100%
Revap (shal aq soil/plants)	43.51mm	28.67mm	28.54mm	<34%	<0.5%	<34.5%
Deep aq recharge	25.78mm	16.94mm	0.00mm	<34%	<100%	<100
Total aq recharge	515.61mm	338.79mm	341.01mm	<34%	>0.7%	<34.7%
Total water yld	603.67mm	400.48mm	387.27mm	<34%	<3.3%	<37.3%
Percolation out of soil	513.02mm	351.43mm	338.37mm	<31%	<3.7%	<34.7
ET	624.1mm	785.4mm	796.3mm	>21%	>1.4%	>22.4%
PET	2196.6.mm	2933.3mm	2860.9mm	>25%	<2.5%	>23%

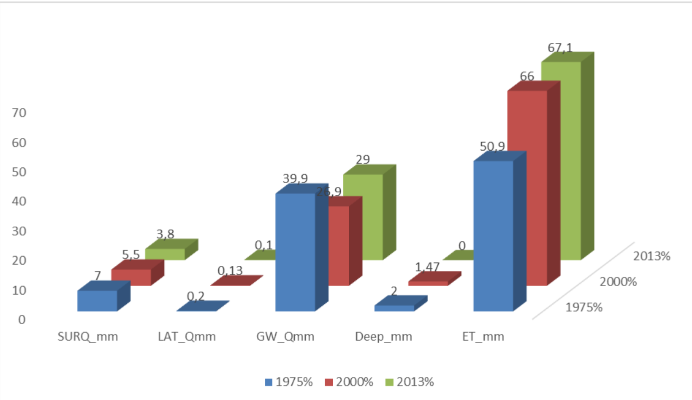

Figure 5. Percentage Water Balance of Hydrological Elements

climatic variation in all aspects of the hydrological processes within the watershed (Table 5): the surface runoff (SUR_Qmm) decreased retrogressively from 86.21 mm to 60.31 mm (30%) reduction in 2000 and further decreased by 26% having 44.68 mm in 2013 (Mahe et al., 2013; Mohammed, 2014; Idowu et al., 2011). This further substantiates Mahé and Olivry (1999), who confirmed about a 60% decrease in West Africa runoff since 1970, and Roudier et al (2014) established a strong correlation between rainfall and runoff in west Africa. A reduction in precipitation and runoff will ultimately impact watershed streamflow, as this was reported by Ndulue and Mbajiorgu (2018). In the Upper Ebonyi River watershed Nigeria, the watershed witnesses a decline in streamflow by 10.3%, 26.2%, 11.8%, and 26.72% for setup 1, 2, 3, and 4 individually.

Further analysis revealed that water in the shallow aquifer (GW_Qmm) reduced from 489.86 mm (1975) to 321.71 mm (2000) and appreciated a little to 341.04 mm (2013) (Figure 4). This slight increase could be attributed to the excess rainfall experienced from July 2012, leading to a major flood in the nation. The two meteorological stations within the watershed put the annual rainfall in 2012 in the south to be 1659.81 mm (Daramola et.al., 2020) and in the northern part to be 1491 (NIMET 2012) ; these are the highest ever recorded in about three decades in the study area. According to IRIN (2012) reporting Nigeria Emergency Management Agency, the excess rainfall is the worst flooding in over 40 years, affecting 30 out of the 36 states in Nigeria and displacing about 1.3 million people. The lateral flow (Lat_Qmm) reduced from 1.81 mm in 1975 to 1.63 mm (10% reduction) in 2000 and further reduced to 1.55 mm (5%) in 2013 (Daramola et.al., 2022). This corroborates Adeogun et al (2014) that revealed that the lateral flow has the lowest percentage of the water yield (upstream of Jebba catchment, Nigeria) of between 0.18% (1998) and 0,39% in 2003.

The deep groundwater aquifer (Deep_mm) dropped from 25.79 mm (1975) to 16.82 mm (2000) and 0 mm (2013). A similar trend was observed by Adeogun et al. (2014) upstream of Jebba catchment in Nigeria, which the authors considered to be very low with a percentage variation of 2-10% of the total rainfall. A distinctive trend of constant groundwater decline was observed by Charles et al. (2016) in Olifants Basin, South Africa, with an annual groundwater recharge decrease of 10.37 mm (30.3%) between 2000 to 2007 and a further decline in groundwater recharge of 12.71 mm (37.2%) in 2013. A similar reduction in groundwater recharge in an East African watershed was stated by Baker and Miller (2013), while Ghaffari et al (2010) likewise described a decrease of about 80% threshold in rangeland in Zanjanrood Basin, Northwest Iran.

Groundwater recharge reductions can have deleterious effects for people living within the watershed as well as wildlife (McCall 1957, 1967). Citing Lake Nakuru National Park the author emphasized that Lake Nakuru is primarily recharged through groundwater flow from the surrounding five watersheds. Therefore, decreased groundwater recharge will impact Lake Nakuru by lowering water available for recharge, resulting in potential negative impacts on wildlife populations in the park that are dependent on the lake and the environment it supports.

Furthermore, Mahe et al (2013) confirmed a long-lasting decrease of baseflow in West Africa, leading to an intense drop of runoff in the regions in places above 750 mm of annual rainfall. The study area rainfall classification falls within an area above annual rainfall of 750 mm, and thus, corroborates Mahe et.al. (2013) of a long-lasting decrease of baseflow in West Africa and Areola et.al. (2014) submissions that the mean annual rainfall of the watershed ranges between 1200 mm in the south to about 1000 mm in the north. According to Ishaku and Majid (2010), these variabilities and patterns of rainfall in Nigeria may probably create water shortages in reservoirs, rivers, irrigation for agriculture, and industrial usage. Pluntke et al (2010) confirmed a general decrease in precipitation and increased temperature, wind speed, relative humidity, and global radiation in Eastern Europe in Ukraine (the river Western Bug). These, according to the authors, have severe implications on the water balance of the region. Corroborating (Adams and Peck, (2002) and (2008) that increased evaporation rates are expected to reduce water supplies in many areas.

Evapotranspiration for the 38years of study in the watershed has the highest water balance percentage of 50.94 (1975), 65.55% (2000), and 67.80% (2013). The scenario is a sign of climate change in the watershed. Literature confirmed that climate change could lead to a decrease in precipitation and an increase in temperature that could reduce water resources (Zhang et al., 2018; Idowu et al., 2011; Odjugo, 2005). Higher evaporation situation in Semi-arid context is a common role (Abouabdillah et al., 2014). The main factor responsible for high evaporation experience in the region is attributed to the high ratio of bare soils (Brouziyne et al., 2018). (Daramola et al., 2022) identified rangeland use class in the study area to consist of the steppe, i.e., an open intermittent herbaceous ground cover, occasionally mixed with shrubs and trees with inadequate cover to withstand severe weather anthropogenic activities. This might be one of the main contributions of the high percentage rate of evaporation in the water balance of the study basin.

The study area water yield (water that remains for runoff and soil/groundwater storage after subtraction of evapotranspiration) shows decline movement in the water balance 1975 (49.27%), 2000 (33.43%), and 2013 (32.98%). Gabiri et al (2019) also witnessed a decrease in annual water yield in Uganda, East Africa, having a similar climate with the study watershed. Charles et al (2016) confirmed a reduction in average water yield by 2.7% in 2013 Olifants Basin, South Africa. A similar trend was observed in Morocco in north Africa by Brouziyne et al (2018). The results revealed that evapotranspiration dominated the water balance taking about 61% of the total rainfall in the R'dom watershed, while the surface runoff and water yield represent 8.3% and 25.2% of rain, respectively, showing uneven water resources distribution within the watershed.

Conclusion

Evapotranspiration in the Kaduna Watershed is on the increase and has the largest percentage of the water balance in 1975 (50.9%), 2000 (65.5), and 2013 (67.8%). Water yield (precipitation minus evapotranspiration) reduced by 37.3% between 1975 and 2013 within a period of 38 years is of great concern. The importance of water yield in any ecosystem is vital been the sources for freshwater supply (drinking and irrigation), hydropower generation, and food production. Therefore, the water yields downward trend in the watershed call for urgent attention because its importance in the watershed is crucial to ecosystem survival.

Of great concern is the downward trends of groundwater (deep aquifer) and Surface runoff of the water balance from 2.10% (1975), to 1.40% (2000) and 0% (2013), and 7.04% (1975), to 5.03% (2000) and 3.80% (2013) respectively. If this trend persist,ss, it will have harmful effects for people living within the watershed and wildlife. Groundwater and surface runoff reduction will have negative Impacts on agriculture, streamflow, and vegetal cover. These will be a threat to the African most populous nation in the area of food production, energy, and water supply. Shiroro dam downstream of the watershed is principally recharged by Groundwater and Surface runoff. Hence, decreased groundwater and surface runoff recharge will impact Shiroro dam by lowering water available for recharge, resulting in potential negative impacts on hydropower generation to about 404, thousands of households that depends on energy generated from the dam.

More also, within the watershed, there is a high dependence of communities on wells, individual and community boreholes as a source of water, therefore, a decrease in groundwater recharge, and surface runoff might lead to serious water stress in the region and further aggravate the tension between headers and farmers within the area. If this condition persists, it will pose a great danger to reservoirs within the watershed, especially water supply and hydropower reservoirs. And threat to the African most populous nations in food production, energy, and water supply. Thus, the study could guide watershed managers, agriculturists and other authorities concern on the best way to salvage this impending doom.

A decline in rainfall and increased evapotranspiration in the watershed is a sign of climate variation. Hence, the urgent need for public enlightenment campaign on afforestation programs, global warming causes, and effects to combat the problem of climate variation in the country.

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Appendix

Table A1. Streamflow Data of Rivers Kaduna, Sarkinpawa, Gutalu and Dinya in The Year 2015-2017.

Year	Month	R. Kaduna Streamflow	R. Sarkinpawa Streamflow	R. Gutalu Streamflow	R. Dinya Streamflow
2015	January	1.261	0.174	0.147	0.147
2015	February	1.141	0.145	0.155	0.155
2015	March	10.009	1.754	2.543	2.543
2015	April	2.332	0.328	0.881	0.881
2015	May	46.249	4.343	5.276	5.276
2015	June	127.252	7.77	8.587	8.587
2015	July	226.248	14.337	12.786	12.786
2015	August	260.275	31.854	28.738	28.738
2015	September	583.377	32.654	28.409	28.409
2015	October	173.073	7.888	7.523	7.523
2015	November	8.091	0.517	0.583	0.583
2015	December	3.188	0.314	0.201	0.201
2016	January	2.049	0.213	0.149	0.149
2016	February	1.414	0.16	0.111	0.111
2016	March	19.827	2.812	3.314	3.314
2016	April	22.519	7.668	15.698	15.698
2016	May	25.835	8.091	7.854	7.854
2016	June	23.956	16.174	18.245	18.245
2016	July	29.26	21.984	16.947	16.947
2016	August	32.213	32.311	30.153	30.153
2016	September	35.778	24.993	25.956	25.956
2016	October	38.52	5.706	8.735	8.735
2016	November	12.291	2.612	1.652	1.652
2016	December	1.764	0.311	0.232	0.232
2017	January	1.278	0.223	0.158	0.158
2017	February	0.968	0.169	0.127	0.127
2017	March	1.858	0.193	0.114	0.114
2017	April	23.061	2.83	3.404	3.404
2017	May	196.363	13.968	14.689	14.689
2017	June	269.649	21.016	25.299	25.299
2017	July	176.03	10.245	12.205	12.205
2017	August	485.275	29.387	33.053	33.053
2017	September	421.122	28.471	31.818	31.818
2017	October	124.441	3.69	4.205	4.205
2017	November	2.976	0.395	0.467	0.467
2017	December	1.901	0.289	0.223	0.223

Appendix

Table A2. Rainfall Records of Shiroro and Kaduna Meteorological Stations 1990 to 2018

Year	Precipitation Shiroro	Precipitation Kaduna
1990	1747.4	1036.1
1991	1368.981	1371.063
1992	1419.7	1096.1
1993	1352.5	1244.5
1994	749.673	1066.9
1995	1662.787	1151.6
1996	1151.309	1217.2
1997	1209.984	1293.6
1998	899.542	1109.4
1999	841.598	1286.1
2000	1150.32	1232.8
2001	1341.28	1188.2
2002	1169.6	1315.4
2003	1344.72	1418.05
2004	1014.81	1379.3
2005	1080.246	1011.3
2006	1536.8	898.7
2007	1403.1	865
2008	1371.2	827.9
2009	1365.9	1217.9
2010	1215.9	1276.3
2011	1236.5	1096.4
2012	1659.81	1491.57
2013	1039.1	1169.94
2014	1450.9	1246.24
2015	1219.62	966.942
2016	1487.3	1352.004
2017	1176.9	1220.293
2018	1579.72	1266.539
Grand Total	40553.1	37722.16