NIGER RIVER BASIN AND SWAT MODEL APPLICATION IN NIGERIA CONTEXT: A REVIEW

Animashaun, I. M. [1, 2*] **Oguntunde, P. G.**[2], **Akinwumiju, A. S**[3]. **and Olubanjo, O. O.**[2]

[1] *Agricultural & Bioresources Engineering, Federal University of Technology, Minna, Nigeria*

[2]*Agricultural & Environmental Engineering, Federal University of Technology, Akure, Nigeria*

[3]*Remote Sensing and Geoscience Information System, Federal University of Technology, Akure, Nigeria*

**Corresponding Author: ai.iyanda@futminna.edu.ng*

ABSTRACT

A quantum number of original research and review articles has been published on River Niger for its socioeconomics importance. In some of the studies, some hydrological models were employed. However, some (if not all) of the available articles focused on a global or continental scale. But, since the effect of the climate change is felt on a regional basis, a need for review on what has been done using a hydrological model on regional basins arise. Soil and Water Assessment Tool (SWAT) is an important tool that has globally been adopted in that regard. Thus, this paper review some works that have been done along river Niger basin in Nigeria using the SWAT model with particular focus on the model performance. SWAT proof has been proven as a model that can be used effectively for water planning and management even in a data scarce region. The future direction of the model application in the region should examine mostly “hydrologic and pollutant loss” or “pollutant loss only” as all the reviewed work concentrate majorly on “hydrologic only”.

Keywords: Climate change, Hydrological model, Nigeria, River Niger, SWAT

1. INTRODUCTION

The intensity and frequency of extreme hydrological events witness across the globe with the advent of the 21st century has made the issue of global warming and climate change more of a reality contrary to the earlier fiction conception by the vast majority (Oguntunde and Abiodun, 2013). Water system is one principal medium through which the impact of the climate change is experienced by man and the ecosystems (Gain *et al.,* 2012). This explain why a number of research has been conducted in an attempt to find mitigation and adaptation strategies towards the water-related problems which are becoming increasingly multidimensional (Masih, 2011). It is evident that while the impact of climate change is experienced globally, the effect is regional. However, there is poor understanding of what the effect of the climate change is or what it will be on the hydrology of a particular region or basin particularly in developing countries such as Nigeria. This suggest a need for studies that will quantitatively predict the impact of climate change on water resources. The achievement of this is possible when a tangible climate change framework is developed with a robust hydrological models such as Soil and Water Assessment Tool (SWAT) model. Thus, this paper presents a review of the hydrological variability in a changing climate over River Niger basin in Nigeria and the use of SWAT model.

The Niger River is the second largest river in Africa by discharge volume. Its largest discharge (5,600 m^3/s) was recorded at Onitsha in Nigeria (1955-1991) and it receives its largest and most important tributary (the Benue River) at Lokoja also in Nigeria (Okpara *et al.,* 2013; Oguntunde *et al.,* 2014). It flows from the Guinea Highlands located in south eastern Guinea into the Gulf of Guinea and eventually into the Atlantic Ocean. The river's unusual flow path delineates the largest basin in West African that is bounded approximately by latitudes 5° N and 22° N and by longitudes 11°30´ W and 15° E (Ogilvie *et al.*, 2010; Grijsen, *et al.,* 2013) (Figure 1). Though, the active river basin is shared by nine countries (Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea, Mali, Niger, and Nigeria), those located in Nigeria has 562,372 km² of the basin area, accounting for 44.2% (Table 1) (Oguntunde *et al.,* 2014; Ogilvie *et al.* 2010).

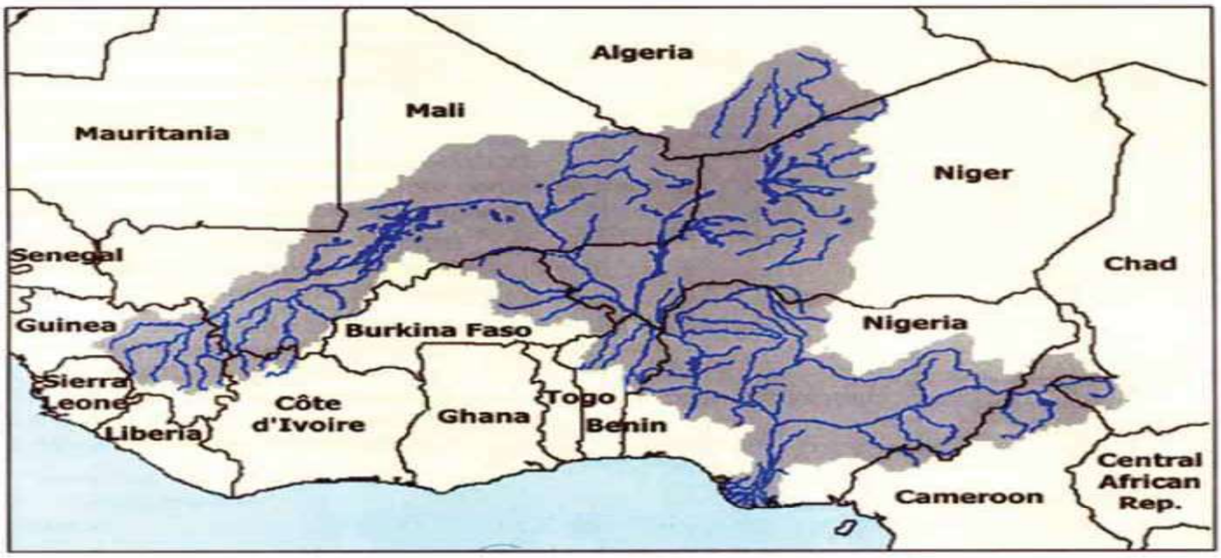

Figure 1: Niger River Basin in West Africa
Source: Oyebande and Odunuga (2010)

In Nigeria context, Niger Basin is also divided into Upper and Lower Niger River Basin. Nigeria has three hydro power plants (Kainji, Jebba and Shiroro) which are on river Niger and Kaduna, all in the basin. The river is of high economic and environmental significance which is why it has attracted the attention of a number of researchers throughout the globe.

Table 1: Niger River Basin

Country	Area (Km^2) of country within basin	Proportion of basin within country	Proportion of country within basin
Benin	44,967	3.5	38.7
Burkina Faso	86,919	6.8	31.5
Cameroon	86,381	6.8	18.4
Côte d'Ivoire	23,550	1.9	7.3
Guinea	98,095	7.7	39.9
Mali	263,168	20.7	20.9
Niger	87,846	6.9	7.4
Nigeria	562,372	44.2	61.5
Chad	19,516	1.5	1.5
Total Active basin	1,272,814	100	

Source: Ogilvie *et al* 2010

2. VARIABILITY AND VULNERABILITY SIGNIFICANCE OF CLIMATE CHANGE WITHIN THE BASIN

Historical records reveal that Niger River Basin is synonymous with high variability in climate (Goulden and Few, 2011). The water resource availability of the basin is highly variable and vulnerable (Okpara *et al.*, 2013). There is high interconnectivity between climate and freshwater systems of the basin as evaporation, rainfall patterns and water demand have great influence on water availability of the river basin (Okpara *et al.*, 2013). River Niger display very strong relationships with rainfall accounting for about 60% -70% of river flow variability (Conway *et al.,* 2009). Goulden and Few (2011) claimed that Nigeria contributes a large amount of flow to river Niger from rainfall within Nigeria.

Aside rainfall and evaporation, another important index of global environmental change having serious impact on the river flow of the basin is the land use (Conway *et al.,* 2009). Land use of a country determines to a large extent how vulnerable the country will be to climate change. This is because of consequential changes in land cover and as such, land use is not without a negative impact on water resources in the basin. The observed shift of rainfall areas results in increasing deforestation and desertification and thus contributes to the persistence of the drought and changes in land use and land cover as it is the case in Niger River Basin. The aftermath of the desertification includes but not limited to migration of farmers and herdsman. The recent incessant attacks by the herdsman could be linked to their migration into new area, the terrain of which they do not understand causing destruction of farm produce and man (Udeh, 2018).

In recent time, droughts and floods are becoming more frequent in the Niger River basin which are often accompanied by loss of materials and lives. At present, climate variability and change in most part of Nigeria results in changes in the onset and cessation dates of rainy season. A number of studies reported significant trends towards a false onset, late or delayed onset and early cessation of rain (Okpara *et al.,* 2013; Oguntunde *et al.,* 2014). This is largely responsible for the droughts experienced in some region around the basin, resulting in drastic reductions in the duration of rainy season and thus shortening the length of growing season. In Nigeria, the impacts of the drought of 1968 and 1973/74 were felt through reduction of farm produce to between 12% and 14% of annual average and death of about 300,000 animals representing 13% of livestock population (Okpara *et al.,* 2013). Aside the causalities of the drought, the flood that occurred in 2005, where the old Nukkai Bridge in Jalingo State, collapsed and sank into the overflowing Jalingo River, killing more than 100 people (Okpara *et al.,* 2013). More recently is the collapse of Sokoto Bridge in 2010. In 1999, Niger state in Nigeria witnessed heavy loss of lives and material due to opening of the floodgates of the three hydro plants (Kainji, Jebba and Shiroro) in response to torrential rains over the River Niger (Oyebande and Odunuga, 2010). Komadugu Yobe Valley (Northern Nigeria) was flooded in 1998 and 2001 leading to displacement of several hundred thousand people as well as loss of lives (Oyebande and Odunuga, 2010).

Spatio-temporal variability of rainfall is high in the basin, initiating not only drought and flood but also water scarcity and stress (Ogilve *et al*., 2010). In terms of surface water availability, Nigeria is ranked low having 2.75 in 1000 m^3 per person per year (Shiklomanov, 2000). This low quantity is still reducing due to swift growth of the world population, improved living standards, industrialization, water pollution coupled with climate change. It has been predicted that by the year 2025, Nigeria will be one of the countries of the world that will possibly face conditions of disastrously low fresh water availability (Merem *et al.,* 2017). High frequency of flood and persistence of drought witness in recent time coupled with water scarcity suggest a need for the use of a tool (such as SWAT) that helps in forecasting the probable impact of climate change taking into consideration change in land use.

2.1 Hydrologic Model and SWAT Application

In an attempt to address a wide-ranging water resources issues such as effects of land use change, future climate change on streamflow and water quality, hydrological simulation models are often employed (Gassman *et al.*, 2014). Development of superfluity of such simulation models is witnessed in recent decades. Each of the models has been designed to operate on a spatiotemporal scale. SWAT model is gaining global acceptance in recent time as a watershed scale model used in assessing water resource and non-point source pollution by simulating hydrologic processes, climate change, land use change, water quality and water management (Gassman *et al.,* 2007).

SWAT has performed wonderfully well in the previous versions due to continued review and expansion of its capability (Gassman *et al.*, 2014). Its interface with ArcGIS in recent version improved its credibility and applicability at various spatial and temporal scales in a wide range of watersheds throughout the world (Gassman *et al.,* 2007). Its ability to predict long term impacts as a continuous model, and to use readily available global datasets, as well as the availability of a reliable user and developer support contribute to its acceptance as one of the most widely adopted hydrological models (Gassman *et al.,* 2010; Tuppad *et al.,* 2013).

It also allows for spatial division of the modeled watershed into a number of sub-watersheds using digital elevation or topographic data according to the stated density by the user (Douglas-Mankin, 2010). The sub-watersheds may then be further subdivided into non spatial hydrologic response units consisting of homogeneous land use, management, and soil characteristics or left at sub-watershed that are characterize with prevailing soil type, land use, and management (Gassman *et al.,* 2007).

The model employs the usage of spatially distributed data on weather, hydrology, topography, land management, soil temperature and properties in predicting water, nutrient, sediment, pesticide, pathogens and bacteria yields (Douglas-Mankin *et al.,* 2010). Some of the basic inputs for river basin modeling are soil temperature and properties, land use, digital elevation model and climate data such as minimum and maximum temperature, daily precipitation, solar radiation data, relative humidity and wind speed data, which are either input from measured and /or generated records. While some of the climatic data are fundamental, the usage of some others depend on a particular method adopted. For instance, wind speed is only necessary if the Penman-Monteith method is used (Gassman *et al.,* 2007). The hydrologic cycle is simulated in SWAT using the water balance equation;

$$SW_t = SW_0 + \sum_{n=1}^{t} \left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right)$$

Where SW_t and SW_owater are the final and initial water content (mm), t is the time (days), R is the amount of precipitation on day i (mm), Q_{surf} is the mount of surface runoff (mm), $E_a$is the amount of evapotranspiration (mm), W_{seep} is the amount of water entering the vadose zone from the soil profile (mm), and Q_{gw} is the amount of return flow (mm) as indices.

A large number of review articles reported different applications of the model addressing a range of hydrological and environmental problems (Arnold and Fohrer, 2005; Douglas-Mankin *et al.,* 2010; Tuppad *et al.,* 2011; Gassman *et al.,* 2007). Vast number of the articles captured in review journal papers reported its application in the developed countries with little mentioning of what has been done in the developing nations. There is therefore a need for the appreciation of the few peer-reviewed journals on SWAT application along river Niger basin in West Africa, and in Nigeria in particular. This will help in summarizing and evaluating some of what have been reported in peer-reviewed journal by looking at their adopted approach *vis-a-vis* the stated aim. This will thus add to the review data base of the SWAT model and reveal the knowledge gap, needed to be filled by researchers in the developing world. Though, different methods were adopted in the few papers considered, the focus here is the evaluation of appropriateness of the models based on performance indicator (fit-to-observations) using Nash–Sutcliffe Efficiency (NSE) and coefficient of determination (R^2)

2.2 SWAT Model Application in Nigeria Basin

Alaba (2010) carried out modeling of an ungauged watershed with the associated uncertainties of the input data. The watershed modeled is along the bank of river Niger in Edu Local Government Area of Kwara State, Nigeria and has a drainage area of about 2,480 km^2. Simulated data were used throughout due to unavailability of measured data, hence the results look realistic. Though, water balance equation was used as validation criteria, giving the correlation coefficient between the simulated rainfall and runoff (0.84) that is impressive, the author submitted that the result of the model is not suitable for application in any hydrological development (e.g. construction of dam, dyke, etc.). Hence he suggested the use of measured data or the use of a model called ´TETIS´ to extrapolate calibrations at gauged basins to ungauged ones.

Olotu *et al.* (2013) simulated runoff and sediment load for reservoir sedimentation of River Ole Dam using SWAT and WEPP Models. The dam is located 54.8 km north of Auchi, Edo State, Nigeria and has 8.1 billion cubic meters (m^3) storage capacities. The coefficient of determination (R^2) reported between monthly modelled and measured rainfall, runoff and sediment yield were 0.94, 0.97 and 0.87 respectively. The computed R^2 for monthly rainfall, runoff and sediment yield simulation were 0.81, 0.76; and 0.73. Their study shows a strong agreement between the measured and simulated model.

Adeogun *et al.* (2014a) applied SWAT model in predicting streamflow of a watershed located upstream of Jebba reservoir in Nigeria. The watershed is located in North Central Nigeria and has an estimated area of 12,992 km^2. Major rivers and tributaries within the area are River Niger, Awun, Moshi, Eku, Kotongora and Oli. The model result showed a good correlation with the observed data having 0.76 for R^2 and 0.72 for NSE during calibration period. For validation periods R^2 was 0.71 and NSE was 0.78. They also predicted water balance and water yield of the same catchment area (Adeogun *et al.*, 2014b). They asserted that a good correlation existed between the observed flow and the simulated flow, with NSE and R^2 of 0.76 and 0.72, respectively, for calibration period, and NSE and R^2 of 0.70 and 0.78 respectively, for the validation period. They also reported correlation coefficient of 0.85 and 0.88 for calibration and validation data respectively and they thus concluded that the experimental data are reliable. Adeogun *et al.* (2015) predicted sediment yield of the same watershed and claimed the model showed a good agreement between the observed and simulated values for both calibration (NSE = 0.82, R^2 = 0.60) and validation (NSE = 0.65, R^2 = 0.52) period for river Awun. The calibration (NSE = 0.66, R^2 0.68) and validation (NSE = 0.55, R^2 = 0.68) were also claimed to be satisfactory for River Eku. However, only the calibration values (NSE = 0.8 and R^2 = 0.57) was satisfactory for river Niger/Kotangora as validation (NSE = 0.48 and R^2 = 0.23) period was unsatisfactory. The unsatisfactory performance of the model for validation period was attributed to excess sediments load reaching the sampling point.

Xie *et al.* (2010) employed SWAT application in modelling a river basin having a total drainage area of about 30,300 km^2. The basin is located in the northwest of Nigeria and extends to the neighbouring country of Niger. The results of their findings showed that the calibrated model achieved a reasonably good model fit with NSE value of 0.54. As against the usage of NSE and R^2 observed in other research works, Xie *et al*. (2010) limited the performance evaluation to the usage of NSE and the work was also completely silent on the model validation.

Begou *et al.* (2016) assessed the performance and predictive uncertainty of the Soil and Water Assessment Tool (SWAT) model on the Bani River Basin. Bani River is the major tributary of the upper Niger River basin. Its drainage basin covers an area of about 100,000 km^2 and is principally located in Mali but spans in a lesser extent over Cote d'Ivoire and Burkina Faso. The calibration and validation of the model on the Bani catchment yielded good results in terms of NSE and R^2 for both daily and monthly time steps except for NSE value of one station. NSE value ranging between 0.66 and 0.79 and R^2 values ranging from 0.68 to 0.82 for daily and monthly calibration were documented. Though, gauging station has a respective low value 0.37 and 0.47 respectively of NSE for validation on daily and monthly, high performance was recorded in the other two (0.77 and 0.85 NSE) for daily and monthly. The R^2 for the three station ranges between 0.57 and 0.91. They concluded that findings on SWAT model performance are very useful, especially in West Africa, where many river basins are ungauged or poorly gauged.

SWAT model was also applied by Oloruntade (2017) in assessing the Niger-South Basin (NSB), a sub-catchment of the Niger River Basin having a total area of about 26,324 km^2. Though, the study adopted auto-calibration using SWAT Calibration and Uncertainty Procedures (SWAT-CUP) software for the auto-calibration, the Nash-Sutcliffe (NS) and R^2 coefficients among others goodness of fit statistics were used for evaluating model predictions. The result of the calibration and validation for NSE is 0.82 and 0.73 respectively and for R^2 0.84 and 0.76 respectively. He opined that model performed well for both the period of calibration and validation.

It is worth mentioning that while SWAT applications reported in the review works of some parts of the world were categorized into hydrologic only, hydrologic and pollutant loss, or pollutant loss only (Table 2) (Gassman *et al.* 2007; SWAT. 2007), virtually all the available works on West Africa fall under hydrologic only indicating underutilization of SWAT model. Hence, there is a need for research work on hydrologic and pollutant loss, or pollutant loss only using the SWAT model. There is also a need to incorporate global warming into the hydrologic only particularly for Nigeria which is one of the highest emitter of greenhouse gases in Africa as about 123 flaring sites have been in operation for more than 40 years, flaring 1.8 billion cubic feet of gas every day (Okpara *et al.,* 2013). This is because the forecasted warming climate triggered by the accumulation of greenhouse gases concentration is very likely to aggravate the present climatic variability and extremes in Nigeria. This will likely have grave consequences on water resources availability and food production not only in the Niger River basin or Nigeria but over the entire West African region (Okpara *et al.,* 2013). A better way to study climate change impact is to consider some of the issues which contribute to the strong vulnerability of the climate.

More so, hydrologic with global warming scenario will make us respond to the clarion call by the UNFCC (2015) in investigating the potential impacts of 1.5°C and 2.0°C on every sectors of the nations. This they claimed will help in formulating the first-ever global and legally binding climate agreement on the target levels. Thus the impact of the target levels (1.5°C and 2.0°C) of global warming on hydrology of the Niger River Basin on regional basis can thus be investigated.

Table 2: Overview of major application categories of SWAT studies

Primary Application Category	**Hydrology only**	**Hydrologic and Pollutant Loss**	**Pollutant Loss Only**
Calibration and/or sensitivity analysis	15	20	2
Climate change impact	22	8	---
GIS interface descriptions	3	3	2
Hydrologic assessments	42	---	---
Variation in configuration or data input effects	21	15	---
Comparisons with other models or techniques	5	7	1
Interfaces with other models	13	15	6
Pollutant assessment	---	57	6

Source: Gassman *et al.* 2007

3. CONCLUSION

The high variability of the hydrological variable over the Niger River basin in a changing climate has brought about series of droughts and flood with consequential loss of lives and properties, particularly in Nigeria. Any increase in global warming could aggravate the extreme events in the near future, hence there is a need for early warning system with hydrological model of high performance in space and time prediction even in a region with minimum hydrological data. This will help in water planning and management in time of severe water stress and shortage arising from decrease in amount of rainfall. SWAT is a useful tool for investigating hydrological processes. It is a comprehensive and flexible model capable of modelling gauged and ungauged catchment. It is helpful in flood forecasting, water resource planning and management, pollutant assessment (nutrient and pesticide), evaluation of water quality, erosion and sedimentation, land use and climate change. The model has however been underutilized particularly in such an important basin like River Niger. While few works had its mentioning on hydrological modelling, they limited its usage to "hydrologic only" with no work reported on "pollutant loss only" and "hydrologic and pollutant loss". There is therefore a need for SWAT exploitation on River Niger basin as it gives not only a qualitative assessment but also a quantitative one under the climate change scenario in order to take adequate measure against the advert effect of global warming. This paper has created the state of art research on global warming and climate change impact on River Niger basin and the need for SWAT model

REFERENCES

Adeogun, A.G., Sule, B. F., Salam, A.W. and Okeola, O.G. (*2014a*): GIS-Based Hydrological Modeling Using Swat: Case Study of Upstream Watershed of Jebba Reservoir in Nigeria *Nigerian Journal of Technology 33 (3),* 351 – 358

Adeogun. A. G., Sule, B. F., Salami, A. W., Daramola, M. O. (2014b) Validation of SWAT Model for Prediction of Water Yield and Water Balance: Case Study of Upstream Catchment of Jebba Dam in Nigeria *International Journal of Mathematical, Computational, Physical, Electrical and Computer Engineering* 8 (2), 264 - 270

Adeogun, A. G., Sule, B. F. & Salami, A. W. (2015) Simulation of Sediment Yield at the Upstream Watershed of Jebba Lake in Nigeria Using Swat Model, *Malaysian Journal of Civil Engineering 27(1):25-40*

Alaba, B. (2010) Hydrologic Modeling and Uncertainty Analysis of an Ungauged Watershed Using MapWindow-SWAT, Dissertation submitted in partial fulfillment of the requirement for theDegree of Master of Sciences in Geospatial Technologies, Universitat JAUMI

Arnold, J.G.; Fohrer, N. (2005). SWAT2000: Current capabilities and research opportunities in applied watershed modeling. *Hydrological Processes* 19:563-572.

Begou, J. C., Jomaa, S., Sihem, Bazie, B. P., Afouda, A. and Rode, M. (2016): Multi-Site Validation of the SWAT Model on the Bani Catchment: Model Performance and Predictive Uncertainty Water 2016, 8, 178, 1-23

Conway, D., Persechino, A., Ardoin-Bardin, S., Hamandawana, H., Dieulin, C. and Mahe, G. (2009). 'Rainfalland river flow variability in Sub-Saharan Africa during the twentieth century', *Journal of Hydrometeorology*, 10, pp. 41–59.

Douglas-Mankin, K. R., Srinivasan, R., Arnold, J. G. (2010) Soil and Water AssessmentSWAT) Model: Current Developments and Application, *American Society of Agricultural and Biological Engineers* 53(5): 1423-1431

Gain, A. K., Giupponi, C., and Renaud, F. G. (2012), Climate Change Adaptation and Vulnerability Assessment of Water Resources Systems in Developing Countries: A Generalized Framework and a Feasibility Study in Bangladesh *Water*, *4*, 345-366

Gassman, P. W. Reyes, M. R., Green, C. H. and Arnold, J. G. (2007), The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions, American Society of Agricultural and Biological Engineers 50(4): 1211-1250

Gassman, P. W., Williams, J. R., Wang, X., Saleh, A., Osei, E., Hauck, L. M., Izaurralde, R. C. and Flowers, J. D. (2010) The Agricultural Policy/Environmental eXtender (APEX) model: An emerging tool for landscape and watershed environmental analyses. *Trans. ASABE* 53(3): 711-740.

Gassman, P. W., Sadeghi, A. M, and Srinivasan, R. (2014) Applications of the SWAT Model Special Section: Overview and Insights Journal of Environmental Quality. 43:1–8

Goulden, M. and Few, R. (2011) Climate Change, Water and Conflict in the Niger River Basin USAID Reliefweb report-*http://reliefweb,int/node/474471*

Grijsen, J. G., Brown, C., Tarhule, A., Ghile, Y. B., Taner, U., Talbi-Jordan, A., Doffou, H. N.

Guero, A., Dessouassi, R. Y., Kone, S., Coulibaly, B. and Harshadeep, N. (2013)

Climate Risk Assessment for Water Resources Development in the Niger River Basin Part I: Context and Climate Projections Downloaded from: http: // www. intechopen. com/ books/climate-variability-regionaland-thematic-patterns

Masih, I. (2011). Understanding hydrological variability for improved water management in the semi arid Karkheh basin, Iran. Unpublished PhD thesis submitted to Delft University of Technology and of the Academic Board of the UNESCO-IHE Institute for Water Education, the Netherlands, (retrieved June 1, 2016)

Merem, E. C., Twumasi, Y., Wesley, J., Isokpehi, P., Shenge, M. Fageir, S., Crisler, M., Romorno, C.,

Hines, A., Hirse, G., Ochai, S., Leggett, S. Nwagboso, E. (2017) Analyzing Water Management Issues Using GIS: The Case of Nigeria Geosciences 7(1): 20-46

Ogilvie, A., Mahé, G., Ward, J., Serpantié, G., Lemoalle, J., Morand, P., Barbier, B., Diop, A. T.

Caron, A., Namarra, R., Kaczan, D., Lukasiewicz, A., Paturel, J., Liénou, G & Clanet, J. C. (2010) Water, agriculture and poverty in the Niger River basin, *Water International*, 35:5, 594-622, DOI: 10.1080/02508060.2010.515545

Oguntunde P.G., Abiodun B.J. (2013). The impact of climate change on the Niger River Basin hydroclimatology, West Africa, *Climate Dynamics* 40:81-94

Oguntunde, P. G., Abiodun, B. J. & Lischeid, G. (2014): A numerical modelling study of the hydroclimatol-ogy of Niger River Basin, West Africa*, Hydrological Sciences Journal, DOI: 10.1080/02626667.2014.980260*

Okpara, J. N. Tarhule, A. A and Perumal, M. (2013) Study of Climate Change in Niger River Basin, West Africa: Reality Not a Myth, available at http://dx.doi.org/10.5772/55186

Oloruntade, A. J. (2017). Modelling the impacts of climate change on hydrology and water resourcesin the Niger-South Sub-Catchment of the Niger River Basin, Nigeria, Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in fulfilment of the requirements for the Degree of Doctor of Philosophy

Olotu Y, Akanbi O. P, Ahanmisi E. & Adeniyi E. A (2013) Simulation of Runoff and Sediment Load for Reservoir Sedimentation of River Ole Dam using SWAT and WEPP Models, *Global Journal of Science Frontier Research Agriculture and Veterinary 13 (13), 6- 12*

Oyebande L. and Odunuga, S. (2010): Climate Change Impact on Water Resources at theTransboundary Level in West Africa: The Cases of the Senegal, Niger and Volta Basins, *The Open Hydrology Journal, 4,* 163-172

Udeh C. (2018) Between Climate Change and Herdsmen crisis, Leadership Newspaper 17/01/2018

SWAT. (2007). Soil and Water Assessment Tool: Peer-reviewed literature. College Station,

Tex.: Texas A&M University. Available at: www.brc.tamus.edu/swat/pubs_peerreview. html. Accessed 17 May 2017.

Shiklomanov, I. A., (2000). Appraisal and Assessments of World Water Resources, *WaterInternational,* 25(1), 11 –32.

Tuppad P. D, Douglas-Mankin K. R. Lee, T. Srinivasan, R. and Arnold J. G. (2011), Soil and Water Assessment Tool (SWAT) Hydrological/Water Quality Model: Extended Capability and Wader Adoption, American Society of Agricultural and Biological Engineers 54(5): 1677-1684

UNFCCC (2015), Paris Agreement, Conference of the Parties, Twenty-first session (COP21) United Nations Framework Conven. Climate Change, Paris, France.

Xie, H., Nkonya, E. & Wielgosz B. (2010) Evaluation of the SWAT Model In Hydrologic Modelling of a Large Watershed In Nigeria, Proceeding of third *IASTED* African Conference Water Resources Management Sept 6-8, 2010