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Water Demand Assessment under Climate Variability Scenarios Using SWAT and WEAP: A Case Study of Kaduna South Catchment

Okoye, Dozie Jerome
Researcher, Department of Water Resources and Environmental Engineering
Ahmadu Bello University Zaria, Nigeria
Dr. Argungu, Abdullahi Sule
Senior Lecturer, Department Of Water Resources and Environmental Engineering,
Ahmadu Bello University Zaria, Nigeria
Ismail, Abubakar
Senior Lecturer, Department of Water Resources and Environmental Engineering,
Ahmadu Bello University Zaria, Nigeria
Okon, Samuel
Researcher, Department of Water Resources and Environmental Engineering,
Ahmadu Bello University Zaria, Nigeria
Yahaya, Abdullahi
Researcher, Department of Water Resources and Environmental Engineering,
Ahmadu Bello University Zaria, Nigeria

Abstract:
This research was structured to examine the impact of the domestic as well as Agricultural water demand on the current and future surface water available within the Kaduna South Catchment of Nigeria. Also taking into consideration climate variability as a factor that will either increase or decrease the temperature as well as the precipitation in the catchment, with significant effect on the stream flow within the Kaduna river basin. A dual Order modelling approach was adopted in this research, in which the Soil and Water Assessment Tool (SWAT) alongside the Water Evaluation and Planning (WEAP) models were engaged to simulate the streamflow of the catchment which was calibrated and validated by the observe streamflow data of the Kaduna river. An Hypothetic approach was employed in observing and analyzing the climate scenarios after which the output data from SWAT model was used as the Input data into WEAP for simulating scenarios of high population of a growth rate of 2.21% and four different climate variability scenarios as temperature were projected to increase by 0.4oC from the observed historical trend. Nevertheless, the overall unmet demand was observed to be 305Mm3 in which 70% account for domestic demand while 30% is the Agricultural unmet demand. The calls for strategic planning and looking out for other source such as underground water and not totally rely on surface water for future water use.

Keywords: *Water demand, climate variability, SWAT, WEAP*

1. Introduction

The demand for portable water has become a growing concern globally as our various water sources especially surface water have been on intense pressure to meet with the increasing demand ranging from domestic, agricultural to industrial demand for water. And among the various sources of water, surface water serves as an indispensable source of water for the sustainability of mankind and other forms of life (Babel et'al 2005).

Water without doubt is a very essential good for human sustainability within any geographical location and it's also vital for the development of any town or city. Also, with the spontaneous growth of commercial, industrial and domestic activities, ample portable water cannot be compromised. Furthermore, municipal water authorities strive to achieve a balance between the supply and demand at a level acceptable to the consumers within the urban development. as this as lead to the increase in population of municipal settlement and the variation in climatic conditions which also tends to affect the available water resources meeting the growing demand. Climate change with its variation in different location has an enduring impact on water resources with reference to the intergovernmental panel on climate change (IPCC) which was established in the year 1988 to understudy climate related matters as it affects agriculture and various water sources. And been able to ascertain significant impacts especially to drought prone areas as well as regions experiencing water issues so as to develop a comprehensive frame work for a long-term water supply planning incorporating economic and regulatory instruments that needs to include an assessment of the sensitivity of the water resources to climate change in addition to forecasts of future water demand.

The 2018 edition of the United Nations World Water Development Report stated that nearly 6 billion peoples will suffer from clean water scarcity by 2050. This is the result of increasing demand for water, reduction of water resources, and increasing pollution of water, driven by dramatic population, change in climate and economic growth. (Alberto, 2019). The outbreak of the novel corona virus popularly known as COVID-19 as exact an in mess economic as well as health challenges on various communities around the world with major reference to the water sector as the demand for water especially domestically as tend to increase as proper sanitation and effective hygiene is big deal with water availability. (Bindler, 2020)

The Nigerian water sector covers a vast range of the various water sources ranging from surface to underground water especially fresh water. And the country as a coastal line of about 800km towards the south as well as the lake chad basin towards the north. It's estimated that a total of about 267 billion cubic meters of surface water is a result of the various rivers in the country such as the Anambra, Kaduna, Imo Gongola etc. and this water source as been a great means of livelihood in the country as it has catered for the various water demand especially domestic, industrial and very importantly agricultural. (FGN, 2011a)

Model scenario simulation is a famous approach in water management as well as planning especially in situations of competing demands from different users. And over time the Water Evaluation and Planning system (WEAP) has been greatly adopted Yates et'al. (2005). Furthermore, Skaggs et'al (2012) attested to the effectiveness of the WEAP model in hydrological management and development alternatives. And it is to be noted that WEAP is a global model that has been successfully tested in various continent of the world. Rodrigues et al., 2015; Mulungu and Taipe, 2012; Van Loon and Doogers, 2006; Arranz and McCartney, 2007; Droogers et al., 2014; Haji, 2011.

Nevertheless, WEAP requires an input parameter usually referred to as head flow which caters for the supply requirement for the model, and this Study adopted the Soil and Water Assessment Tool (SWAT) as a model for simulating the hydrological component of the catchment. After which WEAP was use for the water allocation to the various demand site. And the SWAT model has been used across the globe in different continent with success. And good example is as follow; Githui et al., 2009; Mulungu and Munishi, 2007; Chinasamy et at., 2015; Ndomba et al., 2008.

2. Materials and Methods

2.1. The Study Area and Data

The Kaduna River system is a large river basin which divides the region into north and south, Kaduna city is the capital of Kaduna State in North -Western Nigeria. River Kaduna is a tributary of the River Niger with its source from Kujama Hill in Plateau State and flows for 210 km before reaching Kaduna town. Kaduna is located between latitude 10 31' 23'' north and longitude 7 26' 50'' east. Kaduna state covering a total land mass of about 431km2.The study area belongs to the tropical continental type of wet and dry climate dry season (October to march) wet season (April to September).

This study utilized climatic data such as rainfall and temperature and hydrologic data such as streamflow. The record length of climate data span between 1991 to 2020

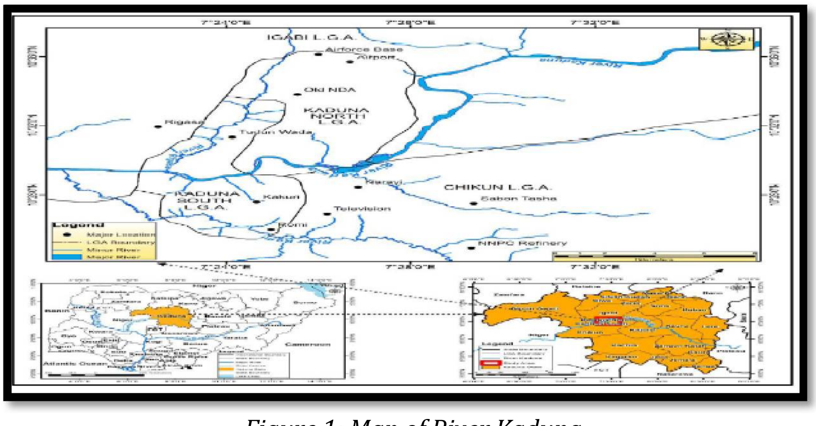

Figure 1: Map of River Kaduna
Source: Ogbozige, Et Al, 2017

2.2. Hydrological Modelling

The hydrological modelling was achieved using the Soil and Water Assessment Tool (SWAT) in which the model was set-up, and the catchment was divided into various Hydrological response unit (HRU). The model was further calibrated and validated using the observed streamflow data from 1991 to 2004 after observing a waiting period of two years. The sensitivity analysis on SWATCUP resulted in to four parameters. Which were optimized. And Moriasi et al (2007). guideline was adopted for the SWAT performance assessment.

2.3. Water Demand and Allocation Analysis

The Water evaluation and planning (WEAP) tool was used for water allocation to the various demand site majorly domestic and agriculture. The output stream flow data from the SWAT model was adopted as the input head flow in WEAP and using the water year method, the high population as well as the various climatic variability scenarios were simulated. The current and future water demand as well as unmet demand were estimated based on existing population data as well as potential irrigable areas.

3. Results and Discussions

3.1. SWAT Model Calibration and Validation

SWATCUP use the discharge data to calibrate the model, data from 1991 to 1997 was used for calibration while data from 1997 to 2004 was used for the validation process and the figure below shows the calibrated to the validated model as well as the observed flow to the simulated flow. The model performance was okay with a Nash-Sutcliffe of 0.84 and R2 of 0.64 and the percent bias (PBIAS) was 0.45.

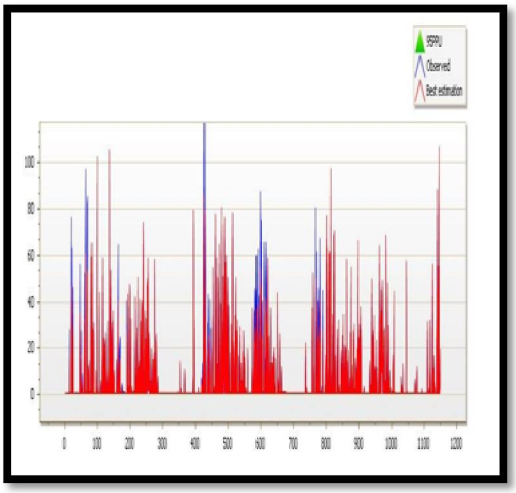

Figure 2: Calibration and Validation of the Hydrological Model
Source: SWATCUP

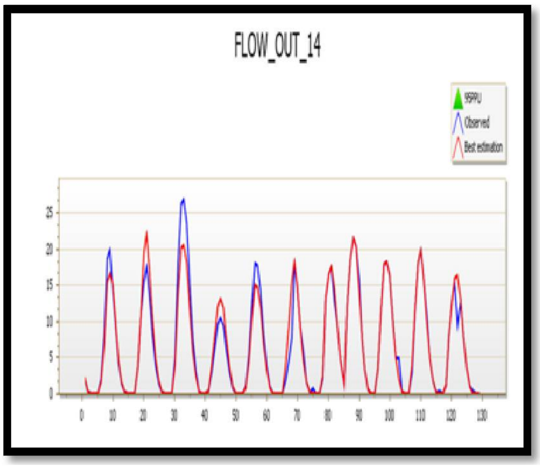

Figure 3: Stimulated Verses Observed Streamflow of the Hydrological Model
Source: SWATCUP

3.2. Water Balance

The results showed no significant difference between the two models. Some past studies, e.g. Obuobie (2008), used both calibrated and validated in his assessment and realized that there was no significant difference between values obtained. On average, the catchment receives about 1480mmof annual precipitation. Return flow is the largest water balance component, which consumed about 674 mm representing 45.5%.

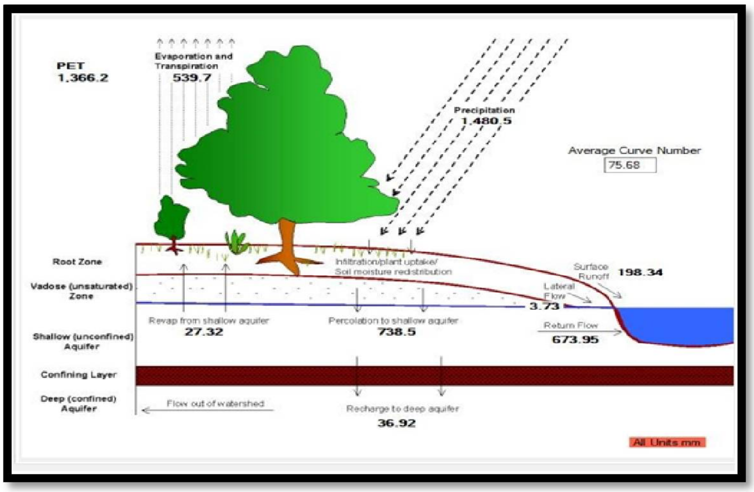

Figure: 4 Water Balance Ratio of the Model
Source: Qswat

3.3. Water Demand and Allocation under Selected Scenarios

3.3.1. Scenario 1: Impact of Population Growth

Under this scenario population growth rate used varied in the range of 2.2%. All other sectors were assumed to grow at insignificant rates and therefore the unmet demand was at a progressive trend till 2030 with the highest unmet demand of 202Mm3. From the progressive trend in the unmet demand in all the sectors, the impact of population growth as well as Irrigation shows high level.

3.3.2. Scenario 2: Impact of Demand as a Result of Climate Variation

Under this scenario, the four different climate situation shows a varied unmet demand with regards to the different climate situation. As the reference scenario serves as the base factor.

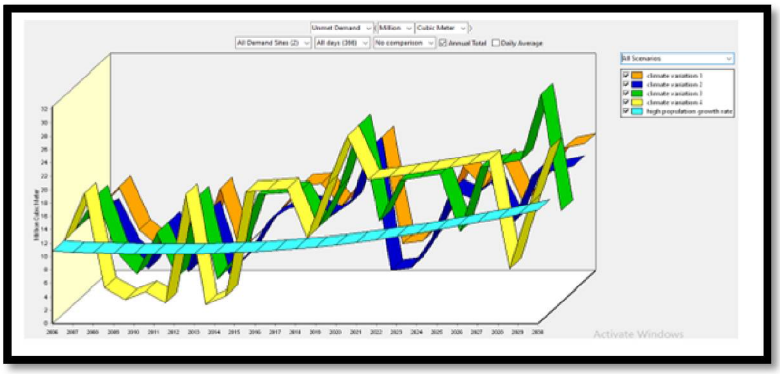

Figure: 5 Unmet Demands for All Scenarios
Source: WEAP

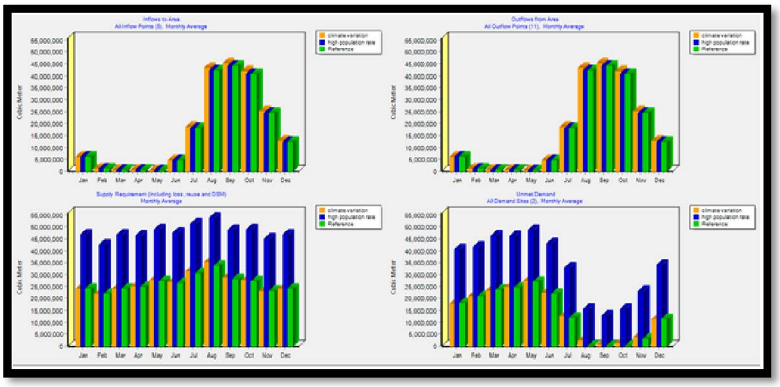

Figure 6: Monthly Averages of Scenarios

4. Conclusions

The model of the Kaduna south catchment was successfully set up the various scenarios approach as regards to population and climate variability. Nonetheless, in as much as the model was subject to quality check under reasonable assumptions of the obtained data, consideration of inherent error should be expected. So therefore, the result of the research should be adopted with maximum caution. Nevertheless, the observe result from the study is as follows;

The scenario of high population growth rate, with a growth rate value of 2.21%, as shown from the WEAP output model result in figure 5, the total unmet demand observed between the period of 2006 to 2030 is found to be 305Mm3 in which domestic unmet demand is about 70% and the unmet demand for irrigation is 30%.

The unmet total future demand due to climate variation in all sectors between the period of 2006 to 2030 is observed to be 301Mm3, 273Mm3, 370Mm3, 368Mm3 for scenario one, two, three and four respectively and showing that scenario three has the highest unmet demand of 370Mm3.

The impact of all future demands due to urban expansion and climate variation is expected to be severe in the irrigation sector with unmet demand as well as the domestic water demand, which will also not be fully met with a total unmet demand of 258Mm3 in the year 2030.

5. References

i. *Arranz, R., McCartney, M., 2007. Application of the Water Evaluation and Planning (WEAP) Model to Assess Future Water Demands and Resources in the Olifants Catchment. IWMI working paper 116. International Water Management Institute, South Africa, Colombo, Sri Lanka.*

ii. *Babel, M. S., Gupta, A. D., & Nayak, D. K. (2005). A model for optimal allocation of water to competing demands. Water resources management, 19(6), 693-712.*

iii. *Bindler, Eric. 2020. "COVID-19: Watershed Moment for Digital Transformation of Water Sector." SmartWaterMagazine.https://smartwatermagazine.com/blogs/eric-bindler/covid-19watershedmoment-digital-transformation-water-sector-0*

iv. *Chinnasamy, P., Bharati, L., Bhattarai, U., Khadka, A., Dahal, V., Wahid, S., 2015. Impact of planned water resource development on current and future water demand in the Koshi River basin, Nepal. Water Int. 40 (7), 1004e1020. http:// dx.doi.org/10.1080/02508060.2015.1099192*

v. *Droogers, P., de Boer, F., Terink, W., 2014. Water Allocation Models for the Umbeluzi River Basin, Mozambique. In: Wetter Skip Frystan and ARA-Sul Report Future Water, vol. 132 (The Netherlands).*

vi. *Githui, F., Mutua, F., Bauwens, W., 2009. Estimating the impacts of land-cover change on runoff using the Soil and Water Assessment Tool (SWAT): case study of Nzoia catchment, Kenya. Hydrol. Sci. J. 54 (5), 899e908.*

vii. *Haji, H.T., 2011. Impact of Cliamte Change on Surface Water Availability in the Upper Vaal River Basin. Masters Dissertation. Tshwane University of Technology*

viii. *Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE, 50(3), 885-900.*

ix. *Mulungu, D.M., Munishi, S.E., 2007. Simiyu River catchment parameterization using SWAT model. Phys. Chem. Earth 32, 1032e1039.*

x. *Mulungu, D.M., Taipe, C.I., 2012. Water evaluation and planning in wami river - basin: application of the WEAP model. In: Beall, E. (Ed.), Bioenergy and Food Security e the BEFS Analysis for Tanzania FAO, vol. 54, pp. 47e69.*

xi. *Ndomba, P., Mtalo, F., Killingtveit, A., 2008. SWAT model application in a data scarce tropical complex catchment in Tanzania. Phys. Chem. Earth 33 (8e13), 626e632. Ntai, P.J., 2011. Critical Factors Determining Successful Irrigation Farming in Lesotho. Masters dissertation. University of Pretoria. ORASECOM, 2013.*

xii. *Obuobie, E. (2008). Estimation of groundwater recharge in the context of future climate change in the White Volta River Basin, West Africa.*

xiii. *Ogbozige, F. J., Adie, D. B., Igboro, S. B., & Giwa, A. (2017). Evaluation of the water quality of River Kaduna, Nigeria using water quality index. Journal of Applied Sciences and Environmental Management, 21(6), 1119-1126.*

xiv. Skaggs, R., Janetos, T.C., Hibbard, K.A., Rice, J.S., 2012. Climate and Energy-waterland Systems Interactions (Washington United States of America).

xv. *United Nations Human Settlements Programme. (2005). Financing urban shelter: global report on human settlements 2005. UN-HABITAT/*

xvi. *Van Loon, A., Doogers, P., 2006. Water Evaluation and Planning System. Kenya report*

xvii. *Yates, D., Sieber, J., Huber-Lee, A., 2005. WEAP21: a demand-, priority-, and preference-driven water planning model: Part 1: model characteristics. Water Int. 30 (4), 487e500.*