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Simulation And Modelling Of Climate Change Effects On River Awara Flow Discharge Using WEAP Model For Effective Water Management

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ABSTRACT: Modelling of streamflow and discharge of river Awara under changed climate conditions using CLIMGEN for stochastic weather generation and WEAP model was used to simulate reserviour storage volume, water demand and river discharges at high spatial resolution (0.5°×0.5°, total 66,420 grid cells). Results of CLM-Based flow measurement shows a linear regression with $R^2 = 0.99$ for IFPRI-MNP- IGSM_WRS calibration. Sensitivity simulation of ambient long-term shows an increase in temperature with $0.5^{o}c$ thus the results of the studies generally show that annual runoff and river discharges could largely decrease. The projection of water demands 150 million m^3 by 2020 against the reserviour storage volume 60 million m^3 and decrease in rainfall depth by -5.7 mm. The output of the combined models used in this study is veritable to create robust water management system under different climate change scenarios.

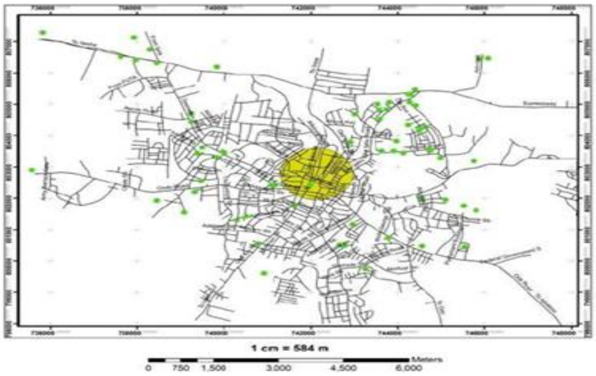
Keywords: Discharge, Simulation, Water, Storage, Climate change, Models, WEAP

1 INTRODUCTION

Population increase by 2050 expected to be +50%globally; +60% in less developed countries; more than doubling in Sub-Saharan Africa (Kavová, 2005). Agriculture is the largest user of water; the sector is highly dependent on water resources, accounting for 70% of total water withdrawals; some 40% of the global food crop is derived from irrigated agriculture (Novický, 2009). Agriculture is in competition with other water users and has impacted negatively on the environment. Food and water supply are key human sectors exposed to climate change. Climate-change impacts are already being felt in many countries; further global warming will be unavoidable (Frederick,1999) Climate change is one of the most important phenomena in our contemporary world. IPCC (2007) defines climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or the variability of its properties, and that persists for an extended period typically decades or longer. In its most recent assessment, the Intergovernmental Panel on Climate Change (IPCC) reported that all of Africa is likely to warm during this century, with the drier subtropical regions warming more than the moist tropics (Huntington, 2004). These changes in the physical environment in thus determines the water supply of plants, influences the air and heat regimes, biological activity and plant nutrient status of soil (Montgomery, 2007). The most significant variables of climate change are temperature and rainfall. Potential future changes is rather difficult, due to the uncertainties in the forecast of global and long-term temperature and precipitation patterns (including their spatial and temporal variability) combined with the changing hydrological cycle such as alternations in precipitation patterns, soil moisture conditions, surface runoff and river flow and discharge. Many of the world's countries already struggle under existing water stress from pressures such as irrigation demands, industrial pollution and water borne sewerage (Groisman, 2005). These pressures will be significantly exacerbated by climate change, which for many regions will result in reduced rainfall and increasing temperatures, further reducing the availability of water for drinking, household use, agriculture and industry. As these competing demands intensify under climate change, effective governance for balancing water demands will become essential, particularly in the face of strong pressures to prioritize industrial uses over other uses such as drinking supplies. Storm event of high intensity causes erodibility and surface flow which leads to reserviour sedimentation (Olotu et al., 2009). Reservoir capacity of Awara dam has greatly reduced as a result of continuous sedimentation and siltation.Having considered global water-stress problems mainly as result of climate variability, this research study is aimed at stimulating and modeling Awara reserviour capacity and river flow in order to provide realistic and robust output for developing and managing effective water resource system.

2.1Materials and Methods

High spatial resolution (0.5°×0.5°, total 66,420 grid cells); and simulation of both water availability (streamflow) and water use at daily-basis was applied. The meteorological input for 10-year at (0.5^0 x 0.5^0; 10 hourly resolution) using daily climatic variables such as air temperature, specific humidity, wind speed, precipitation, short and long wave radiation and precipitation. A Geographical and reserviour map was used. Domestic and industrial data such as domestic and industrial water supply data was simulated to create maximum water supply. Hydrological data such as rainfall (mm), temperature (0^c), river discharge (m^3/s) and sediment load were obtained from the three gauging stations (Oyimo, Otaloke and Gbegbeda gauging stations respectively). Runoff data were computed from the obtained rainfall using the following expressions: Projection of precipitation and temperature used the CLIMGEN models, and hydrological analysis and water management simulation used the WEAP software. The geographic map of the study area is shown in plate 1 below:



2.1 Results and discussion

2.1.1CLM-Based Flow Measurement of Surface

Computation of energy and water fluxes including surface runoff using *CLM-Based* flow and in calculating surface runoff, CLM represents the effects of limited infiltration of soils (i.e. Hortonian flow) as well as runoff from saturated surface conditions, and it also considers the effects of frozen soil conditions and root density on soil hydraulic conductivity.

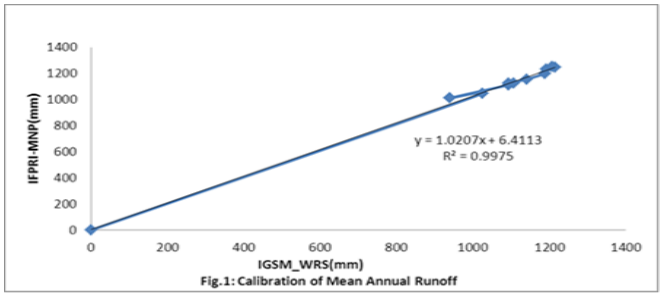


Fig.1: Calibration of Mean Annual Runoff

A linear regression through the origin results in Fig.1 an R^2 of 0.99, suggesting that the CLM runoff captures the regional wetness and dryness at the large spatial scale of the ASRs. In capturing the temporal variabilty and spatial signal of the climate the CLM runoff has shown to be a better tool for analysis of relative climate change impacts, but bias correction is needed if the model is to properly balance water supply with water demand and represent water stress.

2.1.2Discharge rating

14-year streamflow and discharges from 1999 to 2006 shown in Table 1 allowed us to separate the records into three similar periods in length, so as to represent different stages of streamflow regulation by reservoirs in the Awara River watershed. Once a set of characteristics for the watershed have been selected, there is a further assumption that the rainfall-runoff processes will stay reasonably constant under changing precipitation and temperature conditions.

Table 1: Metrological and hydrological data of River Awara

Year	Rainfall (mm)	Runoff (mm)	Discharge (m3/day)
1997	1125	1023.8	10,231
1998	1036.7	939.2	9390.2
1999	1200	1093.4	10930
2000	1214.5	1106.6	11066
2001	1200	1093.6	10934.7
2002	1250	1140.4	11400
2003	1300	1187.4	11874
2004	1305	1192.1	11921.5
2005	1330	1215.6	12156
2006	1322	1208	12080
2007	1346	1231	12310.9

Source: Field study, 2011

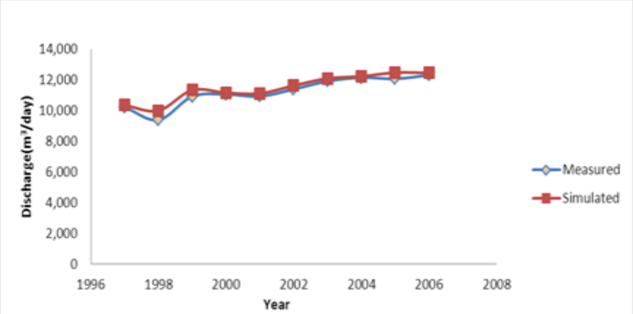


Fig.1: Calibration and validation of river discharge

Figure.1 shows the measured and simulated time series of streamflow. The trend of simulated flow is reasonably close to the trend of observed streamflow and both the calibration and validation periods show a similar fit to the data. However, there are some differences in the observed and simulated values with R^2 =0.8 and 0.9 respectively. The storage capacity of Awara reservoir is 321.3 million m^3 (MCM) and initial storage estimated at 111.4 million m^3, this storage was obtained in the month of January, 1997. The projected reserviour storage was simulated using WEAP model as shown in Fig.2. Figure 3 shows the simulation outp of precipitation for the region. Based on this simulation, the precipitation in increased in 1997 and dropped in 2008 and pick by 15% from 1999. The reason that pattern is so similar over time is that the monthly projected precipitation was based on changes in percentage, which were added or subtracted from each year. Several model studies suggest changes in radiative forcing have played a part in observed trends in mean precipitation. The combination of decreased precipitation in some regions and increased evapotranspiration in most regions indicates that many areas would face decreases in overall available precipitation, affecting their water supplies. Projected available precipitation varies greatly depending on geographic region.

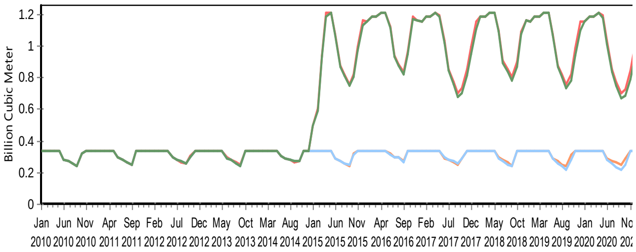


Fig.2: Projected reseviour storage volume

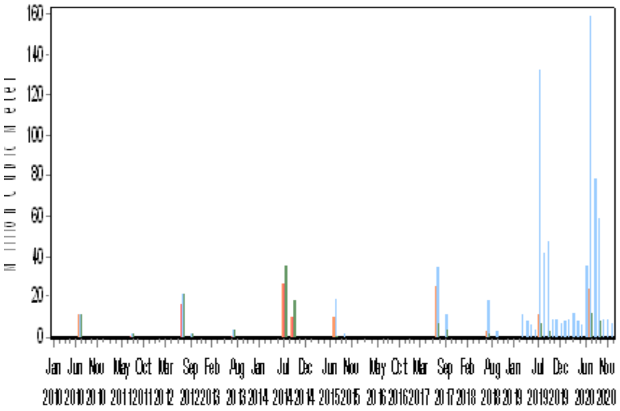


Fig.3: Projected water demand

WEAP analysis shows that climate change would have significant impacts on water supplies throughout the country in the coming decades, with over 700 towns and villages in Nigeria facing greater risks of water shortages due to the effects of climate change. Future water demand is integral to effective water resource management. The model is capable of forecasting demand for numerous water use sectors, at various spatial scales and time horizons. The output of sensitivity simulation analysis is shown in Fig3.1. The temperature changes would have significant effects on many aspects of life in Nigeria. Some of the most profound potential changes are concerned with water, which is certainly scarce and precious here already. Predicted 21st-century climate change is likely to diminish the water supply to the entire Northern part of the country. As the earth's temperature continues to rise, it has significant impact on our fresh water supplies with the potential for devastating effects on these resources. As temperatures increase, evaporation increases, sometimes resulting in droughts. As of 2008, the Nigeria has been experiencing one of the most severe, multi-state, multi-year droughts in decades. The analysis in Fig.4 shows the sensitivity simulation for 14-year period of measures and simulated tempwrature values.

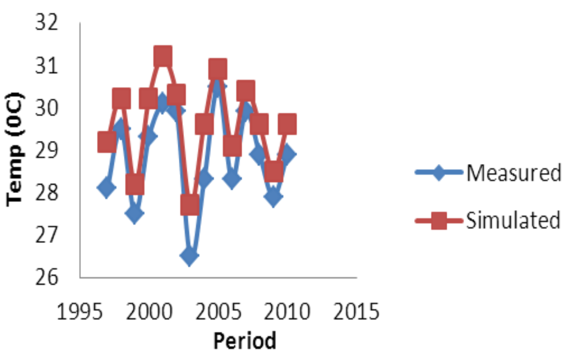


Fig.4: Calibrated and simulated air temperature

4 Conclusion

In this research study, two simulation models (CLIMGEN and WEAP) were used to perform sensitivity analysis on potential impacts of climate change on the water resources in the portion on river, Awara, Nigeria. CLIMGEN was used to generate outputs of global and hemispheric-mean temperatures within resolution (0.5°×0.5°, total 66,420 grid cells). Integration of the applied models using long-term historic meteorological and hydrological variables provides monthly projected changes in temperature, precipitation and river discharges. WEAP model was calibrated to an existing data set for the Awara River Basin. Water management and climate change adaptation plans will be essential to lessen the impacts, they cannot be expected to counter the effects of a warming climate for better water resources management.

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