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Assessment of Water Availability and Demand in Goronyo Reservoir Sokoto, Nigeria

Lukman A. Muhammed, Abubakar Ismail, Babatunde K. Adeogun, Sule A. Abdullahi and Ismail M. Sanni
Department of Water Resources and Environmental Engineering, Ahmadu Bello University Zaria, Nigeria
{m.luqman1010|adeogunbk|abdummu1}@gmail.com |{aismail|imsani}@abu.edu.ng

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Abstract- Climatic parameters are subjected to variation due to atmospheric concentration of greenhouse gases, so it is essential to assess the water availability and demand under the climate variation in Goronyo reservoir since supply of water is one of the significant tasks in water resources management. In this study, estimation of available water, demand and unmet demand was simulated using Water Evaluation and Planning (WEAP) Software with the opinion of assessing the availability of the water for it use under climate change. Firstly, the climatic data was obtained and used to simulate the surface water situation with the model. Secondly, the data was projected based on the initial model output and compared with the existing (observed) data. The comparison involved calibration and validation with the recorded data of river flow. Thirdly, the hypothetical climate change Scenarios were applied to the model so as to know what is to be expected if climate changes. Thus, the model was used to analyse what happened to demand and water availability in the study area. The study found the demand and Unmet demand as the output of the model, and the result showed that the annual total demand for various uses from 2018 to 2070 is 7076.4 million cubic meters (MCM) and annual average of 133.4 million cubic meters (MCM). Meanwhile, the unmet demand ranges from annual total of 1157.5 million cubic meters to 1199.7 million cubic meters and annual average of 21.84 MCM to 22.64 MCM. From the result the highest unmet was recorded under the worst scenario i.e. scenario 9 with 1.2°C increase in temperature and 10% decrease in precipitation. In Conclusion, it was found that the demand in the area is 6 times higher in years to come i.e. 50 years from now and deficit is 61% increased.

Keywords- Climate variation, Goronyo Reservoir, Water Demand and Unmet

1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Water being the most essential component to life on earth, often times it is scare or rare resources which is ultimate for living. It is the most imperative and fundamental in many parts of the universe for both domestic and agricultural uses, the means to achieve sustainability in production systems. It is crucial to maximize net return with the resources available but this could be regarded as a complex problem because of factors that affect this process for example, Climatic variation, configuration of irrigation system, subsidy policies and costs of production. Numerous districts are confronting daunting freshwater management difficulties, distribution of limited water resources, ecological quality and policies for maintainable or sustainable water use are issues of expanding concern (Uitto, 2004; Conway et al., 2009).

The human population is fast growing, the fast advances made in the industry and agriculture have brought about a rapidly expanding or increasing utilization of water by man, to the degree that water availability as well as, the control of unnecessary water use has become an important issue in the advancement of districts of the world (Williams, 2010). Over the last years, it has been established that supply management is inadequate in solving the massive competition for water with increasing per capital water use, population increment, urbanization, pollution and storages (Wang et al, 2009). Similarly, UNESCO (2006), established that the requirement for various uses such as municipal, industrial and farmland and supply is increasing, yet lack of demand management policies implies that increasing demand will likely exceed the supply available, thus water shortage.

*Corresponding Author

The term climate in a slender sense is regularly referred to as the normal weather condition of a place over an extensive stretch of time. Likewise, in a detailed form, as the statistical explanation in terms of the mean and variability of pertinent amounts over some stretch of time extending from months to thousands or a huge number of years. The usual or minimum time frame is 30 years, as characterized by the World Meteorological Organization. The intergovernmental panel on climate change (IPCC) built up the variation of the earth temperature for as long as 140 years (Abdullahi et al., 2014).

The fourth evaluation report of Intergovernmental Panel on climate change demonstrated that the temperature during 1995-2006 in global level have increased and occurrence of hefty precipitation became more recurrent. Additionally, the global average surface temperature as forecasted for 2080 – 2099 will ascend between 1.1°C and 6.4°C greater than what it was from 1980 -1999, and this leads to increase in crop productivity (IPCC 2007). It evidently illustrates the effect of variation in climate. The most advanced tools to simulate the global climate system response to greenhouse gas concentrations is General circulation models (GCMs), with the models, an assessment of the future climate would be possible (Yang *et al*., 2011; Hsu *et al*., 2011), and the issue of uncertainty may be moderated by considering multiple models (Liu, et al., 2009; Huang, et al., 2012).

In accordance with some literatures, there will be additional problems as regards management of water resources because of difference in rainfall distribution and increase in temperature as a result of change in climate. Climatic variation increases changes in atmospheric conditions and thereby changed water resources, their circulation in space and time, the hydrological cycle of water bodies, and water quantity.

The requirement of various water demands would be affected by the variation of meteorological events under the conditions of climatic variability, Countless country is experiencing alarming problems in term of managing their fresh water. Apportionment of this limited resources, environmental nature, and strategies for usage sustainability are concerned issues**.** The reservoir was constructed to cater for flood control, water supply, recreational, fishing etc. Therefore, it is of utmost importance to study the present and future condition of Goronyo Reservoir under the influence of climate change. This is to be able to come up with strategies to ensure future availability to cater for the water demand.

1.2 Study Area

Goronyo Reservoir, is situated between latitudes 13°30'N to 14°N and longitudes 5°30'E to 6°E. The Reservoir has a length of about 20km with a width of about 10km and an area of about 200km^2 and a storage capacity of 942 million cubic metres (Abubakar, et al., 2017; Ita et al., 1982). The study area is located in Goronyo Local Government Area, Sokoto State, Northwest Nigeria. The study area is part of the Sokoto-Rima basin, which has a total catchment area of about 193,000km^2 distributed in Nigeria and the Niger Republic (Gill, 1974).

The climate in the area is semi tropical with a prolonged dry season from October to May and a short-wet season from end of May to early October (Udo, 1970; Ogheneakpobo, 1988; Adeniyi,1993). The temperature in the region ranges from minimum of 20°C to maximum 35°C and a rainfall in the area shows both spatial and temporal variations. The mean annual rainfall varies from about 700mm to about 1,100mm (Gill, 1974; Davis, 1982; Adeniyi, 1993).

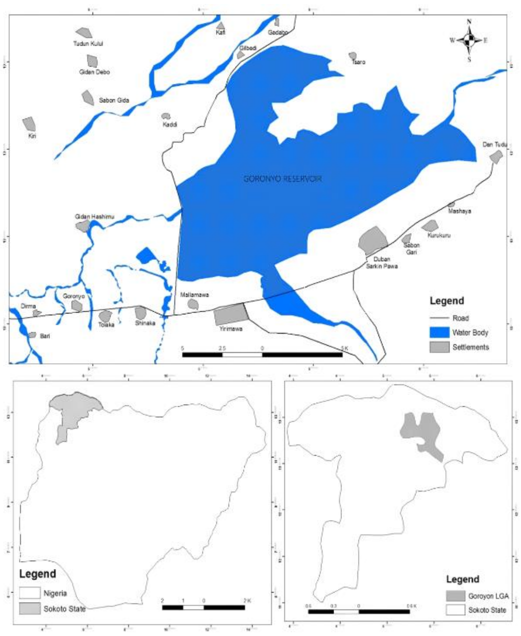

Fig.1: The Study Area (Goronyo Reservoir)

2 Methodology

2.1 Materials and Data

The materials used for this study are; Rainfall, relative humidity, temperature streamflow, reservoir data, population census etc and the software used are WEAP software, and Microsoft Excel.

2.2 Method

(Preliminary investigation (i.e. Reconnaissance visit) was conducted to analyse the hydraulic nature and human activities related to water resources in the catchment. The rainfall, temperature, evaporation, relative humidity, wind speed and sunshine data were collected from the data stations in the area for the period of 1988 – 2017(See Appendix), and were analysed statistically.

The Catchment was delineated with WEAP in built catchment delineation component and the inland waterway was digitized. The hypothetical climatic change scenarios were then applied to the model to observe what happened if climate changes. The model was used to analyse the linkage between the water resources and the demand in the catchment.

2.3 Analysis of the Temperature trend for Generating Climate Scenarios

Statistical analysis of the annual average maximum temperature (1988 – 2017 obtained from NIMET) of the area was done. The maximum average annual temperature and minimum temperature with mean and standard deviation of the data were determined. The linear trend was fit into the data and the gradient of the trend was determined. A linear equation obtained from the trend analysis was used for the projection of temperature increment for this region by considering temperature variation over four decades.

2.4 Analysis of Rainfall trend for Generating Climate Scenarios

Similarly, average annual rainfall (1988- 2017) of the region was analysed statistically. The maximum average rainfall value and minimum average value with mean and standard deviation of the data were determined. The linear trend was fit into the data and gradient of trend was determined. The trend analysis leads to a linear equation relating the rainfall to time. This was used for the projection of climate change effect on Precipitation for this region by considering average rainfall value variation over four decades.

2.5 Climate Scenarios Generation

The method adopted here is hypothetical scenario option which has been adopted by many scholars in climatic influence studies (Islam et al., 2005). Several published worked were done this with this method (e.g. Gleick, 1987; Yates, 1996; Boorman and Sefton, 1997; Bobba et.al, 1999; Hailemariam, 1999; Xu, 1999; Islam et.al, 2005 and Abdullahi, 2014). After successful trend analysis to understand the pattern of temperature and rainfall increment, the hypothetical scenario was used to generate the scenarios so as to answer the question of what if climate changes. Nine scenarios were implemented as follows, first scenario considered an increase in

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temperature of about +0.4°C, over the entire area, second scenario considered an increase in temperature of about +0.4°C and an increase in precipitation of around +10% over the entire region, third scenario considered an increase in temperature of about +0.4°C and decrease in precipitation of around -10% over the entire area, Fourth scenario considered an increase in temperature of about +0.8°C over the entire area, Fifth scenario considered an increase in temperature of about +0.8°C and an increase in precipitation of around +10% over the entire area, the sixth scenario consider increase in temperature of about +0.8°C and decrease in precipitation of around -10% over the entire area, the seventh scenario consider increase in temperature of about +1.2°C, over the entire area ,Eighth scenario consider increase in temperature of +1.2°C and increase in precipitation of around + 10% over the entire area and the ninth scenario consider increase in temperature of 1.2°C and decrease in precipitation of around -10% over the entire area. The nine (9) developed climate change scenarios are shown in Table 1.

Table 1. Hypothetical Climate Change Scenarios

Scenarios	Change in Temperature ΔT(°C)	Change in Precipitation P (%)
Reference	0	0
Scenario 1	+0.4	0
Scenario 2	+0.4	+10%
Scenario 3	+0.4	-10%
Scenario 4	+0.8	0
Scenario 5	+0.8	+10%
Scenario 6	+0.8	-10%
Scenario 7	+1.2	0
Scenario 8	+1.2	+10%
Scenario 9	+1.2	-10%

2.6 Water Year Classification

Water Year Method is the means to represent variation in climate related data such as a streamflow, rainfall and groundwater recharged. The method first involves defining how different climate regimes e.g. very dry, dry, very wet and wet year compare relatively to normal year. Normal year is given a value of 1 which define each non-normal water year type, this help to know how much more or less water flow into the system in that a particular relative to normal water year, Dry year have a value less than one (<1) and very wet has a value (>1). With water year method it is easier to present the effect of hydrological system change in the future through the use of current account as the baseline based on the water year definition the available water can be modelled. Water year value (WYV) is expressed as the ratio of summation of water available per annum to annual average as shown in (1).

$$\text{WYV}=\frac{Summation\ of\ Annual\ Rainfall}{Annual\ Average}\ldots \qquad (1)$$

2.7 Water Demand

In 2010, The Food and Agricultural Organization of the United Nations, online Water use database, indicate that the water use in Nigeria ranges from 78.67 to 118.6 litre per capita per day. Therefore, the value of 120 litres per capita per day was used as the approximate maximum water use value. The demographic data of the area was projected by using the inter census growth rate of 1991 and 2006 population census.

Therein, The Global Rice Science Partnership (GRIP) ,2013: Norton *et al.*,2018 indicate that for flood irrigation system, the water use for rice per hectare is 10750MC. Therefore, the value of 10750MCM was adopted as the water use rate per hectare. since in the area rice is the most water demanding crop plant.

3 Results and Discussions

3.1 Temperature and Rainfall Trend for Climate Scenarios Generation

After careful analysis, the annual average maximum temperature and rainfall was obtained to be 35.1^{0}C and 958.1mm respectively with the annual average minimum temperature and rainfall of 29.1^{0}C and 459mm. Similarly, the mean and standard deviation are obtained as 601.1mm and 107.32 for rainfall while the standard deviation of the temperature is 0.75. Therein, the linear trend as indicated in the figures 2 and 3 revealed the gradient of 0.044 & 10.0 for temperature and rainfall respectively, which designate the decadal increase of 0.40% for temperature and 10% annual increase in rainfall, therefore the value of 0.4^{0}C – 1.2^{0}C was selected for temperature increment considering temperature variation for 4 decades. And 10% increase and 10% reduction in rainfall for projection of climate change considering average rainfall value.

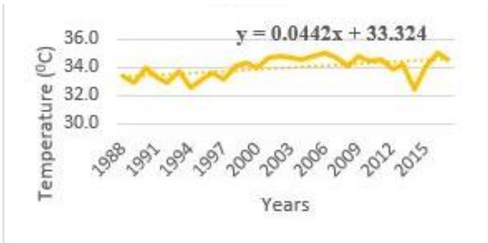

Fig. 2: Temperature Trend Analysis

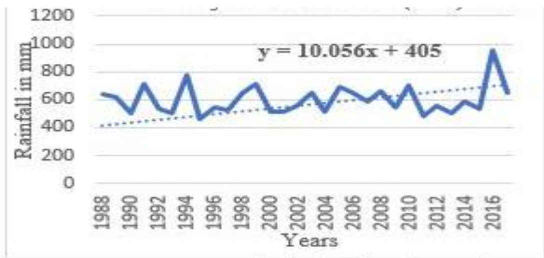

Fig.3: Rainfall in mm Trend Analysis

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3.2 Water Demand

The climate change impact on future water availability to meet the demand requirements was assessed for Goronyo Reservoir by means of nine scenarios-based climate datasets. The situation was projected/forecasted up to the year 2070, which is 51 years from 2019. The water demand was projected and as shown in fig.4, it indicated that the demand will be approximately 6 times higher in 50yrs to come and supply deficit is on the increase order (61%). As shown in fig.5 the monthly unmet demand for all the scenarios becomes more pronounced during the dry months. (November to April).

Additionally, the demand and unmet was further summarized in the table 2. From the table is clearly seen that unmet demand keeps increasing but more serious in scenarios 9 with an annual average unmet of 22.64MCM. which as a result prescribed climate change scenario i.e. increase in temperature by 1.2^{0}C and decrease in precipitation by 10%.

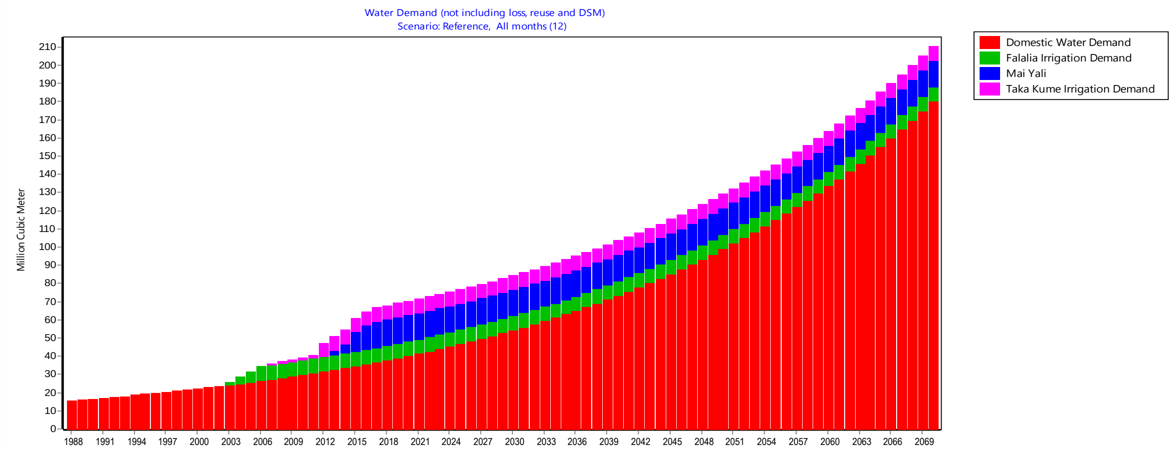

Fig. 4: Water Demand for Uses

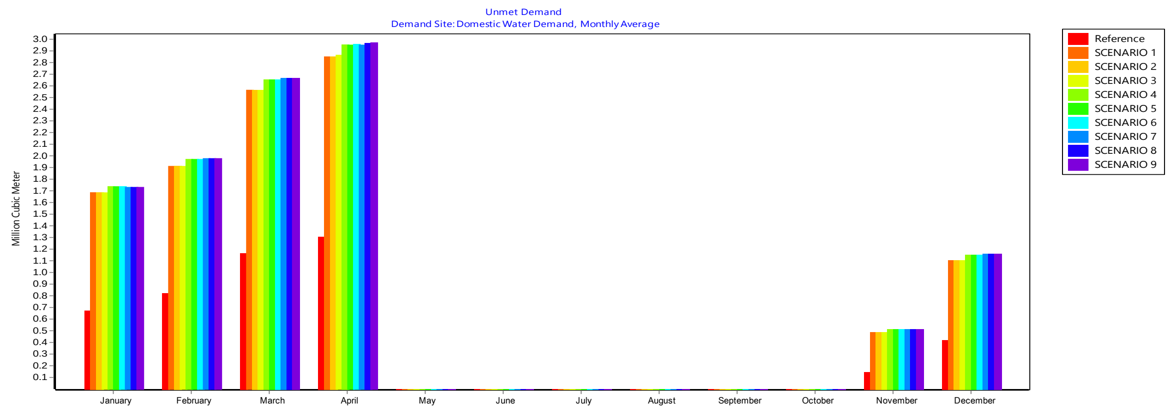

Fig. 5: Average monthly Unmet Demand

Table 2. Summary of Demand and Unmet Demand

			2018-2070 (53/83Yrs)				(Million Cubic Meter)							
	Domestic Demand		Falalia Irrigation		Mai Yali Irrigation		Taka Kume Irrigation							
Scenarios										Annual Total			Annual Average	
	Demand	Unmet	Demand	Unmet	Demand	Unmet	Demand	Unmet		Demand	Unmet		Demand	Unmet
Reference	5,487.80	374.3	419.3	26.7	769.2	49	393.1	24.9		7069.4	474.9		133.38	8.96
SCENARIO 1	5,487.80	902.9	419.3	67.5	769.2	123.9	393.1	63.2		7069.4	1157.5		133.38	21.84
SCENARIO 2	5,487.80	902.9	419.3	67.5	769.2	123.9	393.1	63.2		7069.4	1157.5		133.38	21.84
SCENARIO 3	5,487.80	903.6	419.3	67.6	769.2	124	393.1	63.2		7069.4	1158.4		133.38	21.86
SCENARIO 4	5,487.80	932.6	419.3	69.8	769.2	128	393.1	65.3		7069.4	1195.7		133.38	22.56
SCENARIO 5	5,487.80	932.6	419.3	69.8	769.2	128.1	393.1	65.3		7069.4	1195.8		133.38	22.56
SCENARIO 6	5,487.80	933.5	419.3	69.9	769.2	128.2	393.1	65.4		7069.4	1197		133.38	22.58
SCENARIO 7	5,487.80	935.5	419.3	70	769.2	128.4	393.1	65.6		7069.4	1199.6		133.38	22.63
SCENARIO 8	5,487.80	935.8	419.3	70	769.2	128.4	393.1	65.5		7069.4	1199.8		133.38	22.64
SCENARIO 9	5,487.80	935.5	419.3	70.1	769.2	128.5	393.1	65.6		7069.4	1199.7		133.38	22.64

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4 Conclusions

It is essential to assess the water availability and demand of Goronyo reservoir as it is major source of portable water to area for both domestic and agricultural practise. This study was successfully carried with the aid of WEAP software model to assess the effect of possible climatic variation to available water in the reservoir as to demand. The result revealed that the annual total water demand of 7069.4 MCM with annual average of 133.4MCM and Unmet Demand of Various Scenarios range from 21.84MCM to 22.64MCM. the deficit in satisfying demands was observed to be increasing order of 61%.

It is clearly seen from the research that irrigation system which is furrow irrigation used in the area could be improved so as to minimise water demand and also extraction from other means such as ground water could relief the stress on the available source, the reuse of wastewater for other domestic uses such as washing of lawn and watering of gardening will also help a lot in utilizing limited available resources.

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APPENDIX A

METEOROLOGICAL DATA FOR 1988-2017

Years	Temp. °C	Wind Speed (m/s)	Relative Humidity (%)	Precipitation (mm)	Sunshine Hrs (secs.)
1988	33.37	3.15	41.17	641.4	10746
1989	32.96	3.20	39.60	614.7	10784
1990	33.98	2.80	40.95	505.1	10752
1991	33.23	2.68	45.58	712.4	10768
1992	32.87	3.05	42.01	535.0	10763
1993	33.75	2.79	40.61	498.8	10785
1994	32.54	3.01	45.06	779.6	10754
1995	33.13	2.87	44.68	459.6	10785
1996	33.67	2.71	42.27	544.6	10797
1997	33.18	2.76	44.10	520.7	10769
1998	34.07	2.77	41.91	654.1	10798
1999	34.3	2.62	40.44	716.3	10789
2000	34.01	2.87	42.70	512.4	10800
2001	34.66	2.89	37.82	509.6	10797
2002	34.83	2.65	40.28	558.0	10797
2003	34.63	2.74	41.36	652.6	10797
2004	34.58	2.69	41.91	516.0	10797
2005	34.75	2.78	42.16	697.3	10794
2006	35.08	2.61	38.82	651.3	10772
2007	34.63	2.80	38.82	583.2	10779
2008	34.04	2.94	38.17	657.8	10777
2009	34.78	2.60	40.73	544.7	10790
2010	34.46	2.72	42.02	701.1	10782
2011	34.52	2.88	38.03	478.9	10800
2012	33.86	2.23	42.75	553.7	10783
2013	34.22	2.42	42.60	506.2	10780
2014	32.45	2.70	41.07	582.7	10800
2015	34.11	2.83	39.31	532.2	10775
2016	35.06	2.76	42.05	958.1	10784
2017	34.58	2.86	38.60	655.2	10786

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