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Sensitivity Modeling and Evaluation of Evapotranspiration Effects on Flow Discharge of River Owena in Nigeria

Analysis of discharges, precipitation and temperature and some other meteorological-hydrological variables from 1996-2011 at the section of Owena River Basin. The evaluation, correlations, and the relationship between precipitation and discharge time series indicate a strong relationship. Minimum discharge values of 0.8 m^3/s and 1.2 m^3/s were observed in January and December and these values correspond to rainfall depth of 1.4 mm and 8.2 mm respectively. The average annual rainfall, river discharge were computed as 1,306.7 mm, 1,165 m^3/s and mean temperature and evaporation of 31.1^oC and 4.6 mm. Evapotranspiration computation using pan evaporation model overestimated the evapotranspiration values by 0.5 mm and 0.21 mm over IHACRES and CROPWAT model for the total period of 15-year. Integration of the simulation outputs would be veritable in creating realistic-robust water management system for domestic and agricultural applications.

Keywords: *Precipitation, Discharge, Evapotranspiration, Temperature, Observed, Simulated*

1. Introduction

Owena reservoir in Ondo, Nigeria acts as natural reservoirs of fresh water, storing precipitation during the rainy season. The availability of fresh water is directly influenced by the volume of water stored during storm event. 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). Water development, supply and distribution system have typically been approached as an economic rather than engineering problem. Water supply managers and stakeholders are often applying price increase as water conservation tools, instead relying on price demand management techniques (Idogho et al., 2013).

Accessibility and even distribution of potable water is a serious global issue. Safe drinking water is limited, the population growth, industrial and social advancement have further complicated the already scarce utility through overstressing the provision of potable water and infrastructural mechanisms for water distribution such as reticulation pipeline networking system, reservoir construction, fitting of flowmeter e.t.c. The exponential increase in population and subsequent urbanization of has caused a major strain on waterways including complete loss of rivers and natural watersheds in order to create more structural facilities for the growing population. However, there is drastic reduction of watershed due to increase in development and urbanization of Estako-West as a result of intake of Auchi Polytechnic, Auchi and the commercial activities. Water availability in Auchi is within the range of 500 m^3, this indicate that water a primary constraint to life (*Olotu et al., 2014*). Water scarcity is recognized as an increasingly severe problem with global implications (Sazakli et al., 2007).

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. Understanding and developing sustainable water accessibility-distribution system, analysis of hydro-meteorological data helps to understand weather conditions, available water resources of the region, melting and other flow-generation processes, sediment transport processes, and also to give an insight to the problems related to natural hazards, viz: Flash floods, cloudbursts, landslides/rockslides and avalanches (Shcheglova and Chizhov, 1981; Mazari et al., 2004; Naithani et al., 2001; Singh et al., 2003; Jain et al., 2003; Singh et al., 2005; Haritashya et al., 2006).

As the region grows, excess water resource capacities diminish, it becomes increasingly important to manage existing facilities, improve the efficiency of water use, and make long-range plans in ways that maximize the return on natural, capital, and human resources. Mathematical and physics based-models are among the most sophisticated tools available for analyzing water resource issues. They can use the capabilities of today's digital computers to perform and integrate millions of calculations within seconds, in order to understand and project the consequences of alternative management, planning, or policy-level activities. Having considered the complex situation being faced with limiting water availability-supply in most cities, towns and villages in Nigeria, this study therefore aimed at creating stochastic physics-based model using a large number of water-limiting variables to create robust water planning and management system in the study area.

2. Materials and methods

Precipitation and other meteorological such as evaporation depth, sunshine hours, minimum and maximum temperature, relative humidity, wind speed data was derived from the Global Gridded Climatology (GGC) compiled by the Climatological-meteorological Research Unit of Auchi Polytechnic, Auchi at a resolution of 7° 4' 0" North, 6° 16' 0" (*Olotu et al., 2014*). The provided and evaluated data were used to computed *Evapotranspiration.* To fit the predicted stream flow, two sources of stream discharge, obtained from ERGS and OBSGS Edo Hydrological monitoring systems were used. In the present analysis, hydro-meteorological data of 15 years (1996 -2011) was applied for sensitivity analysis.

River flow and discharge for the streams considered were modelled as follows:

$$Q_m = A^{0.5} * L^{0.9} * V^{0.6} \quad (1)$$

Where;

0.5, 0.6 and 0.9 are catchment, stream length and flow coefficient respectively.

Q_m = Modeled river discharge.

Daily water supply in the study area was computed using the expression in equation 2:

$$DWS\ (m^3/day) = 0.045PD \quad (2)$$

Considering hydro-geographic system of the area, daily water supply is simulated as follows:

$$DWS\ (m^3/day) = \xi\ 0.045PD^{0.3} \quad (3)$$

Where; ξ Coefficient of accurate metered utility (0.00-1.00)

The original formulation for evapotranspiration in the envisaged catchment hydrology model IHACRES (Jakeman and Hornberger, 1993; Croke et al., 2002; Carlile et al., 2002), uses a simple relationship between temperature and evapotranspiration defined as:

$$E_k = C_1 T_{kexp}(-c_2 CMD_k) \quad (4)$$

Where T is temperature $CMD_{k,}$ is a catchment moisture deficit at time step *K* Kand $C_1$and C_3 are parameters. In this formulation ET is directly proportional to temperature and decreases exponentially as CMD increases.

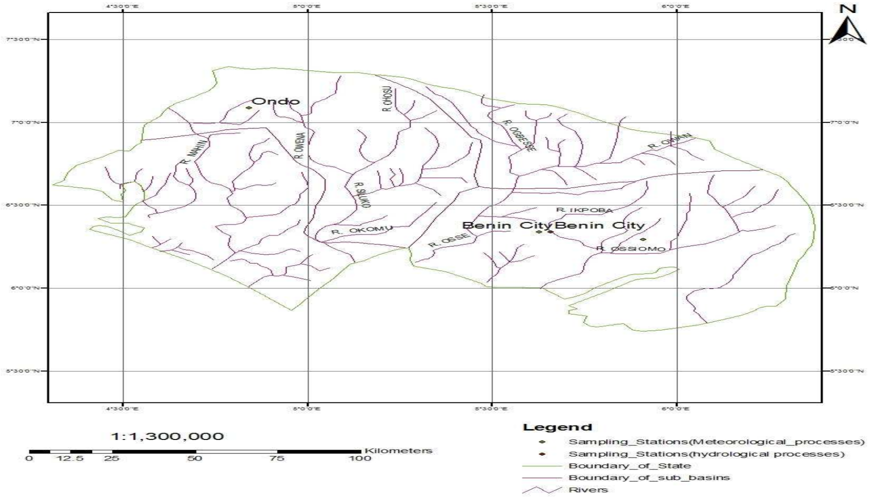


Figure 1. Map of the study area

3. Results and discussion

Hydro-meteorological data observed for a period of 15-year was averaged and shown in table 1. The generated data were used to compute evapotranspiration using evaporation pan, IHACRES and CROPWAT models. The average annual rainfall, river discharge were computed as 1,306.7 mm, 1,165 m^3/s and mean temperature and evaporation of 31.1^oC and 4.6 mm as shown in table 1. Evapotranspiration computation using pan evaporation model overestimated the evapotranspiration values by 0.5 mm and 0.21 mm over IHACRES and CROPWAT model for the total period of 15-year.

Table 1. Summary of measured and computed Hydro-meteorological parameters (1996-2011)

Year	RV (m^3/s)	RF (mm)	$Temp_{mean}$	Humidity	Wind Sp (Km/hr)	Evap (mm)	ETo_{Pan}	ETo_{Ek}
Jan	0.8	1.4	33.6	58.0	66.4	5.4	4.55	4.35
Feb	1.7	10.4	34.6	58.3	70.2	5.6	5.37	5.30
Mar	14.3	34.9	33.3	60.0	71.4	4.5	5.61	5.55
Apri	50.4	79.9	31.6	60.1	73.2	4.2	5.20	5.15
May	82.7	100.1	27.4	77.9	69.3	4.2	4.23	4.20
June	148.3	165.5	26.2	79.4	67.2	4.0	3.88	3.80
July	220.6	230.7	27.5	78.2	67.5	3.8	3.80	3.75

Aug	206.6	210.8	28.4	65.4	70.2	4.1	4.44	4.00
Sept	246.8	241.7	27.9	69.1	68.3	3.7	4.14	4.10
Oct.	189.5	206.0	27.7	73.2	69.4	3.9	3.56	3.50
Nov.	2.3	17.1	37.8	53.6	73.6	6.1	4.50	4.45
Dec.	1.2	8.2	38.5	55.7	72.4	6.4	5.20	5.15

Source : Ministry of Works, Akure, 2012: Sensitivity analysis

Knowledge of the discharge characteristics of catchments is essential to water supply planning and management, flood forecasting and routing, and floodplain regulation. Discharges vary over short lengths of time during storm periods, seasonally with the seasonal changes in evapotranspiration losses, and over longer periods of time as the rainfall regime changes from year to year. Discharge characteristics also vary with climate. Minimum discharge values of 0.8 m^3/s and 1.2 m^3/s were observed in January and December and these values correspond to rainfall depth of 1.4 mm and 8.2 mm respectively. The result in table 1 above indicates that strong relationship exist using the river discharge and the rainfall depth, mean temperature, evaporation depth computed evapotranspiration values using evaporation pan, FAO-Penman and CROPWAT simulation models. Fig.1 shows the trend of simulated and observed flow discharges of river Owena.

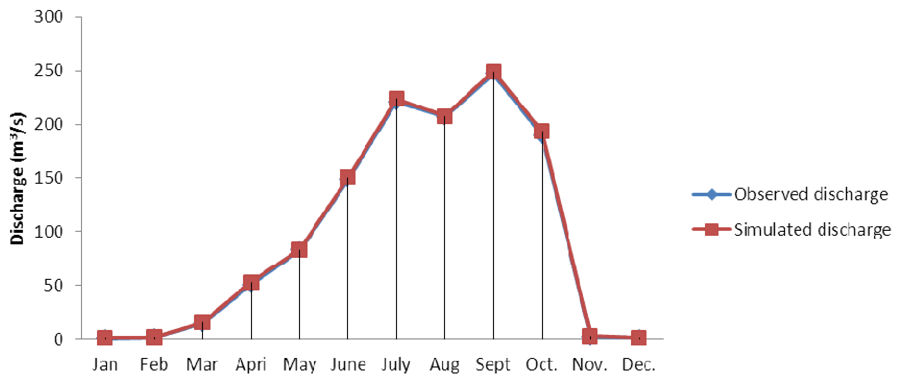


Fig.1: Average observed and simulated discharge at River Owena (1996-2011)

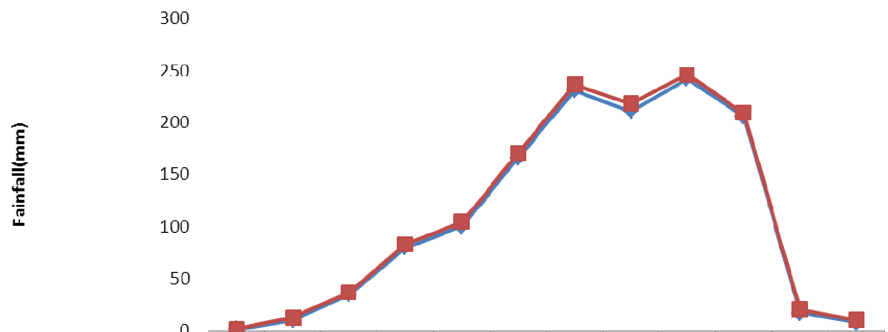
Daily rainfall data was obtained from the Ministry of Works and Auchi Polytechnic, Auchi Meteorological Department for the period 1996-2011. A few of the stations however had few data because of missing values. The data was aggregated into monthly totals and these were analyzed for trend using the same procedure as the river discharge and the results are presented in Table 1. Rainfall depth has direct impact on river discharge. Observed rainfall data was simulated and the output is shown in Fig.2.

Monthly ETo Penman-Monteith - untitled

Country: Nigeria Station: Ministry of Works

Altitude: 351 m. Latitude: 7.58 °N Longitude: 8.46 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	28.2	38.4	57	66	9.1	21.2	5.07
February	28.7	39.1	58	70	9.0	22.3	5.46
March	27.3	37.2	60	72	9.8	24.5	5.80
April	25.2	36.1	62	73	8.2	22.1	5.24
May	25.0	32.1	77	70	6.8	19.4	4.36
June	24.5	28.9	79	72	6.7	18.8	3.97
July	23.6	29.2	78	74	6.5	18.7	3.91
August	24.7	28.9	65	69	7.0	19.9	4.27
September	22.8	27.8	69	66	7.2	20.4	4.17
October	23.3	27.0	73	71	7.8	20.6	3.89
November	30.9	39.2	53	70	8.3	20.3	4.86
December	31.1	39.4	55	72	9.3	21.0	5.26
Average	26.3	33.6	66	70	8.0	20.8	4.69



	Jan	Feb	Mar	Apri	May	June	July	Aug	Sept	Oct.	Nov.	Dec.
Observed rainfall	1.4	10.4	34.9	79.9	100.1	165.5	230.7	210.8	241.7	206	17.1	8.2
Simulated rainfall	1.6	12.6	36.3	83.1	104.2	170.2	236.2	217.9	245.9	209.2	20.2	10.4

Figure 2. Observed and simulated rainfall depth (1996-2011)

4. Conclusion

Precipitation and other hydro-meteorological variables indicate the relationship of river flow and discharge of River Owena This consideration is more probable on large spatial scale, where local effect due to particular conditions will likely averaged out. In general, precipitation has been increasing and this trend is projected to continue. Precipitation increases are particularly pronounced when looking at the seasons and when looking at the few largest rain events of the year, and this is expected to continue. Evapotranspiration (ET) under changed climate was computed using evaporation pan, FAO-Penman, IHACRES and CROPWAT models with 0.5mm, 0.31 and 0.21 mm overestimation of Epan over other simulation models respectively. Sensitivity incorporation of analytical analysis indicates that reductions stream flow, reservoirs storage and lake levels. This further complicates the water supply for the people in the region and it's environ. The output of this study can be applied to create sound and robust policy for effective water resources management and conservation.

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