

INFLUENCE OF ASA DAM ON HYDROMETEOROLOGICAL VARIABLES IN ASA RIVER BASIN, ILORIN, NIGERIA.

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Abstract

The construction of a dam is usually accompanied by some environmental impacts, this usually calls for pre- and post- environmental impact studies to quantify the changes that have taken place. The aim of this study is to assess the influence of Asa dam on Asa River Basin. The hydro-meteorological aspect of the environmental impact studies was carried out and it involved collection and analysis of meteorological and hydrological data. The meteorological data were collected at the Ilorin airport which is within the catchment of Asa river and the hydrological data were collected at the Kwara State Water Corporation which is the body monitoring the four stream gauging stations along Asa river. The mean monthly variations of some meteorological variables such as rainfall, temperature, relative humidity, evaporation, water balance and wind frequency were analyzed using composite bar chart and the detrending time series analyses. The time series analysis for post dam condition revealed negative correlation with temperature, wind speed, evaporation and stream flow. This is an indication that these variables would be decreasing with time. However, positive correlation exists between the time and rainfall, humidity and sunshine hour. This implies that there is tendency for these variables to increase as a result of the construction of the dam.

Keywords

Dam, Hydrological variables, Meteorological variables, Environment.

1. Introduction

Technically, a dam is designed for head water and flood control, water supply, irrigation, power generation, or a combination of two or more of these (Neville and William, 1968). Man's modification of the natural terrain can instigate insightful physical, economic and social changes on the environment. Therefore, the construction of dam is considered as a major form of human intervention within the environment, though, bringing about some changes which are often unintended and unplanned for. Some of such changes are disadvantageous, even dangerous to the local people. The influence of dams on social life and the physical environment have been largely ignored. The main negative effects of dams on people and the environment: reservoir flooding of large areas, population displacement, decreased fishing in downstream areas, and dam failure with loss of lives and properties, sedimentation problem and local micro-climate change within the river basin. On the other hand, the construction of a single purpose dam could

open up opportunities not initially intended with respect to irrigation, flood control, power and communication.

The effects of dams on river basins are quite large and of recent there has been renewed interest in researches into the causes of these effects. The research areas identified by a group of consultant lead by Dr C.J. Hill, on hydrometeorological workshop held in Quebec City Canada in 1998 include;

- (i) Hydrology :- water chemistry, stream flow, and evaporation.
- (ii) Pedology :- salination, silt deprivation, and water logging
- (iii) Local climate :- wind, humidity, temperature, and precipitation
- (iv) Safety :- Engineering failure and inducted seismicity
- (v) Fauna and flora:- habitat flooding, fish migration, nutrient levels, and parasites

Hydrometeorology is an interdisciplinary science involving the study and analysis of the interrelationships between the atmospheric and land phases of water as it moves through the hydrological cycle. To this end, hydrometeorological variables are climatic factors which have direct impact on hydrology. This study is however, limited to the study of the effects of Asa dam on hydrological and meteorological variables in the Asa river basin. It deals with the changes which occurred in climatic variables such as wind speed, temperature, humidity, rainfall, evaporation, sunshine hour and the pattern of stream flow along the river channel due to the construction of Asa dam.

Asa dam is located at a point about 5 km south of Ilorin across the Asa river. The dam is 597 m long and 27 m high at its deepest section, with a crest width of 6 m. Asa dam has a surface area of 10,746,000 m² and total capacity of 43 million m³. The construction of the dam began in 1975 and it was commissioned in 1978.

2.0 Methodology

2.1 Collection of data

Meteorological data (wind speed, temperature, humidity, rainfall, evaporation and sunshine hour) for a period of 41 years (1960 - 2000) were collected from the Meteorological Department of Ilorin International Airport. The minimum, maximum and mean values were computed. The second set of data collected was stream flow. It was obtained from Kwara State Water Corporation. The gauging station with a relatively continuous flow data is Unity Bridge, with data for a period of 29 years (1966 – 1994).

The data collected were subdivided into three periods (Pre – dam construction -, dam construction- and Post – dam construction periods), thus:

For meteorological variables;

- (i) Pre – dam construction period (1960 - 1975)
- (ii) Dam construction period (1976 - 1978)
- (iii) Post – dam construction (1979 - 2000)

For stream flow data

- | | | |
|-------|-------------------------------|---------------|
| (i) | Pre – dam construction period | (1966 - 1975) |
| (ii) | Dam construction period | (1976 - 1978) |
| (iii) | Post – dam construction | (1979 - 1994) |

The mean values for meteorological data are presented in Tables 1 – 3, while the mean stream flow data is presented in Table 4.

2.2 Analysis of data

Two types of analysis were performed on the hydro-meteorological variables:

- (i) Statistical analysis to obtain mean values and to make comparisons between the three periods specified using the composite bar charts.
- (ii) Time series analysis to study the influence of the three specified periods (pre-dam, dam Construction and post-dam periods) on meteorological and hydrological variables.

2.2.1 Composite bar charts

Composite bar charts were used to show pictorially, the relationship between the three periods at specific time (month) of the year. The composite bar charts were prepared by plotting the mean monthly value for each parameter considering a specific period. For example, the mean January temperature in post-dam period was plotted on the ordinate against the respective months on the abscissa. The composite bars for the meteorological variables are presented in Figures 1 to 6 while the composite bar chart for maximum mean stream flow is presented in Figure 7.

2.2.2 Time series

Time series analysis was used in predicting or estimating probable value of the parameters over a period of time. The method of time series analysis employed in this study is the detrending method, which utilizes the regression equation of the form: -

$$Y_{\text{est}} = a_0 + a_1X \quad (1)$$

$$\Sigma Y = a_0 N + a_1 \Sigma X \quad (2)$$

$$\Sigma XY = a_0 \Sigma X + a_1 \Sigma X^2 \quad (3)$$

A standard error of the estimate is determined to give the degree of confidence for the predicted or estimated value. It is given in equation (4)

$$S_{y,x} = \sqrt{\frac{\sum (Y - Y_{\text{est}})^2}{N}} \quad (4)$$

where $S_{x,y}$ = standard error

Y = observed variable (parameter)

Y_{est} = estimated variable

N = no of parameters in the series (no of samples)

X = time interval (years) and a_0 & a_1 = constants of regression analysis

Y_{mean} = average observed variable (parameter)

X_{mean} = average time interval and r = coefficient of correlation.

The coefficient of correlation (r) gives the relationship between the two variables X and Y . It is given in equation (5).

$$r = \frac{\sum (X - X_{mean})(Y - Y_{mean})}{\sqrt{(\sum (X - X_{mean})^2)(\sum (Y - Y_{mean})^2)}} \quad (5)$$

2.2.2.1 Time series analysis for meteorological variables

Time series analysis was performed for all the meteorological variables by solving equations (2) and (3) simultaneously to obtain the constants a_0 and a_1 required in the estimation of Y_{est} for each of the variables within the specified period. From equations (1), (4), and (5) the estimated variables, standard error and coefficient of correlation were obtained, respectively. The results for the three periods are presented in Table 5 for comparison.

2.2.2.2 Time series analysis for hydrological variable (stream flow)

Time series analysis was also performed for the stream flow data following the procedure in section 2.2.1. The results for the three periods are also presented in Table 5 for comparison. The variation between the observed and the estimated variables is shown in figures 8 to 14.

3.0 Results and Discussion

3.1 Results

The result of the statistical analysis for meteorological and stream flow are presented in Tables 1 to 4 while the result of the time series analysis is presented in Table 5. The mathematical model derived from the time series analysis is presented in Table 6. The Composite bar charts (Figures 1 to 7) depict the variation of the variables with the stages of dam construction. The chart indicates that the maximum temperature is highest during the dam construction period and lowest during the post dam condition, while the minimum temperature is lowest during the construction period and highest after construction of the dam (post dam). The chart also indicates

that the rainfall is higher at post dam condition, while it is lowest at pre-dam condition. Therefore, the construction of Asa dam has effect on these variables. Also the variation between the observed and the estimated variables which are presented in Figures 8 to 14 reflect the effect of the dam construction.

Based on the time series analysis on the meteorological variables, with particular reference to the post dam condition, negative correlation exists between the time and, temperature, wind speed, and evaporation. This implies that there is a tendency for these variables to decrease with time. However, positive correlation exists between the time and, rainfall, humidity and sunshine hour. This is an indication that there is an increase in these variables as a result of constructing the dam. There is also a negative value for the correlation coefficient between the time and stream flow; this is an indication of decrease in stream flow as a result of constructing the dam.

4.0 Conclusion and Recommendation

4.1 Conclusion

Based on the outcome of this study, it was observed that the construction of Asa dam has influenced both the meteorological and hydrological variables in Asa river basin. Hence, the construction of the dam is responsible for the increase in values of rainfall, humidity and sunshine hour, and a decrease in the values of temperature, wind speed and rate of evaporation. Also, there is a tendency for a reduction in stream flow as obtained from the analysis.

4.2 Recommendation

The construction of dam is usually accompanied by some environmental effects and generally efforts are concentrated on the structural development of the dam without putting into consideration the environmental impact. It is recommended that both pre and post environmental impact studies should be carried out to quantify the changes that have taken place due to the construction of dams.

5. References

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Table 1. Meteorological variables for (1960 - 1974) pre-dam construction

Month	Mean monthly values for pre-dam						
	Max. temp. (° C)	Min. temp. (° C)	Rainfall (mm)	Wind speed (m/s)	Evaporation (cm)	Sunlight hours	Humidity %
January	34.80	19.06	0.05		0.36	7.23	56.27
February	35.84	20.96	0.42		0.44	7.69	55.29
March	35.91	22.83	1.34		0.42	7.28	63.80
April	34.09	22.70	3.79		0.31	6.84	71.00
May	32.55	22.03	5.34		0.19	6.91	78.00
Jun	31.21	21.14	5.57		0.17	6.42	82.33
Jul	29.81	21.20	5.89	0.07	0.16	4.60	84.20
Aug	28.40	20.93	4.78	0.83	0.16	3.78	84.47
Sept	30.16	20.65	9.08	6.83	0.02	4.89	85.53
Oct	31.54	20.76	4.78		0.10	6.26	81.80
Nov	53.61	19.33	0.14		0.30	7.51	62.93
Dec	34.07	19.40	0.03		0.41	7.73	61.87
Total	391.68	251.04	41.16	7.74	3.02	66.48	867.48
Mean	32.64	20.92	3.43	2.58	0.25	5.54	72.29
Max	53.61	22.70	9.08	6.83	0.44	7.73	85.53
Min	28.40	19.06	0.05	0.07	0.02	3.78	55.29

Table 2. Meteorological variables for (1975 - 1978) dam construction

Month	Mean monthly values for dam construction						
	Max. temp. (° C)	Min. temp. (° C)	Rainfall (mm)	Wind speed (m/s)	Evaporation (cm)	Sunlight hours	Humidity %
January	36.50	14.00	0.00	10.48	0.67	7.47	65.00
February	37.50	18.75	14.08	14.79	0.64	7.68	65.00
March	38.50	21.00	35.89	19.17	0.63	6.45	54.00
April	38.00	20.75	112.65	19.12	0.42	6.50	77.00
May	34.50	19.50	190.93	12.36	0.29	7.05	77.00
Jun	33.50	19.00	167.38	9.47	0.21	6.13	84.00
Jul	31.25	19.50	138.68	12.11	0.19	4.25	84.00
Aug	31.25	19.50	63.83	10.33	0.19	3.10	85.00
Sept	31.75	19.50	191.88	6.12	0.17	3.80	85.00
Oct	33.00	19.25	151.85	18.40	0.25	5.60	83.00
Nov	35.00	16.50	18.33	18.78	0.51	7.53	77.00
Dec	35.25	14.25	0.63	18.19	0.75	7.65	57.00
Total	416.04	221.52	1086.12	169.32	4.92	73.20	893.04
Mean	34.67	18.46	90.51	14.11	0.41	6.10	74.42
Max	38.50	21.00	191.88	19.17	0.75	7.68	85.00
Min	31.25	14.25	0.00	6.12	0.17	3.10	57.00

Table 3. Meteorological variables for (1979 – 2000) post-dam construction

Month	Mean monthly values for post-dam						
	Max. temp. (° C)	Min. temp. (° C)	Rainfall (mm)	Wind speed (m/s)	Evaporation (cm)	Sunlight hours	Humidity %
January	34.27	19.69	5.59	20.76	1.01	5.49	55.33
February	35.47	21.60	5.80	30.44	0.99	6.50	57.67
March	35.21	23.26	55.64	42.18	0.82	5.90	67.76
April	34.14	23.37	93.48	44.26	0.61	6.19	73.45
May	32.02	22.44	162.94	36.14	0.41	6.19	78.42
Jun	30.33	21.66	175.72	34.90	0.33	5.53	81.55
Jul	28.88	21.36	156.01	37.71	0.29	3.84	84.15
Aug	28.31	21.19	165.83	35.33	0.28	3.30	85.35
Sept	29.21	20.96	210.48	29.98	0.25	4.48	84.86
Oct	31.28	21.45	127.50	27.90	0.32	6.18	81.45
Nov	33.41	20.82	32.41	26.96	0.59	6.32	69.90
Dec	33.28	19.16	4.42	38.80	0.82	6.57	61.35
Total	385.80	256.92	1195.80	414.36	6.71	66.48	881.28
Mean	32.15	21.41	99.65	34.53	0.56	5.54	73.44
Max	35.47	23.37	210.48	44.36	1.01	6.57	85.35
Min	28.31	19.16	4.42	20.76	0.25	3.30	55.33

Table 4. Mean monthly flow at unity bridge gauging station (m³/s)

Month	PRE-DAM CONSTRUCTION	DAM CONSTRUCTION	POST DAM CONSTRUCTION
	(1966 -1974)	(1975 - 1978)	(1979 -2000)
January	0.41	1.19	2.81
February	2.43	2.56	2.39
March	4.87	7.05	3.11
April	7.83	27.51	5.08
May	6.85	16.12	11.5
Jun	7.53	7.75	16.64
Jul	12.21	15.21	25.54
Aug	51.34	31.70	23.43
Sept	32.54	18.07	25.76
Oct	29.89	24.00	16.25
Nov	8.30	9.87	12.30
Dec	0.40	3.60	4.03
Total	164.60	164.63	148.84
Mean	13.72	13.72	12.41
Max	51.34	31.70	25.76
Min	0.40	1.19	2.81

Table 5. Result of time series analysis for hydrometeorological variables

PARAMETERS	PRE-DAM (1960-1974)				DAM-CONSTR. (1975-1978)				POST-DAM (1979-2000)			
Temperature (°C)	a ₀	a ₁	S _{y,x}	r	a ₀	a ₁	S _{y,x}	r	a ₀	a ₁	S _{y,x}	r
	31.06	0.28	+1.36	0.61	34.54	-0.04	+0.29	-0.11	34.91	-0.28	+1.16	-0.83
Rainfall (mm)	-13.51	4.5	+24.82	0.68	84.93	4.8	+8.73	0.41	96.29	0.93	+3.72	0.86
Humidity (%)	71.28	-0.51	+3.15	-0.85	55.70	12.63	+4.30	0.92	74.15	0.04	+6.81	0.03
Sunshine hour (hr)	5.99	0.03	+0.23	0.10	5.95	0.12	+0.20	0.46	5.72	0.02	+0.33	2.22
Wind speed (m/s)	-	-	-	-	-	-	-	-	70.92	-1.72	+23.43	-0.45
Evaporation (cm)	1.50	0.07	+1.63	-0.19	4.11	0.0	0.0	0.0	5.99	-0.06	+0.58	-0.52
	PRE-DAM (1966-1974)				DAM-CONSTR. (1975-1978)				POST-DAM (1979-1994)			
Stream flow (m ³ /s)	22.60	-1.41	+3.88	0.68	14.22	-0.71	0	-0.37	18.82	-0.46	9.99	-0.27

N.B a₀ and a₁ = Constant in parameter estimation

S_{y,x} = Standard error r = Correlation coefficient

Table 6. Mathematical model for the variables using detrending time series analysis

S/NO	PARAMETERS	MATHEMATICAL MODEL (Y _{est} = a ₀ + a ₁ x)		
		Pre-dam (1960 -1974)	Dam-construction (1975 -1978)	Post-dam (1979-2000)
1.	Temperature (°C)	T _{est} = 31.06 – 0.28 ∇t	T _{est} = 34.54 – 0.04 ∇t	T _{est} = 34.91 – 0.28 ∇t
2.	Rainfall (mm)	R _{est} = -13.51 + 4.5 ∇t	R _{est} = 84.93 – 4.8 ∇t	R _{est} = 96.29 + 0.93 ∇t
3.	Humidity (%)	H _{est} = 71.28 – 0.51∇t	H _{est} = 55.70 + 12.63 ∇t	H _{est} = 74.15 + 0.04 ∇t
4.	Sunshine hour (hr)	S _{est} = 5.99 + 0.03 ∇t	S _{est} = 5.95 + 0.12 ∇t	S _{est} = 5.72 + 0.02 ∇t
5.	Wind speed (m/s)	Missing data	Missing data	W _{est} = 70.92 – 1.72 ∇t
6.	Evaporation (cm)	E _{est} = 1.50 + 0.07 ∇t	E _{est} = 4.11	Q _{est} = 5.99 – 0.06 ∇t
		Pre-dam (1966 -1974)	Dam-construction (1975 -1978)	Post-dam (1979-1994)
7.	Mean stream flow (m ³ /s)	Q _{est} = 22.60 – 1.41 ∇t	Q _{est} = 14.22 – 0.71 ∇t	Q _{est} = 18.82 – 0.46 ∇t

∇t = time interval (year)

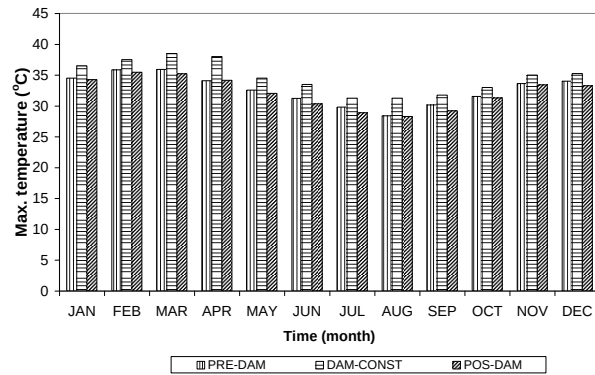


Figure 1. Composite Bar chart for maximum temperature

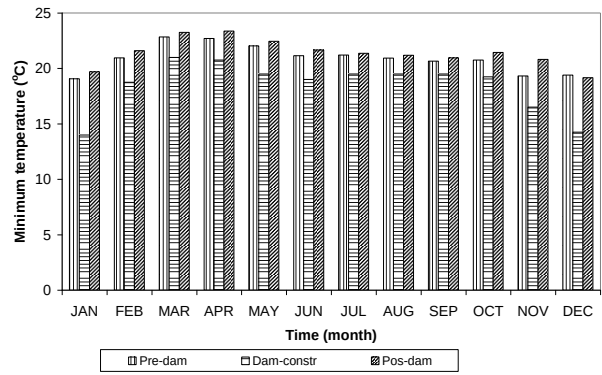


Fig. 2 Composite Bar chart for Minimum temperature

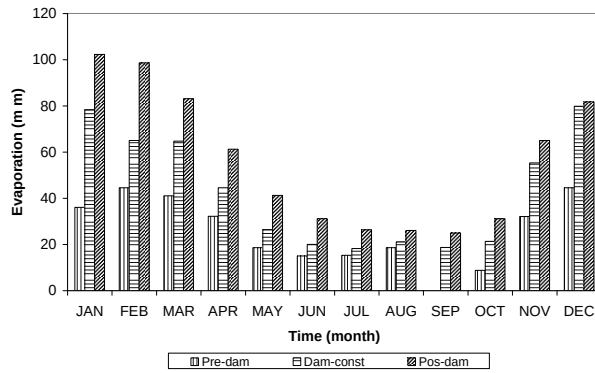


Fig. 3 Composite bar chart for evaporation

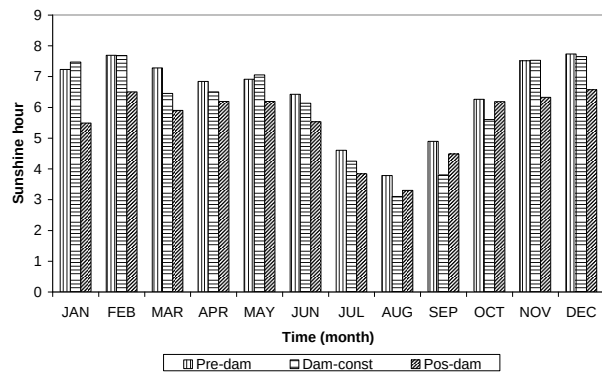


Fig. 4 Composite Bar chart for Sunshine

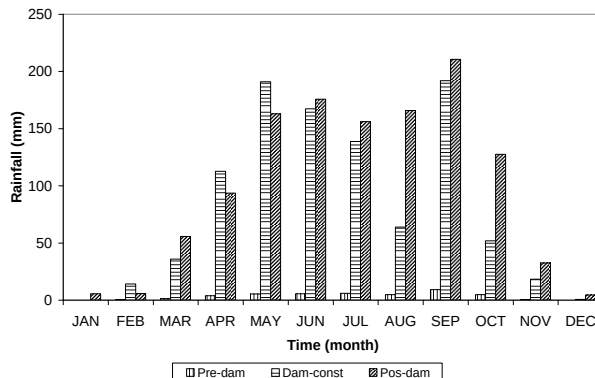


Fig. 5 Composite Bar chart for Rainfall

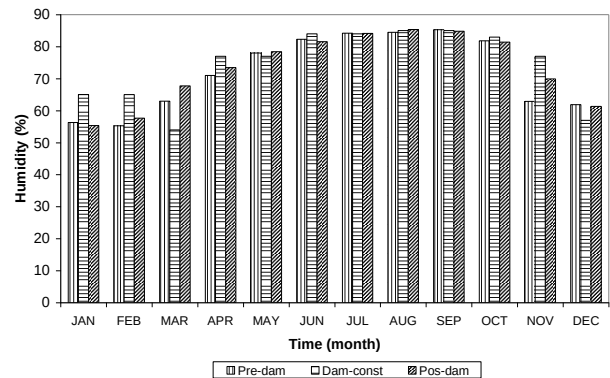


Fig. 6 Composite Bar chart for Humidity

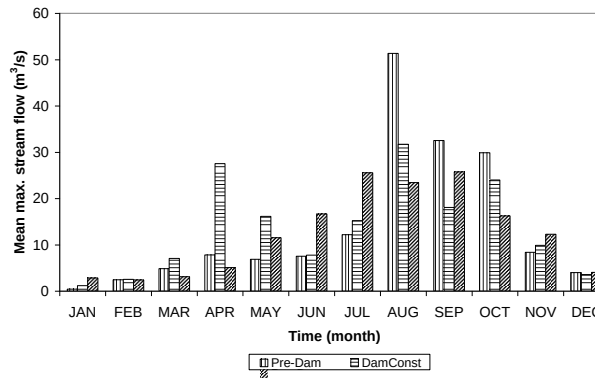


Fig. 7 Composite Bar chat for max. stream flow