

Historical Climate Variability and Water Supply in Ilorin: Perceptions and Predictions

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Introduction

The word climate was derived from the Greek word klima, which stands for tilting of the sun. In a much broader platform, the climate of a place is normally concerned with the weather conditions of that locality, over a long period of time. Weather, itself is the daily variation in the state of the atmosphere in terms of parameters such as temperature, rainfall, wind and other meteorological conditions. The state of the atmosphere depends on numerous factors which vary with time, and inherently affects us directly or indirectly as a community. Hence mitigation and adaptation strategies to climate change are essential. The perceptions of climate variability and its present and future consequences therefore becomes a necessity in order to tackle today's problems and prevent tomorrow's challenges.

Climate variability is bound to have several effects on the society as manifested in humans, vegetation and animals. At times anxiety is expected when perceptions are revealed or predictions are made, but the type and extent of the effects will be influenced by the magnitude of this change in climate. Some of the impacts of climate change on water resources, ecosystems, food, coastal regions and health, are shown in Table 1. Of much importance is the effect of rising temperatures and changes in precipitation on water resources. Water is among the topmost emerging issues that have local, national and global importance. Water typifies the liquid state of matter and it is one of the most abundant natural resources of the earth; distinctively occupying 75% of the earth surface and 50-90% of the weight of living organisms. The main uses of water include application in various spiritual, domestic, commercial and industrial activities; transportation; agriculture; livelihood; recreation and tourism; energy generation; and fire fighting. Under these usages, the rivers may experience a range of impacts, including lower water levels and shrinking surface area. The effects of warmer water also include decreased oxygen-carrying capacity, decreased

volume of water (because of higher evaporation rates), and increased concentration of nutrients and pollutants because of reduction in volume of water for diluting chemical inputs. Presently water stress is high, adversely affecting the poor particularly in the developing world (UN-water, 2010).

Table 1: Expected impacts from climate change

Parameter	Expected impact
Water	Increased water availability in moist tropics and high latitudes. Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes Hundreds of millions of people are exposed to increased water stress
Ecosystems	Increased risk of extinction of some species, coral bleaching, species range shifts , wild fire and changes in ecosystem
Food	Complex localized negative impacts on small holders, subsistence farmers, and fishers. Tendencies for cereal productivity to decrease in low latitudes Tendencies for some cereal productivity to increase at mid to high latitudes and decrease in some regions
Coasts	Increased damage from floods, storms and coastal flooding
Health	Increasing burden from malnutrition, diarrhoeal, cardio-respiratory, and infectious diseases. Increased morbidity and mortality from heat waves, floods, and droughts Changed distribution of some disease vectors

Source: Adapted from Mihaljevic and Zimmerman (2010)

Simulated changes in precipitation, runoff, and soil moisture may be used directly to estimate some hydrological aspects of climate change. The most widely used method for simulation/ trend analysis includes linear regression and reduction pattern analyses. The method of linear regression requires the assumptions of normality of residuals, constant variance, and true linearity of relationship. Regression analysis uses Ryan-Joiner test, autocorrelation test and a probability plot of the parameters (Mc Bean and Motiee, 2008) in order to detect the trend or make predictions. In this regard, plotting climatic and stream flow data with period of occurrence

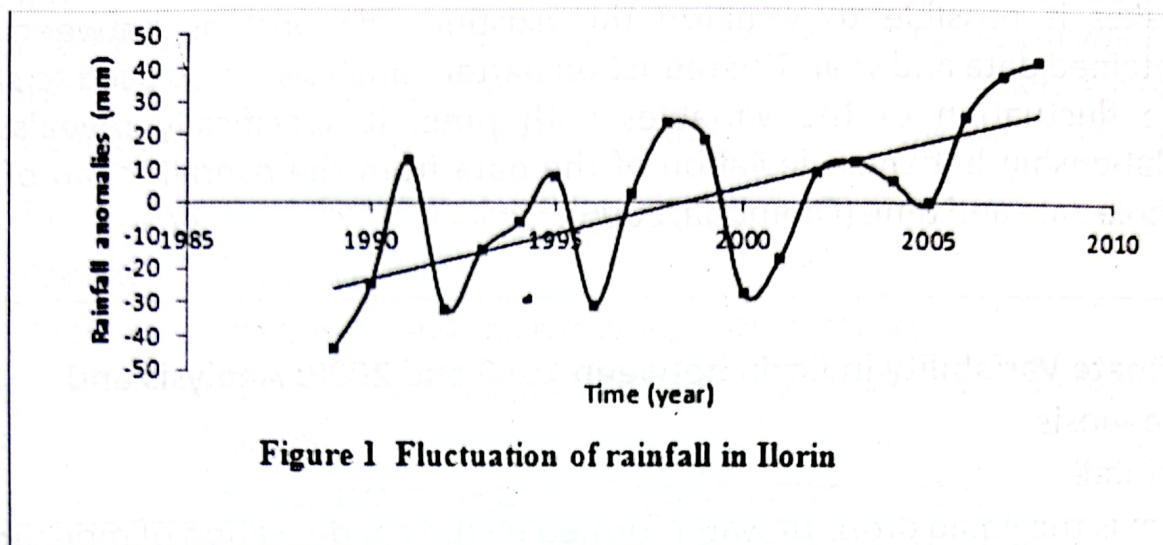
makes it possible to visualize the existing relationships between the obtained data and year. The reduction pattern analysis is also used to show the fluctuation of the variables with time, it specifically reveals the relationship between deviation of the data from the overall mean of the whole data and time (Olomoda, 2006).

Climate Variability in Ilorin between 1989 and 2008: Analysis and Prognosis

Rainfall

Rain is the liquid drops of water formed by the condensation of moisture in the atmosphere. Raindrops generally have a diameter greater than 0.5 mm, their size is about 3 mm in diameter, and their rate of fall increases up to 7.6 m per sec with their size (Blackadar, 2008). Larger drops tend to be flattened and broken into smaller drops by rapid fall through the air. Rainfall (also called liquid precipitation) represents the amount of rain that drops in a location over a period of time. The amount or volume of rainfall is expressed as the depth of water that collects on a flat surface, and it is measured by a rain gauge usually to the nearest 0.25 mm.

The yearly fluctuations in rainfall intensity within Ilorin metropolis is shown in Figure 1 while Table 1 summarizes the statistical parameters of the recorded rainfall data. Large difference in rainfall was observed, and in the 20 year period under review, rainfall had a maximum recorded value of 394.10mm (heaviest amount of rainfall) and a mean value of 100.73mm. From the analysis of daily and monthly data, it was observed that rainfall is usually at its peak between May and September, and rainfall is at its minimum between December and February. In the rainfall record of 1989 to 2008, the average rainfall was 109.74 mm. From 1989-1993, rainfall reduced to 89.41 mm, showing a negative change tendency with a percentage difference of 18.52 %. From 1994-1998, rainfall rose to 108.87 mm and the situation continued from 1999-2003. Between 2004 and 2008, Ilorin metropolis experienced an increase in rainfall; rising sharply to 131.84 mm, denoting 20.14 % increase over the previous years.



The Ryan-Joiner method of regression test (Mc Bean and Motiee, 2008) showed that the data series for rainfall is normal. Also, it has a positive trend line and an R^2 value of 0.459, which indicates that there is an average linear relationship between Rainfall and Year. Also, from the regression equation- $Y = 2.75R - 5491$, it is observed that there is a positive correlation between time (year) and rainfall in Ilorin. This indicates that there will be increment in rainfall relative to time.

Table 1 Summary of statistical analysis for rainfall (mm) between 1989 and 2008

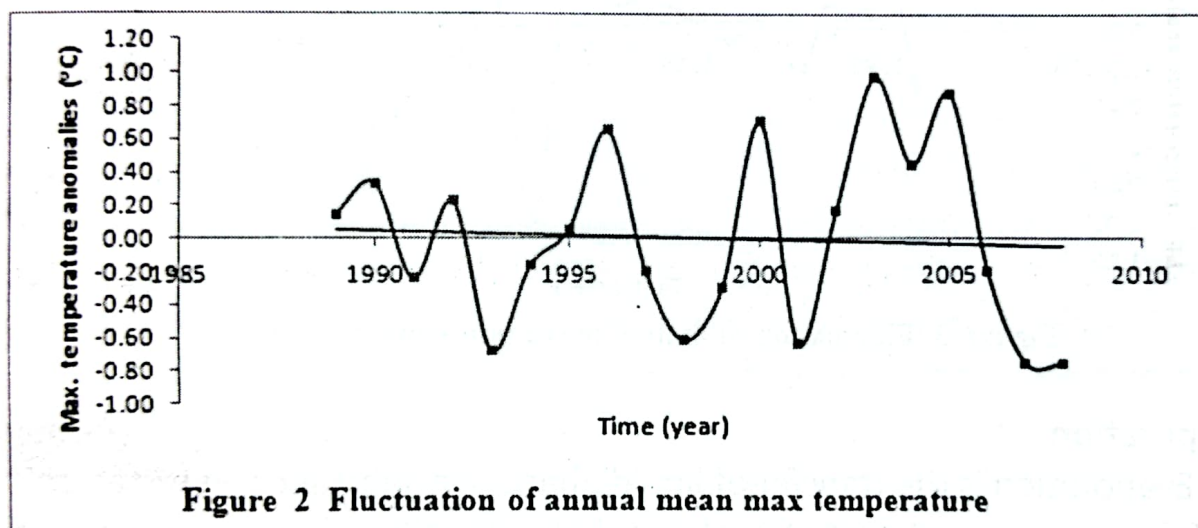
Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	4.8	6.2	32.0	97.2	163.6	182.9	173.2	149.2	241.7	139.0	14.3	4.8
Std. Dev.	11.8	9.0	25.2	52.4	80.2	70.7	80.0	79.77	68.49	59.21	18.88	12.12
Max.	39.30	33.10	92.10	223.00	355.70	360.70	394.10	334.60	343.60	248.30	55.60	46.60
Skewness	2.46	1.76	0.77	0.67	0.66	0.84	1.35	1.11	-0.44	0.07	1.10	2.89

Temperature

Temperature is the degree of hotness or coldness of a body. Between 1989-2008, the maximum temperature was 38.74°C , the minimum

value was 15.88°C, and the mean value was 27.55°C (Table 2 and Figure 2). It was also observed that the maximum temperature was highest between February and April, and it denotes the peak of dry season. From Figure 2, Maximum temperature has a R^2 value of 0.0020, indicating a very weak relationship between maximum temperature and time.

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	28.45	25.99	28.52	26.84	26.65	25.75	25.06	28.08	26.53	28.32	30.12	30.32
Std. Dev.	12.29	15.46	14.77	14.32	12.10	11.47	11.01	6.96	9.36	9.75	10.38	10.39
Max.	34.73	36.54	38.74	36.20	34.13	35.66	35.08	34.67	34.46	33.80	35.59	35.76
Skewness	-2.11	-1.22	-1.56	-1.50	-1.89	-1.86	-1.94	-3.71	-2.56	-2.82	-2.81	-2.86



The regression equation of maximum temperature is $Y = -0.004T_{\text{Max}} + 9.87$, signifying a negative correlation between maximum temperature in Ilorin and time (year). This suggests that the maximum temperature within Ilorin metropolis will reduce with time, but at a very low rate.

Minimum temperature has a maximum value of 26.42°C, and a mean value of 20.89°C (Table 3). It was observed from Reduction analysis that minimum temperature has two peak months; March and August. Regression Analysis (Figure 3) shows that minimum temperature has a R^2 value of 0.0090, indicating a very weak linear relationship between minimum temperature and year. The regression equation of minimum

temperature; $Y = -0.006T_{\text{Min}} + 12.60$ shows that the minimum temperature will continue to reduce over time, at a low rate.

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	18.54	19.61	22.31	21.98	21.20	20.94	20.30	21.79	21.34	21.10	20.99	20.58
Std. Dev.	4.83	6.88	5.48	5.43	5.37	5.41	4.99	1.55	0.94	1.28	1.71	1.96
Max.	23.61	25.96	26.42	25.00	23.90	25.67	22.71	26.10	22.53	23.46	23.39	24.49
Skewness	-3.18	-2.61	-3.91	-4.09	-3.82	-3.58	-4.14	0.91	-2.36	-0.60	-0.96	-0.02

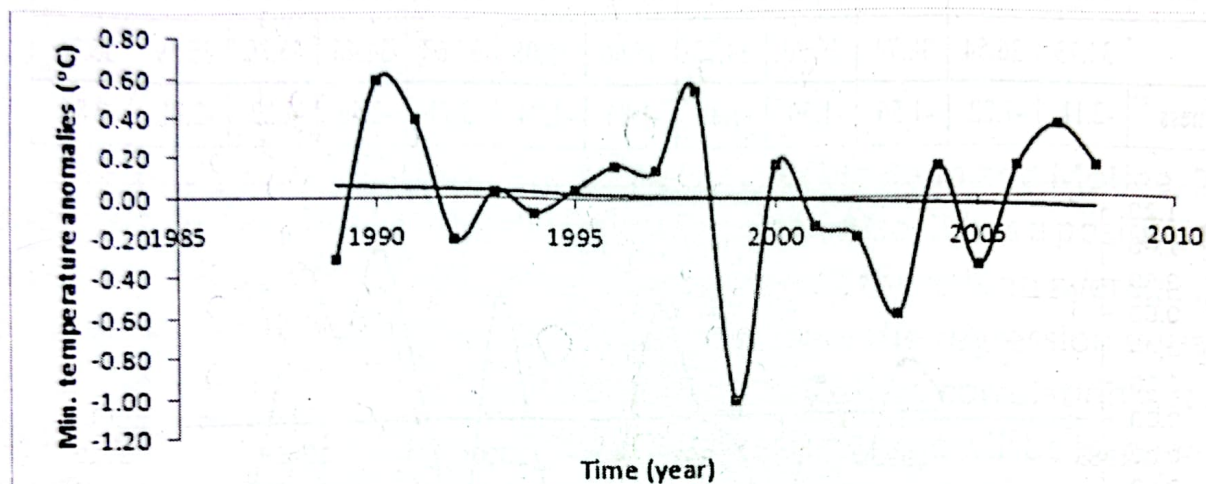


Figure 3 Fluctuation of annual mean min temperature

Evaporation

Evaporation is the transfer of liquid phase of a substance on the earth's surface to gaseous phase in the atmosphere. It typifies the movement from liquid phase to gaseous phase. Evaporation in Ilorin for the 20 year period under consideration has a minimum value of 1.46mm, a maximum value of 13.800mm, and a mean of 4.89mm (Table 4). It was observed that the evaporation value for January-March is very high compared to the evaporation value for April-December. The fluctuation pattern of evaporation between 1989 and 2008 is illustrated in Figure 4.

Table 4 Summary of statistical analysis for evaporation (mm) between 1989 and 2008

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	7.83	9.03	7.26	5.43	3.55	2.88	2.47	2.25	2.35	2.84	5.51	6.80
Std. Dev	3.33	3.38	3.01	1.92	1.22	0.91	0.80	0.74	0.38	0.65	1.57	1.57
Max.	12.40	13.80	13.60	8.50	5.50	4.20	3.30	3.10	3.00	3.84	8.00	8.00
Skewness	-0.74	-0.83	-0.30	-1.51	-1.64	-2.28	-2.28	-1.87	-1.06	-1.10	-0.57	-0.57

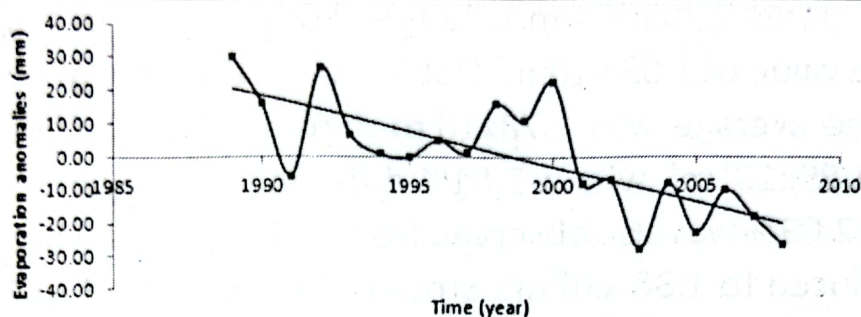


Figure 4 Fluctuation of annual mean evaporation

Stream flow

Stream flow is the volume of water that moves over a designated point (usually a stream or river) over a fixed period of time (<http://water.epa.gov>). The flow of a stream is directly related to the amount of water moving into it from its draining region (<http://en.wikipedia.org>). Stream flow measurements are made by recording the height of the surface of the water above a reference datum. The two prominent rivers in Ilorin are Asa and Oyun River.

Asa stream flow has a monthly maximum value of $147.20 \times 10^6 \text{ m}^3$, a monthly minimum value of $5.64 \times 10^6 \text{ m}^3$, and a monthly mean value of $19.13 \times 10^6 \text{ m}^3$ (Table 5). Peak stream flow occurs in August, which corresponds to one of the months with maximum rainfall. The minimum flow occurs in April. Flow in Asa River has an average of $18.81 \times 10^6 \text{ m}^3$. Between 1966 and 1970, stream flow declined and reduced to $12.32 \times 10^6 \text{ m}^3$, with a percentage difference of 34.51%. However, from 1971 to 1975, the value increased to $21.78 \times 10^6 \text{ m}^3$, having a 15.80 % difference. From 1976 to 1980, the stream flow declined again and reduced to $18.75 \times 10^6 \text{ m}^3$. This situation changed from 1981 to 1985 when it increased to $22.39 \times 10^6 \text{ m}^3$, with a percentage increase of 19.03 %. Based on this observation, the raw water flow in Asa River is likely to increase in future. Asa stream flow has a R^2 value of 0.19

(Figure 5), indicating that there is a very weak linear relationship between Asa stream flow and year, and the trend line is positive. From the regression equation of Asa stream flow, there is a positive correlation between Asa stream flow and time i.e. the stream flow of Asa will increase relative to time.

Oyun stream flow has a monthly maximum value of $9.27 \times 10^6 \text{ m}^3$ in September, a monthly minimum value of $0.001 \times 10^6 \text{ m}^3$ in January, and a monthly mean value of $1.63 \times 10^6 \text{ m}^3$ (Table 6). For the stream flow record of Oyun River, the average was $1.78 \times 10^6 \text{ m}^3$. From 1972 to 1976, the value increased to $1.89 \times 10^6 \text{ m}^3$, with a 5.81% difference. A negative percentage difference of 22.69% was also observed from 1977 to 1981 when the stream flow value reduced to $1.38 \times 10^6 \text{ m}^3$. Stream flow increased to $1.45 \times 10^6 \text{ m}^3$ from 1982 to 1986. However, it showed positive change tendency from 1987 to 1991, when the stream flow rose to $2.42 \times 10^6 \text{ m}^3$ amounting to 35.76 % increase. This shows that the stream flow of Oyun River will likely increase over a long period of time. Oyun stream flow has a R^2 value of 0.17 (Figure 6), indicating a very weak linear relationship between Oyun stream flow and year. The regression equation for Oyun stream flow shows that there will be an increase in Oyun stream flow over time but the rate of stream flow increase will be low.

Table 5 Summary of the statistical analysis for Asa Stream Flow ($\times 10^6 \text{ m}^3$) between 1966 and 1985

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	1.45	1.01	1.25	3.26	11.63	15.80	26.62	48.43	62.61	52.45	2.39	2.65
Std. Deviation	0.74	0.64	0.83	3.39	5.77	8.19	20.83	37.50	37.86	24.57	14.96	1.92
Max.	2.96	3.09	3.10	13.19	22.33	33.20	70.00	145.00	147.20	93.76	69.43	7.46
Skewness	-0.04	1.72	0.59	2.33	0.24	0.22	0.96	1.62	0.48	0.41	1.78	1.17

Table 6 Summary of the statistical analysis for Oyun Stream Flow ($\times 10^6 \text{m}^3$) between 1972 and 1991

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	0.34	0.77	1.73	1.89	1.45	1.77	1.64	1.45	3.97	1.94	1.46	1.15
Std. Dev	0.61	0.95	1.11	1.04	1.07	1.26	1.90	1.17	1.65	0.97	1.63	1.86
Max.	2.27	3.66	5.07	5.14	5.44	6.52	9.24	3.97	9.27	3.87	5.90	7.70
Skewness	2.35	2.09	1.97	1.90	2.96	3.09	3.74	0.89	1.82	0.67	1.81	2.71

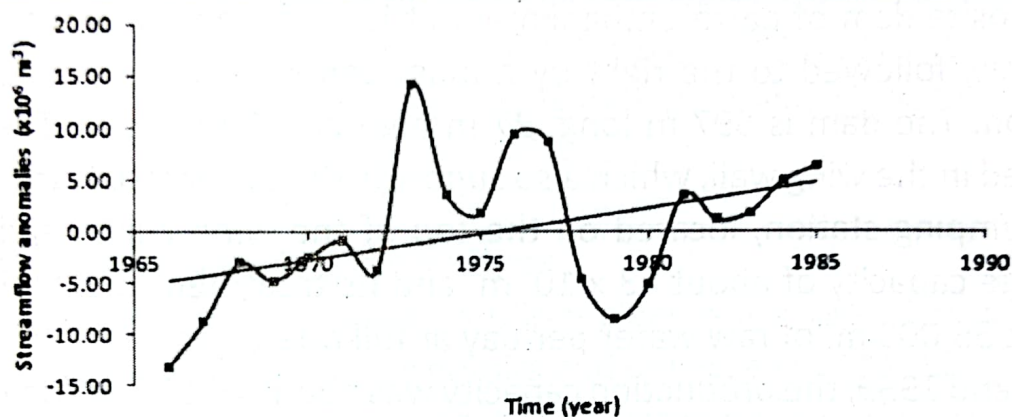


Figure 5 Fluctuation of mean stream flow of Asa river

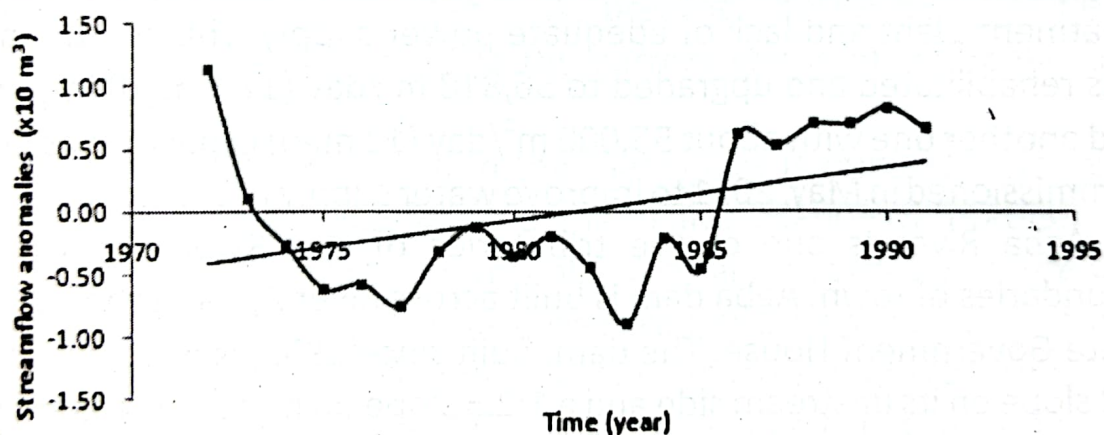


Figure 6 Fluctuation of stream flow of Oyun river

Sources of Water Supply to Ilorin Metropolis

(1) Municipal Water Supply

Municipal water supply system in Ilorin is mainly from the Kwara State

Government and it relies on surface water drawn from Agba, Asa and Moro Rivers. These three rivers are dammed and water is abstracted to treatment plants to supply water to Ilorin metropolis. The three dams have a total reservoir storage capacity of about 49,100,000 m³ and the treatment plants can process about 82,276 m³ of raw water per day. Operations from these dams yielded about 23,402 m³/day in year 2002 against an average of 68,003 m³/day between 1997 and 1999 (Ayanshola, 2013).

Asa dam water works is located at a point 5 km south of Ilorin across the River Asa which flows from the southern part of Ilorin to northern part. It is a composite dam of earth embankment at its extreme ends, with a central spillway, followed to the right by a mass concrete non-over flow gravity section. The dam is 597 m long, 27 m high and 6 m wide. The intake is located in the wing wall, which also supports the super structure of the low lift pumping station, located on the top of the wing wall. Asadam has a storage capacity of about 43×10^6 m³ and its treatment plant can process about 55,000 m³ of raw water per day at full operation capacity. Between 1997 and 1999, the production capacity was about 40,833 m³/day while the production capacity was about 18,800 m³/day in year 2002 (Ayanshola, 2013). The reduction in the production was as a result of depreciation in the treatment plant and lack of adequate power supply. This treatment plant was rehabilitated and upgraded to 56,818 m³/day (12.5 mgd) in year 2009 and another one with about 55,000 m³/day (12 mgd) capacity was built and commissioned in May, 2011 to improve water supply to the city.

Agba River is one of the tributaries of Asa River and within the boundaries of town. Agba dam is built across River Agba at the back of the State Government House. The dam, built since 1952, is an earth dam with 1:3 slope on its upstream side and a 1:2.5 slope on its downstream side. It is 17.68 m high and has a length of 579.27 m. The maximum gross capacity of the impounding reservoir formed by the dam is 3.10×10^6 m³ (KWWC, 1973). An earth gravity dam built on Agba River forms an impounding reservoir that collects the river's water which is augmented from Asa River through a 350 mm diameter asbestos cement pipe. From the Agba impounding reservoir, the water flows to a treatment plant. Low lift pumps are utilized to deliver

water from the impounding reservoir when the storage volume is low; otherwise, the water flows to the treatment plant by gravity. It has a full operation capacity of about 9,000 m³/day. In 1999, another new treatment plant of about 9,000 m³/day capacity was commissioned. The production rate between 1997 and 1999 was about 13,067 m³/day. In year 2002, the treatment plant could only produce about 6,625.44 m³/day.

The Sobi water work is located at the back of the Sobi Barracks, which is at the northern part of the metropolis. Sobi dam is built across River Moro. The dam has a yield capacity of about 14,000 m³/day. There are two separate treatment plants built to treat raw water from the dam. Each treatment plant has a full operation capacity of about 4,500 m³/day. Record from Water Corporation shows that between 1997 and 1999, the average monthly production was about 8,133 m³/day.

Water storage and distribution systems

Water pumped from Asa, Agba and Sobi clear water tanks are normally stored in distribution/service reservoirs and delivered by gravity to various demand areas. Before 1999, seven service reservoirs were connected to the network. Another six overhead steel tanks were introduced in 2001 to enhance the distribution system. At present, the reservoir at Central mosque has been removed while the current status of the remaining is indicated in Table 7.

The distribution system in the metropolis is primarily dictated by street patterns, topography, water demand and location of treatment and service reservoirs. For Ilorin metropolis, the pipe network is made up of Asbestos Cement, Cast Iron, Galvanized Iron and Unplasticized Polyvinyl Chloride pipe ranging from 50 mm to 600 mm diameter, and covering a total distance of about 337.542 km (Ayanshola, 2013). In recent time, there were additional pipelines ranging from 100 mm to 800 mm diameter made of D.I. and UPVC which cover a total distance of about 107.869 km to upgrading the system. Out of the total length of the pipelines, 79.017 km are new pipelines either for rising main or distribution network while the remaining length of about 28.852 km were used to replace some of the existing AC pipelines

within the township.

Table 7: Location, capacities and status of distribution reservoirs in Ilorin township

S/No	Reservoir Type	Location	Source	Capacity (m ³)	Present Status
1.	Underground Concrete	GRA/Fate	Agba	4,600	In use
2.	Overhead Steel	GRA/Fate	Agba	454.45	In use
3.	Eastern Ground Level Concrete	Tanke	Asa	10,000	In use
4.	Western Ground Level Concrete	Adewole Estate	Asa	10,000	In use
5.	Overhead Concrete	Former UITH	Asa	4,600	In use
6.	Overhead Steel	Olanrewaju Estate, Offa Garage	Agba	227.27	Not in use
7.	Overhead Steel	Olanrewaju Estate, Offa Garage	Agba	454.45	In use
8.	Overhead Steel	OkeSobi, Sobi Road	Sobi	227.27	Not in use
9.	Overhead Steel	OkeSobi, Sobi Road	Sobi	454.45	In use
10.	Overhead Steel	Central Mosque	Asa	227.27	removed
11.	Overhead Steel	Central Mosque	Asa	454.45	Removed
12.	Overhead Steel	Unity-Taiwo Junction	Agba	454.45	In use
13.	Overhead Steel	Kwara Hotel	Agba	454.45	In use

[Source: Ayanshola and Sule, 2006]

Status of municipal water works

The status of production at the three municipal water works can be summarized as shown in Table 8. There is a clear indication that there are enough resources to take care of the entire population (about 918,881 people) but the production rate has been so low that it can only take care of about 24 % of the total population. However, if the treatment plants are utilized to full capacity, the present population can still be supplied with adequate pipe borne water.

Table 8: Production status at the water works in Ilorin

Unit	Total Capacity (m ³ /day)	No of People it can serve	Status
Reservoir	49,100,000	409,166,667	Adequate
Treatment	132,725	1,106,042	Adequate (about 20 % in excess of total Population)
Production	26,027	216,892	Not adequate (about 24 % of total population)

Source: Ayanshola, 2013

(1) Other Sources of Water Supply in Ilorin

Over the years, residents of Ilorin have adopted other means of meeting their water demand apart from the public/municipal water supply by the Kwara State Water Cooperation (KWWC). Other sources of water supply within Ilorin metropolis include boreholes, hand dug wells, water tankers, bottled and sachet water, and water vendors. An average estimate of the cost for provision of water from different supply sources is presented in Table 9.

Table 9: Cost of water in Ilorin township

Source	Type	Cost (₦)
Public water supply by KWWC	GRA (per flat)	*750.00
	Others (per flat)	* 500.00
	Standpipe	*1,000.00
	Duplex	*1,000.00
Other sources	Motorized borehole + Steel tank	+4,800,000.00
	Motorized borehole + Plastic tank	+2,600,000.00
	Hand pump borehole	+ 850,000.00
	Borehole (drilling alone)	+360,000.00
	Hand dug well (unlined)	32,000.00
	Hand dug well (lined + cover)	78,000.00
	Water tanker	6,000.00
	Bottled water (per bottle)	70.00
	Sachet water (50cl)	7.50
	Vendor (25 litres)	50.00

*Cost per month; *Cost of purchase and installation

Conclusion

Climate change is a complex problem that affects a sizeable aspect of human life. Observation of previous records of climatic conditions and the use of established models to make prediction offers baseline information for mitigation or adaptation procedures. Historic records of meteorological and hydrological data in Ilorin between 1989 and 2008 have shown that the pattern of temperature, rainfall, evaporation and stream flow has changed over the years. Analysis of fluctuations in these variables using Regression and Reduction Pattern methods suggests that in future Ilorin is likely to experience increase in rainfall and stream flow, while temperature and evaporation are expected to slightly reduce. The major impacts of climate change are domiciled in water resources, agriculture, health, and other aspects of human endeavors. Therefore there is need for all stakeholders to apply mitigation methods or adapt to changes that are expected from climate change. More importantly in terms of water supply, government efforts should concentrate on harnessing the expected increase in fresh water availability while simultaneously guiding vital infrastructure and citizens from floods. Also the production capacity of the existing treatment plants should be increased.

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