EURASIAN JOURNAL OF RESEARCH AND INNOVATION **ISSN(o): 2584-1785**
International Monthly, Peer-Reviewed, Refereed, Indexed Journal
Volume - 2, Issue - 1, Jan - 2024

DOIs:10.2023/EJRI/202401003 --:-- Research Paper / Article / Review

The Impact of Rainfall Variability on Surface Water Resources (Reservoir Water Level). A Case Study of Lower Usuma Dam, Abuja, Nigeria

Mustapha I. Musa[1], Kayode Ojo[2] and Abdulmajeed S. Bello[3]
[1] Researcher at Center for Climate Change and Geographical Information System (CCC&GIS), Kaduna State University, Kaduna, Nigeria
[2] Senior Lecturer at Nigerian College of Aviation Technology, Zaria, Nigeria
[3] Researcher at Center for Climate Change and Geographical Information System (CCC&GIS), Kaduna State University, Kaduna, Nigeria

Abstract: *Rainfall is a finite resource that is prone to depletion or enhancement from both natural and man-made sources. It is also highly changeable in space and time. In order to effectively manage Nigeria's limited water resources—which are always under stress due to rising water demands, population growth, and economic development—it is imperative to comprehend the variability of rainfall. This study looks into how variations in rainfall in the Federal Capital Territory (FCT) of Abuja, Nigeria, have affected the reservoir level of the lower Usuma dam, Abuja, which is the primary supply of portable water to the city. This was carried out by assessing the variations in rainfall characteristics of Abuja and relating them with reservoir level data to observe its impacts for 31 years' study period. These analyses show that the year 2002 recorded the highest mean annual rainfall amount of 1941.6mm, while 2018 recorded the lowest amount (928.8mm). It was noticed that there was a downward trend in the mean annual rainfall from 2015 to 2019 with 2018 recording the lowest value. It was observed that rainfall has been on decrease within this period. The year 2008 has the highest coefficient of variation with a value of 122.9% followed by 1994(121.4%) and 2005 (121.1%), while the least was recorded in 2014 with a value of (84.2%) followed by the year 2013 (84.4%) and 1997(89.5%) respectively. In the last five years of this study from 2015 to 2019, the reservoir water level has been varied with a downward trend below 574ft., within these periods, the reservoir was characterized with low pressure spilling or no spilling, with the highest average annual reservoir level of 573.614ft. in 2015, 573.880ft. (2016), 573.902ft. (2017), 573.570ft. (2018), and 573.161(2019) respectively. All these impacts were due to the downward trend and variability in the mean annual rainfall during this period.*

Keywords: *Rainfall, Rainfall variability, Climate change, Water level, Water supply.*

1. INTRODUCTION :

Climate is basically defined as the description in terms of the mean and variability of prevailing atmospheric variables such as temperature, precipitation and wind. Climate can also be viewed as an element or aggregate of weather (Goosse, Barriat, Lefebvre, Loutre, & Zunz, 2010). This indicates that representation of the climate in a particular region must contain analysis of mean conditions, of the annual cycle, of the chances of extreme such as severe frost and storms, etc. according the World Meteorological Organization (WMO), 30 years is the classical period for performing the statistics used to interpret or define climate. This is well suited for studying recent decades since it needs a reasonable amount of data while still supplying a good sample of the different types of weather that can take place in a specific area (Goosse, Barriat, Lefebvre, Loutre, & Zunz, 2010). The understanding of climate variability over the period of instrumental records and beyond on different temporal and spatial scale is important to apprehend the nature of different climate systems and their influence on the environment and society (Mamman, Bello, & A.A. Usman, 2018). The dispersal of the world's precipitations is changing as our climate changes. moist areas may become wetter, dry areas drier, storms more intense, leading to more chaotic weather around the world (NASA, 2010). In this 21st century, in Africa and Nigeria in particular, the emphasis of many scholars in the study of tropical climatology has been the inducement of rainfall attributes, such as rainfall amount, duration and intensity (Omogbai, 2010). Rainfall is the meteorological event that has the greatest impact on human activities and the most important environmental factor restraining the development of the semiarid regions. Understanding rainfall variability is important to best manage the scarce water resources that are under continuous stress due to the increasing water demands, increase in population, and the economic and industrial development (Nyatuame, Owusu, & Ampiaw, 2014). The climate is moderated by the meridional oscillation of the Intertropical Discontinuity (ITD). The Inter tropical Discontinuity is an area of separation between two air masses, the Northeast (NE) trade Winds and Southwesterly (SW) Winds. These trade winds dominate over the region and over West Africa in general. Normally in January when the Intertropical Discontinuity reaches its southernmost position at latitude 6^0 N, the region and almost the entire country is under the influence of Northeastern trade winds. The weather is then dry, cold and hazy, normally referred to as dust haze or the dry season. The Southwestern maritime winds, prevail over the region/country with the northward retreating of the Intertropical Discontinuity attaining its northernmost spot at about latitude 22^0 N in August. The region experiences rainy season also known as the summer period (NTAT, OJOY, & SULEIMAN, 2018). Generally, in Nigeria, the prevailing feature of rainfall is its diverse seasonal/annual character. The comprehensive energy content of rainfall system is how variable it is from year to year which is mainly associated to the instability in the movement of the two different prevailing air masses, and the ITD (Mamman, Bello, & A.A. Usman, 2018). As water happens to be the lifeblood and the vital spark of the planet, therefore, the state of this resource affects almost all natural, social and economic systems. Water serves as the essential link between the climate system, human society and the environment (UN Water, 2010). The aforementioned were trying to establish the linkages between rainfall, water and human society (IFABIYI, IFATOKUN, ASHAOLU, & ENIOLA, 2013). The World Meteorological Organization (WMO) in alliance with International Glossary of Hydrology defines reservoirs as natural or artificial water bodies used for storage, regulation and control of water resources. Water level is Hight of the free-water surface of a body of water relative to a datum level (Vuglinskiy, 2009). Water level data is collected from a variety of water bodies and is utilized for a number of purposes. A water level record often serves as an alternate for flow in rivers because it is hardly to continuously examine flow directly. Water level used for this purpose requires a good comprehension of the relationship between level and flow, and the obstacles encountered when maintaining that relationship (Watson & Christie, 2016). Most time, water level is frequently analyzed on its own, or used in conjunction with other parameters, such as water quality. It is essential to understand the range of benefits to which the data can be put, and to ensure that data collected for one purpose can be used as widely as possible in the future. Key to planning, maintaining and recording flow measurement is the understanding of, and catering for stationarity (the condition of being stationary) (Watson & Christie, 2016).

2. MATERIALS AND METHODS

Materials

- ➢ Weather variable data
- • Precipitation
- • Evaporation
- ➢ Raw water level data from lower Usuma dam reservoir

Method

Microsoft excel was applied for the analysis. The data obtained were subdued to statistical evaluation/analysis using measures of central tendency such as mean, measures of dispersion such as variance, standard deviation and range as well as a measure of relationship (coefficient of variance), skewness and kurtosis.

Mean (Average) = $\frac{\sum_{i=1}^{n} Xi}{n}$

Variance= $\frac{\sum(x-x)2}{n-1}$

Coefficient of Variation (CV) = $\frac{SD}{X} \times 100$

Where: SD is the standard deviation = $\sqrt{\frac{\sum(x-x)2}{n-1}}$

And X= Mean

Annual Rainfall Statistical Analyses

This section outlines the approaches that were used to analyze or evaluate or quantify rainfall variability and their effects on the water resources of the Lower Usuma dam catchment Abuja. These approaches include computation of coefficient of variation for the quantification of the rainfall variability, rainfall trend analysis for the evaluation of characteristics of the variation’s effects on rainfall and reservoir water level analysis for of the Lower Usuma dam catchment area.

Methods of Rainfall Variability Analysis

Rainfall trend is represented by the coefficient of variability (CV), and is calculated as the standard deviation divided by the mean annual rainfall. This is expressed as a percentage and denotes how much rainfall varies from average annual rainfall.

The coefficient of variation (CV*):* The coefficient of variability (CV) is another measure of Climate Variability. This has extensively been used in literature to evaluate climate variability (Adejuwon, 2006). It measures the size of the standard deviation (which is the most frequently used measure of variability) relative to the mean.

Coefficient of variation (CV)=SD/X

The mean of rainfall rate for each month was determined and these were plotted against the months of the year to reveal variation of rainfall for the decades.

Analysis of The Influence of Rainfall Variability on Water Resources ofthe Study Area;

The graphical presentation of 31 years' rainfall, evaporation and reservoir level data were analyzed to know the amount of impact rainfall variation has on lower Usuma dam reservoir.

Abuja Population Estimation

Abuja is among the fastest growing state in term of population and development. Therefore, to know the amount of water people will consume in a geographic location, we have known the population of that geographic location. This study estimated 10 years' future population of Abuja from (2020 to 2030) using the existing population data available, in order to have insight of how Abuja population will look in the next 10 years. 1991 and 2006 data were used to estimate 2020 population, 2006 and 2020 estimated population were used to estimate 2030 population of Abuja.

Water Consumption Estimation

The higher the population the higher the water consumption of a particular area, Abuja happens to be among the fastest growing cities in Nigeria in term of population and infrastructural development, so the higher the city grows in population the higher the water they consume. In order to estimate the amount of water to be consumed by Abuja citizens in the next 10 years, the forecasted population for 2030 was multiplied by per capital water demand of 200lpcd (200 liters per capital/person per day).

Each of the two new plants (phase 3 and 4) in the FCT water works was designed and capacitated to process 240 million Liters of water a day to the FCT and environs. Raw water delivered to these new plants is being sourced from the lower Usuma reservoir, which also initially supplies water to the phase 1 and 2 plants. The new and existing facilities now provide a combined discharge of 720 million liters of clean drinking water per day to Abuja and its neighboring areas (Technology, 2021).

4. RESULT AND DISCUSSIONS :

4.1 RESULTS

The data were analyzed using measures of central tendency - mean, measures of dispersion such as range, variance and standard deviation as well as a measure of relationship (coefficient of variance), kurtosis and skewness. Tables and charts were presented to analyze the rainfall variability with the impact of Evaporation within FCT Abuja, and how those data impact it has on the reservoir water level of lower Usuma dam Abuja for the period of 30 years from 1989 to 2019.

Mean (x) = $\frac{\sum_{i=1}^{n} Xi}{n}$

Variance=$\frac{\sum(x-x)2}{n-1}$

CV=$\frac{SD}{X} \times 100$

Standard deviation = $\sqrt{\frac{\sum(x-x)2}{n-1}}$

And X= Mean

Table 4.1: Statistical outline of the mean annual rainfall from 1989 - 2019

YEAR	STATISTICS									
	ANNUAL RAINFALL SUM (mm)	AVERAGE (mm)	MIN (mm)	MAX (mm)	RANGE	VARIANCE	SD	KURTOSIS	SKEWNESS	C.V %
1989	1227.2	102.3	0	278.2	278.2	9443.7	97.2	-1.2	0.4	95.0
1990	1438.3	119.9	0	349.3	349.3	12746.1	112.9	-0.4	0.6	94.2
1991	1499.6	125.0	0	381.3	381.3	15370.4	124.0	-0.2	0.7	99.2
1992	1377	114.8	0	297.9	297.9	10942.6	104.6	-1.0	0.4	91.2
1993	1522.7	126.9	0	375.7	375.7	16886.6	129.9	-0.8	0.7	102.4
1994	1651.5	137.6	0	554.9	554.9	27911.4	167.1	2.6	1.5	121.4
1995	1310.9	109.2	0	417.4	417.4	15861.5	125.9	2.1	1.4	115.3
1996	1401.6	116.8	0	326.9	326.9	14185.8	119.1	-1.4	0.4	102.0
1997	1336.3	111.4	0	247.2	247.2	9929.4	99.6	-2.0	0.0	89.5
1998	1455.1	121.3	0	322	322	15189.8	123.2	-1.2	0.5	101.6
1999	1667.9	139.0	0	345.4	345.4	19043.9	138.0	-1.5	0.4	99.3
2000	1198.3	99.9	0	276.6	276.6	11252.9	106.1	-1.2	0.5	106.2
2001	1383	115.3	0	358.5	358.5	17479.6	132.2	-0.5	0.9	114.7
2002	1941.6	161.8	0	487.8	487.8	34924.0	186.9	-1.0	0.8	115.5
2003	1770.5	147.5	0	482.7	482.7	24004.1	154.9	-0.3	1.1	105.0
2004	1541.2	128.4	0	310.7	310.7	16178.4	127.2	-1.8	0.2	99.0
2005	1471.8	122.7	0	477	477	22048.4	148.5	1.7	1.3	121.1
2006	1311.6	109.3	0	384.5	384.5	13436.6	115.9	1.5	1.2	106.1
2007	1388.9	115.7	0	314.9	314.9	14290.6	119.5	-1.1	0.6	103.3
2008	1174.7	97.9	0	370.9	370.9	14472.5	120.3	0.8	1.2	122.9
2009	1444.6	120.4	0	433.8	433.8	16454.2	128.3	2.1	1.3	106.6
2010	1682.2	140.2	0	314.8	314.8	19118.6	138.3	-2.1	0.1	98.6
2011	1212.4	101.0	0	272.6	272.6	9935.0	99.7	-1.3	0.5	98.7
2012	1638.1	136.5	0	376.1	376.1	18041.1	134.3	-1.4	0.4	98.4
2013	1342.1	111.8	0	272.6	272.6	8903.6	94.4	-1.4	0.1	84.4
2014	1482	123.5	0	259.7	259.7	10806.5	104.0	-1.8	0.0	84.2
2015	1071.9	89.3	0	238.4	238.4	7887.2	88.8	-1.3	0.5	99.4
2016	1630.6	135.9	0	360.5	360.5	17136.1	130.9	-1.1	0.5	96.3
2017	1162.3	96.9	0	392.9	392.9	13252.3	115.1	3.3	1.7	118.9
2018	928.8	77.4	0	214.8	214.8	6756.0	82.2	-1.0	0.6	106.2
2019	1140.2	95.0	0	243	243	8825.5	93.9	-1.5	0.4	98.9

Source: NIMET, 2020

4.2 DISCUSSIONS

4.2.1 The Statistics of Rainfall Summaries in Abuja from 1989 To 2019

Table 4.1 highlights the result of statistical evaluation for rainfall from 1989 to 2019. The table shows that on the mean data, rainfall has consistently been on decrease from 2015 to 2019 based on the last decade. 1999 to 2009 recorded the highest amount of mean annual rainfall, followed by 1989 to 1998 and then 2010 to 2019 has the least mean annual rainfall among the decades. The maximum aggregate of rainfall was recorded in 2002 with a recorded value of 1941.6mm followed by 2003 (1770.5mm) other years has skewness of less than one (1) or close to one (1). The minimum amount of rainfall was recorded in 2018 with a value of 928.8mm followed by 2015 (1071.9mm), 2019 (1140.2mm) and 2017 (1162.3mm) respectively. The kurtosis exhibits a negative value in 1989-1993, 1996-2004, and 2007 (i.e., Flatter than normal peak distribution). While the other years shows positive kurtosis (i.e., peak flattest than the average) values during the year of concern.

Table 4.2: Annual Rainfall Data

YEAR	ANNUAL RAINFALL SUM
1989	1227.2
1990	1438.3
1991	1499.6
1992	1377
1993	1522.7
1994	1651.5
1995	1310.9
1996	1401.6
1997	1336.3
1998	1455.1
1999	1667.9
2000	1198.3
2001	1383
2002	1941.6
2003	1770.5
2004	1541.2
2005	1471.8
2006	1311.6
2007	1388.9
2008	1174.7
2009	1444.6
2010	1682.2
2011	1212.4
2012	1638.1
2013	1342.1
2014	1482
2015	1071.9
2016	1630.6
2017	1162.3
2018	928.8
2019	1140.2

Source: NIMET, 2020

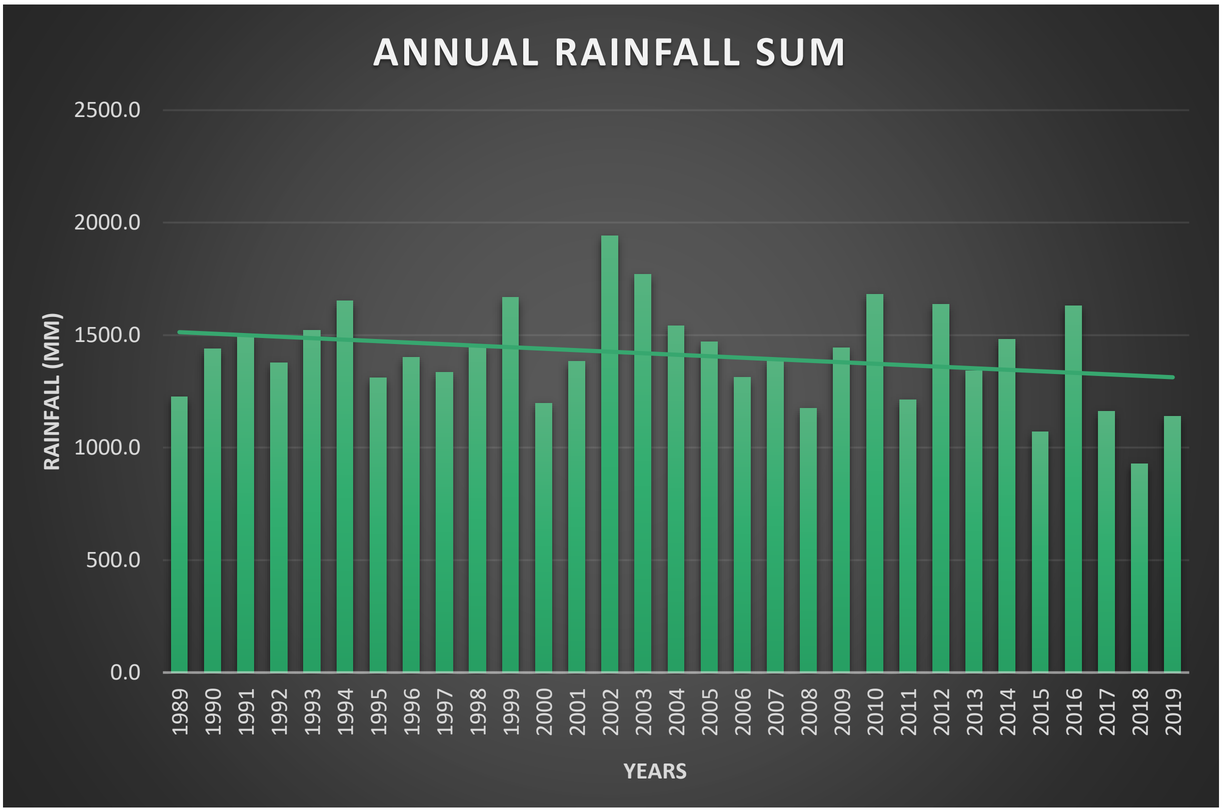


Figure 4.1: Annual Rainfall Chart

4.2.2 Rainfall Distribution Trend

Mean Annual Rainfall Trend

The mean annual rainfall distribution data was from 928.8mm as minimum to 1941.6mm as maximum throughout the entire 31 years of study. This shown that there were upward and downward shifts during these periods. From our chart it was shown that increasing trend of mean annual rainfall was significant from the year 1990 to 1994, then there was a fall up to 1998 then a rise in 1999 respectively. However downward rainfall trend was also observed from 2002 which falls up to 2008, it later rises steadily till 2010. 2010 to 2014 has an average rainfall trend. A downward rainfall trend was noticed again from 2016 till 2019 with 2018 recoding the lowest mean annual rainfall.

Table 4.3: Coefficient of Variation for the Mean Annual Rainfall from 1989-2019

YEAR	C.V %
1989	95.0
1990	94.2
1991	99.2
1992	91.2
1993	102.4
1994	121.4
1995	115.3
1996	102.0
1997	89.5
1998	101.6
1999	99.3
2000	106.2
2001	114.7
2002	115.5
2003	105.0
2004	99.0

ISSN(o): 2584-1785

2005	121.1
2006	106.1
2007	103.3
2008	122.9
2009	106.6
2010	98.6
2011	98.7
2012	98.4
2013	84.4
2014	84.2
2015	99.4
2016	96.3
2017	118.9
2018	106.2
2019	98.9

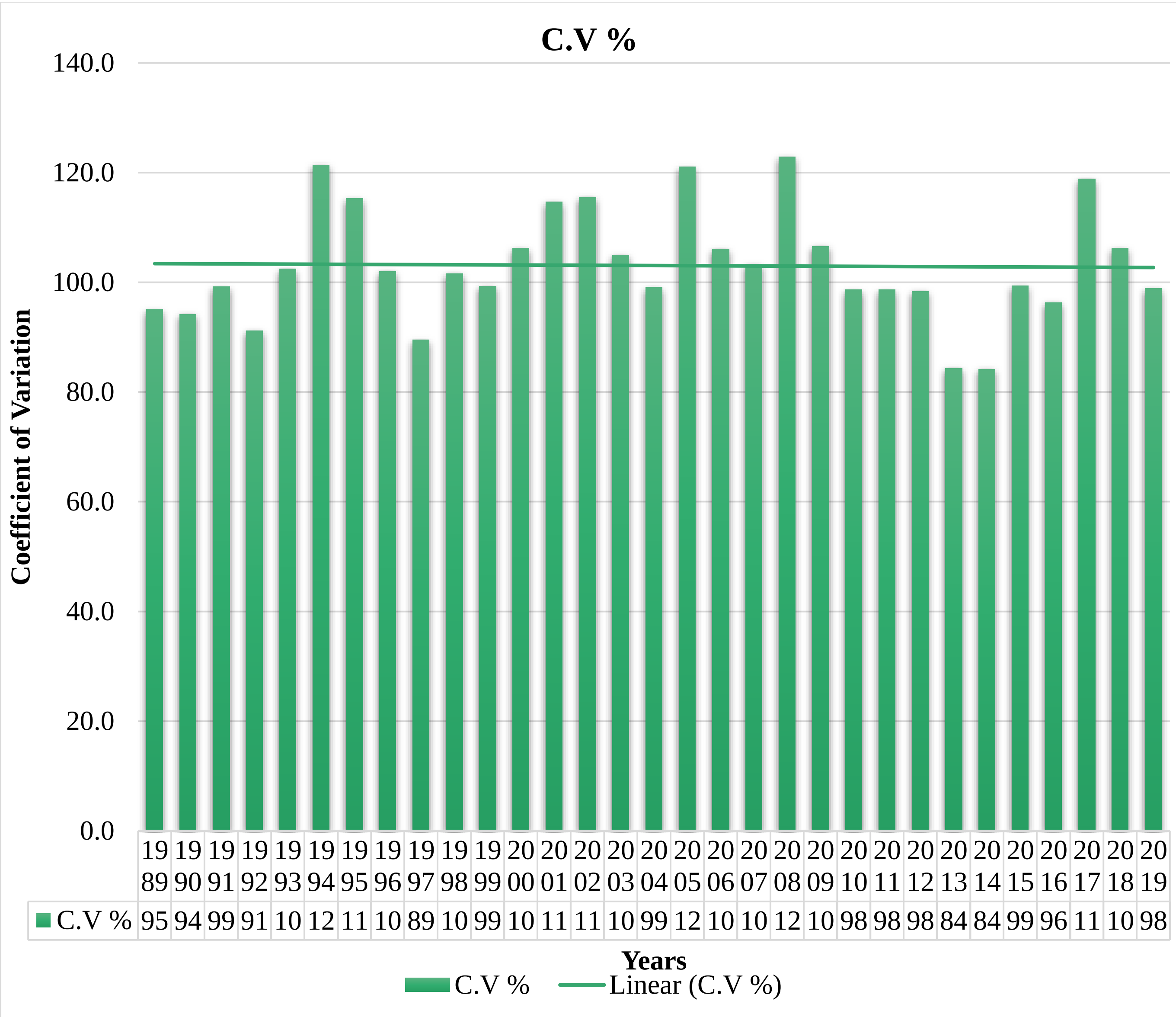


Figure 4.2: Coefficient of Variation Chart

4.2.3 Coefficient of Variation Summary

Rainfall variability is expressed by the coefficient of variability (CV), evaluated as the standard deviation divided by the mean annual rainfall. It is expressed as a percentage and indicates the amount rainfall varies from average annual rainfall.

The year 2008 denote the highest coefficient of variation with a value of 122.9% followed by 1994(121.4%) and 2005 (121.1%), while the least was recorded in 2014 with a value of (84.2%) followed by the year 2013 (84.4%) and 1997(89.5%) as shown in table 3, these years' account for less variable rainfall.

4.2.4 Extreme Climate Events

From our annual rainfall table, the year 2009 to 2014 recorded intense weather events such as serious storm and flooding in the FCT. It was recorded that there was flooding which affected the FCT in 2009 in a study made by (OKOLOYE, AISIOKUEBO, UKEJE, & ANUFOROM, 2013). From our coefficient of variability data in table 3, it was observed that 2008 denoted the highest coefficient of variation with a value of 122.9%, and a recorded value of 106.6% in 2009, this means there is high rainfall variability which might be the cause of the 2009 flooding in the FCT.

4.3 CLIMATOLOGICAL RECORDS FROM 1989 TO 2019

This section analyzed the climatological data from 1989 to 2019, how these data varies and their impact on the reservoir level of lower Usuma dam. Given below are the climatological records for Abuja including rainfall, Evaporation data and Lower Usuma dam Reservoir Water Level Data.

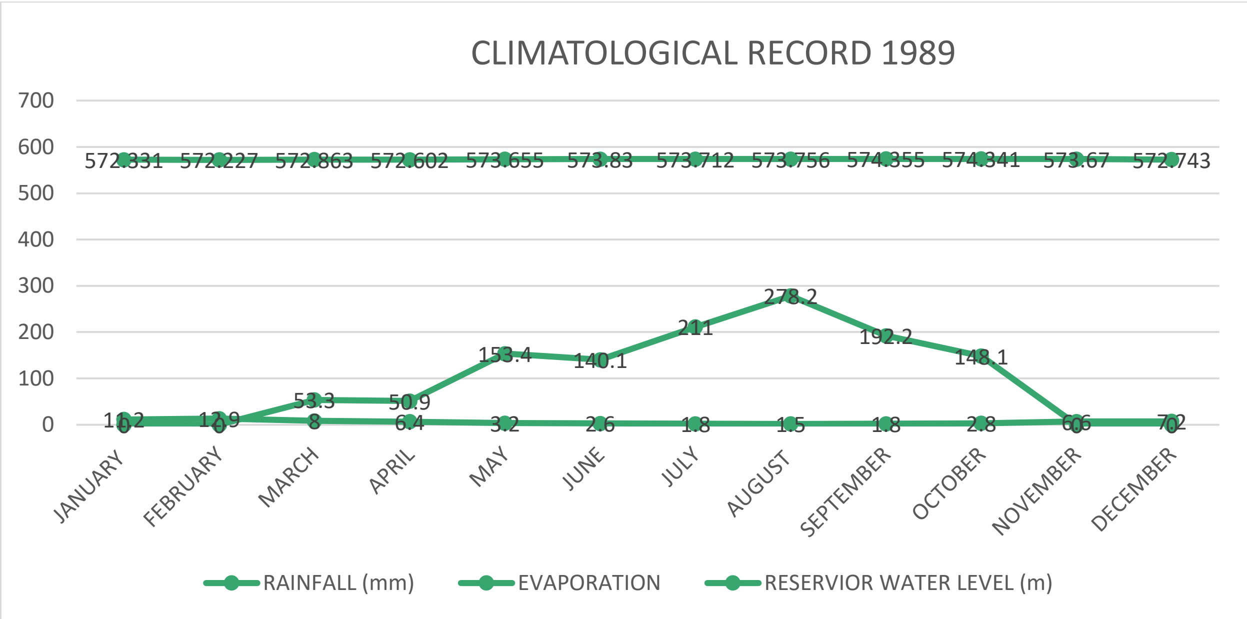


Figure 4.3.1: Climatological Record Chart 1989

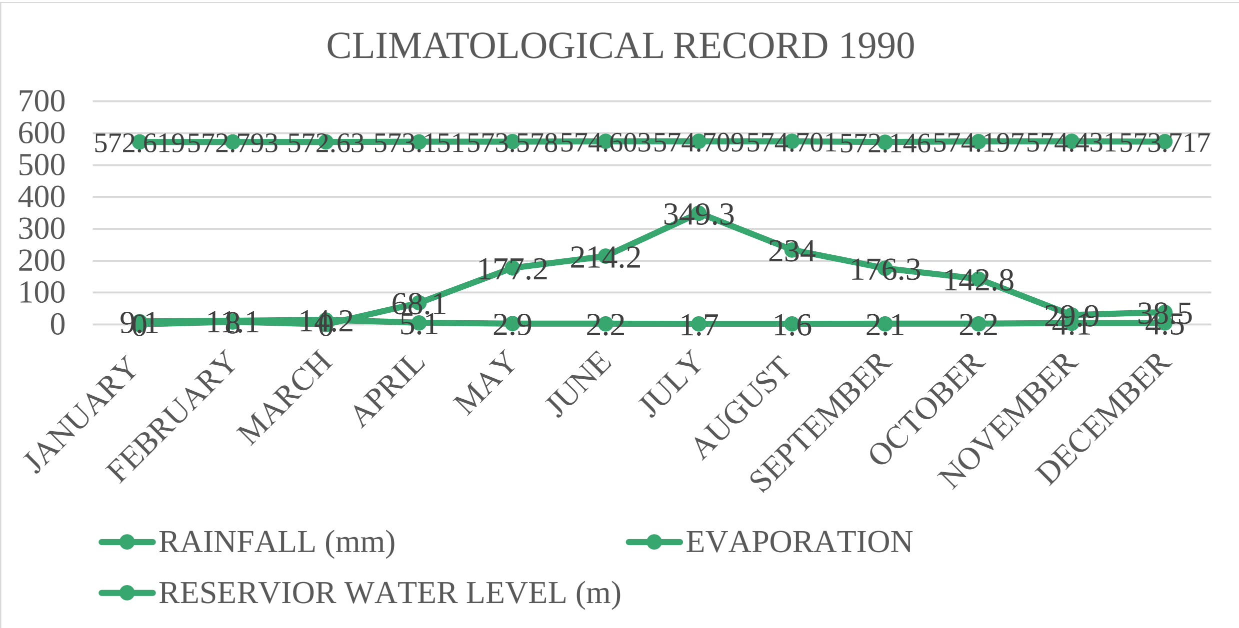


Figure 4.3.2: Climatological Record Chart 1990

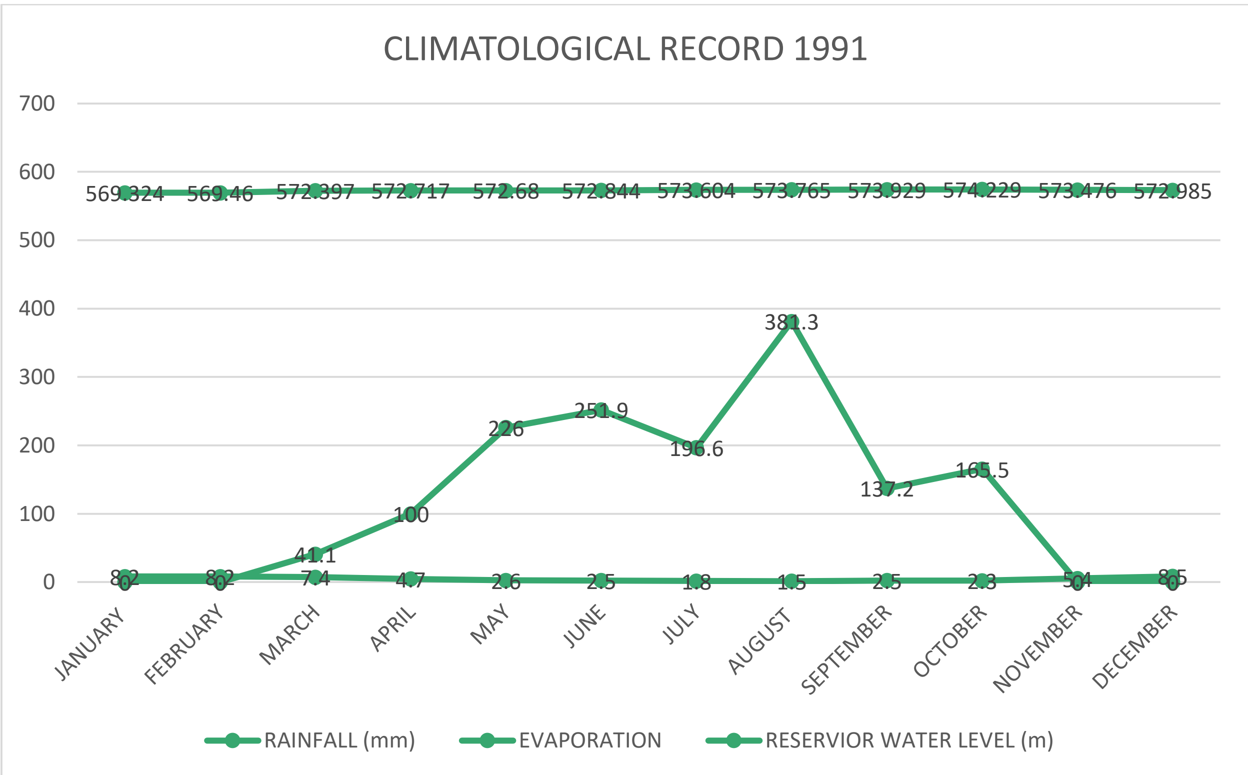


Figure 4.3.3: Climatological Record Chart 1991

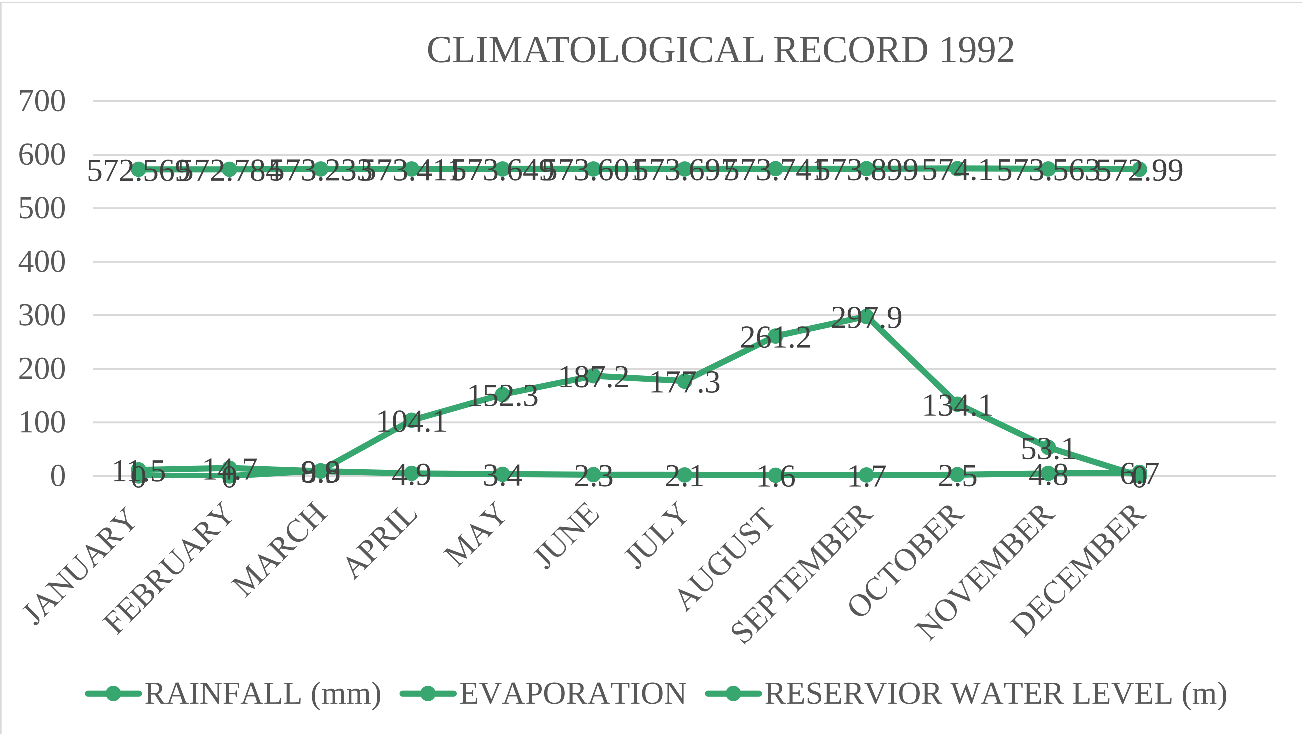


Figure 4.3.4: Climatological Record Chart 1992

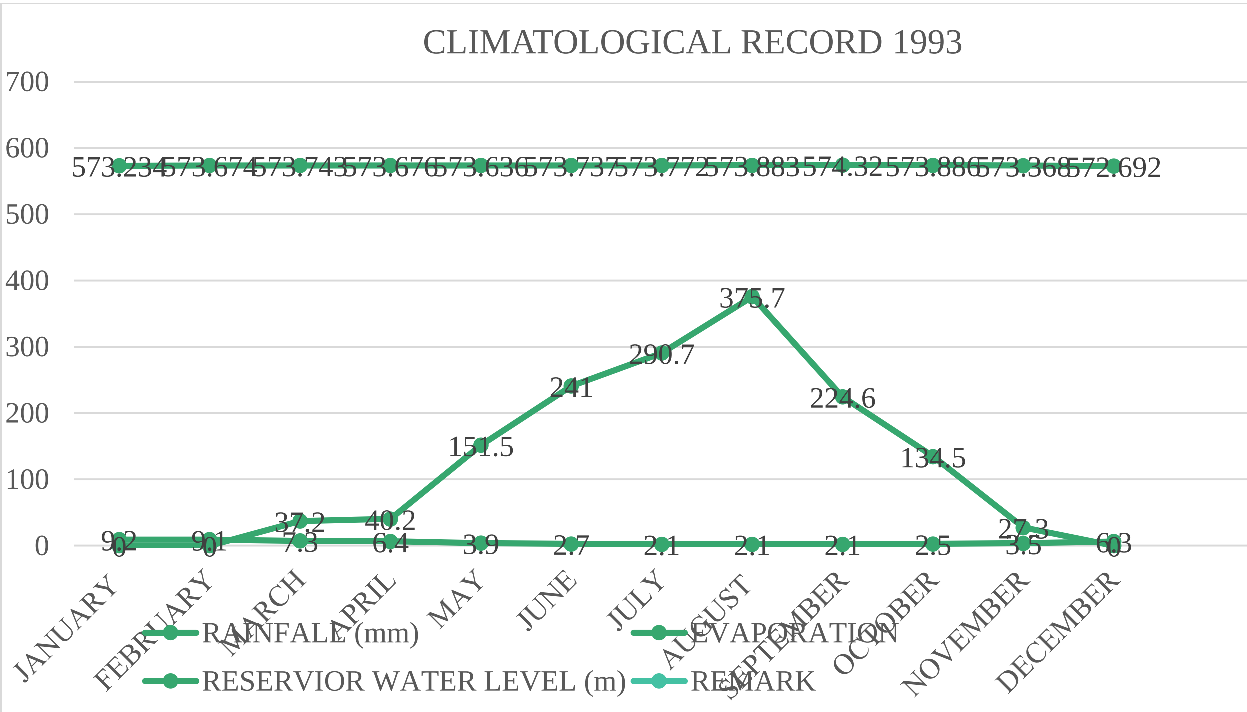


Figure 4.3.5: Climatological Record Chart 1993

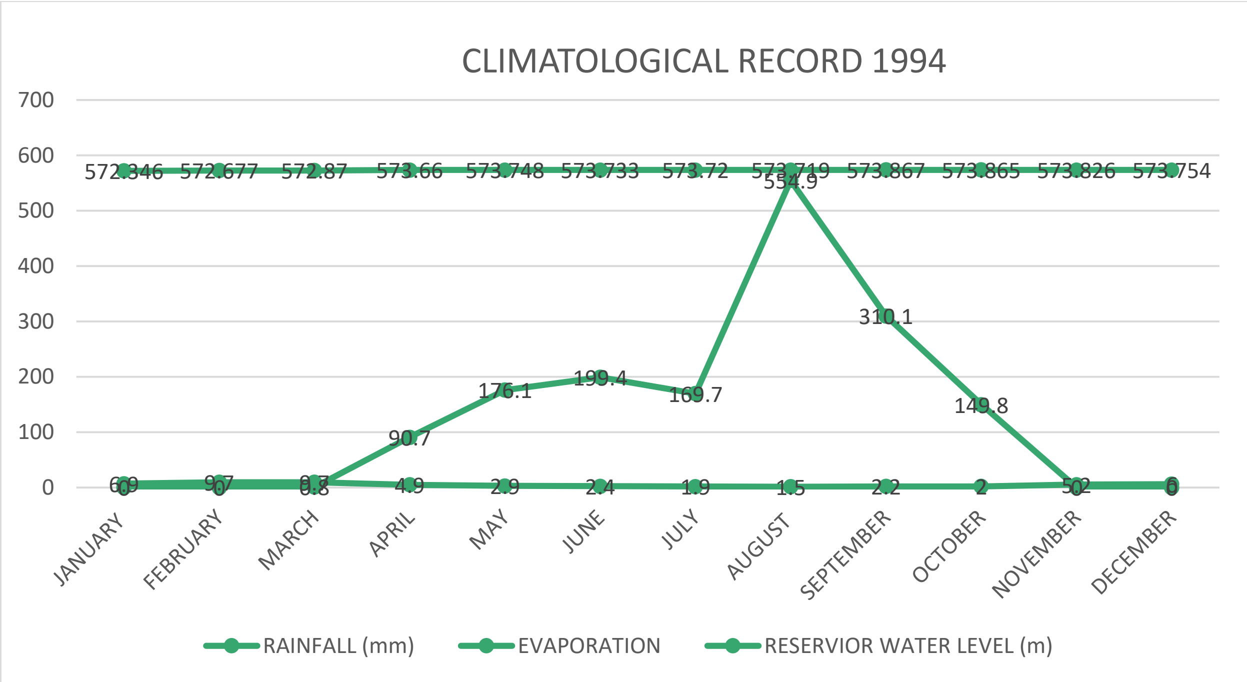
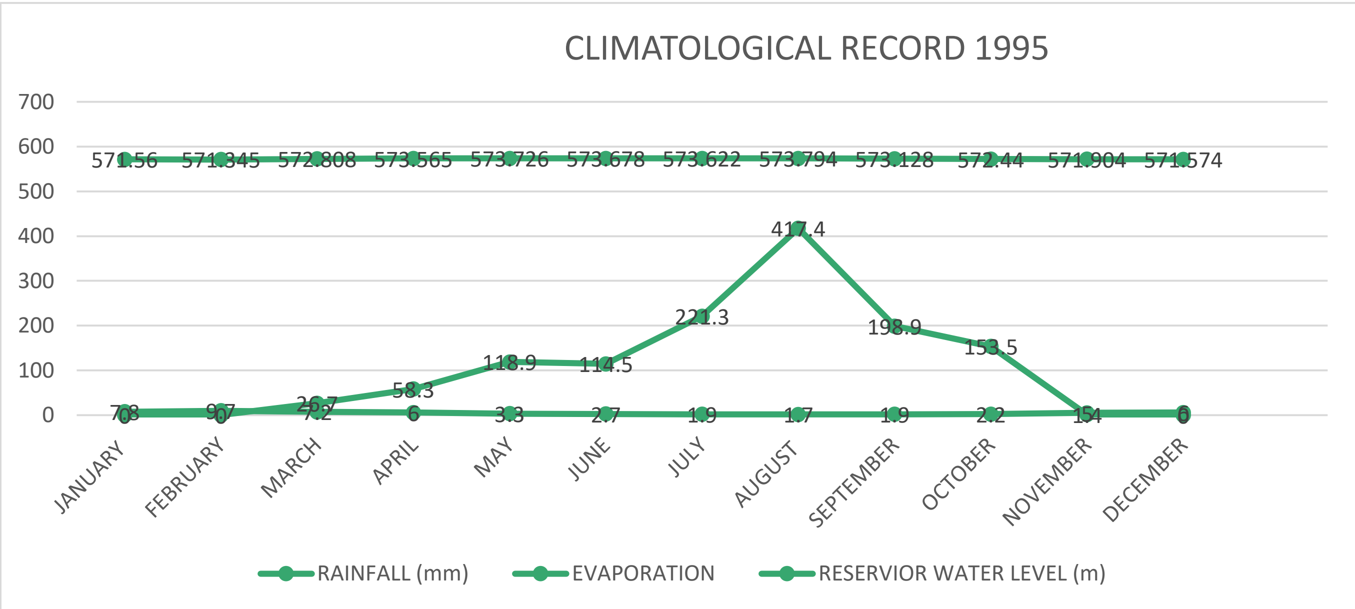


Figure 4.3.6: Climatological Record Chart 1994



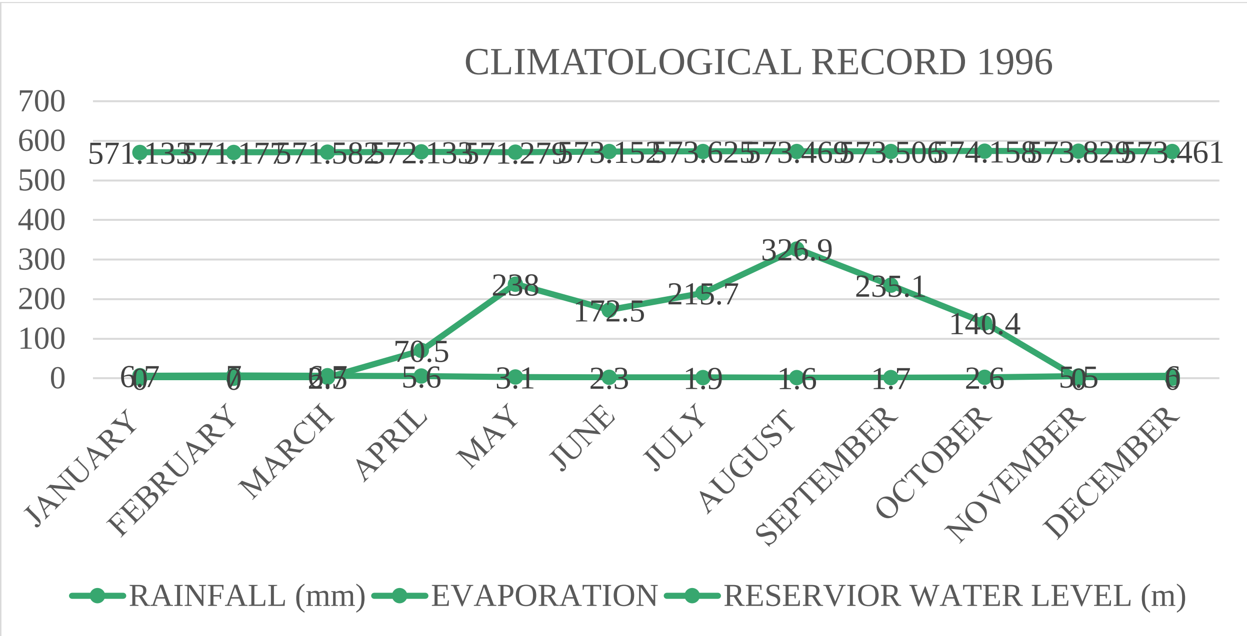


Figure 4.3.8: Climatological Record Chart 1996

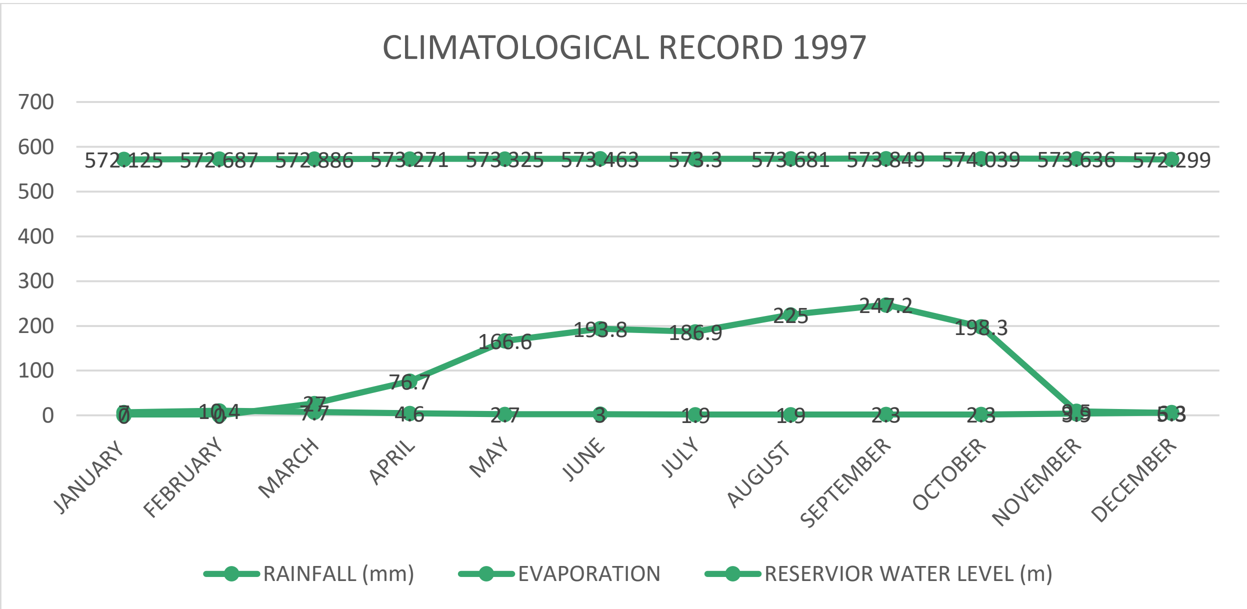


Figure 4.3.9: Climatological Record Chart 1997

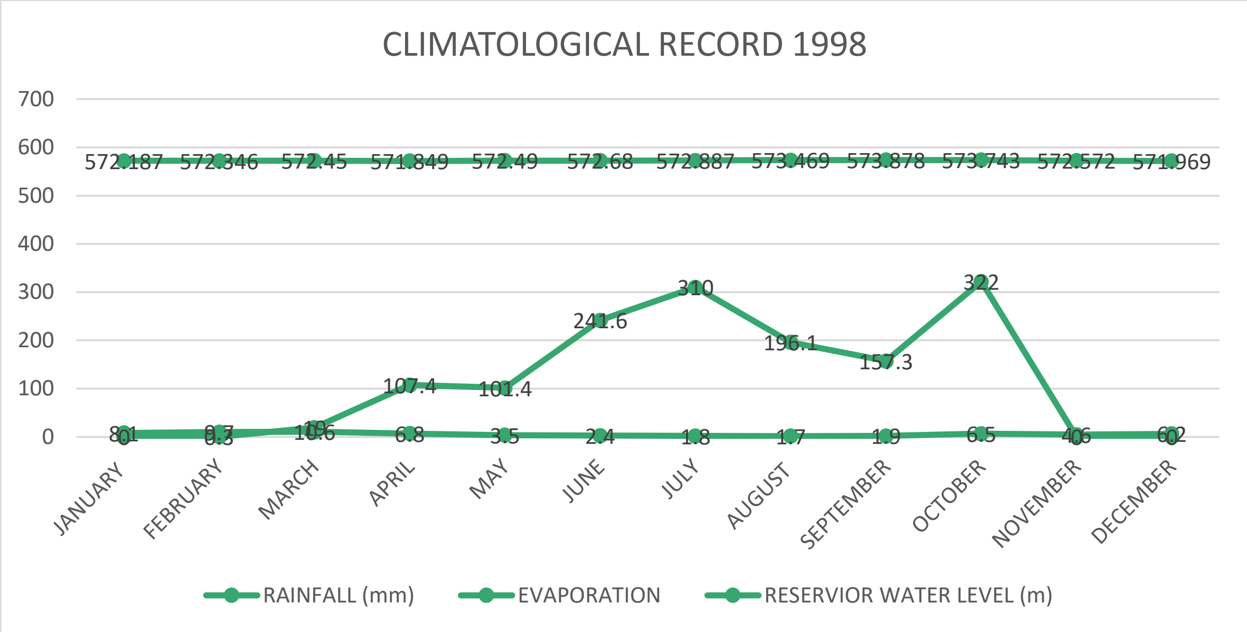


Figure 4.3.10: Climatological Record Chart 1998

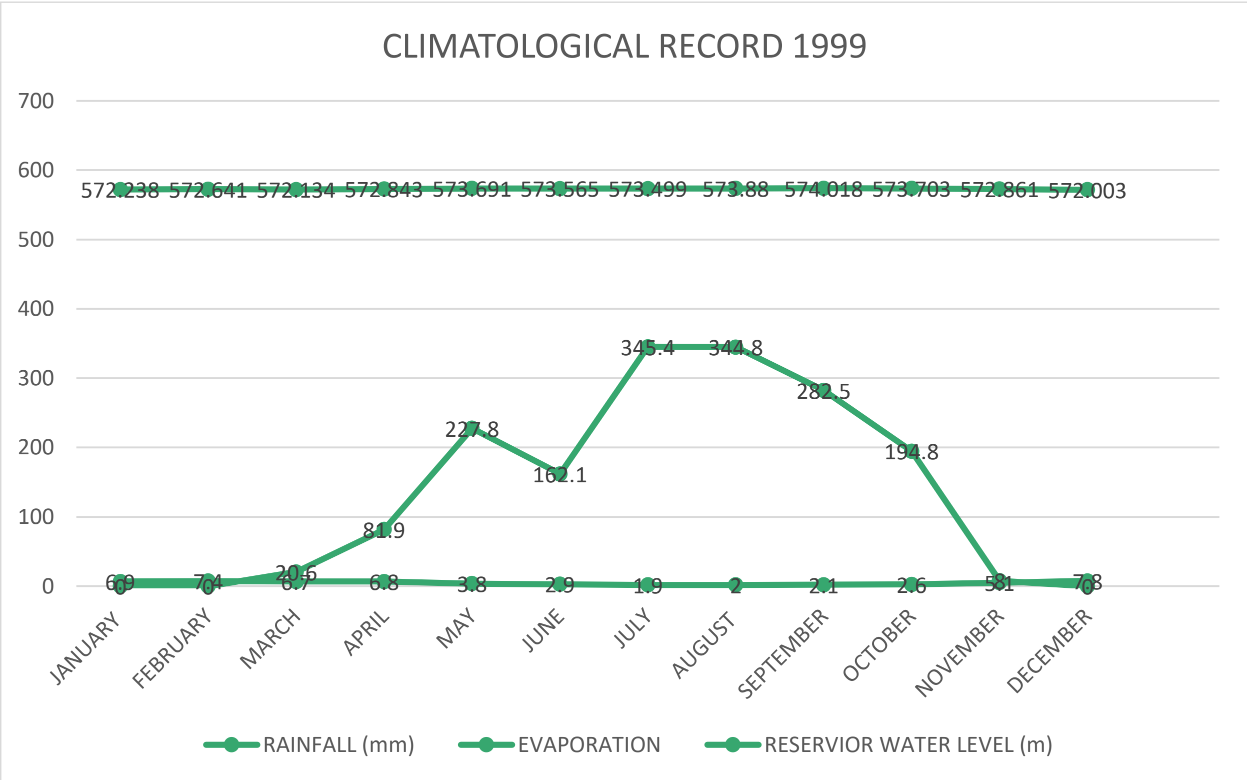


Figure 4.3.11: Climatological Record Chart 1999

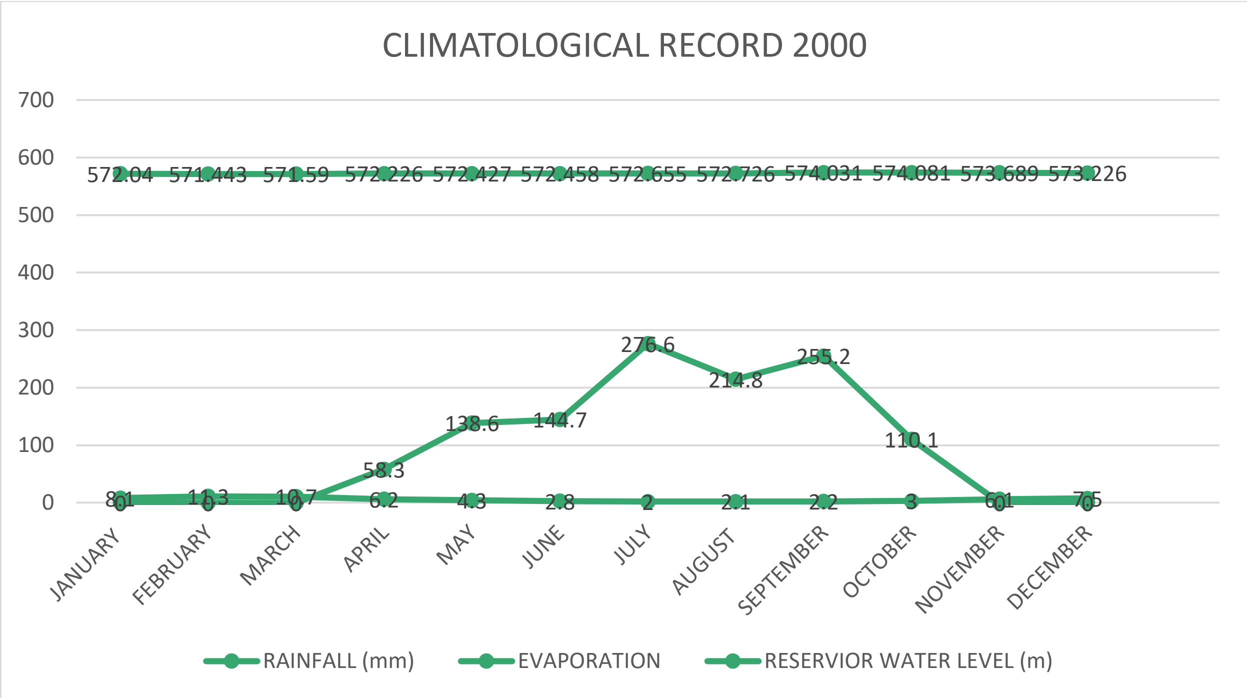


Figure 4.3.12: Climatological Record Chart 2000

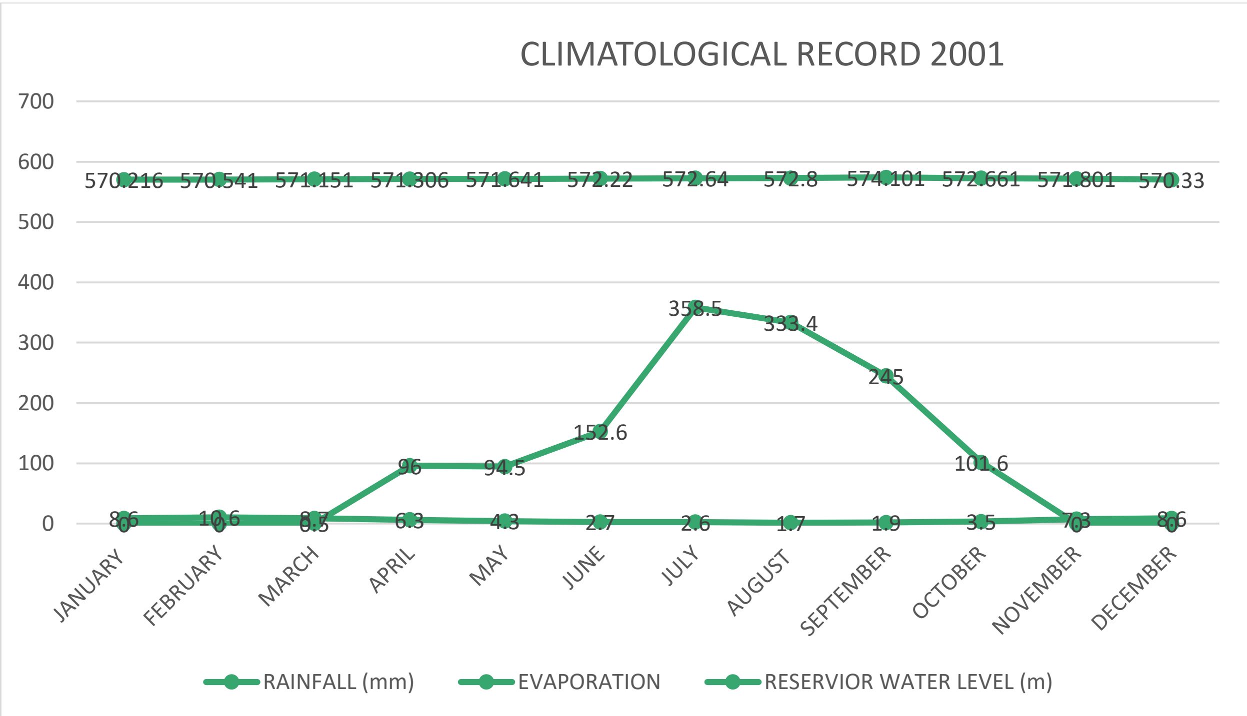


Figure 4.3.13: Climatological Record Chart 2001

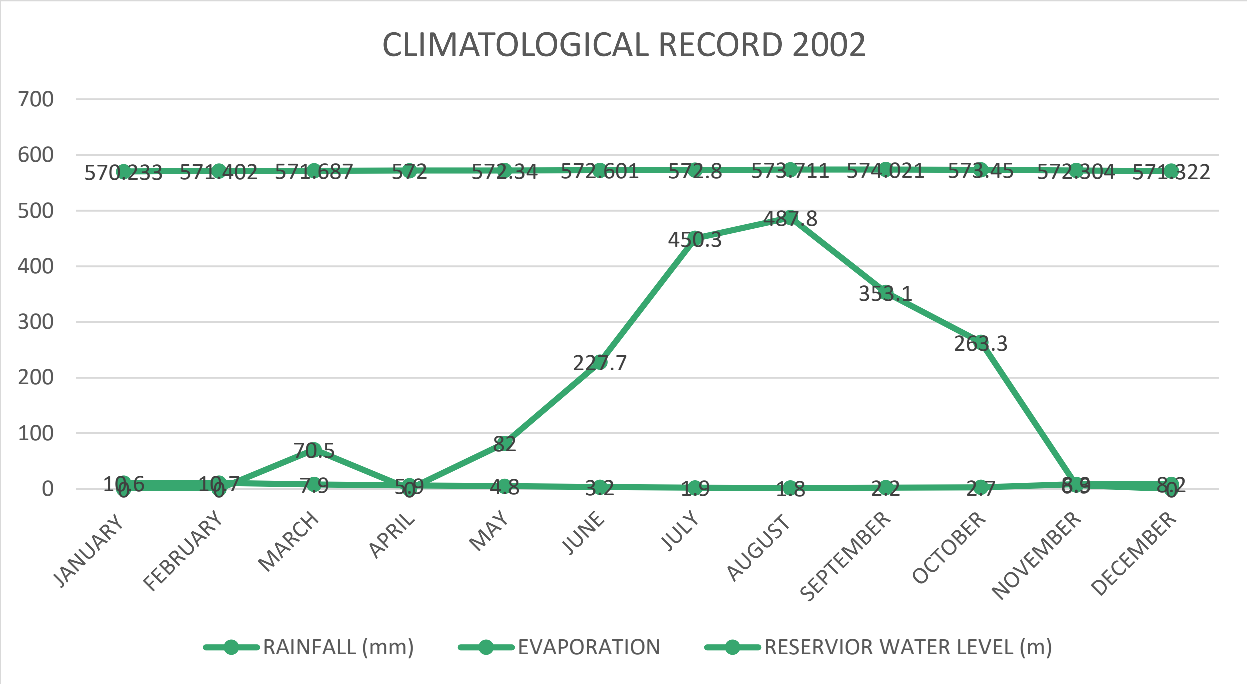


Figure 4.3.14: Climatological Record Chart 2002

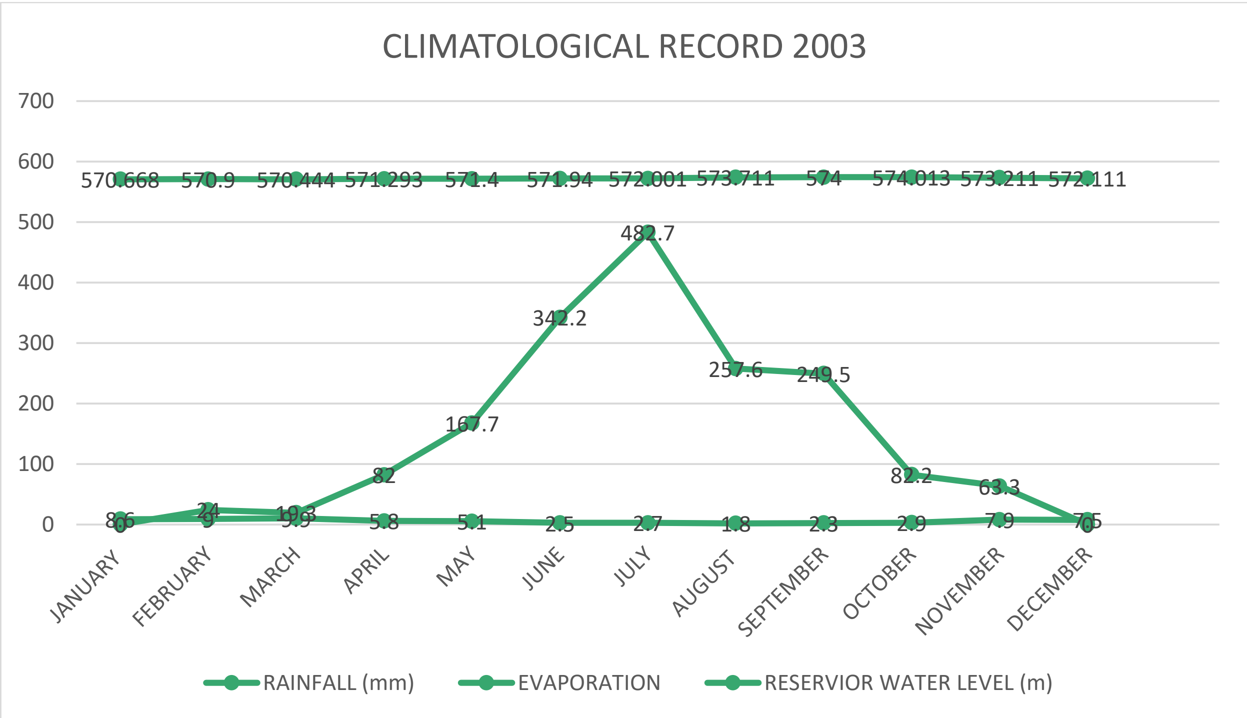


Figure 4.3.15: Climatological Record Chart 2003

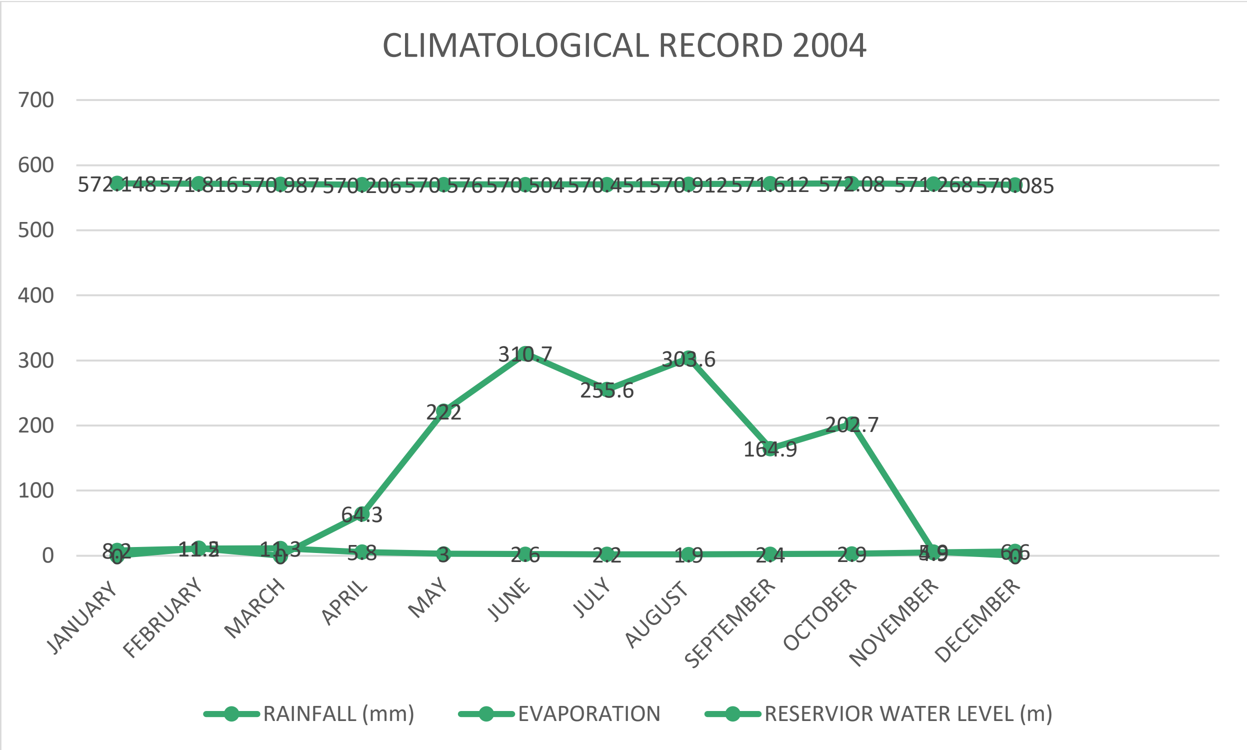


Figure 4.3.16: Climatological Record Chart 2004

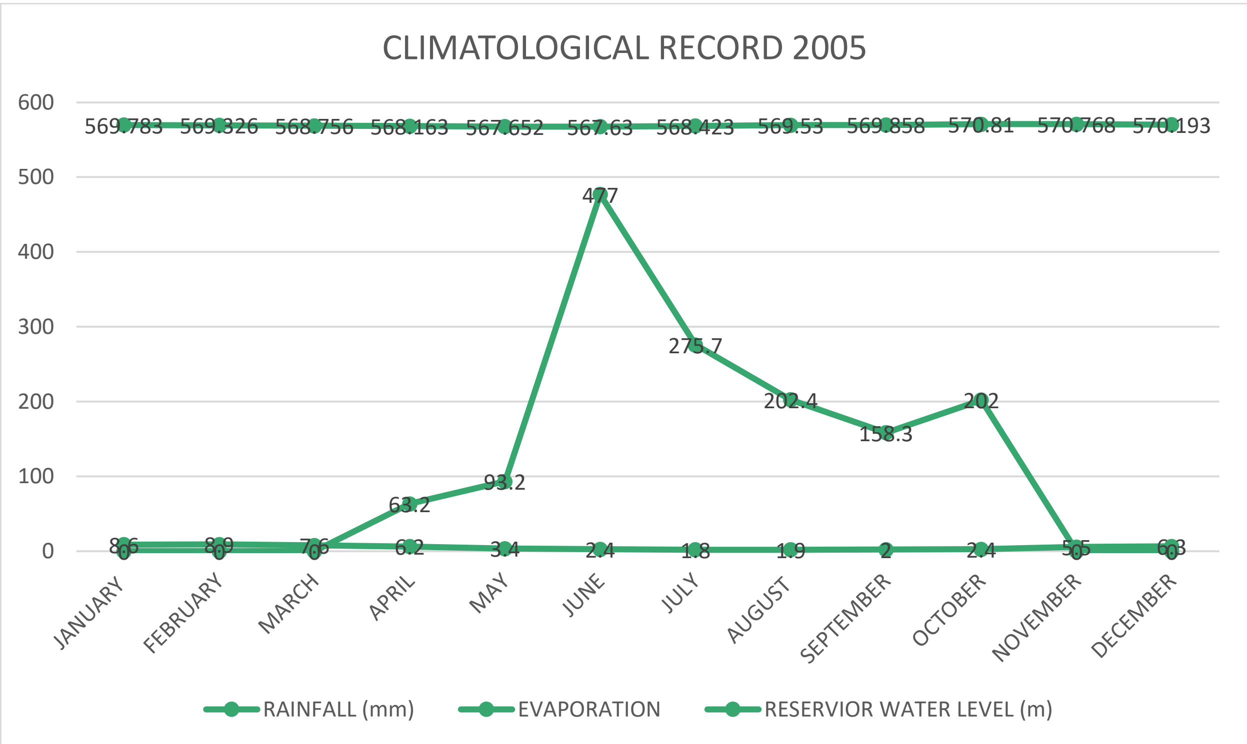


Figure 4.3.17: Climatological Record Chart 2005

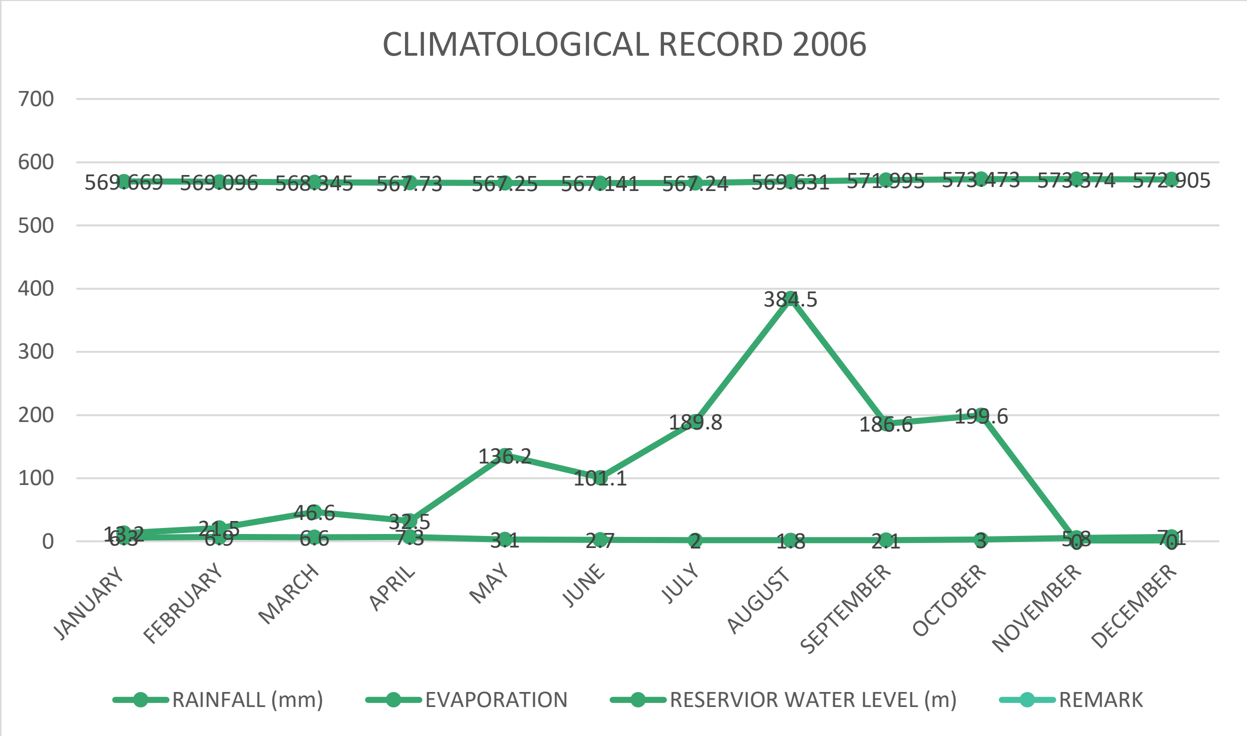


Figure 4.3.18: Climatological Record Chart 2006

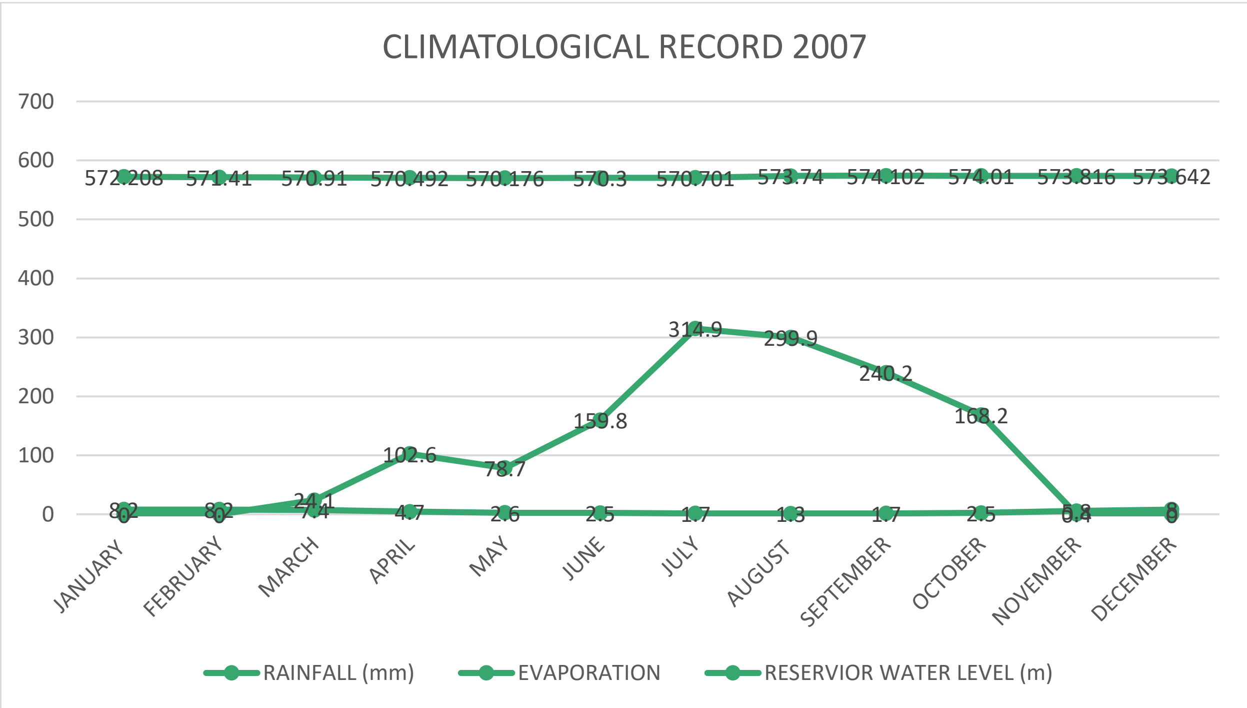


Figure 4.3.19: Climatological Record Chart 2007

In 2007 The onset of rainy season came in March with a low recorded data of 24.1mm. 2007 recorded a peak monthly rainfall of 314.9 mm in July which is within normal monthly rainfall of 300 to 500mm in Abuja. The depth of evaporation for the peak monthly rainfall was 1.7mm, this result shows that wetter than normal rainfall was observed over the city. The reservoir recorded the highest water level of 574.102 ft. in September. It was observed that rainfall cessation came in November. Second gate of the intake tower was opened in March when the water level was as low as 570.91ft. Second gate of the intake tower was closed in September at a level of 573.74ft. when the level rose.

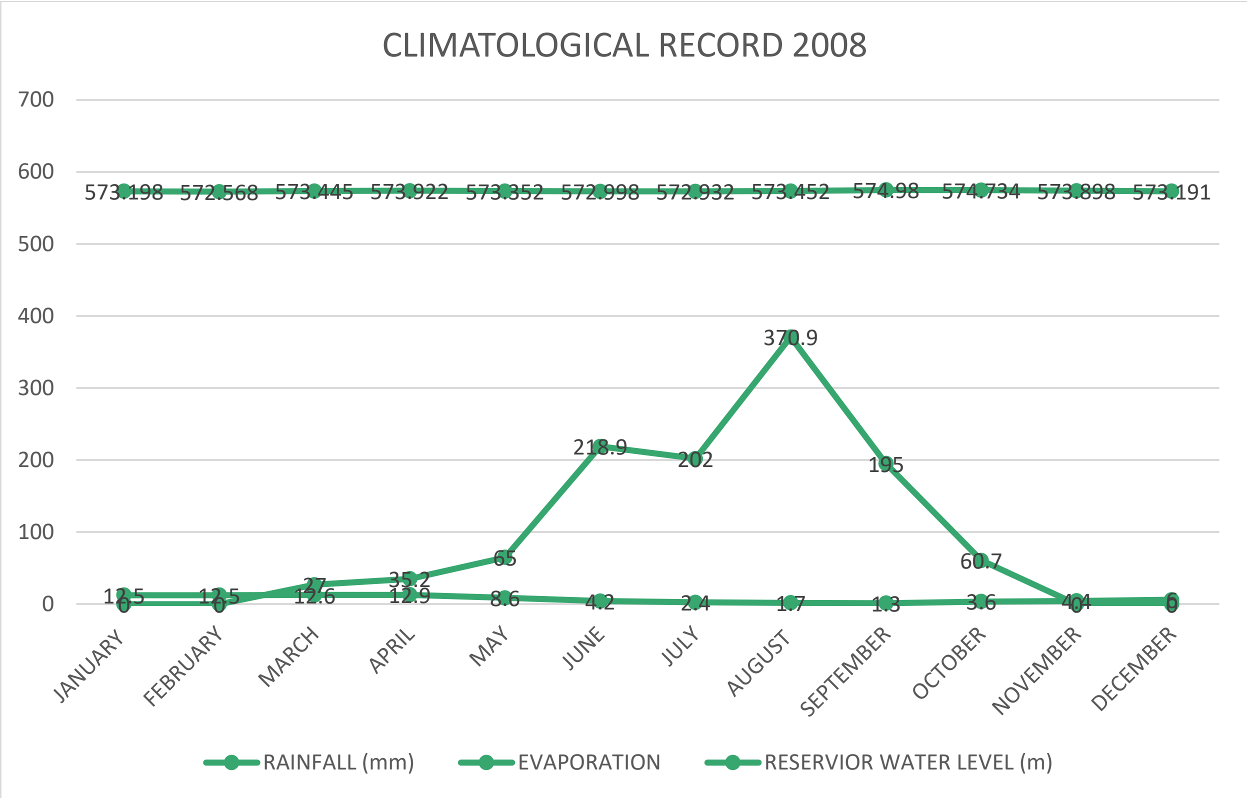


Figure 4.3.20: Climatological Record Chart 2008

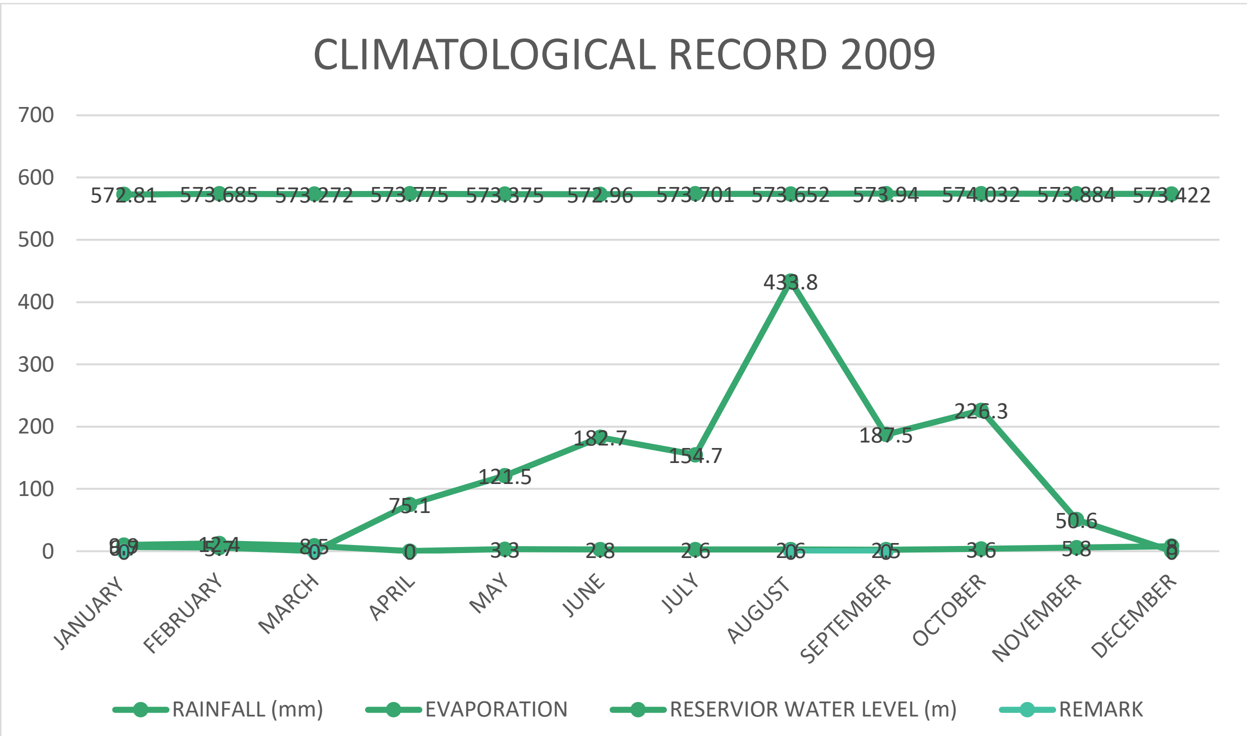


Figure 4.3.21: Climatological Record Chart 2009

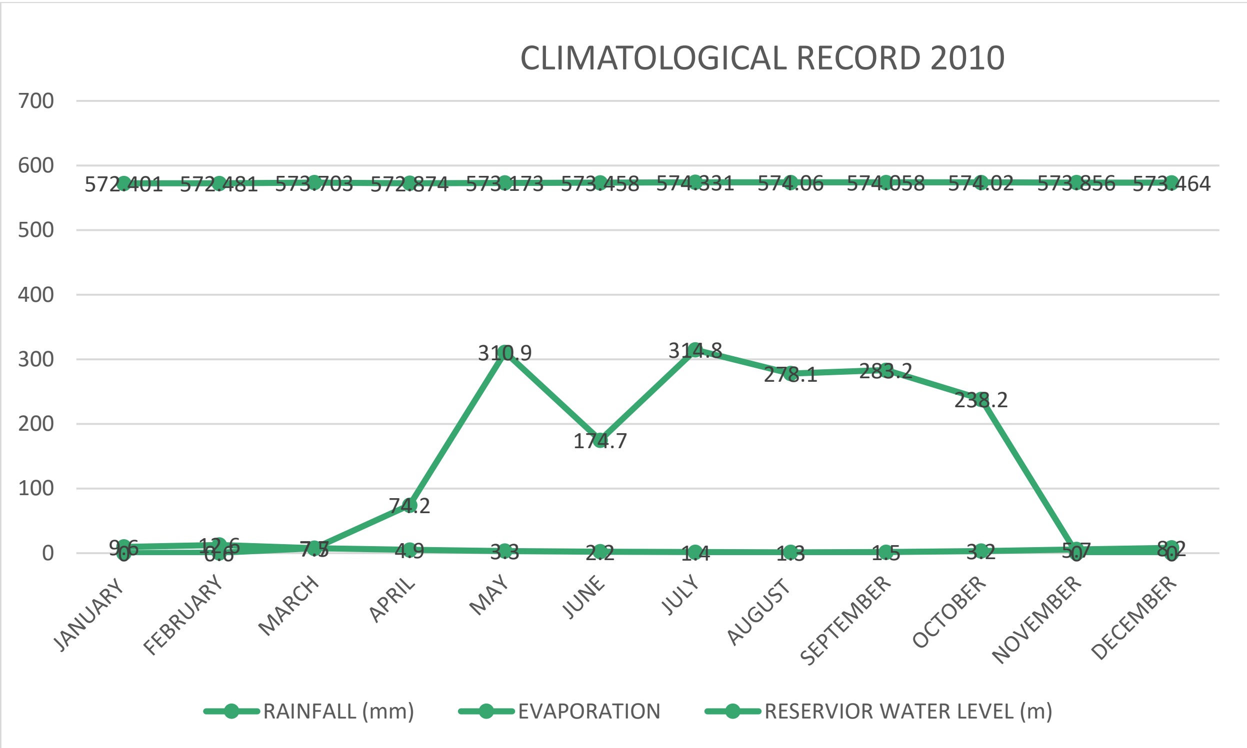


Figure 4.3.22: Climatological Record Chart 2010

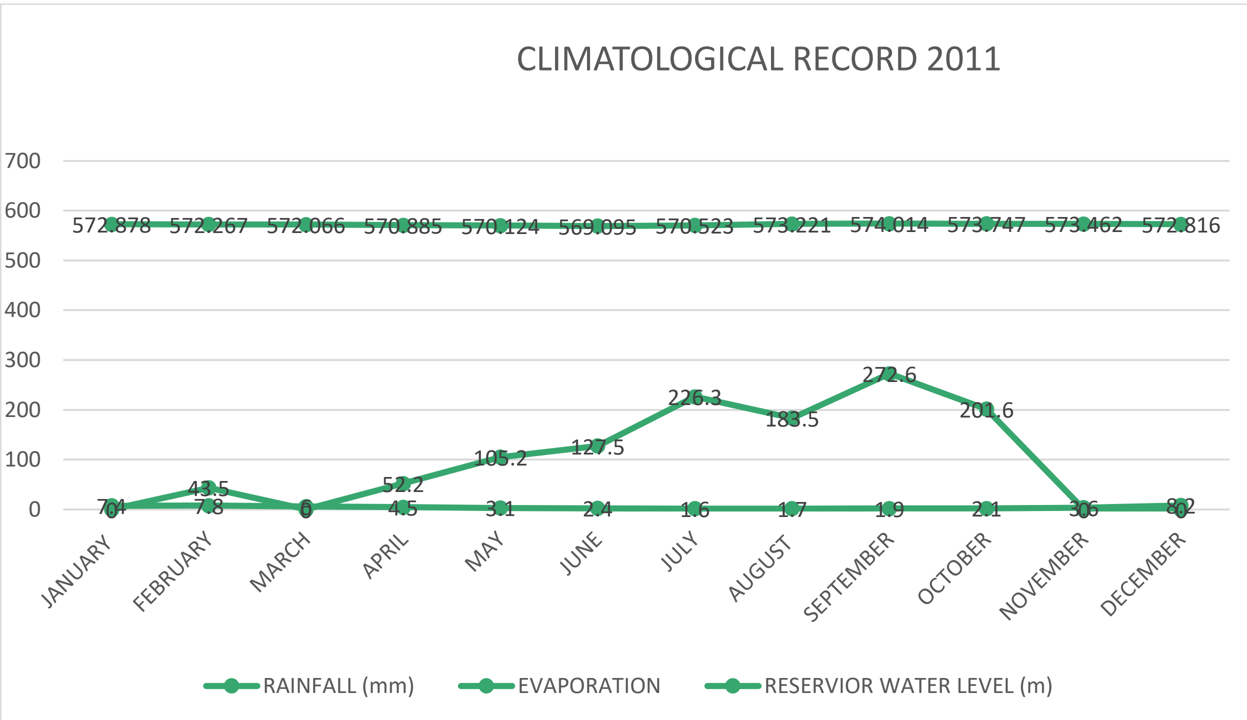


Figure 4.3.23: Climatological Record Chart 2011

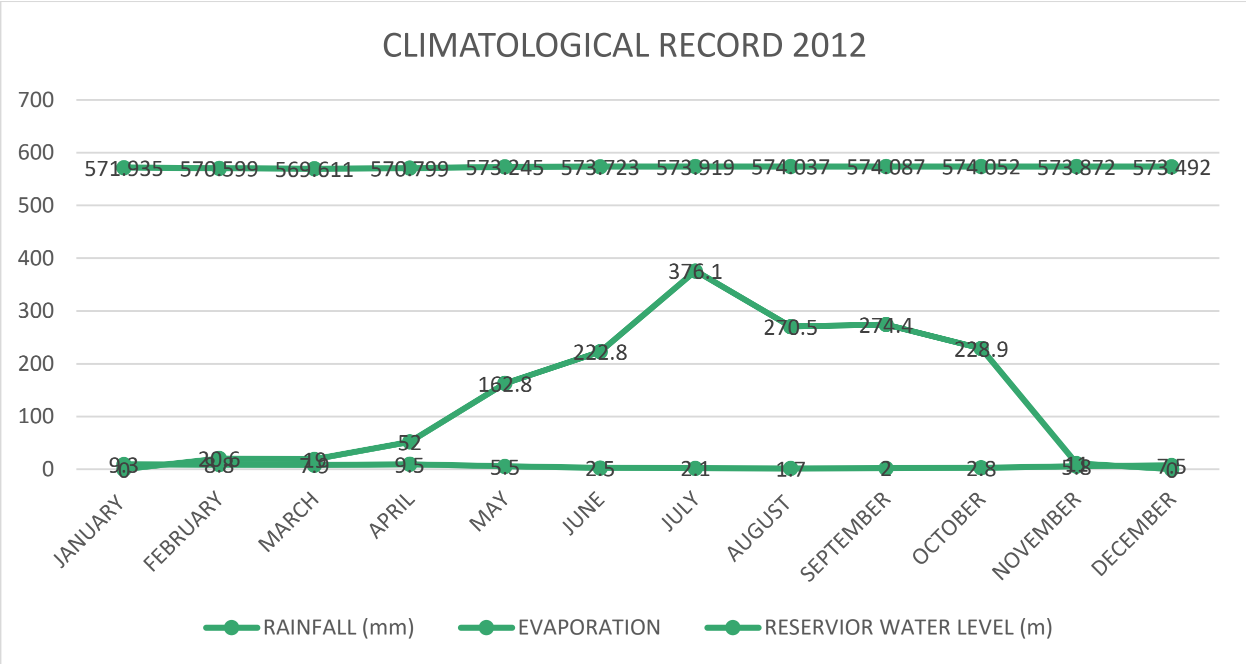


Figure 4.3.24: Climatological Record Chart 2012

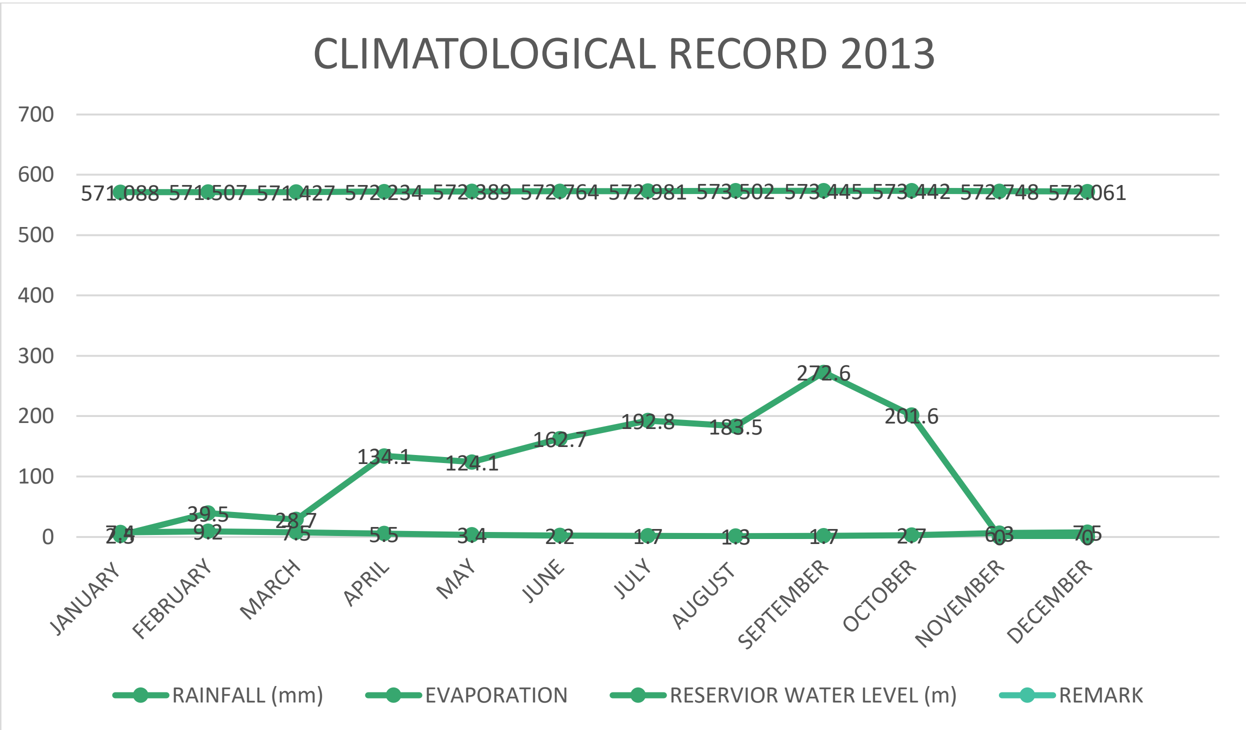


Figure 4.3.25: Climatological Record Chart 2013

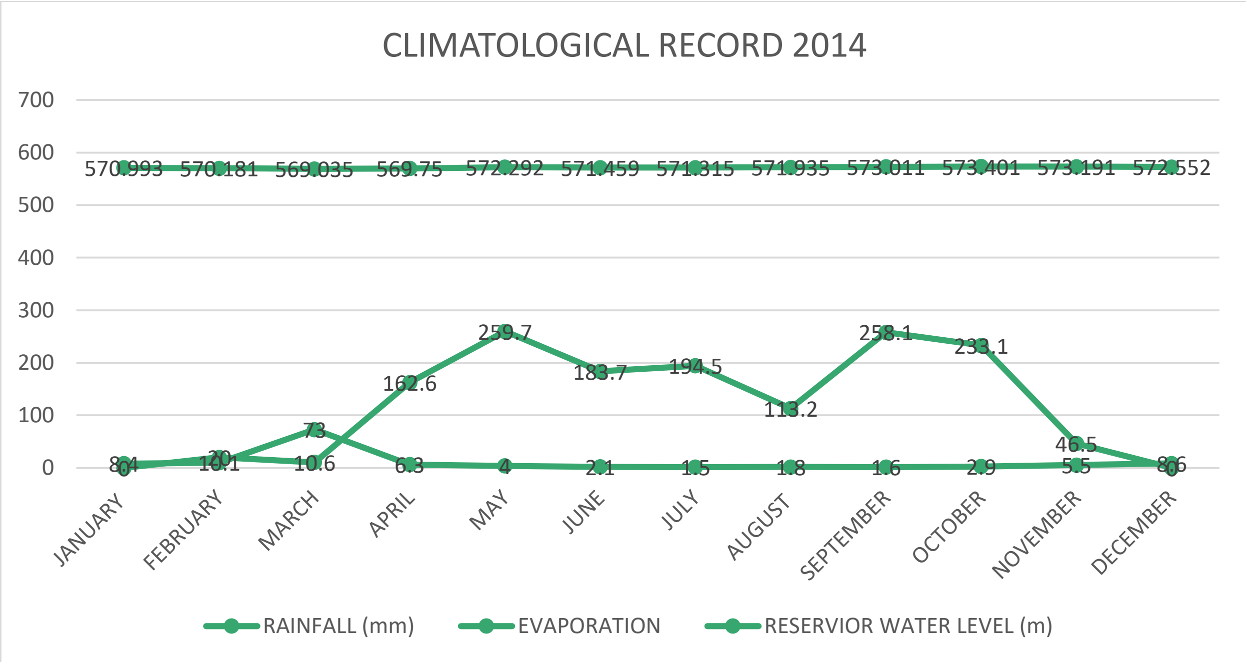


Figure 4.3.26: Climatological Record Chart 2014

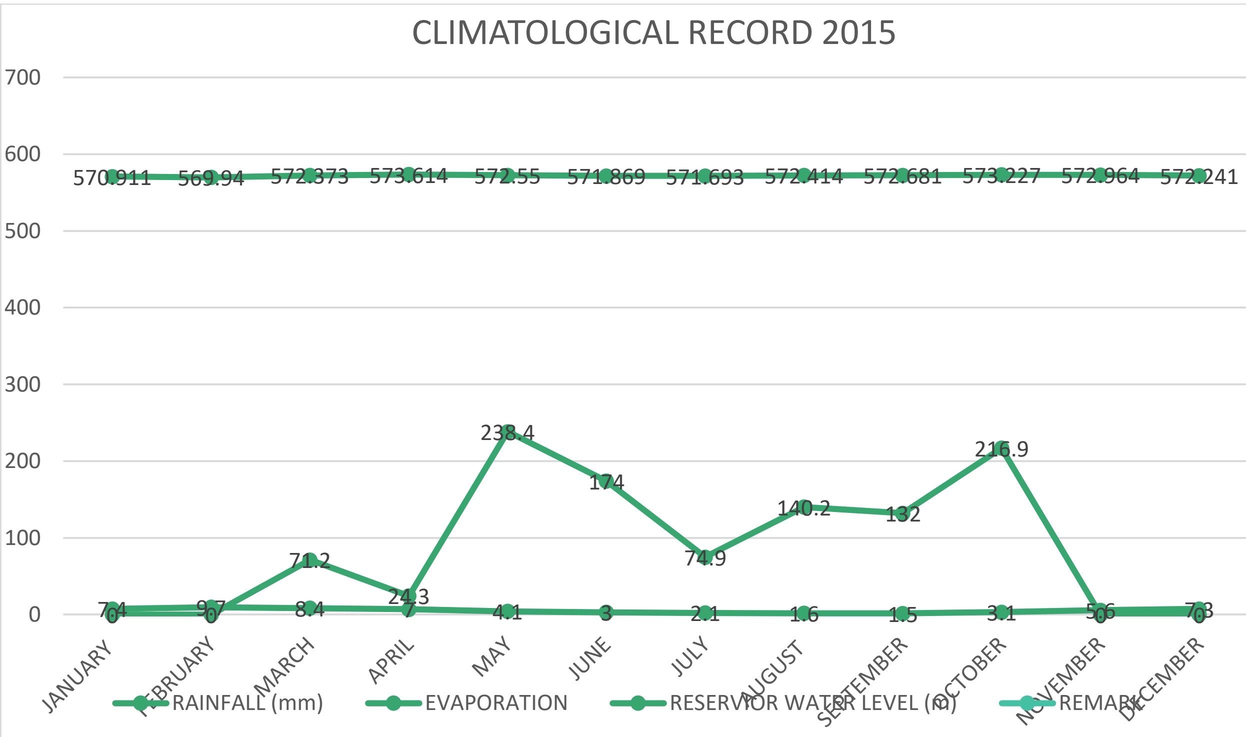


Figure 4.3.27: Climatological Record Chart 2015

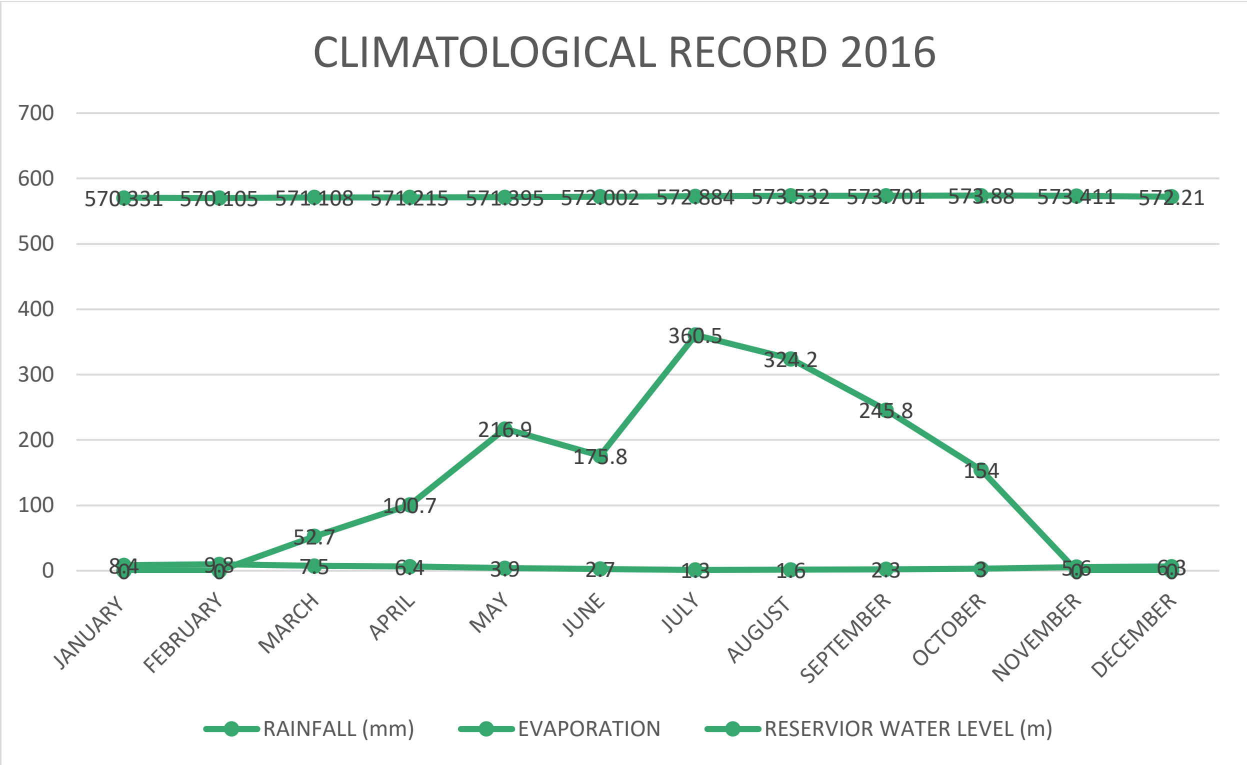


Figure 4.3.28: Climatological Record Chart 2016

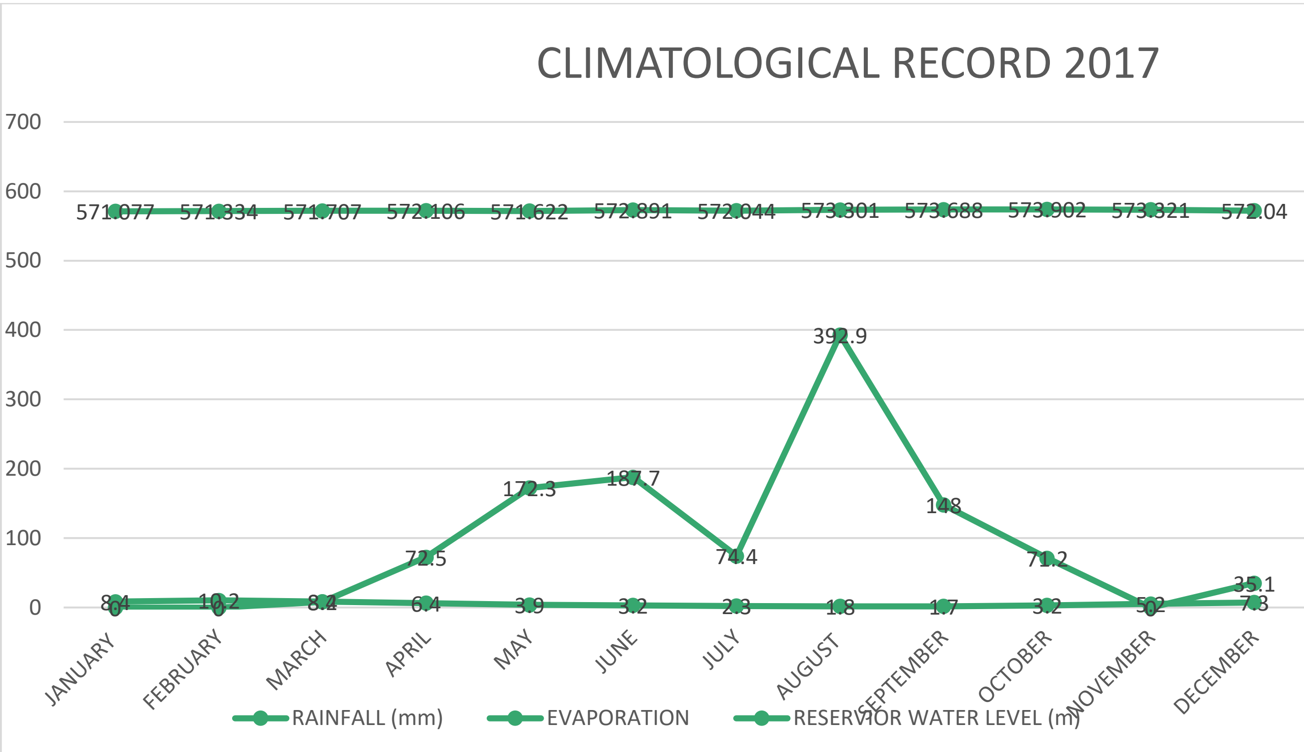


Figure 4.3.29: Climatological Record Chart 2017

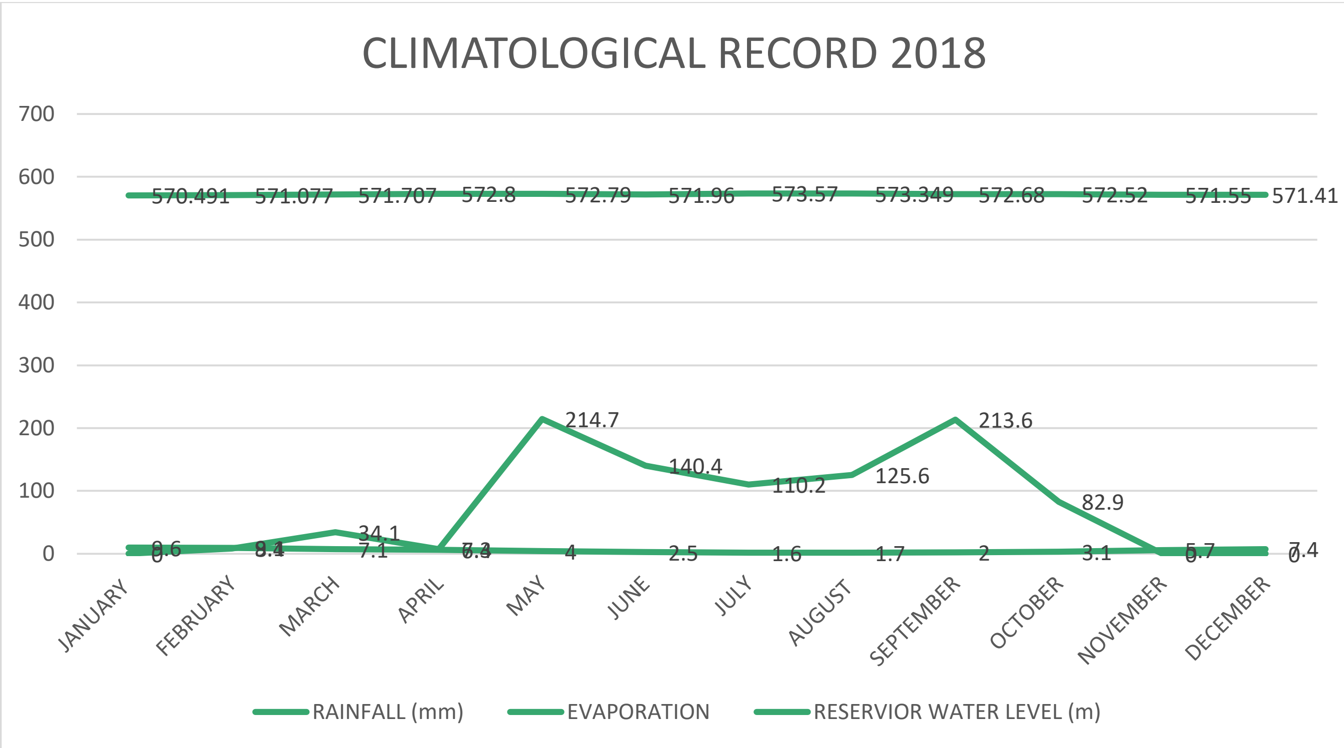


Figure 4.3.30: Climatological Record Chart 2018

In 2018 The onset of rainy season came early in February with a low recorded value of 8.4mm. 2018 recorded a peak monthly rainfall of 214.7 mm in May which is slightly below normal monthly rainfall of 300 to 500mm in Abuja. the depth of evaporation for the peak monthly rainfall was 4mm. this shows that drier than normal rainfall was observed over city. There was a recorded water level with a highest level of 573.570 ft. in July. Gurara gate was opened in January when the water level was low to a level of 570.491ft. The gate was closed in February at a level of 571.077ft.

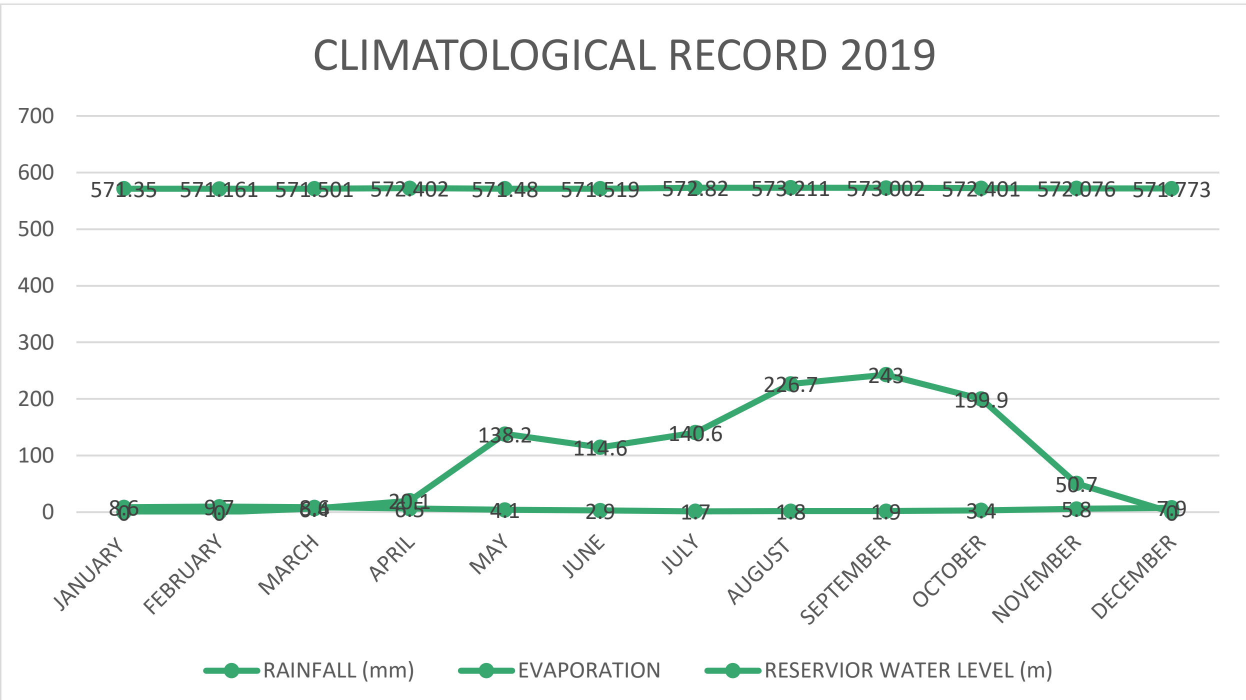


Figure 4.3.31: Climatological Record Chart 2019

Summary of Climatological Records

From our result it was observed that for last five years Gurara reservoir discharge duration was low in which the buildup of water level in the Usuma dam was not as from lasts five years back, this was as a result of variation in rainfall and decrease in rainfall which also affected the water level in Gurara reservoir. So Gurara has to regulate it services to lower Usuma dam for its own normal operation. And also due to high demand for drinking water and increased in the city population, the of raw water treated and Clean water discharged to the community has increased. In the last five years of this study from 2015 to 2019, the reservoir water level has been varied with a downward trend below 574ft., within these periods, the reservoir was characterizing with low pressure spilling or no spilling, with the highest average annual reservoir level of 573.614ft. in 2015, 573.880ft. (2016), 573.902ft. (2017), 573.570ft. (2018), and 573.161(2019) respectively. All these impacts were due to the downward trend and variability in the mean annual rainfall during this period.

4.4 Abuja Population Estimation

1991 and 2006 census and the estimated 2016 population data for Abuja were given in the table below;

Table 4. 4: Abuja Population

YEARS	**POPULATION**
1991 (CENSUS)	371,674
2006 (CENSUS)	1,405,201
2016 (ESTIMATED)	3,564,126

Source: (NATIONAL BUREAU OF STATISTICS (NBS), n.d.)

The above data were used to estimate 2026 and 2036 population using the formulas below.

4.4.1 Estimation of 2026 and 2036 population using 1991, 2006.2016 Data;

1991, 2006 and 2016 data were used to obtained two different Kp i.e. (Kp1 and Kp2), then their average were found (Kp.avr) to get the estimated data for 2026 and 2036 respectively.

Since Abuja is a fast-growing city, therefore its population will grow geometrically. the geometric progression formula for population is given below;

$$P2 = P1e^{kp(t2-t1)}$$

Kp is the coefficient and is express as below;

$$kp = ln(\frac{p2}{p1})/(t2 - t1)$$

Data

P1= P2006= 1,405,201
P2= P1991= 371,674
t2= 2006
t1= 1991

For Kp1

$$kp = ln(\frac{p2006}{p1991})/(t2 - t1)$$

$$kp = ln(\frac{1{,}405{,}201}{371{,}674})/(2006 - 1991)$$

Kp1 = 0.0887

For Kp2

$$kp = ln(\frac{p2016}{p2006})/(t2 - t1)$$

Data

P2016= 3,564,126

P2006= 1,405,201

t2= 2016

t1= 2006

$$kp = ln(\frac{3,564,126}{1,405,201})/(2016 - 2006)$$

Kp2 = 0.0931

For Kp(avr)

Kp (average)= $\frac{kp1+kp2}{2}$

Kp(avg)= $\frac{0.0887+0.0931}{2}$

Kp(avg)= 0.0909

Table 4. 5: Abuja Population Estimation Using Geometry Progression

S/N	YEARS	POPULATION (GIVEN)	POPULATION (ESTIMATE) P2=P1×$e^{Kp(t2-t1)}$	Kp Kp=In(p2/p1)/(t2-t1)
1	1991	371674		
2	2006	1405201		Kp1= 0.0887
3	2016	3564126		Kp2= 0.0931
4	2026		8845588	Kp(avr)= 0.0909
5	2036		21953329	Kp(avr)= 0.0909

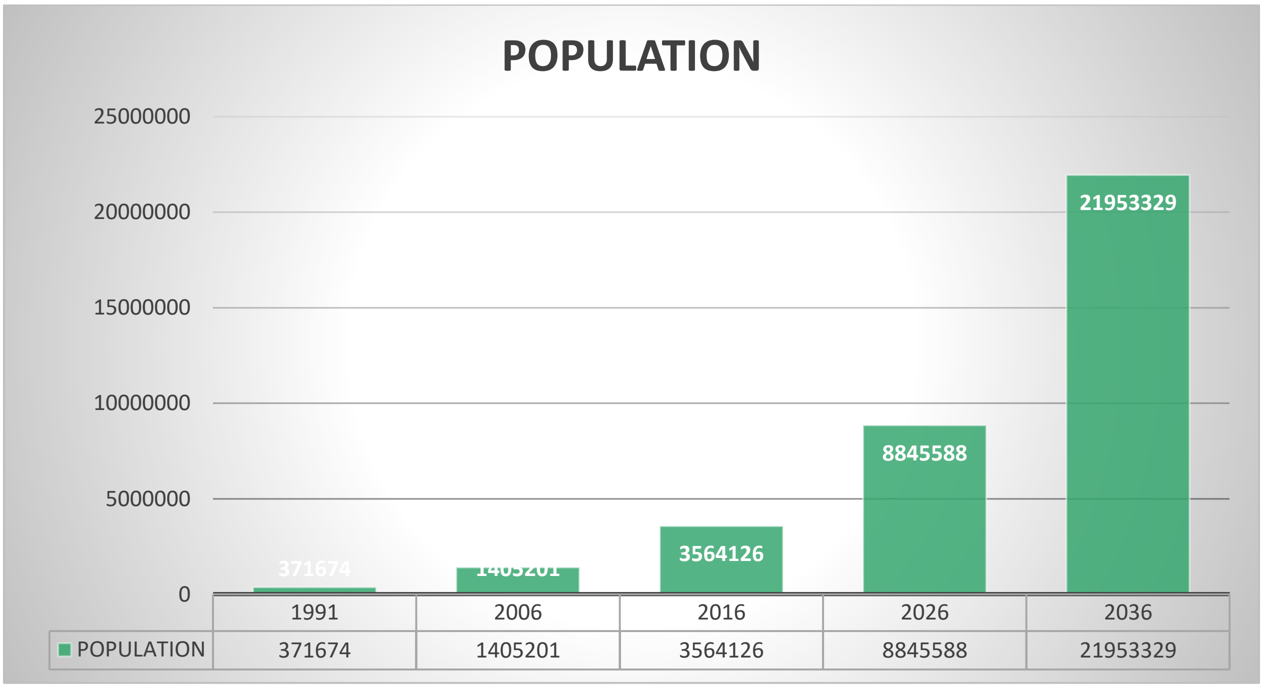


Figure 4.4. 1: Population Estimation Chart

4.5 WATER QUANTITY ESTIMATION

The quantity of water required for municipal uses for which water scheme has to be designed requires following data

1. Water consumption rate (per capital demand in liter per day per head)
2. Population to be served.

Quantity= per capital demand × population

In this study I considered 200lpcd to be the per capital demand for Abuja.

For the Year 2026 Water Quantity Estimation

The quantity of water required for municipal uses which the water scheme need to provide will be, per capital demand of 200Liters multiplied by estimated population of 2026.

Estimated 2026 Population= 8,845,588

Per capital demand= 200Liters

Therefore;

Q= 8845588×200 = 1769117600LPD (Liters Per Day)

= 1769MLPD (Million Liters Per Day)

For the Year 2036 Water Quantity Estimation

The quantity of water required for municipal uses which the water scheme need to provide will be, per capital demand of 200Liters multiplied by estimated population of 2036.

Estimated 2026 Population= 21,953,329

Per capital demand= 200Liters

Therefore;

Q= 21953329×200 = 4390665800LPD (Liters Per Day)

= 4390MLPD (Million Liters Per Day)

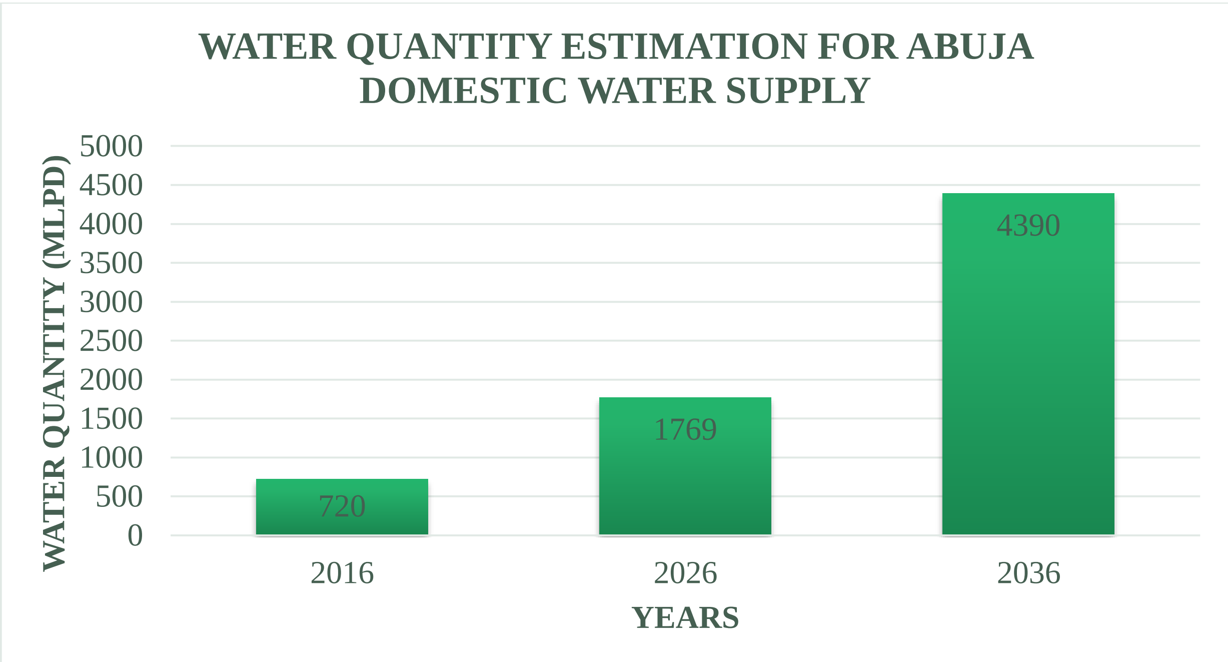


Figure 4.5.1: Water Quantity Estimation Chart

The FCT is still maintaining 720MLPD (million liters per day) water quantity supply to its citizen as domestic water supply till date. From the population chart above it was observed that Abuja population will rise to an estimated value of 8,845,588 in the year 2026 and to 21,953,329 in the year 2036. From the water quantity estimation chart, it was revealed that the water quantity required by the estimated population will rise to 1769 MLPD (million liters per day) by 2026 and to 4390MLPD (million liters per day) respectively. Therefore, with this analysis a proper water resources management should be put in place to carter for this need. And this can be achieved by Understanding the rainfall variability for these upcoming years where by utilizing the findings to solve this problem.

5. CONCLUSION AND RECOMMENDATION :

This paper provides valuable insight on the effect of rainfall variability on reservoir level and water resources of lower Usuma dam FCT Abuja. The study revealed that water level of lower Usuma dam have been adversely affected within the last five years of this study (i.e., from 2015 to 2019) with regard to the reservoir yielding and flow capacities as a result of rainfall variability. The study revealed that there is a general decline in trend of rainfall in volume and occurrence. The results also revealed that 2018 recorded the least mean annual rainfall over the study years while 2002 recorded the highest within the three decades. The year 2008 has the highest coefficient of variation with a value of 122.9% followed by 1994(121.4%) and 2005 (121.1%), while the least was recorded in 2014 with a value of (84.2%) followed by the year 2013 (84.4%) and 1997(89.5%), these years' account for less variable rainfall. 1999 to 2009 decade recorded the highest amount of mean annual rainfall, followed by 1989 to 1998 and then 2010 to 2019 has the least mean annual rainfall among the decades. A downward rainfall trend was noticed again from 2016 till 2019 which might continue to the next decade, therefore a proper investigation on future rainfall trend in Abuja is needed so as to plan for upcoming weather events and also for water resources management in Abuja which will help in providing sufficient water to the citizens.

REFERENCES

3. Adejuwon, J. O. (2006). Food crop production in Nigeria, 1. present effects of climate variability. *Research Gate*, 53-60.
4. Badr, Hegazy, Hanan, & Ahmed, F. a. (2012). Brick Manufacturing From Water Treatment Sludge And Rice Husk Ash. *Australian Journal of Basic and Applied Sciences*, 453-461.
5. Denise, & Mauro. (2014). Utilization of Water Treatment Plant Sludge and Coal Fly Ash in Brick Manufacturing. *American Journal of Environmental Protection*, 1.
6. Goosse, H., Barriat, P., Lefebvre, W., Loutre, M., & Zunz, V. (2010). *Introduction to Climate dynamics and climate modelling.* Belgium: cambridge University Press.
7. Ifabiyi, Ifatokun, P., Ashaolu, & Eniola, D. (2013). Analysis of the impacts of rainfall variability on public water supply in ilorin, nigeria. *Journal of meteorology & climate science*, 18-26.
8. JOEL, I. O. (2008). Use of Cement-Sand Admixture in Laterite Brick Production for Low Cost Housing. *Leonardo Electronic Journal of Practices and Technologies*, 164-165.
9. Johnson, M. N. (2014). Potential uses of Waste Sludge in Construction Industry. *Research Journal of Applied Sciences, Engineering and Technology*, 565-570.
10. Mageed, S. A. (2011). Utilization of water treatment plants sludge ash in brick making. *Journal of Engineering Sciences*, 195-206.
11. Mamman, M., Bello, A. A., & A.A. Usman. (2018). Analysis of rainfall variation over northern parts of Nigeria. *Environmental and Earth Sciences Research Journal*, 74-78.
12. Mary, M. S. (2014). Utilization of sludge in manufacturing Energy Efficient Bricks. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 70-73.
13. NASA, P. (2010). *Precipitation measurement missions*. Retrieved from National Auronautics and Space Administration , Goddard Space Flight Center: https://pmm.nasa.gov/science/climate-change
14. NATIONAL BUREAU OF STATISTICS (NBS). (n.d.). *NIGERIA DATA PORTAL*. Retrieved from NIGERIA POPULATION CENSUS 2006: http://nigeria.opendataforafrica.org/xspplpb/nigeria-census

15. NTAT, G. H., OJOY, S., & SULEIMAN, Y. M. (2018). Rainfall variability and the impact on maize and rice yields in north – central nigeria. *International Journal of Science and Technology (STECH) Bahir Dar-Ethiopia*, 36-45.
16. Nyatuame, M., Owusu, V., & Ampiaw, O. (2014). Statistical Analysis of Rainfall Trend For Volta Region In Ghana. *International Journal of Atmospheric Science*, 11.
17. OKOLOYE, C. U., AISIOKUEBO, N. I., UKEJE, J. E., & ANUFOROM, A. C. (2013). Rainfall variability and the recent climate extremes in nigeria. *journal of meteorology & climate science*, 49-57.
18. Omogbai, B. (2010). An Emperical Prediction of Seasonal Rainfall in Nigeria. *Jornal of Human Ecology*, 23-27.
19. Tariq, J. a. (2007). Compressed Earth Building Blocks For Affordable Housing. *The construction and building research conference of the Royal Institution of Chartered surveyors* (p. 2). atlanta, United State of America: RICS 12 Great George Street London SW1P 3AD United Kingdom.
20. Technology, W. (2021). *lower usuma Dam Water Treatment Plant Expansion, Abuja*. Retrieved from water-technology.net
21. Victoria, A. N. (2013). Characterisation and performance evaluation of water works sludge as bricks material. *International Journal of Engineering and Applied Sciences*, 69-70.
22. Vuglinskiy, V. (2009). *Water level in lakes and reservoirs, water storage.* Rome: Global Terrestrial Observing System.
23. Watson, J., & Christie, R. (2016). *Measurement, Processing and Archiving of Water Level Data.* New Zealand: National Environmental Monitoring Standard.