The International Journal of Engineering And Science (IJES)
||Volume||2 ||Issue|| 01 ||Pages|| 222-231 ||2013||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

Prediction of Water Resource Potentials and Sustainable Supply of Water in Portharcourt, Nigeria from Meteorological Data

[1,] I. Tamunobereton-ari, [2], E. D. Uko, [3], D. H. Davies
[1,2,3,] *Department of Physics, Rivers State University of Science and Technology, Port Harcourt, Nigeria*

Abstract

This work x-rays and predicts the water resource potentials of Port Harcourt, Nigeria that can be harnessed to satisfy the water needs of the area using the city's meteorological data. Meteorological records covering a 10 year period (2001 – 2010) show that Port Harcourt has a rainy season of 9 to 10 months and minimum average annual rainfall of over 185mm with a minimum annual rainfall peak of 354mm for the 10 year data. Within this period, there are only 3 to 4 months of dry season. Rainy and dry seasons are transitional in February and November. Maximum annual evaporation peak was 148mm and a maximum annual average evaporation of 102mm. The water resource potentials of Port Harcourt and its environs are enormous with a favourable hydrogeology of 15m to 30m depth of water table distribution and an overwhelming recharge capacity of water bodies (surface water and groundwater) by the amount of rain fall.

Keywords **-** *Water resource, meteorology, groundwater, recharge capacity, aquifer, percolation.*

Date of Submission: 8th December, 2012 Date of Publication: Date 20th January 2013

I. Introduction

Water is an essential liquid to human lives and continuous existence of the ecosystem; it is colourless, without odour and without taste, which is used for drinking, washing, bathing, cooking, industrial processes, recreational activities etc., that can be gotten from rain, snow, stream, lake, river, sea and aquifer(groundwater). Water indeed circulates from the sea to the atmosphere, to the land and back to the sea and atmosphere in a process known as hydrologic cycle. This cycle is actually driven by the weather (meteorological or atmospheric conditions). When snow or rain falls on the land surface, some volume of the water returns rapidly to the atmosphere by evaporation or by transpiration from plants. The remainder either flows over the land surface as runoff into surface waters or percolates down into the ground to become ground water. The groundwater migrates to streams, rivers and the sea through pore spaces, fractures and faults that eventually evaporates to the atmosphere as water vapour. The water vapour in the atmosphere at an appropriate altitude and temperature condenses to form the water bearing cloud, which at the right condition releases the water by precipitation as rain, snow or hail to the ground surface thereby completing the cycle. This is illustrated by Fig. 1. The emphasis of hydrologic cycle in this work is to establish the sustainability of water supply and the recharge mechanism of the aquifers. Water-bearing formations (aquifers) of the earth's crust act as conduits for transmission and as reservoirs for storage of ground water ([1], [2]).

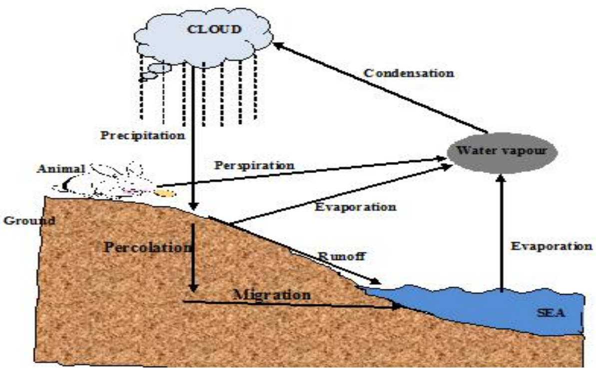

Fig. 1: The Hydrologic Cycle (Tamunobereton-ari, 2011)

II. HYDROGEOLOGY OF PORT HARCOURT

Port Harcourt became the capital of Rivers State; when the State was created in 1967. Port Harcourt is a coastal city located in the Niger Delta region of Nigeria; with coordinates: 4°45′N 7°00′E/4.75°N 7°E, which covers an area well over 2600 km^2. Port Harcourt is the chief trade centre of Nigeria and the business hub of the country because of its strategic location. Apart from being the main trading centre, Port Harcourt in Nigeria is also a great tourist destination. According to the 2006 Nigerian census Port Harcourt has a population of 1,382,592. This figure has been well exceeded as a result of its economic potentials. These economic and recreational potentials resulted to the influx of investors and visitors that had also increased the need for potable and sustainable water supply to meet the water needs for domestic, industrial and recreational uses ([3], [4], [5]).

Geologically, Port Harcourt has a shallow distribution of aquifer (groundwater body); about 15m to 30m depth, which is constantly recharged by percolating water from precipitation (rain). Aquifer is synonymous with the term subsurface water bearing formation that yields economically important amount of water to wells, boreholes etc. Aquifers differ widely in shape, area and thickness. The most productive aquifers of the study area are the ones composed of sand and gravel formation materials of the Benin formation of the Niger Delta, which are of high hydraulic conductivity and transmissivity characteristics. These characteristics are important in determining the natural flow of water through an aquifer and its response to fluid extraction ([6], [7]). To ascertain sustainable water supply to a populated area as is the case in Port Harcourt, it is important to know the aquifer distribution of the area and the climatic conditions of the area; which is very essential in the recharge and replenishment of an aquifer as water is abstracted. The aquifers of the area are basically unconfined as such; the recharge and replenishment capacity is very high even with little precipitation.

Aside the huge water resource potentials of Port Harcourt based on the wide distribution of aquifers and favourable weather for replenishment of depleted saturated zones, there is serious alarming levels of shortages in potable water supply to the citizenry, which have made citizens or inhabitants of the area, in the face of poverty and hardship to unavoidably buying water at high cost per gallon on daily basis to meeting the water needs, thereby adding to the already high cost of living in the area. Therefore, it became a thing of worry that governments and agencies cannot properly harness this abundant resource in the area and adequately supplied same to the people of Port Harcourt and its environs. This indeed exemplifies the indifference of governments and agencies in the developing countries to rendering social and other services to the betterment of the citizenry.

In addition, it is noteworthy that world over, adequate supply of potable water and general water sanitation is the best prophylactic measure to combating communicable diseases. Therefore, it implies that the inadequate supply of potable water in the area of study can create a multiplier effect in the spread of communicable diseases that is dangerous to the wellbeing of the citizens. Diseases are rising at an alarming rate among the human population especially in a country like India. Doctors' clinics are hot spots right now with the increasing number of people falling ill these days. The World Bank estimated that out of the growing spate of diseases, 21% of communicable diseases are water related. According to a 2007 World Health Organization report, more than 1 billion people lack access to safe drinking water. It comes as no surprise that 88% of the 4 billion annual cases of diarrheal disease are attributed to unsafe water and inadequate sanitation and hygiene.Water borne diseases like diarrhoea have been the cause for an estimated 700,000 deaths in India alone in 1999. This disease mostly hits children under the age of five. Other serious water-borne diseases are typhoid, jaundice and cholera that are rampant in India today ([8]).

III. Climate Of Port Harcourt And Its Environs

Climate is the average weather conditions of an area over a long period of time. Meteorology is the scientific study of the earth's atmosphere and its changes, used especially for forecasting weather. Weather systems particularly rainfall in the Niger Delta, specifically in Port Harcourt are primarily as a result of the interplay between two major pressure and wind systems. These are the two dynamically generated sub-tropical high pressure cells centred over Azores Archipelago (off the west coast of North Africa) and St. Helena Islands (off the coast of Namibia). These high pressure centres (or anticyclones), which are permanent generate and drive respectively the North-East trade winds and the South-West winds which are the northward extension of the re-curved South-East trade winds of the South Atlantic Ocean. The moist South-West wind transports its moisture to Nigeria specially Port Harcourt along the coast line. This air stream blows over the area between February and November. This is the period in which the region receives its rains ([9], [10]).

Conversely, the North-East trade winds bring dry conditions, having passed over the hot dry Sahara desert to reach Nigeria from the North. This air blows over Port Harcourt between November and February during which the area experiences its dry season. The boundary zone between these two air masses is devoid of any frontal activity since the two air masses differ a little in temperature and low Coriolis force due to Nigeria's proximity to the Equator. The boundary zone is therefore a moisture discontinuity called Inter Tropical Discontinuity (ITD). Over the ocean surface where there is evidence of convergence, the boundary zone is often called the Inter Tropical Convergence Zone (ITCZ). The seasonal movements of the ITD and its position control the climate of an area. The amount of seasonal distribution and type of rainfall as well as the length of the wet season and general weather conditions in Port Harcourt largely depends on its location with respect to the position of the migrating ITD and the associated weather ([11], [10]).

3.1 RAINFALL IN PORT HARCOURT

Port Harcourt falls in the transitional zones A_f and A_w climate types in Koppen's climate classification scheme. The monthly rainfall in Port Harcourt is almost predictable and follows a temporal sequence of increase from April to October before decreasing in the dry season months of November to February. Rainfall in Port Harcourt exhibits double maxima regime with peaks in July and September. Port Harcourt do experience mostly two weeks window of little or no rain within July and August otherwise described as "August break" though the actual time of occurrence varies from season to season and from year to year. According to Ologunorisa and Ogobonaye ([12]), the reasons for the occurrence of the two weeks window of little or no rain within July and August are:

1) The existence of well marked anti-cyclonic flow coupled with marked inversion.
2) Coldness of the sea in mid-summer derived from eddies of cold water from the cold Benquela currents

Speed, direction and moisture divergence stemming from the high pressure belt in the southern hemisphere that moves towards the Equator. These three phenomena act to reinforce one another in producing the August break.

3.2 TEMPERATURE OF PORT HARCOURT

Port Harcourt has a mean annual temperature of 28^oC. The area has a mean daily maximum temperature of 36^oC, which is mostly recorded between the months of February and March, while a mean daily minimum temperature of 20^oC was recorded in the area. Generally, temperature variation from the lows to the highs is dependent on the location as temperature increases from the coast towards the mainland, and also on the time of the day when the measurement was made. Temperature is low at night and high in the day as a result of the external heat supply by the sun. The mean temperature (28^oC) of the area is enough to cause substantial evaporation of water to saturate the atmosphere with water vapour that in turn condenses and precipitates as rain ([12]).

IV. DATA ACQUISITION

The data used to actualize the aim of this work were obtained from both primary source (observation) and secondary source (meteorological records from Port Harcourt International Airport over a year period 2001 to 2010). It was observed in the area of study over the years (2001 – 2010) of an increasing daily amount of rainfall and the extension of the rainy season which is usually 8 months (i.e. March to October) to 10 months (February to November). The dry season had been observed shorter and hotter as the year's progresses. These phenomena are in conformity with the consequences of global warming resulting from increased anthropogenic activities. The data from the secondary source are shown by Tables 1 to 11 in the result section.

V. RESULTS

The results from the meteorological records for the 10 year period (2001 – 2010) are presented by Tables 1 to 11, showing records of monthly average rainfall, monthly average temperatures, monthly average humidity, monthly average evaporation rates, monthly average wind speed and the annual records of these measured parameters for the 10 year period.

Table 1: Meteorological data for 2001

Month	Rain-fall (mm)	Tempe-rature (°C)	Humi-dity (%)	Evapo-ration (mm)	Wind speed (Km/hr)
Jan.	1.40	27.02	51.55	137.20	2.97
Feb.	78.60	28.25	60.59	124.10	3.49
Mar.	196.10	27.70	72.76	140.80	3.66
April	72.80	28.01	72.56	124.80	3.22
May	300.90	26.80	76.58	100.70	3.10
June	318.70	26.27	72.99	96.80	3.41
July	312.20	26.39	83.94	74.20	3.49
Aug.	433.70	25.39	84.61	59.40	3.79
Sept.	375.00	25.88	81.69	83.20	3.72
Oct.	422.40	25.80	80.30	93.60	3.33
Nov.	76.70	27.06	77.85	111.30	2.31
Dec.	40.20	26.77	73.93	88.60	2.35
	$\bar{X}$ = 216.06	$\bar{X}$= 26.68	$\bar{X}$ = 75.05	$\bar{X}$= 102.89	$\bar{X}$ = 3.24

Table 2: Meteorological data for 2002

Month	Rain-fall (mm)	Tempe-rature (°C)	Humi-dity (%)	Evapo-ration (mm)	Wind speed (Km/hr)
Jan.	0.00	27.32	71.53	111.40	2.76
Feb.	43.80	27.82	72.02	118.90	3.22
March	158.20	27.27	77.22	118.20	2.91
April	288.10	27.25	75.62	121.30	2.74
May	204.20	27.35	77.91	108.90	2.78
June	242.70	26.34	87.38	79.10	2.31
July	204.20	25.36	82.47	79.70	2.28
Aug.	358.00	25.05	84.91	46.40	3.12
Sept.	390.10	25.44	84.22	67.50	3.94
Oct.	265.50	25.87	80.21	98.90	3.12
Nov.	52.00	27.55	80.21	103.30	2.53
Dec.	15.40	27.65	73.92	100.20	2.80
	$\bar{X}$ = 185.20	$\bar{X}$= 26.75	$\bar{X}$ = 77.33	$\bar{X}$= 96.16	$\bar{X}$ = 2.87

Table 3: Meteorological data for 2003

Month	Rain-fall (mm)	Tempe-rature (°C)	Humi-dity (%)	Evapo-ration (mm)	Wind speed (Km/hr)
Jan.	83.20	27.29	71.10	108.50	2.64
Feb.	08.20	27.81	59.94	138.50	2.85
March	116.10	28.34	72.96	108.70	3.72
April	314.40	27.51	75.72	11.50	3.60
May	311.40	26.97	77.73	86.20	3.11
June	311.00	26.19	80.92	71.60	3.31
July	423.20	25.54	80.42	69.70	3.87
Aug.	820.80	25.72	81.84	63.80	3.79
Sept.	198.90	26.70	80.55	77.20	3.51
Oct.	423.00	26.86	79.97	34.90	3.20
Nov.	120.00	26.00	79.18	34.20	2.26
Dec.	28.90	27.48	69.87	95.80	2.48
	$\bar{X}$ = 205.28	$\bar{X}$= 26.92	$\bar{X}$ = 76.03	$\bar{X}$= 91.72	$\bar{X}$ = 3.20

VI. DISCUSSION

The water resource potentials of Port Harcourt and its environs are very clear as shown by the geology of the area and the climatic conditions measured by the meteorological department of Port Harcourt international Airport, Omagua, Rivers State, Nigeria. Figs. 2 to 11 show the graphical presentation of the annual rainfall and evaporation trends of Port Harcourt from 2001 to 2010. Comparing both curves, the rainfall curves are always above the evaporation curve from March to November implying that there was more precipitation than evaporation hence, more percolation of water to recharge and replenish groundwater and more runoff to streams, lakes, rivers etc, to also replenish surface water bodies. The evaporation curves almost only got above the rainfall curves between December and February months where daily average temperatures soar as a result of the dry season. The rainfall curves of the 10 years also show a minimum maximum rainfall peak of 354mm of 2010 and a very high rainfall peak of 820mm of 2003. The rainfall peaks are observed to fall between July and September. While, evaporation has a maximum peak of less than 150mm. Again, the nearness of Port Harcourt to the coast, coupled with the tropical weather (average daily temperature of 25^{o}C to 28^{o}C, and minimal wind speed) favours reasonable evaporation of water and subsequent high level of humidity due to enormous amount of water vapour in the atmosphere. Fig. 12 is a representation of the annual parametric data for the 10 years (200 -2010), which shows that there are no significant annual average temperature, humidity or evaporation changes for the 10 year period. However, there are observed significant annual average rainfall fluctuations within the 10 year period as shown by Fig. 12.

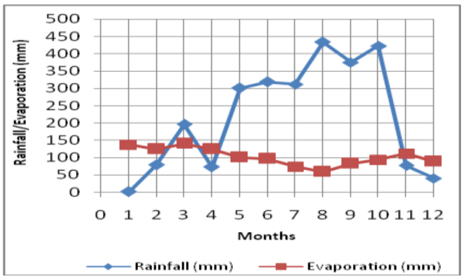

Fig. 2: Rainfall/Evaporation relationship for 2001

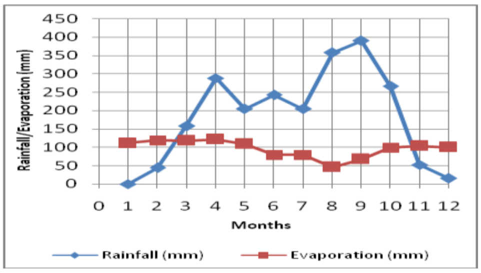

Fig. 3: Rainfall/Evaporation relationship for 2002

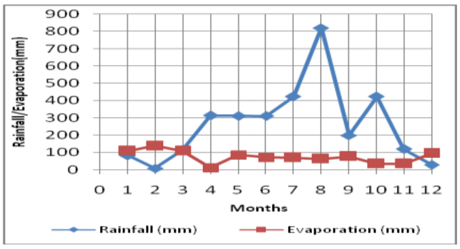

Fig. 4: Rainfall/Evaporation relationship for 2003

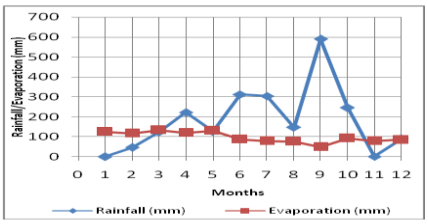

Fig. 5: Rainfall/Evaporation relationship for 2004

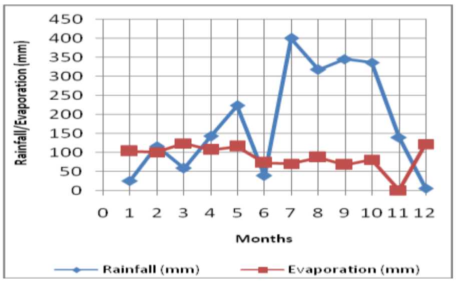

Fig. 6: Rainfall/Evaporation relationship for 2005

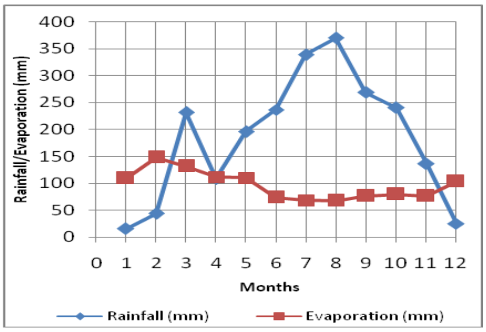

Fig. 7: Rainfall/Evaporation relationship for 2006

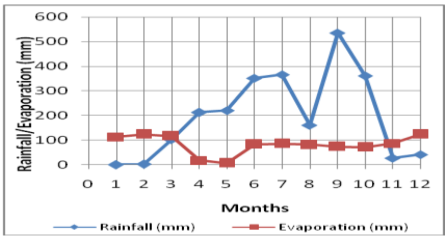

Fig. 8: Rainfall/Evaporation relationship for 2007

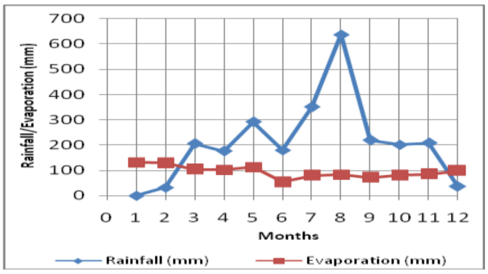

Fig. 9: Rainfall/Evaporation relationship for 2008

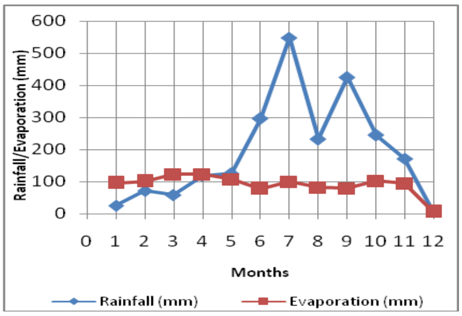

Fig. 10: Rainfall/Evaporation relationship for 2009

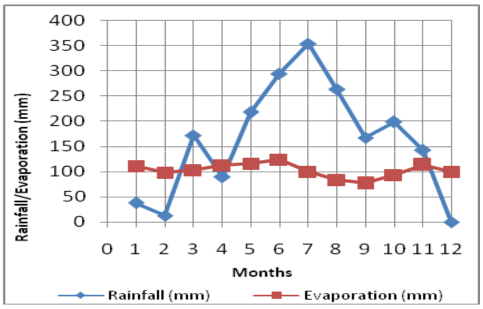

Fig. 11: Rainfall/Evaporation relationship for 2010

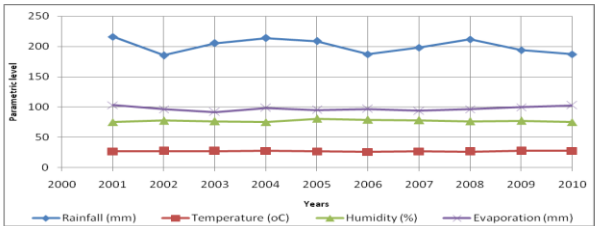

Fig. 12: Annual Rainfall, temperature, Humidity and Evaporation relationship for 10 year period (2001-2010

1. CONCLUSION

From the findings of the study, the following conclusions are reached: The water resource potentials of Port Harcourt and its environs are enormous with a favourable hydrogeology of the area (15m to 30m depth of water table distribution), and the climatic conditions of the area (9 to 10 months of rains, high humidity, minimal wind speed) that recharge and replenish the water bodies. For adequate and sustainable supply of potable water to the citizens, government and relevant agencies should invest in areas of harnessing, pumping, treatment and distribution; so that the associated dangers and health risks to man due to lack of potable water supply can be minimized, so that people of the area can live in clean and healthy conditions.

VII. Acknowledgements

The authors are thankful to Mrs. Jane Iyeneomie and IYETAMS Ventures Nig. Ltd; for the proofreading and typesetting of this work. Our thanks also go to the meteorological department of the Port Harcourt International Airport Omagua, Nigeria for making available the needed records to actualize this work.

References

[1]. A. H. Hornby, *Oxford Advance Learner's Dictionary of Current English*, 5th Ed, (Oxford University Press, UK, 1995).
[2]. I. Tamunobereton-ari, *Fundamentals of Geology*, (Robhas Business Network, Port Harcourt, Nigeria, 2011).
[3]. C. V. Izeogu, Urban Development and Environment in Port Harcourt, *Environment and Urbanization*, 1(1), 1989, 5965.
[4]. L. Williams, *Nigeria: The Bradt Travel guide*, 2nd Ed. (Bradt Travel Guide Ltd, England, 2011) 196-203).
[5]. I. Tamunobereton-ari, E. D. Uko, and V. B. Omubo-Pepple, Anthropogenic Activities – Implications for Ground Water Resource in Okrika, Rivers State, Nigeria, Research Journal of Applied Sciences, 5 **(**3), 2010, 204-211.
[6]. E. W. Kelly, Geoelectric Sounding for Estimating aquifer Hydraulic conductivity, Groundwater, 15, 1977**,** 420-424.
[7]. K. C. Short and A. Stauble, 1967, Outline of Geology of Niger Delta, *AAPG. Bull.* 51, 1967, 761-779.
[8]. www.prurgent.com, 2009
[9]. C. C. Plummer and D. McGeary, Physical Geology, 6th Ed. (Wm.C. Brown Publishers, England, 1993).
[10]. A. E. Ayoade and T. K. S. Abrams, The 1988 Floods in the Niger Delta: The case of Ndoni, *The Journal of Metrology*, 16 (63), 1991, 293-297.
[11]. R. E. Sheriff, R. E., 1991, Encyclopedic Dictionary of Exploration Geophysics, 3rd Ed. (Society of Exploration Geophysicist, USA, 1991).
[12]. R. A. Ologunorisa, and J. W. Ogobonaye, The Seasonal Incidence of Rainfall, *Weather*, 25, 1999, 414-415.

Table 4: Meteorological data for 2004

Month	Rain-fall (mm)	Tempe-rature (^oC)	Humi-dity (%)	Evapo-ration (mm)	Wind speed (Km/hr)
Jan.	1.30	27.10	63.70	125.60	2.55
Feb.	47.50	29.63	68.83	117.60	3.30
March	124.90	29.62	69.20	133.90	3.16
April	222.10	29.15	73.23	120.20	3.70
May	127.30	28.45	73.39	131.00	3.72
June	313.10	27.28	75.45	87.90	2.90
July	304.30	26.33	78.34	80.00	3.38
Aug.	147.40	26.12	79.49	76.60	3.98
Sept.	589.30	26.01	80.67	49.10	3.13
Oct.	245.60	26.71	78.89	92.70	2.73
Nov.	2.50	27.05	80.08	79.50	2.23
Dec.	90.30	26.37	77.00	85.90	1.56
	$\bar{X}$ = 213.80	$\bar{X}$= 27.48	$\bar{X}$ = 74.86	$\bar{X}$= 98.33	$\bar{X}$ = 3.04

Table 5: Meteorological data for 2005

Month	Rain-fall (mm)	Tempe-rature (oC)	Humi-dity (%)	Evapo-ration (mm)	Wind speed (Km/hr)
Jan.	25.70	26.97	75.01	103.10	2.53
Feb.	116.80	27.42	89.38	100.60	2.99
March	58.20	27.88	78.97	123.40	3.57
April	142.70	27.57	79.07	106.50	3.11
May	223.20	27.03	79.89	115.20	2.36
June	38.60	26.53	81.47	72.50	2.93
July	399.70	25.95	82.72	69.80	3.10
Aug.	317.40	26.02	82.31	86.50	3.64
Sept.	345.60	25.73	84.02	67.50	3.42
Oct.	336.50	25.69	84.02	80.90	3.18
Nov.	139.80	26.29	82.20	86,40	2.70
Dec.	5.50	27.32	74.54	121.70	2.49
	$\bar{X}$ = 208.89	$\bar{X}$= 26.70	$\bar{X}$ = 80.32	$\bar{X}$= 94.75	$\bar{X}$ = 3.04

Table 6: Meteorological data for 2006

Month	Rainfall (mm)	Tempera ture (^oC)	Humidit y (%)	Evapora tion (mm)	Wind speed (Km/hr)
Jan.	15.50	27.55	77.42	109.30	3.20
Feb.	44.00	27.91	69.83	148.20	3.48
March	231.80	28.37	82.15	131.60	4.09
April	108.90	27.39	81.00	111.70	3.64
May	196.20	27.13	81.29	110.40	3.54
June	237.00	26.08	81.04	73.50	3.54
July	339.20	25.40	81.89	68.60	3.44
Aug.	370.30	25.19	84.21	67.90	4.13
Sept.	268.60	25.73	84.43	76.20	3.43
Oct.	240.30	26.17	80.44	79.80	2.91
Nov.	136.60	26.64	70.17	76.20	2.56
Dec.	25.30	25.88	69.52	103.40	2.72
	$\bar{X}$ = 186.99	$\bar{X}$= 25.88	$\bar{X}$ = 78.62	$\bar{X}$= 96.82	$\bar{X}$ = 3.42

Table 7: Meteorological data for 2007

Month	Rainfall (mm)	Temperature (^oC)	Humidity (%)	Evaporation (mm)	Wind speed (Km/hr)
Jan.	00.00	26.54	67.86	112.70	3.08
Feb.	02.10	27.85	64.00	123.20	3.75
March	102.00	27.74	75.08	116.80	3.76
April	212.60	27.24	77.58	17.70	3.65
May	220.10	26.96	78.77	6.20	3.54
June	351.10	25.68	81.85	83.00	3.19
July	365.50	25.03	82.86	85.30	4.01
Aug.	160.70	24.97	84.59	81.27	4.28
Sept.	535.10	25.51	83.54	73.31	4.23
Oct.	361.20	25.90	83.34	70.92	2.74
Nov.	26.80	26.32	80.05	86.69	2.52
Dec.	41.68	28.19	75.24	123.60	2.63
	$\bar{X}$ = 198.24	$\bar{X}$= 26.47	$\bar{X}$ = 77.97	$\bar{X}$= 93.64	$\bar{X}$ = 3.45

Table 8: Meteorological data for 2008

Month	Rainfall (mm)	Temperature (^oC)	Humidity (%)	Evaporation (mm)	Wind speed (Km/hr)
Jan.	00.00	26.57	62.66	132.18	2.63
Feb.	31.70	27.36	69.57	128.34	3.85
March	205.60	27.36	79.41	103.77	3.32
April	176.40	27.17	80.44	101.54	3.36
May	291.10	27.35	78.11	112.75	3.34
June	180.60	25.83	81.59	53.01	3.32
July	351.10	25.25	84.84	78.52	3.33
Aug.	637.00	25.75	85.97	82.86	3.12
Sept.	219.50	19.50	65.30	71.00	2.32
Oct.	202.10	25.83	80.49	79.72	2.57
Nov.	208.70	26.68	76.15	84.88	2.50
Dec.	35.40	26.58	70.74	97.29	2.67
	$\bar{X}$ = 211.68	$\bar{X}$= 25.93	$\bar{X}$ = 76.36	$\bar{X}$= 96.32	$\bar{X}$ = 3.03

Table 9: Meteorological data for 2009

Month	Rainfall (mm)	Temperature (^oC)	Humidity (%)	Evaporation (mm)	Wind speed (Km/hr)
Jan.	25.80	27.09	72.75	96.64	3.08
Feb.	72.10	28.30	73.31	101.04	3.58
March	59.20	28.84	74.52	122.82	3.66
April	119.60	28.19	77.29	123.59	3.70
May	125.20	27.25	78.73	108.03	3.53
June	296.00	26.22	81.04	77.95	3.28
July	548.10	26.42	85.15	99.73	2.98
Aug.	232.80	26.21	83,50	82.39	3.79
Sept.	425.00	26.13	80.03	80.18	3.16
Oct.	244.40	27.15	77.71	103.06	3.21
Nov.	172.00	27.19	75.90	95.13	2.81
Dec.	6.30	27.36	68.10	06.20	2.80
	$\bar{X}$ = 193.88	$\bar{X}$= 27.21	$\bar{X}$ = 77.27	$\bar{X}$= 99.73	$\bar{X}$ = 3.30

Table 10: Meteorological data for 2010

Month	Rainfall (mm)	Temperature (^oC)	Humidity (%)	Evaporation (mm)	Wind speed (Km/hr)
Jan.	37.70	28.17	77.00	111.40	2.80
Feb.	12.70	26.05	80.08	98.01	2.76
March	172.60	26.19	78.89	103.20	3.22
April	89.70	26.09	80.67	112.64	2.91
May	218.50	26.18	79.49	116.18	2.74
June	295.10	26.27	78.34	123.95	2.78
July	354.50	27.20	75.45	99.73	2.31
Aug.	264.50	28.64	73.39	83.91	2.28
Sept.	167.30	29.06	73.23	76.90	3.12
Oct.	198.80	28.37	69.20	93.12	3.12
Nov.	142.60	29.44	68.83	113.60	2.53
Dec.	00.00	28.19	63.70	100.20	3.94
	$\bar{X}$ = 187.10	$\bar{X}$= 27.48	$\bar{X}$ = 74.86	$\bar{X}$= 102.74	$\bar{X}$ = 2.87

Table 11: Meteorological data for 10 year period (2001 – 2010)

YEAR	Rainfall (mm)	Temperature (^oC)	Humidity (%)	Evaporation (mm)	Wind speed (Km/hr)
2001.	216.06	26.68	75.05	102.89	3.24
2002.	185.20	26.75	77.33	96.16	2.87
2003	205.28	26.92	76.03	91.72	3.20
2004	213.80	27.48	74.86	98.33	3.04
2005	208.89	26.70	80.32	94.75	3.04
2006	186.99	25.88	78.62	96.82	3.42
2007	198.24	26.47	77.97	93.64	3.45
2008.	211.68	25.93	76.36	96.32	3.03
2009	193.88	27.21	77.27	99.73	3.30
2010	187.10	27.48	74.86	102.74	2.87