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Trend and decadal variability of atmospheric water loss in Ibadan based on multivariate statistical techniques

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Abstract

An understanding of the extent and variability of water loss is expedient in planning for engineering designs of water supply, irrigation, wastewater, and flood control systems, which could give insights on the response of the hydrologic cycle to climate change as well as to how much water, should be expected during planning. This study assessed the trend and decadal variability of potential atmospheric water loss in Ibadan for a period of 30 years (1982-2012) based on multivariate statistical techniques. Potential water loss was computed based on the reference Penman-Monteith method. Descriptive and normality test was used to present the data concisely, trend was analyzed based on the Least Square Regression, standardized index and Mann Kendall test; while the variability was assessed using the One-sample t-test and Analysis of Variance (ANOVA). The study revealed that the monthly distribution of evapotranspiration in the study area had the highest value in the month of March and lowest value in the month of August. The study also revealed that mean annual evapotranspiration was changing in the study area during the period under study. In addition, a decreasing trend in evapotranspiration in the study period was observed. This decrease was significant between 2006 and 2011. While, the 3-years moving average showed that the general decrease in the trend of evapotranspiration had started in 2004. The study also showed that anomalies of potential evapotranspiration were above zero prominently in the periods between 1983 to 1992 and 1993-2002, while an anomaly of less than zero was observed to be proficient in the last decade. The study recommended that further studies should be carried out to model variations in other climatic elements in the study area on daily, monthly and yearly basis.

Keywords: potential water loss, multivariate statistical techniques, penman-monteith method

1. Introduction

Evidence of global climate change is well-documented, with long-term increases observed in average global surface temperature, the atmosphere's carbon dioxide (CO_2) concentration, precipitation and runoff (Gedney *et al*., 2006). However, there are still several unresolved critical issues relating to climate change. One of such is whether evapotranspiration is increasing or decreasing (Ryu *et al*., 2008). The combination of the potential loss of water from plants and water bodies into the atmosphere is the potential atmospheric water loss. An understanding of the extent and variability of water loss is expedient in planning for engineering designs of water supply, irrigation, wastewater, and flood control systems. This could give an insight to the response of the hydrologic cycle to climate change as well as to how much water should be expected during planning. Sadly, the knowledge about the processes is limited in many African countries (Chineke *et al*., 2011) [5].

The IPCC (2007) [10] Fourth Assessment Report projected warmer and more frequent hot days and nights, warm spells/heat waves in most land areas in the tropical region, with a possibility of very high rates of evapotranspiration which may accelerate the hydrologic cycle, resulting in an increase in the amount of moisture circulating through the atmosphere (Ayoade, 1988) [3]. These changes profoundly affect atmospheric water vapour concentrations, clouds, and precipitation patterns (Chineke *et al*., 2011) [5].

Climate change as a global phenomenon affects evapotranspiration and poses economic, social, and ecological obstacles to the global community (Chineke *et al*., 2011) [5]. In particular, smallholder farming communities in low-income countries such as Nigeria will be adversely affected by climate change because of the increased erratic rainfall regimes, increased frequency and intensity of extreme weather events, and general unpredictability of agricultural operations, which are the fallouts that have been predicted to be associated with the phenomenon (Chineke *et al*., 2011) [5]. This shows that potential evapotranspiration if not effectively studied would have adverse effect on agricultural and water resources projects in Nigeria.

Recently, considerable interest has been shown to climate variability and its effect on the hydrological cycle and water supply (Schwartz and Randall, 2003). Research was conducted to detect climate changes, trends and variability in various parts of the world utilizing some climate parameters such as air temperature, rainfall depth, potential evapotranspiration ETo and pan evapotranspiration ETp (Hakan *et al*., 2010) [9]. Potential evapotranspiration is of particular importance because it combines changes in many other climate parameters including temperature, radiation, humidity and wind speed (Mohammad *et al*., 2010) [15]. It is based on this backdrop that the study seeks assess the trend and decadal variability of potential water loss in the study area. To achieve this aim, the specific objectives of the study were to analyze the monthly and annual distribution of potential evapotranspiration in the study area, to analyze trends of annual potential evapotranspiration between 1982 and 2012, to investigate the decadal variability in potential evapotranspiration in the study area for the period under study, and to analyze the impacts of variability in potential water loss on the environment.

2. Description of the study area

Ibadan is the largest city in West Africa, South of the Sahara and it is situated in the Southwest part of Nigeria. It lies between Latitude 7.25^0 and 7.29^0 N and Longitude 3.5^0 and 3.13^0 E (figure 1). The study area comprises eleven contiguous local government areas with sub-division into five (5) urban areas- Ibadan North, Ibadan North-West, Ibadan South-West, Ibadan South-East and Ibadan North-East and six (6) peri-urban consisting of Egbeda, Akinyele, Moniya, Ona-Ara, Lagelu, Oluyole and Ido. The town is bounded in the north by Afijo Local Government Area, bounded in the east by Isokan and Irewole Local Government Area in Osun state, bounded in the west by Odeda Local Government area in Ogun state, and bounded in the south by Ijebu-North Local Government Area in Ogun state.

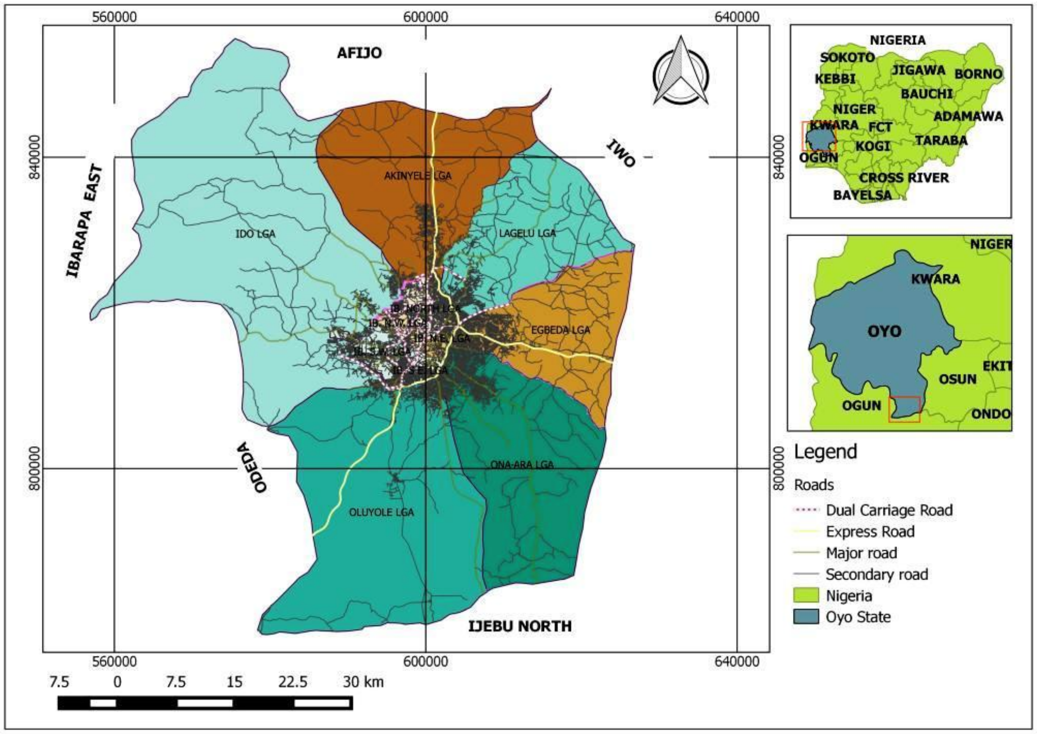

Fig 1: Map of the Study Area

The two main types of hills are recognized as the quartzite ridges and gneissic inselbergs loaves. Of these the quartzite ridges are by far the most impressive, widespread and the best known. Not only do they occur in the immediate vicinity of the town, they also occur widely within the region. The average elevation is 230 m above mean sea level.

The study area is drained by three important rivers, R. Ogunpa, R. Ona and R. Ogbere and their several tributaries including Omi, Kudeti, Alaro and Alapata. The major tributary of R. Ogunpa is the R. Kudeti, both of them drain the eastern part of Ibadan.

The latitudinal location of Ibadan makes it to enjoy the West African Monsoonal climate marked by distinct seasonal shift in the wind pattern. Between March and October, the city is under the influence of the moist maritime south-west monsoon winds which blow inland from the Atlantic Ocean. The mean annual rainfall of the town is between 1258.9 mm to 1981.2 mm. Ibadan experiences violent, tropical conventional storms of small area extent. The mean temperature is highest during the harmattan period with a value of 28^0 C. The mean day length of the town is 12 hours, ranging from minimum of 11.5 hours in December to a maximum of 12.7 hours in June. The season in the area is influenced by the movement of the inter-tropical convergence zone (ITCZ), a boundary zone which separates the tropical continental air mass over the Sahara and the equatorial maritime air mass over the Atlantic Ocean. The ITCZ moves northwards beyond the area at the peak of the raining season in June and July, and southward to the coast in the middle of the dry season in December and January. The change from the raining season to the dry season is rather abrupt while the onset of the rains after the dry season is gradual. Data obtained from the basin shows that February and March are the hottest months of the year. During these months, temperatures are high over the entire area. The mean daily maximum temperature for February is 0 31.40˚ C in the south and as high as 34.6 C in the north**.**

3. Methodology

3.1 Materials

Meteorological data were obtained from the Nigeria Meteorological agency (NIMET) Ibadan, Oyo state station. The meteorological parameter obtained at this station included maximum and minimum temperature, relative humidity, sunshine duration and cup counter anemometer which were required for the computation of potential evapotranspiration. The time series of meteorological data covering 30 calendar years i.e. 1982-2012 was obtained. Missing data in time series were filled using arithmetic mean of adjacent month (Backundukize *et al*, 2011).

3.2 Method of Data Analysis

3.2.1 Descriptive Statistics

Several descriptive statistics comprising the mean, standard deviation, range were used for descriptions potential evapotranspiration used for the study. The descriptive statistics was chosen because it is concerned with the organization and presentation of data in order to provide concise information to make their analysis easier. The mean gives a central tendency of a data set; the standard deviation provides information of how diverse a data is from the mean, while range gives the limit within which a data set lies.

3.2.2 Normality Test

It is important to carry out a normality test on climatic data, to ascertain whether a distribution is normal or not, which will determine the type of inferential statistics to be used. To test for normality of the time series data, Microsoft Excel software was used to calculate both the standard coefficient of skewness (Z_1) and the standard coefficient of kurtosis (Z_2) as follows:

The equation for skewness ($Z1$) is defined as:

$$\frac{n}{(n-1)(n-2)} \sum \left(\frac{xi-x}{s}\right)^3 - \qquad 1$$

Kurtosis is ($Z2$) defined as:

$$\left\langle \frac{n(n-1)}{(n-1)(n-2)(n-3)} \sum \left(\frac{xi-x}{s}\right)^4 - \right\rangle - \frac{3(n-1)^2}{(n-2)(n-3)} \qquad 2$$

Where, Σ = summation of variate, s is the standard deviation. x is the long term mean of xj samples and n is the total number of samples

These statistics were used to test that the samples came from a population with a normal distribution. If Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at 95% confidence level. If this happens, transformation would be used to normalize the data, if not non-parametric statistical analysis will be used to analyze the trends of the data. In order to identify trends, the entire temperature and rainfall time series were divided into a 10-year interval. The means of the 10-year interval were then compared with that of the whole period.

3.2.3 Least Square Regression and One-Sample T-Test

Trend analysis was accomplished with the line graphs as well as the least square regression technique for hypotheses testing and modeling. One-Sample T-Test procedure tests whether the mean of a single variable differs from a specified constant or normal, this test was used for ascertaining the anomalies in the meteorological parameters. Though time series data are not bivariate data, a linear trend line can be obtained by using the simple regression analysis technique (Udofia, 2008, Okoko, 2001). Therefore, in this study, time in years is one independent variable (x) while annual evapotranspiration (1983-2013) were considered the dependent variable (y). The least square model is presented as;

$$Y = a + bx + e \qquad 3$$

Where; Y = Dependent variable (annual Evapotranspiration)

X = Independent variable (time in years).
a = A constant and y – intercept
b = Regression coefficient
c = Error random term

3.2.4 Standardized Index

An index number is a device which measures the relative change in the magnitude of a group of related variables in two or more situations. The standardized index was chosen for the study because it has the ability to reflect movement of the parameter as well as indicating rise and fall of the variable. To analyze annual temperature and rainfall variability, the standardized rainfall anomaly index was used.

The standardized index is represented as (Uduak and Edem, 2012):

$$Z = \frac{(\times i-\mu)}{\sigma} \qquad 4$$

Where, $\times i$ is the annual mean air temperature, μ is the 10-year mean and σ is the standard deviation of the data set.

3.2.5 Mann Kendall's Test

The results obtained from the trend analysis are further verified by using a powerful and nonparametric Mann-Kendall Statistics (S) (Gilbert, 1987) developed by Mann (1945) and Kendall (1976). The test uses the ranking of all the values to determine if there are more increasing or decreasing values in historical records. In the Mann-Kendall each test value x1 ... xn, are compared with all available values. For a positive difference between the data points the so-called S-statistics increases with +1 while it decreases with -1 for a negative difference.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (xj - xi) \qquad 5$$

$$Sgn\ (xj - xi) \begin{cases} +1, > (xj - xi) \\ 0, = (xj - xi) \\ -1, < (xj - xi) \end{cases} \qquad 6$$

$$Var\ (s) = \frac{n(n-1)\ ()\ \sum_{1=1}^{m} t1\ (i)(i-1)(1+5)}{18} \qquad 7$$

Thus a large positive value of S indicates a strong positive (increasing) trend while a large negative value of S implies a negative (decreasing) trend. The nonparametric assumption of Mann-Kendall's test when used for a time series with a large number of values is documented which allow the use of a regular z-test to determine whether a trend is significant or not:

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{\dfrac{n(n-1)(2n+5)-\sum_{j=1}^{9})tj\ (tj-1)(2t+5)}{18}}}, if\ s > 0 \\ 8 \\ \dfrac{s+1}{\sqrt{\dfrac{n(n-1)(2n+5)-\sum_{j=1}^{9})tj\ (tj-1)(2t+5)}{18}}}, if\ s < 0 \end{cases}$$

Where
n = sample size;
q= number of tied groups in the data set; and
t_j = number of data points in the j^{th} tied group.

3.2.6 Standard Penman-Monteith

The standard Penman-Monteith method for estimating evapotanspiration can be mathematically expressed as follows (Allen *et al*., 1998):

$$E_0 = (\Delta/\gamma H + E_a)/\ \Delta/\gamma \qquad 9$$

Where Δ/γ is an empirical parameter depending on temperature
H is calculated as H = (1-r)Rin - Ro where Rin (incoming radiation) is given by:

$$(1\text{-}r)Rin = 0.95 * Ra(0.18 + 0.55n/N) \qquad 10$$

Where Ra is the solar radiation, Ro is the outgoing radiation, r is the albedo (0.05 for water), and n/N is the ration between actual sunshine hours and possible sunshine hours. The term n/N can also be estimated using the cloudiness, e.g., a cloudiness of 60 % gives an *n/N* of 40 % (= 100 - 60). R_0 is calculated by:

$$R_0 = \sigma T_a 4\ (0.56 - 0.09\sqrt{ed})(0.10+0.90n/N) \qquad 11$$

Where ed is the actual vapor pressure, and σT_a^4 is the theoretical black body radiation.
Ea is calculated by:

$$Ea = 0.35(0.5 + u2/100)(ea - ed) \qquad 12$$

Where *u*2 is the wind speed in m/s and ea is the saturation vapor pressure. Relative humidity RH = ed/ea.

3.3 Data Analysis

The analysis of data was aided with the use of the computer software such as Micro Soft Excel sheet and R programming language.

4. Results and Discussion

4.1 Monthly mean potential evapotranspiration distribution between 1983 and 2012

Table 1 shows the statistical summary of the monthly mean potential evapotranspiration distribution in Ibadan. From the distribution, it was observed that March recorded the highest mean evapotranspiration, while the lowest mean evapotranspiration was observed in August. This may be because of the low cloudiness in March and high cloudiness in August. This result is in agreement with Isikwue *et al.* (2015) [12] who stated that evapotranspiration in Ibadan is strongly negatively correlated with humidity and cloudiness. In addition, Chineke *et al.* (2011) [5] reported that evapotranspiration in Nigeria is low in the month of August. It was also observed that the highest maximum and minimum evapotranspiration was observed in March. The high values of evapotranspiration in the month of March could be correlated to the high temperature observed during the month, as reported by Akinsanola and Ogunjobi (2014) [1], who investigated temperature variabilities in Nigeria using observations of air temperature. Their findings showed that temperature was observed to increase southward during the months of January to March with temperature ranging from 21.1° C to 30° C, as well as decreasing in the months of August and October in Southwest Nigeria.

Table 1: Statistical Summary of Monthly Mean Potential Evapotranspiration in Ibadan between 1983 and 2012

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	57.4	74.3	74.5	63.8	54.1	36.8	23.2	19.6	29.6	40.9	57.0	51.1
Maximum	79.8	89.7	97.2	95.3	95.3	49.9	37.4	36.2	43.7	61.1	72.9	67.3
Minimum	36.8	45.5	61.7	48.7	39.9	14.4	12.5	5.7	18.8	28.7	38.7	28.1
Standard Deviation	10.0	9.1	8.1	9.9	12.2	8.7	6.7	8.3	6.9	7.2	10.0	10.5

4.2 Annual distribution of mean evapotranspiration between 1983 and 2012

Table 2 shows the summary of descriptive statistics of the annual mean evapotranspiration in Ibadan, between 1983 and 2012 table shows that during the 30 years of study, the minimum potential evapotranspiration of the study area was 454.9 mm, the maximum potential evapotranspiration was 697.1 mm and mean annual evapotranspiration was 582.28 mm. Furthermore, since, the statistics of Skewness and Kurtosis as could be observed in table 2 were less than 1.96, the annual trend of evapotranspiration was not accepted as indicative of normality at 95% confidence level. This shows that mean annual evapotranspiration was changing in the study area, which could have been influenced by the movement of the tropical continental air mass.

Table 2: Descriptive Statistical Summary of Annual Mean Evapotranspiration in Ibadan

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ETo	30	454.9	697.1	582.28	64.99	-0.358	0.427	-0.766	0.833

4.3 Trend analysis of annual potential evapotranspiration

Figure 2 shows the trend of the annual mean potential evapotranspiration between 1983 and 2012. The figure shows that the lowest annual potential evapotranspiration was observed in the year 2010, while the highest annual mean potential evapotranspiration was observed in the year 1987. Furthermore, the line graph shows a decrease in the trend of potential evapotranspiration between 1983 and 2012. The 3-years moving average observed in figure 2 shows that the general decrease in trend of evapotranspiration began in 2004. The decrease in ETo could be as a result of the increase in cloudiness which resulted to high rainfall in the study area, which corroborates the findings of Obot and Onyeukwu (2010) [17] and Akinsanola and Ogunjobi (2014) [1] whose results indicated that there have been statistically significant increases in precipitation in most parts of Nigeria. In addition, the least square regression model of the trend is shown in the figure 2 and represented as Y= -2.445x + 620.1 with a low coefficient of determination of 0.109 which indicated that the observed ETo are not well fitted with the model, which weakens the ability of the model to predict annual ETo. This means that the model was only 10% accurate in predicting potential evapotranspiration. The Mann Kendall test also shows that there is decrease in the pattern of atmospheric water loss in the study area; this is confirmed by the Kendall's tau value of -0.136 and a p-significance of 0.3 ($p>0.05$) as could be seen in table 3.

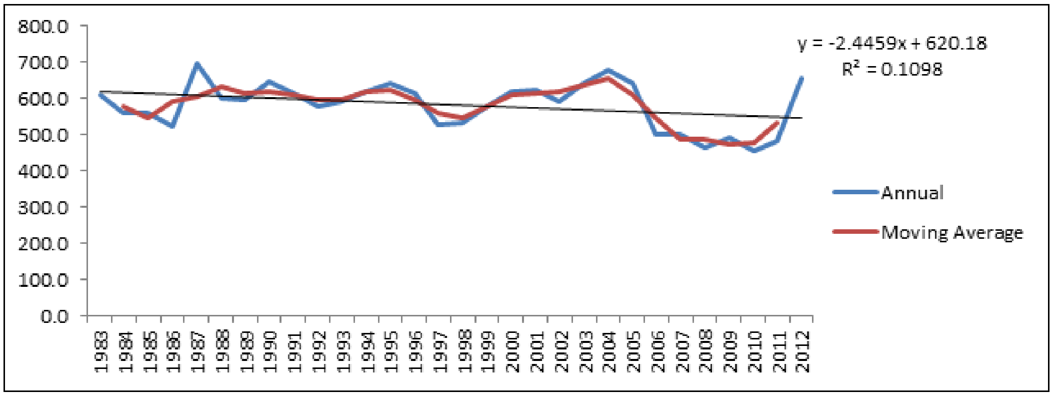

Fig 2: Annual Mean Evapotranspiration Trend in Ibadan

Table 3: Summary of Result of Mann Kendall Test

Mann Kendall Statistics	Kendall's Tau	Var (s)	P-Value (Two Tailed Test)	Alpha	Remark
-59	-0.136	3141.7	0.3	0.05	This is negative non-significant trend

4.4 Decadal mean monthly variability in evapotranspiration

Figure 3 shows the decadal monthly mean of evapotranspiration in the study area. The figure shows that the monthly mean evapotranspiration varied in the three decades. For instance, in the month of January, ETo increased from 53.4 mm in the 1983-1992 decade to 60.3 mm in the 1993-2002 decade before decreasing to 58.6 mm in the last decade. The months of February, March, April, June, July, August, October and November had a similar trend, in that ETo decreased from the first to last decade within the study period. On the other hand, the remaining three months had varied ETo, which is in agreement with the findings Chineke *et al.* (2011) who noted that human alteration of the earth's land cover such as urbanization, deforestation, mining and agricultural activities can significantly affect evapotranspiration variations.

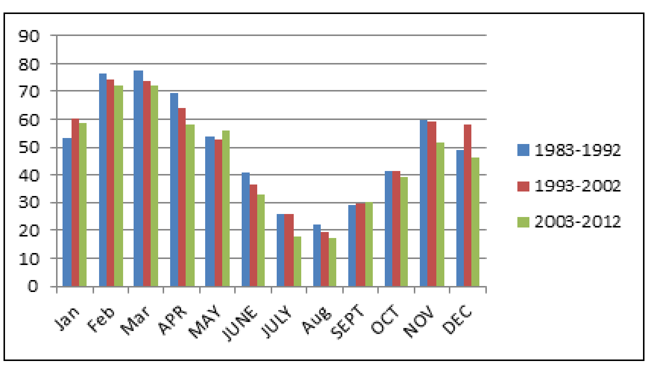

Fig 3: Decadal Monthly Mean Evapotranspiration Trend in Ibadan

4.5 Decadal mean annual variability in evapotranspiration

Table 4 shows the decadal Potential Evapotranspiration summary. In order to investigate the decadal variability of potential evapotranspiration in Ibadan, the 30 years of study was divided into three study periods as shown in table 4. The summary table shows that the potential evapotranspiration between 1983 and 1992 was 598.6 mm and a standard deviation of 48.6 mm, the mean potential evapotranspiration between 1993 and 2002 was 595.5 mm also, the standard deviation for the period was 38.0 mm, while it was observed that the mean annual potential evapotranspiration for the study area between 2003 and 2012 was 552.7 mm with a standard deviation of 90.0 mm. The result shows that there was a slight reduction in ETo from the first decade to the second decade, while there was a very sharp decrease from the second to the third decade showing that the reduction in ETo within the study period was consistent. This could be as a result of climate change that occurred in the study area, which corroborates the findings of NEST (2003) [16] which indicated that an indicator showing the evidence of climate change in a region was a constant decrease and increase in climatic elements.

Table 4: Decadal Potential Evapotranspiration Summary

Year	Mean Potential Evapotranspiration (mm)	Standard Deviation (mm)
1983-1992	598.6	48.6
1993-2002	595.5	39.0
2003-2012	552.7	90.9

Figure 4 shows the mean evapotranspiration anomalies using 2003 to 2012 mean. The figure confirms the presence of climate variability in Ibadan. It was observed that anomalies of values were above zero prominently in the periods between 1983 to 1992 and 1993-2002, while anomalies of less than zero was also observed to be proficient in the last decade. This could be as a result of the high rainfall that has been observed to increase significantly between 2003 and 2012. This is in agreement with the findings of Odjugo (2010) who concluded that rainfall in Southwest Nigeria had been on the increase.

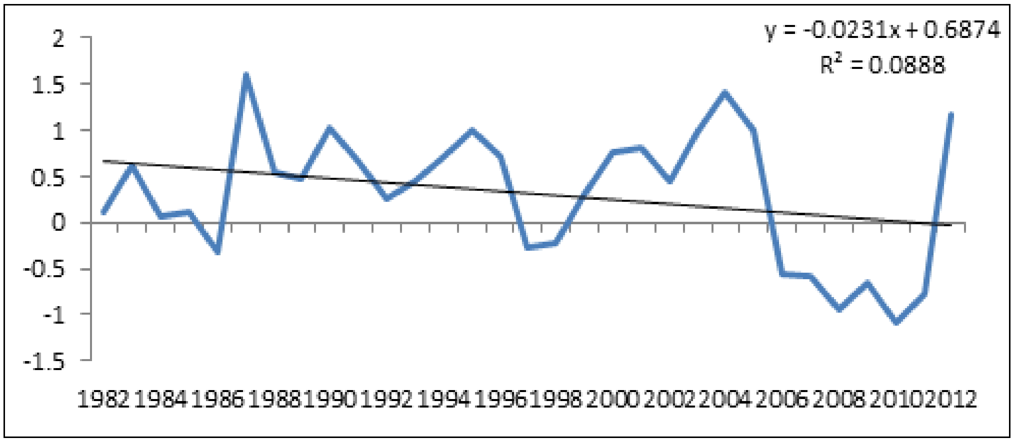

Fig 4: Mean Evapotranspiration Anomalies Using 2003-2012 Normal

Table 5 shows the one sample t-test statistics for potential evapotranspiration. The table shows that there was a decrease in evapotranspiration in the study area with a value of 28.58 mm between 1983 and 2012. Furthermore, since the significant value 0.019 at degree of freedom of 29 is less than 0.05, the null hypothesis which says that there was no significant relationship between variability of potential evapotranspiration and climate change in the study area was rejected, while the alternate hypothesis was accepted. Hence, it can be concluded that the decrease in the mean annual potential evapotranspiration in Ibadan between 2003-2012 was significant and had been influenced by climate change. This in is agreement with NEST (2003) [16], who concluded that climate change could be accessed through noticeable difference in weather parameters within a period.

Table 5: One-Sample T-test Statistics of Variation in Mean Potential Evapotranspiration within the Study Period

	Test Value = 552.7					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
ETo	2.493	29	0.019	29.58000	5.3131	53.8469

Table 6 shows the ANOVA statistics for potential evapotranspiration. The table shows that at degree of freedom (2, 27) the statistical significant p value of 0.021 was less than 0.05 significant level. This informed the rejection of the null hypothesis which stated that there was no significant variation in the average atmospheric condition within the study period. This shows that the atmospheric condition was constantly changing in each decade considered for the study. This is because the mean differences of potential evapotranspiration between each decade was significant and did not occur by chance.

Table 6: Analysis of Variance (ANOVA) Statistics

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	13190.450	2	6595.225	1.629	0.021
Within Groups	109289.558	27	4047.761		
Total	122480.008	29			

4.6 Impacts of variability in potential atmospheric water loss

Variability of climate parameters has been reported to have numerous consequences, for instance, increase in rainfall and temperature which are indications of climate change that result in flooding and urban heat. Furthermore, there may be loss of economic growth, slowing down of economic development, causing damage to crop quality, less food production, increase in food prices. Others include insect infestation, plant diseases, loss from dairy and livestock production, unavailability of water and feed for livestock which leads to high livestock mortality rates, increased predation, range fires and wild land fires, damage to fish habitat, loss from fishery production, income loss for farmers and others affected (Olusina and Odumade, 2012) [20]. The decreasing trend in evapotranspiration in the study area could be as a result of increase in rainfall and reduction of vegetation cover which confirms that climate change and anthropogenic activities in the study area were responsible for the reduction in ETo. Since agriculture in Ibadan is rainfed and the rainfall patterns over the years are changing (Odekunle and Eludoyin, 2008) [18] variability of ETo would negatively affect agriculture. Due to the fact that land-cover is also changing due to urbanization, poor land use planning and land tenure programmes, it is therefore apparent that the negative trend of ETo in Ibadan would continue. The ETo information would help in understanding farm water and soil management for improved water use or introduction of non-native vegetation in the study area.

4.7 discussion of Findings

The variation of monthly evapotranspiration observed in the study is in agreement with similar studies carried out in other parts of Nigeria. For instance, Isikwue *et al.* (2014) [12]

observed that evapotranspiration was high during dry seasons, while it is very low in rainy season having lowest values in August. This is because evapotranspiration demand is high in hot dry weather due to the dryness of the air and the amount of energy available as direct solar radiation and latent heat of vaporization. Under these circumstances, much water vapour can be stored in the air while wind may promote the transport of water allowing more water vapour to be taken up. On the other hand, under humid weather conditions, the high humidity of the air and the presence of clouds cause the evapotranspiration rate to be lower. This is in line with the observation made by (Ram and Anju, 2012) [21], on monitoring of evapotranspiration in major districts of Haryana using Penman Monteith Method.

Evapotranspiration depends on the amount of moisture available in the soil and precipitation. This study revealed a decreasing trend in ETo which could be as a result of increasing rainfall in the area. This agrees with Obot and Onyeukwu (2010) [17] and Akinsanola and Ogunjobi (2014) [1] whose results indicated that there have been statistically significant increases in precipitation in most part of Nigeria. ETo also depend on the influence of the dry, dusty, tropical-continental air mass (which originates from the Sahara region), and the warm, tropical-maritime air mass (which originates from the Atlantic Ocean) that prevail in the study areas (Ekpoh and Ekpenyong, 2011) [6]. Finally since water being accounted as loss into the atmosphere is reducing in the area, there is therefore increasing risk of flooding incidence, which could aggravate other public health problems such as spread of diseases as a result of poor environmental sanitation in the area.

5. Conclusion and Recommendations

There is persistent decrease in atmospheric water loss in Ibadan. This is influenced by climate change and reduced vegetation cover from land use change. The outcome of the study would be most beneficial in the southern parts of the country where flooding is becoming rampant. This also calls for the attention of all stakeholders ranging from government, individuals and corporate bodies to take the issue of climate variability in the study area serious. Based on the findings from this study, it is recommended that further studies should be carried out to model variations in other climatic elements in the study area on daily, monthly and yearly basis. There is need to effectively quantify the effect of land use change on both the ecosystem and hydrological processes, hence there is need to implement sustainable land use concepts in the study area. The ability to respond or cope is known to be a function of the awareness level, income and education. Therefore, greater awareness through education that seems totally lacking and skills through extension services education should be enhanced for informed and efficient reactions. This study was limited to 30 years meteorological data, hence government concerned agency should make longer years data available for a study like this. Availability of such data will increase reliability of results as well as increasing confidence level of prediction of future trends. In understanding climate change relationship with water resources, there is need for measured stream flow data and close monitoring of weather data that will inform planners about climate-induced changes in Nigeria.

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