International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 6 (June 2014), PP.06-12

Trends in Evaporation Rate in North Eastern Nigeria (1981-2010)

Dammo, M. N.[1*] and Sangodoyin, A.Y[2]
[1] *Department of Civil Engineering, Ramat Polytehnic Maiduguri, Nigeria.*
[2]*Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria*

Abstract:- The trend of evaporation rate in north-eastern Nigeria spanning Borno, Yobe, Gombe, Bauchi, Adamawa and Taraba states for the period 1981 to 2010 was carried out. The influence of meteorological variables was tested and found to have significant impact on the spatial and temporal trends of evaporation rate for three consecutive decades across the North Eastern Nigeria. The study seeks to establish whether changes have occurred in the mean value of other climate parameters that are linked with evaporation rate. Data analysis revealed that the highest impact of evaporation on temperature was 81.3%, temperature on evaporation was 96.2% and relative humidity on evaporation was 80.9%. The trend of evaporation was a polynomial function of 4th order with high coefficient of determination ranging from 0.795 to 0.997. Effects of evaporation across the region were all negative except at Yobe. The order of adverse effects was Taraba>Adamawa>Bauchi>Gombe>Borno. The implication of this result is that rise in temperature increased evaporation and relative humidity. Although the effects of climatic variables varied within locations, they generally impacted significantly on the evaporation rate within the sub region. These were consequent to the current increase in major climatic variables across the region over the 30 yr study period.

Keywords:- evaporation, spatial and temporal trend, north eastern Nigeria

I. INTRODUCTION

Evaporation is an important component of the hydrological cycle and has great effect on the water balance of the earth surface. Higher evaporation rate creates more arid environment while downward trend of evaporation results in a more humid environment. Pan evaporation (PE) is important because it gives useful clues to changes in actual evaporation. In recent times, both local and global climate have undergone tremendous changes. This is not unconnected with the increased human activities in the environment ranging from deforestation and air pollution resulting from the fast growing industrial activities[1]. Evaporation over the land is a key component of the climate system as it links the hydrological, energy and carbon cycles[2]. In view of this, all climate variables have equally undergone commensurate modification. The cumulative effect of the above is increased concentration of greenhouse gases which are continuously released into the atmosphere and are impacting the environment. [3]observed that the mean average global temperature has increased by 0.6^{0}C over that of the 20th century. [4] noted that the global temperature will experience an upward trend staggering between 1^{o}C and 5^{o}C by the middle of the 21st century. The global hydrological cycle is not left out in the global climatic changes because it had already been predicted [3,4,5] that there would be an intensified hydrological cycle in response to increasing trend in temperature. Several factors other than the physical characteristics of the water, soil, snow, and plant surface also affect the evaporation process[6].

Studies of evaporation trends from many regions have been conducted and conclusions vary. Increasing pan evaporation trends have been observed in Bet Dagan, Israel, Phoenix, Arizona USA and northeast Brazil by [7,8]. However, decreasing trends in pan evaporation were reported by [9], in Austrailia,[10,11]in the United States and India respectively.

This study is the first attempt at investigating the temporal and spatial trends of evaporation across the entire North-eastern region of Nigeria. The response of evaporation to changes in meteorological variables was observed using Mann-Kendall statistics.

II. MATERIALS AND METHODS

The study site cover an area of aproximately 157,000 sq km located between latitude 10^{0}03´ – 13^{0}50´E and longitude 7^{0}43´ – 12^{0}45´ N. Detailed descriptions of the various sites are as shown in Fig 1

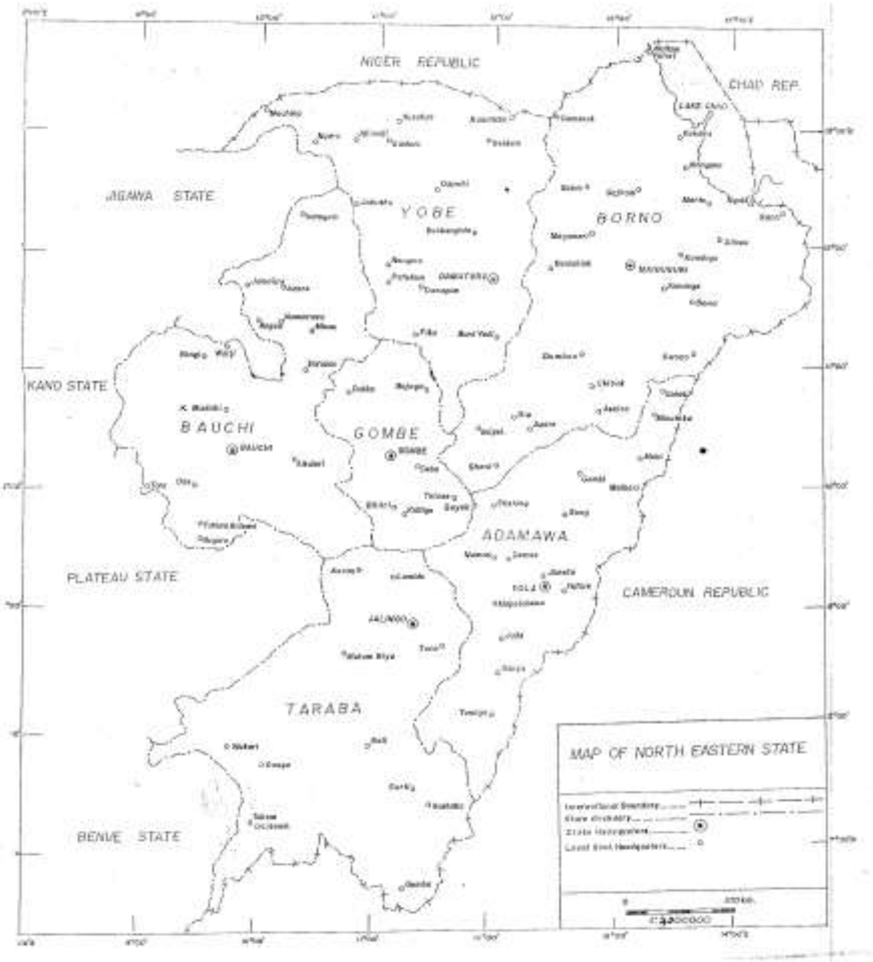

Fig. 1: Showing the map of North Eastern Nigeria
Source: Lands and Survey Maiduguri, 2011

The meteorology variables used for the investigation include: Pan Evaporation, Relative humidity, Temperature and Rainfall. Monthly data of these weather variables were collected from the Nigerian Meteorological Agency (NIMET) in Abuja, Nigeria. The data collected were processed into monthly and annual mean values for all the stations. The integrity of the data was determined by collating the data from each of the data source and checking for inconsistencies and gaps.

III. MANN-KENDALL STATISTIC

The Mann-Kendall (M-K) Test is a simple test for trend. Mann-Kendall is a
Non-parametric test and as such, it is not dependent upon: magnitude of data, assumptions of distribution and missing data and irregularly spaced monitoring periods. Mann-Kendall assesses whether a time-ordered data set exhibits an increasing or decreasing trend within a predetermined level of significance. The test compares the relative magnitudes of sample data rather than the data values themselves [12]. One benefit of this test is that the data need not conform to any particular distribution. Moreover, data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data set. When multiple data points exist for a single time period, the median value is used. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (*e.g.*, no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S. Let 1 x , 2 x , … n x represent n data points, then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

where: x_J represents the data point at time j.
x_k represents the data point at time k

$$sign(x_j - x_k) = 1 \text{ if } x_j - x_k > 0$$
$$= 0 \text{ if } x_j - x_k = 0$$
$$= -1 \text{ if } x_j - x_k < 0$$

IV. RESULTS AND DISCUSSION

Based on the analysis of the presented data, the Mann- Kendall S indicated a highly significant ($p<0.05$) variation in mean evaporation at the different locations, and over the years. Fig.1a shows that mean evaporation was highest at Borno (11.3 mm/day) and lowest at Taraba (0.8 mm/day). In general, there was successive significant increase in evaporation at all locations. Results similarly indicated high variability in evaporation over the years, with the highest in 1998 and lowest in 2010. Location vs year interaction was significant ($p<0.05$), indicating variability in relative evaporation pattern at the different locations over the years (Fig.1b – d). Peak evaporation for Gombe, Adamawa, Taraba, Yobe, Borno and Bauchi were recorded in 1998, 2010, 2009, 2007, 1984 and 2002, respectively (Fig. 1e). These and other annual mean values depicted consistent recent increase in evaporation at Adamawa, Taraba and Bauchi on one hand, in contrast to Gombe, Yobe and Borno on the other hand. Location vs month interaction showed peak evaporation in February for Taraba, March for Gombe and Adamawa, and April for Borno, Yobe and Bauchi (Fig. 1b).

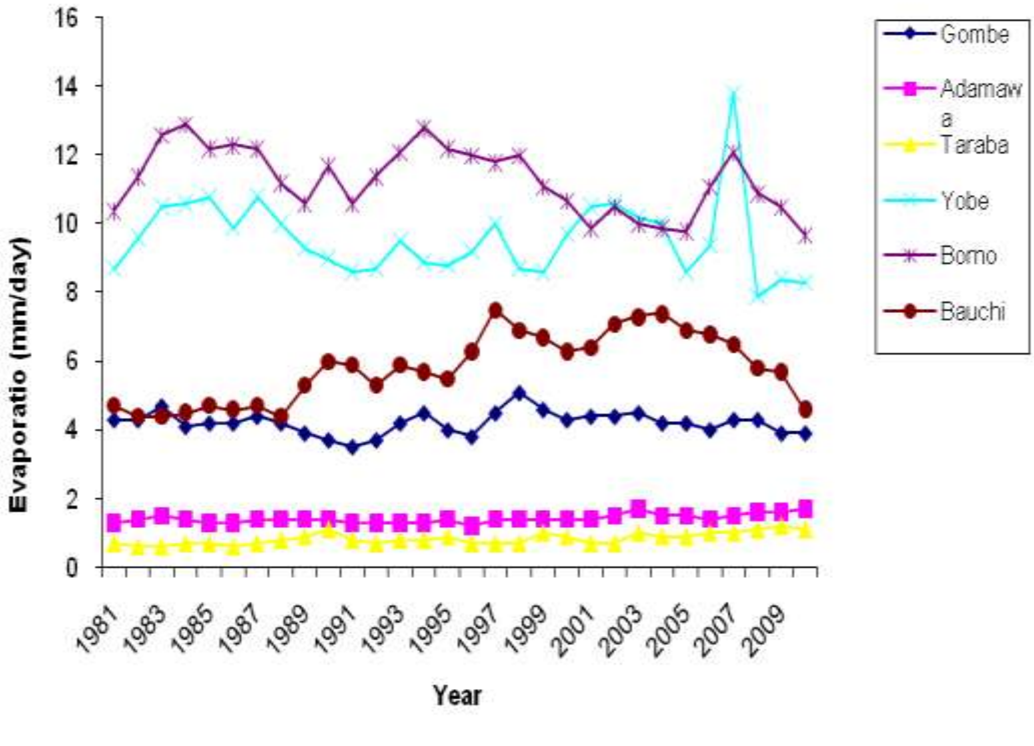

Fig. 1a: Pattern of changes in mean evaporation over the 30 years in different locations

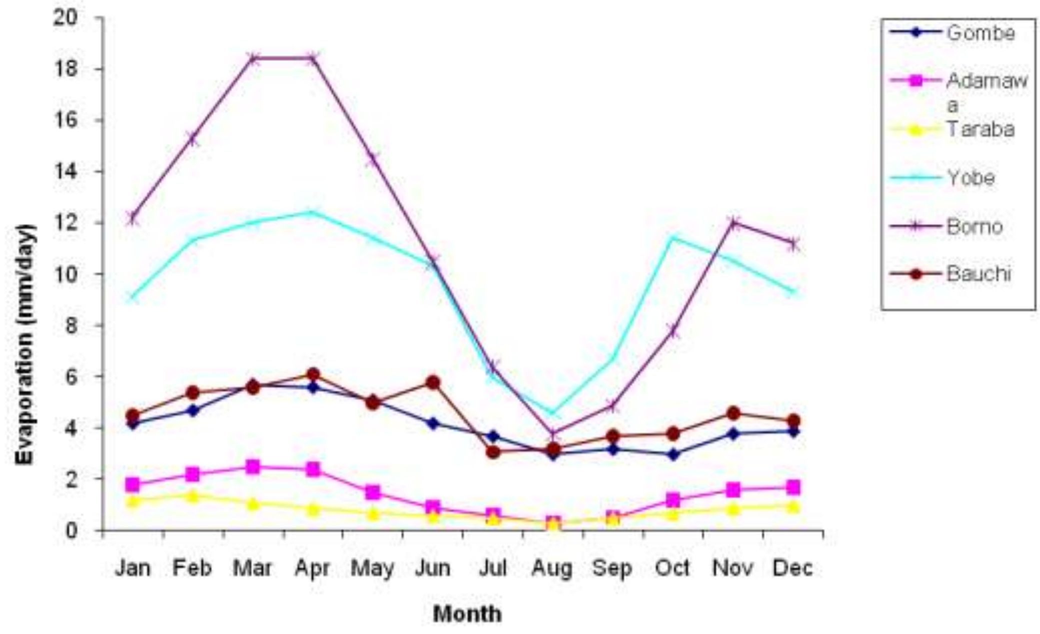

Fig. 1b: Pattern of changes in evaporaion on monthly basis at different locations

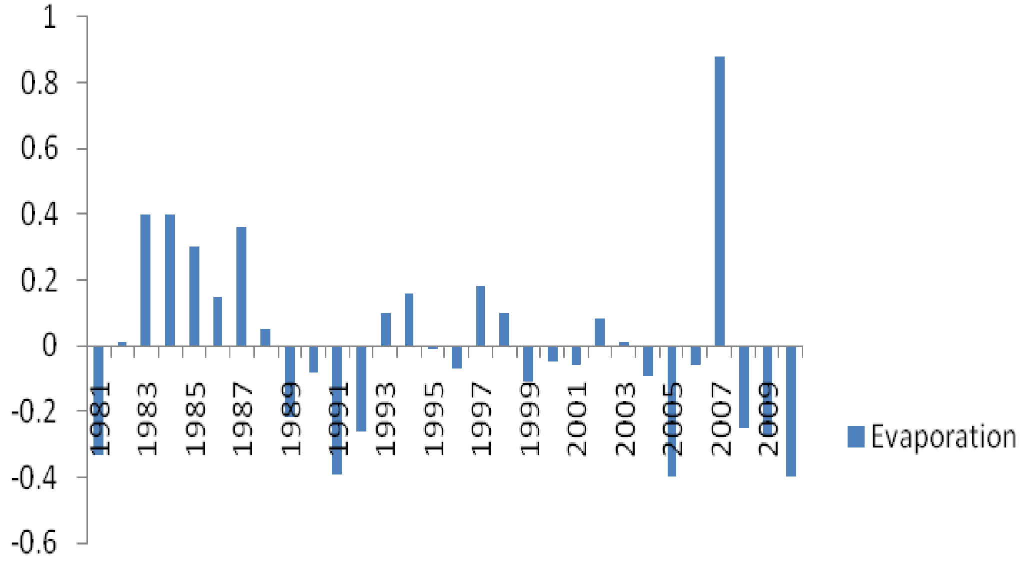

Fig.1c: Change in evaporation over 30 years

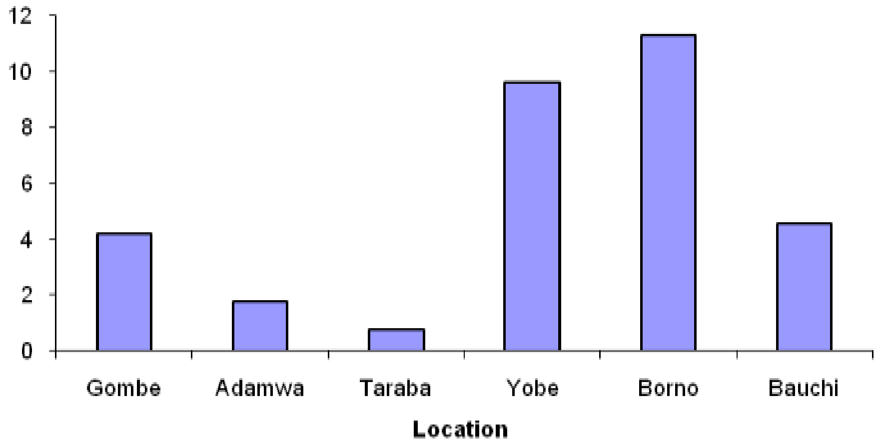

Fig. 1d: Relative mean evaporaion in different locations

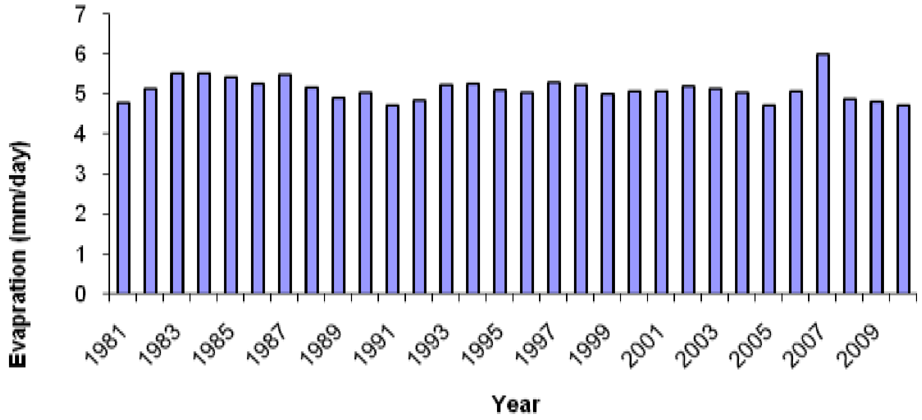

Fig. 1e: Relative mean evaporation over the years across locations

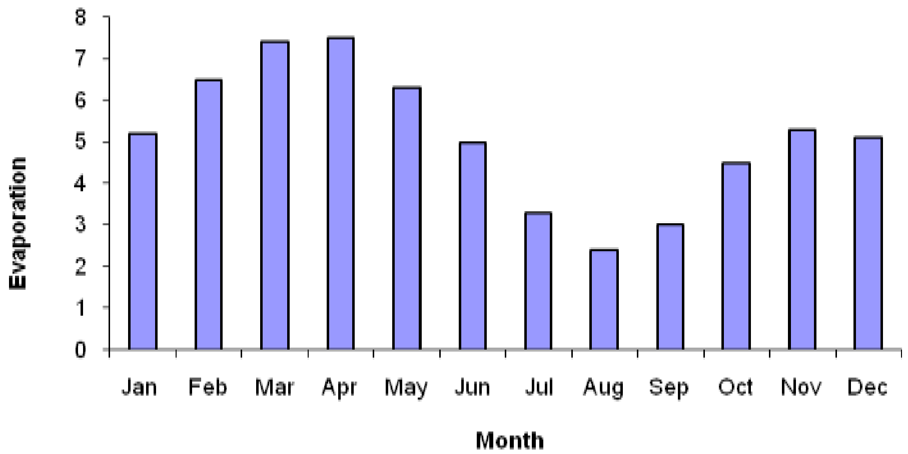

Fig.1f: Relative mean evaporatio over the month across locations

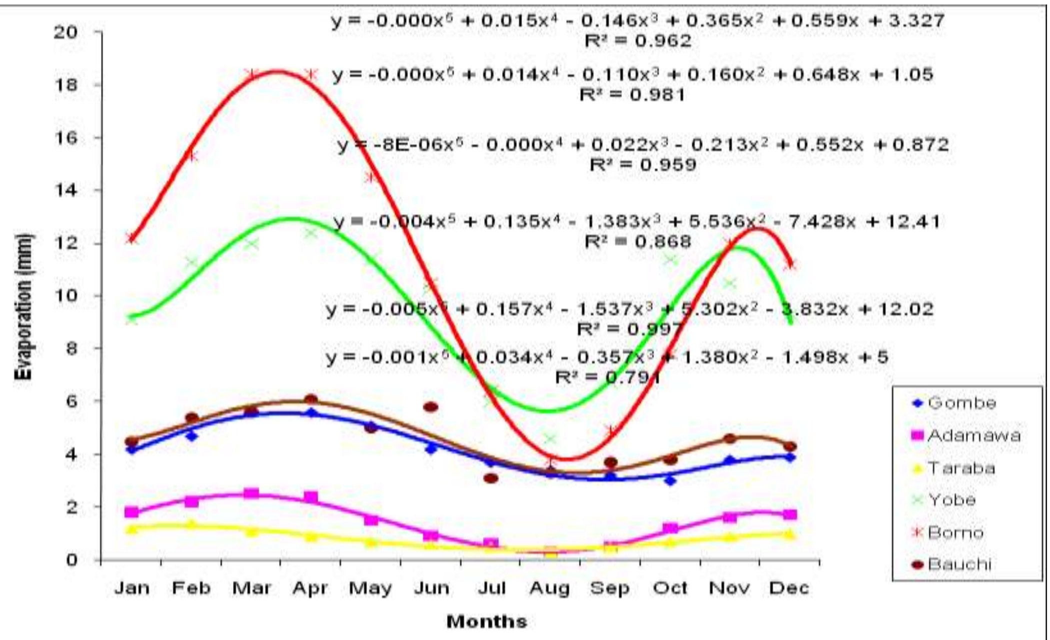

Fig. 2: Mean monthly trend of evaporation across locations

Table 1: Rate of changes in evaporation in different locations

State	Rising	Falling	Rising	Falling	R^2
Gombe	0.6420	0.2050	0.0190	0.0210	0.981
Adamawa	0.6480	0.1100	0.1600	0.0000	0.981
Taraba	0.5500	0.2130	0.0220	0.0000	0.959
Yobe	5.5360	7.4280	0.1350	1.3500	0.868
Borno	1.4500	3.8320	0.1570	1.5370	0.997
Bauchi	1.4500	1.6330	0.0360	0.3710	0.795

Evaporation rates and its effect

Fig. 2 shows a highly amplitudinal trend of 4th order polynomial for evaporation across the locations. The trend is similar in all the locations, except Borno and Yobe. The trend of evaporation across the location varies with rising and falling pattern. Similarly, the rate of changes in evaporation across the locations dipped at monthly rate of 0.110 to 7.428 mm/day, in Adamawa and Yobe while the peaks ranged from 0.550 – 5.536 mm in Taraba and Yobe (Table 1). The changes of evaporation experienced across the location with lower and higher evaporation in Taraba and Yobe respectively indicates variation in infiltration rate, moisture absorption and vegetation cover in the locations. This changes in evaporation has great effects on water level reduction. Each millimetre of evaporation reduce water level by 17.72, 70.96, 95.10, 16.57 and 56.57 mm at Gombe, Adamawa, Taraba, Borno and Bauchi, respectively. It could be deducted that evaporation was a major factor in water level reduction of rivers in these sites. The adverse effects of evaporation on water level was in the order Taraba>Adamawa>Bauchi>Gombe>Borno.

In contrast the positive effects of evaporation in Yobe was attributed to additional inflow received from other sources. Thus, evaporation was not a determinant of decrease in water level in this area.

V. CONCLUSION

The results show that climatic parameters analysed are networked through several pathways but the major impact on evaporation was the high temperature while rainfall was affected by relative humidity. Evaporation was observered to be highest in Borno and Taraba the lowest. The changes of evaporation observered has negative effects thus, causing reduction of water in the river in these sites. It is therefore recommended that a regional perspective can also lead to an improved representation of trend of evaporation in climate models.

REFERENCES

[1]. Ogolo E.O and Adeyemi. B. (2009): Variations and Trends of Some Meteorological Parameters at Ibadan, Nigeria. The Pacific Journal of Science and Technology. 10 (2), 981-987.
[2]. Teuling A.J.; M. Hirschi.; A. Ohmura.; M. Wild.; M. Reichstein.; P. Ciais.;
[3]. N. Buchmann.; C. Ammann.; L. Montagnani.; A. D. Richardson.; G. Wohlfahrt.;
[4]. and S. I. Seneviratne (2009): A regional perspective on trends in continental evaporation. Geophysical Research Letters, vol. 36, l02404, doi:10.1029/2008gl036584, 2009
[5]. Douville, H., Chauvin, F., Planton, S., Royer, J.F.,Salas-Melia, D. D. and Tyteca,S (2002): Sensitivity of the hydrological cycle to incresing amounts of greenhouse gases aerosols. Climate Dynamics, 20, 45-68
[6]. Loaiciga, H.A., Valdes,J.B., Vogel,R. and Garvey,J (1996): Global Warming and the Hydrological Cycle, Journal of Hydrology,USA, 174, 83-127.
[7]. Trenberth, K.E. (1998): Atmospheric Moisture Residence Time and Cycling: implication for Rainfall Rates and Climate Change. Climate Change, 39, 667 – 694.
[8]. 6] Chineke T C, Idinoba M.E and Ajayi O.C (2011).Seasonal evapotranspiration signatures under a changing landscape andecosystem management in Nigeria Implications for agriculture and food security. American Journal of Scientific and Industrial Research,
[9]. 2 (2):191-204
[10]. Cohen S., Ianetz, A and Stabdhill, G. (2002): Evaporative Climate Changes at Bet Dagan Israel, 1964-1998, Agricultural and Forest Meteorology, 111, 83-91.
[11]. 8] Da Silva (2003): On Climate Variability in Northeast of Brazil, Journal of Arid Environments, 58, 575-596.
[12]. Roderick, M. L., and G. D. Farquhar (2004), Changes in Australian pan evaporation from 1970 to 2002, Int. J. Climatol., 24(9), 1077 – 1090.
[13]. 10] Peterson T. C., Golubev, V.S.and Grolsman, P.Y. (1995): Evaporation losing its Strength, Nature, 377, 687-688.
[14]. Chattopadhyay.N. and Hulme.M. (1996): Evaporation and potential Evapotranspiration in India under conditions of recent and future climate change, Agriculture and Forest Meteorology, 87, 55- 73.
[15]. Gilbert, R.O.,(1987). Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York.