International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Effect of Climate Change on Pan Evaporation and Potential Evapotranspiration Trends in Umudike, Abia State Nigeria

Nta S. A.[1], Etim P. J.[1], Odiong I. C.[2]
[1]Department of Agricultural Engineering, Akwa Ibom State University, Uyo
[2]Department of Civil Engineering, Akwa Ibom State University, Uyo

Abstract—*A study to investigate the effect of climate change on pan evaporation and potential evapotranspiration trends in Umudike was conducted to see if there is a trend, and quality of the data is sufficient for such analysis. The variables used were pan evaporation, air temperature, relative humidity, wind speed, number of sunshine hours and solar radiation. The data collected cover a period of twelve years. The monthly mean of these meteorological data were computed for each months of the years and comparative analysis was carried out to see the trends. Then Blaney-morin-Nigeria (Duru, 1984) was used to compute the potential evapotranspiration. Correlation between potential evapotranspiration and some climate variables were made to investigate the effects of these variables on potential evapotranspiration. The results showed that air temperature and solar radiation had strong and positive correlation with potential evapotranspiration (+ 0.034) and (+ 0.148), relative humidity was negatively correlated (− 0.015). Based on the decline in relative humidity and increasing trend in vapor pressure deficit for the short period of analysis, it appears that Umudike is experiencing increase in evaporation and potential evapotranspiration.*

Keywords— *Climate change, pan evaporation; potential evapotranspiration; trends in Umudike.*

I. INTRODUCTION

Literature reports of declining trends in pan and lake evaporation warrants studying the case for every region and its implication for water management (Wossenu, *et al*. 2010). Evaporation from open water surface and evapotranspiration (ET) from vegetated surface has always been challenging to measure or estimated. In recent years, it has also been reported that, evaluation of trends in pan evaporation has been introduced into climate change discussions (Wossenu, *et al*. 2010). Climate change is a significant and consistent deviation from the average values and timings of climatic parameters observed over a long period of time, indicating a change in what is known to be the existing pattern. Climate change is substantially as a result of anthropogenic factors or human activities which result in the generation and concentration of greenhouse gases in the atmosphere. Greenhouse gases refer to any atmospheric gas that is capable of absorbing infrared radiation produced by solar warming of the earth's surface and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and water vapor. Evaporation measurement with a pan is a crude measurement subject to many potential errors including pan environment bias, operator's bias, rainfall estimation on the pan, reading error, data recording error, etc. (Wossenu, *et al*. 2010). Experiment in south florida showed that pan evaporation measurement error occur due to the difference in sampling rainfall event by the rain gauge with smaller surface area, and the pan with larger area (Gunderson, 1989).

Based on pan evaporation data analysis from the Eastern and Western United States, Europe, Middle Asian and Siberian regions of the former Soviet Union, a significant decline of pan evaporation was reported (Peterson *et al*., 1995). The largest change reported was 97mm increase in a warm season (May - September) for Western United States during the past 45 years and the study suggested that a feature of recent climate change includes a decrease in potential evapotranspiration (ETp). The decrease in pan evaporation was attributed to a decrease in the diurnal temperature range and increase in low cloud cover (Wossenu, *et al*. 2010). Acknowledging the decline in pan evaporation in the northern hemisphere, Roderick and Farquhar (2005) evaluated pan data in New Zealand. Their conclusion was that since 1970, pan evaporation declined at a rate of 2mm per year resulting in 60mm decline in annual pan evaporation at the end of 30 years. A suggestion was made that the cause may be global warming. Six of the nineteen pans showed an increase in evaporation although not statistically significant. Six of the remaining thirteen pans shows statistically decline in evaporation. A later study acknowledged that retrofitting of pans with bird guards could cause a decline in pan evaporation (Gifford *et al*., 2007). After applying a 7 percent correction for the bird guards, the study still reported a decline of 3mm yr^{-1} in pan evaporation. Also, the study reported that the rate of evaporation decline for lakes has been 2 - 4 mm yr^{-1} since 1950s. It was also pointed out that spatial and temporal variations in pan evaporation were observed. A follow-up analysis reported the declining trend within the range of 1mm to 4mm yr^{-1}, with an average of 2mm yr^{-1} translating to a change of 4.8 Wm^{-2} in energy term in 30 years (Roderick *et al*., 2009). This decline in energy was compared to the change in energy at the top of the atmosphere due to doubled levels of carbon dioxide (~3.7 Wm^{-2}) reported by the Intergovernmental Panel on Climate Change (IPCC). Jun and Hideyuk (2004) reported that pan evaporation is in a declining trend throughout Japan for all seasons, based on 34 years of pan evaporation data from 13 sites. The cause for the few exceptional stations not following the trend was attributed to local urbanization influence (Wossenu, *et al*. 2010). Stated

Nta S. A., Etim P. J., and Odiong I. C., "Effect of climate change on pan evaporation and potential evapotranspiration trends in Umudike, Abia State Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 3, pp. 274-278, 2017.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

factors for declining pan evaporation were increasing vapor pressure deficit and increasing terrestrial evapotranspiration.

A study on the trend of reference evapotranspiration in the Northern Arid zone of Nigeria (1961 - 1991) showed a decline in annual rainfall, a 1.5 ℃ increase in air temperature and an increasing trend in reference evapotranspiration, although not significant (Hess, 1998). Analysis of evaporation measurements (1964 - 1998) in the central coastal plains of Israel showed a small but statistically significant increase in pan evaporation from screened class A pans (Cohen *et al*. 2002). The purpose of this study is to evaluate the trends of meteorological variables that control the rate of evaporation, and also to investigate the effects of these variables on potential evapotranspiration in Umudike, Abia State, Nigeria. This study will provide a prelude for foresting the impacts of climate change on evapotranspiration in Umudike, Abia State, Nigeria.

II. METHODOLOGY

Study Site: The study area is located at National Root Crops Research Institute Umudike, Abia State Nigeria. The site was chosen due to its location, soil type, and open space for solar energy. Also Agricultural activities and researches are the mandate of the institute. Above all the meteorological station is sited in the institute for data availability. The institute is located at Umudike shearing boundary with Michael Okpara University of Agriculture at 8km east of umuahia, Ikot Ekpene Road, with 140km North of Port Harcourt International and 80km east of Owerri air Port. It is situated on latitude (05'' 29'N 07'' 33'E) with geographical elevation of 122m or above mean sea level (altitude) (Chukwu and Mbanaso, 1999).

III. DATA COLLECTION

The data used in this evaluation was collected from National Root Crops Research Institute meteorological office Umudike. The data includes monthly and yearly pan evaporation, air temperature, relative humidity, wind speed, number of sunshine hours and solar radiation. Data collected cover a period of twelve years.

Method of Analysis: The monthly mean of these meteorological data were computed for each months of the years and comparative analysis carried out to see the trends. Then Blaney-morin Nigeria (Duru, 1984) was used to compute the potential evapotranspiration as shown in equation (1) and correlation between potential evapotranspiration and some climate variables were made to investigate the effects of these variables on potential evapotranspiration.

$$Etp = r_f(0.45T + 8)(520 - R^{1.31})/100 \quad (1)$$

Where

Etp = potential evapotranspiration mmd^{-1}

r_f = Ratio of monthly maximum possible radiation outside the atmosphere to the annual maximum radiation in mld^{-1}

T = Temperature in℃.

R = Daily relative humidity (%).

IV. RESULTS AND DISCUSSION

Temperature

Figure 1 shows the computed average mean temperature (℃). The temperature is considerably even throughout the years and does not rise sufficiently high or fall sufficiently low to seriously affect pan evaporation and potential evapotranspiration. The annual daily average temperature in Umudike varies from 25.8 ℃ in August to 28.8 ℃ in March. Considering the years, high temperature was recorded in February 1998 to be 30 ℃ and March 2004 as 30℃. High temperature is attributed to global warming (Wossenu, *et al*. 2010). Global warming refers to the rising average air temperature of the earth atmosphere and ocean and its related effects. The importance of air temperature variable in pan evaporation and potential evpotranspiration process is distinct with its high direct effect (James 1988; Jensen 1974).

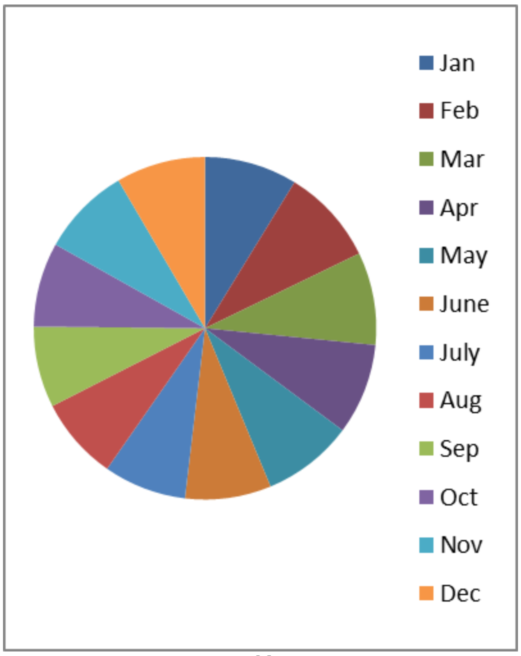

Fig. 1. Mean monthly air temperature.

Sunshine Hours

Figure 2 shows mean monthly sunshine hours. An examination of this figure reveals that the actual mean daily sunshine in Umudike varies from 2.5 hrs in August to 5.6 hrs in December. High sunshine was recorded in April 1998 to be 6.9 hrs in the twelve years considered for this study. Greater solar energy radiation during dry season implies more pan evaporation and potential evapotranspiration. Variation is attributed to the cloud cover associated with rainfall, which reflect much of the direct sunlight back into the upper atmosphere. It is also due to water vapor in the air that reflects and absorbs solar radiation at low latitude.

Relative Humidity

Figure 3 shows that the relative humidity at 3 pm varies from 41.5% in January to 75.2% in August. Relative humidity directly influences pan evaporation and potential evapotranspiration (Etp). High relative humidity decreases pan

Nta S. A., Etim P. J., and Odiong I. C., "Effect of climate change on pan evaporation and potential evapotranspiration trends in Umudike, Abia State Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 3, pp. 274-278, 2017.

evaporation and Etp, low relative humidity increases pan evaporation and Etp, which is the sum of evaporation and plant transpiration from the earth's land surface to atmosphere. Relative humidity directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield. High relative humidity was recorded as 82% in August and September 2001 under the years consider for this analysis.

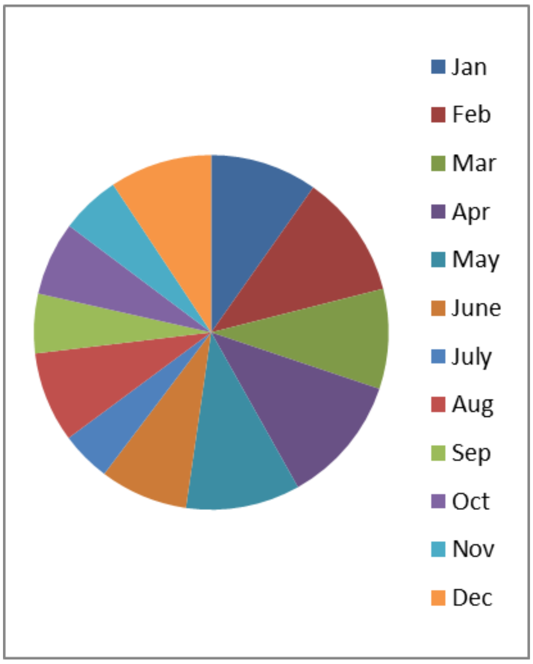

Fig. 2. Mean monthly sunshine hours.

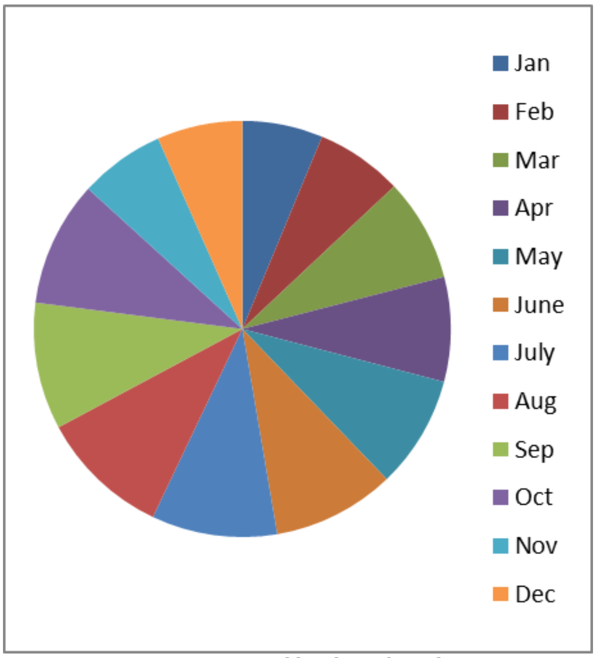

Fig. 3. Mean monthly relative humidity.

Wind Speed

Figure 4 shows mean monthly wind speed measured at 2m above the ground level. An examination of this data reveals that the mean daily wind speeds in Umudike vary from 24.1km/hr in November to 35.8km/hr in August. High wind speed was recorded in August as 35.8km/hr as the highest in 1999. The positive and negative effect of air temperature, relative humidity, sunshine hours and solar radiation are to be considered in selection (Singh and Chaudhary 1985).

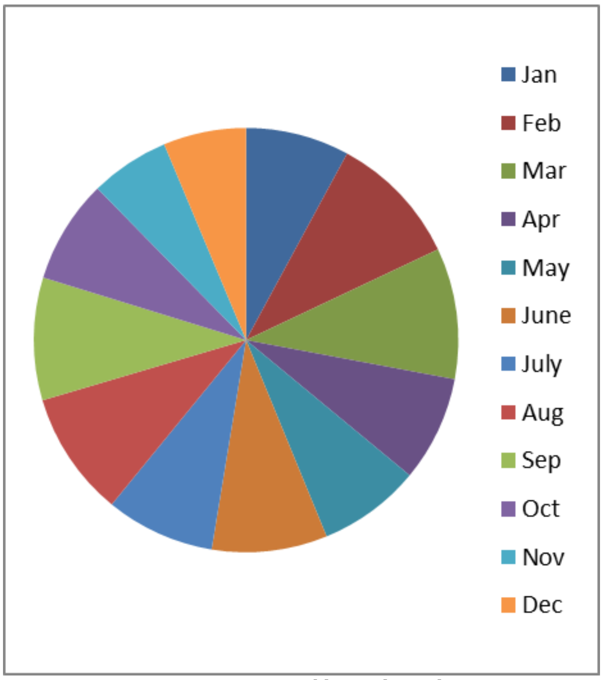

Fig. 4. Mean monthly wind speed.

Pan Evaporation

Figure 5 shows the average meteorological data/variables that control the rate of evaporation. Pan evaporation varies from 2.0mmd^{-1} in August to 5.2mmd^{-1} in February. Based on analysis of the meteorological variables, decreasing trend of reference evaporation was reported (Xu *et al*. 2006). Pan evaporation for the corresponding period was also reported having a decreasing trend. The meteorological parameters analyzed, air temperature and low relative humidity shows an increasing trend while wind speed and high relative humidity showed a declining trend. Decrease in pan evaporation has been reported (Peterson *et al*. 1995; Roderick and Farquar, 2004), which could be explained by decreased solar radiation (e.g., Matsoukas *et al*. 2011; Roderick and Farquar, 2002) and/or wind speed decrease (McVicar *et al*. 2012).

Potential Evapotranspiration

Figure 6 shows potential evapotranspiration to be low in September and August and gradually increases from October to January and decreases in February and increases again from March and finally gradually decreases from April to July. Potential evapotranspiration was obviously affected by solar radiation, relative humidity and air temperature.

High relative humidity and low air temperature and solar radiation decrease potential evapotranspiration while low relative humidity, high air temperature and solar radiation increase Etp. The Etp model could be used to schedule irrigation under different irrigation methods that is, surface, subsurface, sprinkler and drip irrigation.

Correlation Coefficient Study

Table I indicates that potential evapotranspiration is positively correlated to air temperature, solar radiation and negatively to relative humidity. The positive correlation indicates that air temperature and solar radiation increase potential evapotranspiration. However, negative correlation indicates that potential evapotranspiration decreased with increasing relative humidity. Palumbo *et al.* (2011) reported an increase of 14 mm/decade between 1957 and 2008, which has increased the water requirements of the main cultivated crops by 7 mm/decade. Vergni and Todisco (2011) also reported a dominant positive trend between 1951 and 2008.

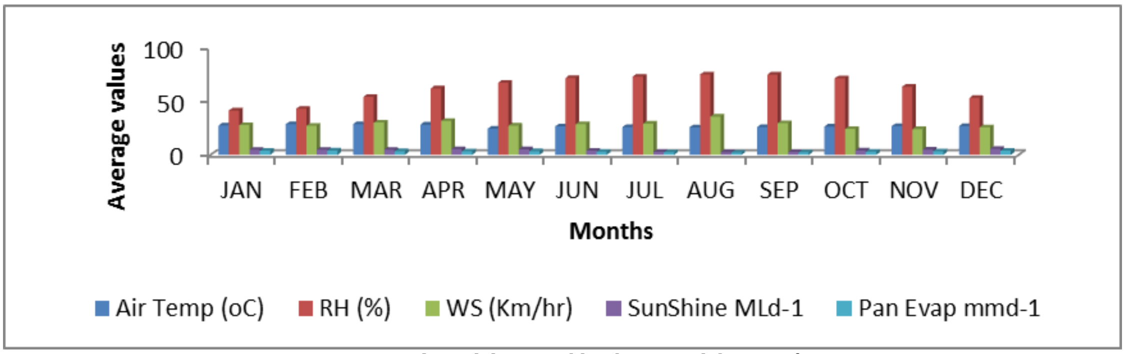

Fig. 5. Average meteorological data/variables that control the rate of evaporation.

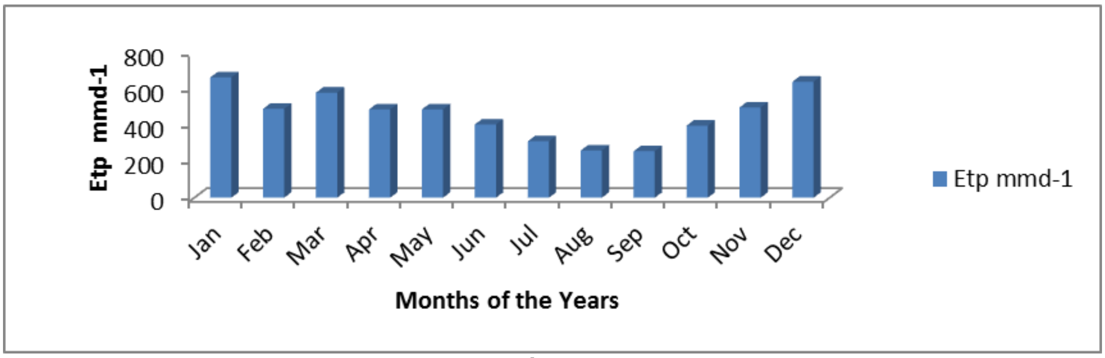

Fig. 6. Potential evapotranspiration.

TABLE I. The correlation between evapotranspiration and climate variables.

Variable	Potential Evapotranspiration mmd^{-1}	Air Temperature °C	Relative Humidity (%)	Solar Radiation Mld^{-1}
Etp	4.96	+ 0.034	- 0.015	+ 0.148

Etp = 4.96 + 0.034 air temperature – 0.015 relative humidity + 0.148 solar radiation

V. Conclusion

The conclusion is that pan evaporation measurements are prone to too many sources of errors to be used reliably for trend analysis. The results showed that high temperature, sunshine and low relative humidity increase pan evaporation, while high relative humidity decrease pan evaporation. Temperature and solar radiation had strong and positive correlation with potential evapotranspiration, relative humidity was negatively correlated. It is assumed that weather station used for this study did not incur systematic errors in measuring and recording meteorological parameters.

VI. Recommendation

Since much climate data has not been readily available in the meteorological station for the comparison of various methods to verify which method will give most accurate prediction of evaporation and potential evapotranspiration. It is recommended that the institute should be equipped with climate data; also field experiment should also be carried out to validate the result of the present work on the field.

REFERENCES

[1] Blaney-Morin-Nigeria (Duru, 1984). *Journal of Agricultural Engineering and Technology*, 12: 2004 Published by the Nigerian Institution of Agric. Engineers (NIAE).

[2] G. O. Chukwu, and E. O. Mbanaso, “Crop Water Requirements and Radish Southern Nigeria,” *Journal of Sustain. Agric. Environ.*, vol. 2, pp. 236–241, 1999.

[3] S. Cohen, A. Ianetz, and G. Stanhill, “Evaporative climate changes at Bet Dagan, Israel, 1964 -1998,” *Agricultural and Forest Meteorology*, vol. 111, issue 2, pp. 83-91, 2002.

[4] R. M. Gifford, M, Roderick, and G. D. Farquhar, “Evaporative demand: Does it increase with global warming?,” *Global Change News Letter*, vol. 69, pp. 21-23, 2007.

[5] L. H. Gunderson, "Accounting for discrepancies in pan evaporation calculations," *Water Resources Bulletin*, vol. 25, issue 3, pp. 573-579, 1989.
[6] T. M. Hess, "Trends in reference evapotranspiration in the North East Arid Zone in Nigeria," *Journal of Arid Environments*, vol. 38, issue 1, pp. 99-115, 1998.
[7] L. G. James, *Principles of Farm Irrigation System Design*, New York, Wiley, 1988.
[8] M. E. Jensen, Consumptions Use of Water and Irrigation Water Requirement; Rep. Tech. Com. on Irrig. Water Requirement, Am. Coc. Civ. Eng, Irrig. Dram. Div, 1974.
[9] A. Jun, and K. Hideyuk, "Pan evaporation trends in Japan and its relevance to the variability of the hydrologic cycle," *Tenki*, vol. 51, issue 9, pp. 667-678, 2004.
[10] C. Matsoukas, N. Benas, N. Hatzianastassiou, K. G. Pavlakis, M. Kanakidou, and I. Vardavas, "Potential evaporation trends over land between 1983 - 2008: Driven by radiative fluxes or vapour-pressure deficit," *Atmospheric Chemistry and Physics*, vol. 11, pp. 7601-7616, 2011.
[11] T. R. McVicar, M. L. Roderick, and R. J. Donohue, "Global review and synthesis of trends in observed terrestrial near-surface wind speeds: implications for evaporation," *Journal of Hydrology*, vol. 416-417, pp. 182-205, 2012.
[12] A. D. Palumbo, D. Vitale, P. Campi, and M. Mastrorilli, "Time trend in Reference evapotranspiration: Analysis of a long series of agrometeorological measurements in Southern Italy," *Irrigation and Drainage Systems*, vol. 25, issue 4, pp. 395-411, 2011.
[13] T. C. Peterson, V. S. Golubev, and P. Y. Groisman, "Evaporation losing its strength," *Nature*, vol. 377, issue 26, pp. 687-688, 1995.
[14] D. P. Rayner, "Wind run changes: The dominant factor affecting pan evaporation trends," *Journal of Climate*, pp. 3379-3394, 2007.
[15] M. L. Roderick, and G. D. Farquhar, "Changes in Australian pan evaporation from 1970 to 2002," *International Journal of Climatology*, vol. 24, issue 9, pp. 1077-1090, 2004.
[16] M. L. Roderick, and G. D. Farquhar, "Changes in New Zealand pan evaporation since the1970s," *International Journal of Climatology*, vol. 25, issue 15, pp. 2031-2039, 2005.
[17] M. L. Roderick, M. T. Hobbins, and G. D. Farquhar, "Pan Evaporation Trends and the Terrestrial Water Balance," *Geography Compass*, vol. 3, issue 2, pp. 746-760, 2009.
[18] R. K. Singh and B. D. Chaudhary, *Biomaterial Methods in Quantitative Genetic Analysis*, New Delhi, Kalyani Publisher, 1985.
[19] L. Vergni and F. Todisco, "Spatial-temporal variability of precipitation, temperature and agricultural drought indices in Central Italy, *Agricultural and Forest Meteorology*, vol. 151, issue 3, pp. 301–313, 2011.
[20] W. Abtew, J. Obeysekera, and N. Iricanin, "Pan evaporation and potential evapotranspiration trends in South Florida," *Hydrological Processes*, vol. 25, issue 6, pp. 958-969, 2011.
[21] C Y. Xu, L. Gong, J. Tong, and D. Chen, "Decreasing reference evapotranspiration in a warming climate - A case of Changjiang (Yangtze) River catchment during 1970-2000," *Advances in Atmospheric Sciences*, vol. 23, issue 4, pp. 513-520, 2006.