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Effect of Temperature Changes on Evapotranspiration in Minna, Niger State

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Abstract: A study was carried out to assess the effect of temperature changes on evapotranspiration in Minna, Niger State. Climatic data of ten years period (1996-2006) were used in estimating potential evapotranspiration, using Blaney-morin Nigeria and water balance models. The estimated potential evapotranspiration obtained were compared statistically with pan evaporation using Correlation and Regression analysis. The results showed that temperature has significant effect on potential evapotranspiration and correlated significantly with evapotranspiration. Evapotranspiration increases with temperature and rainfall amount.

Key words: Evapotranspiration, temperature, pan evaporation, climatic change

INTRODUCTION

The term temperature is a generalized term climate change which can also be refer to as “Global cooling” during the ice ages. Temperature can also be referred to as recent warming. The intergovernmental panel on climate change predicted that global temperatures may increase by 1.4- 0.5°C between 1990 and 2100, the uncertainty in this range results from both the difficulty of predating the volume of future green house gas emission and uncertainty about climate sensitivity.

Relative to the period 1860-1900, temperatures on both land and sea have increased by 0.75°C. According to the instrumental temperature record, based on estimates by NASA’s Goddard Institute for space studies, 2005 was the warmest year since reliable, widespread instrumental measurements became available in the late 1800’s exceeding the previous record set in 1998 by a few hundredth of a degree, estimate proposed by the world meteorological organisation and United Kingdom climatic research unit concluded that 2005 was still only the second warmest year behind 1998.

The prevailing scientific opinion on climate change is that most of the warming observed over the last 50 years is attributable to human activities, the main cause of human and induced component of warming is the increased atmospheric concentration of green house gases such as carbon dioxide which leads to warming of the surface and lower atmosphere by increasing the green house effect. According to the National Academy of sciences, the average surface temperature of the earth has risen by one degree Fahrenheit (°F) during the past 100 years with accelerated warming occurring within the past 20 years. National agency of sanitation association [NASA] Climatologist stated that 2005 was the warmest year in a century

Temperature rise: From 1961-2003, the global ocean temperature has risen by 0.10°C from the surface, to a depth of 700 m. There is a variability both year to year and over longer time interval, with global ocean heat content observations showing high rates of warming for 1991-2003, but some cooling from 2003-2007. As increase in temperatures can in turn cause changes, a rising sea level and changes in the amount and pattern of precipitation. Relative to the period 1860-1900, temperatures on both land and sea have increased by 0.75°C. According to the instrumental temperature record. Based on estimates by NASA’S Goddard Institute for space studies, 2005 was the warmest year since reliable, widespread instrumental measurements became available in the late 1800’s exceeding the previous record set in 1998 by a few hundredths of a degree, estimate proposed by the World Meteorological Organization and United Kingdom climatic research unit concluded that 2005 was still only the second warmest year behind 1998. Higher temperatures, particularly in arid conditions entails a higher evaporative demand where there is sufficient soil moisture. In temperate climate, minor increases in rainfall totals would be expected to be largely taken up by increased evapotranspiration of vegetation or crops the expected higher temperatures.

Evapotranspiration: Evapotranspiration is the transfer of water to the atmosphere by direct evaporation of solid and liquid water from soil and plant surfaces as well as by transpiration. Evapotranspiration can also be defined as a combination of two processes which include

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evaporation and transpiration. Evaporation is the transfer of water from the earth's surface to the atmosphere while transpiration is the process by which water passes through plant's into the atmosphere. Evapotranspiration can also be define as sum of evaporation and plant transportation .

Determination of evapotranspiration

There are direct and indirect methods of determing evaporanspiration: Theoretical (physically-based) approaches; include the Turbulent (mass) transfer and energy balance approaches.

Turbulent (mass) transfer: Turbulent diffusion is a function of wind speed and vapour pressure gradient

$$*\text{Evaporation} = K\ uz\,(e_w - e_z),$$

where:

- k : Is a constant.
- u : Is wind velocity.
- e : Is the vapour pressure.
- w : Is the water surface.
- z : Is a reference height about the evaporating surface.

This approach assumes that heat and vapour move away from the water surface in response to decreasing air temperature and water vapour pressure, thus it does not apply to surface temperature inversions or condensation (dew or frost).

Energy balance approach:

Net radiation = sensible heat +/- soil or water heat +/-latent heat.

Measurement of the first three terms permits the calculation of latent heat, which is the portion of the net radiation used for evapotranspiration.

Direct measurement: The direct measurement includes the Lake water balance/Atomometer and Lysimeter

Lake water balance: Measuring inputs and outputs of water, including changes in storage (lake level) caused by evaporation, Precipitation + ground water + surface inflow = evapotranspiration-surface outflow-seepage +/-changes in storage.

Seepage through the lake floor is difficult to measure and there may be a large cumulative error in the measurement of all the variables.

Evaporation pans: Water loss from a shallow pan, is the simplest and most common method used.

Evaporation = change in water level-precipitation pan date reflect, but always exceed, water loss from lakes and reservoirs.

Empirical correction factors are applied to account for the excess water loss resulting from radiation striking the sides of the pan is and extra source of energy; pans have been embedded in the ground, but these increases the heat flux from the ground and the possibility of shading by plants and splash from the soil.

Size and depth:

- Lakes store heat at depth keeping the surface cooler.
- The small amount of pan water does not influence the humidity of the overlying air and this a constantly higher rate of evaporation is maintained.
- Pans have been floated on lakes but then they are less accessible and more costly to maintain.
- Turbulence as water passes around the pas and over the rim; the water level is always below the rim causing turbulence to develop inside the rim.

Atmometer: A fitter paper or a porous plate supplied with water from a graduated cylinder, More controlled than an evaporation pan, but does not stimulate evaporation from water bodies.

Thus it is mostly used experimentally in monitoring variation in rates of evapotranspiration among sites and with changes in humidity temperature, net radiation and wind.

Lysimeter: Lysimeter method measures evapotranpiration from soil and plant.

Impervious chamber (e.g. sheet metal box) installed in the ground such that changes in the measured weight of soil in the lysimeter represent changes in the soil water balance precipitation-evapotranspiration output by seepage cannot occur or occurs through a hole where it is measured.

Indirect method: The most important factors needed to estimate Evapotranspiration are: The local weather conditions and the cropping system for which estimates are needed are the (type of crop, plating date and crop development).

Local weather conditions are important because Evapotranspiration is driven by weather factors that determine the drying power of air. We can accurately predict Evapotranspiration losses in a given area from the measurements of 4 local weather variables:

- Solar radiation.
- Temperature.

- Humidity.
- Wind.

The data from these measurements is then plugged into equations that accurately predict the daily rate of Evapotranspiration for those conditions and these values are called reference Evapotranspiration and refer to the Evapotranspiration of the reference crop.

Factors affecting evapotranspiration

Weather: The weather factors affecting Evapotranspiration are radiation, air temperature, relative humidity and wind speed. The evaporation power of the atmosphere is expressed by the reference crop evapotranspiration which represents the Evapotranspiration from a standardized vegetated surface.

Crop: Crop type, variety and development stage affect the rate of Evapotranspiration from crops grown in large, well managed paddocks. Differences is resistance to transpiration, crop height, crop roughness reflection, ground cover and crop root characteristics result in different Evapotranspiration levels in different crop types under identical environmental conditions.

Environmental conditions: Factors such as soil salinity, inadequate nutrition, soil compaction, diseases and pests. Limit crop development reduces Evapotranspiration. Evapotranspiration is also affected by ground cover, plant density and soil water content.

Management: The Evapotranspiration rates is also affected by management practices that affect the climate and crop. Here are some of the Evapotranspiration related effects of management. Cultivation practices and irrigation method can alter the microclimate and affect the crop surface.Windbreaks reduce wind velocities and decrease ET rate of the field directly beyond the barriers. Micro-irrigation systems that apply water directly to the root zone of crops leave the major part of the soil surface dry, thereby limiting evaporation losses. Surface mulches, when the crop is small, substantially reduce soil evaporation.

Effect on agriculture: Rising temperatures have made possible the widespread sowing barley, which was untenable twenty years ago. Rising atmospheric temperatures, longer droughts and side-effects of both such as higher levels of ground level ozone gas, are likely to bring about a substantial reduction in crop yields in the coming decades, large scale experiments have shown (The Independent, 2005).

Ecosystem: Increasing global temperature means that ecosystems will change; some species are being forced out of their habitats because of changing conditions, while others are flourishing. Secondary effects of temperature changes, such as lessened snow cover, rising sea levels and weather changes, may influence not only human activities but also the ecosystem. The global temperatures predicted for the coming centuries may trigger a new mass extinction event, where over 50% of animal and plant species would be wiped out (Mayhew *et al.*, 2007).

Water scarcity: Increased evaporation will reduce the effectiveness of reservoirs. Higher temperatures will also increase, the demand for water for the purpose of cooling and hydration.

Direct effect of temperature rise on health: The most direct effect of climate change on humans ought be the impacts of hotter temperatures. Extreme high temperatures increase the number of people who die on a given day. People with heart problems are vulnerable because one's cardiovascular system must work harder to keep the body cool during hot weather, heat exhaustions and some respiratory problems increase Global warming could mean more cardiovascular diseases, doctors warn (EU-MED-Global Warming, 2007). Higher air temperature also increase the concentration of ozone at ground level. In the lower temperature, ozone is a harmful pollutant as it damages living tissue and causes problems for people with asthma and other living diseases (McMichae *et al.*, 2003).

One of the major agricultural problems in Savanna zone of Nigeria is the inadequacy of hydrological information by orderly development and management of the water resources, rainfall, runoff and soil moisture storage which along, with evapotranspiration constituted the components of a water balance. There is a need to study the impact of temperature changes on water resources and evapotranspiration in Minna-Niger State.

Therefore, the aim of this study is to evaluate the effect of temperature changes on Evapotrnspiration in Minna-Niger State.

MATERIALS AND METHODS

Experimental site description and climate: Minna lies with the northern Guinea Savanna zone of Nigeria and has a sub-humid tropical climate with a mean annual rainfall of 1200 mm. The temperature rarely falls below 22°C, which wet season temperature averages about 28°C, the peak is 40°C (March) and 22°C (December).

Models:

- Blaney Morin-Nigeria (BMN) 1980:

PET = r_f (0.45T + 8) (520-R, $^{1-3}$)/100 r $_f$= ratio of maximum possible incident radiation outside the atmosphere to the annual max.

T = Temperature (°C).
R = Relative humidity (%).

- Water balance equation: The model employs periodic determination of rainfall, irrigation, drainage and soil moisture data. The water balance equation is given by:

$$\Delta w = PI - R_0 - D - ET$$

Where:
PI = Precipitation (mm).
R_0 = Runoff (mm).
Δw = Change in soil moisture.
D = Ddeep percolation.
ET = Evapotranspiration.

Climatic data source: All climatological data used in the computation of the equations were obtained from meteorological unit of Federal Airport Authority, Minna, Niger State for a period of 10 years (1996-2006). The climatic data include rainfall, pan evaporation, temperature, solar radiation, wind speed, vapor pressure and relative humidity. Data collection was done by trained meteorological staff and weather instruments installation conformed world meteorological standard.

Statistical analysis: Computer programme was written to compute the yearly and monthly potentials evapotranspiration by Blaney Morin Nigeria and the water balance models. The comparison of yearly potential equations during 1996-2006 period was done using regression and correlation analysis.

RESULTS AND DISCUSSION

The parameters that were considered for investigation such as rainfall, temperature, pan evaporation and evapotranspiration and have been presented in Table 1. Temperature and evapotranspiration data were shown in Fig. 1.

The monthly evapotranspiration is shown in Fig. 1. The month of March has the highest evapotranspiration; this is due to high temperature. March is the peak of dry season hence more water loss from the earth surface and from plant cells, the least evapotranspiration was in the month of August, since the, August is the peak of rainy season in this zone.

Table 1:Annual temperature, runoff, pan evaporation and evapotranspiration

S/no	Year	Temp.	Rainfall	Pan eva.	ET
1	1996	301.95	825.9	52.50	60.88
2	1997	300.50	1058.2	61.60	68.70
3	1998	325.71	1349.2	70.42	70.51
4	1999	324.10	944.6	56.21	72.65
5	2000	331.30	1069.5	63.95	64.86
6	2001	322.15	1397.3	66.36	73.53
7	2002	326.20	974.0	65.66	59.60
8	2003	327.50	1175.8	69.51	64.20
9	2004	326.40	1018.6	98.21	74.81
10	2005	361.55	853.3	72.73	80.40
11	2006	345.80	1007.3	66.78	77.43

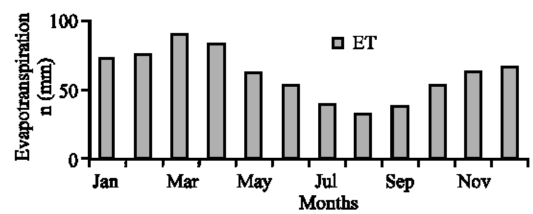

Fig. 1: Monthly evapotranspiration

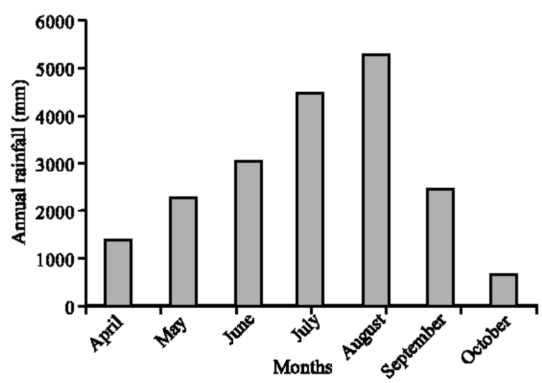

Fig. 2: Monthly rainfall distributionl (mm)

As temperature increases, evapotranspiration also increases due to low humidity in the atmosphere, so much water would be lost from the surface and from plant cells or tissues. During the months of March and April, evapotranspiration is high because of high temp; when there is no rainfall the soil would be dry and more water is evaporated: Baier and Roberson (1982) found similar findings.

The monthly rainfall distribution shown in Fig. 2 indicates that the highest rainfall amount was in the month of August which is the peak of rainy season in this zone. This is followed by July and the least amount of rainfall was in March. Evapotranspiration was least in August because of high rainfall, which made the soil saturated and waterlogged. Relative humidity was also

Table 2: Correlation of temperature with rainfall, evapotranspiration and pan evaporation

	Temperature (°C)	Rainfall (mm)	ET (mm)	Pan evaporation (mm)
Temperature(°C)	1.000	0.724	0.5 34	0.341
Rainfall(mm)	0.724	1.000	0.688	0.155
ET(mm)	0.434	0.688	1.000	0.252
Pan evaporation(mm)	0.341	0.155	0.252	1.000

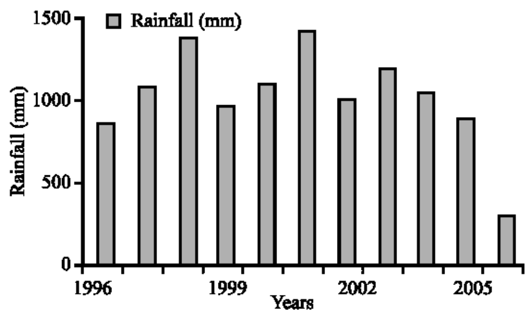

Fig. 3: A graph of annual rainfall

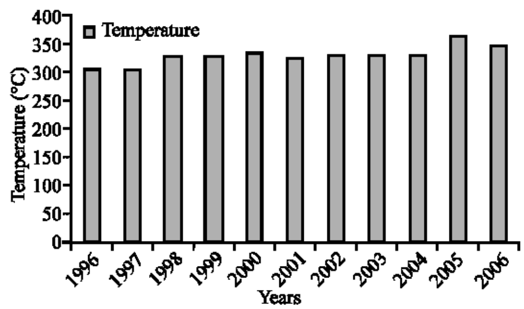

Fig. 4: Annual temperature (1996-2006)

high in this month, so not much water was lost to the atmosphere.

The annual rainfall distribution showed that the year 2001 has the highest amount of rainfall and 1996 has the lowest (Fig. 3). The correlation between temperature, rainfall, evapotranspiration and pan evaporation is shown in Table 2.

From Table 2, it is observed that change in temperature has significant effect on rainfall, evapotranspiration and no effect on pan evaporation

The impact of climate change increases evaporation rate and annual global rainfall which simulate vegetation change agreeing with consequent impact on carbon dynamics (Adesodum, 1999).

The results of pan evaporation indicate that month of April had the highest pan evaporation followed by the month of March and the least was in October. The pan evaporation was constant from 1996-1998 and increased in the year 1999, then dropped in the year 2000. It was constant for a period of four years and it increased slightly in 2004 and then dropped again in 2005 and 2006, the month of April has the highest temperature followed by May and the least in January because of harmattan. The warmest year in 2005 followed by 2006 and the least was in 1997 (Fig. 4).

CONCLUSION

From the results discussed above, it can be concluded that temperature changes has significant effect on evapotranspiration and rainfall. But no significant effect on pan evaporation.

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