SCIREA Journal of Agriculture

http://www.scirea.org/journal/Agriculture

April 23, 2017

Volume 2, Issue 2, April 2017

CORRELATION ANALYSIS BETWEEN CLIMATIC PARAMETERS AND THEIR EFFECT ON EVAPOTRANSPIRATION AT TONO IRRIGATION AREA, UPPER EAST REGION, GHANA

Jerry Asaana[1], Adams Sadick[2], Abunkudugu A. Akunai[3], Tayari Salifa[3]

[1]Civil Engineering, Bolgatanga Polytechnic, Ghana

[2]Analytical Services, CSIR-Soil Research Institute, Ghana

[3]Agricultural Engineering, Bolgatanga Polytechnic, Ghana

Abstract :

A study was carried at Tono irrigation area in the Upper East Region of Ghana to assess the relationship between some selected climatic parameters and their correlation with potential evapotranspiration (PET) estimated using Penman-Monteith method. The selected climatic parameters were temperature, humidity, wind speed and solar radiation. The climatic parameters were sourced at the Tono meteorological station and subjected to statistical analysis using SPSS version 20. PET showed strong positive correlation with temperature (r= +0.9588), solar radiation (r= +0.7185) and windspeed (r= +0.5907) but strong negative with humidity (r= -0.7843). PET was high between the month of November and March which required water to irrigate the major crops in the area. Moreover, rainfall was high between the month of April and October with the highest in August.

Keywords: Temperature, Solar Radiation, Windspeed, Potential Evapotranspiration

1. INTRODUCTION

Water is absorbed into the atmosphere by direct evaporation of solid and liquid water from soil and plant surfaces as well as by transpiration. Since each of these processes involves evaporation which is not easily distinguishable (Dale et al., 2001), they are both referred to as evapotranspiration (ET). ET is found to be differentially dependent on climatic variables and to the period of the year. If sufficient water is available to meet evapotranspiration, the ET will reach its (maximum) potential value, PET, otherwise, the actual evapotranspiration (AET) will be less than PET.

The daily course of transpiration rate indicates a signal peak with a maximum at midday and minimum in the early morning and evening. Transpiration rate varies with plant development (Peng et al., 1999). Climatic parameters are crucial because evapotranspiration is driven by these parameters which determine the drying power of air (Edoga and Suzzy 2008). Evapotranspiration can accurately be predicted for a given area from the estimated climatic parameters such as solar radiation, temperature, wind speed and relative humidity (Edoga and Suzzy 2008).

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes (FAO, 2005). Apart from the availability of water in the topsoil, the evaporation from a cropped soil is mainly measured by the fraction of the solar radiation reaching the soil surface (FAO, 2005). This fraction decreases over the growing period as the crop develops, grows and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main driving power (FAO, 2005).

The Penman-Monteith method as modified by (Allen et al., 1998) was the most precise method to estimate evapotranspiration. Because of its precision, the Penman-Monteith method is used since temperature, relative humidity, wind speed, sunshine hours data are available in the area.

One of the major problems in guinea savannah ecological zone of Ghana, especially irrigation areas, is insufficient hydrological information for the management of water resources: rainfall, runoff and soil moisture. Water resources as above, are affected by the climatic parameters. Therefore, the need to study them and their correlation with evapotranspiration was paramount.

2. MATERIALS AND METHODS

The study area is located on latitude 10 °N and longitude 1 °W (Figure 1).

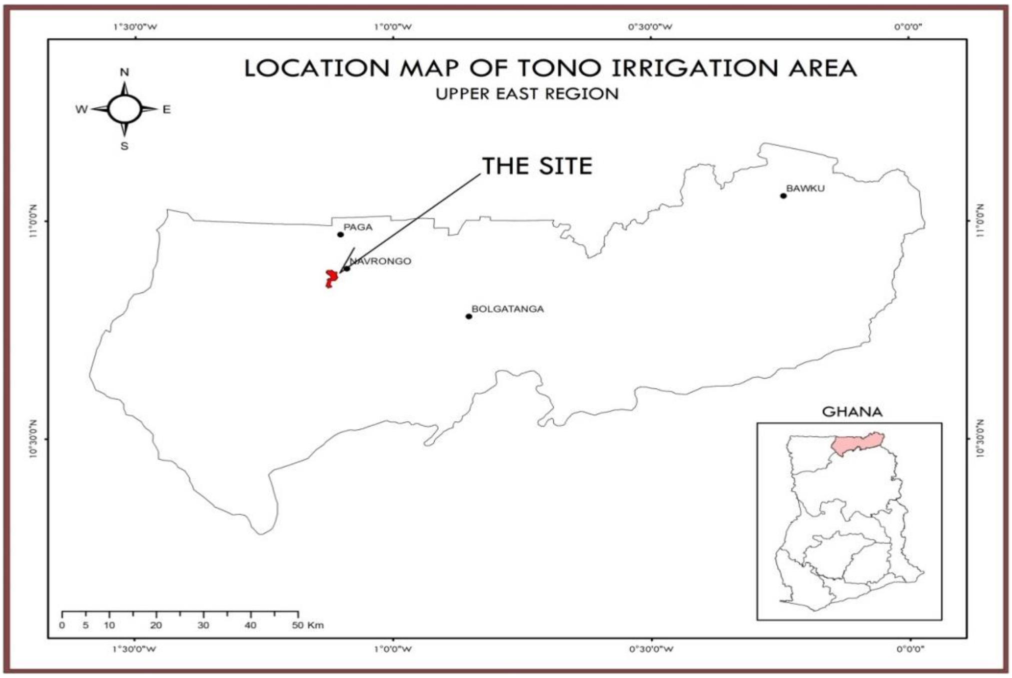

Figure 1. Map of upper east region showing the location of tono irrigation area (Adams et al., 2014).

The climate of the Upper East Region is affected by the movement of two types of air masses: the harmattan and monsoon winds. The harmattan, or North East trade winds, originate from the Sahara desert and are characterized by dry and particle-laden air masses. The south-westerly monsoon winds carrying moist air from the Gulf of Guinea bring rains upon converging with the North East trade winds. Movement of the Intertropical Convergence Zone, where the two air masses meet, affects the climate of the savannah region, allowing more seasonal rainfall in the belt that lies south of the Intertropical Convergence Zone (Kranjac et al., 1998).

The rainy season in the Upper East Region is mono-modal starting in April-May and lasting into September or the beginning of October (Dittoh, 1998). Thereafter, there is an extended dry period from November to the end of April during which period only small amounts of rain are received (Adams et al., 2014). Considerable changes in the amount of rainfall occur from year to year. In certain years the onset of the rain maybe delayed until June whilst in others the rain comes earlier than normal. Exceptionally heavy rains may also be experienced in some years and are then hazardous to crops (Adams et al., 2014).Violent thunderstorm and occasional tornadoes originating from the north-east normally precede the rains (Adams et al., 2014). Rainfall is erratic and spatially variable (Dittoh, 1998). Usually, precipitation in the region exceeds potential evapotranspiration only during the rainy season and vice-versa in the dry season. Annual potential evapotranspiration is estimated to be double the annual precipitation. This translates into a necessity for utilization of water storage reservoirs to ensure availability of water for various uses in the dry season.

Temperatures in the region are consistently high, with the hottest month being March or April (40-45 ℃) and coolest month being August (26 ℃). Mean annual temperatures are around 28-29 ℃ while the absolute minimum temperatures (15-18 ℃) occur in December. Relative humidity is generally higher during rainy season and decreases in the dry season. The region is generally characterized by low wind speed, ranging between 0.4 and 2.5 m/s. Skies are generally clear during the months of October to November and February to May and cloudy throughout the rainy season between June and September. From December to January, skies are hazy due to suspended dust particles in the air carried by the easterly-south hamattan winds from the Sahara desert.

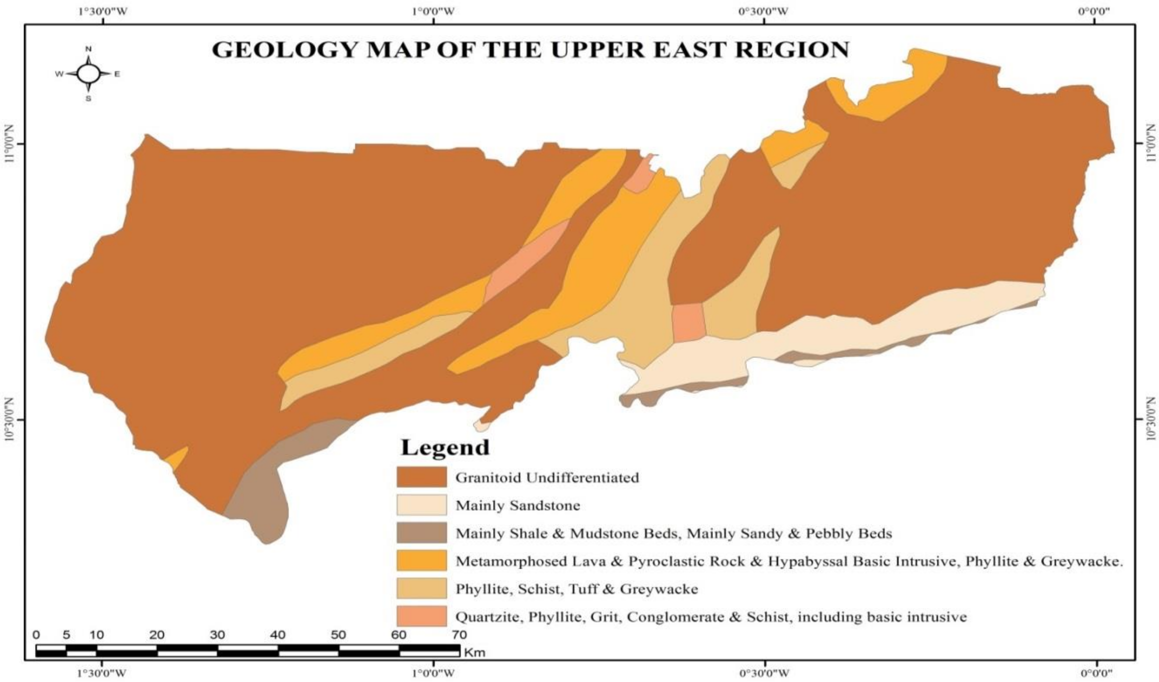

Figure 2: Geology map of upper east region

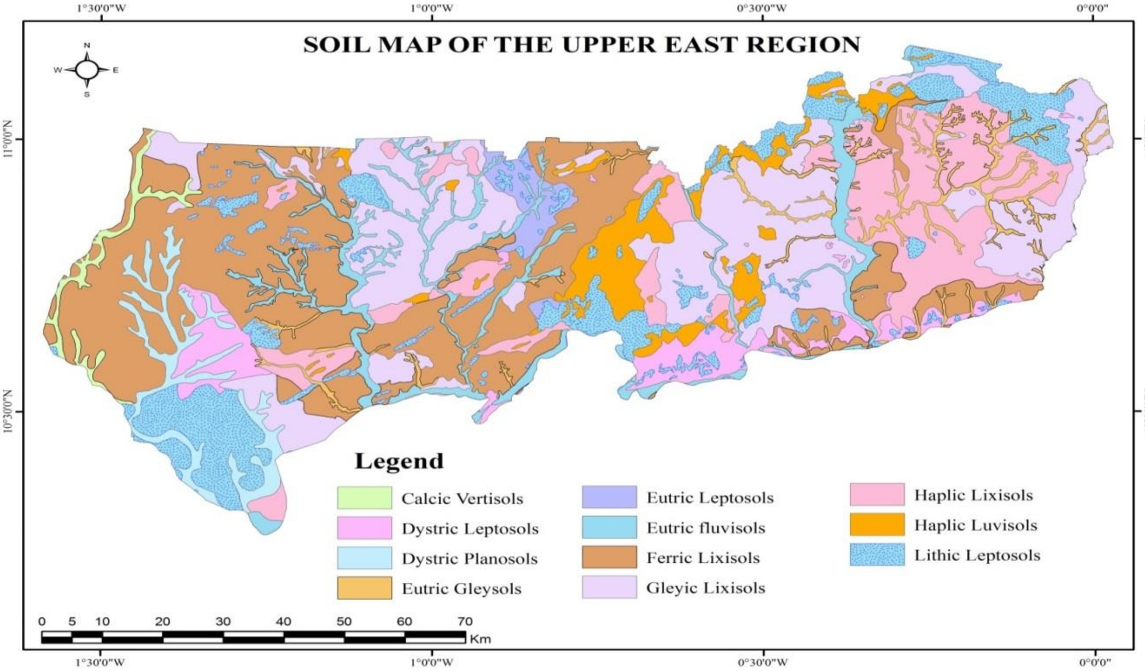

Figure 3. Soil map of the upper east region

The geological formations covering the Upper East Region are divided into three main groups, the Granitic, Voltaian, and Birrimian rocks. The pedology and the description of soil associations developed from these parent materials is discussed in detail by (Adu, 1969). Generally, soils developed over granites cover large areas of the Upper East Region (Figure 3). Gleyic and Ferric Lixisols cover large areas of the Upper East Region followed by Haplic Lixisols in the east and Lithic Leptosols in the southwest of the region. Haplic Luvisols cover the middle and the northeastern part of the region, while Eutric Fluvisols are found along the White Volta, in flood plains of the White Volta River, and in seasonal streams. The majority of soils in the Upper East Region are infertile, except soils occurring in seasonally flooded areas. This is common in savannah zones, which have low accumulation of organic matter in the surface horizons due to the high temperatures that cause rapid decomposition rates. The annual burning of the vegetation cover throughout the area also reduces the amount of organic matter in the soils (Boateng and Ayamga, 1992).

Climatic Data Source

The climatic data used in the study was obtained from the Meteorological Service Division in the Irrigation Company of Upper Region (ICOUR) for a period of 30 years (1985-2015). The climatic data included rainfall, temperature, humidity, wind speed and solar radiation. This data was used to estimate reference evapotranspiration using Penman Monteith method by

Allen et al., 1998. The actual evapotranspiration which involved satellite imageries was also estimated using the Surface Energy Balance System (SEBS) by (Su and Jacobs, 2001).

Statistical Analysis

Data collected were subjected to statistical analysis SPSS version 20. Pearson correlation coefficient was calculated to test the degree of relationship between irrigation water quality parameters.

According to Pallant, 2011, a correlation coefficient can be termed as: small correlation $-0.10 \leq r \leq 0.29$, medium correlation - $0.30 \leq r \leq 0.49$ and large correlation - $0.50 \leq r \leq 1.0$. The positive and the negative point to the direction of the relationship, where the positive indicates an increase in one variable associated with an increase in the other, whilst the negative correlation means an increase in one variable related to a decrease in the other. The coefficient of determination which explains the changes in one variable as explained by the changes in the other variable (r2) was calculated.

3. RESULTS AND DISCUSSION

The basic criteria for estimating evapotranspiration are temperature, wind speed, humidity and solar radiation.

Table 1 and 2 show the selected climatic parameters and correlation coefficient among selected climatic parameters at Tono irrigation scheme. Figure 4 represents the variations of PET and AET at the study area.

Correlation Analysis

According to Pearson correlation coefficient, evapotranspiration showed strong positive correlation with temperature ($r= +0.9588$), solar radiation ($r= +0.7185$) and wind speed ($r= +0.5907$) but negative correlation with humidity ($r= -0.7843$). This implies that changes in temperature, solar radiation and wind speed affect evapotranspiration. The degree of association for temperature, solar radiation and wind speed for evapotranspiration is strong and positive. This is justified because at higher temperatures, more water is lost from the earth surface and from plant cells to the atmosphere due to low humidity in the atmosphere (Edoga and Suzzy, 2008). During this period so much water will be lost from the surface and plant cell or tissues.

Table 1. Climatic parameters of the study area.

Month	Temperature	Humidity	Windspeed	Solar Rad.	PET	AET
	℃	%	m/s	MJ/m²/day	mm/day	mm/day
January	27.3	25.3	1.9	15.91	5.81	1.10
February	29.8	23.6	2.1	16.70	7.10	0.56
March	32.0	28.6	2.1	17.01	6.98	0.55
April	32.1	42.8	2.5	17.08	7.38	0.53
May	30.6	55.8	2.5	17.34	6.47	0.89
June	28.2	68.0	2.1	16.76	5.47	1.85
July	26.9	75.5	1.8	15.91	4.52	3.98
August	26.3	80.0	1.5	15.27	4.07	3.95
September	26.6	78.3	1.8	16.13	4.55	3.99
October	28.3	64.2	1.8	17.18	5.17	2.01
November	28.1	38.1	1.3	22.5	5.90	1.50
December	27.0	29.4	1.5	20.61	5.69	1.32

PET: Potential Evapotranspiration, AET: Actual Evapotranspiration

Table 2. Correlation coefficient among climatic parameters.

Variates	Evapotranspiration	Humidity	Solar	Temperature	Wind
Evapotranspiration	1				
Humidity	-0.7735	1			
Solar	0.2319	-0.4232	1		
Temperature	0.8880	-0.4603	0.0242	1	
Wind	0.6251	-0.1138	-0.4361	0.7567	1

Between February and April evapotranspiration was high due to high temperature, solar radiation and wind speed (Table 1), Baier and Robertson, 1982 did similar study and conclusion was in line with the above findings.

The monthly distribution of PET and AET shown in figure 4 indicated that at the peak of the rainy season where there was sufficient amount of water to meet soil moisture content PET and AET were almost the same. This occurred between the months of July and October and no irrigation was required at this stage (Figure 4).

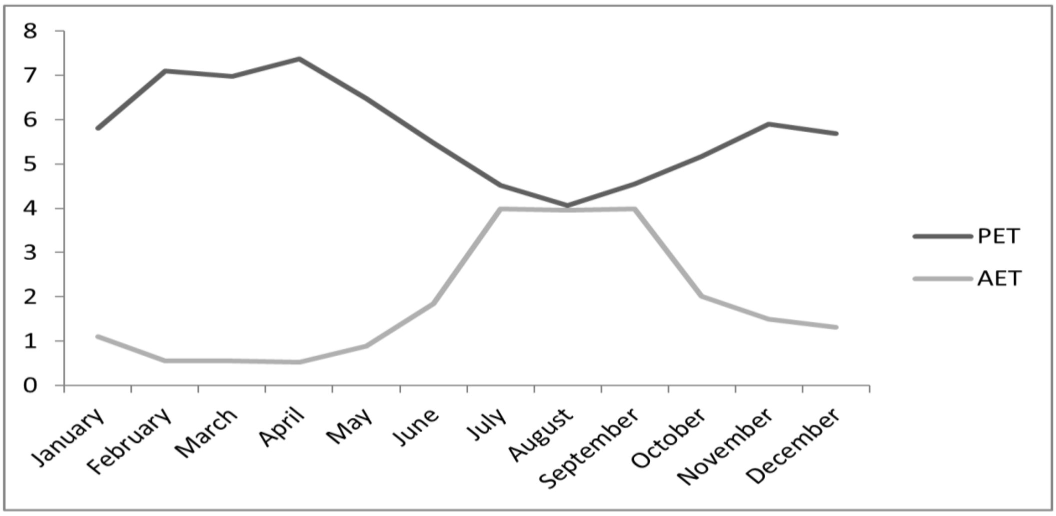

Figure 4. Variations of PET and AET at the study area.

4. Conclusion

The research conducted at the Tono irrigation area in the Upper East Region of Ghana concluded that some parameters that control evapotranspiration are temperature, wind speed, humidity and solar radiation. These parameters are useful for irrigation projects and water management. Evapotranspiration showed a strong positive correlation with temperature, solar radiation and wind speed but negative with humidity. Evapotranspiration was high between the month of November and March which require irrigation water. Moreover, rainfall was high between the month of April and October with the highest in August.

References

[1] Adams, S., Quansah, G. W., Issaka, R. N., Asamoah, E. A., Nketia, K. A., and Amfo-Otu, R. Water requirements of some selected crops in Tono irrigation area. Journal of Biodiversity and Environmental Sciences 4 (3). 2014, 246–257. Available at: http://www.innspub.net/wp-content/uploads/2014/03/JBES-Vol4No3-p246-257.

[2] Adu S. V. Soils of the Navrongo-Bawku area, Upper Region, Ghana. *Memoir No. 5, Soil Research Institute, Kumasi, Ghana. 1969, 100 pp.*

[3] Allen R. G., Pereira L. S., Raes D., and Smith M. Crop evapotranspiration, guidelines for computing crop water requirements, *FAO irrigation and Drainage paper 56. 1998, pp. 300, Rome, Italy.*

[4] Baier, W. and Robertson, G. W. Estimation of Latent Evaporation from Simple Weather Observations. *Canada Journal of Plant Science, 45. 1982, 276-284.*

[5] Boateng E and Ayamga T. Soils and Land evaluation studies at Tono-Navrongo, Wiaga, Zuarungu and Manga Agricultural Stations, *UER. IFAD/MOFA LACOSREP Report. 1992, 24 pp.*

[6] Dale J. B., Liza M. A, Jay M. H and Clenton. E. O. Evapotranspiration in a Praire Ecosystem. Effect of Grazing by Cattle. *Agronomic Journal*, 93. 2001, pp. 338-348.

[7] Dittoh S. Towards sustainable irrigated agriculture: The case of large and small systems in upper east Region, Ghana. *Condensed final research report submitted to African rural social sciences research networks (ARSSRN) and Winrock International, Department of Agricultural Economics and Extension. University for Development Studies, Nyankpala Campus, Tamale, Ghana. 1998, 27 pp.*

[8] Edoga R. N. and Suzzy A. B. U. Effect of Temperature Changes on Evapotranspiration in Minna, Niger State. *Journal of Engineering and Applied Sciences.* 3 (6). 2008, 482-486, ISSN: 1816-949X.

[9] FAO. Irrigation water requirement, In: Irrigation potential in Africa: A basin approach, Chapter 5, *FAO corporate document repository. 2005, Rome, Italy.*

[10] Kranjac-Berisavljevic' G, Blench R. M, Bayorbor T. B, Turton C. N, Abdulai AS, Boyd C, Obeng F and Drake E. Rethinking Natural Resources Degradation in Semi-Arid sub Saharan Africa: the Case of Semi-Arid Ghana. Faculty of Agriculture, University for Development Studies, Tamale, Ghana, and Overseas Development Institute (ODI), London, United Kingdom. http://www.odi.org.uk/rpeg/soil_degradation/ghlit.pdf. Cited 15 May 2005

[11] Pallant, J. SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS fourth Edition. Allen & Unwin, Australia. 2011

[12] Peng F., Huang B., Li J., and Sun J. (1999), "A study on the pattern of plant transpiration evapotranspiration in agroforestry system in sea-coast areas", *Journal of Nanjing*, 23 (6). 1999, pp. 19-22.

[13] Shirazi, S. M., Ismail, Z, Shatirah A, Sholichin, M. and Islam, M. A. Climatic parameters and net irrigation requirements of crops. *International Journal of the Physical Sciences* 6 (1). 2011. 15–26.

[14] Smajstrla A. G., Zazueta F. S., and Schmidt G. M. Sensitivity of potential evapotranspiration to four climatic variables in Florida. *Proceedings of the Soil and Crop Science Society of Florida, 46. 1987, pp. 21-26.*

[15] Su, Z., and Jacobs, C. ENVISAT: actual evaporation. BCRS Report 2001: USP-2 Report 2001. *Publication of National Remote Sensing Board (BCRS), Delft, 57pp.*