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Analysis of Temperature and Rainfall Trends in Vaal-Harts Irrigation Scheme, South Africa

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Abstract: - Agriculture is crucially dependent on the timely availability of adequate amount of water and a conducive climate. Temperature and rainfall patterns impact the availability of water for agricultural uses. Therefore, temperature and rainfall are twin important environmental factors in agricultural activities such as tillage, planting, irrigation and mechanization. The characteristics of the Vaal-Harts temperature data for year 1996 to 2010 and rainfall data for year 1983 to 2010 were examined in this study using statistical techniques. Basic statistical properties of the data were determined using the mean, variance, coefficient of variation and Pearson's correlation coefficient. Temperature and rainfall observations with the average of about 17.44 were used. The minimum and maximum temperatures recorded were 9.72^{0}C and 23.52^{0}C. The Coefficient of variation (CV) was found to be about 29.59. Variance is a measure of how far a set of numbers is spread out; and the variance of this set of observations is 26.625. The average yearly temperature increases insignificantly by a constant of about 0.117 (p = 0.163; 95% CI: -0.054 – 0.288), while rainfall shows decreasing trend annually which means that the dry season will be drier. The involvement of non-zero values in the serial correlation indicated the significance of the deterministic component in the data. The results of this analysis enhance our understanding of the characteristics of air temperature and rainfall in the study area for effective planning of farming operations.

Keywords: - *Environment, temperature, rainfall, Vaal Harts*

I. INTRODUCTION

Farming activities and operations like tillage, planting, plant growth, irrigation and mechanization depend on the temperature and rainfall of the prevailing environment. Adequate analysis and prediction of environmental factors like air temperature and rainfall can enhance the effectiveness of these activities for increased agricultural production. Temperature is a measure of the quantity of heat energy possessed by a body or medium as a result of heat transfer. Air temperature is a consequence of radiation heat transfer (thermal radiation) from the sun. Air temperature is an important atmospheric factor in agricultural production and it influences the rate of evapotranspiration which is a significant component of the hydrologic cycle (Ogunlela 1997). Rainfall is also an important climatic variable because of the critical role it plays in agricultural processes indirectly resulting into water logging and salinity (Ojo *et al* 2009).

Statistical analysis has proven to be an efficient tool for analysing and predicting the effects of environmental factors such as air temperature (Ogunlela 1997). A time series statistical analysis is a set of observations generated sequentially over time. The technique can allow the interdependence of successive observations to be taken into account in employing standard statistical tests that assume the independence of observations; and they could also be used in predicting future events. A stationary time series is one whose properties do not change with time. Usually, a stationary time series can be usefully described by its mean, variance and autocorrelation function or spectral density function. Spectral analysis is the method of estimating the spectral density function or spectrum of a given time series (Chatfield 1989). The spectral density function helps in determining which frequencies explain the variance of the series. Some theoretical insights into the spectral analysis technique were given by Wei (1990), which can be used in analyzing hydrologic and meteorological events or other phenomena where periodicities may be present. The application of the spectral analysis technique for the analysis of soil surface roughness under simulated rainfall was also done and it was found to be effective (Ogunlela 1997). Pearson's correlation coefficient is a measure of the correlation (linear dependence) between two variables *X* and *Y*, giving a value between +1 and −1 inclusive to give the covariance of the two variables divided by the product of their standard deviations. It is used to measure the strength of linear dependence between two variables (Rodgers and Nicewander 1988; Stigler 1989). Since farming and other related activities can be enhanced by accurate analysis of environmental factors like air temperature and rainfall, the focus of this work therefore is to conduct analysis of air temperature and rainfall data for the Vaal Harts irrigation scheme (VHS), South Africa in order to better understand their effect as key environmental factors influencing irrigation system.

II. MATERIALS AND METHODS

The Vaal Harts Irrigation Scheme (VHS) is located in a summer rainfall area of South Africa. This area battles with low, seasonal and irregular rainfall with an average rainfall of 442 mm per year (Jager 1994). The average precipitation in the summer months, October to February varies between 9.1 and 9.6 mm/day while in July precipitation is only 3.6 mm/day. The rainy season in the area is usually from October to March. In the winter months, almost no rainfall occurs. The average rainfall in Jan Kempdrop and in Taung weather stations (close to the study area) is 477 mm and 450 mm respectively (AGIS 2009). The average temperature of the spring and summer months is above 30°C and with the highest in the month of February. The median annual simulated runoff in the area is in the range of 20 to 41 mm, with the lowest 10-year recording at 4.8 to 9.3 mm (Schmidt, and Karnieli 2002).

Rainfall data from 1983 to 2010 and air temperature data from 1996 to 2010 were obtained from the South African Weather Service. For each of these years; the values of the two variables for each month of the year were computed. Basic statistics of mean, variance, standard deviation and coefficient of variation including Pearson's correlation coefficient were determined for the two variables. Pearson's correlation coefficient between the two variables temperature and rainfall were determined to measure the strength of linear dependence between two variables as expressed in equation 1. For a sample of size *n*, the *n* raw scores X_i, Y_i are converted to ranks x_i, y_i and ρ is computed from these:

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (1)$$

Where ρ is the Pearson's correlation coefficient,

x_i and $\bar{x}$ are variable 1 and its mean, while y_i and $\bar{y}$ are variable 2 and its mean respectively. The spectral density function helps in determining which frequencies explain the variance of the series. Equation 2 gave the expression of the spectral analysis technique called Spectral density function, g(f);

$$g(f) = 2\left[1 + 2\sum_{t=1}^{\eta} r_1 \cos(2\pi f t)\right]; 0 \leq f \leq \frac{1}{2} \quad (2)$$

Where, f is the frequency.

Coefficient of variation (CV) aims at describing the dispersion of the variables in such a way that it does not depend on the variable's measurement unit.

III. RESULTS AND DISCUSSION

There were 12 observations of temperature data. The study shows the average yearly minimum and maximum temperatures recorded as 9.72^0C and 23.52^0C respectively. There was a constant increase in temperature over the years, 1996 through 2010. The marginal increases were observed between the years 1998 and 2000, 2002 and 2004 & 2008 and 2010 as shown in Figure 1. The average yearly temperature of the study area increases significantly by a constant of about 0.1168444 (Pearson correlation coefficient, p = 0.163; 95 % confidence level: -0.054 – 0.288) as shown in Tables 1 to 4. The CV for temperature was found to be about 29.590. The variance is a measure of how far a set of numbers is spread out. The variance of this set of observations is 26.625. Figures 2 and 3 showed the spectral density function derived from autocorrelation of Temperature and rainfall respectively, while Figures 1 and 2 showed their graphical patterns. Rainfall data were available for a longer period of years (1983 to 2010) unlike temperature data. Precipitation reached a peak of an average of 60 mm in 1988 and 44 mm in 1991, while the lowest with an average of 12 mm was recorded in 1992 as shown in Figure 4. It was observed that precipitation is maximum in the summer and minimum during winter. The involvement of non-zero values in the serial correlation indicated the significance of the deterministic component in the data.

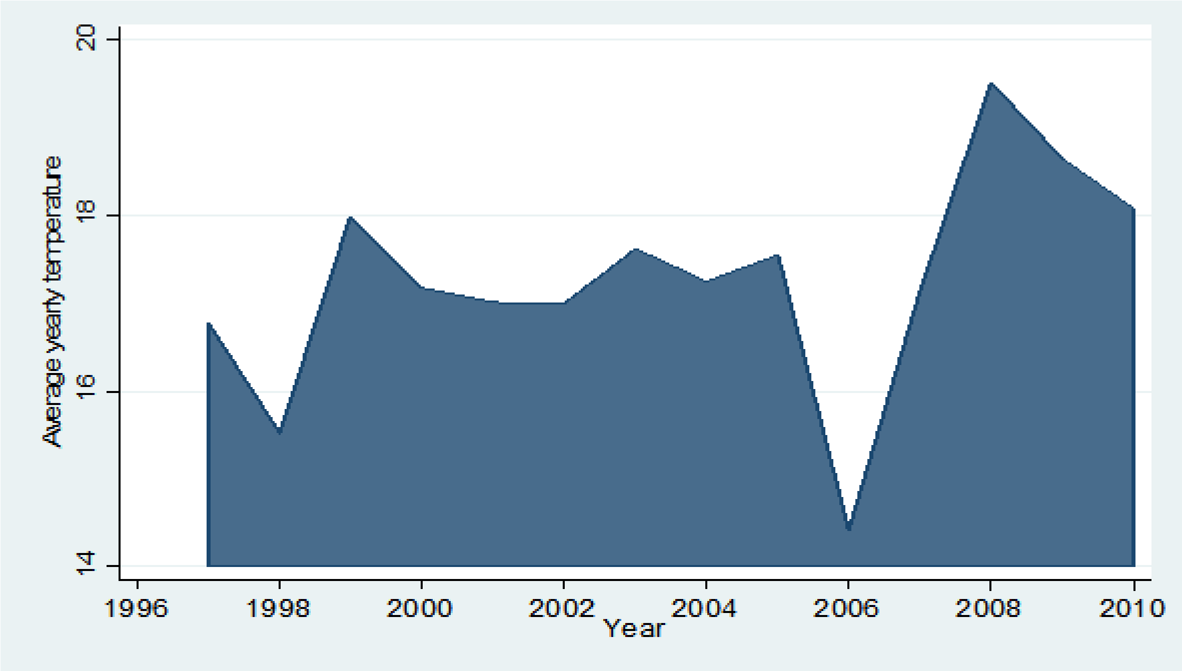

Figure 1: Average yearly temperature for the study area

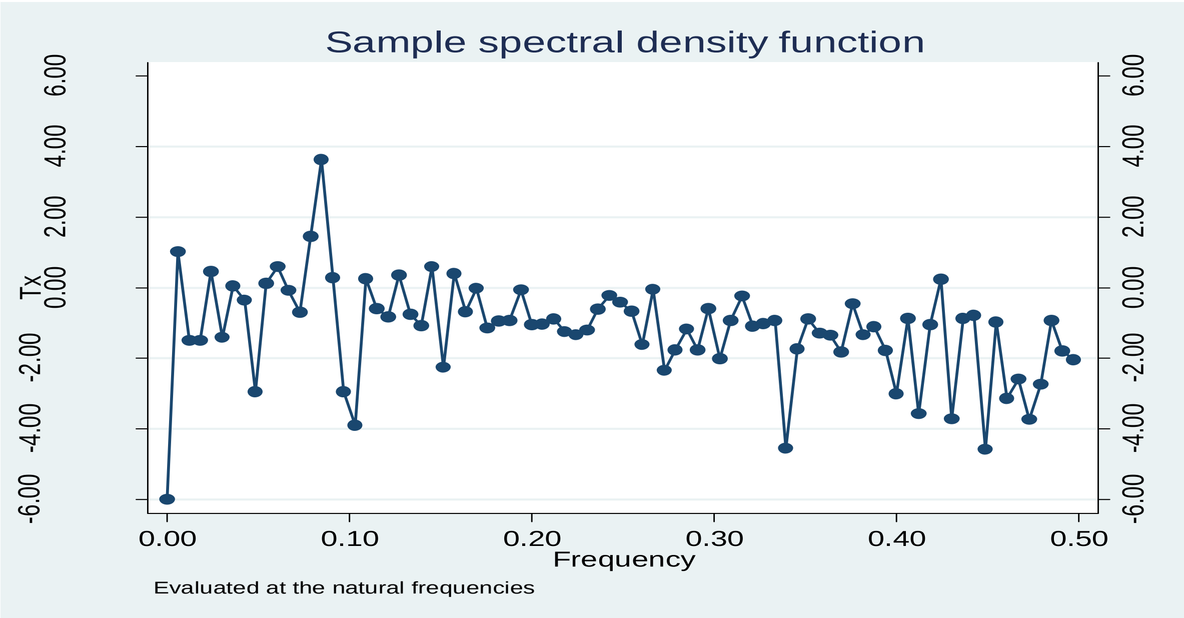

Figure 2: Autocorrelation graph of maximum temperature for VHS

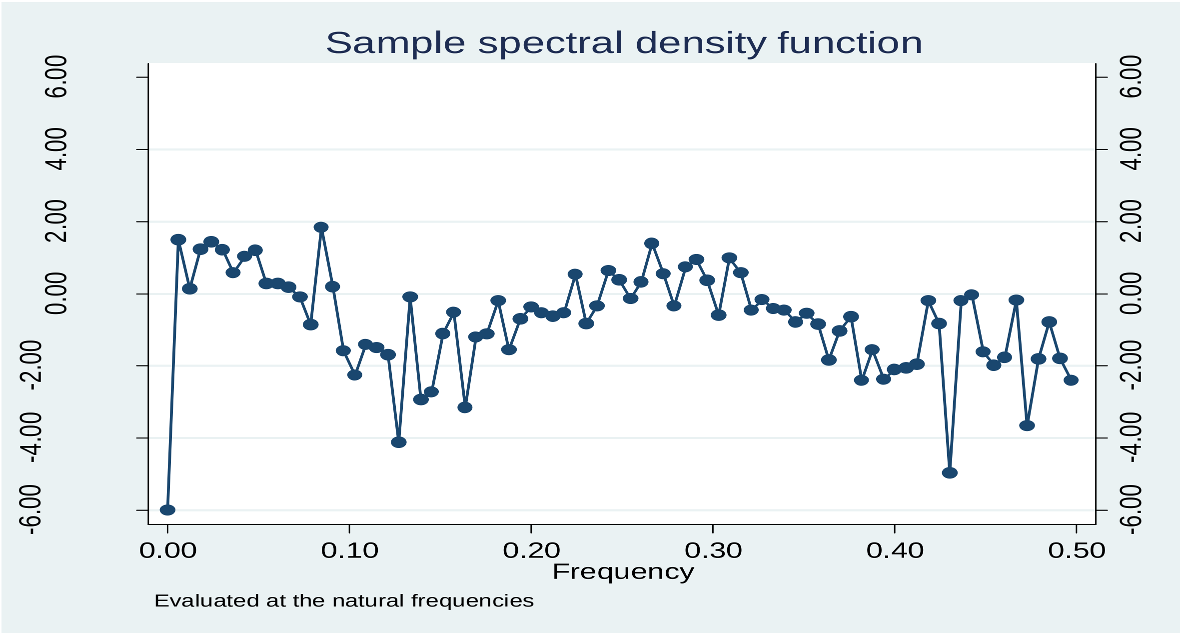

Figure 3: Autocorrelation graph of rainfall for VHS

Table 1: Monthly summary of temperature data

Elem	Start	End	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total for the year
Rainfall (mm)	01\01\1996	25\10\2010	116.58	84.48	56.2	53.31	76.23	42.04	3.36	21.72	12.94	40.25	54.31	59.68	621.1
T * (ºC)	01\01\1996	25\10\2010	22.4	22.63	21.22	17.16	12.78	9.76	9.72	12.43	16.21	19.81	21.62	23.52	

Table 2: Summary of the analyzed basic temperature data

Variable	Observation	Mean	Std. Dev	Ave. Min.	Ave. Max.
Temp ºC	12	17.438	5.160	9.720	23.520

Table 3: Summary of the analyzed temperature results

Temp mean	Coefficient	Std. Error	T	P > |t|	Ave. Max.	Interval
Years	.117	.079	1.490	0.163	-0.544	.288
considered	-216.839	157.427	-1.380	0.194	-559.843	126.165

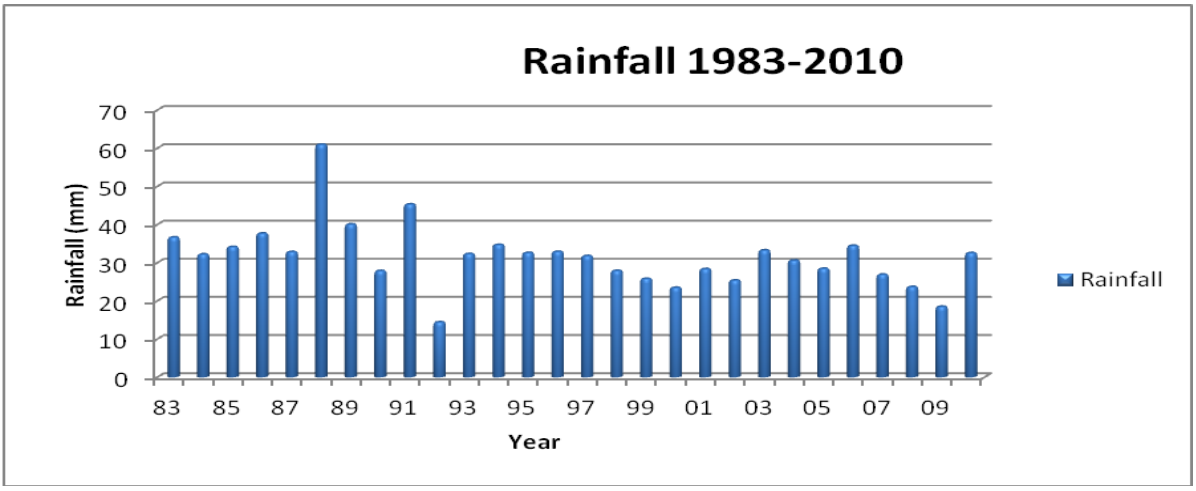

Figure 4: Average yearly rainfall for the study area.

Pearson correlation coefficient was used to test for correlation between rainfall and temperature. The correlation between the two variables was significantly negative (P= -0.036; P < 0.05), meaning that an increase in one resulted in a decrease in the other parameter. However, the strength of the correlation was weak. The strength of the relationship was also very weak as summarized in Table 4.

Table 4: Summary of the analysed weather data

Variable	Obser.	Mean	Std. Dev.	Min	Max
Temp. max ^oC	4330	27.237	7.583	8.1	339.2
Temp. min ^oC	4332	11.833	24.010	-4.0	195.2
Rainfall (mm)	4802	1.766	10.370	0	304.0

Table 5: Pearson correlation for Temperature and Rainfall

	Temperature	Rain
Temperature	1.000	1.000
Rain	-0.036*1.000 0.018	1.000

IV. CONCLUSIONS

VIS air temperature and rainfall data were analyzed using statistical analysis techniques. The mean, variance, coefficient of variation, Pearson's correlation was determined for the data sets. The temperature observations were with the average of about 17.44^{0}C. The minimum and maximum temperatures recorded were 9.72^{0}C and 23.52^{0}C. The variance of this set of observations is 26.625. The average yearly temperature of the study area increases significantly by a constant of about 0.117 (Pearson correlation coefficient, p = 0.163; 95 % confidence level: -0.054 – 0.288). It was observed that precipitation is maximum in the summer and minimum during winter. Precipitation with highest average of 60 mm in 1988, and lowest average was 12 mm in 1992. The involvement of non-zero values in the serial correlation indicated the significance of the deterministic component in the data. The results of this analysis enhance our understanding of the characteristics of air temperature and rainfall in the study area for effective planning of farming operations.

V. ACKNOWLEDGEMENTS

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