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Potential Evapotranspiration Prediction from Other Climatic Variables

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Abstract. This was conducted to establish functional relationships between potential evapotranspiration (dependent variable) computed using Penman Equation; and climatic parameters like maximum air temperature, minimum air temperature, mean air temperature, mean relative humidity, cloud amount, sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity (independent variable), and to determine which of these climatic parameters the best predictor of potential evapotranspiration is.The result of the simple linear regression analysis showed that only solar radiation, maximum air temperature, pan evaporation, sunshine duration, mean air temperature and mean relative humidity can predict accurately the monthly potential evapotranspiration.The multiple linear model developed was an equation describing potential evapotranspiration as a function of all independent variables with a value of coefficient of determination (r^2) of 0.9932 can be used satisfactorily in estimating monthly PET:

ETo = -6.2631 + 2.6247 Tmax + 2.7000 Tmin – 5.3975 Tm + 0.0444 RHm + 0.1997 CA + 0.0040 SD + 0.0511 RA + 0.0177 SR + 0.0449 Epan + 0.0104 WV

where:

ETo	= potential evapotranspiration, mm/day
Tmax	= maximum air temperature, ^oC
Tmin	= minimum air temperature, ^oC
Tm	= mean air temperature, ^oC
RHm	= mean relative humidity, %
CA	= cloud amount, okta
SD	= sunshine duration, minute
RA	= rainfall amount, mm
SR	= solar radiation, Langley
Epan	= pan evaporation, mm/day
WV	= wind velocity, km/day

Keywords: Potential evapotranspiration, Regression analysis, Dependent variable, Independent variable, Linear model, Coefficient of determination

1. Introduction

Evapotranspiration is the process by which precipitation reaching the earth's surface is returned to atmosphere as vapour through evaporation from wet surfaces and transpiration by plants. This hydrologic process is always important whenever moisture conservation and water control are desired. Hagan, et al (1961) have considered it a valid general principle to use the potential evapotranspiration as a guide to water application for the maximum production of a crop with a fully developed canopy. Schwab, et al (1993) reported that many practical applications can be made of evapotranspiration estimates but the principal use is to predict soil water deficits for irrigation. Analyzing weather records and estimating potential evapotranspiration rates, drought frequencies and excess water periods can show potential needs for irrigation and drainage. Stern (1994) stated that the amount of water used in evapotranspiration is the quantity which is important for irrigation planning, because in the absence of rainfall, irrigation has to provide this water. Evapotranspiration varies with climatic conditions in the way as open water evaporation. When the climate is hot and dry, the rate of evapotranspiration is high; when it is cool or humid, the rate is low. When there is a wind it is higher than when the air is still.Nyle and Weil (1999) emphasized that the potential evapotranspiration rate tells us how fast water vapour would be lost from a densely vegetated plan-soil system if soil water content were continuously maintained at an optimum level. The PET is largely determined by climatic variables, such as temperature, relative humidity, cloud cover and wind speed that influence the vapour pressure gradient between a wet soil, leaf or body of water and the atmosphere. They added that the solar radiant energy provides the 2260 joules (540 calories) needed to evaporate each gram of water, whether evaporation from the soil or transpiration from leaf surfaces. Direct sunlight stimulates the greatest evaporation. On cloudy days, less solar radiation strikes soil and plant surfaces; hence, the evaporative potential is not as great. Sunlight striking the land surface at a low angle spread its energy over a larger area, and therefore stimulates less evaporation per unit land area than more perpendicular solar radiation. Hence, evaporation is relatively low in winter and on slopes that face away from the sun.

Since determination of crop water requirements from field experiments is usually laborious, evapotranspiration formulae have been developed by many researchers to relate the water use of crops using past available meteorological data. Among the developed evapotranspiration formulae, Penman Equation give the most accurate and satisfactory result (Dorrenbos and Pruitt, 1977). The combination of the energy and aerodynamic terms in the equation makes it more reliable compared to other formulae. Using Penman Equation, one is able to compute potential evapotranspiration (PET) values. Manipulation of the PET values leads to the development of relationship between PET and some climatic parameters. Relationship of PET and some climatic parameters is important to study to be able to developed models to predict PET to improve irrigation practices; plan cropping schedules and help farmers allocate the available water in the most economical way.

This study was conducted to establish functional relationship between potential evapotranspiration (PET) and some climatic parameters, predict and determine the climatic parameter that is the best predictor of PET.

2. Discussion of Results

Simple linear regression analysis was employed to be able to establish models describing monthly average potential evapotranspiration as a function of some climatic parameters such as maximum air temperature, minimum air temperature, mean air temperature, mean relative humidity, cloud amount, sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity.

2.1. Regression Models Developed

Table 1: Summary of Regression Models Developed

Regression Model	Coefficient of Determination (r^2)	Probability Value
Simple Linear Regression		
ETo = -10.1700 + 0.4601Tmax	0.9743**	1.73×10^{-9}
ETo = -7.7860 + 0.5630Tmin	0.4485^{ns}	0.0703
ETo = -11.1270 + 0.5810Tm	0.8710**	5.74×10^{-6}
ETo = 18.7500 – 0.1812RHm	0.8055**	4.61×10^{-5}
ETo = 9.5120 – 0.8740CA	0.7325**	0.0002
ETo = 0.6480 + 0.0130SD	0.9359**	1.69×10^{-7}
ETo = 4.2217 + 0.0825RA	0.0633^{ns}	0.5700
ETo = -1.3450 + 0.0220SR	0.9807**	0.0004
ETo = 0.8020 + 0.9540Epan	0.9691**	4.34×10^{-9}
ETo = 3.4060 + 0.0025WV	0.1328^{ns}	0.4444
Multiple Linear Regression		
ETo = -6.2631 + 2.6247Tmax + 2.700Tmin + 5.3975Tm – 0.0444RHm – 0.1997CA + 0.0040SD + 0.0511RA + 0.0177SR + 0.0449Epan + 0.0104WV	0.9932**	2.53×10^{-15}

**p < 0.01 (significant at 1%)
*p < 0.05 (significant at 5%)
P > 0.05 (not significant)

With monthly average potential evapotranspiration as dependent variable and monthly average maximum air temperature as independent variable, regression analyses were employed. The developed models above shows that an increase of 1 degree for maximum air temperature, minimum air temperature and mean air temperature will cause an increase of 0.4601 mm, 0.5630 mm and 0.5810 mm on monthly average potential evapotranspiration. An increase of 1 langley, 1 mm, 1 langley, 1 mm and 1 km/hr on sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity, respectively will cause an increase of 0.0130 mm, 0.0825 mm, 0.0220 mm, 0.9540 mm and 0.0025 mm, respectively on monthly average potential evapotranspiration. On the other hand, an increase of 1 percent on mean relative humidity and cloud amount will cause a decrease 0.1812 mm and 0.8740 mm, respectively on monthly average potential evapotranspiration.

The intercepts theoretically signify that monthly average potential evapotranspiration will start to occur when monthly average maximum air temperature is 22.10°C, minimum air temperature is 13.83°C, mean air temperature is 19.15°C and solar radiation is 61.40 langley. On the other hand when mean relative humidity, cloud amount, sunshine duration, rainfall amount, pan evaporation and wind velocity are zeroes, monthly average potential evapotranspiration will have a value of 18.7500 mm, 9.9090 mm, 0.6481 mm, 4.2217 mm, 0.8024mm and 3.0456 mm, respectively.

The coefficient of determination (r^2) value of 0.9743, 0.8710, 0.8055, 0.7355, 0.9395, 0.9807 and 0.9691 which are significant at 1% level implies that 97.43%, 87.10%, 80.55%, 73.55%, 93.95%, 98.07% and 96.91% of the variations in the monthly average potential evapotranspiration is accounted for by the monthly variations in maximum air temperature, mean air temperature, mean relative humidity, cloud amount, solar radiation and pan evaporation, respectively. Thus, the regression models can satisfactorily predict the monthly average potential evapotranspiration and hence, they are highly recommended for prediction purposes.

The multiple regression statistics reveals that the value of coefficient of determination (r^2) is 0.9932 and it is significant at 1% level. This implies that the incorporation of more independent variable in the analysis causes a corresponding increase in the degree of linear association between the independent variables and the dependent variable considered in the study.

Table 2: Summary of Correlation Coefficients for Monthly Average

Predictor Variable	**Correlation Coefficient (r)**	**Description**
Maximum Air Temperature	0.9871	Very High Correlation
Minimum Air Temperature	0.6697	Moderate Correlation
Mean Air Temperature	0.9333	Very High Correlation
Mean Relative Humidity	0.8975	High Correlation
Cloud Amount	0.8559	High Correlation
Sunshine Duration	0.9674	Very High Correlation
Rainfall Amount	0.2516	Low Correlation
Solar Radiation	0.9903	Very High Correlation
Pan Evaporation	0.9844	Very High Correlation
Wind Velocity	0.3644	Low Correlation

As can be gleaned from the table, the computed correlation coefficients are 0.9871, 0.6697, 0.9333, 0.8975, 0.8559, 0.9674, 0.2516, 0.9903, 0.9844 and 0.3644 for maximum air temperature, minimum air temperature, mean air temperature, mean relative humidity, cloud amount, sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity, respectively. This means that maximum air temperature, mean air temperature, sunshine duration, solar radiation and pan evaporation have a very high linear association with monthly average potential evapotranspiration. Mean relative humidity and cloud amount have a high linear association while rainfall amount and velocity have a low linear association with monthly average potential evapotranspiration.

3. Conclusion

Based from the results of the study, the following conclusions were made:

Monthly average potential evapotranspiration is directly related to monthly average maximum air temperature, minimum air temperature, mean air temperature, sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity. An increase of one unit in the monthly average maximum air temperature, minimum air temperature, mean air temperature, sunshine duration, rainfall amount, solar radiation, pan evaporation and wind velocity corresponds to an increase of 0.4601 mm, 0.5630 mm, 0.5809 mm, 0.0133 mm, 0.0825 mm, 0.0219 mm, 0.9538 mm and 0.0252 mm, respectively in the monthly potential evapotranspiration.

Monthly average potential evapotranspiration is inversely related to mean relative humidity and cloud amount. An increase of one percent in the monthly average mean relative humidity or one okta in cloud amount corresponds to a decrease of 0.1810 mm or 0.8740 mm in the monthly average potential evapotranspiration.

Monthly potential evapotranspiration can be estimatedusing climatic parameters like maximum air temperature, mean air temperature, mean relative humidity, sunshine duration, solar radiation and pan evaporation.

The best index for predicting monthly average potential evapotranspiration is solar radiation followed by maximum air temperature, pan evaporation, sunshine duration, mean air temperature and mean relative humidity.

4. References

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