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# Impact of Metrological Parameters on Reference Evapotranspiration using Multiple Linear Regressions

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**A B S T R A C T**

The reference evapotranspiration ($ET_0$) of Morena station was estimated using multiple linear regression (MLR), The climatological data such as maximum temperatures, minimum temperature, mean relative humidity, wind speed and solar radiation were collected for the morena station and district of Madhya Pradesh state of India for the period of thirty years and the missing value of that data series was also determine using SPSS-21 software. The observed reference evapotranspiration ($ET_0$) values were estimated using the Penman monteith (FAO56-PM) equation. Multiple Linier Regression is carried out using $ET_0$ as predictor variable and maximum temperatures, minimum temperature, relative humidity, solar radiation and wind speed as independent variable to find out predominant factor on $ET_0$. This whole procedure is done for three different variable based Models. In model-1, Maximum temperature and minimum temperature speed are correlated with $ET_0$. In model-2, Maximum temperature, minimum temperature and solar radiation are correlated with $ET_0$. In model-3, Maximum temperature, minimum temperature, mean relative humidity and wind speed are correlated with $ET_0$. In case of model 3 the value of R, $R^2$ and RMSE for 70% dataset is 0.975, 0.949 and 0.466 respectively and for 30% dataset it is 0.981, 0.962 and 0.607 respectively. As the value of R and $R^2$ are nearer to 3 and the value of RMSE is low, which is good. As the model-3 gives the best correlation values as compared to model-2 and model-1, it can be accepted as the best fit model for prediction of $ET_0$. Considering maximum temperature the model gives good correlation values hence maximum temperature is accepted as predominant factor and the presence of relative humidity does not play an important role in prediction of $ET_0$ for this study area.

**Keywords**

Multiple linear regression, Performance evaluation, Climate change and reference evapotranspiration

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## Introduction

India is more susceptible to effect of climate change due to its high dependence on climate sensitive sectors such as forestry and agriculture (Mahida and Palel, 2015). According to the IPCC (2007), the average global surface temperature increased by 0.74°C over the last 100 years. General agreement have revealed that global warming and related changes to the hydrological cycle are likely to enhance the frequency and severity of extreme climate events, causing more severe floods and droughts. Global warming due to the enhanced greenhouse effect is expected to cause major changes in various climatic variables, such as precipitation, relative humidity, solar radiation and temperature. Atmospheric temperature is the most widely used indicator of climatic changes as global and regional scales, and global land-surface air temperatures have increased in the Northern Hemisphere by 0.3°C/ decade from 1979 to 2005.

The combination of two separate processes, where water is lost from the soil surface by evaporation and from the crop by transpiration, is called as evapotranspiration. Hydrological parameters such as precipitation, evapotranspiration, soil moisture and ground water are likely to change with climate (Gleick, 1986), and the impact of climate change on evapotranspiration rate is important for hydrologic processes. Crop water requirements depend upon several climatic variables like rainfall, radiation, temperature, humidity and wind speed. Therefore, any change in climatic parameters due to global warming will also affect evapotranspiration (Goyal, 2004). An indirect way to obtain estimates of evapotranspiration is the evaporation rate from pans filled with water, known as pan evaporation (Epan). Trends in Epan have been reported with different conclusions depending on the region studied. Jhajharia (Jhajharia *et al.*, 2009) found both decreasing and increasing tendencies in Epan in northeast India, depending on the location of the station. Decreases in Epan have been attributed to decreasing surface solar radiation and wind speed (Xu *et al.*, 2006) and increases in cloud cover, greater air pollution and higher concentrations of atmosphere aerosols. Pan evaporation depends on the water surface temperature and energy balance between the evaporation pan, water and the atmosphere. If the humidity does not change, increasing water temperature should increase evaporation. If the humidity increases, it will partially offset the impact of higher temperature on the evaporation. Small changes in evapotranspiration can have important consequences in arid climates. 1% temperature increase could increase evapotranspiration by 12.69% in arid regions of Rajasthan, India, where the annual rainfall varies from 100 to 400 mm and mean temperature varies by about 25°C (Goyal, 2004).

Reference crop evapotranspiration ($ET_0$) refers to crop evapotranspiration in the open short grass land where the soil moisture is adequate, ground is completely covered, grass grew normally with the similar height (grass height is about 8-15 cm) (Allen *et al.*, 1998). $ET_0$ is the most important parameter while predicting the crop water requirement. In the context of climate change, changes of temperature, wind speed, rainfall, solar radiation and other factors will lead to the change of $ET_0$, thus affecting the crop water demand and agricultural water usage. In the context of climate change, changes of temperature, wind speed, rainfall, solar radiation and other factors will lead to the change of $ET_0$, thus affecting the plan of crop water demand and agricultural water usage.

## Materials and Methods

### Study area and data collection

Morena is a district of Madhya Pradesh state is located at 78˚00' E longitude, 26˚30' N latitude at an altitude of 177 m above mean sea level.

The daily meteorological data such as maximum temperature, minimum temperature, solar radiation, mean relative humidity and wind speed for the Morena station were collected and used in the data analysis and model development. The monthly average metrological data for the thirty years has been used for this study.

## Methodology

In this study, daily metrological data for the morena station were collected. These data has been converted into the monthly average data. Some data gaps or missing values are indentified in data. The missing values were found out with the SPSS 21 software. The linear trend at a point method is used to find the missing values of the data. To study the impact of metrological data on reference evapotranspiration ($ET_0$) multiple linear regression analysis was performed. The observed $ET_0$ values have been estimated using the general equation of evapotranspiration (FAO-56).The equation is;

According to Allen *et al.*, (1998), recommended form of FAO56-PM model consisting of aerodynamic and surface resistance terms is:

**ET0**=0.408Δ (Rn−G) +γ (900T$av$+273) U2 (es−ea)/ Δ+γ (1+0.34U2) … (1)

Where,
ET0 is reference evapotranspiration (mm d-1), Rn is net radiation at crop surface (MJ m-2 d-1), G is soil heat flux density (MJ m-2 d-1), Tav is mean daily air temperature (oC), U2 is wind speed at 2 m height (m s-1), ea is actual vapour pressure (kPa), es is saturation vapour pressure (kPa), $e_s$-$e_a$ is vapour pressure deficit (kPa), Δ is slope of vapour pressure curve (kPaoC-1), and γ is psychrometric constant (kPaoC-1).

## Multiple linear regression (MLR) model

The objective of the model is the transfer of information among several variables observed simultaneously and the estimation of the dependent variable from the several other observed independent variables. The monthly reference evapotranspiration ($ET_0$) at a meteorological data is expressed as a simple linear model as

$$\mathbf{ET_O = S + a_1 X_1 + a_2 X_2 + a_3X_3 + a_4X_4 + a_5X_5} \quad \mathbf{...(2)}$$

Where, $a_1$, $a_2$ ……..$a_n$ and S are empirical constants and $X_1$, $X_2$……..$X_n$ are the meteorological parameters influencing the region.

Now, MLR is carried out using $ET_0$ as dependent variable and maximum temperature, minimum temperature, relative humidity, wind speed and solar radiation as independent variable to find out predominant factor on $ET_0$ and obtain best model.

This whole procedure is repeated for three different Models.

In Model 1, Maximum temperature and minimum temperature are correlated with $ET_0$.

In Model 2, Maximum temperature, minimum temperature and solar radiation are correlated with $ET_0$.

In Model 3, Maximum temperature, minimum temperature, mean relative humidity and wind speed are correlated with $ET_0$.

This entire data set is divided into two datasets 70% data for training and 30% data for validation. Then, the corresponding co-efficient of correlation (R) for training and testing data set is evaluated.

## Performance evaluation parameters

The performance evaluation parameters used in the present study are the Pearson correlation coefficient (R), coefficient of determination ($R^2$) and root mean square error (RMSE).

## Correlation coefficient (R)

Correlation – often measured as a correlation coefficient which indicates the strength and direction of a linear relationship between two variables (for example model output and observed values). A number of different coefficients are used for different situations. The formula to find out the correlation coefficient is;

$$R = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$$

The correlation is +1 in the case of a perfect increasing linear relationship and 1 in case of a decreasing linear relationship, and the values in between indicates the degree of linear relationship between model and observations. A correlation coefficient of 0 means the there is no linear relationship between the variables.

The square of the Correlation coefficient ($R^2$), known as the coefficient of determination,

The coefficient of determination, $R^2$, is useful because it gives the proportion of the fluctuation of one variable that is predictable from the other variable. It is a measure that allows determining how certain one can be in making predictions from a certain model/graph. The coefficient of determination is such that $0 < R^2 < 1$, and denotes the strength of the linear association between x and y.

The coefficient of determination represents the percent of the data that is the closest to the line of best fit.

## Root mean square error (RMSE)

The Root Mean Square Error (RMSE) is used to measure the difference between predicted values by a model and the actually observed values from the location. These individual differences are also called residuals. The RMSE of a model prediction with respect to the estimated variable $X_j$ is defined as the square root of the mean squared error:

RMSE $$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$$

Where, $X_i$ is observed values and $X_j$ is modeled values at time/place i.

The RMSE values can be used to distinguish model performance in calibration period with that of a validation period as well as to compare the individual model performance to that of other predictive models.

RMSE ranges from zero to infinity and its lower values are preferable.

## Results and Discussion

In this study the performance evaluation parameters such as R, $R^2$ and RMSE has been calculated for the two stages i.e. training and validation for each model and are given in Table 1.

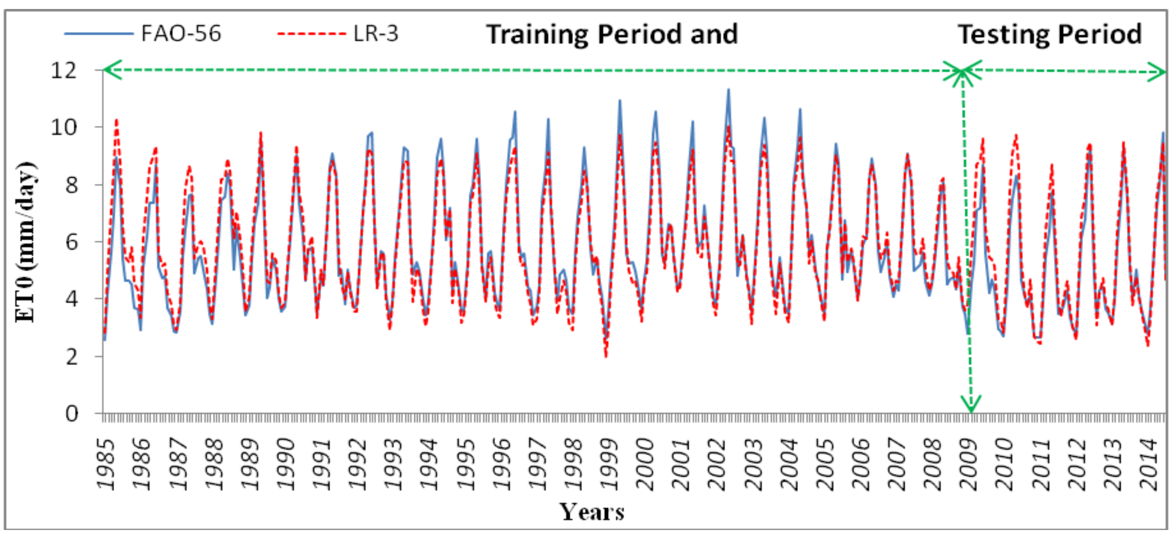
Referring to the table 1, in case of model 1 the value of R, $R^2$ and RMSE for 70% dataset is 0.975, 0.949 and 0.466 respectively and for 30% dataset it is 0.981, 0.962 and 0.607 respectively, which is very good. In case of model -2 the value of R, $R^2$ and RMSE for 70% dataset is 0.954, 0.908 and 0.635 respectively and for 30 % dataset it is 0.956, 0.913 and 0.814 respectively, which is comparatively good. In case of model-1 the value of R, $R^2$ and RMSE for 70% dataset is 0.949, 0.898 and 0.657 respectively and for

30% dataset it is 0.956, 0.914 and 0.735 respectively, which is comparatively low. Here, it is easily noticeable that while, considering maximum temperature co-efficient of correlation achieved as the best. From the above exercise one can observed that value of maximum temperature is significantly affecting the value of $ET_0$ as compared to the value of solar radiation, relative humidity and wind speed. Addition of Relative Humidity does not perform important task. Considering the all models, model 1 gives the best correlation values Hence, It is accepted as best fit model. The Figure 1 show the plot of observed $ET_0$ vs. predicted $ET_0$ for training and validation respectively for model 1.

**Table.1**

| MODEL | R | | $R^2$ | | RMSE | |
|---|---|---|---|---|---|---|
| | Training | Testing | Tanning | Testing | Training | **Testing** |
| **1** | 0.949 | 0.956 | 0.898 | 0.914 | 0.657 | **0.735** |
| **2** | 0.954 | 0.956 | 0.908 | 0.913 | 0.625 | **0.814** |
| **3** | **0.975** | **0.981** | **0.949** | **0.962** | **0.466** | **0.607** |

**Fig.1** Comparison of the value of $ET_0$ by PM-56 model and LR-3 (Tmax, Tmin, $U_2$ and RH) models




Comparing results of all five models, following are the conclusions:

In case of model 3 the value of R and $R^2$ are nearer to 1 and the value of RMSE is low, which is good.

In case of model-2 the value of R and $R^2$ are nearer to 1 but lower than model-3 and also, the value of RMSE is higher than model-1. Hence the model can't be accepted as best fit model.

In case of model 1 the value of R and $R^2$ are nearer to 1 and higher than model-2, also the value of RMSE is less compared to model-2.

As the model 3 gives the best correlation values as compared to model 2 and model 1, it can be accepted as the best fit model for prediction of $ET_0$. When considering maximum temperature the model gives good correlation values hence maximum temperature is accepted as predominant factor and the presence of relative humidity does not play an important role in prediction of $ET_0$ for this study area.

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