International Research Journal of Earth Sciences E-ISSN 2321–2527
Vol. **4(8),** 1-4, August **(2016)** *Int. Res. J. Earth Sci.*

Impact of different Meteorological Parameters and Relationship with Short Crop Reference Evapotranspiration for Humid Climatic Conditions

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Available online at: www.isca.in, www.isca.me
Received 21st July 2016, revised 18th August 2016, accepted 24th August 2016

Abstract

Reference evapotranspiration (ETo) is influence by solar radiation, ambient temperature, relative humidity, and wind speed. The estimation ETo varies from one climate to another and within the climate, and depends on the location and time. The diverse stations were selected to test the influence of different meteorological variables on evapotranspiration under humid climate conditions of Konkan region. The recent twenty four years data (1991-2014) was considered for analysis. The correlation and linear regression analysis was used to find influence of meteorological parameters on evapotranspiration. The results showed that sunshine hours, air temperature and wind speed had strong and positive correlation with reference evapotranspiration and negatively with relative humidity. The evapotranspiration was not significantly influenced by T_{min} and RH_{min}. The maximum relative humidity contributes more in ETo estimation and more emphasis is to be given during estimation for humid region like Konkan region. The maximum temperature influence 24% and 21% ETo at Awalegaon and Mulde station. The sunshine hours affect ETo in the range of 17 to 23% for different stations. The minimum temperature and minimum relative humidity influenced less in prediction of ETo. For Awalegaon and Mulde station more importance should be given to maximum temperature while for Vengurle station wind speed found more important for estimation ETo.

Keywords: Evapotranspiration, Climatic parameters, Correlation, PM-56 model, Regression analysis.

Introduction

Evapotranspiration is paramount parameter of hydrological cycle. Precise estimation of reference evapotranspiration (ETo) is important for agricultural and water resources applications. Evapotranspiration is combined processes of evaporation from soil and transpiration from plants. Evapotranspiration is the principal single component of the terrestrial hydrological cycle. Out of 750 mm of global rainfall, two third is returned to atmosphere due to evapotranspiration[1]. The knowledge of spatial and temporal variability of evapotranspiration is necessary to address a variety of water resource problems on regional and local scale[2]. The estimation of evapotranspiration using climatological parameters is easy as compared to Lysimeter or field studies. The climatic parameters affect the reference evapotranspiration. The climatic parameters such as ambient temperature (Temp.), relative humidity (RH), wind speed (WS) and bright sunshine duration are the major variables affecting the rate of evapotranspiration[3]. To understand the how climatic variables affect ETo, some studies were done to assess evapotranspiration in the context of climate parameters. The influence of different climatic parameters on evapotranspiration was assessed by many researchers. The same the work is reviewed as presented below. Mohan and Arumugamanalyzed the effect of climatic variables like, relative humidity, temperature, and wind velocity using factor analysis and claimed that relative humidity, temperature, and wind velocity are the most influencing parameters on in the evapotranspiration process, in their order. The rainfall and sunshine duration found less influence on the ET process[4].

Thomas studied the spatial and temporal analysis over China for potential evapotranspiration. The study claimed that sunshine found most strongly related with evapotranspiration changes while wind velocity, RH and T_{max} are the primary factors in northwest, central and northeast China, respectively[5].

The direct and indirect effects of climatic variables on evapotranspiration showed that ambient temperature, SSH, and solar radiation had strong positive correlation with evapotranspiration; RH and cloudiness were negatively correlated. The relative contribution of each climatic variable viz solar radiation, RH, ambient Temp,, cloudiness, SSH and WS to evapotranspiration was 31.32, 27.23%, 24.30%, 7.87%, 5.19% and 4.09% respectively[6]. When default wind speed and actual wind speed were used for prediction of evapotranspiration found that ET was underestimated using default speeds, and relationship between ET and WS was not linear, but depended on other factors[7]. The decreasing net radiation and WS had a major impact on ET_o than increase Tmax and Tmin.[8]. The sensitivity analysis for 46 meteorological indicated that RH, WS, and Tmax had stronger effects than SSH and Tmin.[9]. The application of ANFIS found that SSH was most significant single parameter for ETo estimation. The results also indicated that among the input variables SSH, actual vapour pressure (ea) and Tmin are the most important for ETo estimation[10].

Based on these reviews it is observed that climatic variables affect the rate of reference evapotranspiration according to geographical location, season and specified local conditions. An attempt was done to study the effect of various climatic factors on temporal variation of evapotranspiration under humid climatic condition and also to find out the contribution of climatic factors on evapotranspiration.

Materials and Methods

Data: The study was carried out at for Sindhudurg District which is located in coastal belt of Maharashtra State. The region is characterized as humid zone. The climatic conditions are typical coastal i.e. hot and humid. The region comes under heavy rainfall with average annual rainfall of 3500 mm. Three meteorological stations namely Vengurle, Awalegaon, and Mulde are selected for the study. The detail of the stations is given in Table-1. For estimation of reference evapotranspiration the different climatological parameters were collected which includes Tmax, Tmin, RHmax, RHmin, SSH, WS at 2m height. Daily data from year 1991 to 2014 i.e. 24 years was used for analysis. The data was analyzed on daily basis and clumped into standard meteorological weeks (MW) for further analysis.

Estimation of Reference Evapotranspiration (ET): Standardized Reference Evapotranspiration Equation, Short (ETo): Reference ET for a short crop having an approximate height of 0.12 m (similar to grass). The form of the reference Evapotranspiration equation is

$$ET_o = \frac{0.408\,\Delta\left(R_n - G\right) + \gamma \dfrac{900}{T+273} u_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34\,u_2\right)} \quad (1)$$

Where: ET_o is reference evapotranspiration [mm day^{-1}], R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}], G is soil heat flux density [MJ m^{-2} day^{-1}], T is mean daily air temperature at 2m height [ºC], u_2 is wind sped at 2m height [m s-^{1}], e_s is saturation vapour pressure [kPa], e_a is actual vapour pressure deficit [kPa], e_s-e_a is saturation vapour pressure deficit [kPa], Δ is Slope vapour pressure curve [kPaºC^{-1}],γ is psychrometric constant [kPaºC^{-1}].

Linear Regression Analysis: The linear regression model develops a relationship between two variables i.e. dependent and independent variables by developing the linear equation. Linear regression analysis a parametric test and mostly used to detect the trend in the parameters. In linear regression analysis the parameters are checked for relationship between the variables using the scatter plot diagram. The numerical measure or degree of relationship is represented by correlation coefficient. Value of +1 showed perfect relationship and value near to zero means the nonlinear relationship between the variables or the variables are random. The linear regressions model is represented by equation

$$Y = mX + c \quad (2)$$

Where: Y is dependent variable and X is independent variable, m is slope of the line and c is the constant. m and c were determined by least square technique. The relative contribution of climatic parameters under different stations was studied as per methodology explained by Bably[6].

Table-1
Regression parameters of climatic parameters and evapotranspiration

Station	Parameters	Tx	Tn	RHx	RHn	WS	SSH
Awalegaon	Slope	0.20	0.14	-0.07	-0.03	0.45	0.25
	Intercept	-2.35	0.78	10.41	6.22	3.08	2.17
	Correl.	0.76	0.47	-0.68	-0.45	0.63	0.66
	SE	0.61	0.82	0.73	0.83	0.72	0.70
Vengurle	Slope	0.15	0.10	-0.07	-0.02	0.36	0.21
	Intercept	-0.86	1.64	9.55	5.13	3.20	2.45
	Correl.	0.44	0.44	-0.55	-0.26	0.63	0.61
	SE	0.68	0.68	0.64	0.74	0.59	0.60
Mulde	Slope	0.29	0.03	-0.15	-0.03	0.27	0.26
	Intercept	-5.48	3.43	17.41	5.95	3.45	2.34
	Correl.	0.69	0.09	-0.66	-0.49	0.37	0.71
	SE	0.83	1.14	0.86	0.99	1.06	0.80

Results and Discussion

The results of linear regression analysis which define the relationship between reference evapotranspiration and climatic parameters for three stations of Sindhudurg district situated in humid region of Maharashtra state is describe below. From Table-1, it is seen that for Awalegaon station maximum temperature with the maximum correlation coefficient of 0.76 followed by the sunshine hours (r= 0.66). The standard error is less for Tmax than other climatic variables. For Awalegaon station the Tmax and SSH are most directly influencing and RHmax has indirect effect. Similar results are also found for Mulde station. At Vengurle station, wind speed and sunshine hours has direct effect on reference evapotranspiration and effect mostly followed by the maximum relative humidity.

Table-1 indicated that relative humidity shows consistently the negative correlation with reference evapotranspiration. The negative correlation indicates that the rate of reference evapotranspiration is indirectly proportional to relative humidity. Relative humidity indicates the moisture content the air, more the air moisture less the evaporation and transpiration which results in less evapotranspiration. The vapour pressure gradient is less due to high relative humidity which results in less evapotranspiration.

The maximum and minimum air temperature showed consistently the positive correlation with reference evapotranspiration. This result specifies that increase in temperature increases the reference evapotranspiration. The warmer the air, the more the temperature difference results in more reference evapotranspiration. The more temperature gradient enhances rate of evaporation and drier air hold more moisture. The maximum temperature has higher correlation with the reference evapotranspiration than the minimum temperature.

The influence of wind speed is positive with reference evapotranspiration and found more for Awalegaon and Vengurle station as compared to Mulde station. The wind speed drifts the moisture from higher gradient to lower gradient and retained the vapour pressure gradient. The results showed that when wind speed increases the reference evapotranspiration increases.

The sunshine hours are highly correlated with the reference evapotranspiration. As the sunshine hours is the prime source of energy and provides the heat to the evaporation. The bright sunshine hours accelerate the rate of evapotranspiration with less relative humidity conditions and windy conditions. The increase in sunshine hours increases the reference evapotranspiration. Thus the sunshine hours shows significant positive effect on reference evapotranspiration.

The results showed that sunshine hours, air temperature and wind speed had strong and positive correlation with reference evapotranspiration and negatively with relative humidity.

Relative contribution of climatic parameters: Figure-1 shows the relative contribution of climatic parameters on reference evapotranspiration. It is seen that for Awalegaon station, the maximum temperature and maximum relative humidity contributes 21% and 19 % in evapotranspiration. The WS and sunshine hours affect reference evapotranspiration nearly 18 per cent. From these results it is concluded that while estimating the reference evapotranspiration more emphasis should be given to maximum temperature and maximum relative humidity.

For Vengurle station the wind speed and maximum relative humidity along with sunshine hours affects ETo by 23%, 20% and 19% respectively. These three parameters entirely stimulus 62% of ETo. Therefore for calculating the ETo for Mulde station more weightage will be assign to WS, RHmax and sunshine hours. At Mulde station Tmax, RHmax and sunshine hours contributes nearly same amount and affect 70 % of ETo. The wind speed and Tmin affects 11% and 5% in ETo.

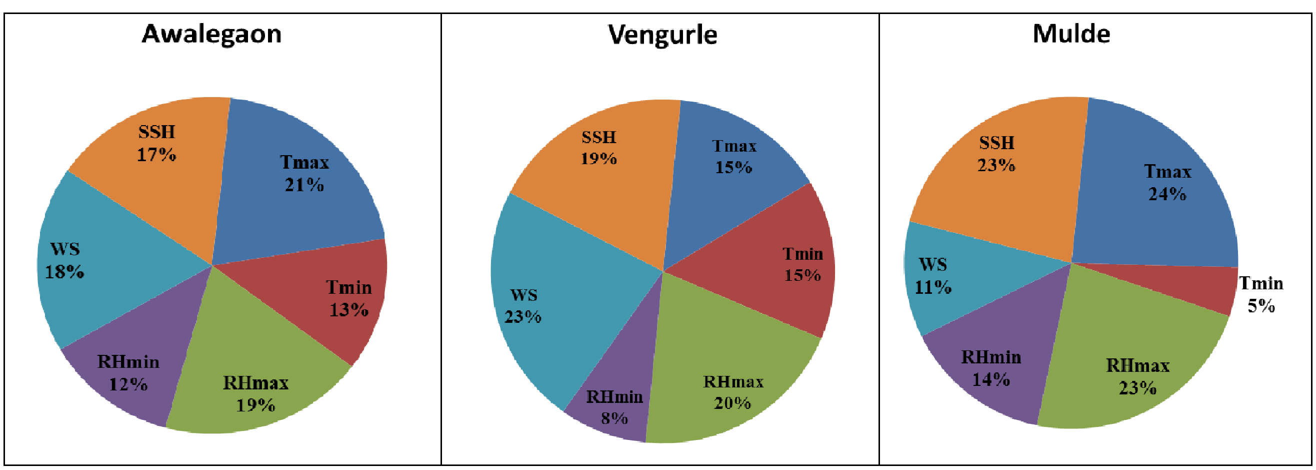

Figure-1
Relative contribution of climatic parameters on reference evapotranspiration

Based on these results maximum relative humidity contributes more in ETo estimation and more emphasis is to be given during estimation. The maximum temperature influence 24% and 21 % ETo at Awalegaon and Mulde station. The sunshine hours affect ETo in the range of 17 to 23% for different stations. The minimum temperature and minimum relative humidity influence is less in prediction of ETo.

Conclusion

The study has been carried out to find the relationship and climatic parameters and their relative contribution in estimation of ETo for different stations Sindhudrug district. The ETo is estimated by PM-56 model and relationship is tested by linear regression analysis. The results showed that sunshine hours, air temperature and wind speed had strong and positive correlation with reference evapotranspiration and negatively with relative humidity. The relative contribution analysis showed that maximum relative humidity contributes more in ETo estimation and more emphasis is to be given during estimation followed by maximum for Awalegaon and Mulde station. The minimum temperature and minimum relative humidity influence is less in prediction of ETo. For Mulde station maximum temperature, maximum relative humidity and sunshine hours contributes nearly equal and hence these parameters should be measure with great precision and should be consider predominantly for estimation of reference evapotranspiration.

Acknowledgement

The second author acknowledge to HDUG, Nasik and Director of Research, BSKKV, Dapoli for providing the necessary climatic data for analysis.

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