Agriculture Association of Textile Chemical and Critical Reviews Journal (2023) 55-58

AATCC Review

21 October 2022: Received
19 January 2023: Revised
25 January 2023: Accepted
18 February 2023: Available Online

http://aatcc.peerjournals.net/

Research Article Open Access

Forecasting Evapotranspiration Using Mathematical Models

R. Pangayar Selvi [1*], R.Vasanthi [2*], M. Kalpana[3], and B. Sivasankari [4]

[1&2]Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India
[3]Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India
[4]Agricultural College & Research Institute, Tamil Nadu Agricultural University, Madurai, India

Abstract

In agriculture, water is the most important factor. Water is supplied to the crops naturally through precipitation and subsurface moisture, but when these supplies prove to be inadequate for crop use, growers must resort to irrigation. In recent years water availability were the major issue faced in Tamil Nadu. This is because of abnormalities in climatic conditions. So identifying evapotranspiration for the crop is important. Evapotranspiration is the movement of water through evaporation from the soil surface and transpiration from the plant into the atmosphere. By forecasting daily evapotranspiration for crops the irrigation pattern can be modeled. For our study rice crop is selected to forecast the evapotranspiration. Rice is a staple food for a large number of people and is the single largest food source for the poor. The weather parameters were observed for the pishanam season for two years (2020-2022). Evapotranspiration was calculated using three models like 1948 penman model, the Penman-Monteith model and the FAO56 Penman-Monteith model. Using less RMSE(3.41) and a high R square (0.98) value FAO 56 Penman-Monteith model was identified as best model for forecasting evapotranspiration.

Keywords: *Agriculture; evapotranspiration; models; rice; weather parameters*

Introduction

In agriculture one of the most important factors is water availability. Water is supplied to the crops naturally through precipitation and subsurface moisture, but when these supplies prove to be inadequate for crop use, growers must resort to irrigation. Water availability is also a critical variable for virtually every other economic activity, including industry, the energy sector, and public use. In recent years, water availability has become an issue in Tamil Nadu because of changes in weather conditions and this leads to stress in both agriculture and non-agricultural sectors. As the population increases, so does water demand.

To schedule irrigation properly, a grower must know the environmental demand for surface water. For the grower, this surface water loss occurs primarily through Evapotranspiration (ET). Evapotranspiration is the movement of water through evaporation from the soil surface and transpiration from the plant into the atmosphere. A good forecast of evapotranspiration plays the important role in accurately determining the crop water requirements for appropriate scheduling. So forecasting a plant's evapotranspiration is an important factor for growing crops.

For our study rice crop is selected to forecast the evapotranspiration. Rice (OryzasativaL.) is a staple food for a large number of people and is the single largest food source for the poor. It is estimated that India will need to produce more rice if it is to meet the growing demand, likely to be 130 million tonnes of milled rice in 2030 [2]. The requirement of water for rice cultivation is more.

Due to changes in weather conditions analysing the need for water for rice cultivation is important to increase the production. The basic water balance for rice includes irrigation water applied, precipitation, infiltration, runoff, drainage, and evapotranspiration.

**CorrespondingAuthor: R. PangayarSelvi and R.Vasanthi.*
E-mail Address: - pangai@tnau.ac.in, vasanthi@tnau.ac.in
DOI:https://doi.org/10.58321/AATCCReview.2023.11.02.55

Being one of the factors, estimating rice evapotranspiration is taken for our study. By forecasting the evapotranspiration the farmers can plan their crops for cultivation.

Methodology

For this study, the field experiment was conducted in AC&RI, Killikulam, Tamil Nadu. The rice variety ASD16 crop was selected and grown in Pishanam seasons. Puddle rice cultivation was repeated for two years 2020-2022. The Daily observations in weather parameters like Maximum Temperature, Minimum Temperature, Wind Speed, Relative Humidity, Sunshine Hours and Rainfall were observed for two years. The two years of data were used for forecasting the evapotranspiration for Pishanam season.

For our study based on the phonological stages for rice (Days after showing) the entire growing period was divided into four stages 1) Active tillering (AT) (35-40 days), 2) Panicle Initiation (PI) (45-50 days) 3) Heading (H) (70-75 days) and 4) Harvesting (Heading+30 days). The ET was calculated for all the four stages of pishnam season.

Evapotranspiration was forecasted using three models namely the 1948 penman model, the Penman-Monteith model and FAO 56 Penman-Monteith model.

1948 penman model

A large number of empirical methods have been developed over the last 50 years to estimate evapotranspiration from different climatic variables. Some of these derived from the now well-known Penman equation [5] to determine evaporation from open water, bare soil and grass (now called evapotranspiration) based on a combination of an energy balance and an aerodynamic formula, given as:

$$\lambda E = \frac{[\Delta(Rn - G)] + (\gamma \lambda Ea)}{(\Delta + \lambda)}$$

where γE =evaporative latent heat flux (MJ m^{-2} d^{-1}), Δ = slope of the saturated vapor pressure curve [Ye^{o}/ YT, where e^{o} = saturated vapor pressure (kPa) and T_{mean} = daily mean temperature (°C)], R_n = net radiation flux (MJ m_d), G = sensible heat flux into the soil (MJ $m^{-2}d^{-1}$), γ = psychrometric constant (kPa $°C^{-1}$), and Ea= vapor transport of flux (mm d^{-1}).

Penman-Monteith model

Various derivation of the Penman equation included a bulk surface resistance term [4] and the resulting equation is now called the Penman-Monteith equation, which may be expressed for daily value as:

$$\lambda ETo = \frac{[\Delta(Rn - G)] + \left[86{,}400 \frac{\rho_a C_p (e_s^0 - e_a)}{r_{av}}\right]}{(\Delta + \gamma)\left(1 + \frac{r_s}{r_{av}}\right)}$$

where ρ_a = air density(kg m^{-3}), Cp = specific heat of dry air, = mean saturated vapor pressure (kPa) computed as the mean e^{o} at the daily minimum and maximum air temperature (°C), r_{av} = bulk surface aerodynamic resistance for water vapor (s m^{-1}), e_a= mean daily ambient vapor pressure (kPa) and r_s = the canopy surface resistance (s m^{-1}).

FAO 56 Penman-Monteith model

An updated equation was recommended by FAO [1] with the FAO-56 Penman-Monteith Equation, simplifying Penmam Monteith equation by utilizing some assumed constant parameters for a clipped grass reference crop. It was assumed that the definition for the reference crop was a hypothetical reference crop with a crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo value (i.e., portion of light reflected by the leaf surface) of 0.23 [6]. The new equation is:

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where ET_o = reference evapotranspiration rate (mm d^{-1}), T= mean air temperature (°C), and u_2 = wind speed (m s^{-1}) at 2 m above the ground.

Model validation parameters like R- squared value and Root Mean Squared Error (RMSE) were usedfor identifying the best model. After identifying the best model the daily evapotranspiration can be forecasted.

R- squared

R^2 criteria known as the coefficient of determination tells about the percentage of variance in the target variable explained by the model. It can be computed as a ratio of the regression sum of squares and the total sum of squares.

$$R^2 = \frac{SS_{reg}}{SS_{tot}}$$

Root Mean Squared Error (RMSE)

Root mean square error also known as Root Mean

Table 1: The average ET values for Pishanam Season.

Phonological Stage	Average Evapotranspiration per day (in mm)								
	1948 penman model			Penman-Monteith model			FAO 56 Penman-Monteith model		
	I Year	II Year	Overall	I Year	II Year	Overall	I Year	II Year	Overall
Active Tillering	2.75	3.11	2.93	6.76	7.93	7.35	4.52	5.15	4.84
Panicle Initiation	3.90	4.14	4.02	11.18	11.4	11.29	6.37	6.75	6.56
Heading	4.68	3.99	4.34	13.94	11.34	12.64	7.78	7.08	7.43
Harvesting	4.82	4.94	4.88	12.98	13.79	13.39	7.41	8.06	7.74
RMSE	4.57	5.13	4.29	7.04	3.29	7.24	**4.00**	**3.13**	**3.41**
R2	0.20	0.45	0.26	0.22	0.28	0.64	**0.68**	**0.67**	**0.98**

Square Deviation (RMSD) is the square root of variance of the residuals of the model. It is the absolute measure of fit also defines as the standard deviation of unexplained variance in the model.

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(\hat{y} - y_t)^2}{n}}$$

Results & Discussion

Evapotranspiration for Pishanam Season

The evapotranspiration was forecasted using three models 1948 penman model, Penman-Monteith model and FAO Penman Monteith model. Average evapotranspiration per day was forecasted for four stages using three models for Pishanam season were presented in table 1. The ET was forecasted for first, second year separately and also the first year and second year Pishanam season were pooled together to find the overall effect of evapotranspiration. From the table, based on less RMSE and high R square value it was observed that for first, second and overall years, FAO 56 Penman Monteith model was identified as the best model for forecasting the evapotranspiration for Pishanam season. In FAO 56 Penman Monteith model, the observed RMSE values for first, second and overall years were 4.00, 3.13 and 3.41 which was lesser when compared to other models. Also R square values for the first, second and overall years were 0.68, 0.67 and 0.98 which was higher when compared to other models. Estimated rice evapotranspiration using a microlysimeter technique and compared it with FAO Penman-Monteith model and in comparison both methods gave good estimates of evapotranspiration [3]. The diagrammatic representation of forecasted evapotranspiration for overall Pishanam season was presented in Figure 1. For active tillering stage the average evapotranspiration was 4.84 mm and in Panicle initiation stage it was 6.56 mm and 7.43, 7.74 during Heading and Harvesting.

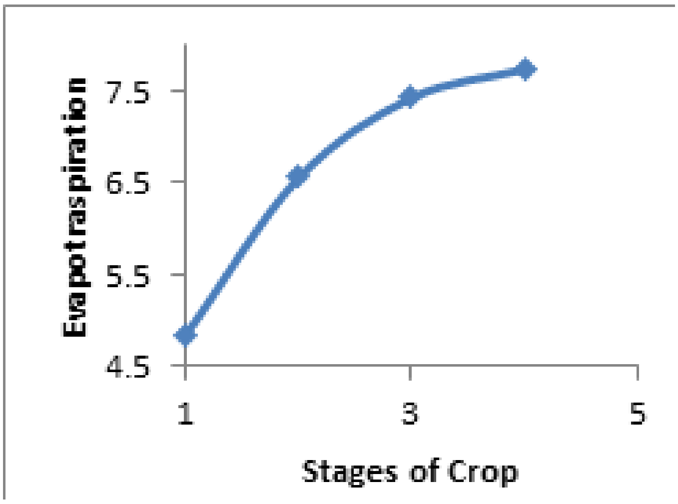

Figure1: ET for overall Pishanam season

Conclusion

Weather parameters were observed on daily basis for two years for Pishanam seasons. Using three models evapotranspiration was forecasted for I & II years Pishanam Season and also for pooled data. The models were validated using RMSE and R square values. As per the results FAO-56 Penman Monteith was found to be the best model for forecasting evapotranspiration for Pishanam season. It was observed that during Pishanam season at the time of active tillering, the average evapotranspiration was 4.84 mm and in the Panicle initiation stage was about 6.56 mm and 7.43, 7.74 during Heading and Harvesting. This helps the farmers to plan for the crop and irrigation pattern. Planning of irrigation patterns using evapotranspiration helps in the effective usage of water.

Future Scope of the Study

This sudy helps to identify the irrigation pattern using evapotranspiration which is useful for the farmers to plan the rice crop in the Pishanam season. Identifying Irrigation pattern using evapotranspiration can be used for all seasons and for all crops.

Conflict Of Interest

The authors declares that there is no Conflict of Interest and the authors take complete responsibility for the integrity of the data and accuracy of the data analysis.

Acknowledgement

I acknowledge the Department of Physical Science and Information and Technology , Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore for providing the necessary facility to carry out the work.

Reference

[1.] Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998) Crop evapotranspiration —guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculture Organization, Rome.

[2.] BikshamGujja and Thiyagarajan TM (2009) New hope for Indian food security? The system of rice Intensification. The Gatekeeper series. 143:1-18

[3.] M. LAGE, A. BAMOUH, M. KARROU, M. EL MOURID , (2003), Estimation of rice evapotranspiration using a microlysimeter technique and comparison with FAO Penman-Monteith and Pan evaporation methods under Moroccan conditions, Agronomie 23 , 625–631.

[4.] Monteith, J.L. (1965) Evaporation and the Environment. 19th Symposia of the Society for Experimental Biology, 19, 205-234.

[5.] Penman, H.L. (1948) Natural Evaporation from Open Water, Bare Soil and Grass. Proceedings of the Royal Society of London, 193, 120-145. https://doi.org/10.1098/rspa.1948.0037

[6.] Smith, M., Allen, R.G., Monteith, J.L., Pereira, L.S., Perrier, A., Pruitt, W.O. 1992. Report on the Expert Consultation on procedures for Revision of FAO Guidelines for Prediction of Crop Water Requirements. Land and Water Development Division, United Nations Food and Agriculture Service, Rome, Italy.