Journal of Agrometeorology 19 (2) : 172-175 (June 2017)

Short Communication

Modified Hargreaves equation for estimation of weekly reference evapotranspiration for Junagadh

K. N. VYAS and R. SUBBAIAH

Soil and Water Engineering Department, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra, Gujarat, India.

*Corresponding author E-mail: *khyativyas46@gmail.com*

Accurate estimation of crop water requirements of any crop is essentially required for irrigation scheduling and water management. FAO 56 (Allen *et al*. 1994a, b) advocated Penman–Monteith method as the standard method for estimating reference evapotranspiration which has been used by various workers in India (Mehta and Pandey,2015; 2016; Sibale *et al.* 2016). The main shortcoming of Penman–Monteith method is that it requires data for large number of climatic parameters that are not always available for many locations of un-gauged basins of India.These limitations make more attractive the application of indirect methods of measurements which are based on easy-to-obtain weather data. Several studies have shown that the Hargreaves (HS) equation may provide reliable estimates of reference evapotranspiration for five days or longer time steps (Hargreaves 1989) which require limited meteorological data (Jensen *et al.*, 1997). Allen *et al*. (1998) have proposed that when sufficient data to solve the FAO-56 PM equation are not available then the Hargreaves equation can be used.

Traore *et al.*(2008) reported that, empirical models do not have universal consensus for different climatic conditions. Studies done under diverse climatic conditions have revealed a widely varying performance of alternative equations which local calibration is required (Allen *et al.*1998). For the better estimation of reference evapotranspiration (ET_0) in the local conditions adjustment of the equation coefficients is an alternative way to improve its estimation.So the main objective of this study is to investigate the adoptability of Hargreaves Samani equation to present condition and if poor predictions are emerged then revise the equation coefficients to keep the predictions at par with Penman approach.

The study was conducted at Junagadh, Gujarat which falls under south Saurashtra agro climate zone. Junagadh has bearings of 69.40° to 71.05 ° East Longitude and 20.44 ° to 21.40 ° North Latitude with 83 m above msl (mean sea level). The climate of the area is categorized under subtropical and semi-arid with an average annual rainfall of 900 mm. The input data were collected for the past twenty-nine years (1984 to 2012) from the agro-meteorological observatory of Junagadh Agricultural University, Junagadh. Out of the 29 years of data, the first 23 years (1984 to 2006) were used in model development and the last 6 years (2007 to 2012) were used in validation or testing of developed model.

Penman Monteith (PM) method

FAO- 56 Penman–Monteith method (Allen *et al.* 1998), calculates ET_0 as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (1)$$

Where, ET_0 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 2 m height (°C), u_2 is wind speed at 2 m height (m s^{-1}), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), (e_s - e_a) is saturation vapour pressure deficit [kPa], Δ is slope vapour pressure curve (kPa °C^{-1}), and γ is Psychrometric constant (kPa °C^{-1}).

Hargreaves and Samani (HS) approach

Hargreaves and Samani(1985) approach calculates reference ET from solar radiation and temperature and is expressed as:

$$ET_{0(HS)} = 0.00094\ R_a\ TD^{0.5}\ (T_a + 17.8) \qquad (2)$$

Where T_a = average (mean of max. and min. temp.) air temperature in °C, TD = difference between maximum and minimum weekly temperature in °C, R_a = the extra-terrestrial radiation for a given latitude and day which can be obtained from either tables or standard equation in $MJm^{-2}day^{-1}$. The above equation was expressed as regression equation by replacing the ordinate values of HS reference

Statistical parameters

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

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - \overline{O_i})(E_i - \overline{E_i})}{\sqrt{\sum_{i=1}^{n}(O_i - \overline{O_i})^2 \sum_{i=1}^{n}(E_i - \overline{E_i})^2}}\right]^2$$

$$AE = \frac{1}{n}\sum_{i=1}^{n}(E_i - O_i)$$

$$AIC = \ln(RMSE) + \frac{2n}{N}$$

$$\overline{R}^2 = \left(R^2 - \frac{k}{n-1}\right)\left(\frac{n-1}{n-k-1}\right)$$

$$EF = \frac{\sum_{i=1}^{n}(O_i - \overline{O})^2 - \sum_{i=1}^{n}(E_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2}$$

$$CRM = \frac{(\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} E_i)}{\sum_{i=1}^{n} O_i}$$

$$MSE = \frac{\sum_{i=1}^{n}(O_i - E_i)^2}{n}$$

$$BIC = \ln(RMSE) + \frac{n\ln(N)}{N}$$

evapotranspiration with PM estimates which is expressed as

$$ET_{0(PM)} = C_H R_a TD^b (T_a + c) \quad (3)$$

With the known input values of R_a, TD and T_a of study area (Junagadh), the coefficients of"b" and "c" were determined for the study region.

Performance evaluation criteria

The efficiency criteria used in this study are root mean square error (RMSE), Nash-Sutcliffe efficiency (EF), coefficient of determination (R^2), coefficient of residual mass (CRM), absolute error (AE), Akaike information criteria (AIC), Bayesian information criteria (BIC) and mean square error (MSE) and Adjusted R^2. A brief of the above criteria is given below.

Where O_i = PM FAO 56 values of ET_0, E_i = Models (Original and modified HS equations) estimated value of ET_0, n = No. of data considered, M = average of observed value, n= No. of parameter estimated (for eq. 15), N= no of sample size, k = no. of variables, R^2 = coefficient of determination, RMSE= root mean squared error.

The weekly reference evapotranspiration was estimated using PM and HS approaches are presented in Fig.(1). The PM ET_0 estimates ranged between minimum 1.41 mmday^{-1} during January to a maximum 9.96 mmday^{-1} during May month. Original HS equation overestimated ET_0 by 15 per cent. The scatter diagram between the HS and PM estimated for 29 years is shown in Fig 1. A poor scatter is observed between them (R^2= 0.78). The efficiency criteria were calculated for both original and modified equations for ET_0 estimation and are presented in Table 1. The efficiency of the original HS model was very poor (63.3%).

Modification of equation (Eq.2) is imperative to reduce the deviation between HS and PM for the study region. The trend surface analysis is the most widely applied procedure, using global surface fit. The data are approximated by a polynomial expansion of the coordinates of the control points. The coefficients of the polynomial are found by the method of least squares, providing that the sum of the squared deviation from the trend surface is a minimum. The polynomial trends function works well for most data distribution. Using the meteorological data for the period from 1984 to 2006, the value of the exponent 'b' and constant 'c' of (Eq.3) were estimated using trend surface analysis and are estimated to be 0.589 and 4.56 respectively. The modified HS equation is written as:

$$ET_0 = 0.00094\ R_a\ (TD)^{0.589}(T_a + 4.56) \quad (4)$$

The scatter diagram between the revised HS approach and PM estimated for testing period (six years) is depicted in Fig 2. Correlation between the approaches drastically enhanced after modification (R^2 = 0.84). The efficiency criteria was calculated for revised HS and PM estimates for weekly ET_0 during the validation period (2007-2012) and are presented in Table 1. The efficiency of the revised HS model was greatly increased (83.4%). Model efficiency is increased by 31.6 per cent after the modification of the equation. Other statistical criteria also supported the revised HS equation.

Thus the modified HS equation developed for this region greatly enhanced the statistical criteria. So in the data scarce regions of semiarid regions the model can be advocated for getting preliminary estimates of reference evapotranspiration. The methodology presented in this paper could be applied to the other regions for requisite regional calibrations.

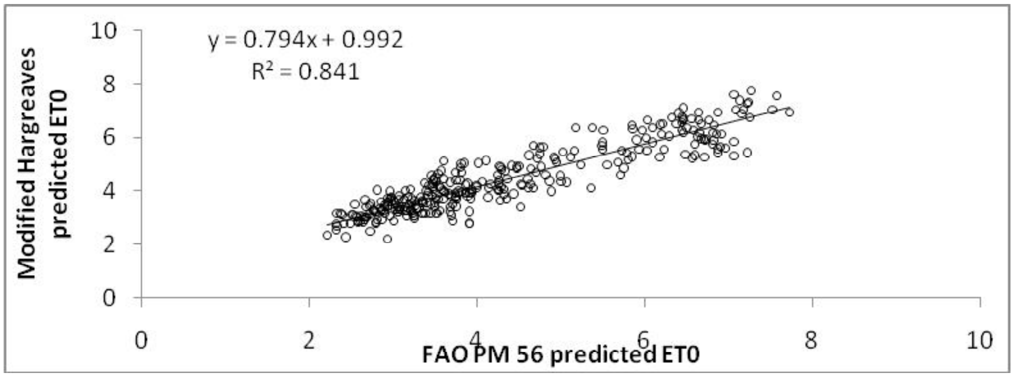

Fig. 1:Weekly scatter plot between PM and Original HS method

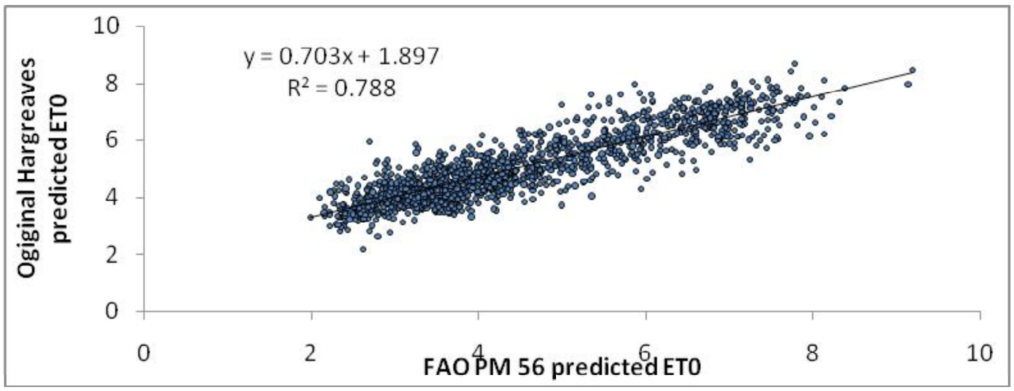

Fig.2:Weekly scatter plot between PM and revised HS method(validation)

Table2: Comparative performance of original and revised HS equation toestimate ET_0

Eq. and Statistical Parameter	AE (mmday^{-1})	CRM (mmday^{-1})	MSE (mmday^{-1})	RMSE (mmday^{-1})	AIC	BIC	EF (%)	R^2	ADJ R^2
Original Hargreaves Samani eq.	0.56	-0.12	0.80	0.89	-0.10	-0.10	63.35	0.78	0.78
Modified Hargreaves Samani eq.	0.10	-0.02	0.35	0.60	-0.51	-0.50	83.40	0.84	0.838

REFERENCES

Allen R.G., Smith, M., Perrier, A., and Pereira, L.S., (1994a)."An update for the calculation of reference evapotranspiration". *ICID Bull.,*43(2): 35-92.

Allen R.G., Smith, M., Perrier, A., and Pereira, L.S., (1994b). "An update for the definition of reference evapotranspiration". *ICID Bull.,*43(2): 1-34.

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M., (1998). "Crop evapotranspiration: guidelines for computing crop water requirements". FAO Irrigation and Drainage Paper 56, Rome, Italy.

Chattopadhyay,N.andHulme,M. (1997). Evaporation and potential Evapotranspiration in India under conditions of recent and future climate change. *Agric. Forest Meteorol.,*87(1): 55–73.

Droogers, P. and Allen, R. G. (2002).Estimating reference evapotranspiration under Inaccurate Data Conditions.*Irrig.Drain. Systems*.,16 (1): 33-45.

Hargreaves, G. H. and Allen, R. G. (2003).History and evaluation of Hargreaves evapotranspiration equation.*J. Irrig. Drain. Engg.,*129(1): 53-63.

Hargreaves, G. H. (1989). Accuracy of estimated reference evapotranspiration, *J. Irrig.Drain.Engg.,*115(6): 1000-1007.

Jensen, D. T., Hargreaves, H., Temesgen, B. and Allen, R. G. (1997).Computation of ET_0 under non ideal conditions.*J. Irrig. Drain. Engg.,*123(5): 394-400.

Mehta, R. and Pandey, V.(2015). Reference evapotranspiration (ET_O) and crop water requirement (ET_C) of wheat and maize in Gujarat, *J. Agrometeorol.,* 17(1);107-113

Mehta, R. and Pandey, V.(2016). Crop water requirement of different crops of middle Gujarat, *J. Agrometeorol.,* 18(1);83-87

Sibale, D., Mane, M.S., Patil, S.T.and Ingle, P.M.(2016). Evaluation of three methods for estimating reference evapotranspiration (ET_O) at Dapoli, Maharashtra. *J. Agrometeorol.,* 18(1);157-158

Subburayan,Sivaprakasam; Murugappan,A. andMohan, S. (2011). Modified Hargreaves equation for estimation of ET_0 in a hot and humid location in Tamilnadu State, India. International *J. Engg. Sci. Tech.,* 3(1).

Traore, S., Wang, Y. M. and Kerh, T. (2008). Modeling reference evapotranspiration by generalized regression neural network in semiarid zone of Africa. WSEAS *Trans. Inf. Sci. Appl.,* 6: 991-1000.

Received : September 2016; Accepted: April 2017