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Comparison of methods for estimating reference evapotranspiration (ET_o) for Rahuri region

P. B. JADHAV*, S. A. KADAM and S. D. GORANTIWAR

Department of Irrigation and Drainage Engineering
Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722 (MS)
Email : jadhavpradnya12@gmail.com

ABSTRACT

Penman Monteith (FAO56-PMM), Modified Penman FAO-24 (MPM), Hargreaves-Samani (HSM), FAO-24 Pan Evaporation (FPEM), Blaney-Criddle (BCM) and FAO Radiation (FRM) methods were used for estimation of ET_o for Rahuri region. The Penman Monteith method was considered as the standard of comparison for evaluating the other five methods. The ET_o values estimated by PMM were correlated with ET_o values estimated by other five methods. The good correlation was found between the ET_o values estimated by MPM, HSM and FRM. The coefficient of determination was high for MPM (R^2=0.99), HSM (R^2=0.97) and FRM (R^2=0.93) and therefore found to be more suitable in the absence of adequate climate data for the use of PMM for this climatic region.

Keywords: Reference evapotranspiration (ET_o), PMM, MPM, HSM, FPEM, BCM, FRM

Reliable estimation of evapotranspiration (ET) is of great importance for the computation of irrigation water requirements, water resources management and determination of water budget especially under arid conditions where water resources are scarce and fresh water is a limited resource. Irrigation engineers want to know how much of the supplied irrigation water is consumed by the crops only then can they estimate, or then calculate the remaining components of the water balance additionally the agriculturist want to know the specific water requirements of a crop so that they can obtain a satisfactory yield. They also want to know whether these specific water requirements are being met under the prevailing irrigation practices.

As reported by Brutsaert (1982) and Jensen *et al.* (1990) numerous methods have been proposed for estimating evapotranspiration. The combination of energy balance and aerodynamic equations generally provides the most accurate results as a result of their foundation in physics and basis of rotational relationship (Jensen *et al.* 1990). The Food and Agricultural Organization of the United Nations (FAO) assumed the ET definition of Smith *et al.* (1997) and accepted the FAO Penman Monteith as the standard equation for estimation of ET (Allen *et al.* 1998; Naoum and Tsanis 2003; Irmark *et al.* 2003; Demirtas *et al.* 2007; Gavilan *et al.* 2008). Reference evapotranspiration (ET_o) is the amount of evapotranspiration that is expected at a location with specified reference conditions under the actual weather conditions. The ET_o is multiplied by a crop coefficient (Kc) to determine actual ET from ET_o. The crop coefficient is obtained with respect to type of the plant, maturity of the plant and local factors such as soil type (Jensen *et al.* 1990).

The aim of this study is to compare the ET_o values estimated by different methods from climatic data and to define the method which gives the most accurate results for ET_o for this region. The Penman Monteith (Allen *et al.,* 1998) method was considered as standard method and used for comparison of other methods *viz.* Modified Penman, Hargreaves-Samani, Pan Evaporation, Blanney-Criddle and Radiation methods.

MATERIALS AND METHODS

The study area is located at 19.38 N latitude and 74.65 E longitude with 510 m altitude above mean sea level.

Daily data for Rahuri station with respect to maximum temperature (Tmax, ^oC), minimum temperature (Tmin, ^oC), maximum relative humidity (RHmax, %), minimum relative humidity (RHmin, %), pan evaporation (Epan, mm), wind speed at a height of 2.0 m (kmh^{-1}), actual sunshine hours (h) and rainfall (mm) were collected for 36 years (1975-2011) from the India Meteorological Department observatory located at Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Table 1: Weekly reference crop evapotranspiration by different methods

Week	PMM	MPM	HSM	FPEM	BCM	FRM	Week	PMM	MPM	HSM	FPEM	BCM	FRM
1	21.6	26.8	27.3	17.4	28.1	31.5	27	29.2	34.9	33.9	57.6	38.0	31.9
2	22.3	27.1	27.4	18.9	28.3	32.5	28	27.7	33.1	32.5	55.4	37.9	30.1
3	23.8	28.2	28.2	19.4	29.1	34.6	29	26.9	32.1	31.7	61.5	37.8	29.7
4	25.7	29.5	28.7	19.4	29.0	36.9	30	25.8	30.6	31.4	56.7	37.4	28.6
5	27.4	32.5	31.2	20.5	29.1	38.6	31	25.9	30.5	31.4	56.0	37.4	28.7
6	29.2	35.0	33.4	21.3	29.7	40.7	32	25.3	29.9	30.0	54.6	36.6	28.3
7	31.2	36.3	33.8	23.2	30.0	42.5	33	26.9	31.8	31.2	53.2	36.5	30.7
8	33.7	38.1	34.7	24.0	30.7	45.8	34	27.3	32.9	31.8	44.6	36.2	31.8
9	38.8	43.9	39.7	25.1	33.5	51.2	35	26.0	31.1	31.5	42.3	36.4	29.8
10	39.9	46.7	41.8	26.4	33.6	51.9	36	27.3	31.6	30.8	40.7	36.2	32.5
11	42.7	48.8	42.3	24.9	34.4	54.6	37	28.2	33.2	32.6	33.2	36.4	34.0
12	46.4	51.7	43.8	27.1	35.1	57.1	38	28.5	34.0	33.1	28.0	36.6	34.7
13	48.3	53.3	43.9	30.1	35.5	59.7	39	27.5	33.6	32.8	23.0	36.7	33.6
14	50.6	58.5	48.6	30.8	37.4	60.8	40	28.3	32.6	31.1	22.0	35.4	35.3
15	52.3	59.5	48.9	34.2	37.7	62.0	41	30.0	35.4	31.8	20.7	35.0	38.9
16	56.2	63.7	49.3	38.0	38.5	65.7	42	29.6	35.8	32.7	20.0	34.3	39.1
17	60.4	68.2	49.6	40.0	39.0	74.9	43	28.9	35.7	33.7	19.8	33.3	38.7
18	62.4	71.5	50.8	44.2	40.4	80.8	44	27.3	33.1	31.5	21.0	32.2	36.1
19	58.1	66.6	51.1	47.5	41.0	64.3	45	25.6	30.2	28.8	20.6	31.3	34.7
20	57.9	66.8	49.8	51.8	41.2	63.6	46	24.3	29.1	28.1	19.7	30.7	33.8
21	55.9	64.5	48.4	55.1	41.3	61.5	47	23.5	29.2	28.3	18.7	30.2	33.0
22	50.7	59.1	46.1	53.9	41.2	56.9	48	23.1	28.9	28.2	17.4	29.6	32.6
23	43.7	51.4	43.3	52.0	40.6	48.3	49	22.5	26.8	26.5	17.4	27.9	32.8
24	35.9	42.0	39.2	51.3	39.4	40.7	50	21.6	26.1	26.7	17.5	27.5	31.1
25	32.2	38.3	36.3	61.3	38.8	35.2	51	21.2	25.8	26.7	17.0	27.1	30.7
26	30.8	36.7	34.7	60.5	38.3	33.9	52	24.0	29.1	30.4	19.3	31.2	35.1

Methods of estimation of ET_o

The weekly reference evapotranspiration were estimated by using following methods,

1. Penman Monteith Method (Allen *et al.*, 1998)
2. Modified Penman Method (Doorenboss and Pruitt, 1984)
3. Hargreaves-Samani Method (Hargreaves-Samani, 1985)
4. FAO Pan Evaporation Method (Doorenboss and Pruitt, 1984)
5. Blanney-Criddle Method (Doorenboss and Pruitt, 1977) and
6. FAO-RadiationMethod (Doorenboss and Pruitt, 1975, 1977)

The Computer program written in FORTRAN (Gorantiwar, 1995) was used to calculate weekly reference evapotranspiration (ET_o) by using Penman-Momteith, Modified Penman, Hargreaves-Samani, FAO Pan Evaporation, Blaney-Criddle and FAO Radiation methods from 36 years data.

The linear regression analysis was performed by considering the ET_o by Penman-Monteith as independent variable and ET_o of the remaining five methods as dependent

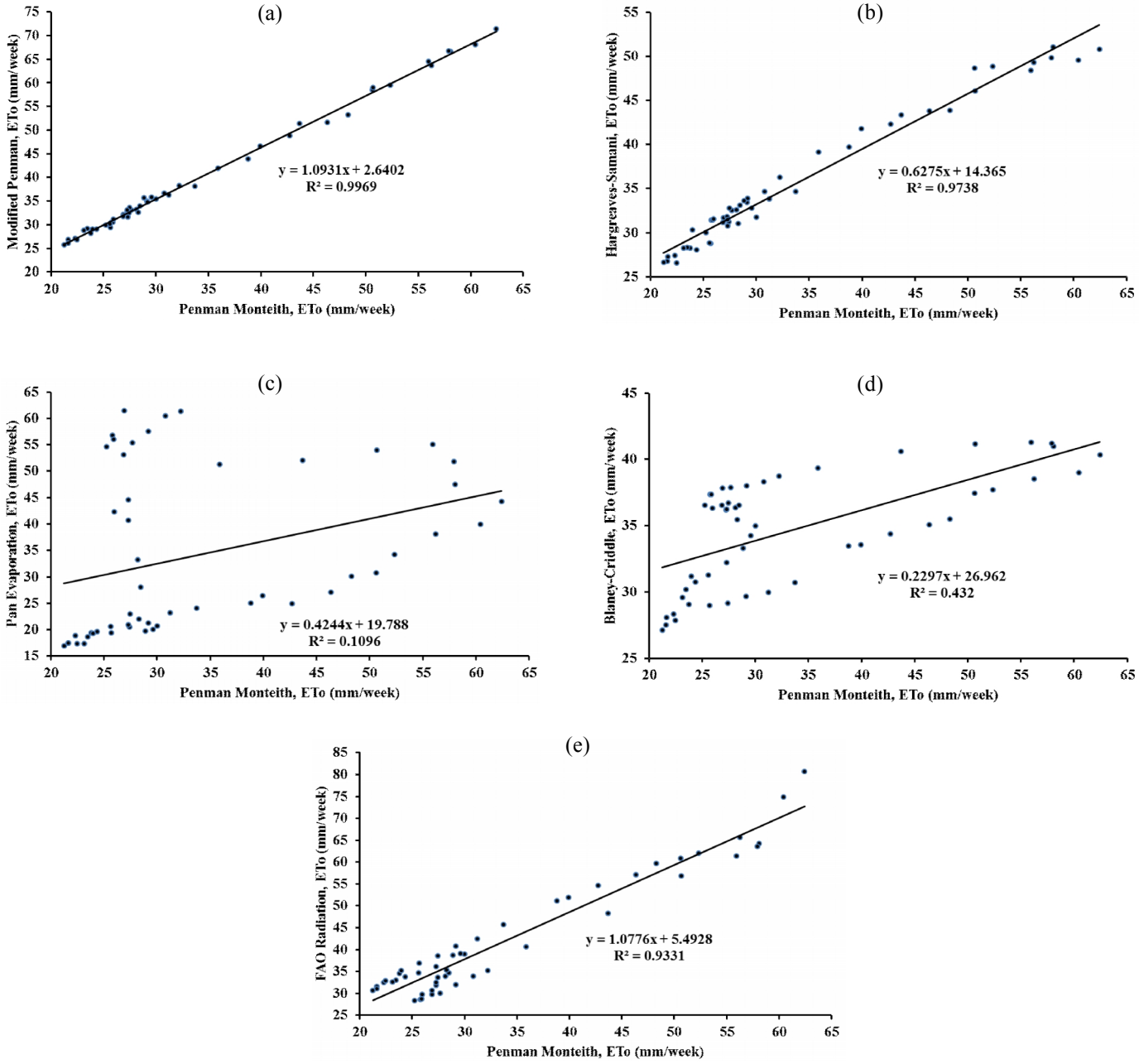

Fig. 1 (a-e) : Regression analysis of ET_o estimates of (a) Modified Penman (b) Hargreaves-Samani (c) Pan Evaporation (d) Blanney-Criddle (e) Radiation Methods for weekly ET_o values at Rahuri Station (mm/week)

variable to investigate the suitability for computing ET_o under limited climatic parameters vis-a-via Penman Monteith method.

RESULT AND DISCUSSION

The weekly reference crop evapotranspiration was calculated by using Penman Monteith method (FAO56-PMM), Modified Penman FAO-24 (MPM), Hargreaves-Samani (HSM), FAO-24 Pan Evaporation (FPEM), Blaney-Criddle (BCM) and FAO Radiation (FRM) methods.

Table 1 shows weekly reference crop evapotranspiration by different methods. The average weekly ET_o estimated by Radiation method was higher followed by Modified Penman, Hargreaves Samani, Blaney Criddle and Pan evaporation.

Comparison of different methods with PMM

The weekly ET_o values estimated by using MPM,

HSM, FPEM, BCM and FRM method were found 17%, 5%, 1%, 3% and 24% higher ET_o than PMM method. Summary statistics for regression of weekly ET_o estimated by each of five methods against that estimated by the standard PM method are presented in Fig 1(a-e). Based on these results, the MPM regression model ranked first with highest coefficient of determination (R^2=0.99) followed by HSM regression model (R^2=0.97) and FRM regression model (R^2=0.93).

CONCLUSION

Six methods (Penman Monteith, Modified Penman, Hargreaves-Samani, Pan Evaporation, Blanney-Criddle and Radiation Methods) were used for estimation of ET_o using climate data for 36 years. The PMM method was assumed as standard for comparing ET_o estimated by other five methods. ET_o estimated by MPM, HSM and FRM methods were in best agreement with the weekly ET_o values estimated by PMM method. It can be noted that the coefficient of determination is high for MPM, HSM and FRM and therefore more suitable in the absence of adequate climate data for the use of PMM for this climatic region but for FPEM and BCM, the coefficient of determination is too low.

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