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Research Article

EVALUATION AND LONG TERM STUDY OF DIFFERENT METHODS OF REFERENCE EVAPOTRANSPIRATION FOR ANAND REGION

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Abstract- This paper represents estimation of reference evapotranspiration (ET_0) with fifteen different methods. Meteorological daily data were used as input parameter to estimate evapotranspiration (ET_0) of 31 years (1984-2015) of Anand station. The FAO 56PM method was used to compare with 1996 KPen, 1948 pn, FP17 pen, CIMICFAO pen, FAO 24Rd, FAO 24BC, 1985 pan, Prs-Harg, 1957 Tylr, 1961 Makk ET_o. Out of all the methods, 1996 Kpen, 1948 pen and FP 17pen methods were found very close to FAO 56PM method with coefficient of determination (R^2) 0.98, 0.99 and 0.98 respectively. The yearly maximum and minimum values of reference evapotranspiration (ET_0) were 6.15 mm/year and 3.34 mm/year and for monthly it was 9.62 mm/month and 2.1mm/month of all the methods.

Keywords- Reference evapotranspiration, FAO Penman-Monteith (FAO56), Crop evapotranspiration.

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Introduction

The knowledge of evapotranspiration of ecosystems and crop plants is a fundamental importance for research and practical purposes. Due to complexity of evapotranspiration as a biophysical phenomenon, several approaches and models were developed. The FAO Penman-Monteith (FAO56) equation is considered as the reference methodology for computing ET0.

Wider application in computation for reference evapotranspiration, such as hydrological and ecosystem, assessment of aridity of particular region, irrigation planning, drought estimation, etc. many other methods are recommended for calculation of evapotranspiration. For humid climate, the Penman-Monteith-FAO-56 method is generally recommended [1]. Different studies preferring Priestley-Taylor's approach [2 & 3], point out that under such climatic conditions it performed better than any other methods. Several research confirmed that temperature and radiation based methods tend to give the highest, while pan-coefficient based ones result in lowest ET_0 values [4 & 5].

In agricultural sciences, the real evapotranspiration as part of the water balance equation is mostly assessed from the potential evapotranspiration (PET). Based on meteorological condition PET refers to the maximum moisture loss from surface and surface type. McMahon is described more other methods for input data calculation of numerous method estimate ET_o [6], but the PM equation is considered the most standard estimate and serves for comparisons with other methods [7]. PM is totally physically based and in this method requires meteorological parameters (air temperature, wind speed, relative humidity and net radiation). It utilises energy balance calculations at the surface to derive ET_0 and is therefore considered a radiation-based method [8]. Standard method, recommended by the Food and Agricultural Organisation [7], is the Penman–Monteith (PM) formulation of ET_0.

Materials and Method

Study area and input parameter

The study was carried out at Department of Agricultural Meteorology, Anand Agricultural University, Anand at latitude of 22.5645^0 N and 72.9389^0 E with an average annual rainfall of about 850 mm. The daily records of meteorological parameters i.e. maximum temperature (Tmax), minimum temperature (Tmin), relative humidity morning and afternoon (RH1, RH2), wind speed (WS), bright sunshine hours (BSS) and Pan evaporation (EP) recorded for the period of 31 years (1984 to 2015). Fifteen different methods as mentioned below were used to estimate ET_o using yearly data. The monthly estimation of ET_0 with coefficient of determination (R^2) compared with FAO 56 method.

Information on the reference evapotranspiration (ET_0) is very important and significant for water resources planning and management. The FAO Penman-Monteith (FAO56) equation is considered as the reference methodology for computing ET_0. The equations of eight methods for estimation of ET_o is given as below:

PM-FAO-56

The FAO-56 Penman-Monteith formula is modified from the Penman (1963) equation. Allen *et al.* [9 & 7] presented the following form of the Penman-Monteith model for estimation of ETo in mm/day:

$$ET_0=\frac{0.408\Delta(Rn-G)+\frac{\gamma 900}{T+273}u2(es-ea)}{\Delta+\gamma(1+0.34u2)}$$

Where ET_o is reference evapotranspiration [mm day^{-1}], , G is soil heat flux density [MJ m^{-2} day^{-1}], T is mean daily air temperature at 2 m height [°C], R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}],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}]. In application having 24-h calculation time steps, G is presumed to be 0 and e_s is computed as

FAO-24 Rad
FAO-24 Corrected Penman (c = 1)

$$ET_0 = a + b\left(\frac{\Delta}{\Delta+\gamma}Rs\right)1/\lambda \quad [10]$$

FAO-24pn
The major modification involved a more sensitive wind function than that used by Penman and an adjustment factor c that is based on local climatic conditions [10]. The resulted equation is given below:

$$ET_0 = C\left(\frac{\Delta}{\Delta+\gamma}(Rn-G)+\frac{V}{\Delta+V}2.7wf(ea-ed)\right)$$

w_f=1+0.86442
v= wind speed of 2m height

1996 Kimberry penman

$$ET_r=\frac{1}{\lambda}\left(\frac{\Delta}{\Delta+\gamma}\right)(Rn-G)+\frac{1}{\lambda}\frac{\gamma}{\lambda(\Delta+\gamma)}6.43wf(ea-ed)$$

Where wf is the wind function for the Kp method $Wf=a_w+b_wu_2$, a_w and b_w are wind function co-efficients given as $a_w=0.4+1.4\exp\{-[\frac{(D-173)}{58}]^2\}$, $b_w=0.605+0.345\exp\{-[\frac{(D-243)}{80}]^2\}$

For southern latitude use D' instead of D is estimated
D'=(D-182) for D>182 and D'=(D+182) for D<182 where D is the day of year [11]

Temperature based method
Blaney-criddle model

$$ET0=a_1+b_1\,[p(0.46T+8.13)] \quad [12]$$

a_1= 0.0041RH_{min}-(n/N)-1.41
b_1= 0.82-0.0041RH_{min}+1.07(n/N) + 0.066u_2d - 0.006RH_{min} (n/N)-0.0006$RH_{min}u_2$d

ASCE penman-monteith(pm) equation which has the form

$$ET_0=\frac{0.408\Delta(Rn-G)+\frac{\gamma Cn}{T+273}u2(es-ea)}{\Delta+\gamma(1+Cdu2)} \quad [13]$$

Hargevas method

$$ET_0=0.0023*(\text{Tmax}-\text{Tmin})b(\frac{\text{Tmax}+\text{Tmin}}{2}+17.8)*Ra \quad [14]$$

Makkink-FAO-24(Makkink1957 Doorenbos-pruit1977b):(mak) (Radiation based)
Doorenbos and Pruitt (1977) were given a radiation method forestimating ET using the solar radiation. This method is adapted from the Makkink method (Makkink, 1957) [15].

$$ET_0=a_2+b_2\,(\frac{\Delta}{\Delta+\gamma})Rg/\lambda \qquad a_2=-0.3,$$

$$b_2=C_0+C_1RH+C_2u_2d+C_3RHu_2d+C_4RH_2+C_5u_2d$$

Results and Discussions
The meteorological data of 31 years of Anand station from 1984 - 2015 were analyzed for purposes of calculating evapotranspiration by the different methods [16]. Estimation of maximum ET_0 for different method were ASCE stPM (4.63 mm/year), 1996 KPen (4.90 mm/year), Prs-Harg (4.68 mm/year) nearly correlated with FAO 56PM and other method produced highly overestimated ET_0 values. The highest and lowest value for ET_0 are 4.71 (mm/year) in 1986 and 1987 and 4.00 (mm/year) respectively in 2013 for FAO 56PM method [Fig-1].

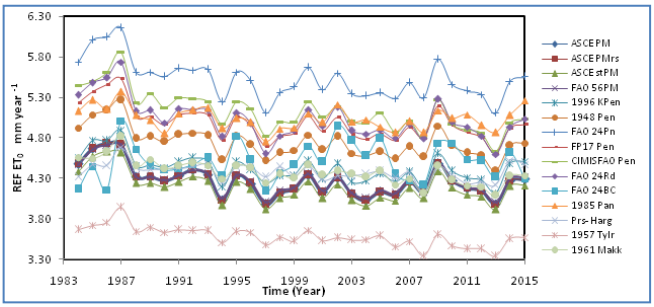
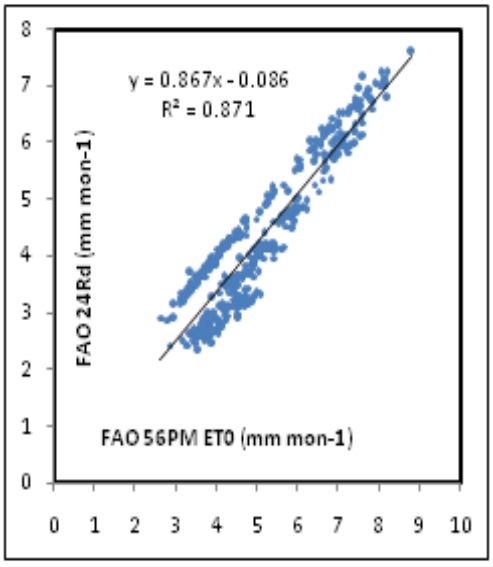
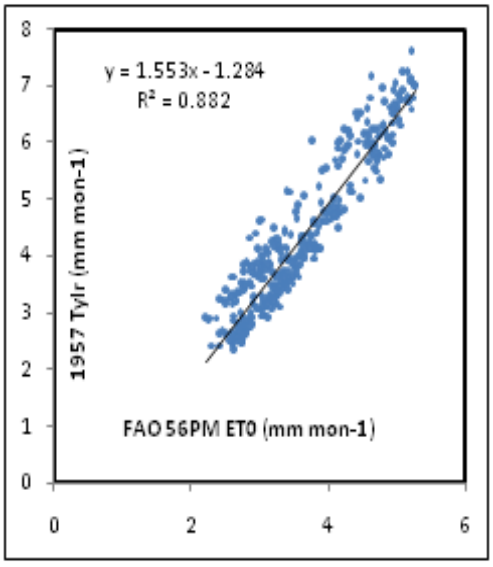


Fig-1 Comparison of fifteen different Reference Evapotranspiration Methods

Results shows that out of fifteen (ET_o) methods, 1996 Kpen, 1948 pen and FP 17pen were found very close to FAO 56PM method [Fig-2 &3].
In regression analysis daily weather data were used to Comparison of monthly ETo values for the 1996 KPen, 1948 pn, FP17 pen, CIMICFAO pen, FAO24Rd, FAO 24BC ,1985 pan, Prs-Harg, 1957 Tylr, 1961 Makk with FAO 56PM [16]. Months of August and September ETo is decreasing, because of highly monsoon season with high relative humidity, low wind speed and lower temperature, comparatively month of November, December and January also decrease that comprises the winter season with low temperature causing low evaporation rates. In [Fig-3] it was observed that the values obtained by the CIMICFAO pen method were low r square value, however other FP17 pen, 1948 pen and 1996 Kpen methods shows values highly correlated to FAO 56PM reference Evapotranspiration (ETo) method and maximum and minimum value are 9.6 mm/month and 2.15 mm/month for all over the ref ETo method.





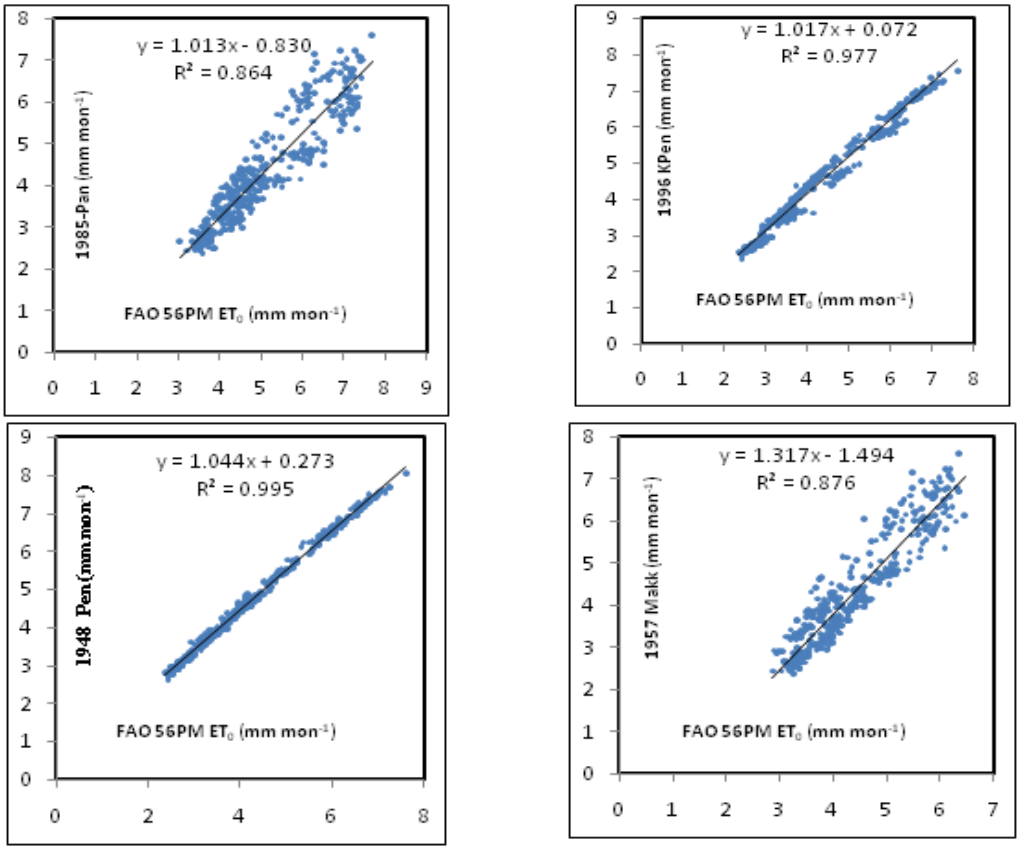


Fig-2 scatter plot of comparison different ref ET_o method with FAO 56PM.

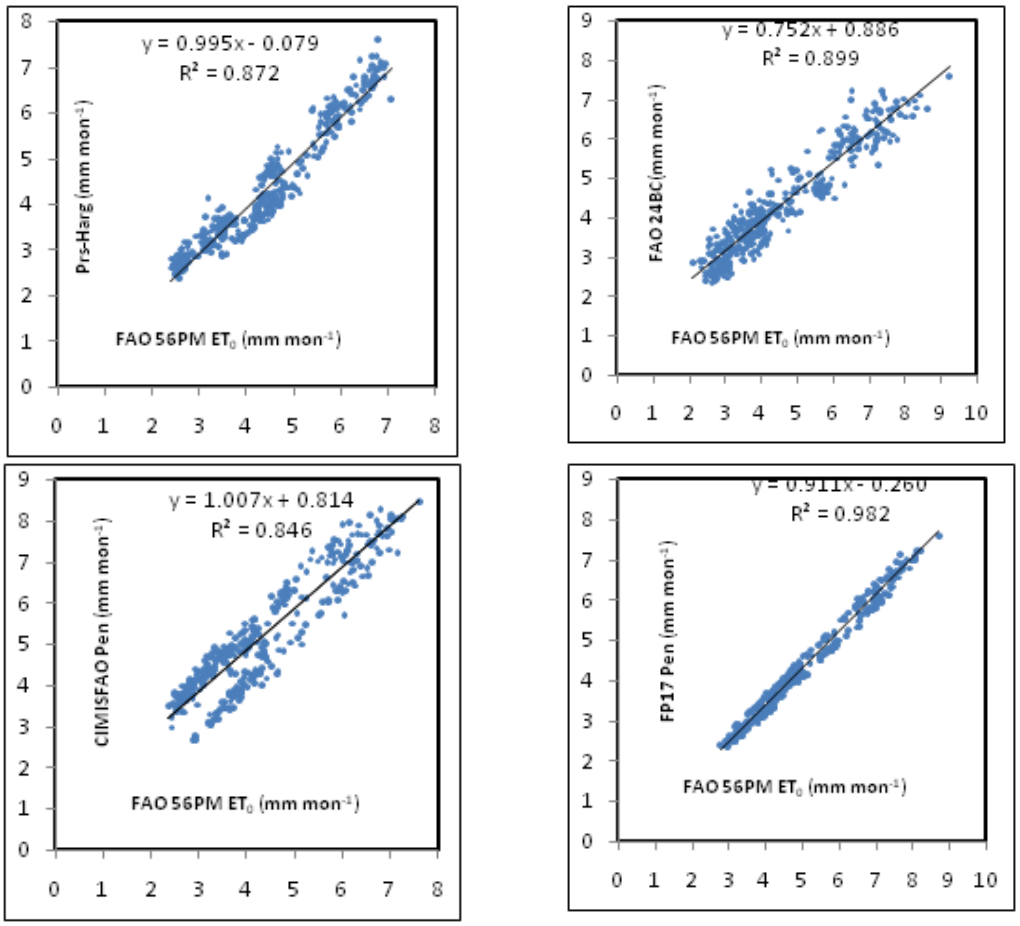


Fig-3 scatter plot of comparison different ref ET_o method with FAO 56PM

Conclusion

The 31 year meteorological data derived from Anand station. The major difficulty is the real ETo is unknow so that here FAO56 PM have shown best method for estimation ETo and also comparing all other method. The FAO 56PM reference evapotrapiration (ETo) is standard method to comparative other method ETo method. R square value were 0.98, 0.99, 0.98, 0.87, 0.89, 0.86,0.87,0.87 for 1996 KPen, 1948 pn, FP17 pen, FAO 24Rd, FAO 24BC, 1985 pan, 1957 Tylr, 1961 Makk ET0 methods.

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Author Contributions: All author equally contributed

Abbreviation: ET_0: Reference Evapotranspiration, PET: Potential Evapotranspiration, Tmax: Maximum Temperature, Tmin: Minimum Temperature, RH: Relative Humidity morning and afternoon, WS: Wind Speed, BSS: Bright Sunshine Hours, EP: Pan Evaporation

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of Interest: None declared

References

[1] Jensen M. E., Burman R. D. and Allen R. G. (1990*) Evapotranspiration and irrigation water requirements: a manual. ASCE manuals and reports on engineering practice (USA). no. 70*

[2] Water Requirements. ASCE Manuals and Reports on Engineering Practice No. 70, Am. Soc. Civil Engr., New York, NY. 332 pp.

[3] Lu Z., et al. (2005) *J Biol Chem* 280 (33), 29689-98

[4] Adeboye M. K. A., Osunde A. O., Ezenwa M. I. S., Odofin A. J. and Bala A. (2009) *Nigerian Journal of Soil Science,* 19(2), pp. 115-120.

[5] Yates D. N. and Strzepek K. M. (1994) The Impact of Potential Evapotranspiration methodology on the determination of River Runof. IIASA Working Paper, WP-94-46, Laxenburg, Austria.

[6] Hossein Tabari , Amir AghaKouchak, Patrick Willems (2014) *Journal of Hydrology,* 519, 1420–1427.

[7] McMahon T. A., Peel M. C., Lowe L., Srikanthan R. and McVicar T. R. (2013) *Hydrol. Earth Syst. Sci.,* 17, 1331–1363, doi: 10.5194/hess-17-1331-2013.

[8] Allen R. G., Pereira L. S., Raes D. and Smith M. (1998) *FAO Irrigation and drainage paper* 56, Rome, 15 pp..

[9] Xu C.-Y. and Singh V. P. (2000) *Hydrol. Process,* 14, 339–349.

[10] Allen C. C., Morris R. V. and McKay D. S. (1996) *Journal of Geophysical Research,* 101, doi: 10.1029/96JE02726. issn: 0148-0227.

[11] Chiew F.H.S., Kamaladasa N.N., Malano H.M., McMahon Penman-Monteith T.A. FAO-24 reference crop evapotranspiration and class-pan data in Australia: Department Civil and Environmental Engineering, University Melbourne Parkville, Victoria 3052, Australia.

[12] Rohitashw Kumar, Vijay Shankar and Mahesh Kumar (2016) *Universal Journal of Environmental Research and Technology,* 1(3), 239-246.

[13] Doorenbos J. and Pruitt W.O. (1977) Guidelines for predicting crop water requirements. Irrigation and Drainage Paper No. 24.144 pps (revised version of the 1975 edition). FAO, Rome.

[14] Allen R. G., Smith M., Perrier A. and Pereira L. S. (1994) *ICID Bulletin*, 43, pp.1-34, 1994.

[15] Hargreaves G. H., Samani Z. A. (1985) *Transaction of ASAE,* 1(2),96-99.

[16] Makkink G. F. (1957) *Journal of the Institution of Water Engineers,* 11, 277–288

[17] Itenfisuel D., Elliott R. L., Allen R. G. and Walter I. A. (2000) *Proc. of the National Irrigation Symposium, ASAE,* 14-16, Phoenix, pp.216-227.

[18] Othoman Alkaeed, Clariza Flores, Kenji Jinno and Atsushi Tsutsumi (2006) *Memoirs of the Faculty of Engineering, Kyushu University,* 66(1).