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Water Requirement for Different Crops in North Western Plateau Zone of Odisha

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ABSTRACT

A study was conducted at College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar during 2014-15 to find out the water requirement of north western plateau zones of Odisha. Water plays a vital role for every living being. Water is and will become scarce natural resource in the near future. A clear understanding of the water balance is essential for exploring water saving measures. Due to economic and environmental constraints on new water resources developments, and increasing municipal and industrial needs, agriculture's share of water use is likely to go down day by day. Water resources management is due to the increase of the population and water demand especially in India, which is classified as arid and semi-arid regions. In India with such large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal distribution of freshwater resources. On an average Odisha receives about 1500mm of rainfall, which is uneven, erratic and uncertain in nature. Therefore efficient and effective water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. Agriculture is the one of important sector which utilises around 60% of fresh water resource. Agriculture is the backbone of India. So it is needed to manage the water in the field of agriculture efficiently. Keeping the above in view, the following objectives are selected for this study, 1. Estimation of reference evapotranspiration for agro-climatic zones of Odisha using weather data of the respective localities.2. Screening of methods to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method. 3. Assessment of crop water requirement for major crops grown in agro-climatic zones of Odisha. Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches to one in most of the zones. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. The correction factor ranges from 0.759 to 1.261 all over the state. Water requirement was found out for all the major crops of this zone for all the seasons.

INTRODUCTION

Water plays a vital role for every living being. Water is and will become scarce natural resource in the near future. A clear understanding of the water balance is essential for exploring water saving measures. Due to economic and environmental constraints on new water resources developments, and increasing municipal and industrial needs, agriculture's share of water use is likely to go down day by day. Water resources management is due to the increase of the population and water demand especially in India, which is classified as arid and semi-arid regions. In India with such large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal distribution of fresh water resources. On an average Odisha receives about 1500mm of rainfall, which is uneven, erratic and uncertain in nature. Therefore efficient and effective water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. Agriculture is the one of important sector which utilises around 60% of fresh water resource. Agriculture is the backbone of India. So it is needed to manage the water in the field of agriculture efficiently.

In agriculture, most of the water is lost due to evapotranspiration by the canopy cover of the plant and surface evaporation. It is the combination of soil evaporation and crop transpiration process. About 70% of the water loss from the earth's surface occurs as evaporation (Almhab and Busu, 2008). Thus, accurate estimation of evapotranspiration is very important for s tudies, such as hydrologic water balance, irrigation system design and management, water resources planning and management, etc. The rate of evapotranspiration from an extensive surface of 8-15 cm tall, green grass cover of uniform height actively growing, completely shading the ground and no shortage of water is called as the reference evapotranspiration (Doorenbos and Pruitt, 1977). Allen *et al.*, (1998) defined ET_0 as "the evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sm^{-1} and albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water". The evapotranspiration rate is normally expressed in millimeters per unit time (mm/day). The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, decade, month or even an entire growing period or year, generally expressed in terms of days. Evapotranspiration is a complex and non-linear phenomenon since it depends on several interdependent parameters such as temperature, humidity, wind speed, radiation, and type of crop and growth stage of the crop. It can be either directly measured by using lysimeter or water balance approaches or estimated indirectly using empirical equations.

Direct measurement of Evapotranspiration using the lysimeter or water balance approach seems to be the most accurate. However, it is a time consuming method and needs precisely and carefully planned experiments for which empirical formulas can be used. Thus, for estimating ET from a well-watered agricultural crop, first reference evapotranspiration (ET_0) from a standard surface is estimated and then an appropriate empirical crop coefficient for a particular crop is multiplied to determine the crop evapotranspiration (ETc). Numbers of empirical equations have been used for ET_0 estimation methods and these methods are mainly grouped into radiation, temperature, pan evaporation based and combination methods. Combination based ET estimation methods includes Penman vapour pressure deficit (VPD#1), Businger-van Bavel, Penman vapour pressure deficit (VPD#3), Penman-Monteith, 1972 Kimberly-Penman, FAO-24 Penman (c=1), FAO-24 Corrected Penman, FAO-PPP-17 Penman,1982-Kimberly-Penman, CIMIS Penman and FAO-56 Penman-Monteith method. Radiation based methods includes Turc, Jensen-Haise, Priestly-Taylor and FAO-24 estimation methods. Thornthwaite, SCS Blaney-Criddle, FAO-24 Blaney-Criddle, and Hargreaves come under temperature based methods.

Estimation of evapotranspiration requires number of parameters, so it is very difficult to estimate it accurately. Therefore, it becomes impractical for many users to select the best ET_0 estimation method for the available data and climatic condition. To overcome this problem, Reddy (1999) developed a decision support system consisting of nine widely used ET_0 estimation methods. This decision support system was further modified to include more ET_0 estimation methods (Swarnakar and Raghuwanshi, 2000) and named as DSS_ET model.

This model was further improved by Bandopadhyay *et al.*, (2008). The DSS_ ET model can be used to identify the best ET_0 method for different climatic conditions. It is developed in Microsoft Visual Basic 6.0. It consists of a model base for estimating ET_0 by twenty two different methods and ranking them and a user-friendly graphical interface.

These available methods can be used for estimating daily and monthly ET_0 values for the time interval considered in this study.

The aim of present study is to estimate the reference evapotranspiration by using the available methods and ranked them to find the best suited method. These ET_0 values can later be used for different purposes such as to derive irrigation water requirement of crops, to obtain ET_0 estimate for locations with no meteorological data and to fill the gaps in available records of ET_0. Keeping the above in view, the following objectives are selected for this study:

1. Estimation of reference evapotranspiration for agro-climatic zones of Odisha using weather data of the respective localities.

2. Screening of methods to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method.

3. Assessment of crop water requirement for major crops grown in agro-climatic zones of Odisha

MATERIALS AND METHODS

The North ewestern platue zone is situated at Kirai of latitude 22.1167 N and longitude 84.0333. Table 1 shows the major crops of this zone.

Table 1: Major crops information of the study area

Sl. No.	Name of zones	Research Station	Soil type	Rabi season
1.	North Western Plateau	Kerai (Sundargarh)	Red & yellow	Paddy, Groundnut, Green gram, Maize

The methods given below are taken for estimation for ET for present study:

a) Standardized form of FAO-56 Penman-Monteith by ASCE 2005

b) Penman Monteith Method (Monteith (1965), Allen (1986), Allen *et al*. 1989)

c) Hargreaves Temperature Method

d) Priestly-Taylor Radiation & Temperature Method

e) Turc Radiation and Temperature Method

f) 1972 Kimberly-Penman Method

g) 1982 Kimberly-Penman Method

h) CIMIS Penman method

i) FAO-PPP-17 Penman (ET_0) method [Frére and Popov (1979)]

j) FAO-24 Penman (c=1) (ET_0) method [Doorenbos and Pruitt (1975, 1977)]

k) Businger-van Bavel (ET_0) method

Statistical Analysis

ET_0 estimates from all methods were compared by using simple error analysis and linear regression. For each location, the following parameters were calculated:

- Standard Error Estimate (SEE)
- Root Mean Square Error (RMSE)
- Percentage Error Estimate (PE)
- Mean Bias Error (MBE)
- Coefficient of Determination (R^2)
- Regression Coefficient (b)
- Monthly Mean (mm/d)

The performance of a model is good when regression coefficient (b) is close to 1.0, $R^2 > 0.6$, RMSE < 0.6 mm d^{-1} and PE < 20%.

Estimation of Crop Water Requirement of Major Crops

Depending upon the cropping season 3 major growing seasons are noticed like kharif, rabi and summer. Eight Rabi crops, one summer paddy and three types of kharif paddy are selected for the study as the major crops of ten different agro-climatic zones of Odisha stated in Table 3.2. Reference crop evapotranspiration for thirty three years for all crops were calculated by using FAO-56 PM method. On the basis of average ET_0 for any day during the crop period of any crops daily crop water requirement was estimated by multiplying crop coefficient (Kc), presented in Table 3.3, value to the estimated ET_0 from FAO-56 PM method.

3.7.1 Crop selection

In Odisha, paddy is major crop during the *Kharif* season, summer season and also in rabi season. In different parts of the state all verities paddy, i.e., long, short and medium duration are almost equally cultivated during the *Kharif* season. During summer and rabi season, short duration and medium duration paddy are cultivated respectively. And also in *Rabi* season, different pulses, oilseeds, are grown as major crops given in Table 2.

3.7.2 Crop coefficient approach

In the crop coefficient approach the crop evapotranspiration, ET_c, is calculated by multiplying the reference crop evapotranspiration, ET_0, by a crop coefficient, K_c

$$ET_c = K_c * ET_0$$

Where

ET_c = crop evapotranspiration [mm d^{-1}],

K_c = crop coefficient,

ET_0 = reference crop evapotranspiration [mm d^{-1}]

Table 2 shows crop coefficient used to calculate the crop water requirement of this zone.

Table 2: Crop coefficient for different crops at different stages

CROPS	Total duration	Stages (in duration)				K_C value for different stages			
		Initial Stage (I)	Crop Dev. (II)	Mid Season (III)	Late season (IV)	Initial Stage (I)	Crop Dev. (II)	Mid Season (III)	Late Season (IV)
Paddy-I	90	15	25	30	20	1.00	1.05	1.20	0.90
Paddy-II	120	15	50	25	30	1.00	1.05	1.20	0.90
Paddy-III	150	15	30	60	45	1.00	1.05	1.20	0.90
Green gram	60	10	20	20	10	0.35	0.70	1.10	0.90
Groundnut	137	25	30	40	25	0.45	0.75	1.05	0.70
Maize	125	20	35	40	30	0.3	0.6	1.2	0.35
Sesamum	90	15	25	35	15	0.35	0.7	1.15	0.25

RESULTS AND DISCUSSION

Reference Evapotranspiration (ET_0) Estimation

For each agro-climatologic zone, climatic data were imported to DSS_ET. The DSS_ET selected the methods applicable for that data availability condition and estimated ET_0 values for all the ten agro-climatic zones of Odisha. Out of 22 widely used available methods, 11 methods were taken for 10 stations in this study. The ET_0 values were estimated by 11 applicable methods for 10 climatic zones using mean daily climatic data of minimum and maximum air temperature, mean relative humidity, wind speed and solar radiation with the help of DSS_ET. Due to the unavailability of pan evaporation data, pan evaporation based methods were not used for the calculation. All the calculations were done on a daily basis from 1981-2013 for each zone by using DSS_ET. The FAO-56 PM method was used as the standard method to estimate ET_0 and the obtained ET_0 values from the other methods were compared with this method.

Comparing the estimated ET_0 values for all different climatic stations, it was found that the performance of different methods varies differently in different stations according to their climatic conditions.

4.2 ET_0 Method Comparison

The ET_0 values obtained by different methods were compared with the FAO-56 Penman-Monteith ET_0 estimate due to the non availability of reliable lysimeter data in ten different agro-climatic zones of Odisha. Comparison studies for different zones are as follows:

4.2.1 ET_0 Comparison for North Western Plateau

The mean monthly ET_0 was estimated using all the methods and compared with the FAO-56 Penman-Monteith estimates. Out of all the 10 methods, the FAO-24 Penman(c=1) method yielded the highest mean ET_0 (6.642 mm/day). The Priestley-Taylor methods estimated the lowest mean ET_0 of 4.216 mm/day. The Penman-Monteith and Priestley-Taylor methods resulted in the minimum and maximum SEE and RMSE values respectively. Similarly, the percentage error (PE) was found minimum and maximum for 1982 Kimberly-Penman method and FAO-24 Penman(c=1) method respectively. Priestley-Taylor and FAO-24 Penman(c=1) methods resulted the minimum and maximum Mean Bias Error (MBE) values respectively (Table 3).

For this zone, the highest ET_0 values was found to be 10.32 mm/d for FAO-24 Penman(c=1) method followed by Businger-van Bavel (9.73 mm/d) and FAO-PPP-17-Penman (9.68 mm/d) in the month of May, whereas, lowest ET_0 value was found in the month of December (2.54 mm/d) for the Priestly-Taylor method followed by 1982 Kimberly-Penman method (3.07 mm/d) (Fig 1).

Table 3: Statistical summary of monthly ET_0 estimates for north western plateau

	ET_0 Methods									
Statistical Parameters	**PM**	**KP-82**	**KP-72**	**FAO-PPP-17-P**	**FAO-24-P(c=1)**	**HG**	**BvB**	**Turc**	**PT**	**CIMIS-Penman**
Mean (mm/d)	5.117	5.148	5.717	6.033	**6.642**	5.523	6.362	4.942	**4.216**	5.808
R^2	**0.993**	0.891	0.985	0.983	0.985	0.811	0.970	0.826	0.464	0.991
SEE(mm/d)	**0.189**	0.679	0.574	0.922	1.516	0.974	1.276	0.863	**1.725**	0.616
B	0.980	0.989	1.093	1.157	**1.267**	1.052	1.218	0.942	**0.771**	1.102
PE	1.99	**1.39**	9.49	15.56	**27.22**	5.78	21.85	5.34	19.25	11.23
MBE	0.104	-0.073	0.495	0.812	**1.421**	0.302	1.141	-0.279	**-1.005**	0.586
RMSE(mm/d)	**0.189**	0.679	0.574	0.922	1.516	0.974	1.276	0.863	**1.725**	0.616

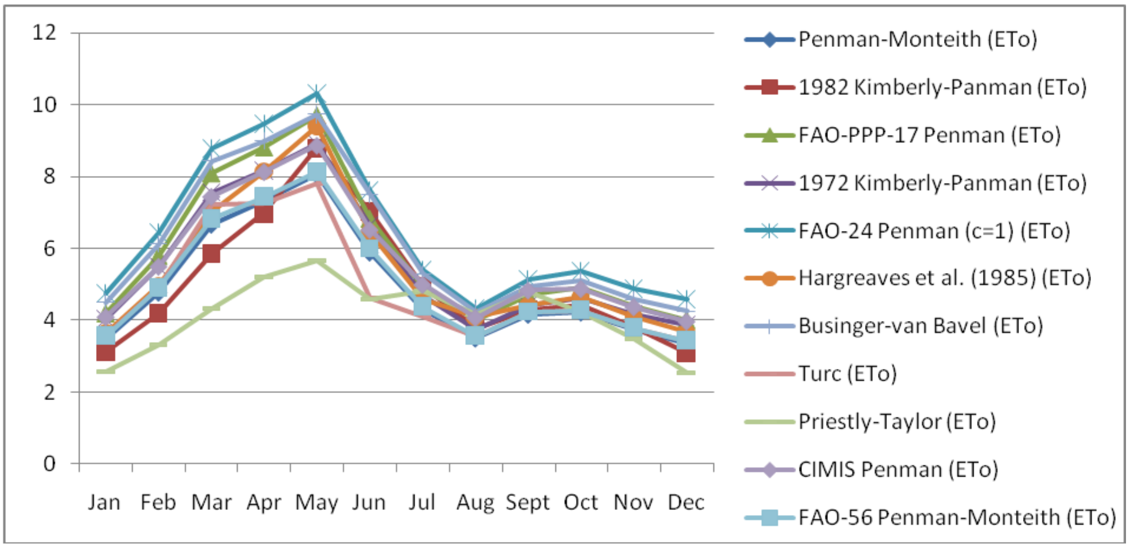

Fig 1: Mean monthly ET_0 by all 11 methods for north western plateau

Table 4 Ranking of different methods for different stations with respect to FAO-56 PM method

Station Name	**PM**	**KP-82**	**KP-72**	**FAO-PPP-17-P**	**FAO-24 P (c=1)**	**HG**	**BvB**	**Turc**	**PT**	**CIMIS-Penman**
AZ-1	1	4	3	5	9	7	8	6	10	2

Table 5 Correction factor with respect to FAO-56 method for all the agro-climatic zones

Station Name	PM	KP-82	FAO-PPP-17-P	KP-72	FAO-24 P (c=1)	HG	BVB	Turc	PT	CIMIS-Penman
AZ-1	1.020	1.014	0.865	0.913	0.786	0.946	0.820	1.060	1.238	0.899

Correction Factor for North Western Plateau

For this zone, correction factor for Penman-Monteith and 1982 Kimberly-Penman approaches to one. The FAO-24 Penman (c=1) and Businger van Bavel give more diversion from FAO-56 Penman-Monteith method. PM method have got highest ranking (Table 4) compared to other methods. The correction factor for north western plateau is shown in fig 2. And Table 5. ETo and CWR of different crops were shown in Fig 3.

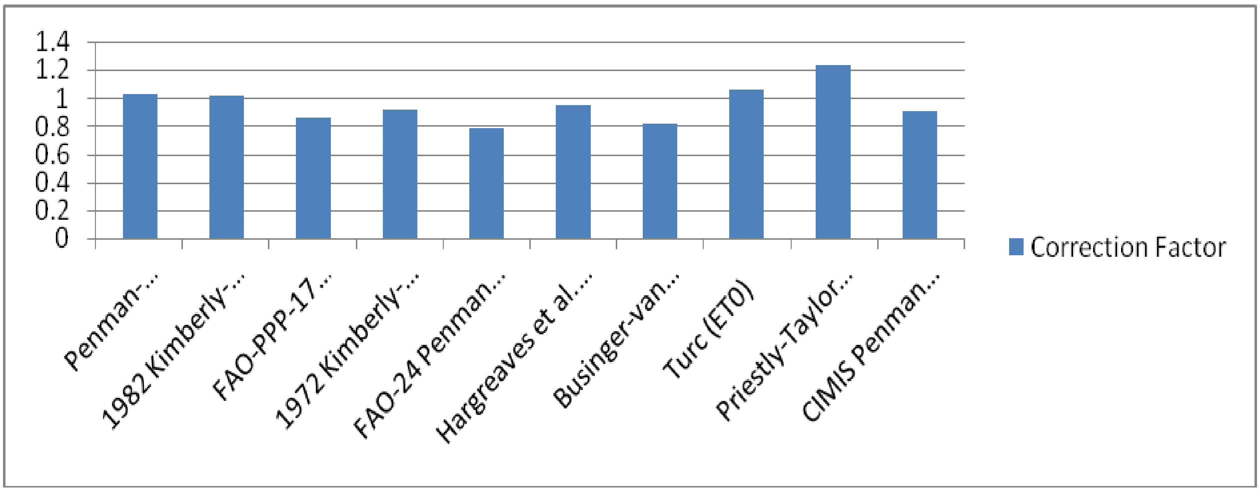

Fig 2 Correction factor for North Western Plateau

Crop Water Requirements (CWR) for major crops for the North Western Plateau zone

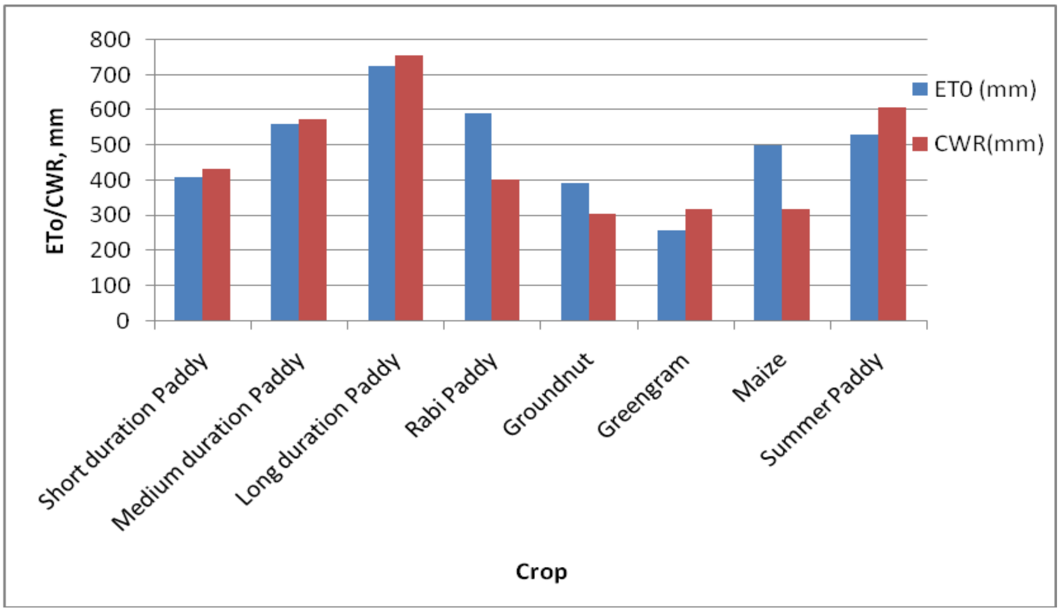

Fig 3: ET_0 Vs CWR for North Western Plateau zone

CONCLUSION

- Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches to one in most of the zones. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. The correction factor ranges from 0.759 to 1.261 all over the state.

- Water requirement for *Kharif* season, short duration paddy crop ranges from 333 mm to 480 mm, medium duration paddy ranges from 470 mm to 629 mm, long duration paddy 600 mm to 821 mm for this zone.

- Water requirement for rabi season, paddy varies from 402mm to 659mm, groundnut ranges from 270mm to 330mm, green gram ranges from 201mm to 317mm, black gram ranges from 242mm to 270mm, maize ranges from 290mm to 363mm.

- In summer season, short duration paddy is cultivated in some areas of this zone The water requirement varies from 540mm to 658mm.

REFERENCES

1. Abdelhadi AW, Hata T, Tanakamaru H, Tada A, and Tariq MA. 2000. Estimation of crop water requirements in arid region using Penman-Monteith equation with derived crop coeffcients: a case study on Acala cotton in Sudan Gezira irrigated scheme, *Agricultural Water Management*, 45: 203-214.
2. Adams S, Quansah GW, Issaka RN, Asamoah EA, Nketia KA, and Amfootu R. 2014. Water requirements of some selected crops in Tono irrigation area, *Journal of Biodiversity and Environmental Sciences (JBES),* 4 (3): 246-257.
3. Allen RG, Pereira LS, Raes D, Smith M. 1998. Crop evapotranspiration: guidelines for computing crop water requirements – *FAO irrigation and drainage paper 56. FAO*, Rome, Italy: 300.
4. Alexandris S and Kerkides P. 2003. New empirical formula for hourly estimations of reference evapotranspiration, *Agricultural Water Management*, 60: 157-180.
5. Azhar AH and Pereira BJC. (2011). Evaluation of reference evapotranspiration estimation methods under Southeast Australian conditions. *Journal of Irrigation and Drainage Engineering*, ASCE, 137 (5): 268-279.
6. Bandyopadhyay A, Bhadra A, Raghuwanshi NS and Singh R. (2008). Estimation of monthly solar radiation from measured air temperature extremes, *Agricultural and forest Meteorology,* 148: 1707-1718.
7. Bandyopadhyay A, Bhadra A, Raghuwanshi NS and Singh R. (2009). Temporal trends in estimates of reference evapotranspiration over India, *Journal of Hydrologic Engineering, ASCE*, 14 (5): 508 -515.
8. Bandyopadhyay A, Bhadra A, Swarnakar RK, Raghuwanshi NS and Singh R. 2012. Estimation of reference evapotranspiration using a user-friendly decision support system: DSS ET, *Agricultural and Forest Meteorology*, 154 (155): 19-29.
9. Benli B, Bruggeman A, Oweis T, and Ustun H. (2010). Performance of Penman-Monteith FAO 56 in a semiarid highland environment, *Journal of Irrigation and Drainage Engineering*, ASCE, 136 (11): 757-765.
10. Beyazgu M, Kayama Y, and Engelsman F. (2000). Estimation methods for crop water requirements in the Gediz Basin of western Turkey, *Journal of Hydrology*, 229: 19–26.
11. Businger JA. 1956. Some remarks on Penman's equations for evapotranspiration, *Netherlands Journal Agric. Sci.* 4: 77-80.
12. Cai J, Liu Y, Lei T, Pereira LS. 2007. Estimating reference evapotranspiration with the FAO Penman–Monteith equation using daily weather forecast messages, *Agricultural and Forest Meteorology*, 145: 22–35.
13. Chattopadhyay N, and Hulme M. 1997.Evaporation and potential evapotranspiration in India under conditions of recent and future climate change, *Agricultural and Forest Meteorology*, 87: 55-73.
14. Chowdhury S, Al-Zahrani M, Abbas A. 2013. Implications of climate change on crop water requirements in arid region: An example of Al-Jouf, Saudi Arabia, *Journal of King Saud University – Engineering Sciences.*
15. Daut I, Irwanto M, Irwan YM, Gomesh N and Ahmad NS. 2011.Combination of Hargreaves method and linear regression as a new method to estimate solar radiation in Perlis, Northern Malaysia, *Solar Energy*, 85: 2871-2880.
16. Doug Dockter, Computation of the 1982 Kimberly-Penman and the Jensen-Haise Evapotranspiration Equations as Applied in the U.S. Bureau of Reclamation's Pacific Northwest Agri-Met Program, *U. S. Bureau of Reclamation Pacific Northwest Region Water Conservation Center.*
17. Espadafor M, Lorite IJ, Gavilán P and Berengena J. 2011. An analysis of the tendency of reference evapotranspiration estimates and other climate variables during the last 45 years in Southern Spain, *Agricultural Water Management,* 98: 1045–1061.
18. Gavila´n P, Lorite IJ, Tornero S, and Berengena J. 2006. Regional calibration of Hargreaves equation for estimating reference ET in a semiarid environment, *Agricultural Water Management*, 81: 257–281.
19. George BA, Reddy BRS, Raghuwanshi NS and Wallender W. 2002. Decision support system for estimating reference crop evapotranspiration. *Journal of Irrigation and Drainage Engineering*, ASCE, 128 (1): 1-10.
20. George BA and Raghuwanshi NS. 2012. Inter-comparison of reference evapotranspiration estimated using six methods with data from four climatological stations in India, *Journal of Indian Water Resources Society*, 32 (3-4): 15-22.
21. Gong L, Xu C, Chen D, Halladin S. and Chen YD.2006.Sensitivity of the Penman Monteith reference evapotranspiration to key climatic variables in the Changjiang (Yangtze River) basin, *Journal of Hydrology*, 329:620-629.

22. Hargreaves GH, Samani ZA. 1985. Reference crop evapotranspiration from temperature. *Appl. Eng. Agric*. 1 (2): 96–99.
23. Itenfisu D, Elliott RL, Allen RG, Walter IA.2003. Comparison of reference evapotranspiration calculation as part of the ASCE standardization effort, *J. Irrig. Drain. Eng. ASCE,* 129 (6): 440–448.
24. Irmak, S., Irmak, A.,Allen R.G.and Jones, J.W.(2003).Solar and net radiation –based equations to estimate reference evapotranspiration in humid climates, *Journal of Irrigation and Drainage Engineering*,129:336-347.
25. Irmak S, Irmak A, Howell TA, Martin DL, Payero JO.and Copeland KS. 2008. Variability analysis of alfalfa-reference to grass-reference evapotranspration ratios in growing and dormant seasons, *Journal of Irrigation and Drainage Engineering,ASCE*, 134 (2): 147-159.
26. Irmak A, and Irmak S. 2008. Reference and Crop Evapotranspiration in South Central Nebraska. II: Measurement and Estimation of Actual Evapotranspiration for Corn, *Journal Of Irrigation And Drainage Engineering, ASCE*, 134 (6): 700-715.
27. Irmak A, Irmak S, and Martin DL. 2008. Reference and Crop Evapotranspiration in South Central Nebraska. I: Comparison and Analysis of Grass and Alfalfa-Reference Evapotranspiration, *Journal of irrigation and drainage engineering*,134 (6): 690-699.
28. Jabloun M, and Sahli A. 2008. Evaluation of FAO-56 methodology for estimating reference evapotranspiration using limited climatic data Application to Tunisia, *Agricultural Water Management*, 95: 707–715.
29. Junior EGC, Oliveira AD, Almeida BM and Sobrinho JE.2011. Methods of estimation of reference crop evapotranspiration for the conditions of northeastern semiarid, Brazil, *Semina: Ciências Agrárias, Londrina*, 32 (1): 1699-1708.
30. Lee TS, Najim MMM. and Aminul MH.2004. Estimating evapotranspiration of irrigated rice at the West coast of the Peninsular of Malaysia, *Journal of Applied Irrigation Science*, 39 (1): 103-117.
31. Martinez CJ. and Thepadia M.2010. Estimating reference evapotranspiration with minimum data in Florida, *Journal of Irrigation and Drainage Engineering, ASCE*, 136 (7): 494-501.
32. Murugappan A, Subburayan S and Mohan S. 2011. Performance evaluation of calibrated Hargreaves method for estimation of Ref-ET in a hot and humid coastal location in India, *International Journal of Engineering Science and Technology*, 3 (6): 4728-4743.
33. Nag A, Adamala S, Raghuwanshi NS, Singh R. and Bandyopadhyay A. 2014. Estimation and ranking of reference evapotranspiration for different spatial scales in India, *Journal of Indian Water Resources Society,* 34 (3): 35-45.
34. Nandagiri L. And Kovoor GM. 2006. Performance evaluation of reference evapotranspiration equation across a range of Indian climate, *Journal of Irrigation and Drainage Engineering*, *ASCE*, 132 (3): 238-249.
35. Praveen P, Kumar S, Puttaswamy H, Patil P and Kumar RR. 2011. Estimation Of Evapotranspiration Rate By Different Methods For Paddy Crop In South Kodagu, Central Western Ghats, *Plant Sciences Feed* 2011, 1 (1): 1- 5.
36. Racz C, Nagy J and Dobos AC. 2013. Comparison of Several Methods for Calculation of Reference Evapotranspiration, *Acta Silv. Lign. Hung.*, 9: 9-24.
37. Reddy BRS. 1999. Development of a decision support system for estimating evapotranspiartion, M.Tech Thesis, Dept. Agri. Food Engg., Indian Institute of Technology Kharagpur, India.
38. Sentelhas PC, Gillespie TJ, and Santos EJ. 2010.Evaluation of FAO Penman–Monteith and alternative methods for estimating reference evapotranspiration with missing data in Southern Ontario, Canada, *Agricultural Water Management*, 97: 635-644.
39. Silva V P R, Borges CJR, Farias CHA, Singh VP, Albuquerque W G, and Silva BB. 2012. Water requirements and single and dual crop coefficients of sugarcane grown in a tropical region Brazil, *Agricultural Sciences,* 3(2): 274-286.
40. Tabari H. 2010. Evaluation of reference crop evapotranspiration equations in various climates after Resources Management, 24: 2311- 2337.
41. Tabari H. and Talaee PH. 2011.Local calibration of the Hargreaves and Priestley-Taylor equations for estimating reference evapotranspiration in arid and cold climates of Iran based on the Penman-Monteith Model, *Journal of Irrigation and Drainage Engineering.ASCE,* 138 (2): 111-119.

42. Temesgen B, Eching S, ASCE M, Davidoff B and Frame K. 2005. Comparison of Some Reference Evapotranspiration Equations for California, *Journal of Irrigation and Drainage Engineering*, 131(1): 73-84.

43. The podia M. and Martinez C J. 2012.Regional calibration of solar radiation and reference evapotranspiration estimates with minimal data in Florida, *Journal of Irrigation and Drainage Engineering ASCE*, 138 (2): 111-119.

44. Walter IA, Allen RG, R. Elliott D. Itenfisu P. Brown ME. Jensen B. Mecham TA, Howell RL, Snyder S. Eching T. Spofford M. Hattendorf D. Martin RH. Cuenca and Wright JL. 2002. The ASCE standardized reference evapotranspiration equation. Rep. Task Com. on Standardized Reference Evapotranspiration, *EWRI-Am. Soc. Civil. Engr.*, *Reston, VA*, 57.

45. http://www.kimberly.uidaho.edu/water/asceewri/main.pdf.

46. Willmott C.J. 1982. Some Comments on the Evaluation of Model Performance, *Bull. American Meteorology Society. AMS,* 63 (11), 1309–1313.

47. Xu C, Gong L, Jiang T, Chen D and Singh V.P. 2004. Analysis of spatial distribution and temporal trend of Reference Evapotranspiration and Pan Evaporation in Changjiang (Yangtze River) Catchment, *Journal of Hydrology,* 327: 81-93.

48. Yin Y , Wu S, ZhenD, YangQ. 2008. Radiation calibration of FAO56 Penman-Monteith model to estimate reference crop evapotranspiration in China, *Agricultural Water Management,* 95: 77-84.