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Crop water requirement (ETc) of Maize crop of Panchmahal Region of Gujarat

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Abstract
Accurate estimation of crop water requirements (ET_c) of any crop is essentially for irrigation scheduling and water management. The present study was undertaken to estimate the crop water requirement (ETc) of maize crops grown in winter seasons in middle Gujarat region of Panam command area Gujarat. The daily reference evapotranspiration (ET_o) was estimated by FAO Penman-Monteith method using 11 years (2006 to 2016) mean meteorological data of Panam command. The most common and practical approach widely used for estimating crop water requirement, and the operational monitoring of soil-plant water balance is the FAO-56 method. In the FAO-56 approach, crop evapotranspiration is estimated by the combination of a reference evapotranspiration (ET_o) and crop coefficients. The Kc values for maize as given in FAO-56 was used in which Kc_{mid} and Kc_{end} were corrected for climatic conditions of stations. The corrected Kc values were used to calculate the daily crop water requirement (ET_c) for maize crops grown at Panchmahal region. The results revealed that during winter season (15 October to 15 January) the mean daily (ETo) varies from 5.5 to 7.32 mm day^{-1}. The mean water requirement of maize during initial stage is 1.085 mm day^{-1}, during developmental stage it varies between 1.085 to 4.35 mm day-1, and during the mid-season stage ETc varies between 4.35 to 5.76 mm day^{-1} and during late season stage it decreases upto 3.20 mm day^{-1}. The seasonal water requirement of winter maize varies between 312.49 mm to 487.08 mm. This study established precise estimation of evapotranspiration which was the only beneficial water loss from the field. The information generated can be used in scheduling irrigation for winter season maize crops of Panchmhal region.

Keywords: Evapotranspiration, FAO-56 penman monteith, crop coefficient, maize crop water requirement

Introduction
Evapotranspiration plays an important role in areas of ecology, hydrology and atmospheric sciences. ET is the second most important element of the hydrological cycle after precipitation because it facilitates the continuation of precipitation by replacing the vapour lost through condensation (Brutsaert, *et al.*, 2009) [3]. ET is also crucial for the transportation of minerals and nutrients required for plant growth; creates a beneficial cooling process to plant canopies in many climates; and influences the Earth's energy and water balance because of the direct association with latent heat flux (LE). ET consumes large amounts of energy during the conversion of liquid water to vapor, hence playing an important role in hydrology, agriculture, climatology and meteorology. Accurate estimates of ET contribute to improved quantification of the catchment water balance and in the facilitation of decision making for sustainable water resource management (Su, *et al*., 2002; Allen, *et al.*, 2007 Mu, *et al*., 2007) [12, 2].
Increasingly higher demands are being placed on water resources each year. With the increasing stress, water resource managers must continually expand methods to assist them in the quantification and allocation of water consumptive use. The quantification of water consumption requires knowledge of the evaporation of water from the earth and plant surfaces as well as how water is consumed by plants by way of transpiration. The combination of these two phenomena, namely surface evaporation and transpiration, are collectively referred to as evapotranspiration. Evapotranspiration (ET) is the largest consumer of irrigated water and quantifying the amount of ET occurring in an area provides water managers a valuable tool for quantifying water consumption. ET is among the most difficult parts of the hydrological cycle to quantify due to the complex interaction between the land surface, vegetation and atmosphere (Xu & Singh 2005; Fang *et al*. 2012) [14, 6]. ET is also difficult and expensive to measure on an operational basis.

The weather conditions of a given area determine, to a large extent, the amount of energy available for evaporation while soil moisture and crop cover determine how that available energy will be used (Wright 1990) [13]. Traditionally water managers have used reference ET and reference ET based crop coefficients (K_c) to assess how much of the available energy is utilized in ET. The reference ET based crop coefficient method was developed for optimal growing conditions, which can overlook actual stressed crop conditions. The crop coefficient method is also limited in its ability to describe spatial variability; therefore, it can only give highly accurate estimates over medium-scale areas. Reference ET is the evaporation from a reference surface of the Earth and it depends on weather conditions. The reference surface can be an open water surface (open pan) or it can be related to weather variables (temperature, radiation, sunshine hours, wind speed, air humidity etc.).

Crop evapotranspiration represents crop water demand and governed by weather and crop conditions and most of the current water demand models are non-spatial models, they use point data of reference evapotranspiration and crop coefficient values from available literature (Doorenbos & Pruitt, 1977) [5]. Crop coefficient (K_c) is an important parameter for irrigation scheduling and water allocation. Crop coefficient values taken from literature may provide a practical guideline for scheduling irrigation, but considerable error in estimating crop water requirement can occur due to their empirical nature (Jagtap & Jones, 1989) [7]. Therefore, it becomes necessary to make corrections in crop coefficient values as per local conditions.

Accurate estimation of crop water requirements (ET_c) of any crop is essentially required for irrigation scheduling and water management. The present study was undertaken to estimate the crop water requirement (ET_c) of maize crops grown in winter seasons in middle Gujarat region of Panam command area. The daily reference evapotranspiration (ET_o) was estimated by FAO Penman-Monteith method using 11 years (2006 to 2016) mean meteorological data of Panam command. The most common and practical approach widely used for estimating crop water requirement, and the operational monitoring of soil-plant water balance is the FAO-56 method. In the FAO-56 approach, crop evapotranspiration is estimated by the combination of a reference evapotranspiration (ET_o) and crop coefficients. There are two different FAO-56 approaches: single and dual crop coefficients. The single crop coefficient approach is used to express both plant transpiration and soil evaporation combined into a single crop coefficient (K_c). The dual crop coefficient approach uses two coefficients to separate the respective contribution of plant transpiration (K_{cb}) and soil evaporation (K_e), each by individual values (Allen *et al.*, 1998) [1]. These results can be used in efficient management of irrigation water.

The adoption of exact or correct amount of water and correct timing of application is very essential for scheduling irrigations to meet the crop's water use demands and for optimum crop production. Estimation of crop water requirements (ET_c) is one of the main components used in irrigation planning, design and operation (Rowshon *et al.*, 2013) [11]. Jensen *et al.* (1990) [8] provided detailed reviews of the methods commonly used to determine evapotranspiration and estimated crop water requirements.

Materials and method

Study Area

The study area of the Panam command which contains two climatic regions, the northern part of the command comprises subtropical wet climate. The major part of command comprises tropical wet climate, caused mainly due to existence of Vindhyas & the Western Ghats. The project area experiences minimum temperature of 14.8°C in January and maximum temperature 43.5°C in May. Average annual rainfall in the area is 940 mm. About 80% of the rainfall occurs during the month of July and August. On an average there are only 35 to 40 rainy-days per annum, which mostly fall during the period mid – June to mid–September. There are frequent dry spells occurring over years. The location map of the study area is presented in Fig. 1.

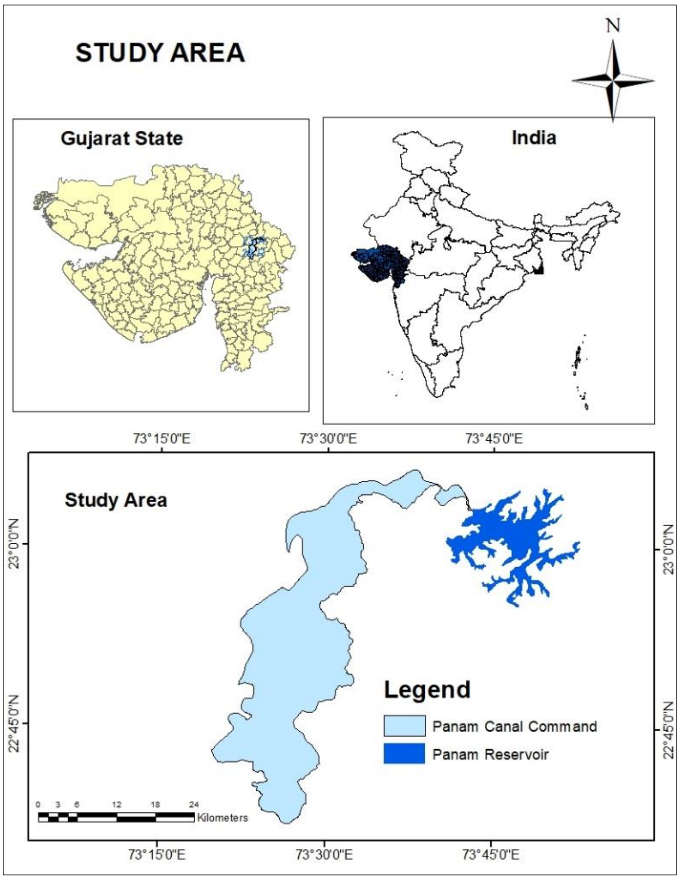

Fig. 1. Location Map of Study Area

Data Collection

Different climatic data required for estimation of ETo were collected for the station of located in Panam command area. A brief description of the data is presented in Table. 1.

Table 1: Meteorological data applied for estimation of ETo for a period of eleven years (2006 to 2016) were used in the study.

Data	Description	Source of Data
Hydrological and meteorological data	Maximum and minimum daily temperature, wind speed, daily sunshine hour, relative humidity Rainfall.	• Sevasadan Department. Godhra • Panam Dam Circle Office, Godhra • MMRS, AAU, Godhra

Methodology

(a) Computation of reference evapotranspiration using FAO-56 Penman-Monteith equations

The FAO-56 PM equation being used for estimating the reference evapotranspiration is given as (Allen *et al*. 1998) [1]. The ET_o was calculated with all necessary data according to FAO-PM, month to month for every year of the series, as well as using only the data from T_{max} (maximum temperature) and T_{min} (minimum temperature) of the air (here after Simplified FAO-PM); finally, it was analyzed by regression. According to Pereira *et al.* (1997) and Allen *et al.* (1998) [1], the FAO-PM equation can be calculated from:

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

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_a 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}].

(b) Computation actual evapotranspiration (ET_a) using crop coefficient (k_c) and reference evapotranspiration (ET_0) for Maize crop.

The calculation of crop evapotranspiration (ET_c) under standard conditions, No limitations are placed on crop growth or evapotranspiration from soil water and salinity stress, crop density, pests and diseases, weed infestation or low fertility. ET_c is determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into ET_o and the crop characteristics into the K_c coefficient:

$$ET_c = K_c\, ET_o \quad \ldots(2)$$

The calculation procedure for crop evapotranspiration, ET_c, consists of:

1. Identifying the crop growth stages, determining their lengths, and selecting the corresponding K_c coefficients;
2. Adjusting the selected K_c coefficients for frequency of wetting or climatic conditions during the stage;
3. Constructing the crop coefficient curve (allowing one to determine K_c values for any period during the growing period) and
4. Calculating ET_c as the product of ET_o and K_c.

Length of growth stages

FAO Irrigation and Drainage Paper No. 24 provide general lengths for the four distinct growth stages and the total growing period for various types of climates and locations. So corrected and FAO k_c values of Maize crops of middle Gujarat:

Total durations of maize crops is 105 days. In initial stage 15 day, development stage 30 day, Mid season stage 35 day and late season stage 25 day. Maize crop coefficient values are for initial stage 0.3, Mid season stage 1.2 and end season stage 0.35.

Crop coefficient for the mid-season stage ($K_{c\ mid}$)

Illustration of the climatic effect

Mid-season Crop coefficient values of any crops not depends only crop types but its varies with the climatic condition and crop height. More arid climates and conditions of greater wind speed will have higher values for $K_{c\ mid}$. More humid climates and conditions of lower wind speed will have lower values for $K_{c\ mid}$.

Determination of $K_{c\ mid}$

For specific adjustment in climates where RH_{min} differs from 45% or where u_2 is larger or smaller than 2.0 m/s, the $K_{c\ mid}$ values (Doorenbos, J. & Pruitt 1977) [5].

$$K_{cmid} = K_{cmid} + [0.04(\mu_2 - 2) - 0.004(R_{hmin} - 45)]\left(\frac{h}{3}\right)^{(0.3)} \quad (3)$$

Where

$K_{c\ mid\ (Tab)}$ value is 1.2,

μ_2 mean value for daily wind speed at 2 m height over grass during the mid-season growth stage [m s^{-1}],

RH_{min} mean value for daily minimum relative humidity during the mid-season growth stage [%],

h mean plant height during the mid-season stage [m] for 0.1 m < h < 10 m.

Result and discussion

Reference evapotranspiration using the FAO-56 PM

The evapotranspiration was estimated using FAO 56 method for three time scales mainly daily, monthly and yearly. The mean ET estimated from FAO-56 PM was plotted for two time scales mainly monthly. The yearly mean ET_0 was varying from 5.53 to 7.61 mm (Fig.2). The monthly mean ET_0 was varying from 10.52 to 3.48 mm (Fig.3). Maximum monthly mean 10.52 mm evapotranspiration was observed on April and minimum monthly mean 3.48 was observed on August.

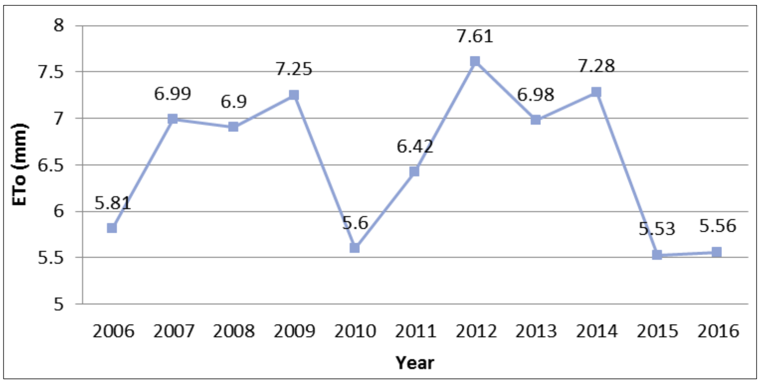

Fig 2: Mean yearly reference evapotranspiration of year 2006 to 2016.

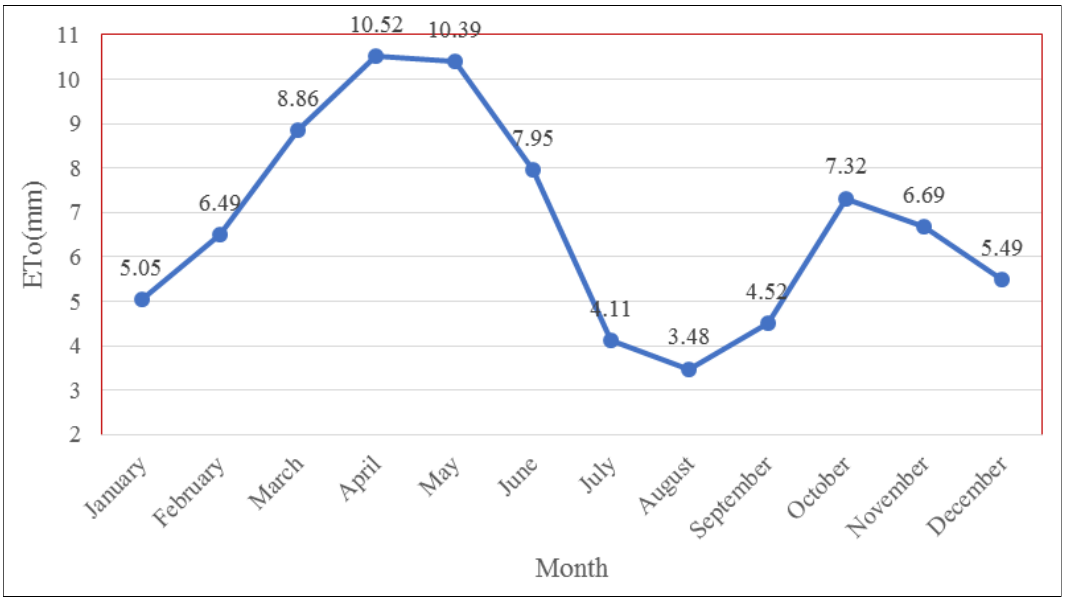

Fig 3: Mean monthly reference evapotranspiration of year 2006 to 2016.

Estimation of Actual Evapotranspiration Using Crop Coefficients and Reference Evapotranspiration for Maize Crop in Panam Command Area.

Mean Monthly variation of reference evapotranspiration (ETo)

The monthly ETo vary from 3.48 to 10.52 mm day^{-1} in January to December. The variation in ET_o is attributed to daily variation in wind speed, temperature and RH_{min} during the year. The ET_o increased continuously from January (5.05 mm day^{-1}) and reached to its peak during April (10.52 mm day^{-1}). It sharply decreased during June and remains low in July and August, there after it slight increased during September and October. It decreased afterwards and reached to the minimum value during December. Since the climatic parameters vary with locations therefore ETo also varies with the locations.

Average monthly standard deviation maximum value observed in June month was 1.74 and minimum value observed in December month was 0.59. The standard deviation for all year (2006 – 2016) was nearly close, so ET_o value for all study data nearly close to each other. Average monthly coefficient of determination maximum value observed in November month was 0.68. These result indicate the these month data for good model regression and connection of data each other is strong. Coefficient of determination minimum value observed in August month was 0.54, so these results indicate very week dependent variable. Average root mean square error maximum value observed in June month was 5.15 and minimum was 2.03 in November Month (Table:1).

Table 1: Summary of statistics of average monthly ET_o (mm/day) estimated method of FAO-56 PM equation of Year 2006 to 2016

S. No	Month	ETo	SD	COD	RMSE
1	January	5.05	0.70	0.61	2.28
2	February	6.49	0.94	0.67	2.87
3	March	8.86	1.18	0.58	3.53
4	April	10.52	1.07	0.66	4.26
5	May	10.39	0.92	0.58	4.34
6	June	7.95	1.74	0.60	5.15
7	July	4.11	1.35	0.59	4.55
8	August	3.48	1.03	0.54	4.49
9	September	4.52	1.34	0.62	4.00
10	October	7.32	1.09	0.56	2.72
11	November	6.69	0.99	0.68	2.03
12	December	5.49	0.59	0.58	2.29

Corrected crop coefficient (K_c)

As the K_c value is influenced by weather parameters and crop growth stages, its value differed not only from stage to stage but also varied with crops. The total crop duration ranged for 100 to 125 days for maize depends on different variety. But generally in Panchmahal region area maize crop duration is 105 which is over survey field. The initial stage generally varied between 15 to 20 days while developmental stage varied between 25 to 30 days; mid-season varied between 35 to 40 days and late season varied between 20 to 30 days for maize crops in winter season. In winter season the Maize crops are generally grown during the month of October – January.

So maize crop taken crop growth stage are, in initial stage 15days, development stage 25 days, mid-season stage 40 days and late season 25 days. Now using a FAO-24 (Crop Water Requirements. Irrigation Drainage paper-24) all stages in k_c values are different, there are in initial stage 0.2, development stage 0.75, mid-season stage 1.2 and end season 0.35

Eleven year (January 2006 to December 2016) of reference evapotranspiration data along with respective stage wise crop coefficient, were applied in this study to calculate the actual or crop water requirement during winter season. The average values of crop water requirement for the winter season over the 10 years is presented in Table 2. The results revealed that during winter season (Octo. 15 to January 13) the daily ETc varies from 0.35 to 7.27 mm day^{-1} (Fig.4). The mean water requirement of maize during initial stage is 1.085 mm day^{-1}, during developmental stage 4.35 to 5.76 mm day^{-1}, during the mid-season stage ETc varies between 3.20 to 5.76 mm day^{-1} and during late season stage it decreases upto 3.20 mm day^{-1} (Table:2).

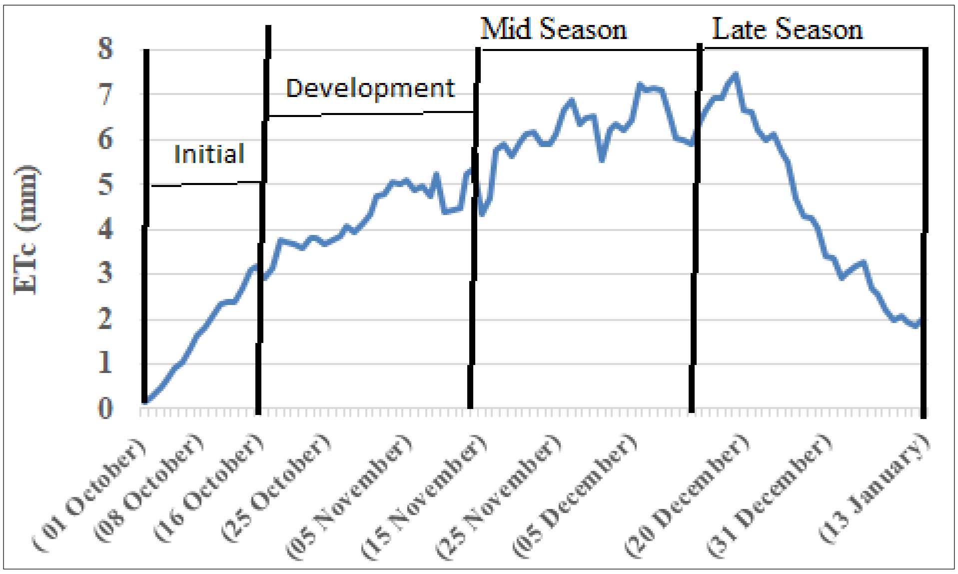

Fig 4: Mean of Daily variation in ETc of winter maize crop of year 2006 to 2016

Table 2: Mean of Stage wise total (mm) and mean daily (mm day^{-1}) crop water requirement (ET_c) of Maize crop of year 2006 to 2016.

S. No	Stages	Godhra	
		Total	**Mean Daily**
1	Initial	16.282	1.085
2	Development	130.47	4.35
3	Mid Season	201.70	5.76
4	Late	79.89	3.20
5	Seasonal Total	428.34 mm	

Use of daily crop water requirement of maize of year 2006 to 2016, estimated seasonal crop evapotranspiration were given in Table.3 by use of all stages water requirement. So highest maize crop water requirement was 487.08 mm in year 2009-10 and lowest maize crop water requirement was 312.49 mm in year 2010-11 and Average maize crop water requirement was 428.14 mm of Panchmahal region.

Table 3: Total (mm) crop water requirement (ETc) of Maize crop of year 2006 to 2016.

S. No	Month	ETc (mm)
1	1stOcto2006 - 13thJan 2007	433.23
2	1stOcto 2007 -13thJan 2008	423.69
3	1stOcto 2008 - 13thJan 2009	442.58
4	1stOcto 2009 - 13thJan 2010	487.08
5	1stOcto 2010 - 113thJan 2011	312.49
6	1stOcto 2011- 13thJan 2012	428.34
7	1stOcto 2012 -13thJan 2013	438.34
8	1stOcto 2013 -13thJan 2014	436.45
9	1stOcto 2014 -13thJan 2015	478.02
10	1stOcto 2015 - 13thJan 2016	401.23
Average		428.14

Conclusions

This study established precise estimation of evapotranspiration which is supposed to be the only beneficial water loss from the field. Initially, reference evapotranspiration was estimated using the most efficient and widely acknowledged physical based FAO-56 PM method. 11 years of climatic dataset. Then, the crop water requirement of Maize crop was estimated, which is one of the important crop grown in the study area. Analysis of reference and crop water requirement for winter maize crop was presented considering daily monthly and yearly scale. The crop water requirement (ETc) was found to vary not only with the crops its stage and duration, but also with the season as well. The crops differed in water demand as the growing season changed. During initial stage of the crops, the ETc was less and increased during development stage, reached to its maximum values during mid season and reduced during crop maturation stages. The information generated can be used in scheduling irrigation for Maize crops in the Panam canal command area and adjoining areas. The results of this study can be used as a guideline for water management for winter maize crop under the semiarid conditions in middle Gujarat also. The study can be useful for short term and long term water management for winter Maize crop considering the daily, monthly and yearly crop water requirement. The results this study can be used as a guideline by irrigation designers, agricultural project managers, consultants, university scientists, producers, and other stakeholders for maize water management also.

References

1. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome. 1998; 300(9):D05109.
2. Allen RG, Tasumi M, Trezza R. Satellite-based energy

balance for mapping evapotranspiration with internalized calibration (METRIC)-Model. Journal of irrigation and drainage engineering. 2007; 133(4):380-394.
3. Brutsaert W. Hydrology: An Introduction, U.S.A: Cambridge University Press, 2009.
4. Doorenbos J, Pruitt WO. Crop Water Requirements. Irrigation Drainage paper-24, FAO, Rome, Italy, 1975.
5. Doorenbos J, Pruitt WO. Crop Water Requirements. Irrigation Drainage paper-24, FAO, Rome, Italy, 1977.
6. Fang J, Shen Z, Tang Z, Wang X, Wang Z, Feng J *et al*. Forest community survey and the structural characteristics of forests in China. Ecography. 2012; 35(12):1059-1071.
7. Jagtap SS, Jones JW. Stability of crop coefficients under different climate and irrigation management practices. Irrigation Science. 1989; 10(3):231-244.
8. Jensen S. Predation by early Cambrian trilobites on infaunal worms-evidence from the Swedish Mickwitzia Sandstone. Lethaia. 1990; 23(1):29-42.
9. Mehta R, Pandey V. Reference evapotranspiration (ETo) and crop water requirement (ETc) of wheat and maize in Gujarat. Journal of Agrometeorology. 2015; 17(1):107.
10. Mehta R, Pandey V. Crop water requirement (ETc) of different crops of middle Gujarat. Journal of Agrometeorology. 2016; 18(1):83.
11. Rowshon MK, Amin MSM, Mojid MA, Yaji M. Estimated evapotranspiration of rice based on pan evaporation as a surrogate to lysimeter measurement. Paddy and water environment. 2013; 12(1):35-41.
12. Su Z. The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes. Hydrology and earth system sciences. 2002; 6(1):85-100.
13. Wright JL. Comparison of ET measured with neutron moisture meters and weighing lysimeters, 1990.
14. Xu CY, Singh VP. Evaluation of three complementary relationship evapotranspiration models by water balance approach to estimate actual regional evapotranspiration in different climatic regions. Journal of Hydrology. 2005; 308(1-4):105-121.