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LONG-TERM MAIZE EVAPOTRANSPIRATION TRENDS DERIVED FROM GROUND-BASED DATASETS FOR GODHRA USING FOOD AND AGRICULTURE ORGANIZATION'S PENMAN-MONTEITH METHOD

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ABSTRACT

Evapotranspiration is a critical parameter in agricultural water management and crop modeling, especially for water-intensive crops like maize. The study was conducted at Main Maize Research Station (MMRS) situated in Godhra and part of Anand Agricultural University (AAU) positioned in Middle Gujarat, India. Study focused on deriving long-term trends of kharif maize evapotranspiration in Godhra using the Food and Agriculture Organization's Penman-Monteith (FAO-PM) method. CROPWAT software was used for the calculation of evapotranspiration for the duration from year 2011 to 2020. The FAO-PM method is recognized for its robustness in estimating reference evapotranspiration (ET_o) based on meteorological parameters. Ground-based datasets including temperature, humidity, wind speed, solar radiation etc. were collected from the meteorological observatory and analysed to compute ET_o and subsequently the crop evapotranspiration (ET_c) for maize, considering crop-specific coefficients (K_c). Estimated seasonal evapotranspiration for *kharif* maize (July-October) varied between 459 mm (2013) and 509 mm (2020). Seasonal ET showed that maize water requirements fluctuate due to climatic factors like temperature, rainfall and humidity. *Kharif* maize evapotranspiration showed upward trend from 2011 to 2020. The results provide insights into temporal variations in ET_c, the impact of climatic factors on maize water demand and strategies for efficient irrigation planning under changing climatic conditions.

Key words : Crop evapotranspiration, CROPWAT, Evapotranspiration, FAO-PM, Maize.

Introduction

By 2050, water scarcity in irrigated agriculture is expected to escalate rapidly due to population growth and rising food demand (Alexandratos and Bruinsma, 2012; Elliott *et al.*, 2014; Molden, 2013; Ray *et al.*, 2013). Accurate and reliable estimation of crop evapotranspiration (ET_c) is crucial and essential for agricultural planning, effective irrigation management and climate change studies at the farmland level. The direct measurement of the actual evapotranspiration of crops is usually tedious and very expensive. For example, the use of specific instruments and precise measurements of physical parameters or soil water balance components in lysimeters is both costly and time-intensive. Although these methods are valuable for validating ET estimates derived from indirect or calculated approaches, they are unsuitable for frequent measurements. In these approaches, crop evapotranspiration (ET) is typically calculated by multiplying reference evapotranspiration (ET_o) with a crop-specific coefficient (K_c). Numerous empirical and semi-empirical models have been developed to estimate crop or reference evapotranspiration based on meteorological data. These include (a) radiation-based models (e.g., Thornthwaite, 1948; Doorenbos and Pruitt, 1977), (b) temperature-based models (e.g., Hargreaves and Samani, 1985) and (c) combination-based models (e.g., FAO-56 PM; Allen *et al.*, 1998). However, the accuracy of these models varies across different climatic conditions (Akhavan *et al.*, 2019). Maize, often known as Indian corn, is globally called the queen of cereals due to its highest genetic yield potential. In India, it is the third most important food crop after rice and wheat. All parts of the crop can be used for food and non-food products. Therefore, as a result of the importance of this crop and the decreasing availability of freshwater resources for agricultural use in numerous areas around the world, the objective of this study was to derive long term maize evapotranspiration using Food and Agriculture Organization's Penman-Monteith Method for long term data. The FAO Penman-Monteith (FAO-56 PM) method is a widely recognized and standardized approach for estimating reference evapotranspiration (ET_o), developed to provide accurate and consistent results across diverse climatic conditions.

Materials and Methods

Description of study area

The study was conducted at Main Maize Research Station (MMRS) situated in Panchmahal district under Anand Agricultural University (AAU) and positioned in Middle Gujarat, India. This region primarily falls under the semi-arid region in agro-climatic zone-III. Middle Gujarat experiences hot and dry temperatures, often exceeding 40°C during the summer months (March to June), while the winter months (October to February) bring mild and pleasant temperatures ranging from 10°C to 25°C. The average annual rainfall in the region is approximately 800 to 1200 mm, with the majority occurring during the monsoon season. This rainfall is crucial for agriculture, supporting crops such as maize, wheat, rice, cotton, groundnut and various fruits and vegetables. The soils of the study area are medium textured. Depending upon the land types, physical as well as chemical properties of soil vary markedly. The soils are slightly alkaline in nature with pH value ranging between 7.9 and 8.2.

Description of Data, Observations and other information

The meteorological data for the duration 2011 to 2020 (10 years) were collected and analyzed to calculate and estimate the evapotranspiration for the maize crop. The meteorological like minimum and maximum temperature, evaporation, rainfall, sunshine hour etc. were collected from the observatory of the research station.

Evapotranspiration

Evapotranspiration (ET) is the combined process of water loss from soil surfaces through evaporation and from plant surfaces through transpiration, resulting in the vaporization of liquid water into the atmosphere. It is expressed as a depth of water lost over a specific period,

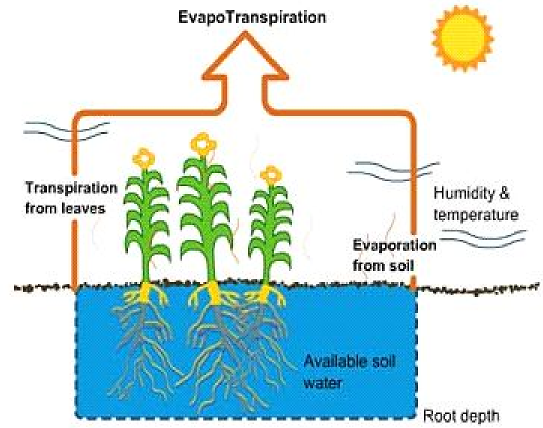

Fig. 1 : Evapotranspiration Process.

typically in millimeters per day (mm/day). ET can be measured directly under specific conditions of crop type, soil properties, and climate, or it can be estimated indirectly. The indirect estimation involves calculating reference evapotranspiration (ET_o), which is determined using various methods depending on the availability and quality of relevant data.

Software used

CROPWAT is a decision-support software developed by the Food and Agriculture Organization (FAO) for irrigation planning and management was used in this study. It assists agricultural professionals, researchers, and policymakers in determining water requirements for different crops and planning irrigation schedules based on climate and soil data. CROPWAT determines reference evapotranspiration (ET_o) by analysing climatic parameters such as temperature, relative humidity, and wind speed. It then estimates the crop water requirements for different growth stages. Crop evapotranspiration (ET_c) was computed by multiplying the reference (ET_o) by the crop coefficient (K_c), which varies with each crop's developmental phase, ensuring precise water management across distinct growth periods. This approach allows users to tailor irrigation schedules based on the specific water needs of crops at their respective stages, optimizing agricultural efficiency and water use. CROPWAT 8.0 version was employ in this study to calculate the crop evapotranspiration (ET_c).

FAO penman Monteith based evapotranspiration estimation methodology

The daily weather data (10 years period) for study location/station was obtained from respective nearby agro-meteorological observatory and suitably utilized to compute ET_o on seasonal basis by adopting globally accepted FAO Penman-Monteith model. Following remained the standard methodological steps.

As per the limitations of various conventional climate base methods, a need kept in view for formulating a sole standard method for the computation of ET_o was offered from consultation of experts and researchers organized by FAO in May 1990, in collaboration with International Commission for Irrigation and Drainage and World Meteorological Organization to review the FAO methodologies on crop water requirements and to advice on the revision and updates of procedures. Adoption of Penman-Monteith combination method was recommended; because it closely approximate grass ET_o at the location evaluated is physically based and explicitly incorporates both physiological aerodynamic parameters. The method overcome shortcomings of the previous FAO Penman method (Doorenbos and Pruitt, 1977) and provides values more consistent with actual crop water use data worldwide. Daily grass-reference ET was computed using the standardized ASCE form of the Penman–Monteith (PM-ET_o) equation (Allen *et al.*, 1998).

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

where,

ET_o = reference evapotranspiration (mm/day)

R_n = net radiation ($MJ/m^2/day$)

G = soil heat flux density ($MJ/m^2/day$)

T = mean daily air temperature at 1.5-2.5 m height (°C)

u_2 = wind speed at 2 m height (m/s)

e_s = saturation vapour pressure at 1.5-2.5 m height (kPa)

e_a = actual vapour pressure at 1.5-2.5 m height (kPa)

Δ = slope of saturated vapour pressure temperature curve (kPa/°C)

γ = psychrometric constant (kPa/°C)

e_s-e_a = saturated vapour pressure deficit (kPa)

Using above generated ground based agro-meteorological data and conceptual framework (i.e. FAO PM); the popular software CROPWAT was used to generate the ET values based on ground observed data on various prime entities as involved in FAO PM model.

CROPWAT

One of the most popular decision support tool developed by the Land and Water Development Division of FAO. It suitably allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions and the assessment of production under rain fed conditions or deficit irrigation. It is always considered as an effective program that uses the Penman-Monteith methods for calculating reference evapotranspiration (ET_o). These estimates were then used in working out crop water requirements and irrigation scheduling determinations. CROPWAT uses monthly data to estimate evapotranspiration, which was further smoothed into daily values for rainfall, minimum temperature (°C), maximum temperature (°C), air relative humidity (%), sunshine duration (h), wind speed at 2 m high (m/s) and also the crop coefficients. As against these sets of inputs, the ultimate output has been the crop water requirement. The basic steps adopted for computing this entity are as follows,

Considering the crop water requirement (CWR) as the amount of water equal to what is lost from a cropped field by the ET; it is expressed in terms of ET per day i.e. mm/day. Estimation of CWR is derived from crop evapotranspiration (ET_c), which was calculated by the following equation.

$$ET_c = K_c \times ET_0 \quad (2)$$

where, K_c is the crop coefficient.

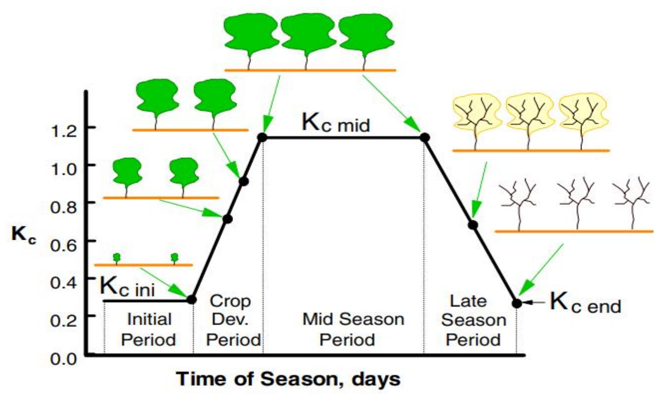

Fig. 2 : Standard Curve on K_c Variability for Crops Owing to Weather and Crop-based Factors (Source: Allen *et al.*, 1998).

Due to the ET differences during the growth stages, the K_c for the crop remain varied (Fig. 1) over the crop developing period which is divided into four distinct stages; namely, initial, crop development, mid-season and late season.

Determination of Crop Coefficient (K_c) : FAO standard crop coefficients (K_c) for maize were used in this study. These values provide a baseline for estimating maize water requirements in irrigation scheduling and hydrological modeling.

Results and Discussion

The results obtained from the study are presented here. The study analyzes evapotranspiration for *kharif* maize from July to October over the years 2011-2020 using the FAO-PM method.

Evapotranspiration from *Kharif* Maize using FAO-PM Method

ET values for *kharif* maize from the years 2011 to 2020 estimated using FAO-PM method are tabulated in Table 1.

Here is a statistical explanation and interpretation:

Range: Seasonal ET for maize (July-October) varied between 459 mm (2013) and 509 mm (2020).

There seems to be a slight increasing trend in evapotranspiration over the years, particularly from 2015 to 2020. Trends include:

- **2011-2012:** ET increased from 484 mm to 503 mm, possibly due to higher temperatures or less rainfall.
- **2013:** A decline to 459 mm, likely due to favorable rainfall or a shorter growing season.
- **2014-2020:** A gradual increase, reaching 509 mm in 2020, possibly due to changing climate conditions or agricultural practices.

Table 1 : Seasonal ET for *kharif* maize from the year 2011 to 2020 using FAO-PM method.

S. no.	Year	Seasonal ET (mm)
1.	2011	484
2.	2012	503
3.	2013	459
4.	2014	464
5.	2015	465
6.	2016	496
7.	2017	498
8.	2018	506
9.	2019	494
10.	2020	509

in 2013 (459 mm) could indicate a drought year or cooler-than-average temperatures. These variations may be influenced by factors such as weather conditions, agricultural practices or climatic changes. These findings suggest maize water requirements fluctuate due to climatic factors like temperature, rainfall and humidity. Manasa and Shivapur (2016) observed similar trend in evapotranspiration and increase in CWR.

The ET values remain relatively consistent, ranging from 459 mm (2013) to 509 mm (2020).

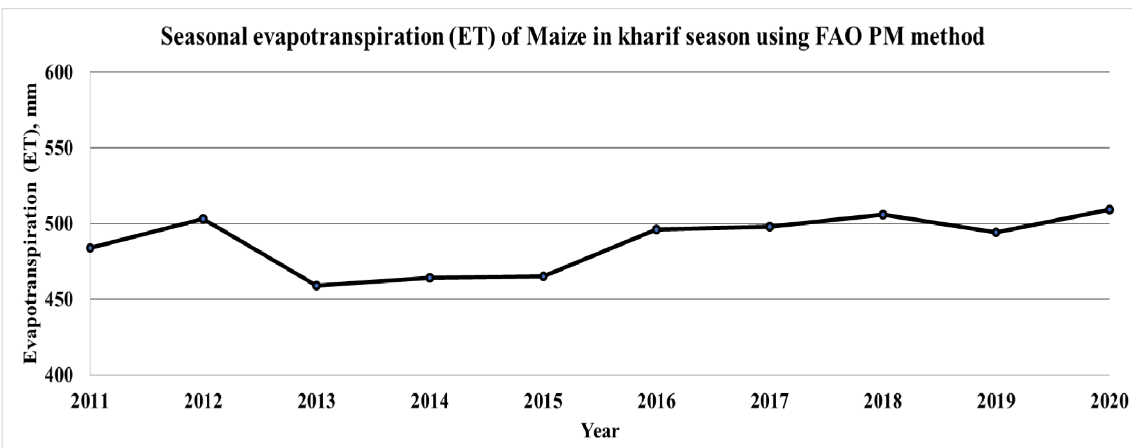

Fig. 3 : Seasonal ET using FAO PM for *Kharif* Maize.

The data shows fluctuations, with notable drops in 2013 (459 mm) and a peak in 2020 (509 mm). The data indicates a general rise in seasonal evapotranspiration over the decade, with values consistently exceeding 490 mm after 2015. This might reflect increased atmospheric demand for water due to warming temperatures or changes in crop management practices. The ET values vary year by year, which might correspond to varying rainfall patterns, temperature changes, or soil moisture availability during the kharif season. For instance, the dip

Conclusion

The current study was conducted to estimate long term *kharif* maize ET for the duration from 2011 to 2020 using FAO-PM method for the MMRS, AAU, Godhra. The variation in seasonal evapotranspiration for kharif maize using the meteorological data from 2011 to 2020, varied between 459 to 509 mm. Present study concludes that selected crops have higher water demands during their peak growth stage. This has implications for irrigation planning, especially in regions with limited water resources. Farmers may need to adopt water-saving technologies or adjust sowing practices. ET is a key indicator of climatic conditions. The upward trend might be attributed to global warming or localized climatic changes, which may also impact crop yields and water demand. Seasonal ET for *kharif* maize remained relatively consistent. Seasonal ET showed that maize water requirements fluctuate due to climatic factors like temperature, rainfall, and humidity. *Kharif* maize evapotranspiration showed upward trend from 2011 to 2020. The results provide insights into temporal variations in ET_c, the impact of climatic factors on maize water demand, and strategies for efficient irrigation planning under changing climatic conditions.

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