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Crop Water Requirement for Cotton Crop in Unchadi Section Command Area of Shetrunji Right Bank Main Canal using WEAP Model

Hiren J. Chavda[1], Kashyap B. Gohil[2]
[1]*Lecturer in Civil Engineering, C.U. Shah Polytechnic Surendrangar*
[2]*Assistant Professor, Shantilal Shah Government Engineering College Bhavnagar*

Abstract: Crop coefficients and reference crop evapotranspiration must be determined in order to estimate irrigation water requirements for any crop and improve irrigation scheduling and water management. The objective of this study is to evaluate the crop water requirements of cotton using the FAO-56 Penman-Monteith Method with dual crop coefficients. Meteorological data for the Unchadi Section Command Area of Shetrunji Right Bank Main Canal, such as maximum and minimum temperatures, mean relative humidity, sunlight hours, and wind speed, are used to calculate reference crop evapotranspiration. The MABIA method in WEAP (Water Evaluation And Planning) software uses the dual-Kc approach to calculate crop evapotranspiration or crop water requirement, which is described in FAO Irrigation and Drainage Paper No. 56, whereby the Kc value is divided into a 'basal' crop coefficient (Kcb) and a separate component (Ke) representing evaporation from the soil surface. The basal crop coefficient represents actual ET conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration. Cotton crop water requirement (ETc) using is found about 940.93 mm during the growing season in region. This result can be useful for agricultural planning and efficient irrigation management for cotton cultivation in Unchadi Section Command Area of Shetrunji Right Bank Main Canal.

Keywords: WEAP, Crop water requirements; Penman-Monteith method; Crop evapotranspiration; FAO-56;WEAP-MABIA

I. INTRODUCTION

One of the most important resources available for agriculture is water. Due to a variety of factors, it has become more limited in India, raising concerns about the country's ever-growing population and food security. India has a wide variety of landforms, including the Himalayan high-altitude forest, the Indo-Gangetic plains' expansive grasslands, the peninsular plateaus of South-East and South-West India, as well as many more geological formations. Indian agriculture is diversified and complicated with both irrigated and dry land areas, able to produce the majority of the food and agricultural products of the world due to the existence of a wide range of geological and climatic circumstances. In order to effectively manage natural resources for planning purposes, prevent environmental degradation, and boost agricultural output for the country's constantly growing population's food and nutritional security. The water requirement for the crops depends on the type of crop. The amount of water needed to compensate for the evaporation loss of the cultivated field is defined as the crop's water demand. On the other hand, the irrigation water requirement of crop production is the amount of water, in addition to precipitation, that must be used to meet the evapotranspiration requirement of the plant without a significant reduction in yield. The water requirement largely depends on the nature and growth phase of the crop and the environmental conditions. Different crops have different water use requirements under the same weather conditions. Hence the crop coefficients appropriate to the specific crops are used along with the values of reference evapotranspiration (ETo) for calculating the crop evapotranspiration (ETc) also known as consumptive use at different growth stages of the crop by water-balance approach. Crops will transpire water the most quickly when soil water is at field capacity.

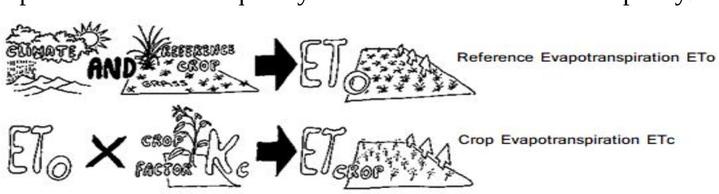

Figure 1 Calculation of the crop water requirement (ET crop) (Source: Irrigation Water Management Training manual no. 3 by C. Brouwer and M. Heibloem)

At the same time, a crop can have different water needs in different parts of the same country; depending on climate, soil type, cultivation method and useful rainfall.

The crop evapotranspiration (ETc) and the reference evapotranspiration (ETo) ratio is known as the crop factor, Kc.

Kc = ETc / ETo ……. (1)

where, ETo = Reference evapotranspiration (mm/day) ETc = Crop evapotranspiration (mm/day)

Both ETo crop and ETc are expressed in the same unit (mm per day)

The crop factor or coefficient, Kc, mainly depends on the type of crop, the growth stage of the crop and the climate.

The crop factor or coefficient is dynamic in nature and varies according to crop characteristics, dates of (trans) planting, stage of growth and climatic conditions.

Kc can be utilised as single Kc and dual Kc. A single Kc that is modified by the combined mild effects of evaporation and transpiration (Allen, 2000). Dual Kc is written separately as soil evaporation coefficient- Ke and crop base coefficient- Kcb (FAO-56). Allen (2000) claims that utilising a single crop coefficient is easier. Furthermore, Suleiman et al. (2007) demonstrated that in humid environments, utilising a single Kc for cotton crop estimation is feasible. According to Allen et al. (2005), crop and climatic variance leads to inconclusiveness in Kc and ET in any location throughout the world. Although proposed coefficients were utilised in estimating crop water requirements, there are variances in the amount and calculation approaches of Kc across distinct crops. The key objectives of this study were to determine the crop water requirement of Cotton in the region.

II. MATERIALS AND METHODS

Water should be given according to crop evapotranspiration for optimum crop yield. Estimating crop evapotranspiration is essential for effective irrigation water planning and management. Crop evapotranspiration estimations require different crop coefficient values for each crop. Crop coefficient values are influenced primarily by crop characteristics, irrigation technique, crop planting date, crop development rate, growing season duration, and prevailing weather conditions.

Shetrunji Sub Watershed, which is shared with the Bhavnagar district depends on agriculture, so the availability of agricultural water must be maintained to minimize the excessive use of groundwater and to get higher yields of crops. Unchadi Section Command Area of Shetrunji Right Bank Canal which draws the water from Shetrunji River and lies under Shetrunji Watershed near latitude 21.35˚N and longitude 72.05˚E. Cotton, the region's main crop, was chosen for this study as a crop with a crop period of 195 days that requires groundwater and canal water throughout crop growth. Daily observed data for maximum temperature, minimum temperature, sunshine hours, wind velocity and relative humidity are collected from State Water Data Centre (SWDC) of Gujarat State and NASA Power Web-portal. The region has Shallow black soils and mainly sandy clay loam in texture.

A. *Reference Crop Evapotranspiration*

ETo or ETref, or reference crop evapotranspiration, is the estimation of evapotranspiration from the "reference surface." A hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s/m, and an albedo of 0.23 is used as the reference surface. The reference surface is similar to a large expanse of green, well-watered grass of uniform height that is actively growing and totally shadowing the ground. A fixed surface resistance of 70 s/m indicates a fairly dry soil surface as a result of a weekly watering frequency. The calculation methods used in the MABIA Method are those described in the FAO Irrigation and Drainage Paper 56 as the FAO Penman-Monteith equation. This equation is expressed as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$ **……. (2)**

Where , ETo = Reference evapotranspiration [mm day^{-1}],

Rn = Net radiation at the crop surface [MJ m-2 day^{-1}],

G = Soil heat flux density [MJ m^{-2} day^{-1}],

T = Mean daily air temperature at 2 m height [°C],

u2 = Wind speed at 2 m height [m s^{-1}],

es = Saturation vapour pressure [kPa],

ea = Actual vapour pressure [kPa],

es - ea = Saturation vapour pressure deficit [kPa],

Δ = Slope vapour pressure curve [kPa °C^{-1}],
γ = Psychometric constant [kPa °C^{-1}].

The Water Evaluation and Planning (WEAP) software have two options to calculate Reference Evapotranspiration (ETref) in MABIA-Model : (1) Directly enter data of ETref which is provided by some climate station, OR (2) Use the Penman-Monteith equation to calculate it. This method has its own data requirements and options. To calculate ETref in WEAP MABIA-Model, you have to enter following data by which WEAP will calculate ETref using Penman-Monteith equation:

1) Minimum daily temperature and maximum daily temperature.
2) Relative humidity. Different formulae are utilised depending on the availability of data.
3) Minimum daily relative humidity and maximum daily relative humidity, OR
a) Maximum daily relative humidity, OR
b) Average daily relative humidity, OR
c) In the absence of humidity data, an approximation humidity can be produced by assuming that the dew point temperature is the same as the daily lowest temperature.
4) Solar radiation. Different formulae are utilised depending on the availability of data.
a) Enter solar radiation data directly, OR
b) Hours of sunshine per day, OR
c) Cloudiness fraction, OR
d) If neither sunshine hours nor cloudiness fraction are available, solar radiation can be estimated using the Hargreaves formula, based on minimum and maximum daily temperature and an adjustment coefficient (Krs)
5) Wind speed.
6) Latitude and altitude of the climate measurement station.

Crop water requirement (CWR) is defined as the depth of water (millimeters) needed to compensate crop evapotranspiration (ETc) by a disease-free crop, growing in large fields under non-restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. According to the definition of "crop evapotranspiration" (ETc), which is the rate of evapotranspiration (millimetres per day) of a particular crop as influenced by its growth stages, environmental conditions, and crop management to achieve the potential yield of a crop, the CWR is the total of ETc over the entire crop growth period. Actual crop evapotranspiration (ETa) is the rate of evapotranspiration that must be adjusted to the prevailing conditions when management or environmental variables depart from the ideal. Irrigated or rainfed crops can both benefit from the CWR and ETc concepts.

B. Crop Coefficients

The reference evapotranspiration, ETo (millimetres per day), can be used to determine ETc by multiplying it by the dimensionless crop coefficient, Kc:

$ETc = Kc * ETo$…. (3)

C. Dual Crop Coefficient (Kcb + Ke)

The process using the single time-averaged Kc coefficient needs fewer numerical calculations than the dual coefficient approach described by Allen et al. (1998). For real-time irrigation scheduling, calculations of the soil water balance, and research investigations where the effects of daily fluctuations in soil surface wetness, the ensuing influences on daily ETc, the soil water profile, and deep percolation fluxes are significant, the dual technique is best. The impacts of crop transpiration and soil evaporation are evaluated independently in the dual crop coefficient approach. The procedure entails dividing Kc into two distinct coefficients, one for soil evaporation (Ke) and one for crop transpiration, known as the base crop coefficient (Kcb).

When the soil surface is dry but transpiration is occurring at a potential rate, the basal crop coefficient (Kcb) is defined as the ratio of crop evapotranspiration over the reference evapotranspiration (ETc/ETo). Accordingly, "Kcb ETo" represents largely the transpiration component of ETc. The "Kcb ETo" does have a residual diffusive evaporation component that is supplied by both soil water beneath dense vegetation and soil water beneath the dry surface.

$Kcb = Kcb\ (Tab) + [0.04(u2-2) - 0.004\ (RHmin- 45)]\ (h/3)\ 0.3$ …… (4)

Where, Kcb (Tab) - Value for Kcb mid or Kcb end (if RHmin $\geq$ 45 %) taken from FAO 56

u2 - Mean value for daily wind speed at 2 m height over grass during the mid or late season growth stage for 1 m /s $\leq$ u2 $\leq$ 6 m / s

RHmin - Mean value for daily minimum relative humidity during the mid- or late season growth stage, % for 20% ≤ RHmin ≤ 80%
h - Mean plant height during the mid or late season stage, m for 20% ≤ RHmin ≤ 80%
The crop is referred to as being under water stress when the potential energy of the soil water falls below a threshold value. By dividing the baseline crop coefficient by the water stress coefficient, Ks, the impacts of soil water stress are calculated.

D. Evaporation Component (Ke ETo)

The evaporation portion of ETc is described by the soil evaporation coefficient, Ke. Ke is at its highest when the topsoil is moist after rain or irrigation. When there is no water present near the soil surface for evaporation, Ke is tiny and even nil when the soil surface is dry. The rate of soil evaporation is highest when the soil is moist. The crop coefficient (Kc = Kcb + Ke) has a maximum value, Kc max, which it can never surpass. The energy available for evapotranspiration at the soil surface determines this number. Less water is available for evaporation when the topsoil dries out, and evaporation starts to decline according to the quantity of water left in the top soil layer.

III. RESULTS AND DISCUSSION

For cotton crop growth stages, crop coefficients for the dual crop coefficient approach shown in Table 1. And Figure 1 shows the Value of Basal Crop Coefficient Kcb and Crop Coefficient Kc for dual crop approach for various crop growth stages for Cotton

Table 1 Basal Crop Coefficient Kcb for dual crop coefficient for various crop growth stages for Cotton

Planting Date	26th May (195 days)			
Growth stages	Initial	Development	Mid	Late
Period (days)	30	50	60	55
RHmean, %	64.64	75.41	83.53	74.04
Basal crop coefficient, Kcb for dual crop coefficient	0.15	1.15	1.15	0.45
Average Kc Value	0.59	0.82	0.84	1.08

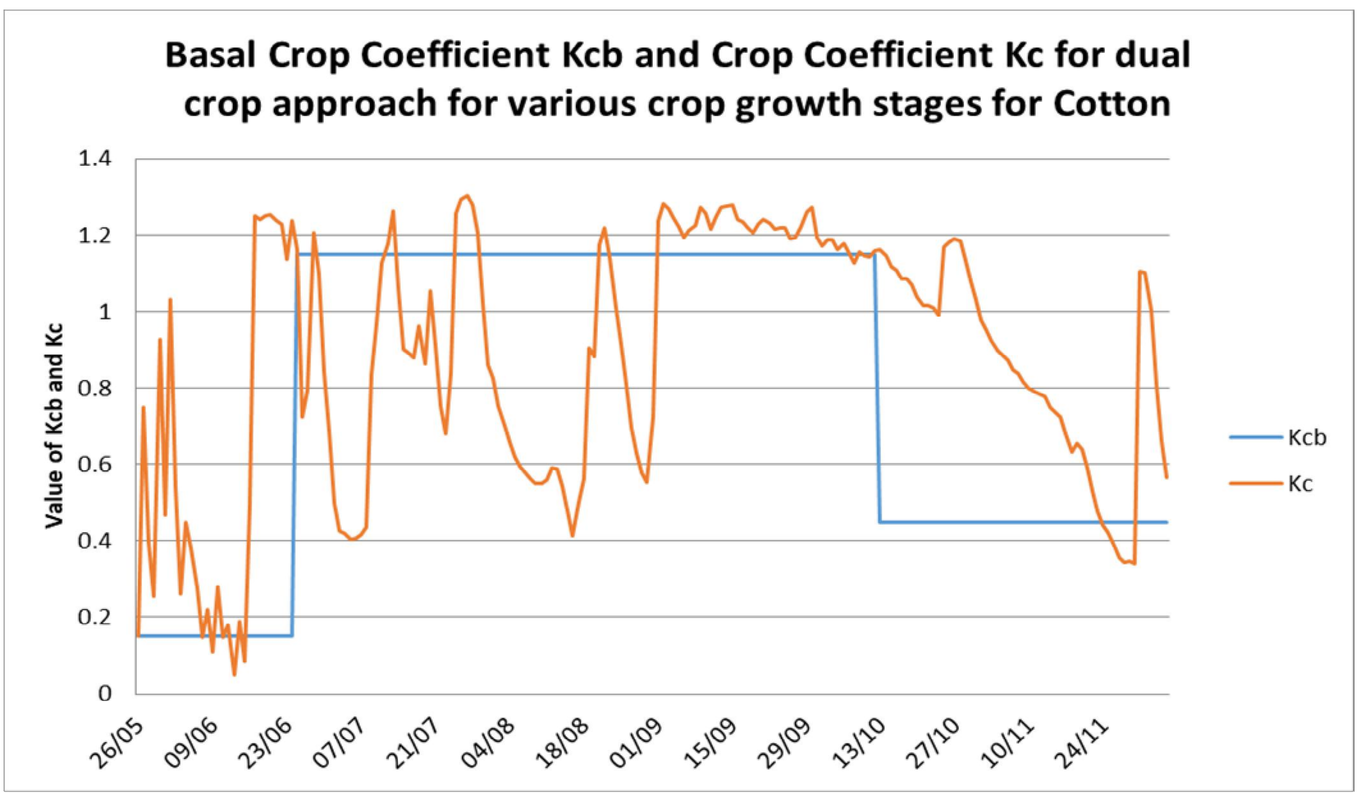

Figure 1 Value of Basal Crop Coefficient Kcb and Crop Coefficient Kc for dual crop approach for various crop growth stages for Cotton

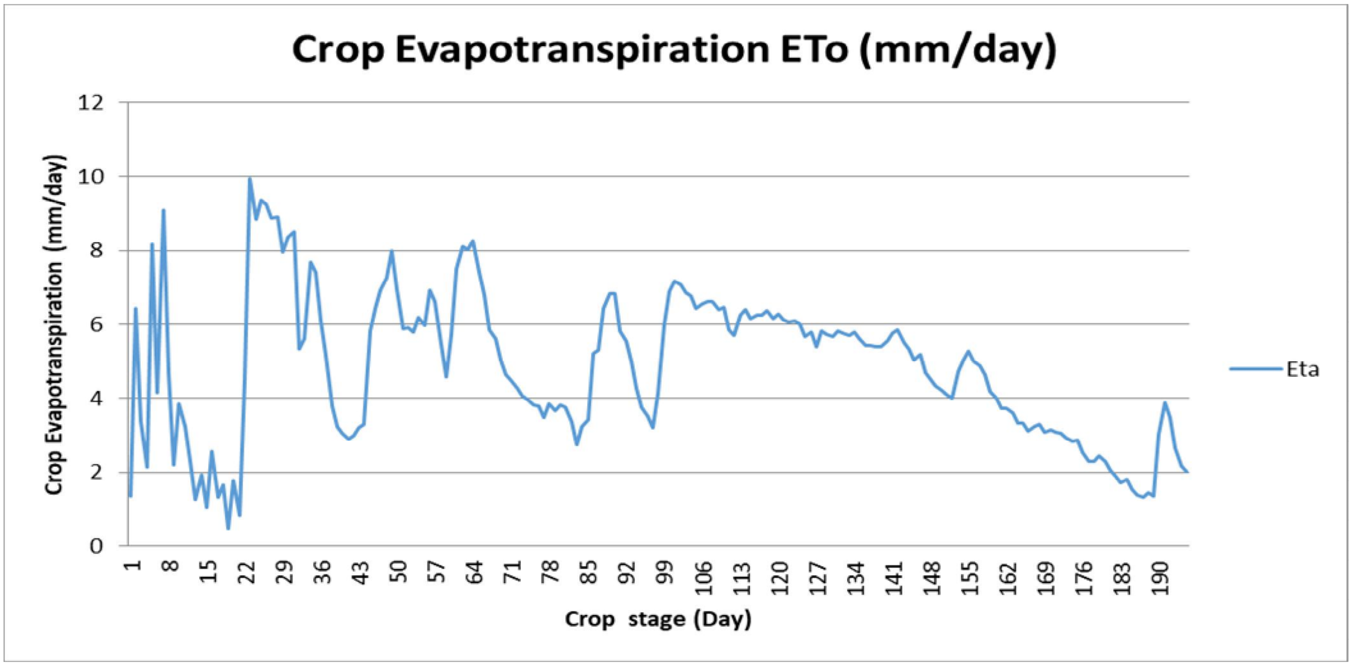

Figure 2 Variation of Kcb, Kc dual with respect to crop period for cotton

From Table 1 and Figure 1, it is observed that in initial period Kc value varies with various stage of growth of cotton crop. The leaf area is small during this initial time, and soil evaporation accounts for the majority of evapotranspiration. As a result, when the soil is moist from irrigation and rainfall, the Kc during the initial phase (Kc ini) is high, and when the soil surface is dry, the Kc is low.

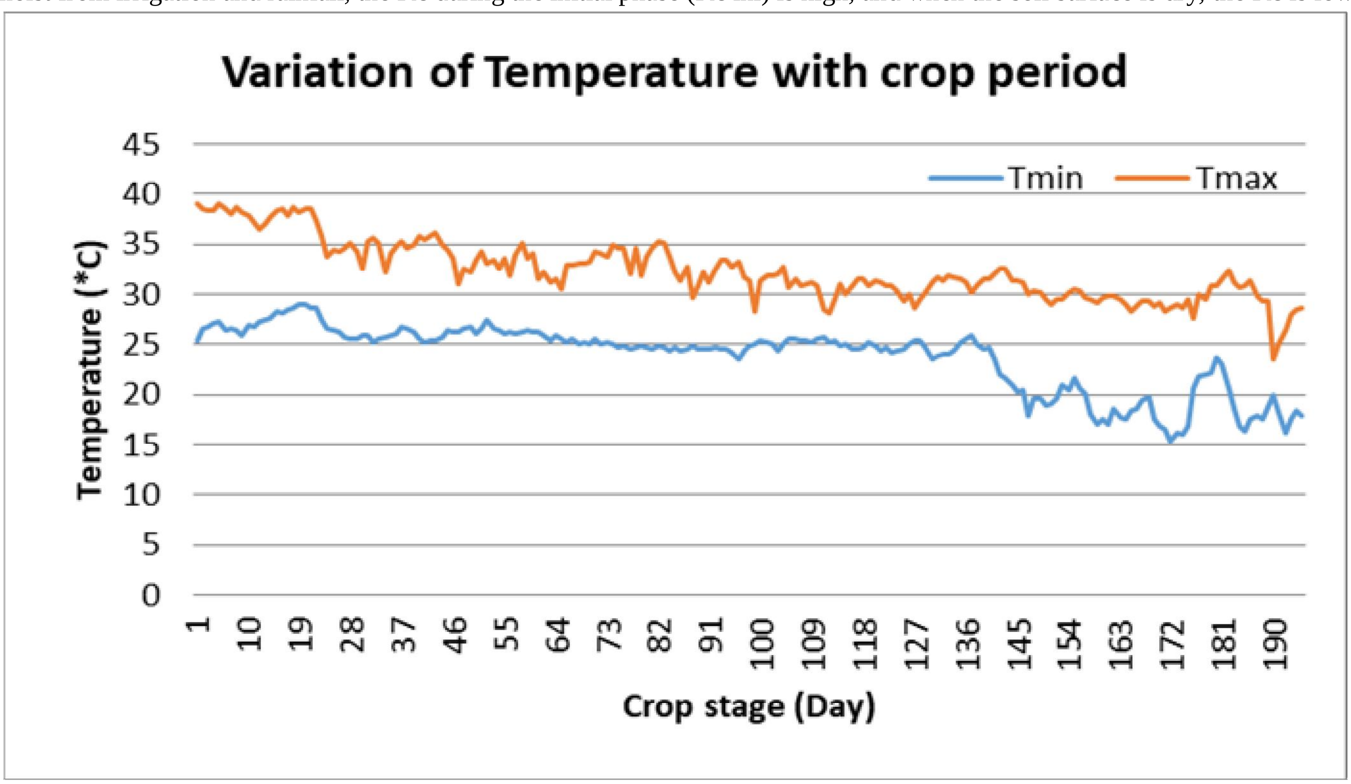

Figure 3 Variation of temperature with crop period

Figure 3 shows the minimum and maximum temperature variation during crop growth stage. From statistics of temperature data we have found that there is highest and lowest temperature is 38.99 ^{o}C and 15.31 ^{o}C during above crop stage for the region.

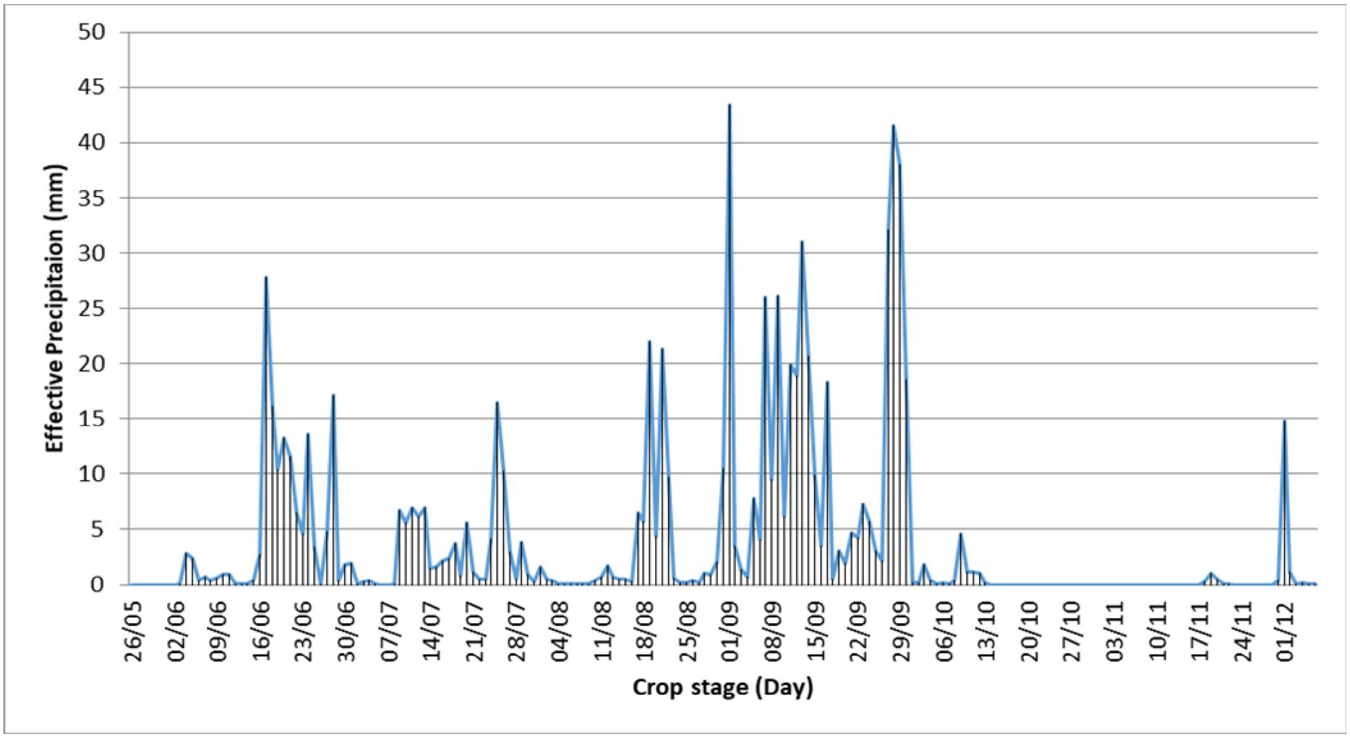

Figure 4 Effective Precipitation

Figure 4 shows the effective precipitation at Unchadi Section Command Area of Shetrunji Right Bank Canal. The effective precipitation during above crop stage is around 776.776 mm.

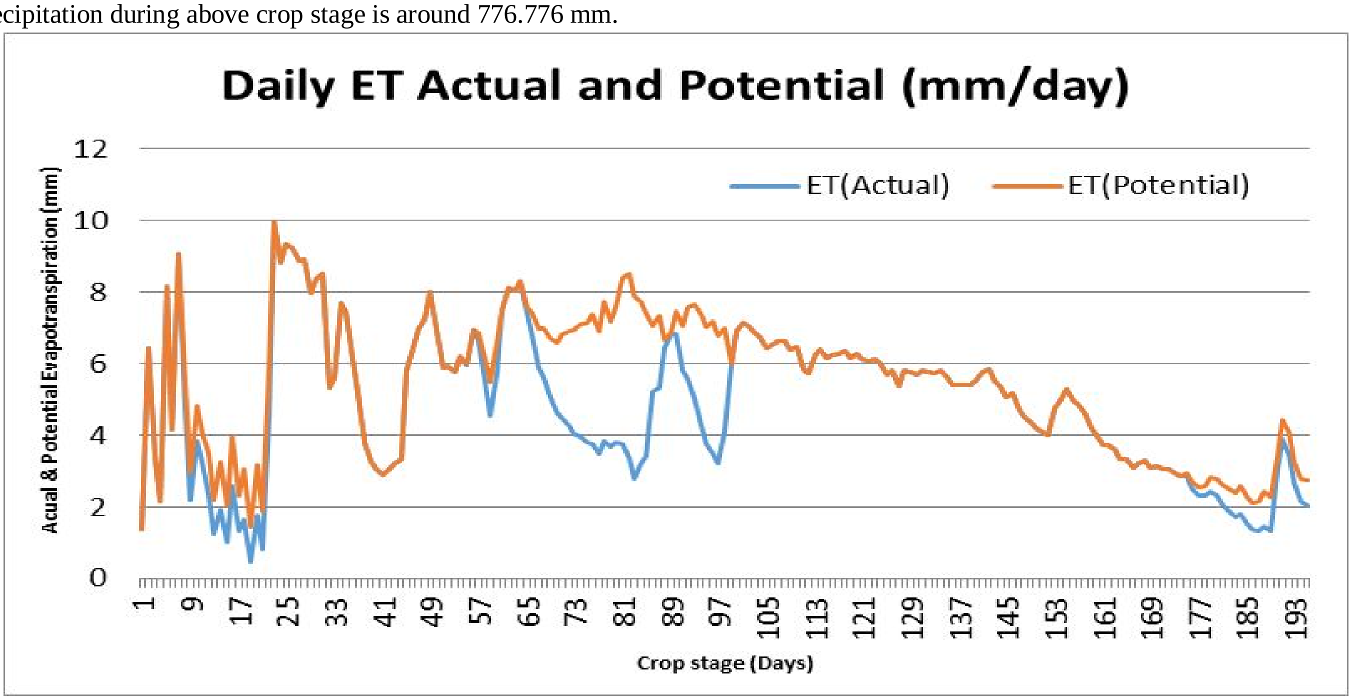

Figure 5 Daily Actual and Potential Evapotranspiration

Figure 5 shows the variation of actual evapotranspiration and potential evapotranspiration during various crop stages of cotton and from statistics we have found that there is highest crop evapotranspiration during June month (Summer) so irrigation is require during that period to compensate the water requirement of cotton crop. An average actual and potential evapotranspiration was found out around 4.83 mm/day and 5.45 mm/day respectively.

IV. CONCLUSIONS

1) Crop water requirement (ETc) for cotton crop growing in Unchadi Section command area of Shetrunji Right Bank Main Canal determined as 940.93 mm for dual crop coefficient approach during the growing season.
2) Crop actual evapotranspiration and potential evapotranspiration is found as 940.93 mm and 1062.03 mm respectively.
3) For real-time irrigation scheduling, calculations of the soil water balance, and research investigations where the effects of daily fluctuations in soil surface wetness and the ensuing consequences on daily ETc and the soil water profile are significant, the dual crop coefficient technique is best.
4) This result can be useful for agricultural planning and efficient irrigation management for cotton cultivation in Unchadi Section Command Area of Shetrunji Right Bank Main Canal.

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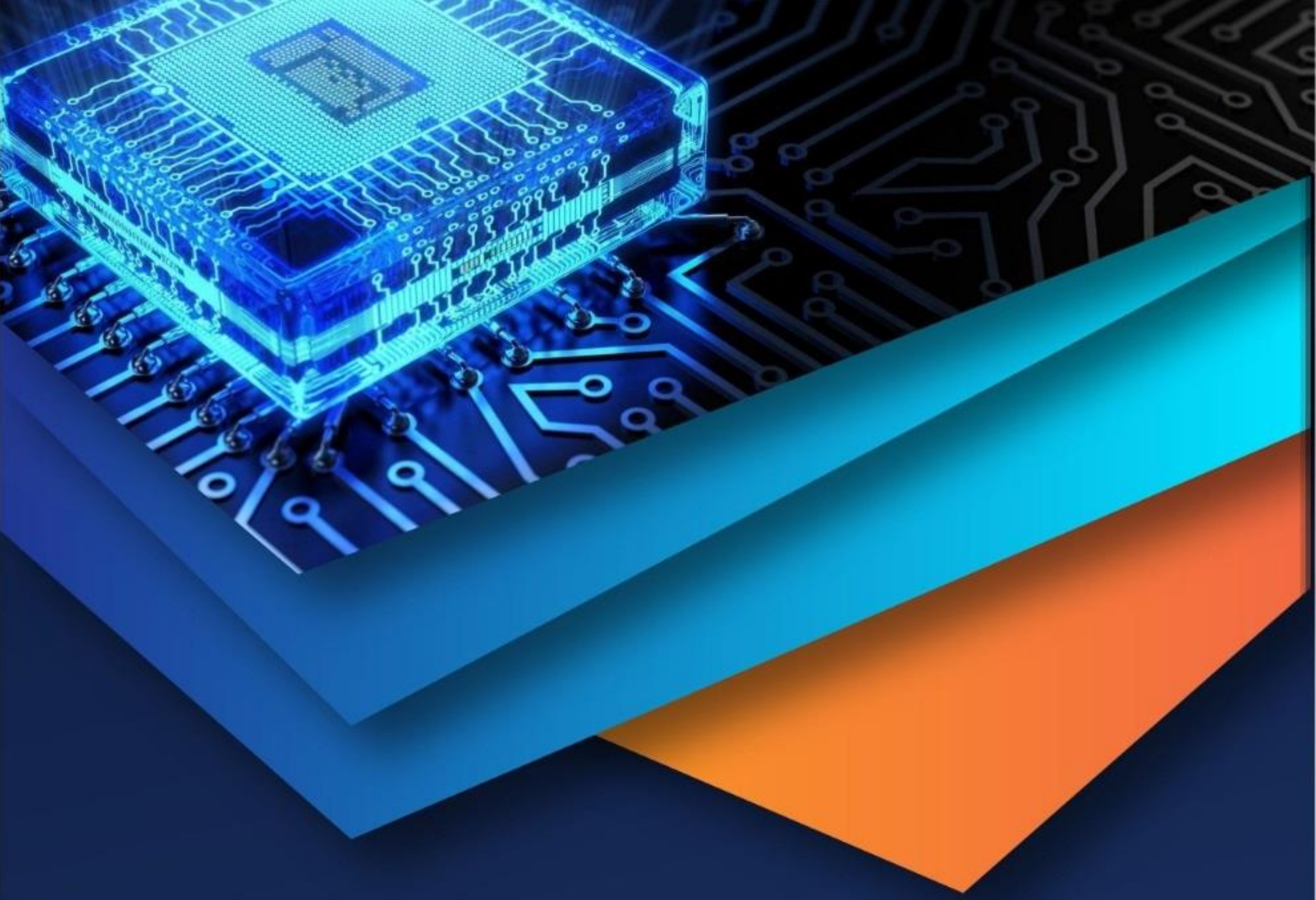

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