Estimation of Evapotranspiration using CROPWAT 8.0 Model

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Abstract—**Evapotranspiration is an important process in the hydrological cycle, and it is critical to accurately measure ET when assessing water requirements. This is particularly true in hot and barren areas. Evapotranspiration is a vital factor in the hydrological cycle and the only entity that connects the water and energy balances of the land surface.**

This study intends to estimate the evapotranspiration from Hesaraghatta Watershed using CropWat 8.0 Model. The study is located located between 77^0 20^0 E to 77^0 42^0 E longitude and 13^{0}10^0 to 13^{0}24^0 N latitude and covering an area of 601.105 km^2. SOI toposheets on scale 1:50000, SRTM-DEM data were used for delineation of watershed boundary. The major crops grown in the study area are paddy, wheat, Ragi and vegetables. The meteorological data such as Minimum temperature (°C), Maximum temperature (°C), Sunshine duration (hrs), Speed of wind (km/day), Relative humidity (%), are used for the estimation of actual evapotranspiration using CropWat 8.0 model. The max average actual evapotranspiration (ETa) and min average evapotranspiration was 4.81mm/day in May and 2.45 mm/day in December due to highest and lowest temperature respectively.

Keywords—Hesaraghatta watershed, crop coefficient, actual evapotranspiration, potential evapotranspiration, Penman-Monteith equation, CROPWAT.

I. INTRODUCTION

Evapotranspiration is a process by which water is lost by evaporation and transpiration. In real world conditions, the evaporation and transpiration can occur at the same time and it is very difficult to differentiate between the two. When the crop is small, soil evaporation is the primary source of evapotranspiration. however, once the crop has matured and fully covers the soil, transpiration becomes the primary source of water loss. Temperature, Relative humidity, movement of wind and movement of air, availability of Soil-moisture, different type of crops available are parameters affecting evapotranspiration. Evapotranspiration calculation is critical not only for the analysis of climate emergency and the assessment of water supplies, and include for crop water demand, drought forecast and tracking effective water resource output and use. ET, from an agricultural perspective, decides the volume of water to be supplied artificially . ET estimation is essential since it defines the size of irrigation channels and other irrigation. Evapotranspiration can be measured directly or indirectly and depend on weather data and soil water balance. These methods are broadly known as empirical (e.g., Thornthwaite method, Blaney and Criddle) or physical methods (e.g., Penman method ; Montheith, and FAO Penman Montheith method (Allen et al., 1998). Commonly used ET models are Surface Energy Balance Algorithm for Land (SEBAL) model, Surface Energy Balance System (SEBS) model, and CROPWAT model. The United Nations Food and Agriculture Organization (FAO) provided the CROPWAT model which uses Penman-Monteith equation to determine evapotranspiration in agriculture. Amatya et al (1995), estimated reference evapotranspiration in three sites in eastern North Carolina and compared with various methods and concluded that the Penman-Monteith method can be used as standard for comparison and good correlation was obtained between other methods and the Penman-Monteith method. Hashem et al., (2016) used CROPWAT model 8 for comparison and calculation of reference evapotranspiration and further developing of reference evapotranspiration model with the SIMULINK tool in MATLAB software and FAO-56 Penman-Monteith equation. The results were evaluated to estimate the models effectiveness by comparing daily estimates of evapotranspiration with devices such as Class A pan and evapotranspiration gauges in the US. The results showed a good match between the model's daily ETo and the ETo measured from devices. Ofentse Moseki et. al., (2017), studied the Jatropha cultivation in Botswana for crop's irrigation requirement. Weather data were collected from the station at the Department of Agricultural Research Station in Sebele, from 2014 to 2016. Data of crop characteristics were obtained from secondary data sources. CROPWAT model was chosen for estimating ETo, ETc, water requirement and yield response and concluded that water requirement was more in late developmental stage. The study emphasis on using CROPWAT model for estimating actual evapotranspiration.

II. STUDY AREA

Study area chosen for the present study is Hesaraghatta watershed, Bengaluru district Karnataka, India. Geographically lies between 77^0 20' to 77^{0}42'E longitude and 13^{0}10' to13^0 24'N. latitude, covering an area of 601.105km2 and is covered in four toposheet of numbers 57G/7, 57G/8, 57G/11, 57G/12 on 1: 50000 scale . The average length of watershed is 33.34 km and average width of watershed is 26.28 km. The highest and lowest relief of the watershed are 1457 m and 851 m respectively. Fig. 1 shows the location map of Hesaraghatta watershed. Fig.1 Location Map of Hesaraghatta watershed. The vegetation in the watershed is characterized by agricultural activity. The major crops grown during Kharif season are Ragi, pulses and oil seeds whereas paddy is grown in command areas of tank.

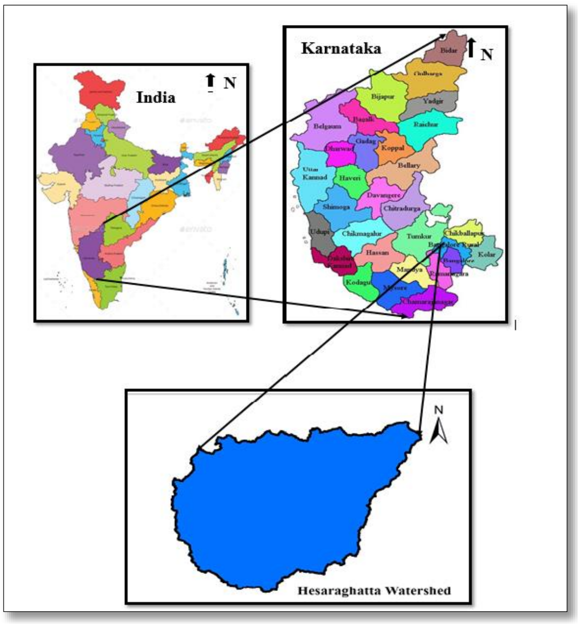

Fig.1 Location map of the study area

III. METHODOLOGY

SoI toposheets on 1:50000 scale of study area were georeferenced, rectified and watershed boundary of the study area was delineated using QGIS software. Watershed boundary was generated using SRTM-30m DEM data. Drainage map was extracted using SRTM 30m DEM data. Fig.2. shows the SRTM-30m DEM data of Hesaraghatta watershed.

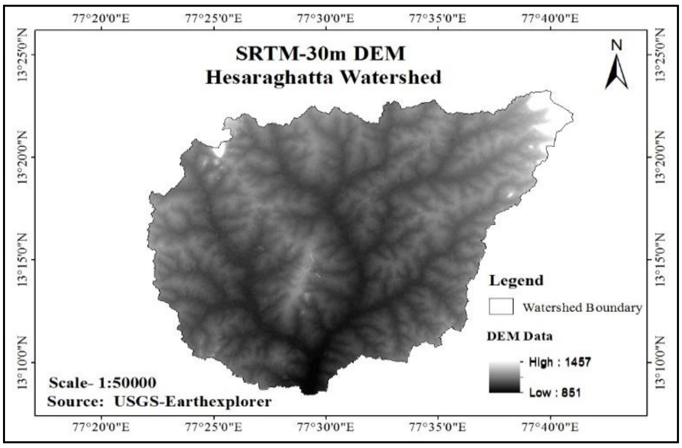

Fig.2. SRTM-30m DEM data of Hesaraghatta watershed

Evapotranspiration is an significant parameter in the hydrological cycle. In this study, evapotranspiration is estimated using the CROPWAT 8.0 model.

The meteorological data input data such as Minimum temperature (°C), Maximum temperature (°C), Sunshine duration (hrs), Speed of wind (km/day), Relative humidity (%), Latitude, Longitude and Altitude of the specified area are required for the computation of Evapotranspiration. Evapotranspiration (mm/day). The primary metrological database required for input data, has been obtained for 10 years period on daily basis from the year 2011 to 2020. The metrological database were obtained from GKVK (Gandhi Krishi Vignan Kendra), Bengaluru station. The Reference evapotranspiration was estimated using CROPWAT 8.0 model. CROPWAT 8.0 uses FAO 56 Penman Monteith method for estimation of evapotranspiration. Actual evapotranspitaion id estimated by multiplying reference evapotranspiration with crop coefficient (Kc). The Kc values are obtained for different crops growing in study area at different seasons of year. The Fig.3 shows the methodology for estimation of actual evapotranspiration.

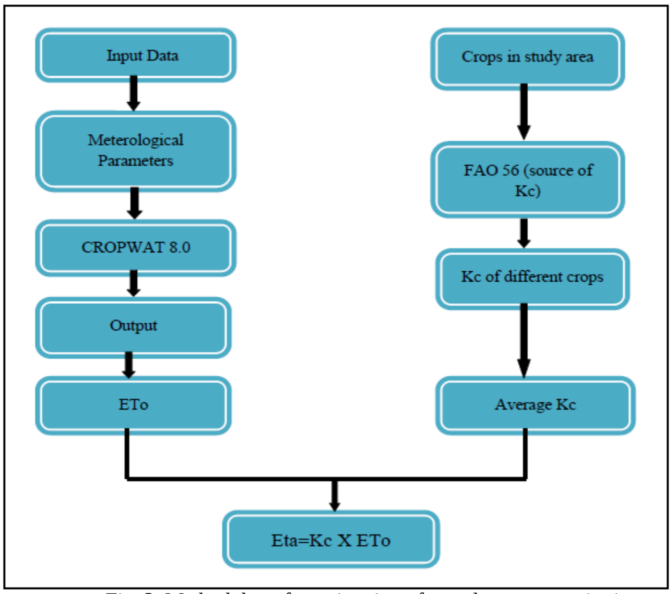

Fig. 3. Methodology for estimation of actual evapotranspiration.

A. *CROPWAT 8.0*

CROPWAT 8.0 is a decision support tool developed for the services of FAO in Water Resources Development and Management Service by Joss Swennenhuis. CROPWAT model is a well-developed program which is designed for the estimating water requirements of crop based on several input data such as: soil data, meteorological data and crop data. CROPWAT can also be used for determining the irrigation frequency and irrigation supply scheme for various crops. This software also facilitates to assess the irrigation practices and facilitates for the estimation of crop performance under different conditions primarily rainfed and irrigated conditions. CROPWAT 8.0 is completely a redesigned user interface for windows.

B. *REFERENCE EVAPOTRANSPIRATION*

Evapotranspiration is an significant parameters in the hydrological cycle, which has to be used in the study. Reference evapotranspiration can be calculated for the total study area using CROPWAT 8.0 software, which uses FAO 56 Penman Monteith method. The Penman–Monteith equation is used for computation of daily reference evapotranspiration. Penman-Monteith equation is mathematically expressed as shown in equation (1)

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

where,

ETo - reference evapotranspiration [mm /day]

Rn - net radiation at the crop surface [MJ /m^2/day]
G- soil heat flux density [MJ/ m^2/ day]
T - mean daily air temperature at 2 m height [°C]
U -wind speed at 2 m height [m/s]
es - saturation vapour pressure [kPa]
ea - actual vapour pressure [kPa]
(es – ea) - saturation vapour pressure deficit [kPa]
Δ- slope vapour pressure curve [kPa/ °C]
γ- psychrometric constant [kPa /°C]

C. ACTUAL EVAPOTRANSPIRATION:

Actual evapotranspiration is mathematically a product of reference evapotranspiration and crop coefficient, which is given in the equation below

$$ET_a = ET_O \times K_c \quad (2)$$

where,

$ET_a = Actual\ evapotranspiration$
$ET_O = Reference\ evapotranspiration$
$K_C = Crop\ Coeffcient$

The crop coefficient changes with the growing stages of the crop. The value of Kc for any crop is most likely to be less in planting stage and reaches a maximum at mid season. In the present study wheat crop is chosen for determination of evapotranspiration. The Kc values for different growth stages as per FAO 56 is shown in Table 1.

TABLE 1. CROP COEFFICIENT FOR DIFFERENT GROWING STAGES OF WHEAT CROP

Sl. no.	Crop	Growing stages of wheat crop		
		Initial	Mid season	Late season
1	wheat	0.3	1.15	0.25-0.4

IV. RESULTS AND DISCUSSION

The reference evapotranspiration was calculated using the CROPWAT 8.0 Model and actual evapotranspiration was calculated by multiplying reference evapotranspiration with the crop coefficient. The input data provided for CROPWAT model includes minimum temperature, maximum temperature, latitude, longitude, altitude, sunshine hours and wind velocity. The input data was collected and analysed for a decade starting from 2011 to 2020 in the Hesaraghatta region. The daily potential evapotranspiration was obtained and tabulated using the CROPWAT 8.0 model as shown in Table 2. Table 3 depicts the estimated daily actual evapotranspiration for the 2011 to 2020. Fig 4 and Fig 5 shows the annual variation of reference evapotranspiration and actual evapotranspiration respectively.

From the Table 2 it can be clearly depicted that maximum monthly average of potential evapotranspiration (ETo) estimated was 4.81 mm in April month of year 2016.The highest average annual potential evapotranspiration (ETo) value obtained is 3.54 mm in the year 2012 which may be due to high temperature.

From table 2 it is observed that the minimum monthly average ETo estimated is 2.45 mm in the month of December due to winter months and considerably low temperature. The lowest average annual ETo value is 3.33mm in the year 2013. Temperature is directly proportional to ETo, as the temperature increases the ETo value increases and as the temperature decreases the ETo value also decreases.
From table 2 the maximum monthly average ETo was in the month of April i.e., 4.81mm due to highest temperature in that month and the minimum monthly average ETo was in the month of December i.e., 2.45 mm due to minimum temperature.

V. CONCLUSIONS

Water requirements of crops varies with climate, soil type and crop variety. CROPWAT 8.0 model is the tool for irrigation planning and management because of considering many input parameters. Evapotranspiration provides the necessary information regarding water requirements for growing different crops in different seasons. The results show that the crop water requirement of different crops will consequently help improving the management of water resources and productivity. The CROPWAT 8.0 model gives sufficiently accurate result and reduce the calculation and also consumes less time.

TABLE 2. ESTIMATED REFERENCE EVAPOTRANSPIRATION (mm/day) FROM 2011 TO 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	3.14	3.55	4.15	4.12	4.2	3.65	3.12	2.91	3.45	3.13	2.75	2.76
2012	3.24	3.69	4.23	4.37	4.25	3.81	3.21	3.23	3.43	3.13	2.99	2.92
2013	3.27	3.68	4.04	4.49	3.97	2.99	2.64	3.1	3.09	3.15	2.76	2.80
2014	3.21	3.57	4.08	4.34	4.33	4.04	3.19	3.09	3.15	2.86	2.91	2.63
2015	3.07	3.89	4.2	4.25	3.95	3.44	3.68	3.56	3.42	3.36	2.29	2.82
2016	2.95	3.75	4.2	4.81	4.32	3.32	3.11	3.53	2.89	3.58	3.25	2.69
2017	3.02	3.92	4.29	4.52	4.2	3.44	3.38	3.11	3.32	3.2	2.72	2.66
2018	3.14	3.8	4.03	4.42	4.08	3.42	3.11	2.95	3.65	3.54	3.07	2.68
2019	3.11	3.89	4.38	4.46	4.22	3.91	3.36	3.11	2.88	2.96	2.92	2.45
2020	3.22	3.8	4.27	4.51	3.89	3.5	3.21	2.99	2.93	2.8	2.73	2.67

TABLE 3. ESTIMATED ACTUAL EVAPOTRANSPIRATION (mm/day) FROM 2011 TO 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	1.88	2.13	2.49	2.47	2.52	2.19	1.87	1.74	2.07	1.87	1.65	1.65
2012	1.94	2.21	2.53	2.62	2.55	2.28	1.92	1.93	2.05	1.87	1.79	1.75
2013	1.96	2.20	2.42	2.69	2.38	1.79	1.58	1.86	1.85	1.89	1.65	1.68
2014	1.92	2.14	2.44	2.61	2.59	2.42	1.91	1.85	1.89	1.71	1.74	1.57
2015	1.84	2.33	2.52	2.55	2.37	2.06	2.20	2.13	2.05	2.01	1.37	1.69
2016	1.77	2.25	2.52	2.88	2.59	1.99	1.86	2.11	1.73	2.14	1.95	1.61
2017	1.81	2.35	2.57	2.71	2.52	2.06	2.02	1.86	1.99	1.92	1.63	1.59
2018	1.88	2.28	2.41	2.65	2.44	2.05	1.86	1.77	2.19	2.12	1.84	1.60
2019	1.86	2.33	2.62	2.67	2.53	2.34	2.01	1.86	1.73	1.77	1.75	1.4
2020	1.93	2.28	2.56	2.70	2.33	2.1	1.92	1.79	1.75	1.68	1.63	1.60

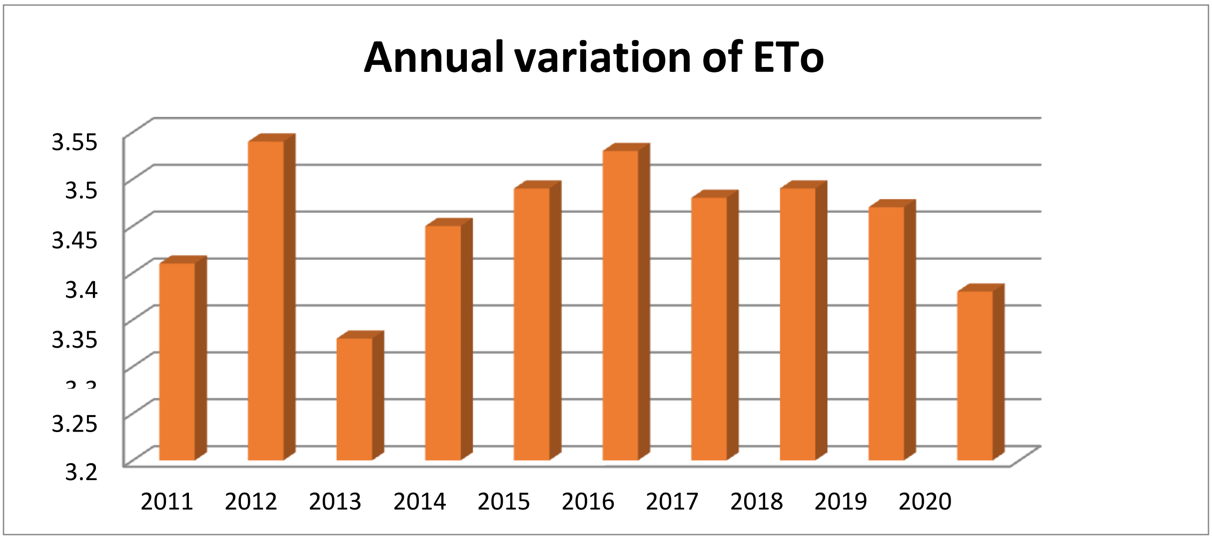

Fig.4 Annual variation of reference evapotranspiration.

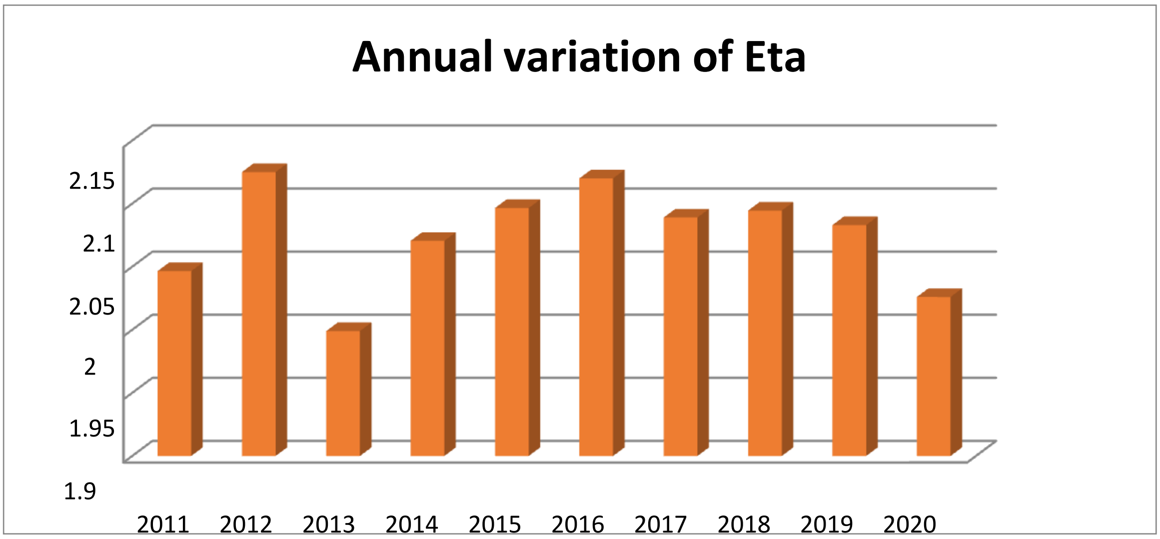

Fig.5 Annual variation of actual evapotranspiration.

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