Estimation of Crop Water Requirement for Paddy crop in Belavanur Village, Davangere District

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Abstract - *This project summarizes the essential definitions and methodologies for estimating Crop water requirements. The concept of reference of evapotranspiration is assumed relative to a crop characteristic. The hypothesis on which this approach is based are discussed relative to crop surface and aerodynamic resistance to heat and vapour fluxes. Actual evapotranspiration is a key process of hydrological cycle and a sole term that links land surface water balance and land surface energy balance. The study was conducted in Belavanur village (Davangere district) to determine actual crop evapotranspiration in the area. Long term daily meteorological data including rainfall, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours of Bangalore IMD station was used as input data in modified Penman method and CROPWAT 8.0 model. The potential evapotranspiration was converted into actual evapotranspiration by using the crop co-efficient. The major crop in Belavanur village area are Paddy. The value of k_c initial stage, k_c mid stage, k_c end stage for the selected crop was obtained from FAO-24. The actual evapotranspiration is estimated as daily, monthly and yearly. Thus, the experiment conclude that potential evapotranspiration and actual evapotranspiration is almost similar when compare to the CROPWAT 8.0 model and by manually using modified Penman method and also conclude that potential evapotranspiration and actual evapotranspiration increases as temperature increases and it decreases as the temperature decreases. Compare to manual method CROPWAT 8.0 model (software) gives accurate result and time consuming.*

Key words: Reference Evapotranspiration, Crop coefficient, Modified Penman method, CROPWAT 8.0, Crop water requirement.

1. INTRODUCTION

Crop water requirements (CWR) are defined as the depth of water needed to meet the water consumed through 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.

Defining crop evapotranspiration (ETc) as the rate of evapotranspiration [mm/day] of a given crop as influenced by its growth stages, environmental conditions and crop management to achieve the potential crop production, then the CWR is the sum of ETc for the entire crop growth period. When management or environmental conditions deviate from the optimal, then that rate of evapotranspiration has to be adjusted to the prevailing conditions and is called adjusted or actual crop evapotranspiration (ETc). Both CWR and ETc concepts apply to either irrigated or rainfed crops.

For irrigated crops, the concept of CWR has to be complemented by that of irrigation water requirement (IWR), which is the net depth of water that is required to be applied to a crop to fully satisfy its specific crop water requirement. The IWR is the fraction of CWR not satisfied by rainfall, soil water storage and groundwater contribution. When it is necessary to add a leaching fraction to assure appropriate leaching of salts in the soil profile, this depth of water is also included in IWR. In practice, IWR has to be converted into gross irrigation requirements to take into consideration the efficiency of the irrigation systems utilized.

1.1Evapotranspiration

Evapotranspiration is a major component of hydrological cycle. Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water crops, lawn, garden, and trees need for healthy growth and productivity. Its estimation is important for water resource management purposes and for understanding soil water balance at a place. In agricultural irrigation, estimates of ET are necessary for system design, irrigation scheduling, water transfers, planning, and other water issues. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes.

Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process.

1.2 Potential and Actual Evapotranspiration

When sufficient moisture is freely available to completely meet the needs of the vegetation fully covering an area, the resulting evapotranspiration is called Potential evapotranspiration (PET). The real evapotranspiration occurring in a specific situation in the field is called the actual evapotranspiration (AET). It has been further established that PET depends upon the climatological factors, whereas the AET largely affected by the characteristics of soil and vegetation. Scientists consider these two types of evapotranspiration for the practical purpose of water resource management. Around the world humans are involved in the production of a variety of plant crops. Many of these crops grow in environments that are naturally short of water. As a result, irrigation is used to supplement the crop's water needs. Managers of these crops can determine how much supplemental water is needed to achieve maximum productivity by estimating potential and actual evapotranspiration. Estimates of these values are then used in the following equation:

Crop water need = potential evapotranspiration - actual evapotranspiration

1.3 Factors Affecting Evapotranspiration

The factors affecting evapotranspiration are:
1. Weather factors
2. Crop factors
3. Environmental and management factors

Weather factors
The principal weather parameters affecting evapotranspiration are radiation, air temperature, humidity and wind speed. Several procedures have been developed to assess the evaporation rate from these parameters

Crop factors
The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics result in different ET levels in different types of crops under identical environmental conditions.

Environmental and management factors
Factors such as soil salinity, poor land fertility and limited application of fertilizers, the presence of hard or impenetrable soil horizons, the absence of control of diseases and pests and poor soil management may limit the crop development and reduce the evapotranspiration. Other factors to be considered when assessing ET are ground cover, plant density and the soil water content. Cultivation practices and the type of irrigation method can alter the microclimate, affect the crop characteristics or affect the wetting of the soil and crop surface.

1.4 Evapotranspiration Concepts

- Reference crop evapotranspiration (ETo)
- Crop evapotranspiration under standard conditions (ETc)
- Crop evapotranspiration under non-standard conditions (ETc adj)

Reference crop evapotranspiration (ET_0):
The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ETo. The reference surface is a hypothetical grass reference crop with specific characteristics. Dorenbos and Pruitt (1977) defined reference crop evapotranspiration as the “Evapotranspiration from an extensive surface of 8 to 15 cm (3 to 6inches) tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water”.

The only factors affecting ET_0 are climatic parameters. Consequently, ET_0 is a climatic parameter and can be computed from weather data. ET_0 expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors.

Crop evapotranspiration under standard conditions (ETc)
The crop evapotranspiration under standard conditions, denoted as ETc, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.

Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors in the Penman-Monteith approach. As there is still a considerable lack of information for different crops, the Penman-Monteith method is used for the estimation of the standard reference crop to determine its evapotranspiration rate, i.e., ET_0. Experimentally determined ratios of ETc/ETo, called crop coefficients (Kc), are used to relate ETc to ET_0 or ETc = Kc ET_0.

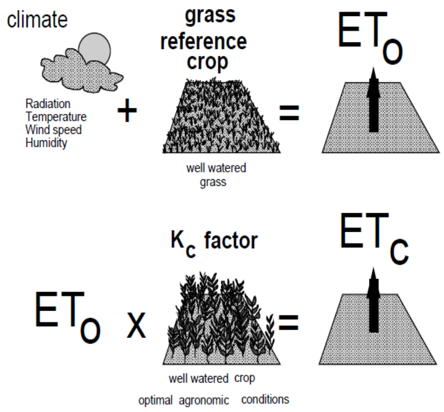


Fig-1.4 Reference crop evapotranspiration (ET_0), crop evapotranspiration under standard (ETc).

Introduction of CROPWAT 8.0:

CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements from existing or new climatic and crop data. Furthermore, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. For the calculation of crop water requirements (CWR), CROPWAT needs data on evapotranspiration (ET_o). CROPWAT allows the user to either enter measured ET_o using the Penman-Monteith formulae. CROPWAT fully supports the PEN and CLI files from the CLIMWAT database.

2. LITERATURE REVIEW

Appasaheb Maruti Ransing, S. R Bhakar, A.B. Joshi, the study was carried out to estimate a reference crop evapotranspiration (ETr) and actual evapotranspiration for Udaipur Region (latitude 24°52" N and longitude 74°21" E) at 522 Mean sea level in the north-western zone, Udaipur. Actual major crop evapotranspiration was determined by the crop coefficient (kc) approach where the effects of various weather conditions were incorporated into reference crop evapotranspiration and crop characteristics into crop coefficient. The average ETr values over the year (2012) by Penman-Monteith method were determined. The result was shown that the average annual values of water to be applied per crop for a season of green gram, maize and sea same crop for Udaipur district are: 471, 586.52 and 552.86 mm by Penman method.

Ayushi Trivedi, S.K. Pyasi and Galkate, R.V. 2018. Estimation of Evapotranspiration using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh, India. Evapotranspiration is a key process of water balance and also an important element of energy balance. The study was conducted in Shipra river basin to determine actual evapotranspiration in the area. Long term daily meteorological data including rainfall, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours of Indore IMD station was used as input data in CROPWAT Model 8.0.

H.V. Hajare, DR N.S. Raman, ER Jayant Dharkar, they worked on exact amount of water required by different crop in a given set of climatological condition of a region is great help in planning of irrigation scheme, irrigation scheduling. The main aim of study is to standardize the fortnightly crop water requirement by introducing the concept of development of iso lines for crop water requirement for the Nagpur region. These iso lines will give directly crop water requirement at any location in region as well as it is useful for well irrigation. This paper has presented iso lines for wheat and sunflower only.

Ratna Raju C, Yella Reddy K, Satyanarayana T.V. and Yogitha P, they investigated that crop water requirements of crops in Appapuram Channel Command under Krishna Western Delta were computed with CROPWAT using the meteorological parameters. The major cultivated crops are rice and maize. The CROPWAT a computer simulation model was used to estimate crop water requirement in Appapuram Channel Command under Krishna Western Delta in Andhra Pradesh for the years 2000 to 2010. The Penman – Monteith method was used for evapotranspiration calculation in the model. The canal operation plan was prepared for estimated gross water requirement.

Salam Hussein Ewaid, Salwan Ali abed, AND Nadhir Al-ansari, they investigated that the climate of Iraq is of the subtropical semi-dry type; however, the country was rich in water resources until a few decades ago. Climate change and the construction of many dams the Tigrisand Euphrates rivers in the neighboring countries have caused waters hortage sand poor water quality. Now, there is a need to decrease consumption, improve management of water resources, and determine the water requirements of the major crops. The Food and Agriculture Organization (FAO) CROPWAT 8.0 simulation software and the CLIMWAT 2.0 tool attached to it have been used in this research for Dhi-Qar Province in southern Iraq to find the crop water requirements (CWRs) and irrigation schedules for some major crops.

Siraj Beshir the objective of this review paper was to collect information on cabbage water requirement, irrigation scheduling and water use efficiency by triangulating different literatures on the topic. In growing crop, irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits. Thus, according reviewed literatures on average twice a week irrigation scheduling

and 2.57 - 5.81 mm/day of crop water requirement is more visible for cabbage production. In addition, climate models were reviewed in detail in this paper CROPWAT 8.0 and DSSAT reproduce acceptably the unimodal and bimodal shapes of the annual variation of rainfall and temperature respectively; there is a time shift between the observed and simulated peaks.

3. CROP EVAPOTRANSPIRATION

3.1 Modified Penman Method

For areas where the measured data on temperature, humidity, wind and sunshine duration or radiation are available an adaption of the penman method (1948) is suggested penman method provides the most satisfactory results compared to other methods.

The penman equation consisted of two terms:
1. The energy(radiation) term and
2. The aerodynamic (wind and humidity) term.

The relative importance of each term varies with climatic conditions. Under calm weather conditions the aerodynamic term is usually important than the energy term. It is under windy conditions and particularly in the more arid regions that the aerodynamic term becomes relatively more important. A slightly modified Penman equation is suggested to determine ETo, involving a revised wind function term. The method uses mean daily climatic data; since day and night time weather conditions considerably affect the level of evapotranspiration, an adjustment for this is included.

The form of equation used in this method is:

$$\mathbf{ETo = c\,[\underbrace{w.\,Rn}_{\text{Radiation term}} + \underbrace{(1-w).\,f(u).\,(ea-ed)}_{\text{aerodynamic term}}]}$$

where;
ETo = reference crop evapotranspiration in mm/day.
W=temperature related weighting factor.
Rn = net radiation in equivalent evaporation in mm/day.
F(u) = wind- related function.
(ea-ed) = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in m bar.
c = adjustment factor to compensate for the effect of day and night weather conditions.

3.2 Selection of crop co-efficient

To account for the effect of the crop characteristics on crop water requirements, crop coefficients, crop coefficients (k_c) are presented to relate ET_o to crop evapotranspiration (ET crop).

The k_c value relates to evapotranspiration of a disease – free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment. ET crop can be found by:

$$ET\ crop = k_c * ET_o$$

Where,
K_c = crop coefficient
ET_o = potential evapotranspiration

4. STUDY AREA

4.1 Description of the study area

The experimental site Chosen for the present study is the Paddy crop (Rice) at Belavanur village, Davangere taluk, Davangere district. The experimental site is located about 7 kms away from Davangere City on the Davangere Channagiri Road. It is situated at an altitude of 602.58m above mean sea level and at the intersection of 14.408 N latitude and 75.93 E longitude. The climate of the area is semi-arid characterized by three distinct seasons namely, summer becoming hot and dry from March to June, the warm rainy monsoon from July through October and mild to moderate cold winter from November to February. The annual precipitation is 644 mm distributed over 60 rainy days in year. The soil is reddish brown and Black soil. The soil is loam to sandy clay in texture.

4.2 Meteorological data:

Meteorological Data required for the estimation of potential evapotranspiration (PET) was taken from the records of Meteorological centre, India Meteorological Department, Palace Road, Banagalore-560001. Measurement of rainfall with a standard non-recording gauge and Class A pan evaporation were recorded once in a day, at 08.30 hours. Mean wind velocity at 2m height and bright sunshine hours during the past 24 hours were recorded daily at 07.20 hours. Maximum and minimum air temperature and estimated relative humidity from measured wet bulb depression were available at 07.20 hours and 14.20 hours every day. Daily mean temperature was calculated as the average of daily maximum and minimum temperatures. Relative humidity at 07.20 hours was considered to represent the daily maximum and those at 14.20 hours the daily minimum.

- Average minimum and maximum air temperature in ℃
- Average minimum and maximum relative humidity in %
- Incoming solar radiation in w/s
- Total precipitation in mm
- Average wind speed in m/s

4. Results and Discussion

Modified Penman Method

Table- 5.1 Year wise potential evapotranspiration (mm).

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PET (mm)	2309.5	2101.77	2329.95	2265.91	2377.87	2174.69	2140.73	2423.42	2313.92	2411.54	2376.34

Table- 5.2 Month wise potential evapotranspiration (mm).

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
JAN	230.04	171.65	179.3	191.03	203.51	202.03	184.92	201.36	181.46	213.52	205.16
FEB	235.72	197.59	203.18	262.43	229.36	198.61	221.78	218.64	197.39	202.18	213.37
MAR	248.54	254.21	265.23	277.59	267.55	224.66	237.3	272.2	223.73	233.18	240.75
APR	264.84	221.13	224.45	215.31	276.66	205.26	209.76	275.34	231.31	209.51	304.26
MAY	251.93	217.15	249.73	246.17	257.85	214.93	188.91	224.19	241.39	222.25	335.51
JUN	186.33	200.3	205.02	197.7	182.85	190.13	176.01	169.81	207.52	187.67	199.96
JUL	181.07	168.26	182.06	162.77	172.09	173.63	176.95	159.06	191.2	192.74	100.01
AUG	164.29	156.13	165.33	148.23	157.91	151.4	159.43	166.28	183.18	192.61	147.32
SEP	115.36	116.6	126.57	111.96	128.71	141.27	134.84	158.41	155.74	164.14	157.66
OCT	162.69	151.17	172.59	162.62	161.44	155.97	147.27	162.99	148.6	188.08	142.85
NOV	133.37	118	180.18	135.58	167.83	164.32	139.51	201.63	169.14	203.1	149.64
DEC	135.32	129.58	176.31	154.52	172.11	152.48	164.05	213.51	183.26	202.56	179.85

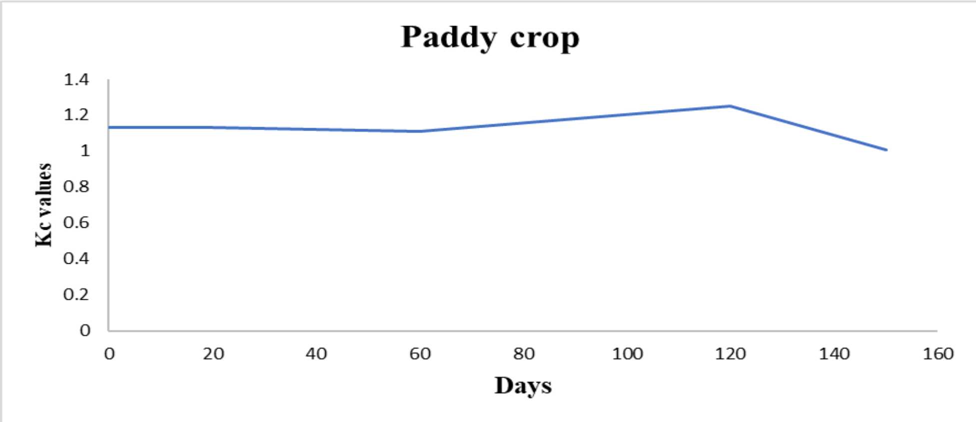


Chart -1 Crop coefficient of Paddy crop.

Table- 5.3 Year wise actual evapotranspiration (mm) of Paddy crop.

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AET (mm)	2376.31	2118.4	2366.64	2306.07	2444.46	2197.64	2184.98	2499.51	2337.23	2453.2	2419.48

Table-5.4 Monthly actual evapotranspiration (mm) of Paddy crop.

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
JAN	259.95	188.82	197.23	210.13	223.86	222.23	203.41	221.5	201.42	234.87	227.73
FEB	261.65	217.35	225.53	291.3	254.59	218.47	243.96	240.5	219.1	222.4	236.84
MAR	310.68	317.76	331.54	346.99	334.44	280.83	296.63	340.25	279.66	291.48	300.94
APR	331.05	276.41	280.56	269.14	345.83	256.58	262.2	344.18	291.45	261.89	380.33
MAY	254.45	219.32	252.23	251.09	260.43	214.93	190.8	228.67	243.8	222.25	342.22
JUN	0	0	0	0	0	0	0	0	0	0	0
JUL	208.23	191.82	209.37	187.19	197.9	199.67	203.49	181.33	219.88	221.65	115.01
AUG	185.65	176.43	188.48	168.98	180.02	171.08	180.16	187.9	206.99	221.5	167.94
SEP	122.28	124.76	136.7	119.8	136.43	151.16	142.93	169.5	165.08	173.99	168.7
OCT	172.45	158.73	182.95	170.75	169.51	163.77	154.63	171.14	156.03	197.48	149.99
NOV	141.37	123.9	192.79	142.36	176.22	172.54	149.28	211.71	177.6	213.26	157.12
DEC	128.55	123.1	169.26	148.34	165.23	146.38	157.49	202.83	175.93	192.43	172.66

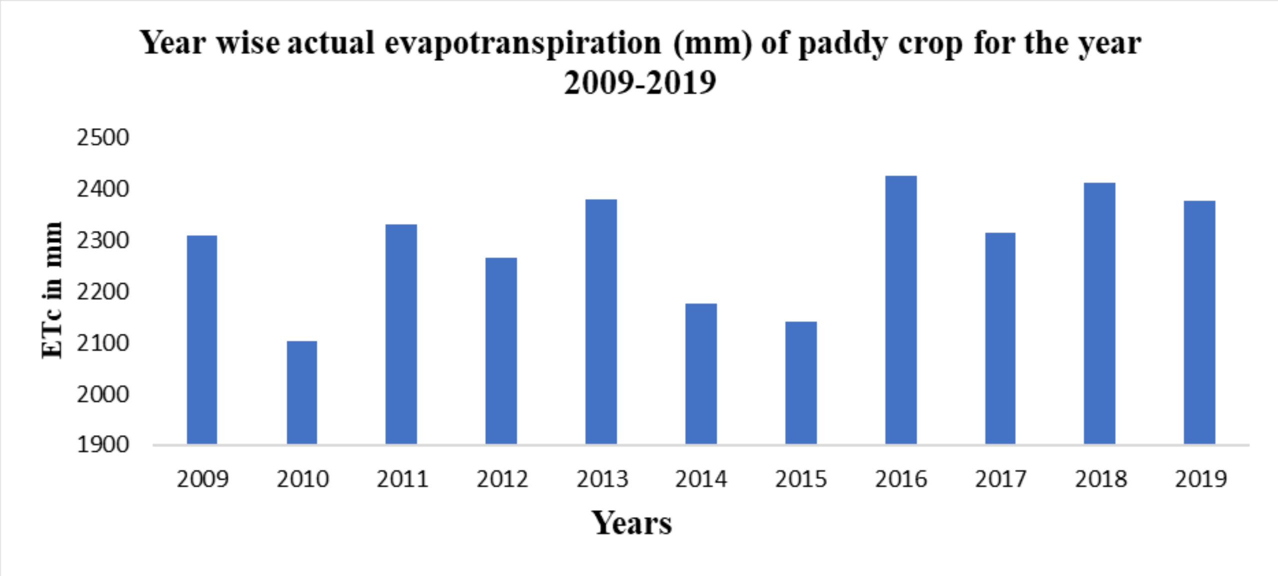


Chart -2 Year wise actual evapotranspiration (mm) for the year 2009 – 2019.

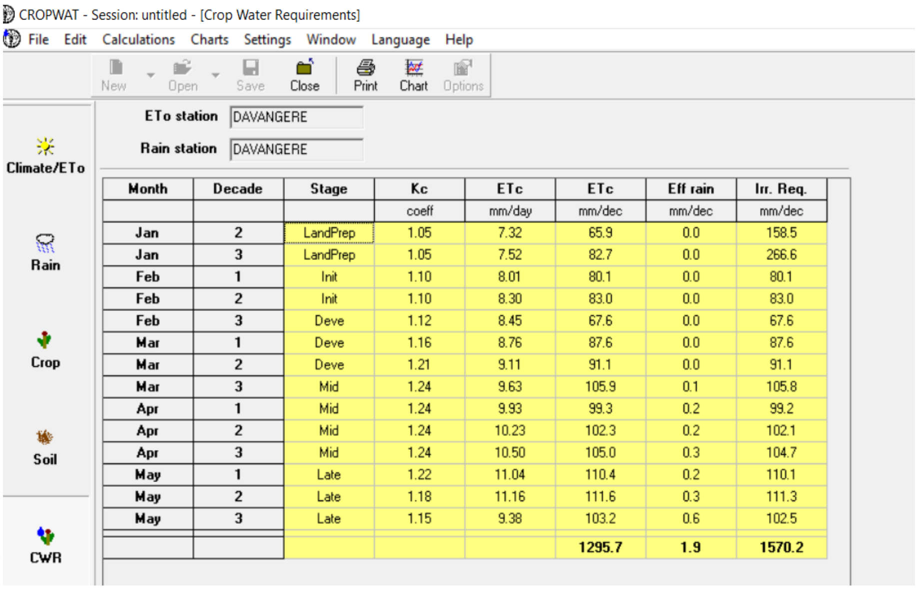
CROPWAT 8.0 Model

The data which were entered into the CROPWAT software included the type of crop, data of planting and harvesting, soil type (Blacky soil). Once all the data were entered into the software, it calculated the climate parameters, ETo, effective rainfall, and total crop water requirement for the studied crop.

Other outputs of the CROPWAT program are presented in tables.

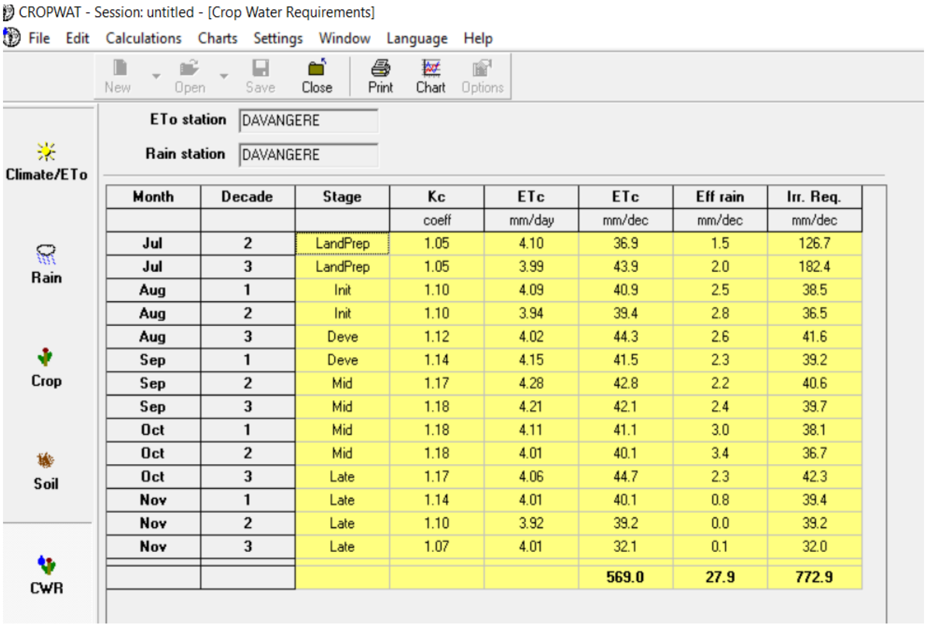
Actual evapotranspiration of Paddy crop for the year 2019.

Season 1



Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	2	LandPrep	1.05	7.32	65.9	0.0	158.5
Jan	3	LandPrep	1.05	7.52	82.7	0.0	266.6
Feb	1	Init	1.10	8.01	80.1	0.0	80.1
Feb	2	Init	1.10	8.30	83.0	0.0	83.0
Feb	3	Deve	1.12	8.45	67.6	0.0	67.6
Mar	1	Deve	1.16	8.76	87.6	0.0	87.6
Mar	2	Deve	1.21	9.11	91.1	0.0	91.1
Mar	3	Mid	1.24	9.63	105.9	0.1	105.8
Apr	1	Mid	1.24	9.93	99.3	0.2	99.2
Apr	2	Mid	1.24	10.23	102.3	0.2	102.1
Apr	3	Mid	1.24	10.50	105.0	0.3	104.7
May	1	Late	1.22	11.04	110.4	0.2	110.1
May	2	Late	1.18	11.16	111.6	0.3	111.3
May	3	Late	1.15	9.38	103.2	0.6	102.5
					1295.7	**1.9**	**1570.2**

Season 2



Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	2	LandPrep	1.05	4.10	36.9	1.5	126.7
Jul	3	LandPrep	1.05	3.99	43.9	2.0	182.4
Aug	1	Init	1.10	4.09	40.9	2.5	38.5
Aug	2	Init	1.10	3.94	39.4	2.8	36.5
Aug	3	Deve	1.12	4.02	44.3	2.6	41.6
Sep	1	Deve	1.14	4.15	41.5	2.3	39.2
Sep	2	Mid	1.17	4.28	42.8	2.2	40.6
Sep	3	Mid	1.18	4.21	42.1	2.4	39.7
Oct	1	Mid	1.18	4.11	41.1	3.0	38.1
Oct	2	Mid	1.18	4.01	40.1	3.4	36.7
Oct	3	Late	1.17	4.06	44.7	2.3	42.3
Nov	1	Late	1.14	4.01	40.1	0.8	39.4
Nov	2	Late	1.10	3.92	39.2	0.0	39.2
Nov	3	Late	1.07	4.01	32.1	0.1	32.0
					569.0	27.9	772.9

Calculated actual evapotranspiration for the year 2019, the daily average value in modified Penman method is 6.35mm/day and in CROPWAT 8.0 is 6.65mm/day.

CONCLUSIONS

Water requirements of Paddy crop (Rice) varies with climate, soil type and crop variety. In present practice to find out crop water requirement by modified Penman method, the data collection as well as calculation of CWR is a tedious work which requires man power as well as consumes time. Using the CROPWAT 8.0 model yielded on interesting result. It can readily be seen that crop water requirement were specific to the local study area owing to the seasonal and ecological features of the provinces.

The study results enhance our understanding of the water requirements of Paddy crop in Belavanur (village), The results show that the crop water requirement of paddy crop which will consequently help improve the management of water resources and productivity. The use of scientific tools like CROPWAT can assess the CWR with a high degree of accuracy and suggest the crop pattern.

The result of this study shows that the CWR of Paddy crop by using modified Penman method is more tedious and time consuming. As compared to the modified Penman method to the CROPWAT 8.0. The CROPWAT 8.0 model gives accurate result and reduce the calculation and also less time consuming.

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