IRRIGATION SCHEDULING USING CROPWAT

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ABSTRACT

Water is becoming a scarce resource as a result of the growing demand in various purposes such as hydropower, irrigation, and water supply etc. With growing population the demand of water for various purposes is ever increasing. On the other hand, the availability of water of water resources is limited in space and time. A systematic and scientific planning for its optimal utilization is high imperative. Use of modern techniques in irrigation will go a long way in economizing consumption and saving of water which will bring greater areas under command and will ultimately result in more agricultural yield. Water requirements and irrigation scheduling of major crops, namely, Sugarcane, Rice, Tobacco, etc. are determined using the CROPWAT model.

Key words*:-Cropwat,Irrigation scheduling, Cropwater Requirement,Evapotranspiration,Iffective Rainfall*

I. INTRODUCTION

IRRIGATION SCHEDULING

Irrigation scheduling involves deciding when and how much water to apply to a field. Good scheduling will apply water at the right time and in the right quantity in order to optimize production and minimize adverse environmental impacts. Bad scheduling will mean that either not enough water is applied or it is not applied at the right time, resulting in under-watering, or too much is applied or it is applied too soon resulting in over-watering. Under or overwatering can lead to reduced yields, lower quality and inefficient use of nutrients.

The efficiency of water in agricultural production is generally low. Only 40 to 60% of the water is effectively used by the crop, the rest of the water is lost in the system or in the farm either through evaporation runoff, or by percolation into the groundwater. Irrigation scheduling, if properly managed can offer a good solution to improve water efficiency in the farm.

Irrigation scheduling makes sure that water is consistently available to the plant and that it is applied according to crop requirements. To carried out irrigation scheduling using CROPWAT considering method of irrigation timing, irrigation at 100% critical depletion, irrigation at fixed interval per stage and method of irrigation application, Refill soil moisture content to 100% to field capacity.

Advantages of Irrigation Scheduling

- Enable farmers to schedule watering to minimize crop water stress and maximize yields
- Reduce farmer's costs of water and labour through less irrigation, thereby making maximum use of soil moisture storage.
- Lower fertilize costs by holding surface runoff and deep percolation (leaching) to a minimum.
- Increasing net returns by increasing crop yields and crop quality.
- Minimize water-logging problems by reducing the drainage requirements.

OBJECTIVES OF THE STUDY

To determine Crop water Requirements of wheat, rice and sorghum through CROPWAT of Waghodia region of Vadodara.

To determine Irrigation Scheduling of above crops through CROPWAT.

II. STUDY AREA

The entire Gujarat is divided in to various Agro climatic zones and Vadodara district is covered in Agro climatic zones-3. The area selected for the present study is the vadodara region and its command area located in Middle Gujarat.

A. METEOROGICAL DATA

Long-term meteorogical data are collected from State Water Data Center, Gandhinagar for Vadodara District of middle Gujarat.

- Maximum Temperature & Minimum Temperature (Celsius)
- Mean Relative Humidity (%)
- Wind Speed (kmph)
- Sunshine Hours (Hrs)

Reference Crop Evapotranspiration (ETo) - (mm/day) are calculated by Penman Method. Table 1 Shows average Metrological data for the Waghodia region on daily data.

Table 1 Meteorogical Data of Waghodia Station (Vadodara)

Month	Min Temp	Max Temp	Humidity	Wind speed	Sunshine	RF
	C	C	%	Km/day	hours	
January	13.5	29.5	55	1.06	8.76	0
February	12	28	53	0.52	9.02	0
March	17	32	51	1.23	8.63	0
April	21	37.5	53	2.25	9.52	0
May	22.5	40	50	4.79	10.6	0
June	22	33.5	64	3.79	6.64	82
July	23	31.5	87	2.38	2.45	320.5
August	23.5	30.75	89	2.14	2.76	240.5
September	24	30.3	86	0.73	4.21	264
October	22	32.35	68	0.35	8.26	0
November	17	28	64	0.4	7.55	0
December	12.5	26.5	65	0.31	6.75	0

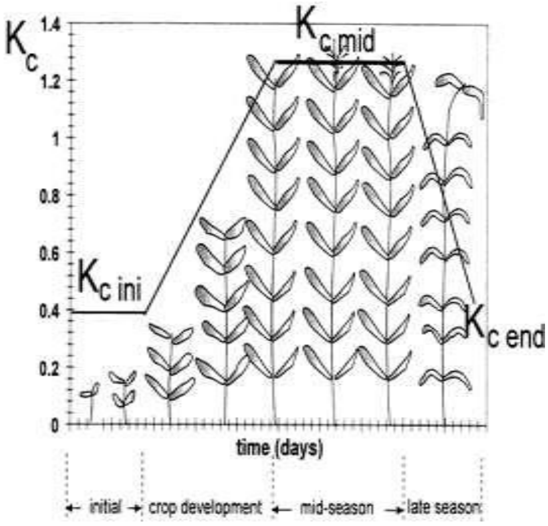

Fig 1 Gen1eralized Crop Coefficient Curve for the Single Crop Coefficient Approach

The generalized crop coefficient curve is shown in fig 1 Shortly after the planting of annuals or shortly after the initiation of new leaves for perennials, the value for Kc is small, often less than 0.4. The Kc begins to increase from the initial Kc value, Kc in, at the beginning of rapid plant development and reaches a maximum value, Kc mid, at the time of maximum or near maximum plant development. During the late season period, as leaves begins to age and senesce due to natural or cultural practices, the Kc begins to decrease unit it reaches a lower value at the end of the growing period equal to Kc end.

FAO Irrigation and Drainage Paper no. 24 provides general lengths for the four distinct growth stages and total growing period for various types of climates and locations. This information is summarized in Table 2

Table 2 Crop Growth Stages

Crop	Init. (lini)	Dev.(Ldec)	Mid. (lmid)	Late (Llate)	Total
Wheat	15	25	50	30	120
Rice	30	20	30	50	130
Sorghum	20	35	40	30	125

B. ROOTING DEPTH AND DEPLETION FRACTION

Table 3shows that range of the maximum effective rooting depth for various crops. The fraction p is a function of the evaporation power of the atmosphere and p values listed in Table 3.4 also.

Table 3 Ranges of Maximum Effective Rooting Depth (Zr), And Soil Water Depletion Fraction For No Stress (P)

Crop	Maximum Root Depth (m)	Depletion Fraction (P)
Wheat	1.5-1.8	0.55
Rice	0.5-0.6	0.50
Sorghum	0.5-0.6	0.55

Table 4 lists typical values for Kc ini, Kc mid, Kc end for various agricultural crops. The coefficients presented are organized by group the (i.e., cereals, root and tubers, oil crops, fibre crops etc) to assist in locating the crop in the table. There is usually close similarly in the coefficients among the members of the same crop group, as the plant height, leaf area, ground coverage and water management are normally similar. Fig. 2 shows Kc curve and crop stages Fig 3 shows general soil data.

Table 4 Single crop coefficients, Kc, and maximum plant heights

Crop	Kc ini.	Kc mid.	Kc end.	Crop height
Wheat	0.7	1.15	0.25	1.0
Rice	0.50	1.05	0.70	1.0
Sorghum	0.30	1..0	0.55	1.2

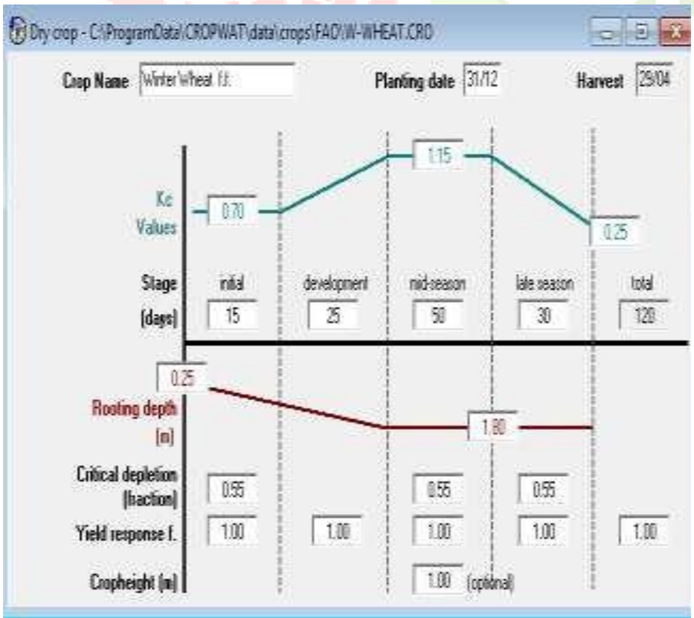

Fig. 2 Kc curve and Crop Growth stages

C. SOIL DATA

Information from the soil surveys carried out for the Waghodia area and general soil data.

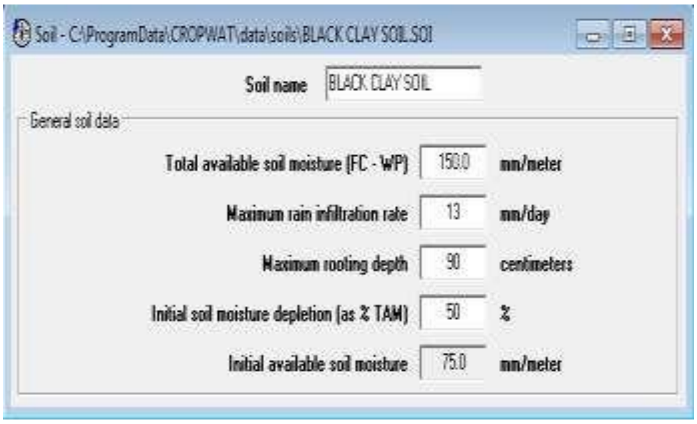

Fig 3 Soil Data

III. METHODOLOGY

A. CROPWAT

The document shows in a practical way the use of CROPWAT 8.0 design and management of irrigation schemes, taking the user , with the help of an actual dada set, through the different steps required to calculate evapotranspiration, crop water requirements, scheme water supply and irrigation scheduling. To learn about hoe the software works and the main calculation procedure, user are invited to read the context specific help available in the software.

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It 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.

CROPWAT is a computer program that uses the FAO Penman-Monteith method to calculate reference evapotranspiration (ETo), crop water requirements (ETC) and irrigation scheduling (FAO 1992). The program allows for the development of irrigation schedules under various management and water supply conditions and to evaluate rain-fed production, drought effects and efficiency of irrigation practices (FAO 2002). CROPWAT is helpful to agro scientists, agro researchers and water resources engineers as a practical tool to carryout standard calculations for evapotranspiration and management of if irrigation schemes. Plants use water for cooling purposes and the driving force 'of this process is prevailing weather conditions. Under the same climate and atmosphere, different crops have different water use requirements.

The program uses the same Penman Monteith methodology as used in CROPWAT versions 5.7 and 7.0 and uses the same data such as the CLIMWAT climate and rainfall files. The program uses a flexible menu system and file handling, and extensive use of graphics. Graphs of the input data (climate, cropping pattern) and results (crop water requirements, soil moisture deficit) can be drawn and printed with ease. Complex cropping patterns can designed with several crops with staggered planting dates.

This manual summarizes the functionalities of crop growth model under water deficit, as it is used in the MPMAS model. It strongly builds on the FAO CROPWAT model and its database CLIMWAT. These databases give robust estimates for crop yield responses to water deficit, with decent accuracy all over the world. For an MPMAS application, it is important to have full coverage of crop coefficients for economically all relevant crops, which should behave consistent and coherent. We acknowledge that more precise models for singular applications might exist.

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CROPWAT for window uses the same equations as in CROPWAT 7.0, but there are some difference between the menu system and the type of calculation permitted. Some of the interpolation method used are slightly different to those used in CROPWAT 7.0 and so calculation can occasionally differ by up to 2%. You will get bigger differences if you change the interpolation method from the defaults.

Following features are included in CROPWAT

Monthly, decade and daily input of climate data.

Possibility to estimate climate data in the absence of measured value.

Decade and daily calculation of crop water requirements based on update calculation algorithms including adjustment of crop-coefficient value.

Calculation for dry crops and for paddy and upland rice

Daily soil water balance output tables.

Easy saving and retrieval of session and of user defined irrigation scheduling.

Graphical presentation of input data and calculation results.

Easy import/export of data and graphics through clipboard or ASCII text file.

Extensive printing routines.

Context-sensitive help system.

Data needed for calculation:

CROPWAT uses daily data to estimate evapotranspiration. The following below lists data requirements for Crop water and Scheduling calculation.

For Crop Water Requirements (CWR)

Reference Crop Evapotranspiration (ETo) values calculated from:

Either your own measured values entered directly from the keyboard using input data, ETo.

Estimate of ETo calculated using the Penman-Monteith equation. ETo is automatically calculated ehen you enter monthly climate data (temperature, humidity, wind speed, sunshine). The data can be input from the keyboard using input data, climate, Enter/Modify or from a data file using input data , climate, retrieve.

Daily Rainfall Data:

Rainfall data is not absolutely necessary, but it should be used if rain falls in the growing season. Use input data, Rainfall to do this.

For Irrigation Scheduling you will need the data listed above and:

Soil type information

Soil data is entered using input data, soil. A seet of typical soil type are provided in C:\CROPWATW\SOILS.

B. REFERENCE CROP EVAPOTRANSPIRATION (Eto)

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. In Fig. 4 the partitioning of evapotranspiration into evaporation and transpiration is plotted in correspondence to leaf area per unit surface of soil below it. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration.

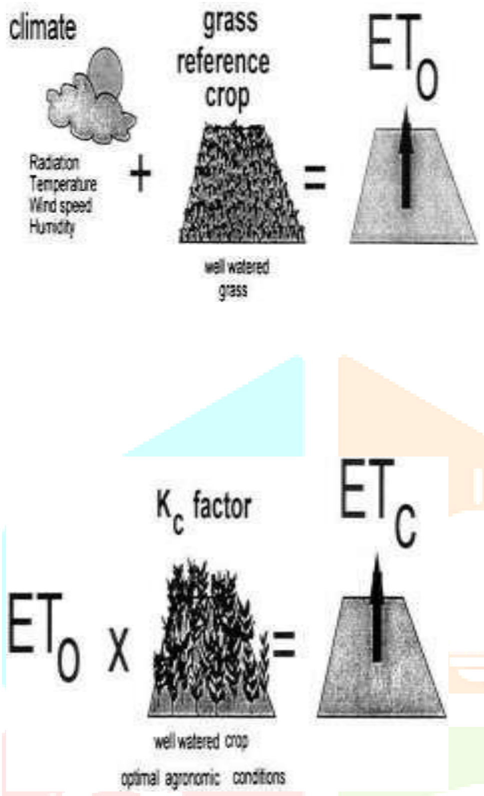


Fig. 4 Factor approach in CROPWAT (all graphs from Smith 1992). Note the difference in notation, as we use ET0 pot _ ET0 and ETC pot _ ETC).

Evapotranspiration concepts Distinctions are made between reference surface evapotranspiration (ET0 pot), crop evapotranspiration under standard conditions (ETC pot). Allen et al. 1998 also distinguish (adjusted) crop evapotranspiration under non-standard conditions (ETC pot,adj).

ETo pot is a climatic parameter expressing the evaporation power of the atmosphere, in reference to a standard surface. ETC pot refers to the (potential) evapotranspiration from excellently managed, large, well-watered fields that achieve full production under the given climatic conditions. Potential evapotranspiration can be interpreted as the total energy available to transpire and evaporate water, from sun, wind and vapor pressure of the air.

(Arnold) Within the coupled multi-agent application, potential evapotranspiration is distinguished from real evapotranspiration (ETreal), the amount of water that is actually lost from the ground into the air. ETreal is subject to the management choice of farmers, actual water availability for irrigation, and of course the potential evapotranspiration, and it also takes into account.

C. PENMAN-MONTEITH METHOD

In 1948, Penman combined the energy balance with the mass transfer method and derived an equation to compute the evaporation from an open water surface from standard climatological records of sunshine, temperature, humidity and wind speed. This so-called combination method was further developed by many researchers and extended to cropped surfaces by introducing resistance factors. One can interpret the equation as the maximum water which could be evapotranspired due to the solar and wind energy within the system, at given air and surface characteristics.

The resistance nomenclature distinguishes between aerodynamic resistance and surface resistance factors. The surface resistance parameters are often combined into one parameter, the 'bulk' surface resistance parameter which operates in series with the aerodynamic resistance. The surface resistance, rs, describes the resistance of vapor flow through stomata openings, total leaf area and soil surface. The aerodynamic resistance, ra, describes the resistance from the vegetation upward and involves friction from air flowing over vegetative surfaces. Although the exchange process in a vegetation layer is too complex to be fully described by the two resistance factors, good correlations can be obtained between measured and calculated evapotranspiration rates, especially for a uniform grass reference surface.

The Penman-Monteith form of the combination equation is

$$ETo = \frac{(\;)-(\;)}{(\qquad)}$$

Where
ETo= reference evapotranspiration
Rn = net radiation at the crop surface
G = soil heat flux density
T = mean daily air temperature at 2m height
es = saturation vapour pressure (kPa)
ea = actual vapour pressure (kPa)
es-ea = saturation vapour pressure deficit (kPa)
Δ = slop vapour pressure curve
Γ = osychromatic constant.

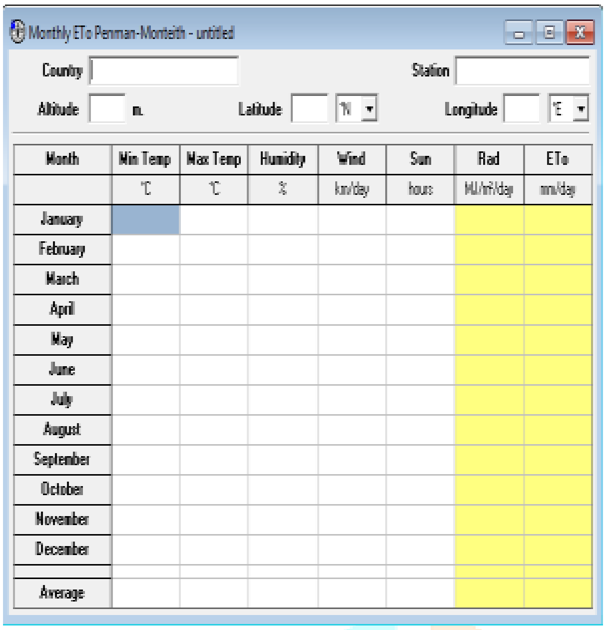


Fig 5 Daily ETo by penman-monteith

CROP COEFFICIENT (Kc) The concept of *Kc* was introduced by Jensen (1968) and further developed by the other researchers (Doorenbos and Pruitt, 1975, 1977; Burman et al., 1980a, Burman et al., 1980b; Allen et al., 1998). The crop coefficient is the ratio of the actual crop evapotranspiration (*ETc*) to reference crop evapotranspiration (*ETo*) and it integrates the effects of characteristics that distinguish field crops from grass, like ground cover, canopy properties and aerodynamic resistance. The estimation of *ETc* relies on the so-called two-step approach, where *ETo* is determined and *ETc* is calculated as the product of *ETo* and the *Kc* for the same day. Reference evapotranspiration is a measure of evaporative demand, while the crop coefficient accounts for crop characteristics and management practices (e.g., frequency of soil wetness). It is specific for each vegetative surface and it evolves in function of the development stage of the crop considered. Evapotranspiration varies in the course of the season because morphological and eco-physiological characteristics of the crop do change over time.

The FAO and WMO (World Meteorological Organization) experts have summarised such evolution in the "crop coefficient curve" to identify the *Kc* value corresponding to the different crop development and growth stages (initial, middle and late, hence it has *Kc in*, *Kc mid*, *Kc end*) (Tarantino and Spano, 2001). Values of *Kc* for most agricultural crops increase from a minimum value at planting until maximum *Kc* is reached at about full canopy cover. The *Kc* tends to decline at a point after a full cover is reached in the crop season. The declination extent primarily depends on the particular crop growth characteristics (Jensen et al., 1990) and the irrigation management during the late season (Allen et al., 1998). A *Kc* curve is the seasonal distribution of *Kc*, often expressed as a smooth continuous function.

For irrigation scheduling purposes, daily values of crop *ETc* can be estimated from crop coefficient curves, which reflect the changing rates of crop-water use over the growing season, if the values of daily *ETo* are available. FAO paper 56 (Allen et al., 1998) presents a procedure to calculate *ETc* using three *Kc* values that are appropriate for four general growth stages (in days) for a large number of crops. In the single crop coefficient approach, the effect of crop transpiration and soil evaporation are combined into a single *Kc* coefficient.

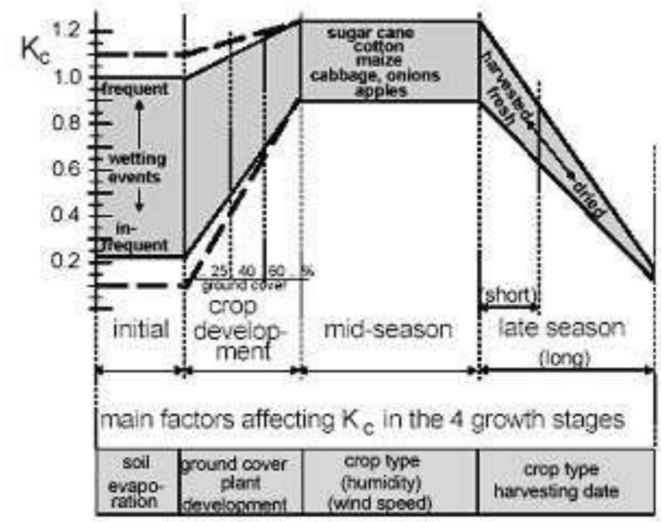


Fig. 6 Typical Range Expected in kc for the four growth stages

The fig.6 illustrates Kc variation for different crops as influenced by weather factor and crop development.

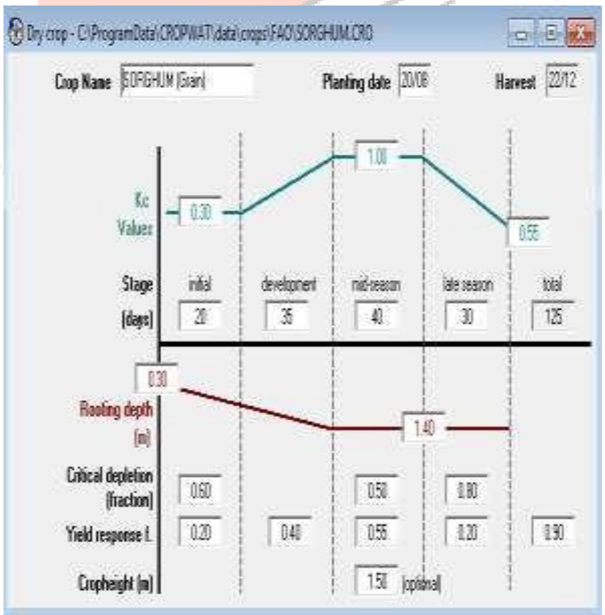


Fig. 7 Kc curve and crop growth stage

Initial stage: The initial stage runs from planting date to approximately 10% ground cover. The length of the initial period is highly dependent on the crop, the crop variety, the planting date and the climate. The end of the initial period is determined as the time when approximately 10% of the ground surface is covered by green vegetation. For perennial crops, the planting date is replaced by the 'greenup' date, i.e., the time when the initiation of new leaves occurs. During the initial period, the leaf area is small, and evapotranspiration is predominately in the form of soil evaporation. Therefore, the Kc during the initial period (Kc,ini) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry. The time for the soil surface to dry is determined by the time interval between wetting events, the evaporation power of the atmosphere (ET0 pot) and the importance of the wetting event. General estimates for Kc,ini as a function of the frequency of wetting and ET0 pot assume a medium textured soil. Both the data and a procedure for estimating Kc,ini is presented in FAO 1998.

Development stage: The crop development stage runs from 10% ground cover to effective full cover. Effective full cover for many crops occurs at the initiation of flowering. For row crops where rows commonly interlock leaves such as beans, sugar beets, potatoes and corn, effective cover can be defined as the time when some leaves of plants in adjacent rows begin to intermingle so that soil shading becomes nearly complete, or when plants reach nearly full size if no intermingling occurs. For some crops, especially those taller than 0.5 m, the average fraction of the ground surface covered by vegetation (fc) at the start of effective full cover is about 0.7-0.8. Fractions of sunlit and shaded soil and leaves do not change significantly with further growth of the crop beyond fc 0.7 to 0.8. It is understood that the crop or plant can continue to grow in both height and leaf area after the time of effective full cover. Because it is difficult to visually determine when densely sown vegetation such as winter and spring cereals and some grasses reach effective full cover, the more easily detectable stage of heading (flowering) is generally used for these types of crops.

Mid-season stage: The mid-season stage runs from effective full cover to the start of maturity. The start of maturity is often indicated by the beginning of the aging, yellowing or senescence of leaves, leaf drop, or the browning of fruit to the degree that the crop evapotranspiration is reduced relative to the reference ET0pot. The mid-season stage is the longest stage for perennials and for many annuals, but it may be relatively short for vegetable crops that are harvested fresh for their green vegetation.

At the mid-season stage the Kc reaches its maximum value. The value for Kc,mid is relatively constant for most growing and cultural conditions. Deviation of the Kc mid from the reference value ’1’ is primarily due to differences in crop height and resistance between the grass reference surface and the agricultural crop and weather conditions.

Late season stage: The late season stage runs from the start of maturity to harvest or full senescence. The calculation for Kc and ETc is presumed to end when the crop is harvested, dries out naturally, reaches full senescence, or experiences leaf drop. For some perennial vegetation in frost free climates, crops may grow year
round so that the date of termination may be taken as the same as the date of ’planting’.

D. CROP EVAPOTRANSPIRATION

Crop evapotranspiration is calculated by multiplying ETo by Kc, a coefficient expressing the difference in evapotranspiration between the cropped and reference grass surface. The difference can be combined into one single coefficient, or it can be spilt into two factor describing separately the difference in evaporation and transpiration between both surface. The selection of the approach depands on the purpose of the calculation, the accuracy required, the climate data available and the time step with which the calculation are executed.
ETc is determined by the crop coefficient approach whereby the effects of the various weather condition are incorporated into ETo and the crop characteristics in to the Kc coefficient:

ETc= Kc*ETo

Calculation procedure for crop evapotranspiration ETc:
Identifying the crop growth stages, determining their lengths, and selecting the corresponding Kc coefficients.
Adjusting the selected Kc coefficient for frequency of wetting or climate condition during the stage.
Constructing the crop coefficient curve.
Calculating ETc as the product of ETo and Kc.

E. CROP WATER REQUIREMENT

The amount of water required to compensate the evapotranspiration loss from the cropped fields is defined as crop water requirement. Although the values for Crop evapotranspiration under standard condition (ETc) and crop water requirement are identical crop water requirement refers to the amount of water that needs to be supplied while crop evapotranspiration refers to the amount of water that os lost through evapotranspiration.

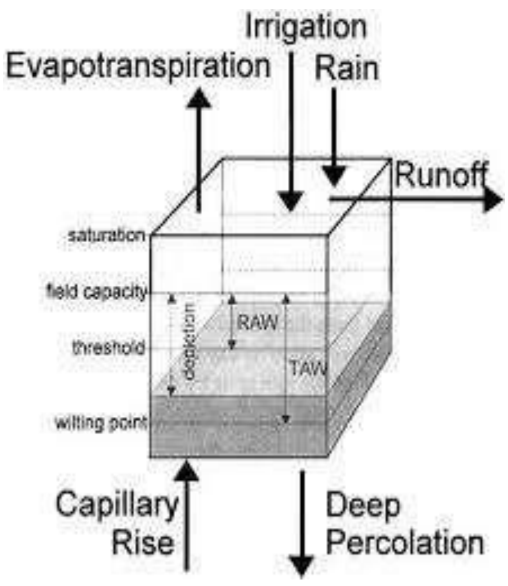
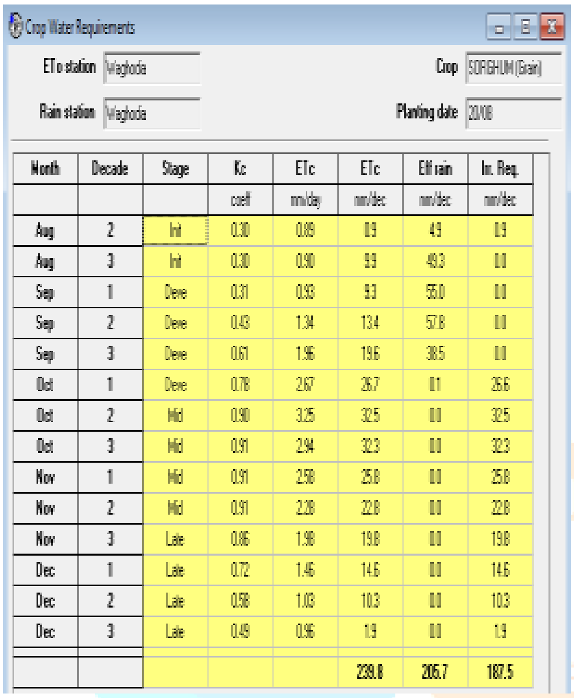


Fig.8Crop water requirement

In above fig 8 the root zone is presented by means of a container in which the water content may fluctuat.

Inductive, descriptive and analytical approaches were employed to estimate crop water requirement based on measured ET soil moisture content and crop coefficient using CROPWAT.



Crop Water Requirements

ETo station: Waghodia | Crop: SORGHUM (Grain)
Rain station: Waghodia | Planting date: 20/08

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	2	Init	0.30	0.89	0.9	4.9	0.9
Aug	3	Init	0.30	0.90	9.9	49.3	0.0
Sep	1	Deve	0.31	0.93	9.3	55.0	0.0
Sep	2	Deve	0.43	1.34	13.4	57.8	0.0
Sep	3	Deve	0.61	1.96	19.6	38.5	0.0
Oct	1	Deve	0.78	2.67	26.7	0.1	26.6
Oct	2	Mid	0.90	3.25	32.5	0.0	32.5
Oct	3	Mid	0.91	2.94	32.3	0.0	32.3
Nov	1	Mid	0.91	2.58	25.8	0.0	25.8
Nov	2	Mid	0.91	2.28	22.8	0.0	22.8
Nov	3	Late	0.86	1.98	19.8	0.0	19.8
Dec	1	Late	0.72	1.46	14.6	0.0	14.6
Dec	2	Late	0.58	1.03	10.3	0.0	10.3
Dec	3	Late	0.49	0.96	1.9	0.0	1.9
					239.8	205.7	187.5

Fig.9

Crop Water Requirement

F. IRRIGATION SCHEDULING

Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount. By calculating the soil water balance of the root zone on a daily basis, the timing and the depth of future irrigations can be planned. The Irrigation requirement, expressed in mm and computed over a certain period of time, expresses the difference between the Crop evapotranspiration under standard conditions (ETc) and the Effective Rainfall contributions over the same time step.

Irrigation requirement indicatively represents the fraction of the crop water requirements that needs to be satisfied through irrigation contributions in order to to guarantee to the crop optimal growing conditions. However, it should be taken in careful consideration that this parameter does not take into consideration soil water contribution to the crop.

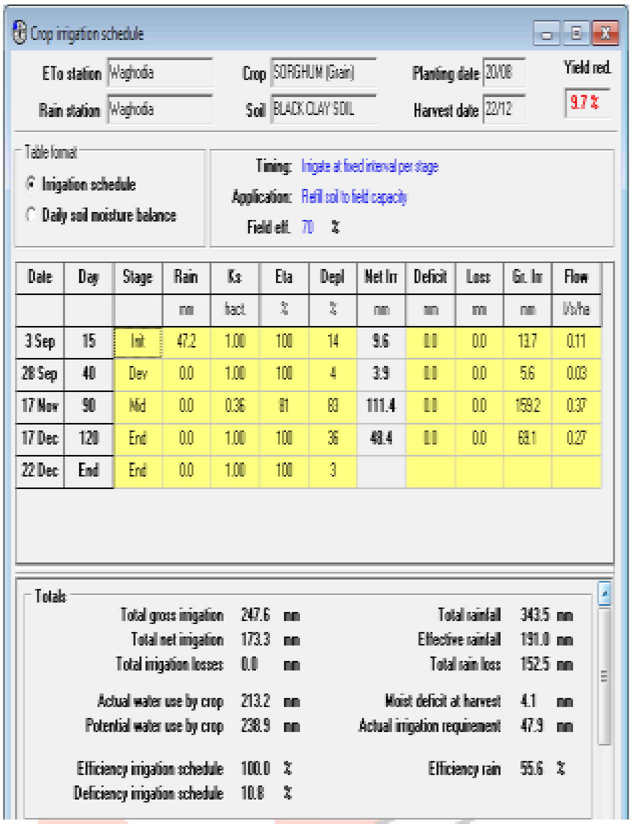
The Schedule module essentially includes calculations, producing a Soil water balance on a daily step. This allows to:

Develop indicative irrigation schedules to Improve water management;

Evaluate the current irrigation practices and their associate crop water productivity;

Evaluate crop production under ram-fed condition and assess feasibility of supplementary irrigation

Develop alternative water delivery Schedules under restricted water Supply conditions.



Crop irrigation schedule

ETo station: Waghodia | Crop: SORGHUM (Grain) | Planting date: 20/08 | Yield red.
Rain station: Waghodia | Soil: BLACK CLAY SOIL | Harvest date: 22/12 | 9.7 %

Table format: Irrigation schedule / Daily soil moisture balance

Timing: Irrigate at fixed interval per stage
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
3 Sep	15	Init	47.2	1.00	100	14	9.6	0.0	0.0	13.7	0.11
28 Sep	40	Dev	0.0	1.00	100	4	3.9	0.0	0.0	5.6	0.03
17 Nov	90	Mid	0.0	0.36	81	83	111.4	0.0	0.0	159.2	0.37
17 Dec	120	End	0.0	1.00	100	36	48.4	0.0	0.0	68.1	0.27
22 Dec	End	End	0.0	1.00	100	3					

Totals

Total gross irrigation	247.6	mm	Total rainfall	343.5	mm
Total net irrigation	173.3	mm	Effective rainfall	191.0	mm
Total irrigation losses	0.0	mm	Total rain loss	152.5	mm
Actual water use by crop	213.2	mm	Moist deficit at harvest	4.1	mm
Potential water use by crop	238.9	mm	Actual irrigation requirement	47.9	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	55.6	%
Deficiency irrigation schedule	10.8	%			

Fig.10 Irrigation Scheduling

IV. RESULTS AND ANALYSIS

GENERAL

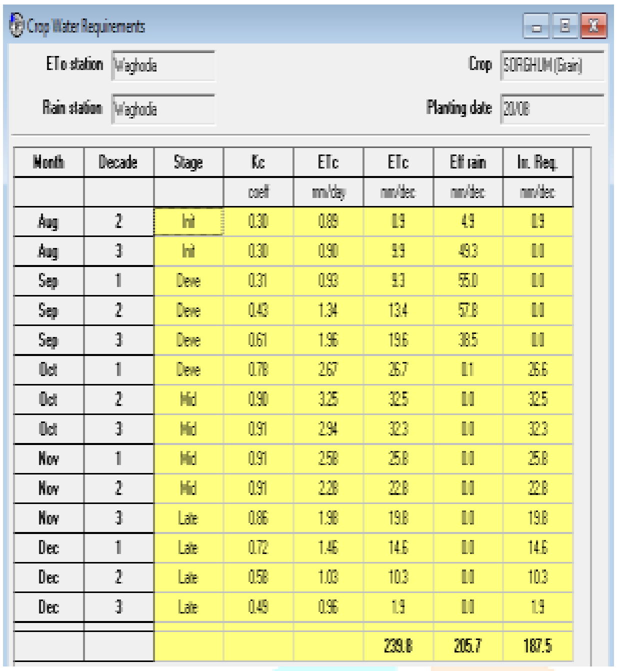
The CROPWAT software is used for calculating the Crop Water Requirements and Irrigation scheduling of the different crops i.e. Wheat, Rice, Sorghum.

The meteorogical parameter, rainfall data, crop data and soil data are considered as input to determine the Crop Water Requirements and Irrigation Scheduling is carried out by two approaches for various crops.

Crop: Sorghum

Crop water requirements

Fig. 9 show computation of crop water requirement of Sorghum. The results show that total Irrigation requirements of wheat are 187.5 mm



Crop Water Requirements

ETo station: Waghodia | Crop: SORGHUM (Grain)
Rain station: Waghodia | Planting date: 20/08

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	2	Init	0.30	0.89	0.9	4.9	0.9
Aug	3	Init	0.30	0.90	9.9	49.3	0.0
Sep	1	Deve	0.31	0.93	9.3	55.0	0.0
Sep	2	Deve	0.43	1.34	13.4	57.8	0.0
Sep	3	Deve	0.61	1.96	19.6	38.5	0.0
Oct	1	Deve	0.78	2.67	26.7	0.1	26.6
Oct	2	Mid	0.90	3.25	32.5	0.0	32.5
Oct	3	Mid	0.91	2.94	32.3	0.0	32.3
Nov	1	Mid	0.91	2.58	25.8	0.0	25.8
Nov	2	Mid	0.91	2.28	22.8	0.0	22.8
Nov	3	Late	0.86	1.98	19.8	0.0	19.8
Dec	1	Late	0.72	1.46	14.6	0.0	14.6
Dec	2	Late	0.58	1.03	10.3	0.0	10.3
Dec	3	Late	0.49	0.96	1.9	0.0	1.9
					239.8	205.7	187.5

Fig 9 Crop water requirement of Sorghum

At Fixed Interval:

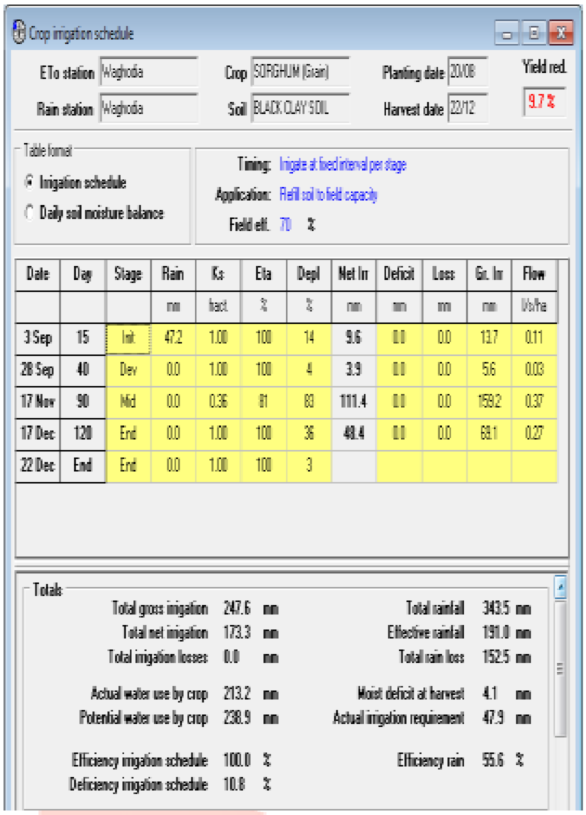
irrigation is applied at fixed interval per stage and it refills soil to field capacity. Field efficiency is considered as 70%

Fig 10 shows computation of Irrigation scheduling. As per irrigation scheduling carried out by CROPWAT it shows that gross irrigation requirement is 247.6 mm and net irrigation requirement is 173.3 mm. The numbers of Irrigation and are presented.

Table 5 shows the irrigation dates of sorghum on which dates irrigation is applied.

Table- 5 Irrigation Dates of Sorghum

Date	**3-Sep**	**28-Sep**	**17-Nov**	**17-Dec**	**22-Dec**
Day	15	40	90	120	End
Net irrigation mm	9.6	3.9	111.4	48.4	0



Crop irrigation schedule

ETo station: Waghodia | Crop: SORGHUM (Grain) | Planting date: 20/08 | Yield red.
Rain station: Waghodia | Soil: BLACK CLAY SOIL | Harvest date: 22/12 | 9.7 %

Table format: Irrigation schedule / Daily soil moisture balance
Timing: Irrigate at fixed interval per stage
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract	%	%	mm	mm	mm	mm	l/s/ha
3 Sep	15	Init	47.2	1.00	100	14	9.6	0.0	0.0	13.7	0.11
28 Sep	40	Dev	0.0	1.00	100	4	3.9	0.0	0.0	5.6	0.03
17 Nov	90	Mid	0.0	0.36	81	83	111.4	0.0	0.0	159.2	0.37
17 Dec	120	End	0.0	1.00	100	36	48.4	0.0	0.0	69.1	0.27
22 Dec	End	End	0.0	1.00	100	3					

Totals

Total gross irrigation	247.6	mm	Total rainfall	343.5	mm
Total net irrigation	173.3	mm	Effective rainfall	191.0	mm
Total irrigation losses	0.0	mm	Total rain loss	152.5	mm
Actual water use by crop	213.2	mm	Moist deficit at harvest	4.1	mm
Potential water use by crop	238.9	mm	Actual irrigation requirement	47.9	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	55.6	%
Deficiency irrigation schedule	10.8	%			

Fig.10 Computation of Irrigation Scheduling of Sorghum

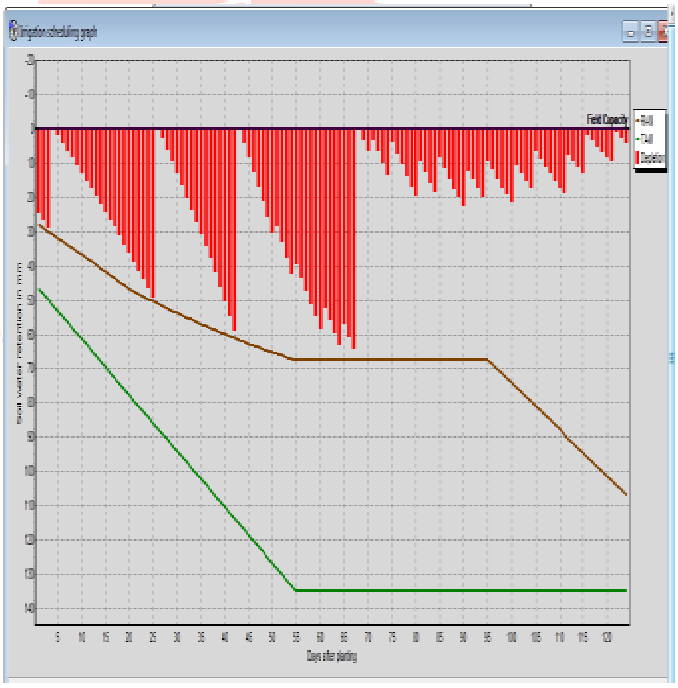


Fig.11 Irrigation Scheduling Graph for Sorghum

Fig 11 shows the graph of Irrigation sceduling for Sorghum.

V. CONCLUSION

This paper summarizes the conclusion carried out by results and analysis of determination of crop water requirement and irrigation scheduling using different approaches by CROPWAT.

Sorghum

Crop water requirements for Sorghum is 187.5 mm.

Net irrigation requirements for Sorghum at fixed interval per stage is 173.3 mm and four irrigation are on date 3- Sep, 28-Sep, 17- Nov, 17- Dec with varying depth of 9.6 mm, 3.9 mm, 111.4 mm, 48.4 mm respectively.

VI. REFERENCES

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