New Technique for Evaluation of Crop Water Requirement

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Abstract: - Knowledge of 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, effective design and management of irrigation system and also for mid term planning in case of mid season drought therefore a case study was undertaken for determination of crop water requirement. 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.

Key Words: - Crop water requirement, crop, reference evapotranspiration, Modified Penman Method

1. Introduction

A The irrigation requirement (IRR) for crop production is the amount of water, in addition to rainfall, that must be applied to meet a crop's evapotranspiration needs without significant reduction in yield. Evapotranspiration (ET) includes water that is needed for both evaporation and transpiration. Evaporation is the change of water from liquid to vapor form. Evaporation occurs from all moist or wet surfaces, including soil, water, plant, and other surfaces. Transpiration is evaporation from plant leaves through small openings in the leaves Both evaporation called stomata. and transpiration occur in response to climate demand. ET is greatest on hot, dry days and lowest on cool, humid days. ET must occur to avoid plant water stress. Plant water stress will occur if ET is limited because water is not available to plants. Water stress will occur quickest on high climate demand days. Water stress is avoided by rainfall or by irrigating to

provide a crop with the water needed for evaporation and transpiration.

To avoid water crop water stress, rainfall and surface irrigation application must be sufficient to meet the crop's ET requirement. This means that for any period of time during the crop growing season, the net irrigation requirement (NIR) is the amount of water which is not effectively provided by rainfall:

NIR= ET - ERAIN	(1)
Where	
NIR= net irrigation requirem	nent,
ET= evapotranspiration, and	
ERAIN = effective rainfall.	

NIR is irrigation water which is delivered to the field and available for the crop to use. This is primarily water which is stored in soil in the crop root zone, although some of the water which is evaporated from water, soil, and plant surfaces during application also effectively reduces climate demand.

To find the crop water requirement, it as must to know evapotranspiration of crop.

Various field methods have been used for direct measurement of evapotranspiration.

- 1. Lysimeter experiment
- 2. Field Experiment
- 3. Soil moisture depletion studies
- 4. Water balance method

but owing to the difficulty in obtaining direct measurement accurate of evapotranspiration under field conditions, it is often predicted on the basis of climatological data. (Temperature, humidity, sunshine, wind). In 1948 commonly used analytical approach is Thornwaite who assumed exponential relationship existed between mean monthly temperature and mean monthly consumptive use. Blaney Cradle (1950) observed that a mount of water consumptively used by crops doing their grooving season was closely co-related with mean monthly temperature and day night hours. Penman (1948) proposed an equation for evaporation from open water surface based on combination of energy balance & sink strength since the Penman equation estimates evaporation from free water surface. The result must be modified to provide evapotranspiration estimate for crops. Christiania's (1968) had proposed a revised empirical formula originally developed by him in 1960 to estimate pan evaporation. Later on Radiation method came into existence considered the radiation reaching the earth contributing as an influence factor for evapotranspiration.

In 1977, a modified form of Penman method was presented which introduces a simplified form of the equation along with correction factor considering day & night weather conditions known as Modified Penman Method.

This paper deals with calculation of reference evapotranspiration by Modified Penman Method as it is globally accepted method.

2 Literature Review

Michele Bernardie (2003) has emphasized on data standardization, collection, analysis and data tools are developed taking into account technical specification of decision support system for irrigation planning and management. Richard G. Allen and Ronal Elliot (2003) have compared reference evapotranspiration calculation as a part of ASCE standardization effort and recommended that the standardization efforts will continue to evolve with time as new information and procedure become available. Dr Wayne Meyer and Alan (2002) to develop national standards as there is a lack of consistency in methodologies to calculate crop evapotranspiation. Peter Mulamba, Larry C Brown (2002) have practisied on assessment of microirrigaton scheduling of cabbage using tensometers indicates that there is an optimal critical point at which optimal yields are achievable. Baisware and Badar (2006) has studied crop water requirement by the use of HYMOS software stated that the crop water supplied in excess could have been utilized for irrigating more land, supplying water to drought prone area.

3 Study Areas

The study is carried out for Nagpur zone in Maharashtra of India which covers six districts as Nagpur, Wardha, Chandrapur, Gondia, Bhandara, Gadchiroli district. There are four meteorological stations at Nagpur Wardha Chandrapur Gondia and Bhandara and 56 rain gauge stations in all districts as shown fig. [1].

Meteorological stations

S.No	Station	Lattitude	Longitude
1	Nagpur	21° 09'	79° 09'
2	Wardha	20° 45'	78°33'
3	Chandrapur	20° 07'	78° 46'
4	Gondia	21°28´	80°12′

4 Methodology

The crop water requirement of different crop in Nagpur region is standardized by using modified Penman method which helps in determination of reference evapotranspiration The steps involve in determination of crop water requirement is as

4.1 Crop Chosen: - Wheat, Sunflower4.2 Data Collection:

The data required to determine crop water requirement is rainfall, maximum and minimum temperature, relative humidity, wind speed etc. The data is collected from 1990 to 2004. The required determination data for of Evapotranspiration is from meteorological station as mentioned in study area and fortnightly rainfall from 56 rainguage station all over the zone from Hydrological Data Users Group, Nashik.



Fig. 1 Map showing meteorological stations and rainguage station of Nagpur Region in Maharashtra of India

4.3 Evapotranspiration (Eto)

It is a matter of common experience that water losses are simultaneously taking place from soil adjacent to the plant through evaporation and through transpiration from plant structure. Hence the term evapo-transpiration is commonly used to denote combined water loss. It is also termed as consumptive use of water. There are different method i.e. direct measurements and use of equations Presently, in India irrigation department uses the Modified Penman Method which is an analytical method to calculate the reference evapotranspiration for Nagpur region. This method is globally accepted as it covers all the parameters and also provides more satisfactory result where measured data on temperature, humidity, wind, sunshine hours are available.

$$Eto = c\{(W \times Rn) + (1 - W)f(u)(ea - ed)\}$$
 (2)
Where

Eto = Evapotranspiration in mm/day

c = Adjustment factor for day and night wind velocity and humidity

W = Weighing factor for altitude and temperature effect on radiation

Rn = Net radiation in equivalent evaporation in mm/day

f(u) = Wind function expressed in terms of equivalent evaporation in mm/day

- (ea-ed)= Vapour pressure deficit expressed in mbar,
- ea = Saturation water vapour pressure of the air
- ed = Saturation vapour pressure at mean air temperature.

To determine evapotranspiration, it is essential to have an accurate value of adjustment factor c. It is used to consider the day and night wind speed which was not in the original penman method. Therefore, adjustment factor is an integral part in the evapotranspiration which is determined by using table suggested by Doorknobs and Prutti (1977) the value of factor c has to be obtained using table interpolation. However, it is necessary to make 15 times interpolation in order to obtain that value which requires 45 different numbers into calculation. This may leads to an error which is directly transferred in crop water requirement. Slavisa Todorovic, MIiomir Traikovic. Branimar Stankavic, (2001) has suggested to estimate FAO Penman C factor By RBF Networks for more accuracy which is directly transferred into the determination of crop water requirement.

Hajare H.V. and Dr. Raman N.S. has proposed a simple way to find out the adjustments factor in Modified Penman Method for finding evapotranspiration.

Amdas Baltas (2006) has carried out the research work for comparison of different methods for the estimation of reference crop evapolranspiration in the Florina region & results of each methods were compared with results of other method which showed differences between the results up to 50%.

4.4 Crop Coefficient (Kc)

To account for effect of crop coefficient characteristics on crop water requirement, crop coefficients are presented to relate reference evapotranspiration Eto to crop evapotranspiration Etc. When crop is growing in large fields under optimal growing condition. ET crop is found by

Etcrop=Kc x Eto(3)

Factor affecting the value of crop coefficient Kc are mainly the crop characteristic, sowing date rate of development, length of growing season and climatic condition. Etcrop is the sum of transpiration by the crop and evaporation of soil surface.

The crop-growing season is divided into four stages. Crop coefficients for given stage of crop development and different climatic conditions for development of irrigated crop is stressed. The four stages of crop development are described herein as

- i) Initial stage
- ii) Crop development stage
- iii) Mid season stage
- iv) Late season stage

Steps

Establish planting or sowing date from local information or from practices of similar climatic zones Determine total growing season and length of crop development stages from local information

Initial stage: -Predict irrigation frequency for predetermined Eto values. Obtain Kc from relation recommended in form of curves between Eto, Kc and frequency of watering i) **Mid season stage**: - For a given climate, select Kc value from table recommended by – FAO and plots a straight line.

ii) **Late season stage**: - For time of full maturity, select Kc value from table recommended by FAO for given climate and plot the value at the end of growing season or full maturity. It is a straight line between Kc value at the end of midseason period and at end of growing season

iii) Development stage: - Assume straight line between Kc value at the end of initial to the start of mid season stage for required period, Kc value can be obtained from prepared graph. A smooth curve might be drawn. Although this may have little effect in terms of accuracy as far as final results are concerned. FAO has suggested to draw crop coefficient curve for all the stages considering evapotranspiration. In the present case the crop coefficient value is considered fortnightly in each stage. Kincaid and Heerman (1974) has suggested the equation for calculation of crop coefficient based upon alfala penman equation. Hajare and Raman (2007) also suggested equation for calculation of crop coefficient based upon grass evapotranspiration.

4.5 Crop Evapo-transpiration

The fortnightly crop evapotranspiration was calculated by multiplying fortnightly reference evapotranspiration with crop coefficient as given by equation [4]. The crop coefficient was calculated fortnightly as per the method suggested by F.A.O.

 $Etc = Kc^*Eto$ (4)

4.6 Average Rainfall

In order to compute the average rainfall over basin or catchment area, the rainfall was measured at a at number of rain gauge stations suitably located in the area. The network density of rain gauge depends upon the use for which the rainfall data is intended. Fortnightly rainfall from 56 rainguage station all over the zone is collected from Hydrological Data Users Group, Nashik

There are three main methods to find out this average depth of rainfall. As the Nagpur region is a plain terrain therefore Thiessen polygon is used to find out the fortnightly average rainfall of the entire district separately of Nagpur region.

As stated in this method the adjacent

rainguage stations are jointed by straight lines and perpendicular bisector are drawn on these lines. In this way Thiessen network is constructed. A station encloses an area everywhere closure to that station. The area of this polygon was found by Planimeter.

The average rainfall is given by eq. [5].

$$P_{av} = \frac{A_1 P_1 + A_2 P_2 \dots A_n P_n}{A_1 + A_2 \dots A_n}$$
(5)

4.7 Effective Rainfall

Effective rainfall is only portion of total rainfall. Different criteria are used in various countries to estimate effective rainfall as a percentage total rainfall.. Evapotranspiration, Precipitation method gives effective rainfall as suggested by USAD, SCA (1969). It gives the relation between effective rainfall and mean fortnightly rainfall for different values of fortnightly crop evapotranspiration.

4.8 Net Irrigation Requirement

Since rain water and ground water is very difficult to control, it is only irrigation water the quantity of which can be varied. The requirement of water is first satisfied by rain ground water and only the balance quantity is supplied as irrigation water.

The net irrigation requirement is calculated by considering crop evapotranspiration, effective rainfall, and water for land preparation this is also calculated for different crop as per their growing season In this study crop water requirement fortnightly are presented for wheat and sunflower in table [1] &[2] only.

Panigrahi B. & Sharma S. D. (1992) has suggested irrigation water requirement model of some major crops. Altes A.G. and Smith M. in (1998) has proposed the guidelines for computing crop water requirements and giving the updated procedure for calculating reference & crop evapotranspiration. It was stated that FAO Penamn method overestimates ET. While other FAO equations, namely Blaney Criddle, radiation method showed variable adherence.

Dist/Month	NOV		DEC		JAN		FEB		Total
	Ι	II	Ι	II	Ι	II	Ι	II	
Nagpur	90.99	30.21	45.19	60.69	66.30	65.08	50.77	22.53	431.77
Wardha	92.17	33.70	49.20	64.62	72.28	57.86	59.42	29.45	458.69
Chandrapur	91.22	33.28	46.64	59.28	66.09	53.89	55.02	28.97	434.41
Gadchiroli	91.66	32.65	45.68	59.35	66.05	56.00	53.30	30.42	435.10
Bhandara	78.97	37.67	57.52	77.20	77.89	63.52	61.64	32.46	486.88
Gondia	91.79	38.16	59.24	77.56	79.90	66.44	61.74	31.98	506.83
K1	91.57	28.75	36.10	46.48	56.27	48.63	47.34	29.31	384.46
K2	92.0	32.15	44.93	59.39	66.02	57.62	81.97	31.53	435.63
K3	101.39	38.53	60.53	77.83	81.41	68.63	61.82	31.62	521.77
K4	91.83	39.82	63.31	83.03	84.06	69.57	64.27	32.45	528.33
K5	90.90	28.97	44.60	61.26	66.38	69.60	49.05	19.93	430.70
K6	92.61	33.89	50.39	67.09	75.15	59.70	61.45	29.66	469.93
K7	92.75	35.40	51.17	66.54	75.21	54.33	63.65	32.83	471.88
K8	98.58	30.65	40.11	48.52	59.01	48.10	51.05	26.88	402.89

Name Of Crop- Wheat CROP PERIOD-1st Nov-28 Feb Total No of Days=120

Table 1 Crop water requirement of wheat in mm

Dist/Month	NOV		DEC		JAN		Total
	Ι	II	Ι	II	Ι	Π	
Nagpur	88.53	26.26	40.30	54.01	53.17	33.89	296.17
Wardha	91.52	36.33	52.59	65.22	60.66	25.61	331.94
Chandrapur	90.61	35.80	51.40	60.97	56.82	26.73	322.32
Gadchiroli	91.05	35.16	50.44	61.03	56.78	27.90	322.35
Bhandara	79.04	42.18	61.87	76.52	64.58	26.97	351.16
Gondia	91.79	42.67	63.74	76.88	66.60	29.47	371.15
K1	90.53	29.86	51.04	49.84	49.84	26.79	287.90
K2	91.39	34.67	49.69	61.08	56.74	28.80	322.37
K3	101.34	43.03	65.14	77.15	68.10	31.35	386.12
K4	92.01	44.92	67.73	81.63	69.54	29.95	385.78
K5	87.69	22.41	35.82	51.20	51.69	36.78	285.59
K6	91.94	36.58	53.14	67.19	62.45	25.09	336.39
K7	92.99	41.26	48.61	70.71	64.34	21.55	349.45
K8	97.56	31.96	44.11	51.63	52.16	26.59	305.00

Table 2 Crop water requirement for sunflower in mm

5 Development of Concept

To introduce a new concept of development of iso requirement curve, it is must to undergo the steps as in methodology therefore calculated the crop water requirement as above. First of all the centroid of each district is located as and then located the boundary points of Nagpur region K1,K2,K3,K4,K5,K6,K7,K8 by using method of extrapolation, the crop water requirement for these located stations was determined assigned the crop water requirement to respective stations. By using software named, Softdesk, and AutoCAD 2004 and Microsoft Excel, iso requirement lines fortnightly for wheat and sunflower are established as shown in fig No. 2 which will gives direct value crop water requirement at any location in the region.







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Fig. 2 Iso lines Crop Water Requirement for Wheat and Sunflower

6 Discussions

To plan a new irrigation project at any place, it is necessary to give more attention towards the crop water requirement in the concerned region. To determine the crop water requirement, we need climatological data as rainfall, maximum and minimum temperature, relative humidity, wind speed etc.These data is required to collect from nearby meteorological stations i.e may be 150 to 200 kms. away from the irrigation project. As the location of the project command in most of the irrigation project are normally distant from the climatological station. Therefore the crop water requirement calculated will not give any realistic value Thus if the two meteorological stations around the command are considered and crop water requirements evaluated individually, as command lies in between, then the intermediate value gives the true representation.

To achieve this, it is decided to establish the pattern of crop water requirement lines in between the stations within Nagpur region. These lines will help to find more precise and realistic crop water requirement. Thus if such graphical map will be available, then it can be use as ready recknor. It is an first attempt to develop such iso requirement lines for different crop of Nagpur region.

The Graphical representation for crop water requirement is represented in terms of iso requirement curve is a new concept. This study is carried out for standardization of crop water requirement by modified penman method i.e by evapotranspiration there are various method to standardize the crop water requirement. This is first attempt in which method is standardized. Presently, in India, the crop water requirement is evaluated by various methods but as far as in Irrigation department is concerned in study area, they have been using modified Penman method for calculation of evapotranspiration.

This paper deals with the isolines for crop water requirement for wheat and sunflower. The isolines curves are given in the figure [2]. If such a isolines are available for Rabi and Kharif crops then the irrigation department along with the agriculture department may prepare crop calander to guide the farmer about the sowing of crops as per their water requirement.

7 Conclusions

This attempt to introduce a new concept which will give directly realistic value of crop water requirement. They will become a basis for planning, design and water management of irrigation system In present practice to find out crop water requirement by modified penman method, the data collection as well as calculation of crop water requirement is a tedious work which requires manpower as well as consumes time. This new concept will help in overcoming the conventional approach. Irrigation department may use this as ready beckoner. This concept is developed based on 10-15 years past data for the present requirement considering that there are little changes in the metrological factors may affect very little on crop water requirement. This will give an idea about the place and the type of

crop to be sow. This may be useful for well irrigation where farmer will supply the required amount of water and reduce wastage of water. Similarly such iso lines for crop water requirement can also be possible for other crop. This will also prove very much useful for well irrigation system. It is time to think to develop such iso line at National level which may be a useful in interlinking river project.

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Notation:-

- Eto Reference evapotranspiration
- Kc Crop coefficient
- Etc Crop evapotranspiration
- F.A.O. Food Agriculture Organization