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Increasing Irrigation Efficiency by Scheduling Using Cropwat Software

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Abstract: Optimum water use in agriculture is more crucial nowadays. This study explores the transformative potential of CropWAT software in enhancing water efficiency and increasing crop yields through precise irrigation scheduling. Our primary goal is to elevate farmers' awareness about the benefits of this advanced tool, particularly in the drought-prone Marathwada region of Maharashtra. We conducted a comparative analysis of two farms: On one land an abundant water supply and another less irrigation water with different types of agricultural soil, as fewer irrigation water sources in Marathwada, known for its challenging water scarcity issues. By considering local climatic, soil, and crop data in CropWAT, we were able to accurately predict the irrigation needs for each crop in the field. The farm in which the water-rich area avoided of over-irrigation, while the farm with less water was given the optimum depth of water then we achieved improvements in water use efficiency. In both scenarios, CropWAT's irrigation scheduling led to significant increases in crop yields. This study highlights the game-changing potential of CropWAT software as a critical tool for modern agriculture. By adopting precise irrigation management strategies, farmers in Marathwada and similar regions can not only conserve precious water resources but also enhance their productivity and contribute to sustainable farming practices. Our findings underscore the importance of embracing technological innovations to secure the future of agriculture in water-challenged environments.

Keywords: CropWAT Module, Meteorological Data, Reference Evapotranspiration, Crop Water Requirements, Irrigation Scheduling, Cropping Pattern, Water Supply Scheme

I. INTRODUCTION

The Irrigation scheduling involves deciding when and how much quantity of water supplied to the field. Good scheduling will apply water at the right time and in the right quantity in order to increases production and minimize adverse environmental impacts. If the scheduling is not properly done then it will mean that either not enough water is supplied or it is not supplied at the right time, resulting in under-watering, or too much is supplied or it is supplied too soon, resulting in over-watering. Under or over irritation can lead to reduced yields, lower quality, and inefficient use of nutrients and can harmful for health of soil. Under-watering leading to wilting, reduced photosynthesis and growth. Over-watering, on the other hand, can lead to waterlogged soils, root rotting, and leaching of essential nutrients beyond the root zone. Both scenarios result in decrease crop performance and economic losses.

In typical crop schedule average data on the regular crop stage can be obtained from the crop calendar, although the date of planting / sowing and harvest may vary because of different factors present in different years and geographical areas due to natural variations, farmer's decision, and weather etc. the typical crop calendar of India, during the Rabi season, sowing of sugarcane is usually done in November, December and January. February, March and April are considered as the growing stages of the crop. Harvesting is usually done in April and May. Crop calendar, Field survey data [8].To carry out irrigation scheduling using CROPWAT, several factors need to be considered, including the method of irrigation timing, irrigation at 100% critical depletion, irrigation at fixed intervals per stage, and the method of irrigation application. CROPWAT is a decision support tool developed by the Food and Agriculture Organization (FAO) that assists in calculating crop water requirements and developing irrigation schedules. The tool considers various parameters such as climate data (temperature, humidity, rainfall), soil characteristics (texture, depth, water holding capacity), and crop data (type, growth stages, water requirements). By inputting these parameters, CROPWAT can generate a tailored irrigation schedule that optimizes water application. The CROPWAT is an irrigation management and planning model simulating the complex relationships of on-farm parameters, the climate, soil and crop. In arid regions, agricultural development strongly depends on the irrigation because of low rainfall conditions and high evaporation.[2].

A) Crop Scheduling Using Cropwat Module

Irrigation scheduling primarily focuses on determining the methods, timing, and quantities of irrigation. The

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CROPWAT model can be utilized individually for managing irrigation scheduling for each crop. This model not only facilitates efficient water management but also helps in developing effective water delivery schedules under conditions of restricted supply. The main goal of scheduling is to ensure an optimal water supply to improve crop productivity by maintaining soil moisture within the readily available water (RAW) range in the root zone. The irrigation scheduling options in CROPWAT offer various choices based on the user's objectives, available water resources, and the condition of the irrigation system. In this study, two approaches are employed for irrigation scheduling, and the more effective method among these is selected [1].

B) Objectives:

- To determine Crop water Requirements of Maize, Wheat, Chilli and Sugarcane through CROPWAT of Agricultural Land.
- To determine Irrigation Scheduling of above crops through CROPWAT.
- To study the irrigation feature of Irrigation Scheme
- To suggest suitable canal operation scheduling to match with the seasonal Irrigation Demand.
- To study and evaluate the various irrigation options and suggests appropriate option for optimizing Net Irrigation Requirement and Irrigation Demand for the cropping pattern.
- To explore the possibility of "CROPWAT" windows version 8.0 model as management tool in irrigation management.

II. LITERATURE REVIEW

Sonu Kumari : "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 commandandwillultimatelyresultinmoreagriculturalyield.Waterrequirementsandirrigation scheduling of major crops, namely Sugarcane, Rice, Tobacco, Soybean etc. are determined using the CROPWAT model." [1]

Mi Yin San, and May Thinzar: "Actual evapotranspiration is defined as the rate of evapotranspiration by particular crop in a given period under prevailing soil water and atmosphere condition. The CROPWAT is an irrigation management and planning model simulating the complex relationships of on-farm parameters, the climate, soil and crop. In arid regions, agricultural development strongly depends on the irrigation because of low rainfall conditions and high evaporation. The transfer of water from the soil surface (evaporation) and plants (transpiration) to the atmosphere is referred to evapotranspiration. From the irrigation point of view, the ET estimates the amount of water to be applied through the artificial means. Using the ET, the sizes of canals and pumps are determined. Many different methods are used to find the ETO. These methods are Blaney-Criddle method, Radiation method, Pan evaporation method, Penman method or Modified Penman method and FAO Penman-Monteith method, etc.

Hashem et al., (2016) made an attempt to compare the reference evapotranspiration computed using a mathematical model with ETO estimated using CROPWAT software program.

Vivekanand Singh et al., (2006) calculated ETO by using seven different methods and as a standard Penman-Monteith method was used and compared with the other six methods. It is found to be good correlation between them. In this study, the ETO is calculated using the CROPWAT 8.0 model and its value is multiplied with crop coefficient to get the actual evapotranspiration." [2].

Jitendrasinh D. Raol, and Prof S.A.Trivedi : "With growing population the demand of water for various purposes is ever increasing Water is becoming a scarce resource as a result of the growing demand in various purposes. 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 result in more agricultural yield." [3]

M.B. Hossain, S. Yesmin, M. Maniruzzaman1 and J.C. Biswas: "Understanding of crop water requirement is essential for irrigation scheduling and selection of cropping pattern in any particular area. A study was conducted to estimate irrigation requirement and made irrigation scheduling of rice in the western region of Bangladesh using CROPWAT model. Historical climate data from three weather stations in the region along with soil and crop data were used as input to FAO Penman-Monteith method to estimate reference evapotranspiration (ETo). Effective rainfall was calculated using USDA soil conservation method.

The model estimated1408 mm annual ETo in the study area, of which the highest amounts of 175 mm was in April and the lowest (70 mm) in December. The average annual rainfall was 1592 mm of which 986 mm was effective for plant growth and development. The model estimated Etc of BRRIdhan49, which was 473 to 458mm, depending on its

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transplanting dates from 15 July to 15 August. Rice transplanted on 15 July required no irrigation, whereas three supplemental irrigations amounting 279 mm were required for transplanting on 15 August. The CROPWAT model estimated seasonal irrigation water requirement of 1212 mm (12 spilt applications) for BRRIdhan28 transplanted on 15 January. The model has a potentiality to make irrigation scheduling of other crops [6].
Nasrin Sultana, Md. Abdus Salam, Tofayel Ahammad and S. M. Abdullah Zahir: Efficiently management of irrigated crop requires proper timing and applying the correct quantity of irrigation water. For this reason it is very important to quantify the specific crop water requirement. Crop water requirements (CWR) are defined as the depth of water [mm] needed to meet the water consumed through evapotranspiration 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 [12]. CWR is the sum of crop evapotranspiration (ETc) forthe entire crop growth period [12]. Conventional method of evapotranspiration computation is based on climate data [2]. It is difficult to estimate spatio-temporal variations in evapotranspiration based on point observation of meteorological quantities. Better regional estimation of evapotranspiration can be retrieved from satellite images. Surface Energy Balance Algorithm for Land (SEBAL) is a robust remote sensing model that can be applied to estimate actual evapotranspiration (ETa) [4]. This research used SEBAL model to calculate actual evapotranspiration, which is used to estimate the amount of water consumed by Boro rice. The main purpose of this study is to implement the SEBAL methodology to quantify spatial variation of crop water requirement of Boro rice using satellite data. Research methodology is applied by synthesizing SEBAL method and Boro rice phenology detection method [8].

III. METHODOLOGY

The various methods used in the study, description of the study area and collection of data. The methods pertaining to the analysis of variability in ET, water requirement and scheduling of irrigation were explained in detail. A comparison was made between irrigation scheduling at critical depth and at fixed intervals during different stages.
We carried out a field survey in the study areas during the period of March and April, 2024, when most maize fields are in growing phase. For above mention cropwat software we conducted study in two different field having a different soil and weather condition and availability of water. First we visited first site of Harsul Lake near Aurangabad city area where ample availability of water even for high delta crop such as sugarcane, cotton, winter wheat etc. The soil in Harsul region comes under the category which is a Black Cotton soil. The major data requirements for soil include total available soil water content, maximum infiltration rate, maximum rooting depth and initial soil water content. For calculation of water requirement using cropwat software required is total available soil moisture which present in soil natural condition. For this we conducted water content test using oven drying method. For this we collected soil sample from selected filed of two and half acres of land. Due to large field soil sample is collected eight different places four sample from each corner and remaining sample from inside area of field at different places. After collecting sample we tested this in college geo technical lab.Using oven drying method we find initial soil moisture and average it for one input data. Initial soil moisture is very important parameter for calculation of water depth of crop after same procedure is repeat for second study area of kanchanwadi and find soil type and average initial soil moisture.

A. Study area

The area around Harsul Lake which is allotted to farmers bythe government, comingunder the Aurangabad citylimit was selected for the study,Along with the Farmland in Kanchanwadi behind theAgriculture College. Harsul Lake and Kanchanwadiboth arelocated in Aurangabad district of Maharashtra in India. HarsulLake and Kanchanwadiboth arelocated in Aurangabad district of Maharashtra in India.

- Altitude: 628 m
- Latitude :19.93˚N19.85˚N
- Longitude:75.33˚E75.29˚E

The area was selected due to the availability of all parameters needed for this study.

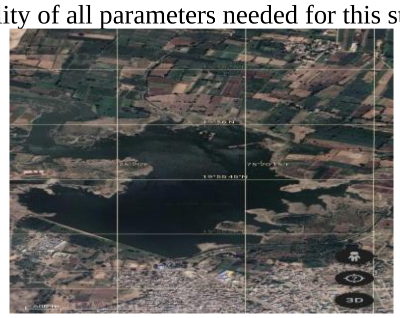

Fig.1. Study area Kanchanwadi

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B. Climate

The climatologically data of Weather Station representing Irrigation Scheme command it includes the daily values of temperature (maximum and minimum), humidity, wind speed, bright sunshine hours, and rainfall for 10 years The daily climatologically data are converted in to mean value over the monthly and then averaged over the period of 10 years to arrive at the monthly. The minimum and maximum temperature of Aurangabad city is19.20℃ and 32.40 ℃ respectively. The region falls under humid tropical climate. The average annual rainfall of the region is about 731.0mm.TherainyseasoninthaeareabeginsinlateMayandendsinthemonths of September. Summer season is hot with a maximum temperature of 39.8℃ during April and May. The relative humidity is low in summer with 72%duringits the monsoon season. The wind speed in the region is about 213 km/day.

C. Soil data

The soil in Harsul region and Kanchanwadi areas comes under the category which is a Black Cotton soil. The major data requirements for soil include total available soil water content, maximum infiltration rate, maximum rooting depth and initial soil water content.

Soil is a naturally occurring mixture of mineral and organic components, as well as living organisms, that together support the growth of plants. It is a vital natural resource that is essential for human survival and plays a critical role in sustaining life on Earth.

Soil formation is a complex process that involves the breakdown of rocks and organic matter by physical, chemical, and biological processes. Over time, the gradual decomposition of rocks and organic matter forms a mixture of minerals, organic compounds, and living organisms that we call soil. We have collected the soil data from actual field, then we performed the laboratory method i.e. Oven Dried Method.

Table 1. Soil data

Sample No.	Container	Empty Weight	Weight with Soil Sample	Dry Weight	Moisture Content	Average Moisture Content
A.1	11	15.04	74.71	63.34	23.54	33.17
A.2	9N	15.53	74.12	64	20.88	
B.1	12	14.89	74.89	60.54	31.43	
B.2	7	15.73	72.44	57.54	35.64	
C.1	98	8.11	37.87	29.71	37.78	
C.2	96	8.24	36.44	30	29.60	
E.1	15	8.3	31.15	25.34	34.10	
E.2	17	8.16	40.92	29.66	52.37	

IV. PERFORMANCE ANALYSIS

We are collected samples from two different locations harsul lake area and paithan road, kanchanwadi for comparison of these locations. After collecting samples we test moisturecontent.Moisturecontentis33%and 13% for Harsul Lake and kanchanwadi respectively. The total available soil moisture (TAM) of black cotton soil can vary based on several factors including its specific compositions and structure, but generally, black cotton soil is known for its high water holding capacity.

The total available soil moisture (TAM) of black cotton soil can vary based on several factors including its specific compositions and structure, but generally, black cotton soil is known for its high water holding capacity. Typical values for TAM in black cotton soil range between 150 to 250mm per meter of soil depth. This means that for every meter depth of black cotton soil, it can hold approximately 150 to 250 millimeters of water that is available for plant use.

Table2. Comparative analysis of soil data

Soil data	For Harsul lake samples	Kanchamwadi samples
Total available soil moisture (FC-WP)	200mm/meter	200mm/meter
Maximum infiltration Rate mm/hr	50mm/day	120mm/day
Maximum rooting depth (cm)	90cm	90cm
Initial soil moisture depletion%	33 %	13 %
Initial Available soil moisture	134.0 mm/meter	174.0mm/meter

The results analysis suggests that in Harsul crop water requirement for sugarcane crop is 1430.4mm/dec,spinachis148.4mm/dec, 27.0 mm/dec and winter wheat is 524.4 mm/dec. In Kanchanwadi cropwater requirement of Sugarcane is 1430.4 mm, small vegetable (Spinach) is 73.4 mm, Maize is 27.0 mm, and Winter Wheat is 338.3 mm.

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Table 3. Result analysis

Crop	Harsul		Kanchanwadi	
	Gross Irrigation Req.	Net Irrigation Req.	Gross Irrigation Req.	Net Irrigation Req.
Sugarcane	1694.0mm	1185.8mm	1694.0mm	1185.8mm
Spinac h	190.8mm	133.5mm	86.1mm	60.3mm
Maize	0.0mm	0.0mm	0.0mm	0.0mm
Winter Wheat	677.8mm	474.5mm	320.5mm	224.4mm
Total	2562.6mm	1793.8mm	2100.6mm	1470.5mm

V. CONCLUSION

Following conclusions are drawn based on the results and analysis discussed. Determination of crop water requirement and irrigation scheduling using different approaches by CROPWAT, crops: Soybean, Sugarcane and Winter Wheat.
The study, it is concluded that reference Crop Evapotranspiration, Effective rainfall, crop water requirement and irrigation water requirement can be estimated using CROPWAT Software with the input of climatic data like maximum and minimum temperature, relative humidity, wind speedand sunshine hours and rainfall.
The Comparative study on different fields with the help of CropWAT software gives us Flexibility in scheduling the Irrigation along with greater predictions on weather and rainfall based on previous trends. The use of modern scientific tools like CropWAT can access the water requirement of crops with large accuracy and suggest the crop and crop rotation which can be readily acceptable to farmer.

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