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DETERMINATION OF WATER REQUIREMENTS AND IRRIGATION SCHEDULING OF WHEAT CROP IN SINDH USING CROPWAT MODEL

Ateeque Rehman[*1], Dr. Ashfaque Memon[*2], Dr. Shafi M. Kori[*3]

[*1]Post Graduate Student, Department Of Civil Engineering, Mehran University Of Engineering And Technology, Jamshoro, Sindh, Pakistan.

[*2,3]Professor, Department Of Civil Engineering, Mehran University Of Engineering And Technology, Jamshoro, Sindh, Pakistan.

ABSTRACT

Water is getting scarce around the world. Aridity and dry season are viewed as common reasons for the shortage of water on earth. Man-made desertification and water deficiencies have additionally disturbed the regular shortage of water around the world. Water shortage hugely affects food production. Irrigation systems are essential to boost crop productivity so as to satisfy future food demand and guarantee food security. Dwindling water resources and increasing food necessities need bigger potency in water use, each in rain-fed and in irrigated agriculture. To conserve water, some sort of irrigation planning ought to be utilized by the farming community. The objective of this study is to work out the Crop Water requirement and irrigation scheduling of Wheat crop in Sindh using FAO- CROPWAT model. The CROPWAT model that is developed by the Food Agricultural Organization (FAO) is a computer program for the calculation of crop water requirements and irrigation scheduling from existing or new climatic and crop information. The crop data required by the CROPWAT software was obtained through various online resources and published information. Climatic data incorporated in the CLIMWAT tool attached with CROPWAT was utilized. Furthermore, average rainfall data of past 20 years (1995-2015) observed at Metrological station of the DRIP Tando Jam was used in the software.

The results of water requirements for the crop were obtained for Wheat as (468.7 mm/dec).

Keywords: Crop Water Requirement, Irrigation Requirement, CROPWAT Model, Irrigation Scheduling, FAO, Irrigation Scheduling.

I. INTRODUCTION

In many countries, water shortages are emerging, especially in Pakistan, and water for agriculture is becoming scarce due to the growing demand for fresh water as a consequence of population growth.

In southern Asia, Pakistan lies between 24° to 37° Northern latitude and 61° to 75° Eastern longitude. The total area of the nation is 796100 km^2 and its length is approximately 1400 km and its width is 500 km. In the semitropical region, Pakistan is situated and its climate is mostly semi-arid. The annual rainfall is 495 mm on average, much of which comes during the monsoon season. The country's total population is around 173.2 million from which almost 64 percent of the inhabitants live in rural areas, and agriculture and related activities continue to be their occupation (FAO, 2010). The country's total agricultural area is approximately 22 million hectares and 87% of the area is irrigated by surface and groundwater supplies (approximately 19 million hectares). The total land area of Sindh is approximately 14.09 million hectares at 25.8° N latitude and 68.5° E longitude, of which 5.18 million hectares (37 percent) are cultivated (Agriculture Statistics, 2013-14). Pakistan contains two major crop seasons, the summer season (Kharif) which starts in April-May and ends in October-November, and the winter season (Rabi) which starts in October-November and ends in April-May. The main Rabi crops are wheat, gram, and barley, while Kharif crops are corn, paddy, cotton, and maize.

Agriculture is the main consumer of water in Pakistan. Modernization and good management of irrigation systems must be precisely assessed by water system requirements. To keep track of the irrigation demand, awareness of crop water requirements (CWRs) and irrigation scheduling is necessary. Software modeling with tools like AQUACROP, CROPWAT 8.0 is an efficient practice for scientists to test CWR, evapotranspiration of crops, and irrigation scheduling. These computer software programs have been developed by the Food and Agriculture Organization (FAO) as instruments to help irrigation engineers and agronomists perform normal calculations for irrigation water studies and specifically, for the management and design of irrigation schemes. The requirement for crop water depends on the agro-climatic conditions, the type of soil, the type of crop

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grown, the structure and textural conditions of the soil, and, to some degree, on cultural practices.

The criteria for irrigation water and the scheduling of irrigation for Wheat in Sindh is determined using the CROPWAT model.

II. METHODOLOGY

The Study Area

The province of Sindh comprises a 140,900 sq km area between latitudes of 23^{o} and 29^{o} North and longitudes of 67^{o} & 71^{o} East. The province stays largely surrounded by land in every direction, with the exception of the Arabian Sea in the southwest.

Figure 1. The Province of Sindh and its adjacent borders

The climate of Sindh is arid and damp. As a result, according to the conditions off the soil and the climate of the province, different areas are fit for different crops, e.g., For sugar cane, cotton and plantation of banana, lower part of the province is ideal. The plains of central Sindh are ideal for the dry crops. The Indus River crop is largely rich in the higher Sindh and Right Bank regions. For crops fed by rain, such as millets and leguminous plants, the east part of sindh and areas of Kacho remain suitable.

Agriculture primarily depends upon the water provided by the river Indus. However, concerning 365 days of the gross command space is underneath waterlogging and salinity because of a lack of adequate avoidance facilities.

Sindh falls into four agro-ecological zones. A major portion close to the river Indus is termed Southern Irrigated Plain (Zone II), the Indus Delta (Zone I), Sandy Desert (Zone III-a), and Dry Western highland (Zone IX). Most of the agriculture is practiced in Zone-II within the neighborhood of the stream Indus.

Estimation of Water Requirement

The ET, the form of soil, the bulk density of the soil, the unit of volume, and the permanent wilt point of soil, as well as the effective root zone of the project site, are used to determine crop water requirements in general. The Penman-Monteith method was found to be the most accurate and consistent in all climatic conditions on both a monthly and daily basis by the Irrigation and Drainage Council of Environmental and Water Resources, based on the recommendation of the American Society of Civil Engineers (ASCE) Task committee, which was obtained after evaluating 19 estimating methods and carefully screened lysimeter data from 11 worldwide locations of different climates ranging from arid to humid conditions. As a result, the Penman-Monteith equation, as shown below, will be used to estimate crop evapotranspiration. This equation is also utilised in the CROPWAT model for calculating crop evapotranspiration (ETc).

$$ETc = Kc\ (ETo) \quad Eq..... (i)$$

Where the

ETc = Evapotranspiration of Crop

ETo = Reference Crop Evapotranspiration

Kc = Crop Factor / Coefficient of Crop

CROPWAT Model Description

CROPWAT is a computer decision-support program that uses data from climate, crop, rain, and soil to calculate reference evapotranspiration (ETo), crop water requirement (CWR), irrigation scheduling, and irrigation water requirement (IR) using a set of equations developed by the Food and Agriculture Organization.

The software gives thorough information on various crop features, the local environment, and soil characteristics, which aids in the establishment of irrigation schedules and the calculation of water supply schemes for various crop patterns under irrigated and wet conditions.

In the CROPWAT program developed by the Food and Agriculture Organization, estimate crop water demand and irrigation application arrangement for all the crops under consideration. It's based on the Penman-Monteith model. Environmental data is used, including minimum and maximum temperatures, mean relative humidity (percent), wind velocity (km/hr), hours of daylight (h), rainfall data (mm), and effective rainfall readings (mm).

Working Principle of the CROPWAT Model

The primary purpose of software is to calculate crop water requirements, reference evapotranspiration, and crop and system irrigation. Through a daily water balance, the consumer can simulate various water supply scenarios and estimate yield reductions and irrigation and rainfall efficiencies.

The FAO Penman-Monteith approach is based on evapotranspiration measurements as a reference (ETo). Temperature (maximum and minimum), humidity, sunshine, and wind speeds are all included in the monthly and daily input files. Crop water requirements (ET crops) are computed across the growing season using ETo, and crop evaporation rate estimations, expressed as crop coefficients (Kc), are aided by well-established methodologies using the equation below.

$$ET\ crop = kilohertz \times ETo \qquad Eq......(ii)$$

The FAO has given updated numbers for crop coefficients. Crop irrigation requirements are determined by rainfall estimates, assuming the best water system. With inputs on the cropping pattern, it will be feasible to determine the topic irrigation demands.

The CROPWAT model will assess the root region's water balance on a daily basis, as well as the root zone depletion at the end of the day, is determined by the equation below.

$$Dr, i = Dr,i - 1 - (P - ROi) - Ii - CRi + ETci + Dpi \qquad Eq....(iii)$$

Where

Dr,i = depletion of the root region at the end of the day, i (mm)

Dr,i-1 = Water content at the end of the preceding day in the root zone (mm)

Pi = rainfall on the day i (mm)

ROi = surface soil runoff on day i (mm)

Ii = net depth of irrigation on day i which infiltrates the soil (mm)

Cri = capillary rise from the groundwater table on day i (mm)

ETci = crop evapotranspiration on day i (mm)

DPi = Water wastage in the root region on the day i (mm).

Irrigation Scheduling

Irrigation scheduling determines the specific amount of water to irrigate and the precise time to water. The CROPWAT model is used to compute ETo and CWR in order to design irrigation schedules in various administrative scenarios and water supply plans. The model then generates an irrigation schedule based on the acquired data from the model.

Selected crop and Data Collection

The representative crops for the Rabi season Wheat have been selected for the study.

As an essential CROPWAT model parameter, the crop constant values (Kc) are taken from the published information of DRIP, FAO handbooks, etc. Kc values are used for seasonal crops for the initial, development, middle, and late growth phases.

Plant Growth Stages

In deciding the water requirements of the crop, four stages of plant growth are utilized, as required by CROPWAT model. The stages of crop growth include the initial stage, stage of production, and stage of mid-season and late-season.

III. RESULTS AND DISCUSSION

The nation data for Pakistan, the climatic station Hyderabad, the date of cultivation, and the type of soil were all used in the CROPWAT software for selected crop. All relevant data was entered into the software, which then generated climatic parameters such as ET0, effective rainfall, total irrigation requirements of crop, and irrigation schedules for the crop under study based on that data.

Table 1 contains the data of crop under study. Table 2 contains the climatic data of Hyderabad, Sindh.

Table 1. Data of the selected crop in the study

					Crop Growth Period (Days)			
Crop Name	Scientific Name	Planting and Harvesting Date	Critical Depletion Fraction	Rooting Depths (cm)	Initial	Development	Mid-season	Late Season
Wheat	Triticum	10 Nov-29 Mar	0.55	30	30	40	40	30

The ET0 values obtained from CROPWAT software for different months are shown in Table 2. Because of the increased temperatures in the summer, it is higher, and the highest value was recorded in the month of May. (11.19 mm). It reduces in the winter, with the lowest figure (3.58 mm) recorded in December due to lower temperatures, and the annual average being (7.05 mm). The fluctuation in ET0 values in the research region reflects the diversity in weather conditions. During the dry seasons, evapotranspiration is increased by low relative humidity, higher temperatures, and higher wind speeds. The ETc values were lower at the start and end of the crop's productive stage, and higher in the middle. Using the USDA technique, the CROPWAT model calculates effective rainfall using input data from 20 years of average rainfall (1995-2015). The CROPWAT model calculates water requirements and irrigation schedules for the crop during the study period based on the input and computed data. The results in Table 2 demonstrate that the average annual rainfall is 146.8 mm, with an effective rainfall of 117.4 mm.

Table 2. Climatic characteristics, Rainfall, and ET_o of Hyderabad District area obtained using CLIMWAT tool attached to the CROPWAT software.

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m^2/day)	ET_o	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	10.9	25.2	45	190	7.5	14.5	3.62	1.0	0.8
February	13.7	29.0	43	190	8.1	17.3	4.44	4.3	3.4
March	18.9	34.7	39	233	9.0	20.8	6.41	0.2	0.2
April	23.0	39.3	36	294	8.4	21.9	8.43	4.7	3.8
May	26.3	42.4	42	467	9.7	24.5	11.19	3.8	3.0

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June	28.2	40.9	53	613	8.3	22.5	10.74	9.7	7.8
July	28.0	38.4	60	570	8.0	21.9	9.00	43.3	34.6
August	27.2	37.1	62	553	7.3	20.3	8.16	46.1	36.9
September	25.9	37.4	58	467	8.4	20.5	8.06	23.3	18.6
October	22.4	37.6	43	233	9.0	18.9	6.57	6.0	4.8
November	17.0	32.5	42	156	8.1	15.5	4.43	0.5	0.4
December	12.2	26.8	48	173	8.1	14.4	3.58	3.9	3.1
Average	**21.1**	**35.1**	**48**	**345**	**8.3**	**19.4**	**7.05**	**146.8**	**117.4**

Determination of the Crop Water Requirements

Crops require varied amounts of water based on their location, climate, soil type, cultivation method, effective rain, and so on, and the total amount of water required by a crop during its life cycle is not evenly distributed. Irrigation water requirement (IR) of the selected crop (Wheat) under the study is 468.7 mm/dec.

Net Irrigation Requirement (NIR) and Irrigation Schedule

Irrigation management in the field is improved by understanding crop irrigation water requirements and irrigation time schedules. Irrigation water management is the process of efficiently controlling the amount, rate, and timing of irrigation. Table 4.3 and figure 4.1 shows the field crop irrigation schedules for the Wheat crop. The NIR is the amount of water required for crop development, or the amount of water required to reach the soil's field capacity. Cropping patterns and climate have an impact on NIR. To transform the NIR into a Gross Irrigation need, data on irrigation efficiency is also necessary. During the application and transfer of irrigation water, various losses such as runoff, evaporation, seepage, and percolation occur. Leaching, land preparation, and transplanting all necessitate a certain amount of water. As a result, CWR includes ET, as well as losses incurred during the application of water required for these objectives, as shown in Equation (iv).

NIR = ETc - Eff. rain Eq...(iv)

This calculation helps the farmers to choose the type of crops to grow based on the availability of irrigation water.

Table 3. Crop Water Requirements for Wheat

Month	Decade	No of days in decade	Stage	Kc (Coeff)	ETc (mm/day)	Etc (mm/dec)	Eff: Rain (mm/dec)	Irr. Req. (mm/dec)
Nov	1	10	Init	0.30	1.52	1.5	0.0	1.5
Nov	2	10	Init	0.30	1.30	13.0	0.0	13.0
Nov	3	10	Init	0.30	1.22	12.2	0.2	12.0
Dec	1	10	Dev	0.30	1.17	11.7	0.9	10.8
Dec	2	10	Dev	0.44	1.58	15.8	1.2	14.6
Dec	3	11	Dev	0.67	2.41	26.5	0.9	25.6
Jan	1	10	Dev	0.90	3.24	32.4	0.4	32.0
Jan	2	10	Mid	1.11	4.02	40.2	0.1	40.1
Jan	3	11	Mid	1.17	4.56	50.1	0.4	49.7
Feb	1	10	Mid	1.17	4.80	48.0	1.0	47.0
Feb	2	10	Mid	1.17	5.08	50.8	1.4	49.4
Feb	3	8	Late	1.17	5.87	46.9	0.9	46.0
Mar	1	10	Late	0.98	5.65	56.5	0.1	56.3

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Mar	2	10	Late	0.69	4.43	44.3	0.0	44.3
Mar	3	9	Late	0.42	2.95	26.5	0.1	26.4
						476.5	**7.8**	**468.7**

Table 4. Irrigation Schedules for Wheat

Date	Day	Stage	Rain (mm)	Ks fract.	Eta %	Depl %	Net Irr. (mm)	Deficit (mm)	Loss (mm)	FIR (mm)	Flow (l/s/ha)
20 Dec	41	Dev	0.0	1.00	100	55	113.9	0.0	0.0	162.8	0.46
39 Jan	81	Mid	0.0	1.00	100	55	165.2	0.0	0.0	236.0	0.68
06 Mar	117	End	0.0	1.00	100	61	184.5	0.0	0.0	263.5	0.85
29 Mar		End	0.0	1.00	0	30					

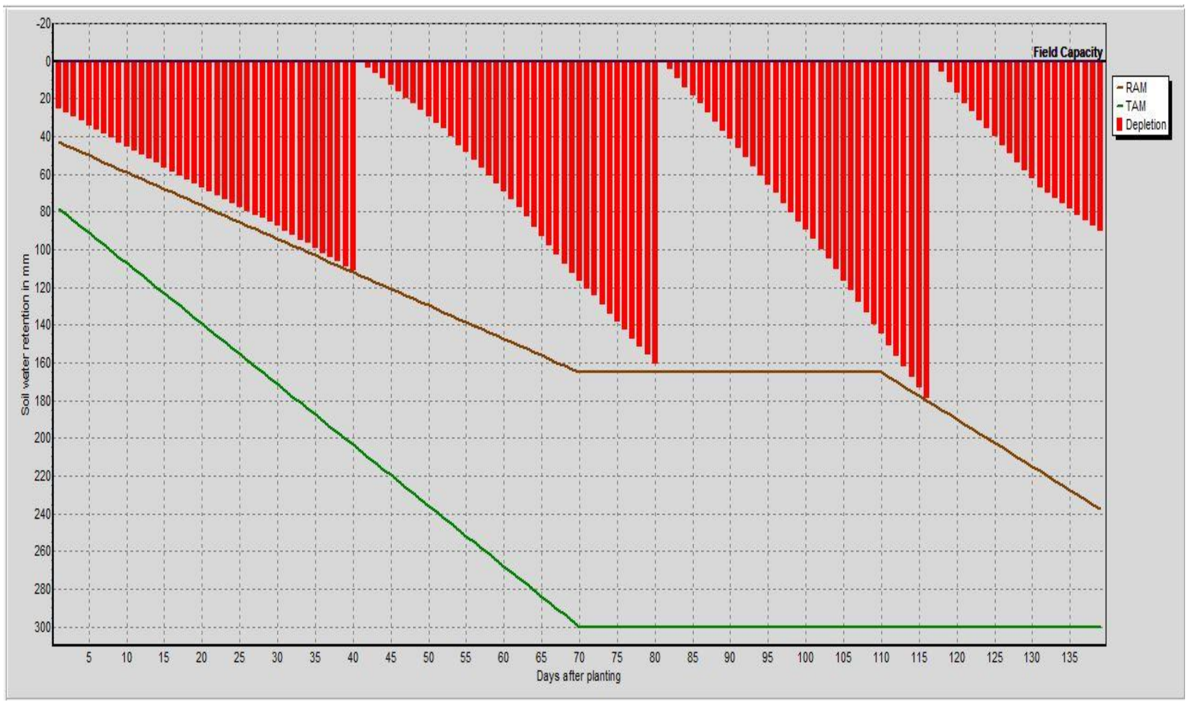

Figure 2. Irrigation schedules for Wheat.

The (TAM) stands for total available moisture, or the amount of total water available to the crop in the data above. The (RAM) is the amount of moisture that is easily available to the crop or the proportion of (TAM) that the plant can obtain from the root zone without experiencing water stress.

IV. CONCLUSION

Based on the above results of crop water requirements and irrigation schedules computed by the software following conclusions can be made:

- The use of FAO CROPWAT model provided precise results pertaining to crop water requirements and irrigation schedules specific to the selected study area based on the seasonal and ecological features of the area.
- The results increase our understanding of the crop water requirements of some of the major crops in Sindh, which will subsequently help improve the management of water resources and the productivity through strategies based on these results.

- Scientific technologies like CROPWAT can accurately measure CWRs and offer crop patterns and crop rotations that farmers can accept.

V. SUGGESTIONS

- The findings of this study can be used by water resource planners for future planning, allowing them to save water while meeting the CWRs, and as a guide for farmers when deciding how much and how often to irrigate the crops under study.
- A strategy should be prepared to estimate the CWRs for the remaining crops cultivated all over Pakistan. It is possible to use such a plan as a basis for agricultural projects. However, practical tests must confirm the use of these software tools.

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VI. REFERENCES

[1] B.A George, S.A Shende, N.S Raghuwanshi (2000), "Development and testing of an irrigation scheduling model", Agricultural Water Management, Volume 46, Issue 2, December 2000, 121-136.

[2] Brooke Mason, Marti Rufi-Salis, Felipe Parada, Xavier Gabarrell, Cyndee Gruden (2019), "Intelligent urban irrigation systems: Saving water and maintaining crop yields" Journal of Agricultural Water Management, Volume 226.C (2019).

[3] CROPWAT Software, FAO, Land and Water Division.

[4] CROPWAT for Windows: User Guide (2001), University of Southampton, Southampton, UK.

[5] CROPWAT Software, FAO, Land and Water Division. (2018): http://www.fao.org/landwater/databases-and-software/cropwat/en/

[6] Ewaid SH, Abed SA, Al-Ansari N. (2019) "Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq". *Water* 11, no. 4: 756. https://doi.org/10.3390/w11040756.

[7] Gheorghe Stancalie, Adriana Marica, Leonidas Toulios, Doorenbos, Pruitt (2010), "Using earth observation data and CROPWAT model to estimate the actual crop evapotranspiration" Physics and Chemistry of The Earth - PHYS CHEM EARTH. 35. 25-30. 10.1016/j.pce.2010.03.013.

[8] Jensen, M.E., R.D. Burman and R.G. Allen, (2016), Handbook of Evaporation and irrigation water requirements" Published by "American Society of Civil Engineers".

[9] Kang Shaozhong, B. Guc, T. Dua, and J. Zhang (2003) "Crop coefficient and ratio of transpiration to evapotranspiration of winter wheat and maize in a semi-humid region" Journal of Water Management Volume 59, Issue 3, 239-254.

[10] Michael AM (2009), "Irrigation Theory and Practice'', 2nd Edition Published by "Vikas Publishing House Pvt Limited".

[11] Muhammad Awais (2016), "Modeling the water and nitrogen productivity of sunflower using OILCROP-SUN model in Pakistan" Field Crops Research. 205. 67-77. 10.1016/j.fcr.2017.01.013.

[12] Muhammad Nazeer (2009), "Simulation of Maize crop under irrigated and rainfed conditions with CROPWAT model" Asian Research Publishing Network ARPN, Journal of Agriculture and Biological Science, Vol 04, No02, Pages 68-73.

[13] National Engineering Handbook, Part 652 (2008), Irrigation guide published by "United States Department of Agriculture (USDA)"

[14] Rao, Muhammad & Ashraf, M. & Bhatti, Ahmad & Abdul Salam, Hafiz & Gul, Nazar (2016) "Water Requirements of Major Crops in Sindh" Published by Pakistan Council of Research in Water Resources (PCRWR) pp:68.

[15] R.G., A.J. Clemmens, L. S. Willardson (2005), "Agro-Hydrology and Irrigation Efficiency". http://www.researchgate.net/publication/228654129 "Agro Hydrology and_Irrigation_Efficiency" ICID Working Group Water and Crops (2005).

[16] R.W Hill, R.J Hanks, J.L Wright (1987), "Crop Yield Models Adapted to Irrigation Scheduling Programs," Proc. Irrigation Systems for the 21st Century Proceedings International Conference on Genetic Algorithms, Portland.

[17] Richard G. Allen, Marvin E. Jensen (2015), "ASCE Manual 70-Second Edition: Evaporation, Evapotranspiration and Irrigation Requirements", Published by the American Society of Agricultural and Biological Engineers.

[18] Shire, Abdishukri & Ayanle, Abdirizak & PG Student, (2020). "Design of A Drip Irrigation system for maize Case Study LWAMPANGA Subcounty, NAKASONGOLA District-UGANDA". International Journal of Emerging Technologies and Innovative Research, Volume 7, Issue 1, Pages 304-319.

[19] T.Sammis, P.Sharma, M.K Shukla, J. Wang, Smith (2012), "A water-balance drip-irrigation scheduling model" Journal of Agricultural Water Management, Volume 113, October 2012, 30-37.

[20] Zhe Gu, Zhiming Qi, Gary Feng, Annandale, English, Singh (2017), "Development of an irrigation scheduling software based on model predicted crop water stress" Computers and Electronics in Agriculture Volume 143, 208-221.