Crop Water and Net Irrigation Requirement of Major Crops Grown in Mandya City using Cropwat 8.0

Madhusudhan M S[1], Vinay S N[2], Savitha J C[2], Nazeer M Gadad[2], Srikanth M N[2]
[1]Assistant Professor, Dept. of Civil Engineering, PESCE, Mandya, Karnataka, India
[2]U.G. Students, Dept. of Civil Engineering, PESCE, Mandya, Karnataka, India

***Abstract*—India being the second most populous country in the world, agriculture is their prime source of livelihood and the country is home to vast agro-ecological diversity. To meet the demands of growing population, agricultural sector is looking for the best management practices for the efficient use of water. In this direction, water requirement of crops and its net irrigation requirement plays a vital role. In the present study, an attempt is made to study the water requirement of the major crops grown in Mandya city using CROPWAT 8.0 software. The main crops grown in the city include Rice, Millet, Sugarcane and Pulses. The crop water requirements for each crop were determined using the data collected from V.C Farm, Mandya district for the period 2010-2020. The four crop growth stages (initial, development, mid and late) were considered for all crops and crop co-efficient (K_c) of various growth stages of the crops were obtained from Irrigation manual for each crop. Reference crop evapotranspiration (ET_o) was determined by using FAO Penman Monteith method and effective rainfall was calculated using USDA S.C method. The study shows that reference crop evapotranspiration, ET_o varied from 2.95mm/day to 6.97mm/day. The crop evapotranspiration (ET_c) and Net irrigation for Rice varied from 0.64mm/day to 8.61mm/day and 1145.8mm, for Millet 1.76mm/day to 7.23mm/day and 366.0mm, for Sugarcane 2.43mm/day to 7.57mm/day and 1164.3mm and for Pulses 2.29mm/day to 8.23mm/day and 361.8mm respectively. This study demonstrates that the CROPWAT model is helpful for computing the crop water requirement which needs for the appropriate administration of water assets.**

Keywords—Agriculture, Evapotranspiration, Crop water requirement, CROPWAT, Effective rainfall.

I. INTRODUCTION

India is basically regarded as the country which is fond of agriculture. Country's economy has been boosted up by the agricultural sector over the past few decades. As per the 2020-2021 estimates, the GDP (Gross Domestic Product) contribution from agriculture alone constitutes around 14% of the country's economy. The agriculture and its allied sectors are very critical to the sustainable development and advancement of the Indian economy. In addition to the fact that it meets the food and wholesome necessities of 1.3 billion Indians, it contributes essentially to creation, work and demand generation through various backward and forward linkages. Also, the role of the agricultural sector helps in lightening destitution and in guaranteeing the sustainable improvement.

Every year, India's food grain production rises, and the country ranks among the world's top producers of wheat, rice, pulses, sugarcane, and cotton. Agriculture necessitates the use of two vital resources: soil and water. It is a well-known truth that the second most important resource for agriculture is water, particularly fresh water which is becoming increasingly scarce as a result of several factors such as industrialization, urbanisation, changing life styles, and people's luxury living standards, among others.

Currently, about 51% of the agricultural area cultivating food grains is covered by irrigation. The rest of the area is dependent on rainfall (rain-fed agriculture). Sources of irrigation include ground water (wells, tube-wells) and surface water (canals, tanks) [1]. There is a need to improve the efficiency of water use, especially in agriculture. Irrigation currently consumes about 84% of the total available water in the country [2].

Agriculture in India has achieved grain self-sufficiency but the production is, resource intensive, cereal centric and regionally biased. The resource intensive ways of Indian agriculture have raised serious sustainability issues too. Increasing stress on water resources of the country would definitely need a realignment and rethinking of policies. Desertification and land degradation also pose major threats to agriculture in the country [3].

Fertilizer and pesticide contamination of water occurs primarily as a result of excessive and improper application, as well as inefficient water use. Competition for water resources is expected to increase as a result of population growth, urbanisation, and climate change, which will have serious impact on agriculture. In order to bring about judicious, optimal allocation and management of water resource it requires the thorough knowledge and understanding of actual evapotranspiration and irrigation water requirement [4].

Because of their conservative mentality, local farmers adopt conventional farming methods, wasting important irrigation water, resulting in water loss and a reduction in production. The farmers are in need of technical support which helps in irrigating crops without compromising with their high yield returns and also by managing the water resources in an effective manner. Hence the role of Crop Water Requirement (CWR) becomes very crucial in agricultural sector as each crop requires varying amount of water depending upon the local conditions. In achieving the above task, a research needs to be carried out in evaluating the water required by the different crops suiting the local conditions.

In order to estimate the CWR and irrigation scheduling, many of the methods are available such as open pan evaporation rate [5]; [6], soil moisture depletion [7], aerodynamic method, ratio of irrigation water to cumulative pan evaporation [8]. But these methods are found to be expensive and tedious. To better estimate crop water requirements, the Food and Agriculture Organization recommends the use of CROPWAT software. CROPWAT is frequently used for crop evapotranspiration, reference crop evapotranspiration, irrigation scheduling, and cropping patterns prediction [9]; [10]; [11]; [12]; [13].

In the present study, an attempt is being made to evaluate the Crop Water Requirement (CWR) required by the commonly grown crops in the Mandya district, Karnataka using the CROPWAT 8.0 software. The following objectives have been set to carry out the research.

1. Establishing the existing cropping pattern in the study area for different cropping season.
2. Estimating the CWR for major crops grown in the study area using CROPWAT 8.0.
3. Validation of the software by comparing the reference crop evapotranspiration (ET_o) values.
4. Developing the Net Irrigation requirement for each crop.

II. STUDY AREA AND DATA USED

The Mandya district lies between North latitude 12^{o} 13^{l} to 13^{o} 04^{l} and East longitudes 76^{o} 19^{l} to 77^{o} 20^{l} falling in the survey of India degree sheet No s-57H and 57D. The region is limited on northwest by Hassan locale, on the North and upper east by Tumakuru region, on the east by Bangalore region and south by Mysore and Chamarajanagar area. Total geographical area of the district is 4961 km^2. The entire district is partitioned into seven taluks going under two development (Mandya, Maddur, Malavalli taluks) and the Pandavapura sub division (Pandavapura, S.R. Patna, Nagamangala and K.R. Pet taluks). The total populace in the area is around 17.64 lakhs with a populace thickness of 355/sq.km. Pastoral populace comprise 14.81 lakhs and urban populace establish 2.83 lakhs. Out of the total geographical area of 4,98,244 ha, 2,48,825 ha forms sowed area. More than half of the total land area in the district is put to agriculture use. The greater part of the total land territory in the area is put to agriculture use. The total irrigated area by K.R Sagar reservoir is 1,16,901 ha and around 16,000 ha by Hemavathi reservoir, rest of the land is irrigated by different sources like tanks, wells and borewells.

In the present study, since the data collected are concentrated in the Mandya urban region, Mandya taluka has been considered for the estimation of CWR its location has been illustrated in the below fig 1. The taluka irrigation is quite intensive as the river Cauvery flows through it and many of the farmers practice dual crop per year. The major crops grown in this region are Sugarcane, Rice, Millet, Pulses, etc.,

The climate data and the Meteorological data are collected and processed from the University of Agricultural Sciences, V C Farm Mandya from a period 2010-2020. The soil data are partially collected from the same university and the partial data are taken from the FAO-56 manual depending upon the crop and finally the crop data are obtained from the FAO-56 manual for different stages of the crops like – initial, development, mid-season, late season, harvest, etc.,

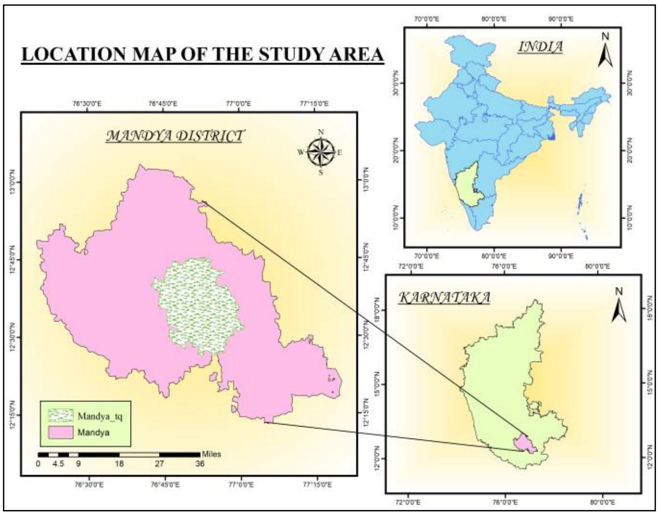


Fig. 1: Location of the Selected study area – Mandya Taluk

Following are the data used in CROPWAT 8.0 software to estimate CWR and Net Irrigation requirement for each crop:

1.	**Climate data**	Sunshine hours, Minimum & Maximum temperature, Humidity and Windspeed.
2.	**Meteorological data**	Rainfall data (Monthly)
3.	**Soil data**	Total available soil moisture, Maximum rain infiltration rate, Maximum rooting depth, Initial soil Moisture depletion, Initial available soil moisture
4.	**Crop data**	Crop coefficient (K_c) values for different stages

III. METHODOLGY

The methodology adopted in the present research has been shown in the below flowchart:

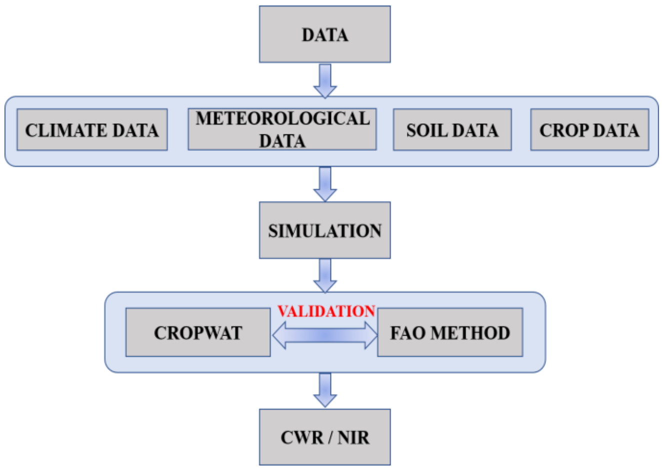


Fig. 2: Work flow process in determining CWR/NIR

A. CROPWAT

In order to achieve the above stated objective, the widely accepted software to predict the CWR and Net irrigation requirement, CROPWAT 8.0 software has been used in the present study. CROPWAT was developed by department of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

Land and Water Resources of FAO. CWR depends on climatic conditions, crop area and type, soil type, growing season and crop production frequencies [14]. CROPWAT software utilises FAO approved Penman-Monteith equation in estimating reference evapotranspiration (ET_o), crop evapotranspiration (ET_c) and irrigation water management in the software.

B. DATA

The data collected from University of Agricultural Sciences; V C Farm is used in the CROPWAT 8.0 for the period 2010-2020. To estimate the reference crop evapotranspiration and effective rainfall the following formulae has been used;

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where,

ET_o = reference evapotranspiration, mm day^{-1} ;

R_n = net radiation at the crop surface, MJ m^{-2}d^{-1};

G = soil heat flux density, MJ m^{-2}d^{-1};

T = mean daily air temperature at 2 m height, °C;

u_2 = wind speed at 2 m height, ms^{-1}

e_s = saturation vapor pressure, kPa;

e_a = actual vapor pressure, kPa;

$e_s - e_a$ = saturation vapor pressure deficit, kPa;

The effective rainfall calculation in CROPWAT offers many methods, out of which for the present study USDA soil conservation service method is employed, which is illustrated as below:

$$P_{eff} = \frac{[P \times (125 - 0.2 \times P)]}{125} \text{ for } P \leq 250mm \quad (2)$$

$$P_{eff} = 125 + 0.1 \times P \text{ for } P > 250mm \quad (3)$$

The soil data and the crop data necessary to run the software has been partly obtained by the V C farm and the partly by the default values as specified by the FAO manual for the different crops.

C. VALIDATION

Validation of the CROPWAT model is done by comparing the Evapotranspiration (ET_o) values as obtained by the software with the manually calculated values by applying Penman-Monteith equation. This is to verify if the model is behaving with the actual results or not.

D. CROP WATER REQUIREMENT

The Crop water requirement (ET_c) for the various crops is obtained by multiplying reference crop evapotranspiration (ET_o) values with the Crop co-efficients (K_c). The Kc values for the different growth stages for a crop is obtained by the FAO-56 manual. The CWR is obtained as;

$$ET_c = K_c \times ET_o \quad (4)$$

IV. RESULTS AND DISCUSSIONS

A. Effective Rainfall

The rainfall data collected from V C Farm for the period 2010-2020 has been averaged to get the annual average rainfall for each of the months. The effective rainfall (P_{eff}) for the Mandya city has been calculated by using USDA-SCS method and has been tabulated in the below table.

TABLE I. EFFECTIVE RAINFALL BY USDA-SCS METHOD

Month	Rainfall (mm)	Effective Rainfall (mm)
January	1.5	1.5
February	0.7	0.7
March	8.8	8.7
April	66.8	59.7
May	145.6	111.7
June	40.2	37.6
July	45.3	42.0
August	80.1	69.8
September	136.7	106.8
October	162.6	120.3
November	37.4	35.2
December	4.3	4.3
TOTAL	**730.0**	**598.2**

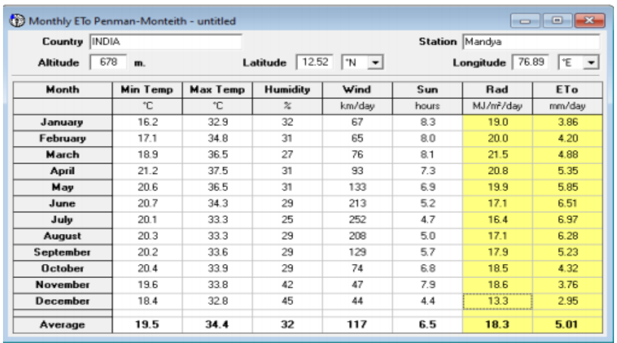
B. Reference Evapotranspiration (ET_o)

The ET_o calculations for each month are carried out using MS-Excel for the study area as per FAO-56 Penman's method and checked by the CROPWAT software and has been presented in the below table-II. The results shows that ET_o value ranges from 3.21 mm/day in December to 6.54 mm/day in the month of June.

TABLE II. CALCULATED ET_O VALUES IN MS-EXCEL

Month	ET_o (mm/day)
January	3.83
February	4.72
March	5.08
April	5.70
May	6.01
June	6.54
July	6.39
August	6.02
September	5.86
October	4.26
November	4.25
December	3.21

The average input data of 10 years collected from V C Farm Mandya, which is the nearest station for the study area is used in CROPWAT software to calculate the ET_o in mm/day and has been presented in the below fig-3.


Monthly ETo Penman-Monteith - untitled
Country INDIA Station Mandya
Altitude 678 m. Latitude 12.52 °N Longitude 76.89 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	16.2	32.9	32	67	8.3	19.0	3.86
February	17.1	34.8	31	65	8.0	20.0	4.20
March	18.9	36.5	27	76	8.1	21.5	4.88
April	21.2	37.5	31	93	7.3	20.8	5.35
May	20.6	36.5	31	133	6.9	19.9	5.85
June	20.7	34.3	29	213	5.2	17.1	6.51
July	20.1	33.3	25	252	4.7	16.4	6.97
August	20.3	33.3	29	208	5.0	17.1	6.28
September	20.2	33.6	29	129	5.7	17.9	5.23
October	20.4	33.9	29	74	6.8	18.5	4.32
November	19.6	33.8	42	47	7.9	18.6	3.76
December	18.4	32.8	45	44	4.4	13.3	2.95
Average	19.5	34.4	32	117	6.5	18.3	5.01

Fig. 3: ET_o values in CROPWAT software

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

A comparison on both the ET_o values has been made to validate the model. Below figure shows the comparative results of the ET_o calculations, from which it is clear that the calculated and simulated values almost matches and we can conclude that, CROPWAT software can be used effectively in estimating the ET_o values and also for the use of predicting CWR for different crops.

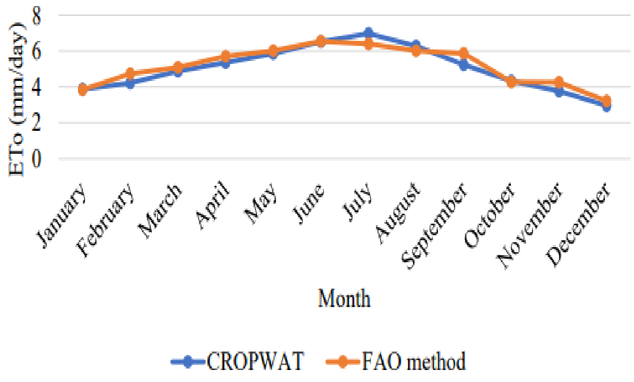


Fig. 4: ET_o comparison between FAO method and CROPWAT software

C. Crop Water Requirement

The amount of water needed by each crop as the depth to meet the water loss through evapotranspiration can be referred as CWR. The CWR for various crops have been calculated by multiplying with their respective crop co-efficients as discussed in the above sections. The results of the CWR for each crop selected in the study area has been presented as below:

1) Pulses:

The total CWR for Pulses was found to be 609.7mm for the decade 2010-2020, during which the effective Rainfall was observed to be 208.5mm, hence Rainfall feeds insufficient water to the crop. Therefore additional 424.1mm of water is required for the Pulses growth. The CWR for various growth stages of Pulses have been presented in the below table and the relationship between the CWR, Effective rainfall, and Irrigation Requirements of the Pulses at various growing stages have been illustrated in the fig 5.

TABLE III. CWR & IRRIGATION REQUIREMENT FOR PULSES

CROP	Growth Stages	Kc	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irr. Req mm/dec
PULSES	Initial	0.40	2.34	7.0	13.0	7.0
		0.40	2.43	26.7	33.0	0.0
	Development	0.43	2.68	26.8	18.3	8.5
		0.64	4.18	41.8	8.8	32.9
		0.90	5.97	59.7	10.6	49.1
	Mid-Season	1.13	7.74	77.4	12.8	64.7
		1.16	8.23	82.3	12.9	69.3
		1.16	7.92	87.1	16.4	70.8
		1.16	7.57	75.7	19.9	55.8
	Late Season	1.10	6.92	69.2	22.9	46.4
		0.72	4.25	46.7	27.1	19.6
		0.41	2.29	9.2	12.9	0.0
			TOTAL	**609.7**	**208.5**	**424.1**

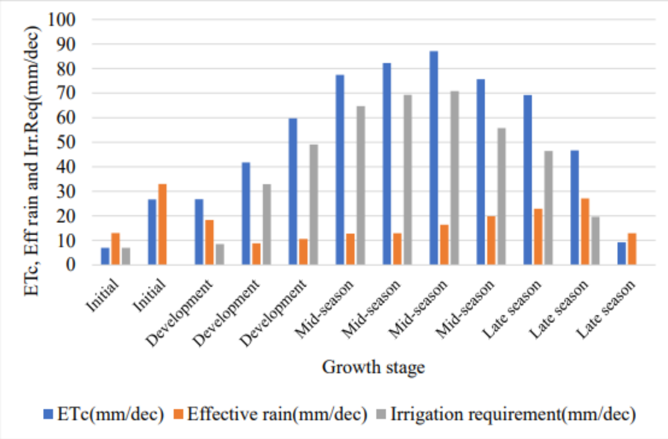


Fig. 5: ET_c, P_{eff} & Irrigation req. for PULSES

2) Millets:

The total CWR for Millets was found to be 518.3 mm for the decade 2010-2020, during which the effective Rainfall was observed to be 193.1 mm. Additional amount of 350.2 mm of water is required for the Millets growth. The CWR for various growth stages of Millets have been presented in the below table and the relationship between the CWR, Effective rainfall, and Irrigation Requirements of the Millets at various growing stages have been illustrated in the fig 6.

TABLE IV. CWR & IRRIGATION REQUIREMENT FOR MILLETS

CROP	Growth Stages	Kc	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irr. Req mm/dec
MILLETS	Initial	0.30	1.76	5.3	13.0	5.3
		0.30	1.82	20.0	33.0	0.0
	Development	0.43	2.71	27.1	18.3	8.8
		0.72	4.68	46.8	8.8	38.0
	Mid-Season	0.98	6.53	65.3	10.6	54.7
		1.02	7.04	70.4	12.8	57.6
		1.02	7.23	72.3	12.9	59.4
		1.02	6.97	76.6	16.4	60.3
	Late Season	0.98	6.38	63.8	19.9	43.9
		0.72	4.52	45.2	22.9	22.3
		0.43	2.55	25.5	24.7	0.0
			TOTAL	**518.3**	**193.1**	**350.2**

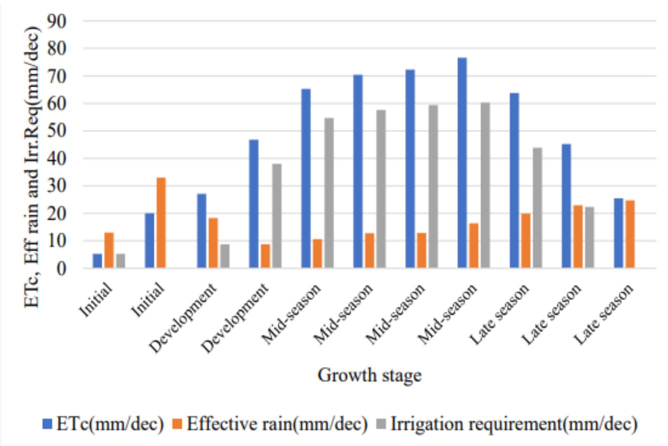


Fig. 6: ET_c, P_{eff} & Irrigation req. for MILLETS

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

3) Sugarcane:

The total CWR for Sugarcane was found to be 1796.1 mm for the decade 2010-2020, during which the effective Rainfall was observed to be 598.8 mm. Hence, 1202.5 mm of additional water is required for the effective growth of sugarcane. The CWR for various growth stages of Sugarcane have been presented in the below table and the relationship between the CWR, Effective rainfall, and Irrigation Requirements of the Sugarcane at various growing stages have been illustrated in the fig 7.

TABLE V. CWR & IRRIGATION REQUIREMENT FOR SUGARCANE

CROP	Growth Stages	Kc	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irr. Req mm/dec
SUGARCANE	Initial	0.76	4.43	13.3	13.0	0.0
		0.40	2.43	26.7	33.0	0.0
		0.40	2.52	25.2	18.3	6.9
	Development	0.41	2.69	26.9	8.8	18.1
		0.53	3.53	35.3	10.6	24.7
		0.67	4.58	45.8	12.8	33.1
		0.80	5.67	56.7	12.9	43.8
		0.95	6.44	70.8	16.4	54.5
		1.09	7.09	70.9	19.9	51.0
	Mid-Season	1.20	7.57	75.7	22.9	52.8
		1.22	7.23	79.5	27.1	52.4
		1.22	6.80	68.0	32.2	35.8
		1.22	6.37	63.7	36.7	27.0
		1.22	6.00	60.0	37.8	22.0
		1.22	5.63	56.3	41.7	14.6
		1.22	5.26	52.6	44.7	7.9
		1.22	5.03	55.4	33.7	21.6
		1.22	4.81	48.1	19.5	28.6
		1.22	4.58	45.8	9.2	36.6
		1.22	4.25	42.5	6.6	35.9
		1.22	3.76	37.6	4.0	33.6
		1.22	3.35	33.5	0.1	33.4
		1.22	3.80	41.9	0.2	41.6
		1.22	4.34	43.4	0.8	42.6
		1.22	4.71	47.1	0.4	46.6
		1.22	4.85	53.3	0.4	52.9
		1.22	4.98	49.8	0.1	49.7
	Late Season	1.20	5.03	50.3	0.0	50.3
		1.15	5.10	40.8	0.7	40.1
		1.11	5.14	51.4	0.7	50.8
		1.06	5.15	51.5	0.9	50.6
		1.00	5.05	55.5	7.2	48.3
		0.95	4.93	49.3	14.2	35.1
		0.90	4.81	48.1	19.9	28.2
		0.85	4.69	46.9	25.7	21.2
		0.80	4.55	45.5	35.4	10.0
		0.76	4.43	31.0	30.2	0.0
			TOTAL	**1796.1**	**598.8**	**1202.5**

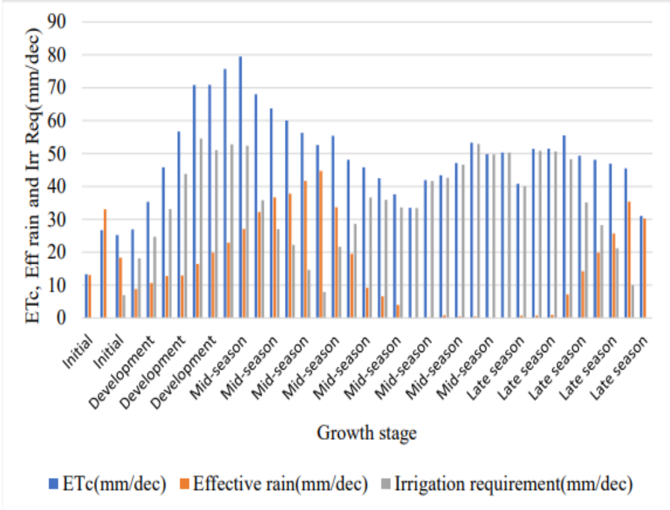


Fig. 7: ET_c, P_{eff} & Irrigation req. for SUGARCANE

4) Rice:

The total CWR for Rice was found to be 1017.3 mm for the decade 2010-2020, during which the effective Rainfall was observed to be 339.8 mm. So, 830.0 mm of additional water is required for growing Rice. The CWR for various growth stages of Rice have been presented in the below table and the relationship between the CWR, Effective rainfall, and Irrigation Requirements of the Rice at various growing stages have been illustrated in the fig 8.

TABLE VI. CWR & IRRIGATION REQUIREMENT FOR RICE

CROP	Growth Stages	Kc	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irr. Req mm/dec
RICE	Nursery	1.20	0.64	1.9	6.0	1.90
		1.16	2.23	22.3	25.7	25.0
		1.06	6.05	60.5	35.4	25.1
	Initial	1.08	6.29	62.9	43.2	141.5
		1.10	6.68	73.5	33.0	40.5
	Development	1.10	6.94	69.4	18.3	51.1
		1.14	7.40	74.0	8.8	65.2
		1.18	7.84	78.4	10.6	67.8
	Mid-Season	1.21	8.34	83.4	12.8	70.6
		1.22	8.61	86.1	12.9	73.2
		1.22	8.29	91.2	16.4	74.8
		1.22	7.93	79.3	19.9	59.4
	Late Season	1.21	7.59	75.9	22.9	53.1
		1.15	6.85	75.3	27.1	48.2
		1.09	6.11	61.1	32.2	28.9
		1.05	5.52	22.1	14.7	3.70
			TOTAL	**1017.3**	**339.8**	**830.0**

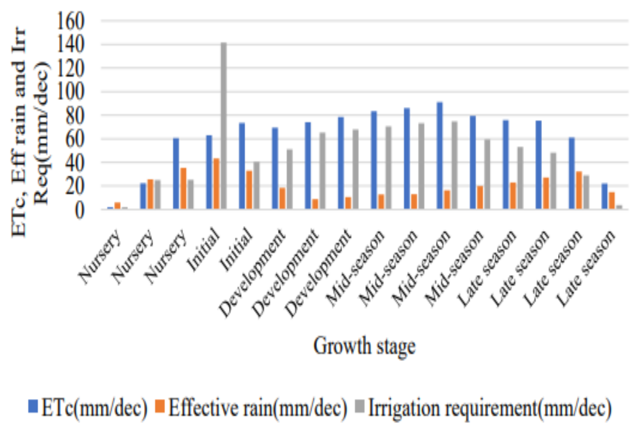


Fig. 8: ET_c, P_{eff} & Irrigation req. for RICE

D. Irrigation Scheduling

CROPWAT software allows the users to select on how irrigation schedule is to be planned. Many of the options are available in selecting Irrigation timing, Irrigation application and Irrigation efficiency. In the present case for all the crops, timing is selected as Irrigation at critical depletion (100%), applying water to fields when it reaches the field capacity of the soil at 100%. Also, the irrigation efficiency is assumed to be 70%. The Net irrigation requirement and Gross irrigation requirement for the crops considered in the present study has been illustrated in the below table.;

TABLE VII. NIR & GIR OF MAJOR CROPS GROWN IN MANDYA

Sl. No	CROPS	Duration (Days)	NIR (mm)	GIR (mm)
1.	Pulses	110	361.8	516.9
2.	Millet	105	366.0	522.9
3.	Sugarcane	365	1164.3	1663.2
4.	Rice	120	573.0	818.6

V. CONCLUSIONS

Pulses, Millets, Sugarcane, and Rice are among the principal crops farmed by irrigation farmers in Mandya city, and their crop water demand was evaluated using the FAO CROPWAT 8.0 model. From the results, it was evident that, the effective rainfall was lower than the crop water requirements for all the crops grown in the study area. The NIR and GIR required for all the crops for the irrigation timing and application considering 70% of the irrigation efficiency have been presented in the table VII.

The findings of this study can assist policymakers and water resource managers prepare for the future and save water while meeting agricultural water requirements. It is vital to identify strategies to save water in the present scenario in order to satisfy the irrigation requirements for the rising population and the stress on larger productivity requirements. The study approach will be useful in determining the year with the most effective rainfall and the least irrigation water consumption, thereby water saved from these can be utilized in bringing more area under irrigation which in turn helps in producing more crops and more returns. Also, farmers must be educated in adopting most advanced irrigation techniques such as drip, sprinkler system, etc., which saves huge amount of water rather than using the traditional irrigation systems.

ACKNOWLEDGMENT

Authors thank all the staff members of the University of Agricultural Sciences, V.C Farm Mandya for their continuous help and support provided during this research work. Authors also thank all the staff members of the Department of Civil Engineering, PESCE, Mandya for their valuable suggestions and input provided during this research work which helped us in improving our work.

REFERENCES

[1] Pocket Book of Agricultural Statistics, 2015, Ministry of Agriculture and Farmers Welfare, Accessed on 15th May 2021. (http://eands.dacnet.nic.in/PDF/PocketBook2015.pdf).

[2] (Raising Agricultural Productivity and Making Farming Remunerative for Farmers", NITI Aayog, December 16, 2015,) http://www.niti.gov.in/writereaddata/files/document_publication/RAP3.pdf.

[3] (http://www.fao.org/india/fao-in-india/india-at-a-glance/en/) . Accessed on 15th May 2021.

[4] Banerjee S, Chatterjee S, Sarkar S & Jena S (2016). Projecting future crop Evapotranspiration and Irrigation requirement of Potato in Lower Gangetic Plains of India using the CROPWAT 8.0 Model. Potato Research, 59 (4), pp. 313-327.

[5] Singh BP. Effect of irrigation on the growth and yield of okra. Horticulture Science. 1987; 22, pp. 879-880.

[6] Manjunath BL, Mishra PK, Rao JV, Reddy GS. Water requirement of vegetables in a dry-land watershed. Indian Journal of Agricultural Sciences. 1994; 6(12), pp. 845-846.

[7] Home PG, Kar S, Panda RK. Effect of irrigation scheduling on water and nitrogen balances in the crop root zone. Zeitschrift fuer Bewasserungswirtschaft. 2000; 35(2), pp. 223-235

[8] Aiyelaagbe IOO, Ogbonnaya FC. Growth, fruit production and seed yield of okra (Abelmoschus esculentus L.) in response to irrigation and mulching. Research Bulletin No. 18. National Horticultural Research Institute, Ibadan, 1996.

[9] Song L, Oeurng, Hornbuckle J. Assessment of rice water requirement by using CROPWAT model. In linea], En: The 15th Science Council of Asia Board Meeting and international Symposium, 2016.

[10] Tan M, Zheng L. Different Irrigation Water Requirements of Seed Corn in Heihe River Basin. Water. 2017; 9(8):606.

[11] Abirdew S, Mamo G, Mangesha M. 2018. Determination of Crop Water Requirements for Maize in Abshege Woreda, Gurage Zone, Ethopia. Journal of Earth Science and Climate Change. Vol. 9, Issue 1, ISSN: 2157-7617.

[12] Ewaid SH, Abed SA, Al-Ansari N. 2016. Crop Water Requirements and Irrigation Schedules for Major Crops in Southern Iraq. Water. 11(4), 756.

[13] Moeski O, Murray-Hudson M, Kashe K. 2019. Crop Water and Irrigation Requirements of Jatropha Crop in Botswana: applying the CROPWAT Model. Agricultural Water Management. Vol 225, 105754.

[14] George B, Shende S, Raghuwanshi N. Development and testing of an irrigation scheduling model. Agricultural Water Management. 2000; 46(2), pp. 121-136.

[15] D.M.Onyancha, C.K.K Gachene, G.Kiranchi, 2017. FAO-CROPWAT model-Based Estimation of the crop water requirement of major crops in Mwala, Machakos country. Researchjournali's Journal of Ecology, vol.4, Issue:2, pp. 1-13.

[16] Manasa HG, Anand V. Shivapur, 2016. Implications of climate change on crop water Requirements in Hukkeri Taluk of Belgavi District, Karnataka, India. International Journal of Research in Engineering & Technology. Vol.5, ISSN:2319-1163, pp. 236-241.

[17] Nithya.K. B, Shivapur AV, 2016. Study on water requirement of selected crops under Tarikere Command Area using CROPWAT Irrigation & Drainage Systems Engineering. Vol.5, ISSN: 2168-9768, pp. 1-4.