Available online at http://www.ijims.com
ISSN: 2348 – 0343

Determination of Water Requirements of Main crops in the Tank Irrigation Command area using CROPWAT 8.0.

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Abstract

A study was carried out to determine the water requirement of main crops in the perumal tank irrigation command area in Cuddalore district. The main crops include rice, groundnut, and sugarcane. The crop water requirements were determined using 15 year climatic data using CROPWAT 8.0. The seven crop growth stages (nursery,nursery/land preparation,land prepearation,initial,development,mid season,late season) and three decades (I,II,III) were considered for all crops. Crops were planted during 2012 kuruvai season and the crop coefficient was determined for each crop. Reference Crop Evapotranspiration (ET_o) was determined using the FAO Penman Monteith method and the effective rainfall was calculated using USDA S.C. Method. The study shows that for the study area, reference evapotranspiration (ET_o) varied from 3.67 to 6.42 mm/day and the effective rainfall varied from 12.8 to 166.8 mm. Crop evapotranspiration (ET_o) and the crop water requirement for Rice varied from 0.74 mm/day to 6.23 mm/day and 0.0 mm/dec to 244 mm/dec, for groundnut 2.4 mm/day to 5.03 mm/day and 0.0 mm/dec to 29.2 mm/dec, for Rice (Navarai) 0.45 mm/day to 6.49 mm/day and 0.0 mm/dec to 152.5 mm/dec, for Groundnut (Navarai) 1.78 mm/day to 5.79 mm/day and 4.1 mm/dec to 54.8 mm/dec and for Sugarcane 2.07 mm/day to 6.57 mm/day and 0.0 mm/dec to 63.9 mm/dec respectively. The peak water requirement was 1.11 l/s/ha or 9.6 mm/day with an application efficiency of 70%.

Keywords: Crop water requirement, Reference Crop Evapotranspiration, Crop Evapotranspiration, CROPWAT, Irrigation water requirement and Effective rainfall.

Introduction

The continuing growth of world population places new demands on water resources every day. Improved management and planning of water resources are needed to ensure properuse and distribution of water among competing users. Fortunately there are opportunities for conservation and significantly more effective use of water use by the world's largest user, agriculture (Aghdasi, 2010). Accurate planning and delivery of the necessary amount of water in time and space can conserve water. The primary objective of irrigation is to apply water to maintain crop Evapotranspiration (ET_c) when precipitation is insufficient. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Each and every crop has individual water requirements. Net irrigation water requirement (NIWR)is the quantity of water necessary for crop growth. It is expressed in millimeters per year or in m3/ha per year (1 mm = 10 m3/ha). It depends on the cropping pattern and the climate. Information on irrigation efficiency is necessary to be able to transform NIWR into gross irrigation water requirement (GIWR), which is the quantity of water to be applied in reality, taking into account water losses. Multiplying GIWR by the area that is suitable for irrigation gives the total water requirement for that area. 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 (FAO, 1992). Water use requirement for same crop varies under different weather conditions. The objective of this study was to determine crop water requirements of rice, groundnut and sugarcane.

Materials and Methods

Study area: Perumal tank is located in the Kurinjipadi taluk of Cuddalore district in Tamilnadu.It is located 29km east of Neyveli and 16.7 km south of Cuddalore. The length of the tank bund is 16 km with total perimeter of 31.31 km the tank is located between the geographical coordinates latitude- 11°35'longitude-79°40'. The source of the water for this tank is from Gadilam River and Walajah tank as well as from the Neyveli mine. Perumal Tank under Sethiathope Anicut System is one of the major tanks with an ayacut of 2632 ha. The Length of its bund is 16.286 km. The original capacity of the tank was about 16.25 Mm^3. The water spread area of the tank is 14.07 km^2. It has got 11 sluices, the sill level of the highest sluice is + 12.00 m (Andarmullipallam Channel) the sill level of lowest sluice is +6.30 m (Omaiyan Channel). It has got two surplus weirs of length 122.75 m. and 91.35m. The total supplying capacity of the two surplus weirs is 752 m^3/s. Water available in tank allows for production of rice, groundnut and sugarcane for the whole year (kuruvai and navarai season).

Stages of growth: Three decades and seven stages of plant growth were used in crop water requirement determination. The decades include I, II and III while the crop growth stages include nursery, nursery/land preparation, land preparation, initial stage, development stage, mid-season stage and late season stage.

Crop water requirement estimation: The term crop water requirement is defined as the "amount of water required to compensate the evapotranspiration loss from the cropped field". "Although the values for crop evapotranspiration 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 is lost through evapotranspiration"[Allen et al. 1998]. FAO (2005) defined crop water requirement (CWR) for a given crop as:

$$CWR_i = \sum_{t=0}^{T}(kc_i . ET_O - P_{eff}) \quad \text{Unit mm;}$$

where kc_i is the crop coefficient of the given crop i during the growth stage t and where T is the final growth stage. $ET_c = K_c * ET_o$ where K_c = crop coefficient and ET_o = reference crop Evapotranspiration (mm/day) is as defined in equation below as:

$$ET_o = \frac{0.408\ \Delta(Rn-G) + \gamma\frac{900}{T+273}u_2(e_s-e_a)}{\Delta + \gamma(1+0.34u_2)} \quad \text{Unit mm/day;}$$

where ETo = reference evapotranspiration [mm day^{-1}], R_n = net radiation at the crop surface [MJ m^{-2} day^{-1}], G = soil heat flux density [MJ m^{-2} day^{-1}], T = mean daily air temperature at 2 m height [°C], u_2 = wind speed at 2 m height [m s^{-1}], e_s = saturation vapour pressure [kPa], e_a = actual vapour pressure [kPa], [es – ea] = saturation vapour pressure deficit [kPa],Δ = slope vapour pressure curve [kPa $°C^{-1}$], γ = psychrometric constant [kPa °C-1]. The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water). The climatic data used for the calculations were collected from a meterological station located at palur.

Results

Soil properties: The soils in the study are predominantly coarse textured ranging from loamy to sandy in the surface and from sandy loam to clay in the sub surface. The soil pH ranges from 5.4 to 5.9 showing the soil is mostly acidic. The cation exchange capacity was generally high from 30.21 to 38 meq/100g, which means that the soils available have high potentials for retaining plant nutrients.

Reference crop Evapotranspiration: The results obtained from the 15 year climatic data was used in the CROPWAT 8.0 to determine the reference crop evapotranspiration (ET_o) for the study area varied from 3.66 mm/day in December to 6.42 mm/day in May (Table 1). The results show that ET_o was lowest during the rainy season to highest during the summer season.

Crop water requirement: Results show that for rice, crop evapotranspiration (ET_c) and the crop water requirement varied from 0.74 mm/day to 6.23 mm/day and 0.0 mm/dec to 244 mm/dec respectively (Table 3). For groundnut, crop evapotranspiration (ET_c) and the crop water requirement varied from 2.4 mm/day to 5.03 mm/day and 0.0 mm/dec to 29.2 mm/dec respectively (Table 4). For rice (navarai), crop evapotranspiration (ET_c) and the crop water requirement varied from 0.45 mm/day to 6.49 mm/day and 0.0 mm/dec to 152.5 mm/dec respectively (Table 5). For groundnut (navarai), crop evapotranspiration (ET_c) and the crop water requirement varied from 1.78 mm/day to 5.79 mm/day and 4.1 mm/dec to 54.8 mm/dec respectively (Table 6).For sugarcane, crop evapotranspiration (ET_c) and the crop water requirement varied from 2.07 mm/day to 6.57 mm/day and 0.0 mm/dec to 63.9 mm/dec respectively (Table 7).

Irrigation Scheming: The estimation of actual irrigation requirement of the perumal tank command area was carried out (Table 8). This is summation of the NIR2 values from January to December. Using an irrigation application frequency of 70%, the gross water requirement of 1301.8 mm/year was obtained. Therefore the entire land area of 2632 ha will require 34.26 MCM. The tank capacity is 18.01 MCM. The tank was filled twice in a year and thus the volume of 36.02 MCM is sufficient to irrigate the irrigation water requirement for the entire command area, which is 36.02 MCM. The results show that the tank can conveniently supply the water required for irrigation in the area.

Discussion

The results showed that reference and crop evapotranspiration (ETo and ETC) were higher for crops with longer growing season than for those with shorter grower season. Also ETo and ETC were more during the summer season than the rainy season. FAO (2005) reported that crops grown in the summer season needs more water than those grown during the rainy season. The range of water requirement for lowland rice was particularly high because the water requirement during the peak rainy season (due to large amount of rain water) was very low while that of the peak dry season (no rainfall) was very high.

Conclusion

The study shows that the dam can conveniently supply the water required for irrigation in the area used at present and also in the entire land area. The results obtained from the study can be used as a guide by farmers for selecting the amount and frequency of irrigation water for the main crops.

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Tables and Figures

Table 1. Reference Crop Evapotranspiration

Country: India		Station: Palur		Altitude: 20m		Lat: 11.50^{o}N	Long: 79^{o}E
Month	Max Temp (^{o}C)	Min Temp (^{o}C)	Humidity (%)	Wind (km/day)	Sunshine (hours)	Radiation (MJ/m^2/day)	ET_o (mm/day)
January	30	23	77	120	9	20.2	4.09
February	31	23	76	96	9	21.6	4.35
March	34	27	76	120	11	26	5.70
April	35	28	76	120	10	25	5.70
May	39	31	71	144	10	24.6	6.42
June	38	30	66	168	8	21.2	6.04
July	35	28	67	144	8	21.3	5.49
August	35	28	71	120	7	20.1	5.02
September	35	27	76	120	8	21.4	5.13
October	31.5	26.5	81	96	8	20.4	4.43
November	32	25.5	84	120	7	17.6	3.86
December	30	24	80	144	7	16.9	3.66
Year	33.8	26.8	75	126	8.5	21.3	4.99

where ET_o = Reference Crop Evapotranspiration computed using the FAO Penman-Monteith Method

Table 2. Effective Rainfall

Station : Perumal Tank	Method: USDA S.C. Method	
Month	Rainfall (mm)	Effective Rainfall (mm)
January	13.1	12.8
February	24.1	23.2
March	24.1	23.2
April	26.3	25.2
May	46.9	43.4
June	15.5	15.1
July	43.2	40.2
August	78.5	68.6
September	85.3	73.7
October	278.6	152.9
November	418.2	166.8
December	190.9	132.6
Total	1244.7	777.6

Table 3. Evapotranspiration and Irrigation Requirement for Rice

Station: Palur		Planting Date: 2 July 2012			Crop: Rice		
Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rain mm/dec	IR mm/dec
Jun	1	N	1.20	0.74	6.7	5.9	0.1
Jun	2	N/LP	1.08	5.86	58.6	2.5	148.4
Jun	3	N/LP	1.06	6.23	62.3	6.2	244.0
Jul	1	I	1.10	6.22	62.2	10.5	51.7
Jul	2	I	1.10	6.04	60.4	13.3	47.1
Jul	3	D	1.10	5.89	64.8	16.5	48.3
Aug	1	D	1.11	5.76	57.6	20.5	37.2
Aug	2	D	1.12	5.63	56.3	24.0	32.3
Aug	3	M	1.13	5.69	62.6	24.2	38.5
Sept	1	M	1.13	5.74	57.4	21.7	35.7
Sept	2	M	1.13	5.78	57.8	21.1	36.8
Sept	3	L	1.13	5.51	55.1	31.0	24.1
Oct	1	L	1.09	5.06	50.6	44.2	6.4
Oct	2	L	1.02	4.53	45.3	54.0	0.0
Oct	3	L	0.96	4.09	36.8	44.6	0.0
				Total	794.6	340.1	750.6

where N = Nursery Stage, N/LP = Nursery/Land Preparation Stage, I = Initial Stage, D = Development Stage, M = Mid-Season Stage, L = Late Season Stage, K_c = Crop coefficient, ETc = Crop Evapotranspiration, IR = Irrigation Requirement

Table 4. Evapotranspiration and Irrigation Requirement for Ground nut

Station: Palur		Planting Date: 2 July 2012			Crop: Groundnut		
Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rain mm/dec	IR mm/dec
Jul	1	I	0.45	2.55	23.0	9.5	12.4
Jul	2	I	0.45	2.47	24.7	13.3	11.4
Jul	3	I	0.45	2.40	26.4	16.5	9.9
Aug	1	D	0.52	2.71	27.1	20.5	6.6
Aug	2	D	0.66	3.29	32.9	24.0	8.9
Aug	3	D	0.79	4.02	44.2	24.2	20.0
Sept	1	M	0.93	4.75	47.5	21.7	25.8
Sept	2	M	0.98	5.03	50.3	21.1	29.2
Sept	3	M	0.98	4.80	48.0	31.0	17.0
Oct	1	M	0.98	4.57	45.7	44.2	1.5
Oct	2	M	0.98	4.34	43.4	54.0	0.0
Oct	3	L	0.94	4.00	44.0	54.5	0.0
Nov	1	L	0.80	3.26	32.6	55.6	0.0
Nov	2	L	0.68	2.62	20.9	46.3	0.0
				Total	510.5	436.2	142.7

where I, D, M, L, K_c, ETc, IR are defined as in Table 3.

Table 5. Evapotranspiration and Irrigation Requirement for Summer Rice

Station: Palur		Planting Date: 2 Jan 2013			Crop: Rice		
Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rain mm/dec	IR mm/dec
Dec	1	N	1.20	0.45	3.6	40.6	0.0
Dec	2	N/LP	1.09	3.21	32.1	48.2	53.0
Dec	3	N/LP	1.06	4.05	44.6	33.6	152.5
Jan	1	I	1.10	4.33	43.3	11.0	32.3
Jan	2	I	1.10	4.50	45.0	0.0	45.0
Jan	3	D	1.10	4.61	50.7	1.9	48.8
Feb	1	D	1.11	4.66	46.6	6.9	39.7
Feb	2	D	1.12	4.75	47.5	8.2	39.3
Feb	3	M	1.12	5.30	42.4	8.0	34.4
Mar	1	M	1.12	5.95	59.5	7.7	51.9
Mar	2	M	1.12	6.49	64.9	7.7	57.3
Mar	3	M	1.12	6.46	71.0	7.9	63.1
Apr	1	L	1.10	6.26	62.6	7.7	54.9
Apr	2	L	1.05	5.97	59.7	7.6	52.1
Apr	3	L	1.00	5.92	59.2	9.9	49.3
May	1	L	0.97	6.06	6.1	1.4	6.1
				Total	738.9	208.3	779.6

where I, D, M, L, K_c, ETc, IR are defined as in Table 3.

Table 6. Evapotranspiration and Irrigation Requirement for Ground nut (Navarai)

Station: Palur		Planting Date: 2 Jan 2013			Crop: Groundnut		
Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rain mm/dec	IR mm/dec
Jan	1	I	0.45	1.78	16.0	9.9	5.0
Jan	2	I	0.45	1.84	18.4	0.0	18.4
Jan	3	I	0.45	1.88	20.7	1.9	18.7
Feb	1	D	0.52	2.20	22.0	6.9	15.1
Feb	2	D	0.66	2.80	28.0	8.2	19.8
Feb	3	D	0.78	3.69	29.5	8.0	21.5
Mar	1	M	0.90	4.79	47.9	7.7	40.2
Mar	2	M	0.99	5.72	57.2	7.7	49.5
Mar	3	M	0.99	5.70	62.7	7.9	54.8
Apr	1	M	0.99	5.64	56.4	7.7	48.7
Apr	2	M	0.99	5.64	56.4	7.6	48.7
Apr	3	L	0.97	5.79	57.9	9.9	48.0
May	1	L	0.86	5.37	53.7	13.9	39.8
May	2	L	0.72	4.72	47.2	16.6	30.6
May	3	L	0.65	4.13	4.1	1.2	4.1
				Total	578.1	115.1	463.1

where I, D, M, L, K_c, ETc, IR are defined as in Table 3.

Table 7. Evapotranspiration and Irrigation Requirement for Sugarcane

Station: Palur		Planting Date: 12 July 2012			Crop: Sugarcane		
Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rain mm/dec	IR mm/dec
Jul	2	I	0.66	3.60	32.4	12	3.6
Jul	3	I	0.40	2.13	23.5	16.5	7.0
Aug	1	I	0.40	2.07	20.7	20.5	0.2
Aug	2	D	0.47	2.34	23.4	24.0	0.0
Aug	3	D	0.60	3.01	33.1	24.2	8.9
Sept	1	D	0.72	3.69	36.9	21.7	15.2
Sept	2	D	0.85	4.34	43.4	21.1	22. 3
Sept	3	D	0.97	4.74	47.4	31.0	16.4
Oct	1	M	1.09	5.07	50.7	44.2	6.6
Oct	2	M	1.13	5.01	50.1	54.0	0.0
Oct	3	M	1.13	4.80	52.8	54.5	0.0
Nov	1	M	1.13	4.58	45.8	55.6	0.0
Nov	2	M	1.13	4.37	43.7	57.9	0.0
Nov	3	M	1.13	4.30	43	53.3	0.0
Dec	1	M	1.13	4.22	42.4	50.7	0.0
Dec	2	M	1.13	4.15	41.5	48.2	0.0
Dec	3	M	1.13	4.31	47.4	33.6	13.8

Jan	1	M	1.13	4.47	44.7	11.0	33.7
Jan	2	M	1.13	4.63	46.3	0.0	46.3
Jan	3	M	1.13	4.73	52	1.9	50.1
Feb	1	M	1.13	4.75	47.5	6.9	40.7
Feb	2	M	1.13	4.82	48.2	8.2	40.0
Feb	3	M	1.13	5.36	42.9	8.0	34.9
Mar	1	M	1.13	6.02	60.2	7.7	52.5
Mar	2	M	1.13	6.57	65.7	7.7	58.0
Mar	3	M	1.13	6.53	71.8	7.9	63.9
Apr	1	L	1.13	6.44	64.4	7.7	56.7
Apr	2	L	1.09	6.22	62.2	7.6	54.5
Apr	3	L	1.04	6.18	61.8	9.9	51.9
May	1	L	0.99	6.19	61.9	13.9	48.0
May	2	L	0.94	6.13	61.3	16.6	44.7
May	3	L	0.89	5.64	62.1	12.8	49.3
Jun	1	L	0.83	5.14	51.4	6.5	44.9
Jun	2	L	0.78	4.73	47.3	2.5	44.8
Jun	3	L	0.73	4.30	43	6.2	36.8
Jul	1	L	0.68	3.88	38.8	10.5	28.3
Jul	2	L	0.66	3.60	3.6	1.3	3.6
				Total	1715.2	777.6	977.6

where I, D, M, L, K_c, ETc, IR are defined as in Table 3.

Table 8. Irrigation scheming

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice	0.0	0.0	0.0	0.0	0.0	384.5	146.9	107.2	95.6	6.5	0.0	0.0
Groundnut	0.0	0.0	0.0	0.0	0.0	0.0	33.7	36.0	73.2	1.9	0.0	0.0
Sugarcane	132.4	117.8	177.6	165.4	141.3	122.8	36.8	9.4	55.6	7.4	0.0	14.6
Rice	126.0	113.5	172.2	156.3	6.1	0.0	0.0	0.0	0.0	0.0	0.0	204.6
Groundnut	42.1	56.5	144.5	145.4	74.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NIR 1	3.7	3.8	5.4	5.2	1.2	9.6	3.7	2.6	2.9	0.2	0.0	4.7
NIR 2	114.4	105.6	168.9	156.0	36.6	287.5	113.4	81.8	86.3	5.9	0.0	145.4
NIR 3	0.43	0.44	0.63	0.60	0.14	1.11	0.42	0.31	0.33	0.02	0.00	0.54
IR_a	0.43	0.44	0.63	0.60	0.14	1.31	0.42	0.31	0.33	0.02	0.00	0.64
IA (%)	100	100	100	100	100	85	100	100	100	100	100	85

where NIR 1 = Net Water Requirement (mm/day), NIR 2 = Net Water Requirement (mm/month), NIR 3 = Net Water Requirement (l/s/h), IA = % of the total area that is actually irrigated, IR_a = Net Water Requirement for Actual Irrigated Area (l/s/h).

Figure 1: Location Map of Perumal Tank