Optimization of Irrigation Scheduling Under Kapuwaththa Irrigation Tank in Hambantota District, Sri Lanka

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Abstract- *Land use and irrigation management become vital for sustainable agriculture in the context of climate change. The model CROPWAT 8.0 was used in this study for the determination of crop water requirement and irrigation scheduling with the objectives to optimize irrigation scheduling under the Kapuwaththa irrigation tank and to recommend better water management options. Three years (2018-2020) of weather data, soil data and crop data from relevant sources were used as input in the model. The CROPWAT automatically calculated the daily soil moisture balance until the end of the growing season, the totals of effective rainfall and irrigations applied. Based on the modelling application, the respective water requirements per season were 691 mm and 830 mm for Maha and Yala seasons, respectively, whereas the actual amounts applied were 725 mm and 967 mm. The study indicates that the farmers over irrigated the fields by 5.0% and 16.5% in Maha and Yala respectively, when the irrigation efficiency of the scheme is 40%. If the actual application efficiency of the scheme is more, the over irrigation will be more than the amounts given by the model. CROPWAT model can be used as a good tool to schedule the irrigation for paddy under a village tank. The model could be used in optimizing the use of rainfall and saving water, but the effective rainfall calculation method needs to be applied with caution from place to place, and the coefficients of the dependable rainfall method needs to adjusted accordingly to get accurate results.*

Keywords: Crop water requirement, CROPWAT Model, Effective rainfall, Evapotranspiration, Irrigation scheduling, Rice

I. INTRODUCTION

Irrigated agriculture consumes about 70% of the world's freshwater withdrawals, making it largest user of water resources by far (Li et al., 2020). However, this amount is not good enough to meet actual irrigation needs, and it is expected to decline further in the coming years as competition with other users intensifies, especially in arid and semi-arid regions.

Irrigation scheduling ensures the reliable accessibility of water to the plants and its distribution in accordance with crop needs. Irrigation scheduling is used to assess the precise amount of water to apply to the field as well as the basic application preparation (Broner, 2005). Under and over application of water are the two aspects of bad irrigation scheduling. The water is applied either in inadequate amount or incorrect time during under irrigation meanwhile excessive and / or too often watering is done in over-irrigation. Both can result inefficient use of nutrients in turn lower the quality and yield of produce (Kumari, 2017). Proper scheduling applies water at the correct time and in correct amount to maximize production while minimizing negative environmental impacts. Irrigation scheduling optimization makes sure efficient water usage in cropping systems with the shortage of agricultural water resources (Li et al., 2020).

Irrigation scheduling helps farmers to reduce crop water stress while increasing yields; lower the farmers' water and labour costs by reducing irrigation and maximizing soil moisture storage; increase net returns by increasing crop yields and crop quality; and restrict water logging issues by declining drainage requirements (Pujara, 2016). Irrigation scheduling improves the quality of irrigation whereas definite measurement of the quantity or application depth of water is crucial. The amount of water applied is managed by using a model to determine irrigation requirements as well as the technique for application at a given situation. Lee *et al*. (2005) analysed water deliveries during pre-saturation and regular supply times, finding that pre-saturation should not be performed constantly to save scarce water and need to schedule the irrigation based on the available flow.

Rice is the main crop cultivated in Sri Lanka and irrigation plays an essential role in plant growth and agricultural production. According to the Razmy and Ahmed (2005) they reported that the maximum average yield in 2001 was obtained as 3954.3 Kiligrams per hectare (Kg/ha). Rice cultivation in Sri Lanka is hampered by rainfall variability and a lack of irrigation water, resulting in a variety of problems. Hambantota district in Sri Lanka is well known for agriculture where rice is the primary crop grown by the farmers as the economy and staple food requirement are dependent on it. The key factors to increase rice production are efficient use of water resources and partial water allocation with appropriate water management practices. In Kapuwaththa village, in Hambantota, the farmers and crops face various types of problems due to lack of specific water schedules, low water availability and poor water management. Zaman *et al*. (2017) addressed that the insufficient and unstable water supply are the main problems towards the equity of water distribution. While Donaldson (2013) stated that water losses in conveyance canals and field applications have huge impact on efficiency of irrigation system. Gamage and wijesekara (2017) had addressed that if better water management practices can be identified, these agricultural lands can contribute to Gross National Product (GNP) by achieving national food security. Improving the water supply management of irrigation tanks in Sri Lanka is a very important process to reach a higher crop intensity as a large number of irrigated lands are not being utilized deu to water scarcity from year to year. Bandara (2013) reported that the irrigation efficiency in Sri Lankan agricultural systems to change from 47.5% to 71.1%. Department of Agriculture (2004) revealed an average paddy yield of 1213.52 Kilograms per acre (kg/ac) which is lower than the average paddy yield (1857 kg/ac) obtained by farmers in Anuradhapura district in Maha season. Average paddy yield in Kapuwaththa in maha is 2800 kg/ac, which has potential to be increased. Hence, Overall irrigation efficiency of rice schemes is less than 50%, and lower in the wet than in the dry season (Haque *et al*., 2004). Accordingly, an irrigation water delivery schedule at Kapuwaththa area in Hambantota may assist the farmers to increase rice yields by efficiently water management practices. Considering this, the present study was done to optimize irrigation scheduling under the Kapuwaththa irrigation tank.

II. METHODOLOGY

A. *Study Area*

This study was conducted in Kapuwaththa village in Hambantota district, Southern province of Sri Lanka. The geographical coordinates of the centre of the Kapuwaththa village is 6° 22′ N (North), 81° 13′ E(East) and the altitude is 7.76 m. The location of the Kapuwaththa farming area with the irrigation tank considered for the study is shown in Figure 01. Hambantota district received the average annual rainfall was 1175 mm, average mean temperature was 28.3 celious (°C), average evaporation rate was 4.3 mm/day and average hours of sunshine per day was 6.9 hours (Ehelepola et al.,2021).

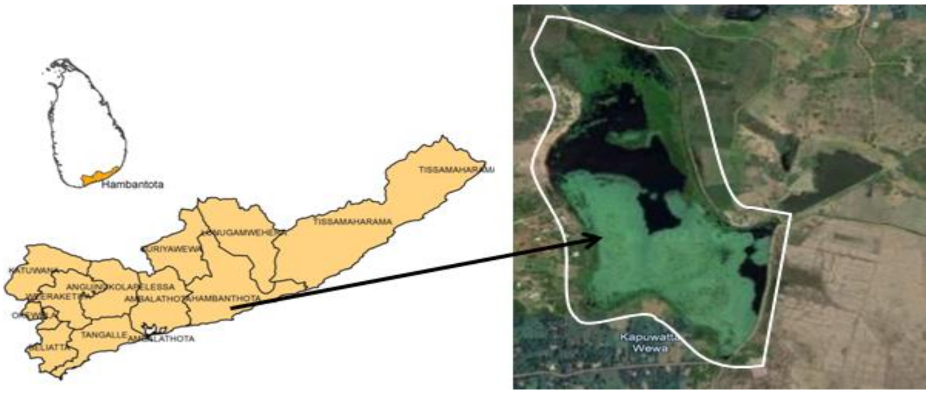

Figure 1: Location of the study area

Kapuwaththa tank covers an area of 60 hectares of irrigation tank and 32 hectares of rice field and nearly 8 hectares of upland crop area. Normally the farmers in the study area cultivate red rice varieties namely AT-362 (Red Nadu) based on their soil type, climate and relatively high yields comparing to the others.

B. *Climate data*

Monthly climatic data such as rainfall, temperature, humidity, wind speed, and sunshine hours were collected from the meteorological station for the years of 2018 to 2020 and inter cropping season were collected for the Maha and Yala season. Maha season falls during north east monsoon from late September to March and yala season effective during the period from early April to early September. As the durations of these two seasons in order to explain the accurate relationship between the paddy acreage and rainfall variations in the respective seasons. Therefore the effective rainfall period of growing season is taken according to the crop calendar presented by Yoshino et al. (1983c).

C. Soil data

The important soil data such as Total Available Water (TAW), maximum infiltration rate, maximum rooting depth and initial soil moisture depletion were collected from published data (Narmilan and Sugirtharan, 2018). Hambantota district has Reddish Brown Earth soils in the upland crop areas. However, major soil type in paddy lands is Low Humic Gley soil. Soil data collected for the study area is given in Table 1.

Table 1: Soil data of study area

Description or parameter	**Data**
Type of soil	Clay
Total available soil moisture (mm/m)	150 mm/m
Max. rain infiltration rate (mm/day)	62 mm/day
Maximum rooting depth (cm)	60 cm
Initial soil moisture depletion (as % TAM)	0 %
Initial available soil moisture (mm/m)	150 mm/meter

(Source: Narmilan and Sugirtharan, 2018)

D. Crop data for rice

Crop coefficient values (Kc), critical depletion fraction and yield response factors were taken from accessible published informatio. In addition, planting dates (Yala-November 10, Maha-April 20), harvesting dates (Yala- February 22, Maha-August 2) and crop data for rice (rooting depth, and height for the crop) were collected from the farmers in Kapuwaththa village via a survey considering 2020 (Table 2)

Table 2: Crop data for rice (gain)

	Growth Stages				
	Initial	Development	Mid	Late	Total
Stage Lengths [Days]	20	25	35	25	105
Crop Coefficients (Kc wet)	1.05	1.10	1.20	1.05	-
Crop Coefficients (Kc dry)	0.30	0.50	1.05	0.7	-
Rooting Depths [m]	0.10	-	0.60	0.60	-
Depletion Levels	0.20	-	0.20	0.20	-
Yield Response Factors	1.00	1.09	1.32	0.50	1.10
Crop height [m]	0.2	0.6	1	0.9	1

(Source: Irrigation planing with the help of cropwat 2016, viewed 24 April 2021, https://www.slideshare.net/iamsidu/irrigation-planning-with-the-help-of-cropwat-80)

E. Estimation of crop water requirement (CWR)

CWR was estimated from crop evapotranspiration (ETc) using the equation below (Ewaid et al., 2019).

$$ET_c = K_c \times ET_o$$

where, Kc is the crop coefficient and ET_o is the reference evapotranspiration. ET_0 was estimated using the Penman-Monteith equation as below (Memon and Jamsa, 2018).

$$= \frac{0.408\,\Delta(R_n - G) + y\left(\frac{900}{T+273}\right)U_2(ea - ed)}{\Delta + y(1 + 0.34U_2)}$$

where ETo is reference crop evapotranspiration (mm/day), Rn is net radiation at the crop surface (MJ/m^2 /day), G is soil heat flux density (MJ/m^2 /day), T is air temperature at 2 m height (°C), u_2 is wind speed at 2 m height (m/sec), es is mean saturation vapour pressure of the air (kPa), ea is mean actual vapour pressure of the air (kPa), (es – ea) is saturation vapour pressure deficit (kPa), D is slope of the vapour pressure curve (kPa/°C), G is psychometric constant (kPa/°C) and 900 is conversion factor.

Further, Crop Water Requirement (mm) was determined according to FAO (2005) as;

$CWR_i = \sum_{t=0}^{T} (Kc_i . ET_o - P_{eff.})$

where Kc_i is the crop coefficient of the rice during the growth stage t and T is the final growth stage and P_{eff} is effective monthly rainfall (mm).

The actual applied amount were calculated for yala and maha seasons separately by using data of flow rate of water in the canal and time duration of water supply. Then these were compaired with model calculated values and farmers applies actual amount for the decide water and losses from farmers.

F. Estimation of irrigation requirement (IR)

The CROPWAT model computed the daily water balance of the root zone by the following equation (Ewaid et al., 2019):

$$Dr_{,i} = Dr_{,i-1} - (P_i - RO_i) - I_i - CR_i + ET_{c\,i} + DP_i$$

where $Dr_{,i}$ is the root zone depletion at the day's end (mm), i (mm),$Dr_{,i-1}$ is the water content in the root zone at the previous day's end (mm), P_i is the precipitation on day i (mm), RO_i is the surface soil runoff on day i (mm), I_i is the net irrigation depth on day which infiltrates the soil (mm), CR_i is the capillary rise from the groundwater table on day i (mm), $ET_{c\,i}$ is crop evapotranspiration on day i (mm), and DP_i is the lost water of the root zone on day i (mm).

G. Irrigation scheduling

For the rice irrigation scheduling irrigates at fixed interval per stage separately for Maha (10 days) and Yala (7 days) season was set as the irrigation timing in the scheduling criteria. Irrigation application was done to refill to a water depth of 100 mm at an assumed irrigation efficiency of 40%. Scheduling options included the general settings for land preparation, which was set to FAO formula method. For the scheduling criteria of pre puddling, irrigation timing was assumed to irrigate at 25 % of depletion of field capacity and irrigation application was set to irrigate at fixed application depth (100 mm). Meanwhile, for the scheduling criteria of puddling, the irrigation timing and application were set at fixed water depths of 25 mm and 100 mm, respectively.

H. Simulations

The model was run for rice crop with monthly climatic data obtained for the study period and single scheduling criteria. The model results were analysed and the best fit irrigation scheduling option was selected.

III. RESULTS AND DISCUSION

A. Effective rainfall

Effective rainfall calculated under different methods (Table 03) indicates that maximum effective rainfall was obtained from USDA SC method and minimum result was from Dependable rain (FAO/AGLW formula) method. Furthermore, maximum Net Irrigation Requirement was noted in dependable rain method whereas the minimum was obtained from USDA SC method. Hence, net irrigation supplied by farmers (calculated by flow rates, irrigation timing and application frequency) in Kapuwaththa was approximately the same as net irrigation required from each method (Table 03) in the dependable RF method compared to other methods. Accordingly, dependable rainfall method was considered as a suitable method for effective rainfall estimation for irrigated paddy fields.

Table 3: Effective rainfall and net irrigation requirement from different effective rainfall methods

Month	RF (mm/month)	ETo (mm/month)	Effective rainfall (mm)				
			USDA	Fixed % (80%)	Dependable RF	Empierical	No Eff RF
Jan	16.9	115.01	16.4	13.5	0.1	3.4	0
Feb	29.4	123.6	28	23.5	7.6	9.7	0
March	32.6	137.64	30.9	26.1	9.6	11.3	0
April	99.2	117.88	83.5	79.4	55.4	89.4	0
May	50.1	117.18	46.1	40.1	20.1	55.1	0
June	22.4	108.9	21.6	17.9	3.4	6.2	0
July	32.5	115.01	30.8	26	9.5	11.3	0
Aug	72.5	124	64.1	58	34	70.8	0
Sep	174.7	117.3	125.9	139.8	115.8	142.3	0
Oct	170.4	115.63	123.9	136.3	112.3	139.3	0

Nov	125.9	109.2	100.5	100.7	76.7	108.1	0
Dec	153.7	105.71	115.9	123	99	127.6	0

Month	RF	ETo (mm/month)	Net Irrigation Requirement (mm/month)				
			USDA	Fixed %	Dependable RF	Empierical	No Eff RF
Jan	16.9	115.01	98.61	101.51	114.91	111.61	115.01
Feb	29.4	123.6	95.6	100.1	116	113.9	123.6
March	32.6	137.64	106.74	111.54	128.04	126.34	137.64
April	99.2	117.88	34.38	38.48	62.48	28.48	117.88
May	50.1	117.18	71.08	77.08	97.08	62.08	117.18
June	22.4	108.9	87.3	91	105.5	102.7	108.9
July	32.5	115.01	84.21	89.01	105.51	103.71	115.01
Aug	72.5	124	59.9	66	90	53.2	124
Sep	174.7	117.3	0	0	1.5	0	117.3
Oct	170.4	115.63	0	0	3.33	0	115.63
Nov	125.9	109.2	8.7	8.5	32.5	1.1	109.2
Dec	153.7	105.71	0	0	6.71	0	105.71

Table 4: Crop water requirement of rice in Maha

Month	Decade	Stage	Kc	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Oct	3	LandPrep	1.05	3.89	42.7	34.5	316.5
Nov	1	Initial	1.06	3.87	38.7	27.7	121.5
Nov	2	Initial	1.10	4.00	40.0	22.9	17.1
Nov	3	Developing	1.10	3.92	39.2	26.2	12.9
Dec	1	Developing	1.09	3.80	38.0	34.3	3.6
Dec	3	Mid	0.90	3.16	34.7	25.8	8.9
Dec	3	Mid	1.06	3.72	40.9	25.8	15.1
Jan	1	Mid	1.06	3.82	38.2	0.2	38.0
Jan	2	Mid	1.06	3.93	39.3	0.0	39.3
Jan	3	Late	1.06	4.06	44.7	0.0	44.6
Feb	1	Late	1.01	4.02	40.2	1.9	38.3
Feb	2	Late	0.95	3.92	39.2	2.8	36.4
Feb	3	Late	0.92	3.87	7.7	0.7	7.7
					483.5	215.9	691.0

B. The crop water requirement of rice in Maha season

Crops' water requirements vary with location, climate, soil, method of cultivation and effective rainfall. The water requirement of a crop differs with its growth stage. The model calculated the irrigation requirement (IR) for the entire growth period, in a decade wise pattern (10 days). The results obtained from the model are shown in Table 4 based on Dependable RF method.

A range of ETc values between 3.16 to 4.06 mm/day was recorded in Maha season. Total irrigation water requirement was 691.0 mm per decade and that value increases due to different reasons as bellow. In rice cultivation, crop water requirement increased from initial stage to end of the mid stage from 3.87 mm per day to 3.93 mm per day, respectively. Then, it increased from 3.92 mm per day to 4.06 mm per day during the middle of the late stage when the rice absorbs a lot of water for growth and reaches its maximum height. Finally, the water requirement of rice decreased to 3.87 mm per day at end of the late- season, which is the period of ripening. This is also the time for draining water in preparation for paddy harvesting. The initial and development stages do not need additional irrigation water since the demands were met from rainfall. In Maha season, the initial and development stages of paddy cultivation fall in November and December in

Table 5: Crop water requirement of rice in Yala season

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
				mm/day	mm/dec	mm/dec	mm/dec
Mar	3	Land Prep	1.05	4.58	4.6	0.6	28.5
Apr	1	Land Prep	1.05	4.50	45.0	15.9	299.5
Apr	2	Initial	1.06	4.44	44.4	22.3	139.3
Apr	3	Initial	1.10	4.48	44.8	17.1	27.7
May	1	Developing	1.10	4.32	43.2	10.0	33.1
May	2	Developing	1.08	4.09	40.9	5.8	35.0
May	3	Developing	1.05	3.91	43.0	4.3	38.7
Jun	1	Mid	1.02	3.76	37.6	2.3	35.3
Jun	2	Mid	1.02	3.71	37.1	0.1	37.0
Jun	3	Mid	1.02	3.73	37.3	1.1	36.2
Jul	1	Late	1.02	3.75	37.5	1.9	35.6
Jul	2	Late	0.98	3.64	36.4	2.3	34.1
Jul	3	Late	0.93	3.54	38.9	5.3	33.6
Aug	1	Late	0.90	3.50	7.0	1.4	7.0
					497.8	90.4	820.7

which highest rainfall was recorded during 2018 to 2020. Therefore, the additional irrigation was not done by farmers at these stages except during the land preparation period in 2020. Because of the land preparation takes mare water due to percolation and seepage, high evaporation and surface runoff in the land. Percolation occurs in vertical direction due to different topography , soil characteristics and depth of water table. Seepage occurs in horizontal movement of water affecting the normal flows in to soil surface or stream, drains while percolation from land.Due to low rainfall in the month of January and February, the mid and late stages require water and need to be supplied through irrigation. Similar to the present results, Narmilan and Sugirtharan (2018) also recorded that ETc values were ranged between 1.76 and 3.66 mm/day in Maha season during November to January in Batticaloa district. They also mentioned that in the early stages, rice only needs around 60 mm per decade to compensate for crop water requirements. During the growing season, rice's water demand declined from 56.2 mm to 46.7 mm at the end of the decade. Then, it increased from 39 mm to 48 mm at the start of the mid-season stage, when rice requires a lot of water to develop.

C. *The crop water requirement of rice in Yala season*

The model calculated the IR for the entire growth period, in a decade wise pattern (7 days) for Yala season. The results obtained from the model are shown in Table 5 based on Dependable RF method.

A range of ETc values between 3.50 and 4.58 mm/day were recorded in Yala season. Crop water requirement decreased from initial stage to mid stage from 4.44 mm per day to 3.76 mm per day, respectively in Yala season. Then, it further decreased from 3.76 mm per day to 3.50 mm per day during the late stage. This is the time for draining water for the harvesting of paddy. The initial and development stages do not need additional irrigation water since the demands were met from rainfall.

Similarly, Narmilan and Sugirtharan (2018) recorded the Crop evapotranspiration ($ET_{C)}$ values in between 2.13 and 4.5 mm/day in May to July during the Yala season. The total crop water requirement was 436.7 mm/ season through the growing season, but successful rainfall was only 133 mm/ season in their study. As a result, irrigation should be carried out in Yala to meet the paddy water demand.

D. *Irrigation schedule for the rice in Maha*

The Figure 2 represents the irrigation schedule obtained from CROPWAT model for rice at fixed interval (10 days). It was found that the gross irrigation was 2774.7 mm and total Net Irrigation Requirement (NIR) was 1109.9 mm.

Figure 2: Irrigation schedule of Rice in Maha

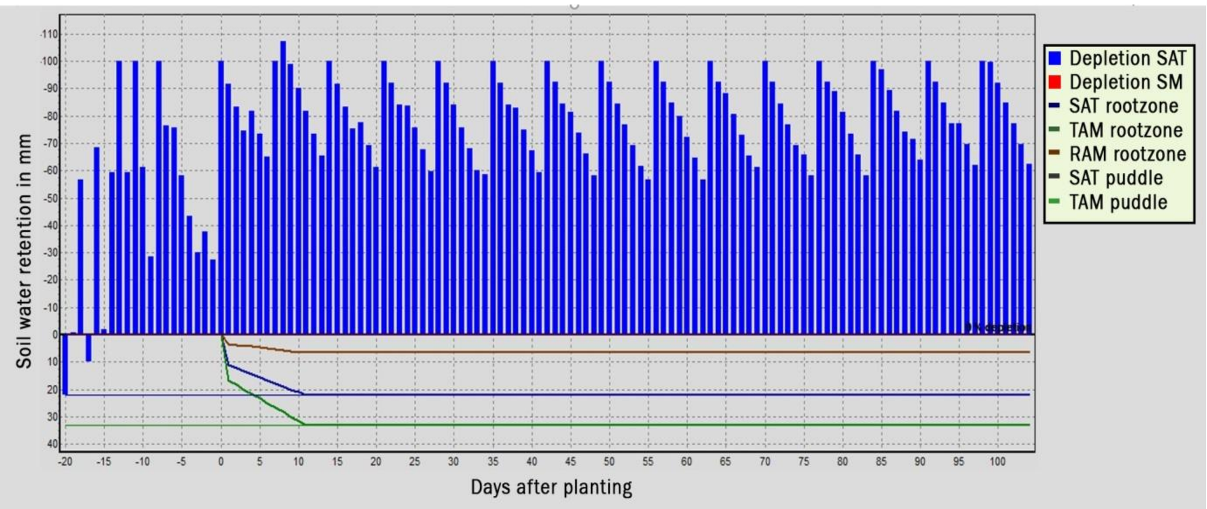

Figure 3: Irrigation scheduling of rice in Yala

E. Irrigation schedule for the rice in Yala

Figure 3 represents the irrigation schedule obtained from CROPWAT model for rice at fixed interval (7 days). It was found that the total gross irrigation was 3353.5 mm and total NIR was 1341.4 mm

F. Actual Irrigation requirement of Yala and Maha

Table 6: Comparison between actual IR and estimated IR

		mm/ month	Net schem Irr.Req In mm/ day	Net schem Irr.Req In mm/ Month	Irrigated area(% of ideal area)	Irr.Req for actual area l/s/h	Actual applied amount mm/month
Rice Maha	Oct	316.5	10.2	316.5	100.0	1.18	145.08
	Nov	151.5	5.1	151.5	100.0	0.58	145.08
	Dec	18.7	0.6	18.7	100.0	0.07	145.08
	Jan	121.9	3.9	121.9	100.0	0.45	145.08
	Feb	82.5	2.9	82.5	100.0	0.34	145.08

Rice Yala	Mar	28.5	0.9	28.5	100.0	0.11	193.44
	April	466.5	15.5	466.5	100.0	1.80	193.44
	May	108.3	3.5	108.3	100.0	0.40	193.44
	Jun	112.8	3.8	112.8	100.0	0.44	193.44
	July	106.9	3.4	106.9	100.0	0.40	193.44
	Aug	7.1	0.2	7.1	100.0	0.03	193.44

According to 40% efficiency, actual applied amounts were 145.08 mm/month and 193.44 mm/month for Maha and Yala season, respectively (Table 6). Model calculated total irrigation requirement of Maha season is 691.1 mm for the land preparation to harvest. But farmers applied 725.4 mm in Maha season in 2020. According to the model, more water required for land preparation during the month of October, and month of February required low water amount because of the harvesting period. Also, in December 2020 calculated amount was 18.7 mm and farmers applied amount was 145.08 mm and it indicates over irrigation. This is because of irrigating the fields without considering the rainfall. Considering all the applied amounts and model calculated amounts, farmers applied 4.96 % more than the requirement in Maha season.

Model calculated total irrigation requirement of Yala season was 830.1 mm for the land preparation to harvest. But farmers applied 967.2 mm in the Yala season. According to the model, month of April required more water for land preparation. Considering all the amounts applied and model calculated amounts, farmers applied 16.51 % more than the requirement in Yala season.

IV. CONCLUSION

Dependable rain method is the best method to estimate effective rainfall at Kapuwaththa irrigation scheme. The USDA –SC method over predicts the effective rainfall hence it is not suitable for paddy irrigation. Based on the modelling application, the water requirement per season are 691 mm and 830 mm for Maha and Yala, seasons, respectively. The actual amounts applied to the fields are 725.4 mm and 967.2 mm per season for Maha and Yala seasons, respectively. Hence, the farmers over irrigate the fields by 4.96 % and 16.51% in Maha and Yala seasons, respectively, when the irrigation efficiency of the scheme is 40%. If the application efficiency of the scheme is more, the over irrigation will be more than the amounts given above. The model estimated irrigation practice can save water than existing farmer's practices. Since, the study area is facing water shortage, judicious use of irrigation water for maximization of the agricultural productivity can be a solution to safeguard the environment. The results of the study could also be used as a guide for the farmers in scheduling their irrigation and choosing a good irrigation practice. The study results can be extrapolated in the future and the future water demand of crops can be determined by using a probability analysis of irrigation requirement. Further, it can be assessed whether the future rainfall could meet the future water demand of crops or not.

REFERENCES

Bandara, K.M.P.S. (2003) 'Monitoring irrigation performance in Sri Lanka with high-frequency satellite measurements during the dry season'. Agricultural water management, 58(2), pp.159-170.

Broner, I. (2005) 'Irrigation Scheduling',Fact Sheet 4.708.

Department of Agriculture. (2004) 'Cost of Cultivation of Agricultural Crops- 2003/2004 Maha'. Socio Economics and Planning Centre, Department of Agriculture, Peradeniya.

Donaldson, M. (2013) 'Rehabilitation and modernisation of irrigation schemes',Proceeding of the institution of civil engineers-water management , 166(5),pp.242-253.

Ehelepola N.D.B.Ariyarathne, K. and Dissanayake, D.S. (2021) 'The inter relationship between meteorological parameters and leptospirosis incidence in Hambantota district, Sri Lanka 2008-2017 and practical implication',PLos one 16(1).

Ewaid, S. H., Salwan, A.A. and Nadhir A.A. (2019) 'Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq',Water, 11, 756.

Food and Agricultural Organization (2005) 'Irrigation potentials in Africa; a basin approach. Chapter 5: Irrigation water requirements',FAO corporate document repository. FAO, Rome.

Gamage P.R and wijesekara N.T.S. (2017) 'Attempting to improve seasonal performance of Land and water productivity through systematic analysis: Case study of Dahanaka Minor Irrigation Tank in Anuradhapura District of Sri Lanka', UMCSAWM Water Conference.

Haque, M.A. Najim, M.M.M. , and Lee, T.S. (2004) 'Modeling Irrigation Water Delivery Schedule for Rice Cultivation in East Coast Malaysia',Tropical Agricultural Research,16, 204-213.

Kumari, S. (2017) 'Irrigation scheduling using cropwat',Creative Research Thoughts,394–403.

Lee, T. S. Haque, M. and Najim, M.M.M. (2005) 'Modeling water resources allocation in a run-of-the-river rice irrigation scheme',Water resources management, 19(5), 571-584.

Li, J. Jiao, X. Jiang, H . Song, J. and Chen, L. (2020) 'Optimization of Irrigation Scheduling for Maize in an Arid Oasis Based on Simulation – Optimization Model',Agronomy, 10, 935.

Narmilan, A and Sugirtharan, M. (2018) 'Modelling the Crop Water Requirement in Batticaloa District, Sri Lanka', FAO-Cropwat Modelling for Rice,Proceedings of the 4th Jaffna University International Research Conference (JUICe2018), pp 19-24.

Pujara, M. (2016) 'Criteria for Scheduling Irrigation'.

Razmy A.M and Ahmed A. N. (2005) 'Trends in Paddy Production in Sri Lanka' Journal of Management Vol. III. No. pp 26.33.

Siddharthh, U. (2016) 'Irrigation planing with the help of cropwat', Available at https://www.slideshare.net/iamsidu/irrigation-planning-with-the-help-of-cropwat-80 (Accessed:24 april 2021).

Yoshino M. M. et al. (1983c) 'Climatic fluctuation and its effects on paddy production in Sri Lanka' Climat. Notes, 33, 9-32.

Zaman, A. et al. (2017) 'Water Resource Development and Management for Agricultural Sustainability', Journal of Applied and Advanced Research, 2(2),p.73.