CLIMATE CHANGE IMPACT ON IRRIGATION WATER REQUIREMENT FOR PADDY

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ABSTRACT

Anuradhapura district is one of the major low-land paddy cultivation areas in Sri Lanka fed by a large number of reservoirs. The cultivations are done according to traditional cultivation calendar, where Maha season starts on October 01, while Yala season starts on April 15. According to experts, climate change is causing changes in rainfall intensities and patterns and a considerable increase in average temperature. If rainfall and water evapotranspiration rate change, irrigation water requirement (IWR) from the reservoirs also change, resulting in either water shortage or surplus. Therefore, objective of this study is to see whether climate change has influenced IWR, so that measures can be taken to optimize the use of available water resources in the area. CROPWAT 8.0 software was used for calculating IWR using daily rainfall data of seven gauge stations and temperature data of Anuradhapura climatic station. Other unavailable climatic data were obtained from the CLIMWAT database for the nearest station. IWR for both Yala and Maha seasons were calculated, based on commonly cultivated paddy varieties and cultivation calendar, from 1980 to 2016. The spearman's rank correlation method was used to check possible trends in IWR for the study period. According to trend analysis the IWR for the Yala season showed neither an upward nor a downward trend. However, the same for the Maha season showed a considerable downward trend. Obviously, Maha season IWR has gradually been decreasing since 1980. Therefore, paddy cultivation in Anuradhapura district is positively impacted by climate change during the Maha season, while there is no impact during Yala season. It is suggested to increase cultivation extents during the Maha season to obtain maximum productivity from water resources. Additional extents have to be decided after carrying out new operation studies for each reservoir based irrigation scheme.

Keywords: Climate change, Paddy, Irrigation water requirement, Anuradhapura district.

1. INTRODUCTION

Rice is the staple food of almost all Sri Lankans. Anuradhapura district of Sri Lanka is one of the major low-land paddy cultivation areas in the country. Paddy lands in the district are mainly fed by a large number of major and medium reservoirs, most of which have originally been constructed in the ancient kings' time and rehabilitated later. Paddy cultivations in the area depend on this reservoir system to get the additional water as the rainfall itself is not sufficient. The cultivations are done according to the traditional cultivation calendar, which based on the rainfall pattern of the country. Accordingly paddy is cultivated in two season called "Yala" and "Maha" in local language. Generally, cultivations of Yala season starts on April 15, while starting date of Maha season is October 01. Duration of each season depends on the variety of paddy cultivated and according to mostly cultivated paddy varieties Yala and Maha seasons extend to 105 daysand 135 days respectively.

However, with climate change it has been noticed that not only the rainfall intensity but also rainfall pattern has changed throughout the country and Anuradhapura

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district is without exception. Although there are many climate change prediction models, each model is associated with a considerable amount of uncertainty with regard to predictions. On the other hand, these models are used for future climate change forecasts. Therefore, rather than using climate change models, this study used past climatic data to calculate irrigation water requirement (IWR) for paddy cultivation. Hence, the logic is, if there is a considerable trend in IWR for the period considered then that is due to climate change, as climatic data are the only variables used in the calculations.

The design storage capacity of an irrigation reservoir often determined according to the IWR of the cultivation extent under it. In other words, the required storage capacity is the additional water requirement after taking the effective rainfall during the cultivation period into account. Therefore, if temporal pattern and intensity of rainfall changes, the IWR from these reservoirs also change. As storage capacities of reservoirs are almost constant this scenario will create either water shortage or surplus for the cultivations. Thus, the main objective of this study is to see how climate change has affected the IWR for the paddy cultivation in the Anuradhapura district.

2. METHODOLOGY

2.1 Trend Analysis for a Time Series

The main objective of this study is to check whether IWR for paddy cultivation in each cultivation season has any influence from climate change. A 37-year period from 1980 to 2016 is considered for this study. If such influence from climate change is present, the time series of IWR for the period should denote a considerable trend. Therefore, a statistical test is to be done for checking any possible trend.

The Spearman's rank correlation method is a useful tool for trend analysis of a time series. The Spearman's rank correlation coefficient R_{sp} is defined in equation 1.

$$R_{SP} = 1\text{-}\frac{6\times\sum_{i=1}^{n} D_i^2}{n(n^2-1)} \quad \ldots(1)$$

Where n is the total number of data and D is difference, and i is chronological order number.The difference between rankings is computed with;

$$D_i = Kx_i\text{-}Ky_i \quad \ldots(2)$$

Where, Kx is the rank of the variable x which is the chronological order number of the observations? The series of observations, y_i is transformed to its rank equivalent Ky_i by assigning the chronological order number of an observation in the original series to the corresponding order number in the ranked series y.

$$t_t = R_{sp}[\frac{n-2}{1-R_{sp}^2}] \quad \ldots(3)$$

Where t_t, has Student's t-distribution with $v = n-2$ degrees of freedom.At a significance level of 5 per cent (two-tailed) and the time series has no trend if;

$$t\{v, 2.5\%\} < t_t < t\{v, 97.5\%\} \quad \ldots(4)$$

Accordingly, this methodology is applied to check whether calculated IWR time series has got any trend.

2.2 Use of Crop wat 8.0

CROPWAT8.0, a computer software developed by World Food and Agriculture Organization (FAO) was used for this study. In the study area paddy cultivation is done twice a year and these seasons are called “Yala” and “Maha”. Generally, land preparation for Yala season cultivation is started on 15th of April while that of Maha season is started on 1st of October.

Growth stages of paddy during each season is shown in Table 1.

Table 1. Growth stages of paddy in each season

Season	Start date	End date	Land preparation	Initial	Development	Mid	Late	Total/(days)
Yala	Apr 15	July 30	15	20	30	30	10	105
Maha	Oct 01	Feb 12	15	30	40	45	5	135

Based on the common practices in the field, irrigation timing was set to irrigation at 5 mm water depth, while irrigation application set to refill water depth to 100 mm. An irrigation efficiency of 70% was applied for the calculations. Figure 1 and 2 shows the other crop data, as available for Paddy crop in the CROPWAT model itself, for Maha and Yala seasons respectively.

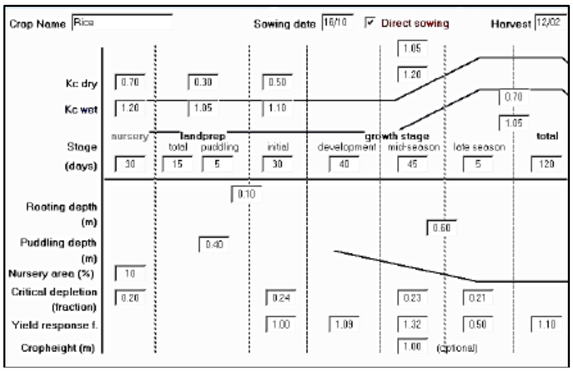

Figure 1. Crop data for Maha season

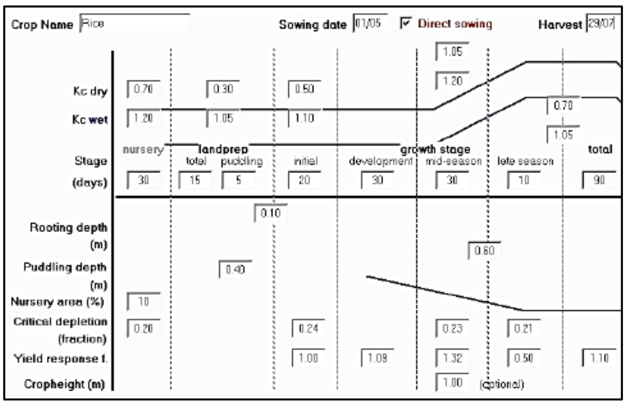

Figure 2. Crop data for Yala season

Daily rainfall of seven-gauge stations within and around the district were used for the study and temperature data were obtained from Anuradhapura climatic station. Thiessen polygon method was used to calculate the average rainfall. Division of the area to Thiessen polygons is shown in figure 3.

Other climatic data of the area, wind speed, humidity and daily sunshine hours were obtained from the CLIMWAT database for Vauniya station about 40 km away from the study area, being the closest climatic station available. Figure 4 shows climatic data for year 1981 as obtained from CLIMWAT database together with the calculated reference evapotranspiration values for each month for Anuradhapura using Penman-Monteith method.

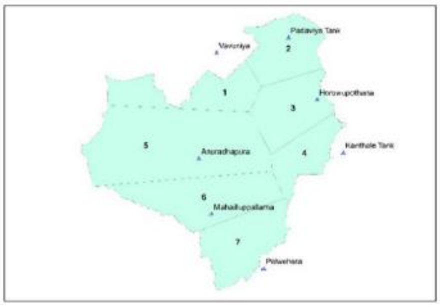

Figure 3. Thiessen polygon map of rain gauge stations

Country: SRI LANKA | Station: VAUNIYA
Altitude: 100 m. | Latitude: 8.31 °N | Longitude: 80.40 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	20.8	30.4	81	328	7.0	18.1	4.16
February	21.2	32.2	76	251	7.7	20.2	4.77
March	24.1	35.5	72	173	7.9	21.5	5.34
April	24.7	33.9	74	173	7.5	21.0	5.13
May	25.3	33.4	74	285	7.4	20.4	5.39
June	25.1	32.2	69	380	7.7	20.4	5.87
July	24.7	33.0	68	346	7.2	19.8	5.82
August	24.7	33.2	69	320	7.1	20.1	5.75
September	24.0	31.4	70	285	7.5	20.8	5.42
October	23.6	31.8	78	225	6.3	18.3	4.43
November	22.7	31.2	83	233	5.9	16.7	3.87
December	21.2	29.9	84	320	5.6	15.7	3.63
Average	23.5	32.3	75	277	7.1	19.4	4.96

Figure 4. Climatic data for Year 1981

Anuradhapura district mainly consists of Reddish Brown Earth, of which properties are almost similar to the soil type Red Sandy Loam available in the CROPWAT database. Therefore, soil type of the area is selected as Red Sandy Loam and default soil properties available in the model are used for calculation of crop water requirement. The relevant soil properties are shown in figure 5.

Soil name: RED SANDY LOAM

General soil data		
Total available soil moisture (FC - WP)	140.0	mm/meter
Maximum rain infiltration rate	30	mm/day
Maximum rooting depth	900	centimeters
Initial soil moisture depletion (as % TAM)	0	%
Initial available soil moisture	140.0	mm/meter
Additional soil data for rice calculations		
Drainable porosity (SAT - FC)	40	%
Critical depletion for puddle cracking	0.40	fraction
Maximum Percolation rate after puddling	3.1	mm/day
Water availability at planting	50	mm WD
Maximum waterdepth	100	mm

Figure 5. Soil data for the study area

According to the cultivation calendar of the area IWR for both Yala and Maha seasons were calculated from 1980 to 2016. The spearman's rank correlation method was used to check whether there were any trends in IWR for each season. The output for Yala season of year 1981 is shown in figure 6.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	2	LandPrep	1.05	5.39	27.0	20.5	168.4
Apr	3	LandPrep	1.05	5.48	54.8	34.8	203.9
May	1	Init	1.10	5.83	58.3	27.7	30.6
May	2	Init	1.10	5.92	59.2	23.7	35.5
May	3	Deve	1.12	6.22	68.4	16.6	51.8
Jun	1	Deve	1.16	6.62	66.2	2.8	63.4
Jun	2	Mid	1.20	7.02	70.2	0.0	70.2
Jun	3	Mid	1.21	7.08	70.8	4.4	66.3
Jul	1	Mid	1.21	7.05	70.5	29.6	40.9
Jul	2	Late	1.21	7.02	70.2	43.2	27.0
Jul	3	Late	1.12	6.48	58.4	29.1	22.8
					673.9	232.5	780.9

Figure 6. Irrigation water requirement calculation for 1981 Yala season

It can be noted that out of the crop water requirement, IWR has been calculated as 538.5 mm while 445 mm is received by effective rainfall during the period. The time series plot of calculated IWR for Yala season is shown in figure 7.

3. RESULTS & DISCUSSION

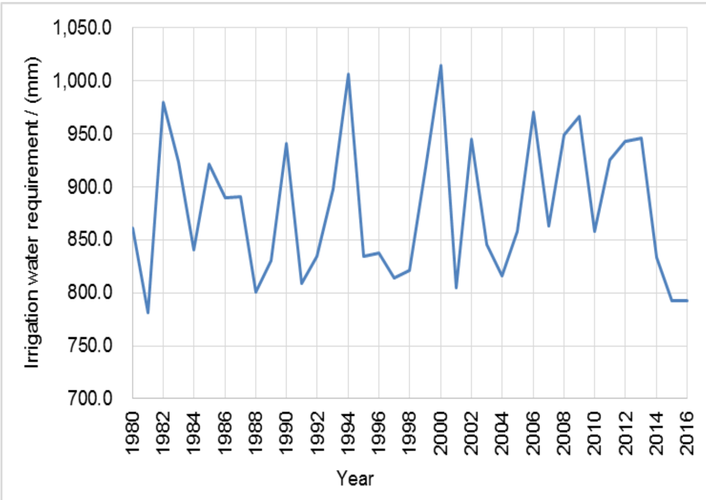

Figure 7. Irrigation water requirement for Yala season

was 0.04, where $-2.03 < t_t = 0.25 < 2.03$. Summary of the statistics of the test is shown in table 2.

The time series of Yala season was tested with Spearman's rank correlation test to see whether there was any trend. The calculated IWR for the study period showed neither an upward nor a downward trend as Spearman's rank correlation coefficient

Table 2. Statistics of Spearman's rank correlation test for Yala season

Parameter	Value
n; number of data	37
$R_{sp;}$ Spearman's rank correlation coefficient	0.04
$t_t$of students t distribution	0.25
For 2.5% of t distribution	-2.03
For 97.5% t distribution	2.03

The time series plot of calculated IWR for Maha season is shown in figure 8. The Maha season showed a considerable downward trend, where Spearman's rank correlation coefficient was -0.35 while t_t = -2.18 < -2.03. Summary of the statistics of the test is shown in table 3. According to the results IWR for the paddy cultivation of the Maha season is gradually decreasing since 1980.

Table 3. Statistics of Spearman's rank correlation test for Maha season

Parameter	Value
n; number of data	37
R_{sp};Spearman's rank correlation coefficient	-0.35
$t_t$of students t distribution	-2.18
For 2.5% of t distribution	-2.03
For 97.5% t distribution	2.03

It is evident that Maha season paddy cultivations are positively affected by climate change as the IWR has been gradually decreasing since 1980. The CROPWAT model calculated the IWR based on two main variables i.e., effective rainfall and evapotranspiration. Evapotranspiration is a function of many climatic factors like temperature, solar radiation, wind speed and humidity. Therefore, without a detailed analysis of all these factors, it is not possible to ascertain which parameters contributed to the decrease in IWR during the Maha season paddy cultivation of the study area. In fact, identifying such parameters and quantifying their contribution to the reported decrease in IWR is beyond the scope of this study.

4. Conclusions & Recommendations

Contrary to the often highlighted negative consequences of climate change the results obtained in this study show that climate change has a positive impact on paddy cultivation in Anuradhapura district during the Maha cultivation season, as the

IWR has gradually been decreasing since 1980. However, there is no impact on Yala season cultivations. In a study done by M. Rajedran et al. (2017) also, using climate change models focussing an area closer to the study area have found out that annual rainfall would be increased by 27-32% for the period from 2041 to 2070 compared to annual rainfall during 1972-2001, as a result of climate change.

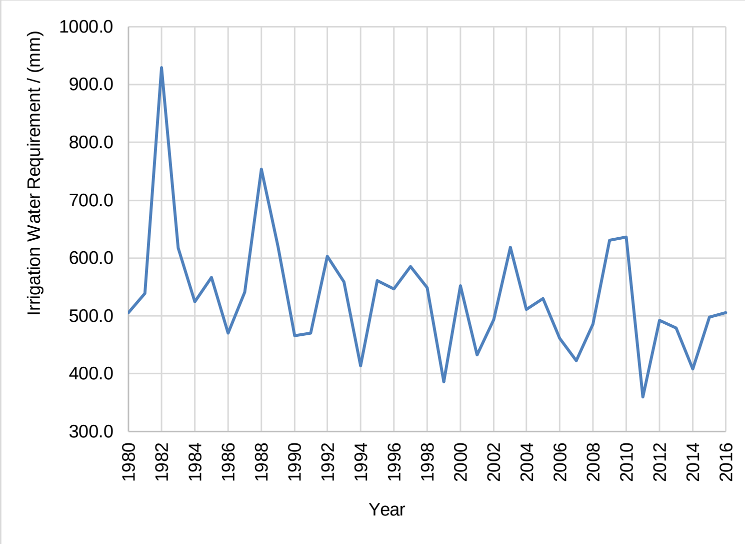

Figure 8. Irrigation water requirement for Maha season

Therefore, this scenario will create a water surplus in irrigation reservoirs during the Maha season and, hence, it is possible to increase the cultivation extent under each irrigation scheme during the Maha season of the year to obtain maximum productivity from water resources. The possible cultivation extents have to be decided after carrying out new operation studies for each irrigation scheme using latest rainfall, relevant crop data and technical parameters of reservoirs and water distribution systems.

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