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Impact of Climate Change on Crop Water Requirement of Rice in Central Zone of Kerala : An Assessment Using CROPWAT Model

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ABSTRACT

The study was to investigate the possible impact of climate change on crop water requirement of rice in central zone of Kerala during different time period and future climates 2030, 2050 and 2080. Climate data for the years 2030, 2050, 2080 were collected from MarkSim DSSAT weather file generator under Representative Concentration Pathways (RCP) 4.5 scenarios. The crop water requirement of rice for different seasons during these periods was predicted using CROPWAT 8.0 model by assuming same crop management practices for all these years. It was found out that evapotranspiration, effective rainfall and irrigation requirement showed different trends in different seasons during 2030, 2050, and 2080. In *virippu* season percentage deviation of irrigation requirement from that of 2021 value was found to be 180. 7, 179.0, 181.0 for the years 2030, 2050, 2080, respectively. In *mundakan* season percentage deviation of irrigation requirement from that of 2021 was found to be -40. 4, -41.1, -29.8, respectively. In *puncha* season percentage deviation of irrigation requirement from that of 2021 was found to be -5.4,-5.3,-3.6 for the years 2030, 2050, 2080, respectively. The increase in irrigation requirement during *virippu* season in future compared to 2021 might be due to decrease in effective rain fall during this period and the decrease in irrigation requirement in future compared to 2021 during *puncha* and *mundakan* season might be due to increase in effective rainfall during this period. Considering the probability of increase irrigation requirement during *virippu* season in future, proper water management strategies should be adopted to sustain farmer's income in addition to current irrigation management practices.

Key Words: Climate, Crop, Evapotranspiration, Irrigation, Rainfall , Requirement, Water.

INTRODUCTION

Rice is the major crop cultivated in Thrissur district with an area spread of 21564 ha and a production of 1611 t (ECOSTAT, 2019). It is a semi aquatic plant with a water requirement of 1200-1500mm. Hence, rice production is entirely depends on the availability of water. Even though the mean annual rainfall in Kerala is 3000mm, its temporal distribution is uneven, resulting in five to six months of dry spell (Surendran, 2014). Water shortage might have serious consequences in rice production. Climate change will affect irrigation requirement of rice by changing physiology, phenology, soil water balance, evaporation and effective rain fall. FAO Land and Water Development Division have developed CROPWAT model to determine crop evapotranspiration and yield responses to water (Smith, 1992). CROPWAT model was used to evaluate crop water requirement of rice at different planting dates in Thrissur district of Kerala (Vysakh *et al,* 2016). The possible implications of climate change on crop water requirement of rice can be estimated using CROPWAT model. Investigations on response of irrigation water requirements for rice to climate change are beneficial to develop adaptation strategies to climate change like long

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Table 1: Effective rain fall received (mm/day) during base line and future climates under RCP 4.5 and 8.5

Season	RCP 4.5				RCP 8.5			
	2021	2030	2050	2080	2021	2030	2050	2080
Virippu	769.1	719.5	721	682.4	864.3	813.3	861	862.27
Mundakan	233.7	488.8	432.3	448.8	174	218	208.3	237.9
Pucha	13.5	90	88.1	83.9	11.2	76.9	84.2	85

term water resource development and planning and thus ensure food security and the sustainable use of water resources. This study aims to estimate crop water requirement of rice (*Oryza sativa* L.) for three different crop seasons during 2020 and projected climates of 2030, 2050, and 2080 to understand the possible impact of climate change on crop water requirement of rice in Central Zone of Kerala.

MATERIALS AND METHODS

Study area

The data required for the experiment was collected from Vellanikkara, The station is located at 10^0 32' N latitude and 76^0 20' E longitudes at an altitude of 22 m above mean sea level.

Climate change projections

Among the four representative concentration pathways (RCP), RCP 8.5, RCP 6, RCP 4.5 and RCP 2.6 that describe possible future climates, India follows RCP 4.5 (Garg *et al*, 2015). NorESM1-M model was found to represent the Indian monsoon as well as air temperature in a better way (Garg *et al*, 2015).In this study, the projected daily weather data since 2021-2080 was simulated using NorESM1-M global climate model under RCP 4.5 and 8.5 scenarios. Projected daily weather data was downloaded from MarkSim DSSAT weather file generator (http://gisweb.ciat.cgiar.org/MarkSimGCM/).

Estimation of crop water requirement using CROPWAT model

Daily weather data on maximum temperature, minimum temperature, rainfall and bright sunshine hours were given as input. Crop data like crop coefficient, duration of each stage and rooting depth for short duration rice variety was given as input. Reference evapotranspiration (ET_0), crop water requirement, effective rainfall and irrigation requirement was estimated using CROPWAT model developed by the Land and Water Development Division of FAO, Italy. Crop water requirements (ETcrop) for rice (short duration) three agricultural seasons *viz*. *Virippu, Mundakan and Puncha* for baseline and future climates of 2030, 2050 and 2080 were estimated from ET_o (calculated by the model) and crop coefficients (Kc, given as input to the model), based on well-established procedures (Doorenbos and Pruitt, 1977), according to the following equation:

$$ETcrop = Kc \times ETo$$

RESULTS AND DISCUSSION

Using CROPWAT model, effective rainfall, crop evapotranspiration (ETc) and irrigation requirement were calculated for three agricultural seasons were calculated for 2021, 2030, 2050 and 2080 were calculated.

Effective rainfall

The effective rainfall received during the baseline period (2021) and future climate of 2030, 2050 and 2080 under RCP 4.5 and 8.5 were estimated and represented in Table 1. The effective rainfall received was more during *virippu* season compared to *mundakan* and *puncha* season under RCP 4.5 and 8.5 scenarios. Under RCP 4.5, the effective rainfall received during *mundakan* season was found to be decreasing in future climate where as in case of *mundakan* and *puncha* maximum effective rainfall

Table 2: Crop evapotranspiration (ETc) (mm/day) during base line and future climates under RCP 4.5 and 8.5

Season	RCP 4.5				RCP 8.5			
	2021	2030	2050	2080	2021	2030	2050	2080
Virippu	349.8	357	375.1	366.7	829.5	948.2	936	989
Mundakan	517	543.2	502.9	566.7	957	998.1	1011.8	1039
Pucha	618.4	640.2	643	664.4	680.4	771.2	963.7	1021.1

was received in 2030 compared to other periods. Effective rainfall received during both mundakan and puncha in all the three future climates were higher compared to the base line period *i.e.,* 2020. Under RCP 8.5, maximum effective rainfall was received during base line period *i.e.,* 2020. The effective rainfall received during *virippu* season was less in 2030. Under both scenarios effective rain fall received during future climate was less than that of baseline period (2021). The change in the effective rainfall pattern was also noticed by Chen and Liu (2022). They suggested that the effective rainfall increased in flooding season and it decreased during dry season. Similary, in this study, when comparing both the RCPs the effective rainfall during *virippu* season was more under RCP 8.5 compared to RCP 4.5, whereas in other two seasons (*mundakan* and *puncha*) effective rainfall received was higher under RCP 4.5.

Crop evapotranspiration

Table 2 represents crop evapotranspiration received during the baseline period (2020) and future climate of 2030, 2050 and 2080 under RCP 4.5 and 8.5. Among the three seasons crop evapotranspiration was more during *puncha* season and crop evapotranspiration in all seasons were found to be increasing in future climates of 2030, 2050 and 2080 under both RCPs.

Irrigation requirement

Irrigation requirement was calculated by the model for baseline period of 2021 and future climates of 2030, 2050 and 2080 under RCP 4.5 and 8.5 and presented (Table 3). Compared to the other two season minimum irrigation requirement was recorded in *virippu* season but the irrigation requirement was found to increase in future climates. Maximum irrigation requirement in mundakan and puncha season was observed in 2020, the amount of irrigation water required was reduced in future climates. In a similar way Makar et al (2022) estimated irrigation water requirement for wheat, citrus and berseem using CROPWAT 8 model in Alexandria city.

Percentage deviation in irrigation water requirement of future climates from 2021

Percentage deviation in irrigation water requirement from 2021 during each season under RCP 4.5 was calculated for 2030, 2050 and 2080. The results were depicted in Figure 1. The percentage deviation was positive during *virippu* season. Irrigation requirement was found to be increased by 180.7 percent, 179 percent and 181 percent during 2030, 2050 and 2080, respectively. The percentage deviation was positive during *mundakan* and *puncha* season. Irrigation requirement for *mundakan* season was found to be decreased by 40.35 per cent, 41.14 per cent and 29.8 per cent during 2030, 2050 and 2080, respectively. Irrigation requirement for *puncha* season was found to be decreased by 5.4 per cent, 5.3 per cent and 3.6 per cent during 2030, 2050 and 2080, respectively. Figure 2 explains the same under RCP 8.5 scenario. Under RCP 8.5 scenarios the percentage deviation in irrigation water was positive during *virippu* season, irrigation requirement was found to be increased by 5.6 percent, 107.6 percent and 151.9 percent during 2030, 2050 and 2080 respectively. Irrigation requirement was found to be decreased in *mundakan* and *puncha* season. A decrease of 10.3 percent,

Table 3: Irrigation requirement (mm/day) during base line and future climates under RCP 4.5 and 8.5

Season	RCP 4.5				RCP 8.5			
	2021	2030	2050	2080	2021	2030	2050	2080
Virippu	35.9	100.8	100.4	101	257.9	272.3	535.4	649.7
Mundakan	419	249.4	246.6	294.8	493	442	382.1	385
Pucha	703.5	665.8	665.7	678.9	1002.8	991.3	988.7	960.4

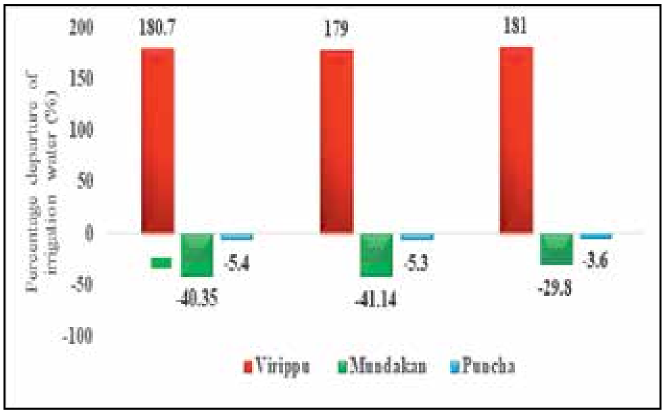

Figure 1: Percentage departure in irrigation requirement calculated for baseline and future climate during three seasons under RCP 4.5

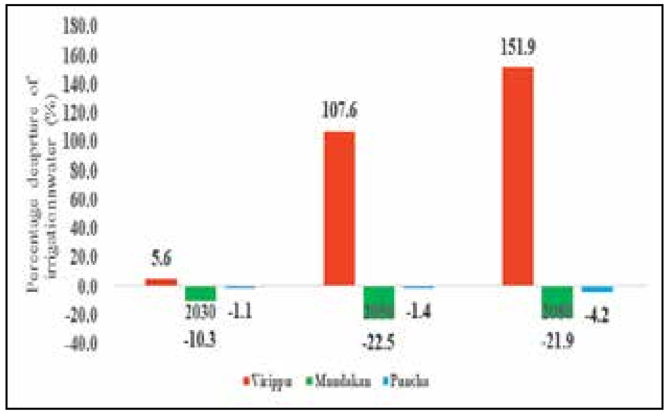

Figure 2: Percentage departure in irrigation requirement calculated for baseline and future climate during three seasons under RCP 8.5

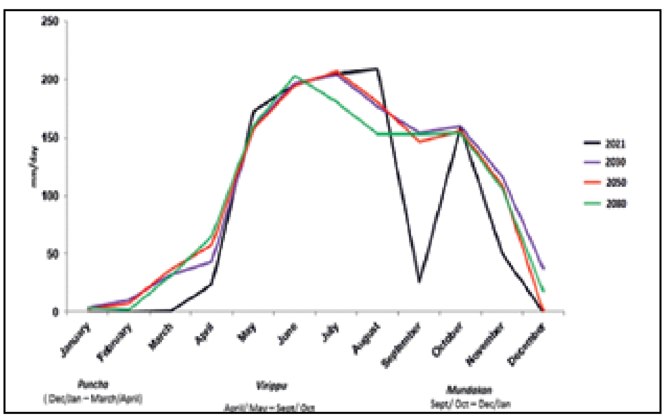

Figure 3: Monthly effective rainfall during base line and future climates

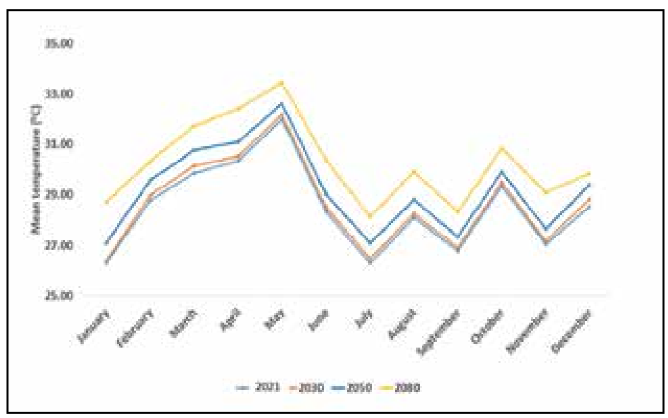

Figure 4: Monthly mean temperature (^{0}C) during base line and future climates

22.5 percent and 21.9 percent were estimated in *mundakan* season and a decrease of 1.1 percent, 1.4 percent and 4.2 percent were estimated in *puncha* season. The decrease in irrigation requirement was more in *mundakan* season compared to *puncha* in future climates. The decrease in irrigation requirement during *puncha* and *mundakan* season was attributed to increased effective rainfall in future climates of 2030, 2050 and 2080 compared to 2021, whereas the amount of effective rainfall received during *virippu* season reduced in future climates that may be reason for increased irrigation requirement in future climates (Figure 3). Monthly mean temperature was calculated during 2021, 2030, 2050 and 2080 and were represented in Figure 4. From the figure it was evident that mean monthly temperature was more in future climate compared to base line period. According to the findings of McCabe and Wolock (1992), based on irrigation model, the increase in mean annual water use was strongly associated with increase in temperature. The warming of climate is consistently associated with changes in the hydrological cycle like changing precipitation pattern and intensity. Increase in mean monthly temperature combined with the decline in effective rainfall during the month of June, July and August (Figure 3 and Figure 4) might be the cause of increase in irrigation requirement during *virippu* season.

CONCLUSION

The study suggested that climate change have serious implications on irrigation requirement of rice by influencing precipitation pattern and crop evapotranspiration. Warming of atmosphere is also associated with changes in components of hydrological cycle. There is a substantial future increase of irrigation requirement during *virippu* season and a decrease during *mundakan* and *puncha* season. The increase in irrigation requirement may influence negatively unless the proper irrigation is given. Proper water management strategies should be adopted during *virippu* season in addition to current practices to adapt the impact of climate change and sustain farmers income.

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