Abstract

The growing population and competition for water from other sectors lead to water-scarce situation, which results in expensive rice production. In addition to this, the changing climatic conditions have already started showing their negative effect on rice productivity. This challenging condition suggests that the rice cultivation with efficient irrigation water management practices must be adopted to save a significant quantity of water and reduce water footprints. Considering the management factors and climate change scenarios, a comprehensive study was carried out on consumptive water footprints and productivities of rice under different non-conventional (i.e. alternate wetting-and-drying (AWD) and system of rice intensification (SRI)) irrigation techniques with climate change adaptation strategies (i.e. shifting transplanting dates) to identify the most favourable irrigation technique with the most suitable transplanting date in both present and future climatic conditions. Field experiments were carried out with IR-36 (medium duration, 120 days) rice cultivar during the kharif (July-October) and rabi seasons (January-April) of 2015/16 and 2016/17 in the experimental farm of Agricultural and Food Engineering (AgFE) Department, Indian Institute of Technology (IIT) Kharagpur under conventional (CON), SRI and AWD irrigation practices. Rice evapotranspiration (ETC) under each irrigation management was measured by the non-weighing type field lysimeters. The observations of the field experiments were used to calibrate the phenological parameters of the APSIM-Oryza model for IR-36 and simulate the water footprints and productivity for CON, SRI and AWD irrigation techniques. Finally, APSIM-Oryza model was used to evaluate agro-adaptation (i.e. transplanting time) under current as well as future climatic conditions for the study area. For future climatic projections, the HadGEM3-RA provided daily meteorological data for two RCPs (RCP4.5 and 8.5) were considered. The climate projection analysis was carried out under these two RCPs using bias-corrected (by quantile mapping method) climate data of three future periods i.e. 2030s (2018–2044), 2060s (2045–2071), and 2090s (2072–2099).

Overall, the total water input for SRI and AWD was significantly ($p < 0.05$) reduced by 18-21% and 22-29%, respectively, as compared to CON for all seasons. The ETC was reduced by 1% under SRI and by 6% under AWD as compared to CON. The deep percolation loss was declined by 23-29% under SRI and 26-31% under AWD as compared to CON. The rice yield in SRI was found to be significantly higher ($p < 0.05$) by 20-30% in comparison with CON. In case of AWD practice, the yield was not significantly different than that of CON. xx

The blue and consumptive water footprints were reduced by 18-29% ($p < 0.05$) under SRI and no significant difference was observed under AWD as compared to CON.
The APSIM-Oryza simulation results showed that under present climatic conditions, the SRI with early transplanting (i.e. 01st July in kharif and 15th December in rabi) was found to be capable of enhancing yield and total water productivity significantly ($p < 0.05$) by 31-38%, 32-56%, and 66-73%, respectively with substantially ($p < 0.05$) reduced water footprints by 55-59%, 27-39%, and 24-36%, respectively as compared to CON with the existing transplanting date (i.e. 16th July in kharif and 15th January in rabi).
The future climate change projections up to 2100 for the study site indicated an overall increase in temperature by 3-4˚C along with the increase in precipitation as compared to the historical period (1976-2005). For the 2030s, 2060s, and 2090s climate change scenarios, the IR-36 yield under CON with the existing transplanting dates was projected to be reduced by 9-13%, 19-28%, and 25-41%, respectively with increased blue and consumptive water footprints by 21-37% in 2030s, 49-69% in 2060s and 60-111% in 2090s as compared to the historical period (1976-2005). The AWD with early transplanting showed no substantial ($p > 0.05$) improvement (3-5%) in the yield during both seasons and reduction (1-3%) in consumptive water footprints during kharif as compared to CON with existing transplanting date. However, the future rabi season scenarios exhibited significant ($p < 0.05$) reduction (24-26%) in consumptive water footprints under the AWD with early transplanting in comparison with CON under existing transplanting. The SRI with early transplanting was found to be capable of increasing yield significantly ($p < 0.05$) by 35-44% in the 2030s, 41-48% in 2060s, and 45-55% in 2090s with substantially ($p < 0.05$) reduced consumptive water footprints of 26-38%, 29-41% and 30-44% in 2030s, 2060s and 2090s, respectively as compared to CON under existing transplanting date. Hence, the SRI with early transplanting was recommended to be the best irrigation practice during both kharif and rabi seasons for IR-36 in the present study area under both present and future climatic conditions. However, SRI management practice is not rigid for all locations. Therefore, irrigation scheduling under SRI and variety of rice need to be adjusted based on local demand and availability to improve productivity with least water footprints in different regions.
Keywords: Alternate wetting and drying, APSIM-Oryza, Blue water footprint, Consumptive water footprint, Evapotranspiration, Lysimeter, System of rice intensification, Water Productivity.