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Impact assessment of climate change on rice yield using simulation model

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Abstract
Rice crop yield prediction using normalized yield difference analysis on seasonal basis reveal that maximum temperature may cause the reduction in yield of rice in Eastern U.P. by 1% to 1.2% / ha during 2020 to 2080. Minimum temperature may decrease the yield of rice by 1.5% to 1.8% / ha. South-West monsoon rainfall will remain the major factor for controlling the yield of rice by the end of 2080. Increase of yield in Eastern U.P. may increase to the extent of 28% to 30% / ha. Future prediction of Tmax & Tmin scenario on monthly basis predicts that the month of December and January will be hotter than November contrary to normal trends. For T minimum the prediction in Eastern U.P., increase of temperature will be during month of December and January for 2020 to 2080. The rate of increase of Tmax those during months in Eastern U.P. will be higher during 2050-2080 (2 to 4 ºC) as compared to 2020 to 2050(1 to 2 ºC). During 2020, the rainfall will be lower in Eastern U.P. Terminal drought (60 DAT -75 DAT) at 50% flowering to milking stage is more severe to reduce the rice yield as compared to drought at early tillering (15 to 25 DAT) and vegetative stage (45 to 60 DAT). Simulated yield of rice reduced from average 2020 to 2080 in the tune of 15.13%, 11.19%, and 14.09% under July 5th, July 15th, July 25th transplanting of rice variety Sarjoo-52 respectively. The Rate of decrease of simulated yield of rice Sarjoo-52 variety under 2020 to 2080 was faster under delayed transplanting of July 25th. Integrated crop management emphasized in future besides developing short duration, drought tolerant varieties responsive to low inputs.

Keywords: Simulation, Climate, Eastern U.P, Rice, Prediction

1. Introduction
Crop simulation models can integrate knowledge of physiological process and morphological traits to help explain yield formation in environments varying in physical, biological and agronomic factors. These simulations can be used to evaluate key interactions quickly and identify traits with the greatest impact on yield potential (Aggarwal *et al*., 1997) [1] and for assessing the relationship between crop productivity and environmental factors.
Crop simulation models can predict responses to large variations in weather. At every point of application weather data are the most important input. The main goal of most applications of crop models is to predict commercial output like grain yield, fruits, root, biomass for fodder, etc. Crop simulation models are used in USA and in Europe by farmers, private agencies and policy makers to a great extent for decision making. Under Indian climatic condition, these applications have an excellent role to play. Rice is mainly grown as rainfed crop in Uttar Pradesh but Uttar Pradesh is highly risk prone in respect of rainfall either due to delayed monsoon, intermittent drought or terminal drought and even floods in north Eastern part of Uttar Pradesh causing great loss of rice production. Therefore, prediction of rice production not only in state as a whole but also at district level is rather uncertain due to vagaries of monsoon. Hence, modeling approach can be adopted for prediction in the state at macro or micro level. Simulation models which help in predicting the yield of a crop is therefore is the need of the day. It is essential to have pre-harvest estimate of production for Uttar Pradesh due to its importance on state as well as national economy. Hence present investigation was undertaken.

Materials and Methods
Collection of daily historical weather data of last (20 years), crop data & soil data were made. Minimum data set for Rice crop for last three years was required for operation and evaluation of simulation model. Calibration of simulation model was made with the historical data of kharif rice 2013 and 2014. Validation of the model was done with the experimental data of kharif rice 2015 and 2016. For impact assessment of climate change on Rice yield of Future prediction of Rice crop under Agro-climatic conditions of Eastern U.P., Prediction of

Normalized Yield difference (NYD) in Eastern U.P. of rice crop and Projected trends in Temperature and rainfall over Eastern U.P. were identified for the region.

Average model for the period of 2020, 2030, 2040, 2050 and 2080 for the weather and crop management for 2020, 2030, 2040, 2050 and 2080 of the region were generated in the model. Simulated yield of rice transplanted under three dates of sowing were obtained. CNRM-CM3, CSIR MK3.5 model, EC HAM5, and MIROC 3.2 model for average 2020,2030,2040,2050 and 2080 were created for weather of the region.

Results and Discussion

Future prediction of Rice crop of Eastern U.P.

Rice crop yield prediction using Normalized yield difference (NYD) on seasonal basis it has been observed that maximum temperature may cause the reduction in yield of rice in Eastern U.P. by 1% to 1.2% per ha during 2020 to 2080.(Fig-1) Similarly minimum temperature may decrease the yield of rice by 1.5% to 1.8% per ha in Eastern U.P. From future scenario of rainfall it was observed that South-West monsoon rainfall will remain the major factor for controlling the yield of rice by the end of 2080. The increase of yield in Eastern U.P. may increase to the extent of 28% to 30% per ha. (Anonymous, 2007, Anonymous, 2013 and Aggarwal *et al.*, 1997) [2, 3, 1]

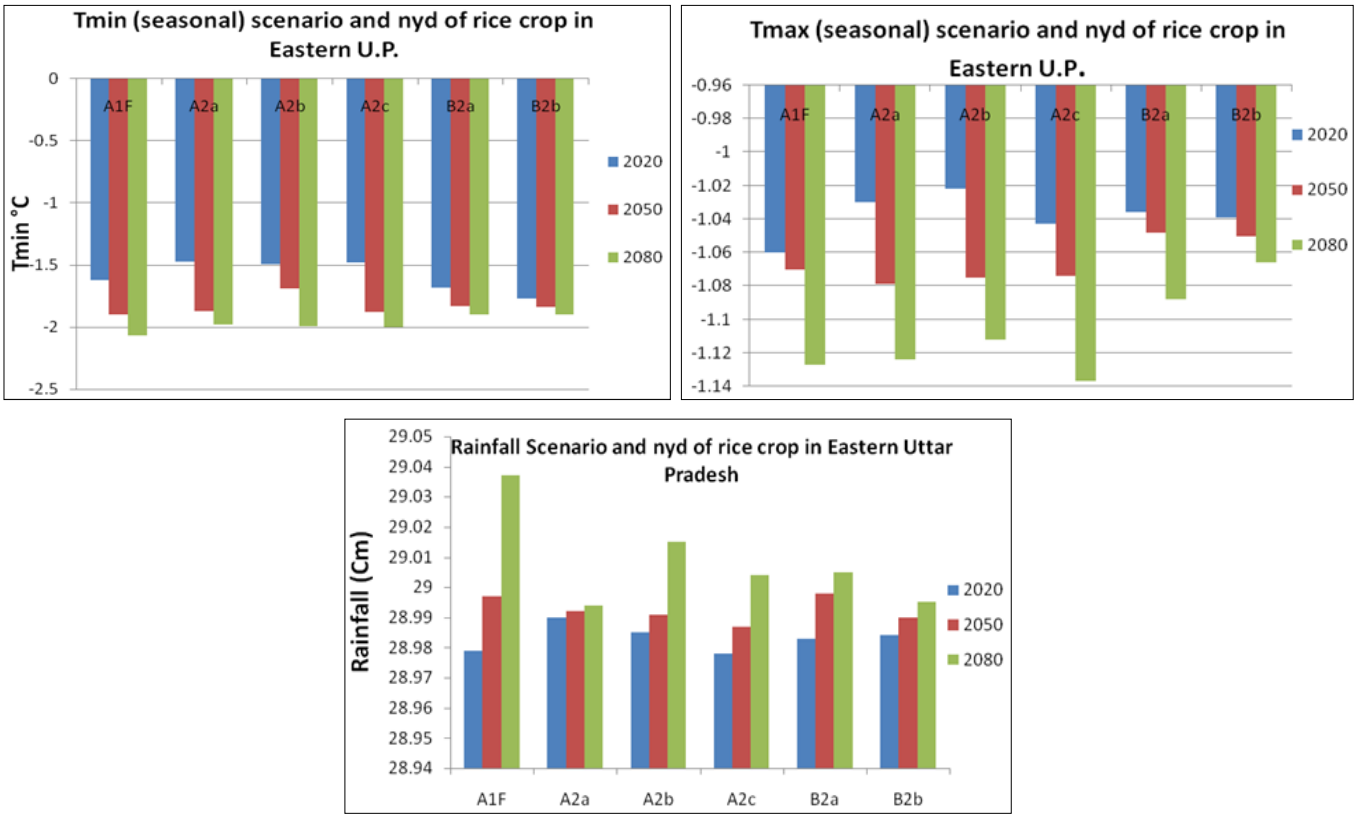
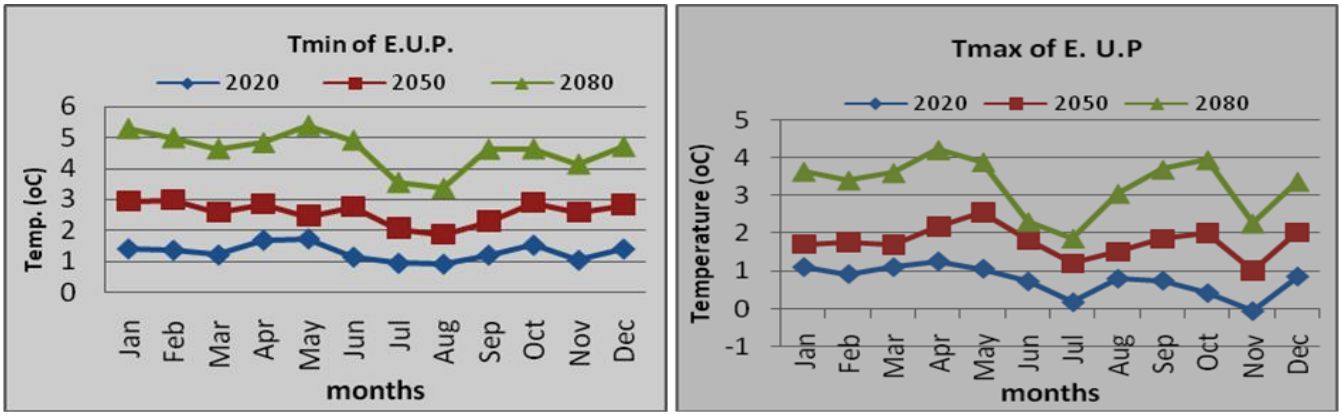


Fig 1: Prediction of Normalized yield Difference of Rice crop (Seasonal basis)

Prediction of Normalized Yield difference (NYD) of rice crop

Future prediction of Maximum Temperature & Minimum Temperature Scenario on monthly basis of Eastern U.P. predicts that the month of December and January will be hotter than November contrary to normal trends. (Fig-2) For minimum temperature the prediction in Eastern U.P. increase in temperature will be during the month of December and January for 2020 to 2080. In general, the rate of increase of Maximum Temperature those during months in Eastern U.P. will be higher during 2050-2080 (2 to 4 ºC) as compared to 2020 to 2050(1 to 2 ºC). Similar observation was recorded for variation with greater magnitude in Eastern U.P. ranging between 3 to 5 ºC in later part of century as compared to early part by 2 to 3 ºC (Anonymous, 2013, Bemal *et al.*, 2009 and Tripathi, *et al.*, 1999) [3, 4, 9].



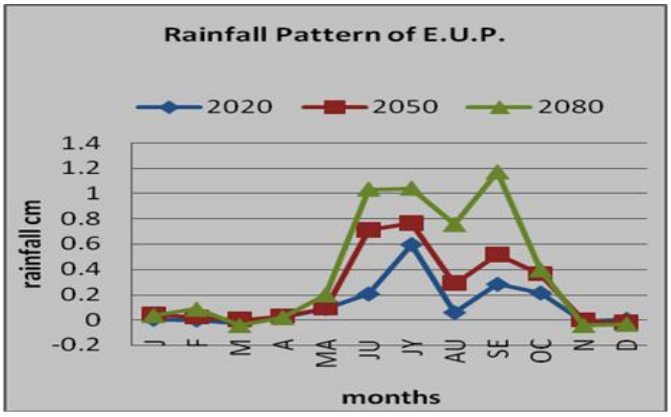


Fig 2: Future prediction of Tmax./Tmin. and Rainfall for Eastern U.P.

Projected trends in Temperature and rainfall over Eastern U.P

The maximum temperature is likely to increase between 0.6 ^{0}C and 3.0 ^{0}C in Eastern U.P while minimum temperature is likely to increase between 1.0 and 4.5 ^{0}C during ensuing decades by 2080. (Fig-3) A slight increase in rainfall is likely to be over Eastern U.P by 2080 (Anonymous, 2007 and Boote *et al.*, 2008) [2, 5].

Simulated yield of rice reduced from average 2020 to 2080 in the tune of 15.13%, 11.19%, and 14.09% under July 5th, July 15th, July 25th transplanting of rice variety Sarjoo-52 respectively (Table-1). The Rate of decrease of simulated yield of rice Sarjoo-52 variety under 2020 to 2080 was faster under delayed transplanting of July 25th. (Rao *et al.*, 1996, Geethalakshami *et al.*, 2008) [7, 6] Decrease in the yield was reported from average 2020 to 2080 irrespective of dates of transplanting of rice in the Eastern U.P. Reduction in simulated yield of Sarjoo-52 variety of rice under average of 2020 to 2080 was in the tune of 2.1% (July 5th transplanting) to 4.8% (July 25th transplanting) indicating faster decrease under delayed transplanting (July 25th) in the region. July 5th transplanting of rice Sarjoo-52 in the region was more efficient and profitable over delayed transplanting (July 25th)

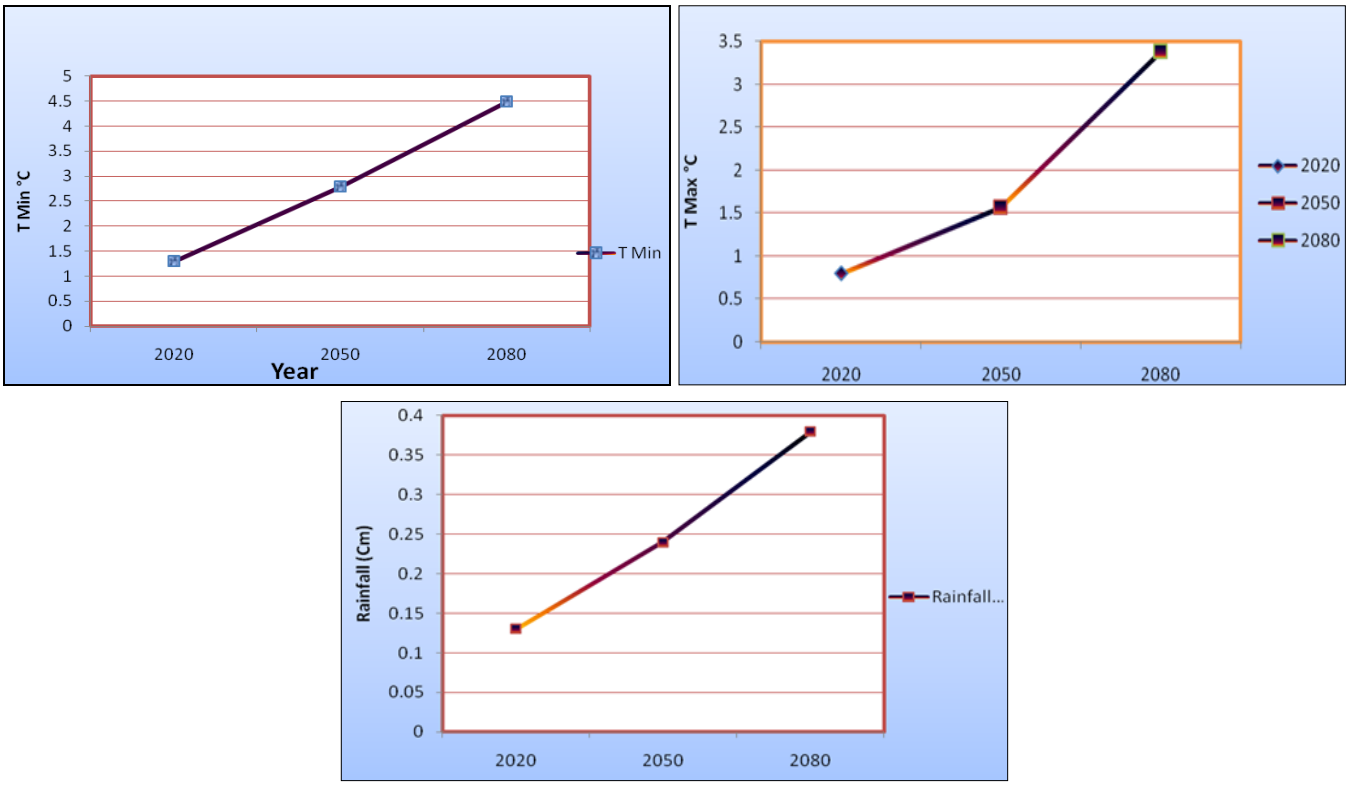


Fig 3: Projected trends in Temperature and rainfall over Eastern U.P

Table 1: Simulated yield of Rice during average 2020 to 2080 under different growing environment

Particulars	Date of Transplanting	Simulated Yield (Kg/ha)
Ave. 2020	5 July	4153
	15 July	3686
	25 July	3723
Ave.2030		
	5 July	3841
	15 July	3567
	25 July	3569

Ave.2040		
	5 July	3979
	15 July	3833
	25 July	3659
Ave.2050		
	5 July	3747
	15 July	3518
	25 July	3279
Ave.2080.		
	5 July	3616
	15 July	3315
	25 July	3263

Identification of adaptation strategies

As temperature (maximum/minimum) of Eastern U.P. showed the increasing trend in Eastern U.P. whereas a slight increase in minimum temperature was noticed during 2080. The rainfall scenario of Eastern U.P. showed much variation trend on monthly basis and observed that in Eastern U.P. The rainfall will increase during South-West monsoon period during 2020, 2050 and 2080 but the month of August will face sharp decline of the rainfall. In winter season, the low rainfall prediction is also reported as compared to present normal. (Swain *et al.*, 2007) [8]

A peculiar picture for rainfall indicated that during 2020 the rainfall will be lower in Eastern U.P. except 2080. Terminal drought (60 DAT -75 DAT) at 50% flowering to milking stage is more severe to reduce the rice yield over to drought given at early tillering (15 to 25 DAT) and vegetative stage (45 to 60 DAT). Vegetative stage drought is next to terminal drought for reduction in yield over early tillering. Integrated crop management need to be emphasized in future besides developing short duration, drought tolerant varieties responsive to low inputs.

Conclusion

Minimum temperature may decrease the yield of rice by 1.5% to 1.8% / ha. South-West monsoon rainfall will remain the major factor for controlling the yield of rice by the end of 2080. During 2020, the rainfall will be lower in Eastern U.P. Terminal drought (60 DAT -75 DAT) at 50% flowering to milking stage is more severe to reduce the rice yield as compared to drought at early tillering (15 to 25 DAT) and vegetative stage (45 to 60 DAT). Simulated yield of rice reduced from average 2020 to 2080 in the tune of 15.13%, 11.19%, and 14.09% under July 5th, July 15th, July 25th transplanting of rice variety Sarjoo-52 respectively. The Rate of decrease of simulated yield of rice Sarjoo-52 variety under 2020 to 2080 was faster under delayed transplanting of July 25th. Integrated crop management emphasized in future besides developing short duration, drought tolerant varieties responsive to low inputs.

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