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Impact assessment of seasonal climate change on kharif rice under various future scenarios

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Abstract
Global climate change has potentially grave consequences for rice production and, consequently global food security. Negative effects on yields and availability of rice will directly translate into major shortages. Hence, it is essential to study the impact of climate change on *Kharif* rice yield. This study was conducted to assess the impact of climate change on productivity of rice *cv.* Hasanta in three future scenarios namely 2030, 2050, 2070 for Khordha district of Odisha, using four global climate change Representative Concentration Pathways (RCPs) scenarios namely 2.6, 4.5, 6.0 and 8.5. Weather parameters for climate change scenarios include projection of rainfall, maximum temperature, minimum temperature and radiation for Khordha district by using Mark Sim GCM -DSSAT weather file generator. In this study growth, development and yield of four rice cultivars are verified transplanted under four different dates of planting. The experiment were laid out in split plot design with four dates of transplanting in main plots and four varieties in sub plots with three replications.
In cv. Hasanta seasonal temperature increasing by 1-2 °C combining with increase in rainfall and solar radiation as per RCP scenarios causes increase in yield of kharif rice however, grain yield decreased with increase in temperature of more than 2 °C along with solar radiation more than 3.8 MJ/day. that the projected impact under RCP 4.5, RCP 6.0 and RCP 8.5 scenarios is much severe as compared to RCP 2.6 scenario on the grain yield characteristic of rice resulting in drastic decrease of the yield in future for the years 2030, 2050 and 2070.

Keywords: Climate change, RCP, Marksim, kharif rice

Introduction
Changes of climate will be one of the deciding factors that affect for future food production in the world because crop growth is highly sensitive to any changes of climatic conditions. Impacts of climate change on Agriculture will be one of the major deciding factors influencing the future food security of mankind on earth. Since rice is the staple food of India, it is essential to identify the impacts of climate change on rice yield to increase the country's rice production.
Rice (*Oryza sativa* L.) is the most important and extensively grown crop in tropical and subtropical regions of the world as it is the staple food for more than 60% of the world population. It is the source for 35-80% of total calorie intake of Asian population and again two third of the peoples in this region receive their daily calories from rice (Rahman and Masood, 2012). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth. Being the major source of food after wheat, it meets 43% of the calorie requirement of more than two third of the Indian population. The world's total rice area is 167.2 M ha and production is about 769.6 MT with the productivity of 4.6 t ha^{-1}. India has the largest area among rice growing countries and stands second in production next to China, where it is grown in an area of 43.7 M ha annually with a production and productivity of 168 MT and 3.8 t ha^{-1} respectively and accounts for 45% of food grain production in the country.
Climatic factors such as temperature, rainfall, atmospheric CO_2 and solar radiation are important parameters to rice production (Nyangau *et al.,* 2014) [7]. The average daily maximum temperature and rainfall pattern will be changed as a result of increasing concentrations of CO_2 and other greenhouse gases in atmosphere. These changes have become the most important considerations for rice production (Dharmarathna *et al.,* 2011) [2]. Earth climate is rapidly changing and alteration to global climate change can have important effect on crop growth, development and yield by increasing carbon dioxide, temperature and

uncertainity in rainfall. The relationship between climate change and agriculture is an important issue. The impact of climate change on rice production is of particular interest due to its importance as a food source in all over the world. Khordha district is one of the rice cultivation districts in Odisha and have a good potential for rice cultivation. Most of the farmers in this area cultivate improved rice varieties but their yield is always lower than the potential yield due to the different level of management practices and the variation of climatic conditions. Yield gap can be increased in the future due to climate change especially if current agricultural practices are continued (Basak *et al.*, 2012) [1]. Understanding rice production in relation to weather changes is of great importance to boost food productivity Conducting the field experiments for identify impacts of climate change on rice cultivation will take long time period.

Materials and Methods

The field experiment was conducted at central research centre, Odisha University of agriculture and technology, Bhubaneswar, Odisha during *kharif* 2019. Bhubaneswar is located between 85° 44' E and 85° 55' E longitude and 20° 12' N and 20° 25' N latitude in Khordha district of Odisha. It is situated in the east and south-eastern coastal plains at an altitude of 25.9 m above sea level. The field experiment was conducted during kharif season of 2019 for verification of growth, development and yield of four (4) rice varieties transplanted under four (4) different dates in a split plot design. There were 16 treatments combination consisting of four different transplanting dates and four rice varieties.

Pre-harvest observations like Plant height, total leaves, no. of tillers/hill, dry matter production, Leaf area index, phonological observations at different phenophases were taken as well as post harvest observations like no. of panicles, total no. of grains/panicle, 1000 grain weight, grain yield, harvest index, CGR, RGR were also recorded.

DSSAT cropping system model

The decision support system for agro technology transfer (DSSAT) was originally developed by an international network of scientists, cooperating in the International Benchmark Sites Network for Agro technology Transfer project (IBSNAT), to facilitate the application of crop models in a systems approach to agronomic research.

CERES-Rice model

The CERES-RICE: Crop Estimation through Resource and Environment Synthesis-Rice is a generic and dynamic simulation model which was developed under International Benchmark Sites for Agro-technology Transfer (IBSNAT) project (Richie *et al*., 1986) [7]. It was part of Decision Support System for Agrotechnology transfer (DSSAT) developed by Hoogenboom *et al*. is a processed based model that stimulate growth and development of cereal crops under varying weather, soil, and management levels.

The climatic projection for Khordha district in four RCPs scenarios (2.6, 4.5, 6.0, 8.5) are done for rainfall, Tmax., Tmin., radiation using Mark Sim GCM-DSSAT weather file generator working off a 30 arc-second climate surface derived from World Clim.

Prediction of growth and yield of kharif rice cultivar Hasanta under projected climate change

Database of changes in temperature, rainfall and solar radiation in Odisha for future climates was prepared. Representation Concentration Pathways (RCP) data for Khordha were used for three future years, namely 2030, 2050 and 2070 which were used in Fifth Assessment Report of IPCC (Van Vuuren, *et al*., 2011) [8]. The growth and yield of rice under projected climate change was studied using CERES-Rice model. The growth and yield under present climatic condition was simulated, which is compared with the growth and yield simulated under future climate.

Climatic projection for Khordha using Mark Sim – DSSAT weather file generator (Software)

The climatic projection for Khordha district in four RCPs scenarios (2.6, 4.5, 6.0, 8.5) are done for rainfall, Tmax., Tmin., radiation using Mark Sim GCM-DSSAT weather file generator working off a 30 arc-second climate surface derived from World Clim. Using Marksim for any location, Mark Sim makes use of a climate record. This is independent of the scale of the data but is constant in its form and acceptability to the rest of the Mark Sim software. A climate record contains the latitude, longitude and elevation of the location, and monthly values of rainfall, daily average temperature and daily average diurnal temperature variation. It also includes the temporal phase angle, that is, the degree by which the climate record is ''rotated'' in date.

Results and Discussion

In 2030, scenario of RCP 2.6 shows and increase of 1.76 MJ/day in mean seasonal solar radiation from present weather scenario. There is an increase of 0.08 °C in mean seasonal maximum temperature and 1.04 °C in mean seasonal minimum temperature. Total seasonal rainfall shows a decrease of 92.99 mm. In RCP scenario 4.5, there is an increase of 1.86 MJ/day in mean seasonal solar radiation, an increase of 0.31 °C in mean seasonal maximum temperature and 1.14 °C in mean seasonal minimum temperature. There is decrease of 107.69 mm in seasonal rainfall from present scenarios. RCP scenario 6.0 shows a increase of 1.8 MJ/day in mean seasonal solar radiation with an increase of 0.11 °C in mean seasonal maximum and 1.07 °C minimum temperature. There is decrease of 154.99 mm in seasonal rainfall from present scenario. RCP scenario 8.5 shows an increase of 2.06 MJ/day in mean seasonal solar radiation and an increase of 0.61 °C in mean seasonal maximum and 1.22 °C minimum temperature. Mean seasonal rainfall shows a decrease of 140.69 mm from present scenario.

In RCP scenario 2.6 for year 2050, there is an increase of 1.61 MJ/day in mean seasonal solar radiation, an increase of 0.16 °C in mean seasonal maximum temperature and 1.22 °C in mean seasonal minimum temperature. However, mean seasonal rainfall decreases by 129.09 mm from the present scenario. RCP scenario 4.5 shows little change in mean seasonal solar radiation with an increase of 0.24 °C both in mean seasonal maximum and 0.32 °C minimum temperature and rainfall decreases to 1 mm compared to RCP 2.6. RCP scenario 6.0 shows a decrease of 0.05 MJ/day in mean seasonal solar radiation and a slight decrease of 0.22 °C in mean seasonal maximum and 0.12 °C decrease in minimum temperatures. There is decrease of 16.3 mm in seasonal rainfall from RCP 4.5. RCP scenario 8.5 shows little difference in mean seasonal solar radiation but an increase of 0.48 °C in mean seasonal maximum temperature and 0.55 °C in mean seasonal minimum temperature. There is a decrease of 37.9 mm in mean seasonal rainfall from RCP 6.0.

In RCP scenario 2.6 for year 2070, there is an increase of 1.66 MJ/day in mean seasonal solar radiation, increase of 0.34 °C in mean seasonal maximum temperature and an increase of 1.25 °C in mean seasonal minimum temperature. However, mean seasonal rainfall decreases by 121.9 mm from present scenario. RCP scenario 4.5 shows a similar trend in mean seasonal solar radiation with an increase of 0.19 °C both in mean seasonal maximum and 0.59 °C in minimum temperature compared to RCP 2.6.RCP scenario 6.0 shows an increase of 0.08 MJ/day in mean seasonal solar radiation and 0.05 °C in mean seasonal maximum. Minimum temperatures from RCP 4.5 shows little increase of 0.16 °C. There is some decrease (28.3 mm) in seasonal rainfall from RCP 4.5. RCP scenario 8.5 shows little difference in mean seasonal solar radiation of 0.17 MJ/day but an increase of 0.98 °C in mean seasonal maximum temperature and 0.92 °C in mean seasonal minimum temperature. There is a decrease of only 16.4 mm in mean seasonal rainfall from RCP 6.0.

Table 1: Seasonal (*Kharif*) climate change projection

(a) 2030

Variable	Present weather scenario	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Rainfall, mm	1394.19	1301.2	1286.5	1239.2	1253.5
Mean Maximum Temperature, °C	32.52	32.6	32.83	32.63	33.13
Mean Minimum Temperature, °C	24.11	25.15	25.25	25.18	25.33
Mean Solar Radiation, MJ/day	16.15	17.91	18.01	17.95	18.21

(b) 2050

Variable	Present weather scenario	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Rainfall, mm	1394.19	1273.1	1272.1	1255.8	1217.9
Mean Maximum Temperature, °C	32.52	32.68	32.92	32.70	33.18
Mean Minimum Temperature, °C	24.11	25.33	25.65	25.53	26.08
Mean Solar Radiation, MJ/day	16.15	17.76	17.76	17.81	17.85

(c) 2070

Variable	Present weather scenario	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Rainfall, mm	1394.19	1272.9	1306.7	1278.4	1294.8
Mean Maximum Temperature, °C	32.52	32.86	33.05	33	33.98
Mean Minimum Temperature, °C	24.11	25.36	25.95	26.01	26.93
Mean Solar Radiation, MJ/day	16.15	17.81	17.81	17.73	17.9

Grain yield

In year 2030, Grain yield (kg/ha) was simulated by Ceres-Rice model and are given in Table 2 for four transplanting dates. Simulated grain yield decreases from 10% to 33% under RCP 2.6, 4.5, 6.0 and 8.5 on 21 July planting. Yield decreases from 11% to 34% under all RCPs in 5 August planting. Yield decreases from 14% to 31% in RCP 2.6, 6.0 and 8.5 in 20 August. Yield decreases from 11% to 48% in RCP 2.6, 4.5 and 6.0 and it increases by +3.29% in RCP 8.5 in 4 September.

In 2050 there is decrease in grain yield from 18% to 48% in all the RCPs in 21 July. Yield decreases from 5% to 56% in all the RCPs in 5 August planting. Yield increases by 7.31% in RCP 4.5, 8.31% in RCP 6.0 and it decreases from 14% to 29% in 20 August planting. Grain yield increases from 12% to 21.7% in RCP 6.0 and 8.5 and it decreases from 23.4% to 47.9% on 4 September planting.

In 2070 grain yield decreases from 15% to 52% in all the RCPs in 21 July planting. Yield decreases from 4% to 52.8% in all RCPs on 5 August planting. Grain yield decreases from 19% to 45% in all the RCPs on 20 August planting. In 4 September planting, yield decreases from 17% to 41.09% in RCP 2.6, 6.0 and 8.5 whereas yield increases by 6.4% in RCP 4.5.

Table 2: Observed and Simulated grain yield of *cv.* Hasanta of four transplanting dates under four RCP projections for the year 2030, 2050 & 2070

	Planted on 21 July					Planted on 5 August					Planted on 20 August					Planted on 4 September				
Grain Yield at harvest maturity, kg/ha	Observed	Simulated				Observed	Simulated				Observed	Simulated				Observed	Simulated			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2030	4155	3732	2652	2780	2934	4225	3758	2762	2835	3008	3800	3238	4233	2612	2874	3217	2840	2674	1670	3323
2050	4155	3377	2851	2153	3003	4225	3986	3559	2757	1853	3800	3239	4077	4116	2695	3217	1676	2464	3914	3260
2070	4155	3531	1987	2290	1976	4225	4025	2626	2561	1992	3800	3078	2547	2221	2077	3217	2071	3423	1895	2652

Conclusion

In cv. Hasanta Simulation by Ceres-Rice model in present condition underestimated the grain yield but simulated phenology as same as observed phenology with a little variation. For the year 2030, RCP 2.0, 4.5, 6.0, 8.5 scenarios are likely to cause an increase in seasonal maximum temperature, seasonal minimum temperature but seasonal rainfall shows decreasing trend with four RCPs scenarios. Solar radiation also shows a increasing trend in RCPs 2.6, 4.5, 6.0 and 8.5 from present scenario. For the year 2050, same (but more prominent than 2030) increasing trends of seasonal maximum, minimum temperature and solar radiation are likely to occur but the decrease in rainfall is more prominent in all scenarios. In 2070 maximum temperature shows an increasing trend, same in the case of minimum temperature except RCP 2.6. The solar radiation shows a similar increasing trend but the rainfall also remain same with huge differences. The grain yield of Hasanta is likely to decrease under four scenarios in 2030 but to decrease in yield by 2050 in and in case of 2070 the yield is likely to decrease in early and late planting but shows no significant change for mid-season planting under all RCPs scenarios. It was also found that production potential of Swarna was higher than other varieties. In mid-season planting, all the varieties performed well whereas their performance was poor in delayed transplanting dates.

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