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Assessment of seasonal climatic variability and its impact on *kharif* rice yield of Ganjam, Odisha, India

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Abstract
Potential impacts of climate change on rice production have been estimated in several studies. This study was conducted to assess the impact of climate change on productivity of *kharif* rice *cv.* Hasantaa for the year 2030, 2050, 2070 for Ganjam district of Odisha, using four global climate change Representative Concentration Pathway (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 solar radiation for Ganjam district by using Mark Sim GCM -DSSAT weather file generator. In this study growth, development and yield of four rice cultivars are verified under four different dates of planting. In *cv.* Hasantaa by increasing the CO_2 concentration 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 ^{0}C along with solar radiation more than 3.8 MJ/day. In 2030, there is an increase in yield but in 2050, there is almost no change in yield except for late transplanting date. However, in 2070 no significant changes in yield under early and late transplanting date but declines in midseason transplanting. RCP 8.5 scenario results in declining yield in all transplanting dates in 2070.

Keywords: ganjam, climatic variability, *kharif* season, hasantaa

Introduction
Rice (*Oryza sativa* L.) is the most important food crop in the world, directly feeding more than 78% of the world population, including virtually all east and Southeast Asia. Nearly 640 million tons of rice is grown in Asia, representing 90% of global production. Among the rice growing countries of world, India has highest area 43.2 million hectares in rice cultivation and ranks second with respect to production. In Odisha rice cultivation is synonymous with food. Rice covers about 69% of cultivated area. Rice is grown in Odisha mainly in *kharif* season. Rice accounts for 41.80 lakh hectors of area with a production of 76.13 lakh metric tons; moreover contribution of Ganjam district is about 406 ha. Ganjam contributes about 6.70% towards total area. Climate variables such as rainfall, temperature, solar radiation and carbon dioxide concentration are most important factors affect crop variability and productivity. 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. The major effect of temperature on crop growth is to control duration of period. Increased temperature accelerates plant phenological development; however it can decrease grain filling period (Amothor, 2000). Hence temperature increases may shorten the length of growing period. Climatic change may modify precipitation, runoff, evaporation and soil moisture which in term can affect duration of growth through effect on leaf area duration and also may affect the photosynthetic efficiency through stomatal closure (Olesen and Bindi, 2002). It is therefore extremely important to know the future scenarios of climate change at regional as well as global level and mitigation measures to solve problems of crop sustainability and food security. Here in this context Marksim weather generator has been used to model changing climate in temperature, rainfall solar radiation for future climate. Representation Concentration Pathways (RCP) data for Ganjam 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) [3].

Methodology
The present study was carried out during *kharif* season of 2018 at Research field of Krishi Vigyan Kendra, Ganjam district of Odisha. Ganjam is situated at an elevation of 3m above sea level, 19.38 °N latitude and 85.07 °E longitude. There were 16 treatments combination

consisting of four different transplanting dates in main plot and four rice varieties in sub-plots. The treatments are laid out in a split plot design with dates of transplanting in the main plot and varieties as the sub plot treatments replicated thrice. The dimension of the experimental area was $30x35m^2$ ($1050m^2$) with each sub plot dimension. The experimental plots are provided with irrigation channels of 1 meter and the individual plots are demarcated with bunds.

Several observations were taken according to the need of research work including pre-harvest and post observations.

Pre-harvest observations

Pre-harvest observations include tagged hill data where three tag hill plants will be selected from each plots and data on height of the plants, number of tillers, total number of leaves and number of leaves in main shoot will be observed in 15 days interval. For taking leaf area-data sample plants will be collected and leaf area data will be taken and dry weight of root, shoot and leaf is taken. Phenological observation dates of occurrence of following phenological stages are visually noted. tillering, panicle initiation, heading, 50% flowering, 100% flowering, soft dough, hard dough, physiological maturity

Post-harvest observation

Observations on following post-harvest operations are noted

Number of panicle, Number of grains/panicle, 1000 grain weight, Height and numbers of 5 panicles fertile and sterile grains, Weight of straw, Weight of total grains/plots and Harvest index.

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, 1993; Tsuji, 1998; Uehara, 1998; Jones *et al*., 1998), to facilitate the application of crop models in a systems approach to agronomic research.

The CERES-RICE model

Crop Estimation through Resource and Environment Synthesis-Rice is a generic and dynamic simulation model which was developed under International Benchmark Sites for Agrotechnology Transfer (IBSNAT) project (Richie *et al*., 1987). 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. It simulates soil water balance and water use by crop and soil nitrogen transformations and uptake by crop besides growth and different phenophase of crop.

The climatic projection for Ganjam 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 (Jones & Thornton 2000, Jones *et al*., 2002) working off a 30 arc-second climate surface derived from World Clim (Hijmans *et al.*, 2005).

Statistical analysis and interpretation of results

The index of agreement (***d***) proposed by Willmott *et al.*, (1985) was estimated through the following equation. According to the *d*-statistics, the closer the index value is to 1, the better the agreement between the two variables that are being compared and vice-versa. The d-value determines the degree of agreement between the simulated values with their respective observed values. The d-Index was estimated through the following equation.

$$d = 1- [\sum_{i=1}^{n}(P_i - O_i)^2 / \sum_{i=1}^{n}(P_i + O_i)^2]$$

Where, n is the number of observations,

P_i is the predicted observation,

O_i is the observed value.

$P_i = P_i - M$ and $O_i = O_i - M$ (*M* is the mean of the observed variable).

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 Ganjam were used for three future years, namely 2030, 2050 and 2070 which were used in Fifth Assessment Report of IPCC (VanVuuren, *et al*., 2011) [3].

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 Ganjam using Mark Sim –DSSAT weather file generator (Software)

The climatic projection for Ganjam 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 (Jones & Thornton 2000, Jones *et al*., 2002) working off a 30 arc-second climate surface derived from World Clim (Hijmans *et al.*, 2005)

Mark Sim model

Mark Sim tool was developed by Waen Association by other CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS). Mark Sim is a weather generator that uses 720 classes of weather, worldwide, to calculate the coefficients of a third order Markov rainfall generator. This constitutes 'stochastic downscaling' as it fits a Markov model to the GCM output and uses it to generate weather data for the site indicated. The third weapon in Mark Sim GCM is built into the weather typing in the clustering process. The 720 classes of world weather define each set of regression equations that Mark Sim uses to determine the coefficients for the modelling process. When a climate changes, such that it no longer applies to the original class, then the whole regression structure changes. This means that a changing climate will be modelled by the one most like it in the real world. The only drawback is that the system cannot model completely new climates except by extrapolation of the regression models from the nearest cluster. But then we are still to see a new climate in sufficient detail to fit the model to it and GCM results are not precise enough to do this for the future. In the meantime, we have to wait (Jones P. G. and Thornton P. K. 2013) [5].

Results and Discussion

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 the increase in maximum temperature is slightly more than the minimum temperature, seasonal rainfall shows increasing trend with four RCPs scenarios. Solar radiation also shows a decreasing 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 increase in rain fall 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 decreasing trend but the rainfall diverted from the increasing trend and shows a decreasing trend. The grain yield of Hasanta is likely to increase 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. Rice yield is likely to increase in 2030 and a decrease in yield in 2050 and similar decreasing trend is observed in 2070 in early and late dates of planting but in case of mid-season planting no significant change in observed in all RCPs scenarios. It was also found that production potential of Hasanta was higher than other varieties. In mid-season planting, all the varieties performed well whereas their performance was poor in earliest and latest transplanting dates.

Table 1: Projected change in seasonal Climate

Variable	Present weather scenario	Difference from present weather scenario											
		RCP 2.6			RCP 4.5			RCP 6.0			RCP 8.5		
		2030	2050	2070	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rainfall, mm	1103.2	1118.5	1135.7	964.9	1106.3	1133.6	994.2	1110.9	1124.1	976.4	1118.9	1132.3	988.8
Mean Maximum Temperature, ^{0}C	30.8	31.3	31.5	31.1	31.5	31.9	31.7	31.4	31.8	31.8	31.6	32.3	32.7
Mean Minimum Temperature, ^{0}C	23.9	24.1	24.3	23.7	24.2	24.6	24.4	24.1	24.5	24.4	24.3	25.1	25.3
Mean Solar Radiation, MJ/day	14.2	17.9	17.8	17.3	17.9	17.8	17.2	18	17.9	17.1	17.9	17.9	17.1

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

Grain Yield at harvest maturity, kg/ha	Planted on 12th July					Planted on 27th July					Planted on 11th August					Planted on 26th August				
	Observed	Simulated				Observed	Simulated				Observed	Simulated					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	3675	3759	3985	3865	3965	4035	4126	4056	4256	4532	5990	6032	6326	5998	6125	3275	3364	3589	3412	3012
2050	3657	3689	3789	3986	3512	4035	3965	3989	4129	4026	5990	5899	5910	5980	6012	3275	3280	3282	3280	3270
2070	3657	3365	3965	3678	3548	4035	3233	3233	3713	3713	5990	3345	3345	3347	3347	3275	3276	3270	3280	3270

Conclusion

The RCP projection of climate change showed an increase in seasonal maximum temperature, minimum temperature, increase in solar radiation and rain fall increases up to 2050 but it shows a declining trend in 2070. Rice yield is likely to increase in 2030 and a decrease in yield in 2050 and similar decreasing trend is observed in 2070 in early and late dates of planting but in in case of mid season planting no significant change in observed in all RCPs scenarios. It was also found that production potential of Hasanta was higher than other varieties. In mid season planting, all the varieties performed well whereas their performance was poor in earliest and latest transplanting dates.

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