

## Estimation of Kharif Rice Yield in Khordha District under Future Climate Using DSSAT Model

S. Mohanty<sup>1</sup>, S. Pasupalak<sup>1</sup>, M.K. Beck<sup>2\*</sup>

<sup>1</sup>Department of Agrometeorology, College of Agriculture, OUAT, Bhubaneswar, India

<sup>2</sup>Department of Agrometeorology, College of Agriculture, IGKV, Raipur-492012, India

\*Corresponding author

### ABSTRACT

#### Keywords

Climate change, Rice, CERES model, Yield, Transplanting dates.

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Odisha is important for cereal crop. In Odisha region the adverse climatic condition is the main cause for lower productivity. Whereas per the different climatic change scenario (RCP 2.6, 4.5, 6.0, and 8.5) at Odisha region for rice crop of variety Khandagiri and Lalat in 2020, 2050 and 2080 projected years. Whereas simulated with the CERES-rice model and found that there is rice yield in both varieties is likely to increase in 2020, almost no change in 2050 and started declining by 2080 except in early and late transplanting dates. In August 1 transplanting, all the varieties performed well whereas their performance was poor in earliest and latest transplanting dates.

### Introduction

Rice is the very important cereal crop of Odisha. But unfortunately productivity of rice crop in Odisha is below the national average. Rice is the major cereal crop of Odisha mainly grown in the kharif season both in irrigated as well rainfed track. Kharif rice area has declined by 10.5% from 4.336 million hectares in 1970-71 to 3.88 million hectares in 2013-14 whereas, Kharif production increased from 3.913 million tonnes in 1970-71 to 6.585 million tonnes in 2013-14 due to increase in productivity by 88% during the period, reaching 1697 kg/ha in 2013-14 (Pasupalak, 2016). Adverse climatic condition is the main cause for lower productivity. Further global climate change possesses a

high threat to agriculture. Mainly change in weather pattern affects the cropping area and productivity. Rice crop needs a hot and humid climate. It is best suited to regions which have high humidity, prolonged sunshine and an assured supply of water. The average temperature required throughout the life period of the crop ranges from 21 to 37°C. At the time of tillering, the crop requires a high temperature for growth. The temperature requirement for blooming is in the range of 26.5oC to 29.5oC while at the time of ripening the temperature should be in between 20-25oC (De Datta, 1981). Hence, there is a need to study about adverse climatic factors which impact Rice yield under projected

climate change. Field experiment rice was conducted during kharif 2015 in the Agrometeorology field experimental area of OUAT, Bhubaneswar to validate simulated duration to developmental stages and yield with observed experimental data using DSSAT CERES-rice model software. Khandagiri and Lalat were experimental cultivars. Climate change scenarios included weather parameters i.e. temperature, rainfall and solar radiation at Bhubaneswar following RCP 2.6, 4.5, 6.0 and 8.5 scenarios (VanVuuren *et al.*, 2011). Future rice yield projections were made for 2020, 2050 and 2080.

## Materials and Methods

Bhubaneswar is taken as the representative experimental site for Khordha district. The field experiment was carried out at Agricultural meteorology Research farm of College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. It is situated at an elevation of 45m above mean sea level at 20° 15' N latitude and 85° 52' E longitude. It comes under East and South Eastern Coastal Plain agroclimatic zone of Odisha, Eastern coastal plain, hot sub humid to semi-arid agroecological region of Odisha and Eastern ghat, hot moist subhumid agroecological sub regions of Odisha. It also falls under Tropical wet-dry or Tropical Savanna.

Daily weather and soil data of the study area used in study were collected from the Agricultural meteorology Research farm of College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. Genotype (Table 1) and crop management input files were prepared using the available datasets for the specified simulation experiment, and then the CERES- Rice model was run and then used for studying the different scenarios. The field data on growth

and development of wheat crop season 2015-16 were taken from the Department of rice. The growth and development data of rice crop were observed in the field experiment conducted at department of agricultural meteorology, OUAT, Bhubaneswar.

## Results and Discussion

### Future scenario of kharif rice yield under projected seasonal climate change for cv. Khandagiri

Projection yield of rice cv. Khandagiri in five transplanting dates under the projected climate RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenarios for 2020, 2050 and 2080 are given in Table 2 a-e. It also shows the percent of increase or decrease in yield with respect to the present yield. For the year 2020, Model simulated the changes in yield of +8.1%, +9.4%, +8.2%, +8.8% for July 7 transplanting, +17.6%, +10.7%, +17.6%, +15% for July 15 transplanting, +8.6%, +10.9%, +8.6%, +10.8% for August 1 transplanting, +4.1%, +2%, +4.1%, +5.2% for August 14 transplanting, -17.2%, +17.1%, +18.3%, +24.1% for September 8 transplanting under RCP 2.6, 4.5, 6.0 and 8.5 scenarios respectively. For the year 2050, Model simulated the changes in yield of +2.2%, +4.9%, +3.8%, -0.4% for July 7 transplanting, +12.7%, +5.5%, +5.2%, +3.8% for July 15 transplanting, +7.4%, +2.0%, +1.6%, +2.6% for August 1 transplanting, +2.6%, +1.5%, -3.1%, +0.7% for August 14 transplanting, +23.7%, +19.7%, +14.2%, +15.7% for September 8 transplanting under RCP 2.6, 4.5, 6.0 and 8.5 scenarios respectively.

For the year 2080, Model simulated the changes in yield of +2.2%, +2.5%, +3.7%, -7.3% for July 7 transplanting, +12.7%, +3.2%, +4.2%, -8.1% for July 15 transplanting, +7.4%, -1.0%, -2.7%, -13.5%

for August 1 transplanting, +23.7%, +8.2%, +10.4%, -7.3% for August 14 transplanting, -17.2%, +17.1%, +18.3%, +24.1% for September 8 transplanting under RCP 2.6, 4.5, 6.0 and 8.5 scenarios respectively. Geethalaksmi *et al.*, (2008), was found rice production declines in Tamil Nadu by 8.7, 23.6 and 42.2 per cent from the production level of the year 2000 in 2020, 2050 and 2080 respectively.

**Future scenario of kharif rice yield under projected seasonal climate change for cv. Lalat**

Projection yield of rice cv. Lalat in five transplanting dates under the projected climate RCP 2.6, RCP 4.5, RCP 6.0 and RCP

8.5 scenarios for 2020, 2050 and 2080 are given in Table 3 a-e. It also shows the percent of increase or decrease in yield with respect to the present yield. In general for the year 2020, 2050 and 2080 there is increase in yield under four scenarios for five transplanting dates.

For the year 2020, Model simulated the changes in yield of +5.0%, +5.1%, +5.0%, +3.7% for July 7 transplanting, +5.7%, +3.7%, +5.7%, +5.3% for July 15 transplanting, +10.6%, +2.8%, +12.8%, +12.4% for August 1 transplanting, +1.2%, +0.9%, +8.0%, +6.7% for August 14 transplanting, -5.3%, +57.6%, -2.5%, -18% for September 8 transplanting under RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 projected climate scenarios respectively.

**Table.1** Genetic coefficient of different rice varieties

Cultivers	P <sub>1</sub>	P <sub>2</sub> R	P <sub>5</sub>	P <sub>20</sub>	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>
Khandagiri	410	35	290	12.5	42.0	0.0200	1	1
Lalat	600	80	350	12.0	45.0	0.220	1	1

**Table.2** Predicted yield and percent change in yield of cv. Khandagiri in five transplanting dates under four scenarios of climate change for 2020, 2050 and 2080

**(a) Transplanting on July 7**

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2417		2417		2417	
RCP 2.6	2613	+8.1	2469	+2.2	2469	+2.2
RCP 4.5	2645	+9.4	2536	+4.9	2478	+2.5
RCP 6.0	2614	+8.2	2508	+3.8	2507	+3.7
RCP 8.5	2629	+8.8	2407	-0.4	2000	-17.3

**(b) Transplanting on July 15**

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2433		2433		2433	
RCP 2.6	2862	+17.6	2743	+12.7	2743	+12.7
RCP 4.5	2693	+10.7	2566	+5.5	2512	+3.2
RCP 6.0	2862	+17.6	2560	+5.2	2544	+4.6
RCP 8.5	2799	+15.0	2526	+3.8	2235	-8.1

(c) Transplanting on August 1

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2388		2388		2388	
RCP 2.6	2594	+8.6	2565	+7.4	2565	+7.4
RCP 4.5	2648	+10.9	2435	+2.0	2365	-1.0
RCP 6.0	2594	+8.6	2426	+1.6	2324	-2.7
RCP 8.5	2646	+10.8	2450	+2.6	2065	-13.5

(d) Transplanting on August 14

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2419		2419		2419	
RCP 2.6	2519	+4.1	2481	+2.6	2565	+2.6
RCP 4.5	2467	+2.0	2455	+1.5	2365	-3.1
RCP 6.0	2519	+4.1	2344	-3.1	2324	-4.0
RCP 8.5	2545	+5.2	2435	+0.7	2065	-25.0

(e) Transplanting on September 8

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2146		2146		2146	
RCP 2.6	1776	-17.2	2655	+23.7	2655	+23.7
RCP 4.5	2513	+17.1	2568	+19.7	2323	+8.2
RCP 6.0	2538	+18.3	2451	+14.2	2369	+10.4
RCP 8.5	2663	+24.1	2482	+15.7	1989	-7.3

**Table.3** Predicted yield and percent change in yield of cv. Lalat in five transplanting dates under four scenarios of climate change for 2020, 2050 and 2080

(a) Transplanting on July 7

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	4842		4842		4842	
RCP 2.6	5084	+5.0	4935	+1.9	4935	+1.9
RCP 4.5	5091	+5.1	4895	+1.1	4816	+0.5
RCP 6.0	5084	+5.0	4855	+0.3	4858	+0.3
RCP 8.5	5022	+3.7	4926	+1.7	4109	-15.1

(b) Transplanting on July 15

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	4907		4907		4907	
RCP 2.6	5187	+5.7	5080	+3.5	5080	+3.5
RCP 4.5	5088	+3.7	5995	+1.8	4922	+0.3
RCP 6.0	5189	+5.7	4962	+1.1	4928	+0.4
RCP 8.5	5165	+5.3	4948	+0.8	4116	-16.1

**(c) Transplanting on August 1**

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	4218		4218		4218	
RCP 2.6	4663	+10.6	4552	+7.9	4552	+7.9
RCP 4.5	4334	+2.8	4431	+5.0	4251	+0.8
RCP 6.0	4760	+12.8	4420	+4.8	4336	+2.8
RCP 8.5	4743	+12.4	4397	+4.2	3309	-21.6

**(d) Transplanting on August 14**

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	3996		3996		3996	
RCP 2.6	4045	+1.2	4207	+5.3	4207	+5.3
RCP 4.5	3961	-0.9	4026	+0.8	3964	-0.8
RCP 6.0	4314	+8.0	3958	-1.0	4091	+2.4
RCP 8.5	4265	+6.7	4249	+6.3	3603	-9.8

**(e) Transplanting on September 8**

Scenario	2020		2050		2080	
	Yield	Change (%)	Yield	Change (%)	Yield	Change (%)
present	2328		2328		2328	
RCP 2.6	2452	+5.3	2225	-4.4	2225	-4.4
RCP 4.5	3669	+57.6	3434	+47.5	3572	+53.4
RCP 6.0	2270	-2.5	3246	+39.4	3201	+37.5
RCP 8.5	1900	-18.4	1900	-18.4	3486	+49.7

For the year 2050, Model simulated the changes in yield of +1.9%, +1.3%, +0.3%, +1.7% for July 7 transplanting, +3.5%, +1.8%, +1.1%, +0.8% for July 15 transplanting, +7.9%, +5.0%, +4.8%, +4.2% for August 1 transplanting, +5.3%, +0.8%, -1.0%, +6.3% for August 14 transplanting, -4.4%, +47.5%, +39.4%, -18.4% for September 8 transplanting under RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 projected climate scenarios respectively.

For the year 2080, Model simulated the changes in yield of +1.9%, -0.5%, +0.3%, -15.1% for July 7 transplanting, +3.5%, +0.3%, +0.4%, -16.1% for July 15 transplanting, +7.9%, +0.8%, +2.8%, -21.6% for August 1 transplanting, +5.3%, -0.8%, +2.4%, -9.8% for August 14 transplanting, -4.4%, +53.4%, +37.5%, +49.7% for September 8 transplanting under RCP 2.6,

RCP 4.5, RCP 6.0 and RCP 8.5 projected climate scenarios respectively. Naresh Kumar *et al.*, (2011) also found similar results as he predicted a marginal increase of less than 5% in irrigated rice yields in some coastal districts of Orissa, by 2030. Similar findings are also obtained by Mohapatra and Kar (1991), who reported that mean grain yield of CR-1009 variety of rice were 3.88,3.82,3.63,AND 3.43T ha<sup>-1</sup> when transplanted on 16 July, 31 July, 15 August, and 30 August.

For Khandagiri, in 2020, there is a marked increase in yield under four scenarios but in 2050, almost no change in yield occurs except for the latest transplanting date where yield increases. In 2080, yield increases under early and late transplanting dates whereas declines under midseason transplanting dates. RCP 8.5 scenario results in declining yield in all

transplanting dates in 2080. For Lalat, in 2020, there is a marked increase in yield under four scenarios but in 2050, almost no change in yield occurs except for the latest transplanting date. In 2080, RCP 8.5 scenario results in declining yield in all transplanting dates except for latest transplanting. However, in other RCP scenarios there is almost no change in yield except for latest transplanting where there is a marked increase in yield. Rice yield in both variety is likely to increase in 2020, almost no change in 2050 and started declining by 2080 except in early and late transplanting dates. In August 1 transplanting, all the varieties performed well whereas their performance was poor in earliest and latest transplanting dates.

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