Projection of futuristic climatic scenario of Cuttack district of Odisha using CMIP5

Abstract

The Changing climatic scenario has already started affecting the crop coverage area and productivity arousing as the most challenging issue to be faced by the farmers in attaining sustainable farm income. This study aimed to explore the projected climate change for Cuttack district of East and South Eastern Coastal plain agro-climatic zone of Odisha using four global climate change Representative Concentration Pathways (RCP) scenarios 2.6, 4.5, 6.0 and 8.5 for four future years 2030, 2050, 2070 and 2090. CMIP5 (Coupled Model Inter comparison Project Phase 5) was employed to generate these climate projections with included weather parameters i.e temperature, rainfall and solar radiation for the study area. The model results revealed that the RCP projections of climate change showed an increase in seasonal maximum temperature, minimum temperature and solar radiation and a decrease in the rainfall condition in future for Cuttack district of Odisha for the years 2030, 2050, 2070 and 2090 and there will be an maximum increase in seasonal maximum temperature by 2.56 ^{o}C and by 3.96 ^{o}C in seasonal minimum temperature in the year 2090 under RCP 8.5 scenario.

Keywords*:* Cuttack, climatic projection, RCP, CMIP5, climate change

Comment [D1]: The abstract may kindly be modified after adding the materials as suggested in the paper below.

Introduction:

The Changing climatic scenario and its impact on various sectors of the economy have emerged as one of the greatest challenges before the scientists and policy makers all over the world in twenty-first century. The impact of climate change is expected to be different in different parts of the globe. Some regions and economic systems may explore positive impacts, whereas others may experience losses due to climate change. Under changing climate, Higher temperatures will reduce crop yields due to reduction in the rate of photosynthesis, increase of respiration process and also a shortened vegetative and grain-filling period (Radziah *et al.*, 2010). This may eventually reduce the crop yield and rate of productivity. Climate models predict occurrence of more extreme weather events, like increased droughts, heavy rainfall, cyclones, storms etc. that cause severe risks leading to potential crop failure. General circulation models on climate change specify that due to increasing concentration of greenhouse gases (GHGs), global average surface temperature will increase by 1.5 to 4.5 °C in next 100 years (Senapati *et al.*,

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2013). Some projection studies using multiple climate models and CMIP5 data reveal that heat waves (extreme temperature events) over India are projected to be more intense, of longer durations and will occur at higher frequency (Murari *et al*., 2014). Most of the studies have claimed that climate change is altering the agricultural environment through occurrence of extreme weather events and affecting the crop production. (Feng, Hu 2004; Moonen et al., 2002). It is found that optimum combinations of temperature and rainfall are needed to increase agricultural production of Odisha (Pasupalak, 2009).

Comment [D3]: Recent reference may be cited

Comment [D4]: Kindly rephrase the sentence and the introduction can be lengthened with supportive evidence including recent references.

Materials and methods:

Description of the study area

Odisha is located in the eastern part of the Indian peninsula extending from 17° 31′ N to 22° 31′ N latitudes and from 81° 31′ E to 87° 29′ E longitudes and is bounded by Bay of Bengal to its east, Chhattisgarh to the west and north-west, West Bengal to the north-east, Jharkhand to the north and Andhra Pradesh and Telangana to the south by spreading over a geographical area of 155,707 km^2. It is further divided into 10 agro-climatic zones comprising of total 30 districts. Here Cuttack district is studied. Geographically, it is located at a latitude of 20° 03′ to 20° 40′ N and a longitude of 84° 58" to 86° 20′ E. The District experiences tropical climate, with the summer being hot and the winter cold. The maximum temperature that this District experiences is well above 40 °C (during summer) and the minimum is as low as 10 °C (during winter). Summer generally lasts from March to June and winter from October to February. Rainfall is generally heavy during the monsoons, which occur during the months of July and August. The average rainfall received is around 1892.55 mm in the District. South West monsoon is primarily responsible for the rainfall.

Comment [D5]: Highlighting Cuttack district is sufficient. You can include a map showing the study area from the State.

Comment [D6]: After tropical climate, the sentence can be changed by including the climate normal also.

Comment [D7]: Kindly provide reference for the seasons. Winter and summer season months might be different.

Projection of futuristic climatic scenario

Futuristic climatic scenario

The changes in major weather parameters ~~like~~ namely temperature, rainfall and solar radiation for ~~in~~ future years (2030, 2050, 2070 and 2090) for Cuttack district of Odisha were projected under four possible climatic scenarios (RCP 2.6, 4.5, 6.0 and 8.5), which were used in Fifth Assessment Report of IPCC (Van Vuuren *et al*., 2011).

Comment [D8]: Kindly elaborate the reason for choosing these particular years.

Representative Concentration Pathways (RCPs) is considered as pathways in order to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations. In addition, the term pathway is meant to emphasize that

it is not only a specific long-term concentration or radiative forcing outcome, such as a stabilization level, which is of interest, but also the trajectory that is taken over time to reach that outcome. They are representative in that they are one of several different scenarios that have similar radiative forcing and emissions characteristics.

The pathways are possible depending on how much greenhouse gases (GHGs) are emitted in the years to come. The value in each pathway determines radiative forcing value in the year 2100 relative to pre-industrial values, i.e. +2.6, +4.5, +6.0 and +8.5W/m2, respectively. Accordingly, there are four types of scenarios, which with a wide range of possible changes in future anthropogenic GHG emissions as follows.

Scenario 2.6: Global annual GHG emissions (measured in CO_2 equivalents) peak between 2010 and 2020 with emissions declining subsequently thereafter.

Scenario 4.5: Emissions peak around 2040 and then decline.

Scenario 6.0: Emissions peak around 2080.

Scenario 8.5: Emissions continue to rise throughout the 21st century.

3.3.2 Climatic projection model CMIP5 (Coupled Model Intercomparison Project Phase 5)

We used present day simulations (2001-2017) and future projections (2030, 2050, 2070 and 2090) of global climate at original GCM resolution (200 Km) from GFDL-ESM2G (NOAA, USA) GCM under CMIP5, and all RCPs namely, RCP 2.6, 4.5, 6.0 and 8.5. GCM data included monthly time series of maximum temperature, minimum temperature, solar radiation and rainfall. All GCM data were downloaded and later downscaled to 3 km resolution. Downscaling ~~of the~~of the GCM data is often required for climate change impact studies.

The Coupled Model Intercomparison Project Phase 5 (CMIP5), coordinated by the World Climate Research Programme in support of the IPCC Fifth Assessment Report (AR5), provides simulations from state-of-the-art GCMs. CMIP5 provides, for a large number of models, climate projections for all four Representative Concentration Pathways (RCPs). CMIP5 monthly data on single level provides monthly climate projections on single levels from a large number of experiments, models, members and time periods computed in the framework of fifth phase of the Coupled Model Inter comparison Project (CMIP5).

CMIP5 data are used extensively in the Intergovernmental Panel on Climate Change Assessment Reports (the latest one is IPCC AR5, which was published in 2014). ~~The use of these data is mostly aimed at:~~

Comment [D9]: No two RCP's has similar radiative forcing. Can you explain, What does the line represents?

Comment [D10]: Kindly use the global term RCP 2.6, RCP 4.5 instead of scenarios.

Comment [D11]: Method of downscaling need to be included

- addressing outstanding scientific questions that arose as part of the IPCC reporting process;
- improving the understanding of the climate system
- providing estimates of future climate change and related uncertainties
- providing input data for the adaptation to the climate change
- examining climate predictability and exploring the ability of models to predict climate on decadal time scales
- evaluating how realistic the different models are in simulating the recent past

The term "experiments" refers to the three main categories of CMIP5 simulations

- Historical experiments which cover the period where modern climate observations exist. These experiments show how the GCMs performs for the past climate and can be used as a reference period for comparison with scenario runs for the future. The period covered is typically 1850-2005.
- Ensemble of experiments from the Atmospheric Model Intercomparison Project (AMIP), which prescribes the oceanic variables for all models and during all period of the experiment. This configuration removes the added complexity of ocean-atmosphere feedbacks in the climate system. The period covered is typically 1950-2005.
- Ensemble of climate projection experiments following the Representative Concentration Pathways (RCP) 2.6, 4.5, 6.0 and 8.5. The RCP scenarios provide different pathways of the future climate forcing. The period covered is typically 2006-2100, some extended RCP experimental data is available from 2100-2300.

Hence, the data provided will be of great potential to aid researchers, resource managers, and other policy makers in the assessment of climate change impacts on the environment.

Projection scenario of climate change

Data on climate scenarios (RCP 2.6, 4.5, 6.0 and 8.5 for the years 2030, 2050, 2070 and 2090) need to be converted to suitable input format from individual years with the excel file for simulating in the DSSAT model. Seasonal climate change projection scenario (RCP 2.6, 4.5, 6.0 and 8.5 for the years 2030, 2050, 2070 and 2090) was performed for Cuttack of Odisha. Kindly include the bias correction and seasonal analysis.

Results and Discussion:

Projection 2030

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Comment [D13]: 1.Major revision needs to be done in correlating the results and discussion writing part. The presentation of result and discussion shall be combined like a storyline instead of presenting them as separate.
2.Tables are not cited in the text. Kindly cite them in results
3.While discussing kindly give them in the graph format to understand the trends over the study area.
4. Kindly include bias correction.

For Cuttack district, the RCP 2.6 scenario is expected to decrease in rainfall by 95.57 mm from present weather scenario and increase in maximum temperature, minimum temperature and solar radiation by 0.32 ^{o}C, 1.49 ^{o}C and 1.02 MJ/day respectively. RCP 4.5 scenario is likely to cause increase in rainfall by 96.43 mm, maximum temperature by 0.52 ^{o}C, minimum temperature by 1.64 ^{o}C and solar radiation by 1.10 MJ/day. RCP 6.0 scenario shows an increase of 0.39 ^{o}C in maximum temperature, 1.49 ^{o}C in minimum temperature, 1.06 MJ/day in solar radiation, however, rainfall is predicted to decrease by 118.17 mm. RCP 8.5 scenario shows an increase of maximum temperature, minimum temperature and solar radiation by 0.56 ^{o}C, 1.67 ^{o}C and 1.30 MJ/day respectively but the rainfall is likely to decrease by 102.87 mm.

Projection 2050

For Cuttack district, the RCP 2.6 scenario is expected to increase in maximum temperature by 0.34 ^{o}C and minimum temperature by 1.56 ^{o}C along with an increase of 1.18 MJ/day in solar radiation from the present weather scenario whereas the rainfall is expected to decrease by 39.97 mm. The RCP 4.5 scenario shows an increase of 0.87 ^{o}C in maximum temperature, 1.86 ^{o}C in minimum temperature, 1.44 MJ/day in solar radiation. However, rainfall is predicted to decrease by 134.27 mm in the RCP 4.5 scenario. RCP 6.0 scenario shows an increase in maximum temperature, minimum temperature and solar radiation by 0.62 ^{o}C, 1.79 ^{o}C and 1.32 MJ/day respectively but the rainfall is likely to decrease by 106.27 mm. RCP 8.5 scenario shows a further increase in maximum temperature, minimum temperature and solar radiation by 1.22 ^{o}C, 2.27 ^{o}C and 1.51 MJ/ day. However, there is a decrease of rainfall by 215.57 mm.

Projection 2070

For Cuttack district, RCP 2.6 scenario predicted a decrease in rainfall by 75.67 mm, however it shows a increase in maximum temperature by 0.27 ^{o}C, minimum temperature by 1.47 ^{o}C and solar radiation by 1.27 MJ/day. In RCP 4.5 scenario, there is an expected decrease in rainfall by 42.97 mm and increase in maximum temperature by 1.07 ^{o}C, minimum temperature by 1.82^{o} C and solar radiation by 1.87 MJ/day. RCP 6.0 shows an increase in maximum temperature by 1.09 ^{o}C, minimum temperature by 2.21 ^{o}C and solar radiation by 1.47 MJ/day however the rainfall is predicted to decrease by 68.37 mm. RCP 8.5 shows a decrease in rainfall by 39.17 mm whereas there is an increase in maximum temperature by 2.19 ^{o}C, minimum temperature by 2.40 ^{o}C and solar radiation by 1.98 MJ/day.

Projection 2090

For Cuttack district, RCP 2.6 scenario expected a decrease in rainfall by 125.87 mm and increase in maximum temperature by 0.17 ^{o} C, minimum temperature by 1.34 ^{o} C, and solar radiation by 1.32 MJ/day from the present weather scenario. RCP 4.5 scenario shows an increase in maximum temperature by 1.27 ^{o} C, minimum temperature by 2.02 ^{o} C and solar radiation by 1.42 MJ/day however the rainfall is predicted to decrease by 156.97 mm. RCP 6.0 scenario also shows an increase in maximum temperature by 1.69 ^{o} C, minimum temperature by 2.72 ^{o} C and solar radiation by 1.55 MJ/day however the rainfall is predicted to decrease by 190.77 mm. In RCP 8.5 scenario also there is an increase in maximum temperature by 2.56 ^{o} C, minimum temperature by 3.96 ^{o} C and solar radiation by 2.20 MJ/day however the rainfall is predicted to decrease by 227.67 mm.

Findings of present study are similar to the results of Garg *et al*. (2015) who examined the increase in temperature of more than 2 ^{0}C would be observed by 35 % of the India during RCP 8.5 scenario and this might have complex repercussions on agriculture, water resources and many other sectors. All India mean temperature is projected to increase by 3.5 ^{0}C by the end of 21st century under future climate and significant increase in mean air temperature will lead to rise in extreme temperatures.

Similar results were found in the study was conducted by Carvalho *et al*. (2016) in Angola to analyze the projected changes in temperature and precipitation during the 21st century. These changes included an increase in both the maximum and minimum temperature of upto 4.9 ^{0}C by the end of the century and an intensification of droughts. The precipitation generally decreases over time (approximately-2% by 2100), with the southern region experiencing a stronger decrease in precipitation. Rajegowda *et al*. (2009) reported that the Karnataka state's mean annual rainfall showed decreasing trend in the first half century (1901 to 1950) from 1204 mm to 1140 mm during the second half century (1951 to 2050).

Summary and conclusion:

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Comment [D15]: The conclusion shall be rewritten completely by adding the bias correction and seasonal analysis. The current result is showing repetition except for the years.

For the years 2030 and 2050, projected climatic condition under RCP 2.6, 4.5, 6.0 and 8.5 scenarios are likely to cause an increase in seasonal maximum temperature, minimum temperature and solar radiation as compared to present condition but a non-significant trend of decrease in rainfall is showed under RCP 2.6, 6.0 and 8.5 scenarios for Cuttack district of East

and South Eastern Coastal Plain agro-climatic zone of Odisha. However, RCP 4.5 scenario in the year 2030 is likely to cause increase in rainfall for Cuttack. For the year 2070, projected climatic condition under RCP 2.6, 4.5, 6.0 and 8.5 scenarios also likely to cause increase in seasonal maximum temperature, minimum temperature and solar radiation as compared to the present condition but a non-significant decrease in rainfall is showed for Cuttack district. For the year 2090, projected climatic condition under RCP 2.6, 4.5, 6.0 and 8.5 scenarios showed an increasing trend in seasonal maximum temperature, minimum temperature and solar radiation but, there is a non-significant trend of decrease in rainfall for Cuttack district.

References:

Comment [D16]: Kindly refer minimum 30 articles.

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Table: 1

Projection 2030

District	Variable (Seasonal mean value)	Present weather scenario	Future climate projections for the year 2030							
			RCP 2.6	Diff.	RCP 4.5	Diff.	RCP 6.0	Diff.	RCP 8.5	Diff.
CUTTACK	Rainfall (mm)	**1435.77**	1340.20	-95.57	1532.20	+96.43	1317.60	-118.17	1332.90	-102.87
	Max Temp (^{o}C)	**32.49**	32.81	+0.32	33.01	+0.52	32.88	+0.39	33.05	+0.56
	Min Temp (^{o}C)	**23.69**	25.16	+1.47	25.33	+1.64	25.18	+1.49	25.36	+1.67
	Solar radiation (MJ/day)	**16.43**	17.45	+1.02	17.53ZZ	+1.10	17.49	+1.06	17.73	+1.30

Table: 2

Projections for the year 2050

District	Variable (Seasonal mean value)	Present weather scenario	Future climate projections for the year 2050							
			RCP 2.6	Diff.	RCP 4.5	Diff.	RCP 6.0	Diff.	RCP 8.5	Diff.
CUTTACK	Rainfall (mm)	**1435.77**	1395.8	-39.97	1301.50	-134.27	1329.50	-106.27	1220.20	-215.57
	Max Temp (^{o}C)	**32.49**	32.83	+0.34	33.36	+0.87	33.11	+0.62	33.71	+1.22
	Min Temp (^{o}C)	**23.69**	25.25	+1.56	25.55	+1.86	25.48	+1.79	25.96	+2.27
	Solar radiation (MJ/day)	**16.43**	17.61	+1.18	17.87	+1.44	17.75	+1.32	17.94	+1.51

Table: 3

Projections for the year 2070

District	Variable (Seasonal mean value)	Present weather scenario	Future climate projections for the year 2070							
			RCP 2.6	**Diff.**	**RCP 4.5**	**Diff.**	**RCP 6.0**	**Diff.**	**RCP 8.5**	**Diff.**
CUTTACK	Rainfall (mm)	**1435.77**	1360.10	-75.67	1392.80	-42.97	1367.40	-68.37	1396.6	-39.17
	Max Temp (^{o}C)	**32.49**	32.76	+0.27	33.56	+1.07	33.58	+1.09	34.68	+2.19
	Min Temp (^{o}C)	**23.69**	25.16	+1.47	25.51	+1.82	25.90	+2.21	26.09	+2.40
	Solar radiation (MJ/day)	**16.43**	17.70	+1.27	18.30	+1.87	17.90	+1.47	18.41	+1.98

Table: 4

Projections for the year 2090

District	Variable (Seasonal mean value)	Present weather scenario	Future climate projections for the year 2090							
			RCP 2.6	**Diff.**	**RCP 4.5**	**Diff.**	**RCP 6.0**	**Diff.**	**RCP 8.5**	**Diff.**
CUTTACK	Rainfall (mm)	**1435.77**	1309.90	-125.87	1278.80	-156.97	1245.00	-190.77	1208.10	-227.67
	Max Temp (^{o}C)	**32.49**	32.66	+0.17	33.76	+1.27	34.18	+1.69	35.05	+2.56
	Min Temp (^{o}C)	**23.69**	25.03	+1.34	25.71	+2.02	26.41	+2.72	27.65	+3.96
	Solar radiation (MJ/day)	**16.43**	17.75	+1.32	17.85	+1.42	17.98	+1.55	18.63	+2.20