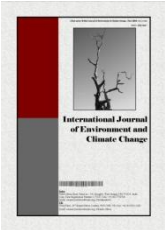

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Projection of Futuristic Climatic Scenario of Cuttack District of Odisha using CMIP5

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The Changing climatic scenario is found as the most challenging issue to be faced by the farmers in future for 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 using bilinear interpolation for downscaling 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. Hence through the findings of the present investigation it is found that there is a need for farmers of Cuttack district of Odisha to follow necessary adaptation strategies in future to avoid the major risk caused to the agriculture production potential under the changing scenario of climate.

Keywords: Cuttack; climatic projection; RCP; CMIP5; climate change.

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1. 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. Garg *et al*. [1] examined the increase in temperature under the most represented scenario (RCP 4.5) and concluded that by 2035, air temperature would rise by more than 2 ^{0}C in approximately 10% of India. Baker and Allen [2] reported that the futuristic climate change projection includes a strong likelihood of increase in concentration of atmospheric carbon dioxide (CO_2) and possible increases in air temperatures. Studies on the impact of minimum temperature on rice yields revealed that the warmer nights have an extensive impact on the yield of rice, every 1°C increase in night time temperature led to a 10 % reduction in yield [3]. 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 [4]. 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 [5]. Garg *et al*. [1] reported that the 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. The study conducted by Homsi *et al*. [6] in Syria using CMIP5 showed that annual changes in precipitation is projected to decrease by −30 to −85.2% for RCPs 4.5, 6.0, and 8.5, while by < 0.0 to −30% for RCP 2.6. The precipitation is projected to decrease in the entire country for RCP 6.0, while increase in some parts for other RCPs during wet season. The dry season of precipitation is simulated to decrease by −12 to −93%, which indicated a drier climate for the country in the future. 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 [7]. 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 [8,9]. The RCP projections of climate change using Marksim GCM for Ganjam district of Odisha revealed that there is an increase in seasonal maximum temperature by about 1.9 ^{o}C and seasonal minimum temperature by 1.4 ^{o}C by 2070 effecting the rice yield [10].

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The present study (Fig. 1) was carried for Cuttack district under East and South Eastern Coastal Plain agro-climatic zone of Odisha. Geographically, it is located at a latitude of 20^o 03″ to 20^o 40″ N and a longitude of 84^o 58” to 86^o 20″ E. The district experiences tropical climate with mean annual rainfall of 1577 mm, mean maximum summer temperature of 39 ^{o}C and mean minimum temperature of 11.5 ^{o}C. The climate condition of the district is generally hot with high humidity during April and May and cold during December and January [11]. South West monsoon is primarily responsible for the rainfall. Rainfall is generally heavy during the monsoon, which occur during the months of July and August.

2.2 Projection of Futuristic Climatic Scenario

The changes in major weather parameters like temperature, rainfall and solar radiation in future years *viz*., 2030, 2050, 2070 and 2090 which were purposively selected to assess the climate change for every 20 years difference 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 [12].

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. In this context, CMIP5 model is used to project changing climatic conditions in temperature, rainfall and solar radiation for future climate.

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.

RCP 2.6: Global annual GHG emissions (measured in CO_2 equivalents) peak between 2010 and 2020 with emissions declining subsequently thereafter.
RCP 4.5: Emissions peak around 2040 and then decline.
RCP 6.0: Emissions peak around 2080.
RCP 8.5: Emissions continue to rise throughout the 21st century.

2.3 Climatic Projection using CMIP5 (Coupled Model Intercomparison Project Phase 5) Model

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. The method of downscaling used is Bilinear interpolation. Downscaling 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 [13].

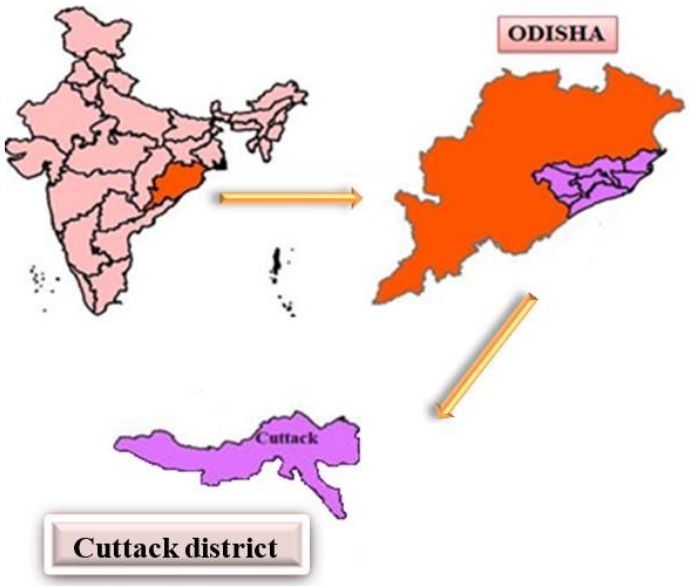

Fig. 1. Map of the Study Area

2.4 Projection Scenario of Climate Change

CMIP5 monthly data on single levels was projected using Copernicus data server which is implemented by European Centre for Medium-Range Weather Forecasts. Data on climate scenarios under RCP 2.6, 4.5, 6.0 and 8.5 for the years 2030, 2050, 2070 and 2090 was performed for Cuttack district of Odisha. The seasonal projection was carried for the months June to November.

3. RESULTS AND DISCUSSION

For Cuttack district, the seasonal projections under 2030 (Table 1) revealed that 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 an 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.

Likewise, the projections under 2050 (Table 2) showed that 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.

In the projections of 2070 (Table 3), 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.

Under the projections of 2090 (Table 4), 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.

The futuristic changes of maximum and minimum temperatures under four RCP scenarios are represented in the Figs. 2 to 5. In general, the results of the present study with the increase in seasonal maximum and minimum temperatures by about 2.56 ^{o} C and 3.96 ^{o} C, respectively, by 2090 could be due to the increasing level of green house gases in the atmosphere majorly because of burning of fossil fuels, deforestation and other man made activities. The Recent Sixth Assessment Report of Intergovernmental Panel on Climate change 2021, also reported that there is a chance of increase in the global warming level by 1.5 ^{o}C in the next two decades.

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

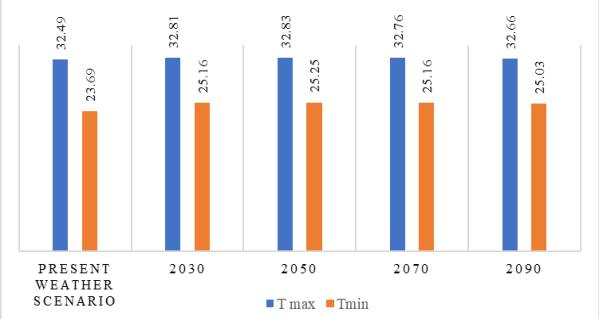

Fig. 2. Futuristic maximum and minimum temperature changes under RCP 2.6 scenario

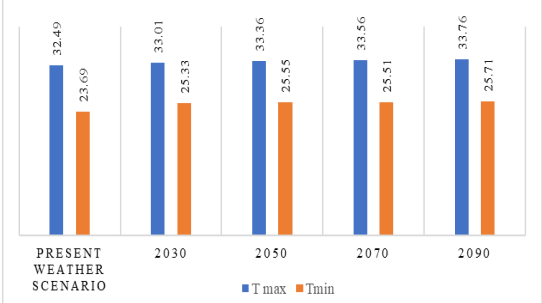

Fig. 3. Futuristic maximum and minimum temperature changes under RCP 4.5 scenario

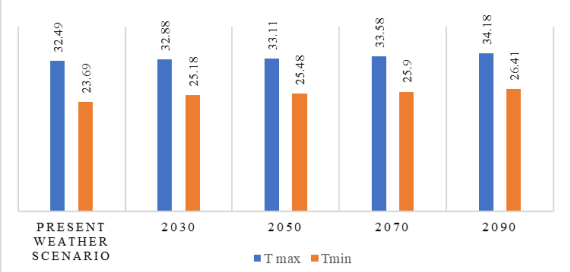

Fig. 4. Futuristic maximum and minimum temperature changes under RCP 6.0 scenario

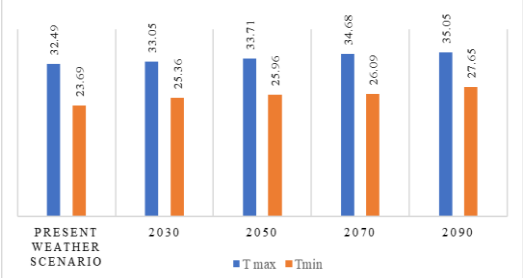

Fig. 5. Futuristic maximum and minimum temperature changes under RCP 8.5 scenario

Findings of present study are similar to the results of Garg *et al*. [1] 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 conducted by Carvalho *et al*. [14] 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), [15] with the southern region experiencing a stronger decrease in precipitation. Rajegowda *et al*. [16] 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).

4. SUMMARY AND CONCLUSION

The RCP projections of climate change showed an increase in seasonal maximum, minimum temperature and solar radiation in the future for Cuttack district. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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