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Future projections of rainfall and solar radiation for Coastal districts of Odisha state

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ABSTRACT

Understanding the various characteristics of rainfall in the current era of global warming requires investigating changes in rainfall patterns and events at the regional and district levels historically for predicting futuristic changes. This knowledge will be valuable for developing policy plans for rainfed agricultural states like Odisha, which is also highly vulnerable to floods and droughts. The changing climatic scenario and its impact on various sectors of the economy have emerged as one of the greatest challenges before scientists and policy makers all over the world in the 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. The present study in assessing the futuristic changes in seasonal precipitation and solar radiation helps to determine the impact of climate change on coastal districts of Odisha state. Where rainfed crops are grown in a large scale in coastal districts of Odisha, rainfall and solar radiation are two important weather variables that drive crop growth and development that greatly influence the Kharif agricultural productivity, these two parameters are considered for the current research. The Coupled Model Intercomparison Project Phase 5 (CMIP5) has been used to derive the futuristic projections of seasonal rainfall and solar radiation for the years 2030, 2050, 2070, and 2090 under four different Representative Concentration Pathways (RCP) scenarios 2.6, 4.5, 6.0 and 8.5. The results of the present study showed an increasing trend of solar radiation in the future by about a maximum of +2.60 MJ/day in Puri district by 2090 under RCP 8.5 scenario. For the year 2090, there is a maximum decrease of rainfall by -399.05 mm. under RCP 2.6 scenario in the Puri district and by -394.42 mm. under RCP 8.5 scenario in Kendrapara district.

Keywords: *Rainfall, solar radiation, CMIP5, RCP scenario*

Introduction

As global temperatures have risen over the past century, droughts and decreasing precipitation are likely to persist [4], [5] and [2]. Being the coastal state, the climate of Odisha varies due to various factors like the late onset of monsoon and more pre-monsoon rainfall, reduced post-monsoon rainfall [8]. For the state of Odisha, [7] found a long-term non-significant decline in annual and monsoonal precipitation but an increase in post-monsoonal precipitation. The state experiences 1451.2 mm of rainfall on average. About 84 % of rainfall is received during the period from June to September. Even though the quantum of rainfall is quite high, its distribution during the monsoon period is highly uneven and erratic. Odisha state has 6 coastal districts namely Puri, Jagatsinghpur, Kendrapara, Balasore, Bhadrak and Ganjam. The state experiences frequent cyclonic events due to rise in sea levels by changing climatic conditions causing it to lose its coastal line. As the solar radiation is distributed unevenly throughout the surface of the earth, it warms the atmosphere and causes global wind patterns. [11] reported that during the rainy season, photosynthesis is commonly impeded on account of decrease in light intensity and duration achieved about by the unreasonably cloudy climate. Apart from rainfall, the amount of solar radiation received also shows a significant impact on agriculture yields.

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 [10]. Hence, an improved forecasting model is necessary for an early warning system that can reduce risks and manage agricultural farms. 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). The projected future climate change includes a strong likelihood of increased atmospheric carbon dioxide concentration (CO_2) and possible increases in air temperatures [1].

Materials and Methods

Study Area

Odisha being one of the coastal states of India is located in the eastern part of the Indian peninsula, bounded by Bay of Bengal on the east, and has a coast line of 450 kms. Three major coastal districts viz, Puri, Jagatsinghpur and Kendrapara were drawn for the present study. The geographical location of Puri extends from 19° 48' N latitude to 85° 52' E longitude, Jagatsinghpur extends from 20° 19' N latitude to 86° 31' E longitude and Kendrapara from 20°30' N latitude to 86°28' E longitude (Fig. 1).

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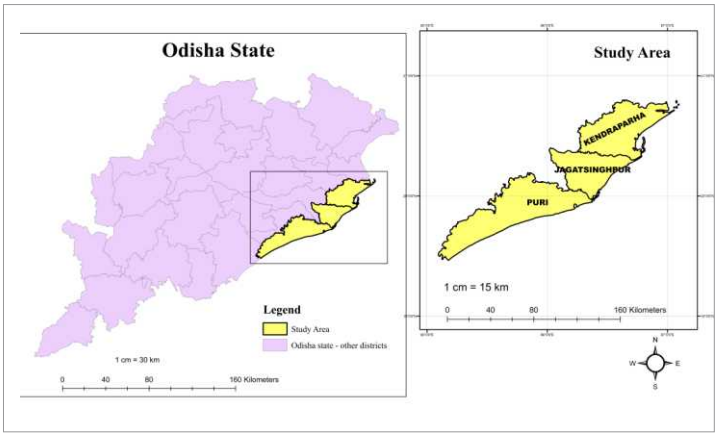

Fig. 1 Map showing study locations of three coastal districts of Odisha state

Datasets Used

The observed daily mean rainfall and solar radiation of the seasonal period i.e, June to November (that includes South west monsoon period of June to September and the retreating monsoon of October to November) from 2001 to 2017 was taken as baseline data from the Dept. of Agricultural Meteorology, OUAT, Bhubaneswar. The future scenarios were generated using CMIP5 (Coupled Model Inter comparison Project Phase 5) database of IIT, Bhubaneswar. The seasonal changes in rainfall and solar radiation of the period June to November for future years (2030, 2050, 2070, and 2090) for coastal districts *viz.,* Puri, Jagatsinghpur, and Kendrapara 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].

The future projections (2030, 2050, 2070, and 2090) of global climate at original GCM resolution (200 Km) were extracted from GFDL-ESM2G (NOAA, USA) GCM under CMIP5, with all RCPs namely, RCP 2.6, 4.5, 6.0 and 8.5. GCM data that included monthly time series of rainfall and solar radiation. All GCM data were downloaded and later downscaled to 3 km resolution.

RCP 2.6 scenario includes GHG emissions that peak 2010 to 2020 with emissions weakening thereafter. RCP 4.5 Scenario comprises emissions rising around 2040 and declining later. RCP 6.0 scenario involves emissions increasing around 2080. RCP 8.5 scenario contains emissions to continue and rise all over 21st century.

Results and Discussion

Projected changes in seasonal rainfall

The results revealed that, for Puri and Kendrapara districts, there is a decrease in rainfall for all four future years under all RCP's with a maximum decrease of -399.05 mm. by 2090 under RCP 2.6 scenario in Puri district (Fig. 2) and by -394.42 mm. in 2090 under RCP 8.5 scenario in Kendrapara district (Fig. 4). Whereas, there is an increase in rainfall in all four future years under all the RCPs in Jagatsinghpur district (Fig.3). But, the increase of rainfall is in a decreasing trend from 2030 to 2090. The following are the results as indicated in Table 1.

Table. 1 Futuristic seasonal rainfall (mm.) projection of three coastal districts of Odisha state

District	Present weather scenario	Year	Future climate projections							
			RCP 2.6	diff	RCP 4.5	diff	RCP 6.0	diff	RCP 8.5	diff
PURI	1638.85	2030	1282.40	-356.45	1617.50	-21.35	1294.30	-344.55	1247.30	-391.55
		2050	1291.7	-347.15	1394.90	-243.95	1262.90	-375.95	1343.40	-295.45
		2070	1258.20	-380.65	1276.30	-362.55	1267.30	-371.55	1291.40	-347.45
		2090	1239.80	-399.05	1279.10	-359.75	1263.40	-375.45	1282.00	-356.85
JAGATSINGHPUR	1169.67	2030	1303.30	+133.63	1301.20	+131.53	1286.50	+116.83	1199.40	+29.73
		2050	1366.5	+196.83	1271.70	+102.03	1298.40	+128.73	1189.90	+20.23
		2070	1331.40	+161.73	1263.30	+93.63	1282.60	+112.93	1188.30	+18.63
		2090	1274.80	+105.13	1253.10	+83.43	1208.50	+38.83	1178.80	+9.13
KENDRAPARA	1713.22	2030	1346.70	-366.52	1503.00	-210.22	1391.60	-321.62	1324.10	-389.12
		2050	1365.9	-347.32	1382.30	-330.92	1345.50	-367.72	1397.3	-315.92
		2070	1381.70	-331.52	1398.70	-314.52	1386.00	-327.22	1328.40	-384.82
		2090	1330.70	-382.52	1352.00	-361.22	1320.50	-392.72	1318.80	-394.42

The findings are similar to the study conducted by [3] in Angola to analyze the projected changes in precipitation during the 21st century. These changes included an increase in intensification of droughts and the precipitation generally decreases over time by 2100, with the southern region experiencing a stronger decrease in precipitation. Likewise, the present CMIP5 projections of rainfall in Jagatsinghpur district are also in harmony to the findings of [6] who predicted 10% increase in rainfall by 2030 at Odisha coast of Paradeep, a city in Jagatsighpur district.

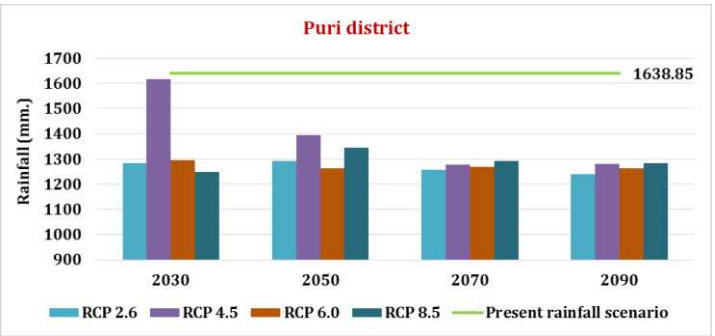

Fig. 2 Futuristic seasonal rainfall projection of Puri district

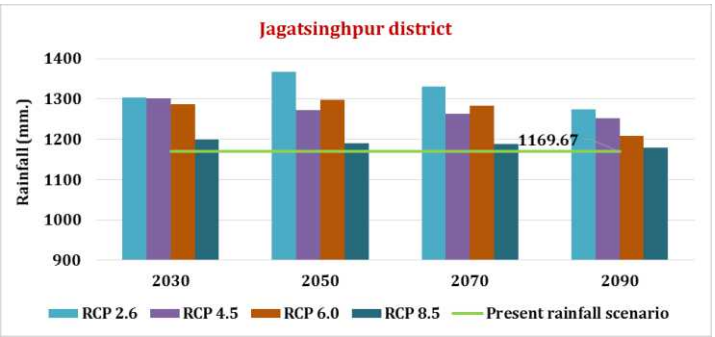

Fig. 3 Futuristic seasonal rainfall projection of Jagatsinghpur district

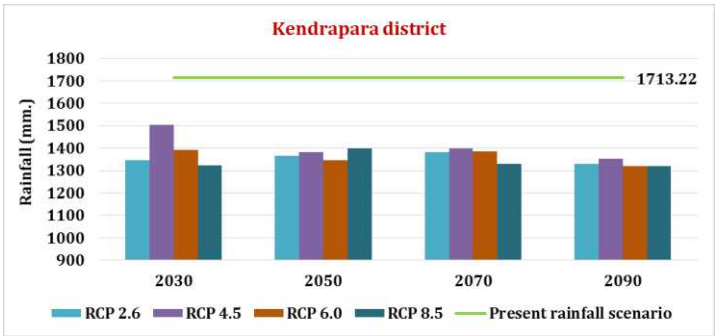

Fig. 4 Futuristic seasonal rainfall projection of Kendrapara district

Projected changes in seasonal solar radiation

The projections of solar radiation revealed that, there is an increase in the amount of solar radiation under all the RCPs in all the years. By the year 2090, there is a maximum increase of solar radiation in about +2.60 MJ/day in Puri district and by + 1.93 MJ/day in Jagatsinghpur and Kendrapara districts in comparison to the present weather scenario. Under all the RCPs, the RCP 8.5 scenario showed the maximum increase of solar radiation in all the four future years for all three coastal districts (Table 2).

Table. 2 Futuristic climatic projection of solar radiation (MJ/day)

District	Present weather scenario	Year	Future climate projections							
			RCP 2.6	diff	RCP 4.5	diff	RCP 6.0	diff	RCP 8.5	diff
PURI	**16.58**	2030	17.36	+0.78	17.53	+0.95	17.36	+0.78	18.00	+1.42
		2050	17.28	+0.70	18.01	+1.43	17.88	+1.30	18.23	+1.65
		2070	17.70	+1.12	18.60	+2.02	17.93	+1.35	18.66	+2.08
		2090	17.85	+1.27	18.15	+1.57	18.46	+1.88	19.18	+2.60
JAGATSINGHPUR	**16.58**	2030	17.18	+0.60	17.38	+0.80	17.33	+0.75	17.65	+1.07
		2050	17.11	+0.53	17.76	+1.18	17.71	+1.13	17.83	+1.25
		2070	17.38	+0.80	18.25	+1.67	17.61	+1.03	18.28	+1.70
		2090	17.65	+1.07	17.71	+1.13	17.98	+1.40	18.51	+1.93
KENDRAPARA	**16.43**	2030	16.98	+0.55	17.21	+0.78	17.15	+0.72	17.45	+1.02
		2050	16.93	+0.50	17.63	+1.20	17.51	+1.08	17.66	+1.23
		2070	17.20	+0.77	18.08	+1.65	17.45	+1.02	18.16	+1.73
		2090	17.45	+1.02	17.55	+1.12	17.73	+1.30	18.36	+1.93

Conclusion

It is concluded from the present study that, though all three districts namely Puri, Jagatsignhpur, and Kendrapara are coastal regions, there is a change in the distribution of rainfall in future under the changing climatic scenario with an increasing trend of solar radiation. The rainfall is going to decrease in Puri and Kendrapara districts, while there is a prediction of an increase in rainfall in Jagatsinghpur district too with a decreasing trend from 2030 to 2090 under all the RCPs. As the coastal regions are highly populated and experiencing sudden environmental changes, the present investigation was essential to provide a clear understanding of changes in precipitation and solar radiation in the future. This helps the policy makers in identifying the coastal districts that are with a chance of risk-prone to floods, droughts, and increasing intensity of solar radiation with differential heating up of sea and land surfaces that cause the development of low-pressure areas in future in the changing climatic conditions for developing better adaptation and water management strategies.

Future scope of the study

In order to preserve agricultural productivity and sustain food security in the future, policymakers may base their actions on the predicted precipitation projections of the present study. The increasing intensity of solar radition in the coastal districts can drive to increasing sea and river water temperatures which may affect fish breeding, migration, and harvests. Hence developing suitable management practices in fish cultivation is also necessary for coastal districts of Odisha state where there are large number of communities depending on fisheries sector for their livelihood.

Conflict of interest : None

Acknowledgment

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