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Future Projections of Precipitation from CMIP5 Models in the Western Ghats Region, India - A Case Study

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ABSTRACT

The analysis of meteorological variables, particularly in countries where rainfall dependent agriculture is predominant, is vital to assess climate-induced changes and suggest feasible adaptation strategies. To that end, statistical analysis has been employed to inspect the changes in rainfall of Kokkarne catchment belonging to Seetha River basin using CORDEX (Coordinated Regional Downscaling Experiment) data for South Asia from 2021 to 2050. Rainfall data have been analyzed using coefficient of variation, and standard deviation. The outcome of the study revealed intra-annual and inter-annual variability of rainfall. Nearly 87 % of annual rainfall is contributed by monsoon season only with standard deviation of 424.4 mm and CV of 12%.

Key words *: Statistical analysis, Co-efficient of variation, Ensemble, CORDEX, GCM.*

Introduction

Climate change and changes in rainfall patterns have become a major source of concern around the world in recent years. Scientists are attempting to analyse the various options for mitigating the environmental changes that are occurring. Because rainfall is so vital source in agriculture, its analysis requires special care. Rainfall is also a major component in the construction of major hydraulic structures such as bridges and canals, culverts, road drainage, and storm water sewer systems, among other things. The estimation of varied input values for design and analysis of these engineering structures, as well as crop planning, requires a complete statistical study of rainfall data in the region. Changes in climate in the Indian subcontinent, notably the south west monsoon, have a substantial impact on agricultural production, water resource management, and the total economy of the country. The analysis helps in understanding the rainfall pattern of the Kokkarne catchment region, as well as efficient crop planning and water availability in the region. For decades, hydrologists and scholars have used statistical analysis of hydro-meteorological variables such as rainfall and temperature to determine the impact of climate change on discharge. The economic and social wellbeing of India is depicted by the agricultural industry of the country (Goswami and Paul, 2010). It is necessary to handle the current resources well in order to prevent water resource related issues. From the standpoint of agriculture, understanding the pattern of rainfall and its statistical parameters is critical. It is crucial to have information and understanding of rainfall variability in order to provide required amount of water to the crops throughout their growth stages. The present analysis will aid climate scientists in their search for climate change implications and its consequences. In light of the aforementioned concerns, the

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primary goals of this study are to (1) To assess the inter-annual and intra-annual rainfall variations and (2) To analyse statistical parameters associated with rainfall data. This type of analysis will help in the assessment of measures in the provision of enough irrigation and food security.

Study area

The study area under consideration is the Kokkarne catchment, belonging to the Seetha River. Seetha river originates in the Western ghats of India in Karnataka.

Methodology

The various steps followed in the present study were as follows:

1. The ensemble mean of the rainfall dataset from the following five selected GCMs (Global Climate Model) under RCP 4.5 scenarios from CORDEX-SA data (Coordinated Regional Downscaling Experiment-South Asia) for the future period of (2021-2050) after bias correction is used in the present study.
2. The annual rainfall data is evaluated, mean monthly rainfall distribution is calculated and statistical factors are used to investigate the variation in distribution across the area. To see if there was any notable difference in rainfall data over the Kokkarne catchment, a statistical analysis was performed on rainfall data from 1991 to 2020. The graphs were plotted to show the mean monthly rainfall distribution and C.V of the rainfall data that was taken into account for the study. The mean, S.D., C.V., minimum, and maximum were all determined using statistical analysis in this study.

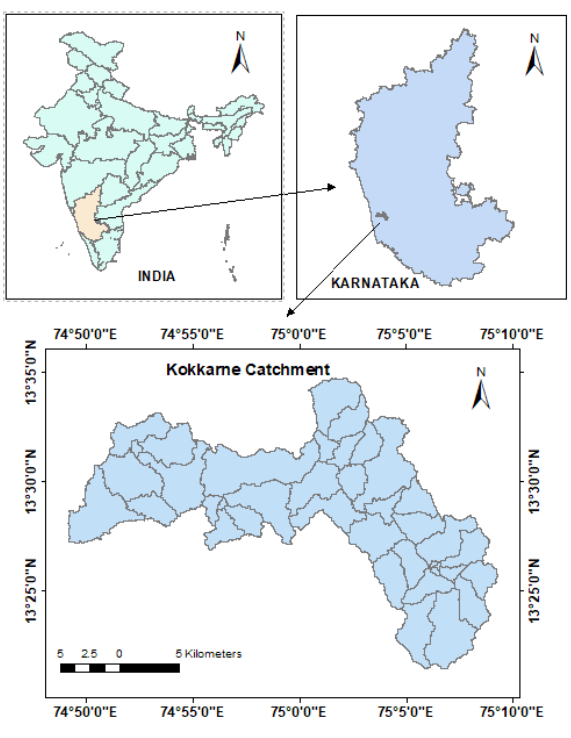

Fig. 1. Location map of the study area (Kokkarne catchment)

Results and Discussion

Mean monthly rainfall distribution

The analysis of monthly rainfall of the study area (Fig. 2) reveals that June–September is the predominant rainy season (monsoon), with 86–87 % of the annual rainfall falling during this time. Though there has been some rain in the other months as well. July is the wettest month (Bhan *et al.*, 2015; Chinchorkar *et al.*, 2013) in the study area. The remaining rainfall normally occurs after the monsoon season has ended, during the post-monsoon season, and during the winter season. Fig. 2 depicts the seasonal distribution of mean precipitation in the study area. According to Table 2, the monsoon months see the most precipitation (Rakhecha and Pisharoty 1996), totaling 106403.3 mm which is 87 % of annual rainfall on an average, while June, July, and August are frequently the months with the most observed precipitation. In the post-monsoon months of October and November, the study area receives a significant amount of precipitation, with precipitation totalling 8214.9 mm (6.7 % of annual rainfall).

Statistical analysis

Table 2 shows the statistical features of the annual, and monthly rainfall data that were evaluated using statistical analysis. According to the findings, the mean annual rainfall of the study area during the study period was 4076.94 mm, with a standard deviation of 447.96 mm and a 10.99 % CV (Bekele, Korecha, and Gebreyes, 2017). The expected minimum and maximum annual rainfalls are 3161.08 mm in 2049 (the driest year) and 5191.50 mm in 2041 (the wettest year) respectively.

As seen in Table 2, monsoon is the most important rainy season in the study area, accounting for the highest contribution of around 86.9% of total

Table 1. List of CMIP5 GCM models used in the present study (http://cccr.tropmet.res.in)

GCM code	GCM-1	GCM-2	GCM-3	GCM-4	GCM-5
GCM Models	ACCESS1.0	CNRM-CM5	GFDL-CM3	MPI-ESM-LR	NorESM1-M
Horizontal grid spacing (long x lat)	1.875 x 1.25	1.4 x 1.4	2.5 x 2.0	1.9 x 1.9	2.5 x 1.9

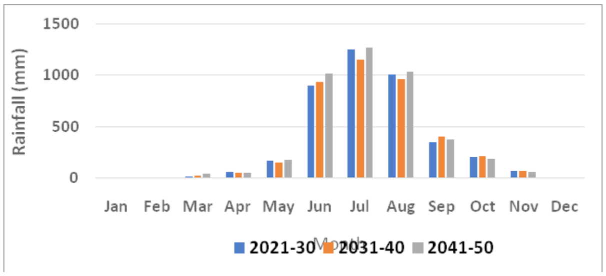

Fig. 2. Mean monthly rainfall distribution.

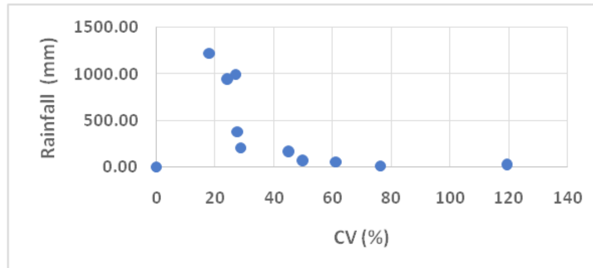

Fig. 3. Mean annual amount of rainfall and its coefficient of variation (CV)

rainfall (Kumar *et al.,* 2010; Laddimath and Patil, 2020; Mondal *et al.,* 2015; Salvi *et al.,* 2013) where nearly 77.7 % comes from three months i.e June, July, and August while September contributed only 9.3 % of the monsoon rainfall. This clearly demonstrated the presence of a high rainfall concentration. The short rainy season (known as the post-monsoon season) that lasts from October to November also contributes a significant amount of rainfall (around 6.7 % of the total annual rainfall).

From Table 2, it is found that the months of June, July, August, and September have a lower CV (coefficient of variation), indicating that rainfall changes are more consistent during these months. March, on the other hand, had the highest CV of 119.5 % (Bekele *et al.,* 2017; Chinchorkar *et al.,* 2013) indicating higher inconsistency during the month. The rest of the months had a similar rainfall trend, indicating that the rainfall variation was similar during these months.

30 years of annual rainfall data of the study area for the period 2021-2050 revealed a coefficient of variation ranging from 17.9 % to 119.4 %. The month of March depicts extreme rainfall variations across the region (Fig. 3). According to Haile *et al.,* 2021; Hare, 2003; Mehzabin and Mondal 2021; Mekonnen *et al.,* 2021 and Tran Van *et al.,* 2021, CV is used to categorise rainfall occurrences into three categories i.e low (CV < 20), moderate (20 < CV < 30), and high (CV > 30) (Eshetu *et al.,* 2017). Accordingly, the projected rainfall in the study area is found to be extremely unpredictable.

Table 2. Statistical summary of monthly precipitation series for Kokkarne catchment (2021-2050).

Variable	Min (mm)	Max (mm)	Mean (mm)	%	SD (mm)	CV (%)
Jan	0.00	0.00	0.00	0	0.00	0.00
Feb	0.00	0.00	0.00	0	0.00	0.00
Mar	0.17	156.31	26.91	0.7	32.16	119.49
Apr	16.28	152.40	53.59	1.3	32.78	61.18
May	49.61	359.26	166.53	4.1	75.05	45.06
Jun	543.54	1756.60	947.33	23.2	228.61	24.13
Jul	780.57	1650.10	1222.69	30	219.18	17.93
Aug	456.10	1526.96	998.26	24.5	270.15	27.06
Sep	194.92	670.02	378.50	9.3	104.34	27.57
Oct	99.06	324.48	203.33	5	58.46	28.75
Nov	17.60	169.18	70.50	1.7	35.16	49.87
Dec	1.25	32.54	9.30	0.2	7.11	76.45
Annual	3161.08	5191.50	4076.94	100	447.96	10.99

Note: SD=standard deviation, CV=Co-efficient of variation

Conclusion

The current study examines the impact of global climate change on rainfall data in the Kokkarne catchment from 2021 to 2050 (30-year period). The current statistical analysis of rainfall data provides a clear picture of rainfall data variations in relation to many statistical factors. The mean, standard deviation, and coefficient of variation of annual rainfall were calculated to check the rainfall variability.

Following were few of the observations from the present research

1. The rainfall pattern can be said to be slightly scattered based on the computed results of standard deviation and coefficient of variation.
2. The study area is subject to a bimodal (single maxima) rainfall regime, with the majority of rainfall falling during the monsoon season (June to September) and a significant amount of rainfall falling even during the post-monsoon season (October to November). Monsoon rainfall is concentrated, with June, July, and August accounting for more than 77.7% of annual precipitation. The presence of a high concentration of rainfall is revealed by the mean monthly maximum rainfall concentration.

Local farmers and agricultural activities are affected by climate extreme events as rainfall variability increases. As a result of the findings of the present study, decision-makers may establish climate-friendly agriculture programmes which would help in the development of self-sufficient agriculture.

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Conflict of Interest

The authors do not have any conflict of interest.

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