Long-term rainfall trend analysis for six homogeneous monsoon regions of India

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Rainfall recharges natural sources of water, which directly or indirectly impacts India's economy. Rainfall-induced natural calamities coupled with climate change have a vast impact on water resources. The present study attempts to examine the spatial and temporal variability of rainfall across six homogeneous monsoon regions of India, viz. Central Northeast, Northeast, Northwest, South Peninsular, West Central and Hilly. In this study, the non-parametric Mann-Kendall (MK) test, Sen's slope estimator (SSE) and entropy method have been used for trend analysis of 100-year gridded rainfall data. Here, monthly, seasonal and annual trends were analysed with the help of *Z*-statistics, Sen's slope, marginal disorder index (MDI) values, and for visualisation of results, box plot and GIS-based Kriging approaches were used. Rainy-day trends were also considered in the analyses. Thus, Central Northeast, West Central and Hilly regions showed decreasing annual and monsoon trends, whereas Northeast, Northwest, South Peninsular regions showed increasing annual and monsoon trends. The Central Northeast region was the only region that showed a significant decreasing rainfall trend at a 5% level of significance, with a *Z*-statistics of –3.31. Trends of remaining regions were not significant. The Northwest region, comprising dry, arid region, showed an increasing rainy-day trend with a *Z*-statistics of corrected as 0.89. Entropy-based variability analysis indicated the Northwest region with maximum variability with an MDI value of 0.04 each, for monsoon and annual rainfall series. The maximum MDI value was found for Northwest region, indicating highest variability in the rainy-day series.

Keywords: Entropy, homogeneous monsoon regions, Mann–Kendall, rainfall trend, Sen's slope.

prevailing direction of the surface winds[1]. Notably, the east coast of the southern peninsula experiences its primary rainfall between October and November. Indian summer monsoon rainfall (ISMR) is a large land–ocean–atmosphere coupled system[2]. ISMR is a weighted average of the June–September rainfall at well-distributed rain gauge stations across the country[3,4]. By the year 2012, there are 8579 rain gauge stations, out of which 3540 stations report their data to India Meteorological Department (IMD), Pune. Furthermore, the combined interactions between the ocean and atmosphere of the Indian and Pacific Oceans have been observed to influence the variability of the Indian monsoon[5]. Researchers emphasised a notable gap in understanding how various large-scale and regional factors influence the ISMR across different time scales[6]. Rainfall estimation is useful for planning and management of water resources system. Scientists require immediate attention to the rainfall change pattern, as it affects both food production and freshwater availability. Spatiotemporal variation of precipitation influences the hydrological cycle, soil characteristics, weather patterns, crop production and ultimately affects the population. The trend of 100 years ISMR, has been performed and concluded a non-significant rainfall trend[7]. Numerous research studies have performed trend analyses of annual and seasonal Indian rainfall[8–12]. The dynamical mechanism of El Niño southern oscillation (ENSO) has shown an impact on the monsoon circulation due to the inconsistent low pressure in the Eastern and Central Pacific region and high pressure in Western Pacific and Eastern Indian Ocean[13]. There is a low and high amount of rain observed over Indian region due to shifting of convection and change in location of tropical circulation because of El Niño/La Niña[14,15]. Historical rainfall trend analysis across India, using data from 306 stations for 135 years, was performed[16]. Researchers