



## Twentieth Century Rainfall Trends of Uttarakhand, India: A Spatio-Temporal Analysis

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**Abstract** Rainfall is a prime input of the hydrological cycle and therefore its variability analysis plays a key role in designing of engineering structures and crop planning. The increase in uncertainty of rainfall events may affects the water resources which lead to decrease the production in agricultural sector especially in hill region like Uttarakhand. The present study was based on spatio-temporal analysis of rainfall variation in the state of Uttarakhand, India over the 20th century (1901–2000). Sen's slope and Mann-Kendall statistics were used to test the trend in annual and seasonal rainfall pattern, and the maximum decrease in monsoon rainfall was observed in Champawat district (2.16 mm year<sup>-1</sup>) followed by Bageswar (1.82 mm year<sup>-1</sup>), and Pithoragarh (1.80 mm year<sup>-1</sup>). Rainfall in winter and post-monsoon seasons also decreased in all the districts but the changes observed were not significant ( $p > 0.05$ ). Pettitt's test was employed to know the most probable change year for seasonal and annual rainfall trend. After 1986, a significant declining trend over the year was observed in annual, post-monsoon and monsoon rainfall showed at the probability levels of 0.052, 0.085 and 0.059, respectively. Whereas, after 1964, a declining trend during winter rainfall was observed but the change was found to be non-significant ( $p = 0.452$ ). To know the periodicity of rainfall pattern, Wavelet analysis was done and observed an increasing frequency of annual and monsoon extreme rainfall events with stronger periodicity of 2–8 years in the recent decades. These findings will be helpful for the policy makers for optimal water allocation and also for making scientific management strategies for constructions of engineering

structures, utilization of rain water for agriculture such as land preparation and sowing, and other uses.

**Keywords:** Change point analysis, Mann-Kendall test, Pettitt test, Rainfall trend analysis, Sen's slope, Twentieth century, Uttarakhand, Wavelet analysis

### 1. Introduction

Climate change is one of the most serious problems, the world is dealing with the moment and the importance of climate change issues is very well established by the fact that many organizations are working solely on this front, such as UNFCCC, Ministry of Environment, Forests and Climate change, so on. The impact of climate change plays a pivotal role for future agricultural planning and crop production in the world, including India (Piao *et al.*, 2010). In the climate change scenario, the Indian agriculture is facing two main climatic problems such as drought and flood. The Indian Himalayan Region too has been suffering from erratic monsoons and thus repercussions are felt to every sector in general and to agriculture in particular. Climate of a particular region is the driving force for selection of farm enterprises and determining the potential productivity. Out of 140 million hectares of the net sown area of India, about 68% of it is prone to drought (Gupta *et al.*, 2014; Alam *et al.*, 2015a, 2015b; Alam *et al.*, 2016). In India, 103 districts out of a total of 688 districts, and 16 states out of 29 states are chronically drought prone (Alam *et al.*, 2014; Gupta *et al.*, 2014).

Indian water resource is mainly dependent on precipitation, planning and designing of water resource

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