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A REVIEW

Rainfall trend analysis

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Abstract : This article aims to review studies pertaining to trends in rainfall, rainy days over India. Non-parametric tests such as Sen's Slope were used as estimator of trend magnitude which was supported by Mann-Kendall test. The findings of various studies indicate variance with respect to the rainfall rate, which contributes to an uncertain picture of the rainfall trend. In the study of monsoon of different locations in India some places showed increasing trends however, there is signifying decrease in trend all over India. It was also mentioned that analysis can vary from for a location if done using different source or types of collection of data. Spatial units range from station results and sub-division to sub-basin/river basins for trend analysis. The outcomes of the different experiments vary and a simple and reliable picture of the trend of rainfall has not appeared. While there can be a non-zero slope value for the multiple units (sub-basins or sub-divisions), few values are statistically important. In a basin-wise trend analysis report, some basins had a declining annual rainfall trend; at a 95 per cent confidence stage, only one basin showed a strong decreasing trend. Out of the six basins exhibiting a rising trend saw a major positive trend in one basin. Many of the basins have the same pattern direction on the annual and seasonal scale for rainfall and rainy days.

Key Words : Climate change, Rainfall, Trends analysis, Intensity, Monsoon, Seasonal analysis

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INTRODUCTION

Rainfall is a significant meteorological parameter, which has direct application in fields like agriculture and other related divisions in India. These parts are exceptionally reliant on the accessibility of water just as satisfactory climatic conditions. The measure of precipitation in a region satisfies different needs including farming, industry and local and pressure driven power age. Agriculture and related sectors, food security, and energy security of India are crucially dependent on the timely availability of adequate amount of water and a conducive climate. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands, such as agricultural, industrial, domestic water supply and for hydroelectric power generation. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods. The southwest (SW) monsoon, which brings about 80 per cent of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. Changes in climate over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall

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economy of the country. In water resource engineering there are several applications and requirements of adequate data analysis of rainfall, for example, rainfall depth, its return period, rainfall trend, etc. Rainfall helps in designing and modelling water management studies, rainwater harvesting, estimation of the flood, pond design, groundwater recharge techniques, irrigation plans, evapotranspiration estimation, etc. The heavy concentration of rainfall in the monsoon months (June–September) results in scarcity of water in many parts of the country during the non-monsoon periods. In view of the above, a number of studies have attempted to investigate the trend of climatic variables for the country. These studies have looked at the trends on the country scale, regional scales and at the individual stations. This article gives an exhaustive coverage of the reported studies dealing with one variable which are critical in hydrologic studies: rainfall. Rainfall data can be analysed in different forms in the context of different requirements. These requirements may include trend analysis, frequency analysis, rainfall intensity, extreme events analysis, future prediction, etc. Trend analysis is a method that helps in determining the spatial variations and temporal changes for different parameters of climate. In view of the above, numerous studies have attempted to investigate the trend of variable climate in our country. These studies have looked at the trends on the country scale, regional scale and at the individual stations.

MATERIAL AND METHODS

Trend analysis – general methodology:

Trend analysis of a time series consists of the magnitude of trend and its statistical significance. Obviously, different workers have used different methodologies for trend detection. The methodology for rainfall analysis generally follows the statistical approach. The statistical methods used included the mean, standard deviation, co-efficient of variation, co-efficient of Skewness, Kurtosis, Chi-square, Anderson Darling test, Kolmogorov - Simornov test and Mann-Kendall test.

Rainfall trend research in India:

A variety of studies have been performed on rainfall data at both national and international levels. These studies helped establish a foundation for the next generation and offered insights and angel of study for various aspects. There are a few studies mentioned below:

Parthasarathy and Dhar (1974) observed that there was a positive trend in annual rainfall over Central India and the neighbouring parts of the peninsula for the period 1901-1960 and a declining trend over certain parts of eastern India. A stable northeast monsoon rainfall was noticed by Dhar *et al.* (1982) over Tamil Nadu. Pant and Hingane researched geographic areas of Punjab, Haryana, Rajasthan and west Madhya Pradesh between 1901– 1982 in the year 1988 and noticed a growing pattern in the mean annual and south western monsoon. Rupa Kumar *et al*. (1992) recorded that in the monsoon rainfall, the northeast peninsula, northeast India and northwest peninsula observed a decreasing pattern (ranging from-6% to-8% of the normal per 100 years). However, in monsoon rainfall, the western coast, central peninsula and northwest India experienced a growing trend (about 10-12 % of the normal every 100 years).

A research undertaken by Kumar *et al.* (1999) showed that the relationship between the Indian monsoon and ENSO has deteriorated in recent decades. Subbaramayya and Naidu (1992) analysed patterns in monsoon rainfall in various sub-divisions and the whole of India for the period 1871-1988. During the late 19th century and again in the 1960s, declining patterns were found in the central and western Indian sub-divisions. In the early 1970s, the later trend was reversed. For 1910-2000 in 2004, Sen Roy and Balling (2004) evaluated daily rain, which revealed a growing pattern in a contiguous area from the north-western range of mountains in Kashmir through much of the Deccan Plateau in the south and decreasing values in the eastern part of the Gangetic Plains and some parts of Uttarakhand. Trend rain identification for 1901-1984 at 11 stations in Himachal Pradesh shows a rise in annual rain at 8 stations announced in 2005 by Kumar *et al*. (1999) with 8 stations displaying a declining trend in the monsoon. At a 95 per cent confidence mark, the declining pattern of annual and monsoon rain in Shimla was statistically critical. Singh and Sontakke (2002) analyzed rainfall data over the Indo-Gangetic Plains (IGP) for the period 1829-1999 and noticed a substantial growing trend (170 mm/100 yrs) from 1900 in the summer monsoon precipitation over western IGP; non-significant decreasing trend (5 mm/100 yrs) from 1939 over central IGP and non-significant decreasing trend (50 mm/100 yrs) between 1900 -1984 and non-significant increases.

In Singh *et al.* (2005) observed that annual rain showed a declining pattern since the sixties over major basins in Middle India (Sabarmati, Mahi, Narmada, Tapi, Godavari and Mahanadi), while Indus, Ganga, Brahmaputra, Krishna and Cauvery basins showed a rise since the sixties. For the period from 1951 to 2003, Ramesh and Goswami (2007) analyzed daily gridded observed rainfall data and noticed declining patterns in early and late monsoon rainfall and rainy days across India. During various seasons, rainfall quantity analysis revealed a declining trend in summer monsoon rainfall over the Indian land mass and a growing trend in pre-monsoon and post-monsoon rainfall. Trends in severe rain indexes for 1901-2000 were analyzed by Joshi and Rajeevan (2006) using 100 stations throughout India. Vital positive patterns over the west coast and northwest peninsula were seen by most of the extreme rain indexes for the southwest monsoon season and annual number. Nevertheless, 2 hill stations (Shimla and Mahabaleshwar) showed a decline in the volume of heavy precipitation. Pattanaik (2007) observed a decreasing trend in northwest and northwest monsoon precipitation during 1941–2002 in central India.

Goswami *et al.* (2006), by high resolution daily grid rainfall for 1951-2003, that there have been important growing patterns in the frequency and magnitude of ultimate monsoon rain events over central India. In comparison, they observed a declining trend over an equal sum within the number of mild events, so that within the mean rain there was no critical trend. Temporal variance studies by Krishnakumar *et al.* (2009) studied weekly, seasonal and annual rainfall over Kerala for 1871-2005 found a substantial decrease in SW monsoon rainfall and a rise in the post-monsoon season. During the winter and summer seasons, rainfall shows insignificant increasing trend. The rain quantity study for various seasons by Dash *et al.* (2007) revealed a declining pattern across India during the summer monsoon and the trend improved during the pre-monsoon and post-monsoon months. Basistha *et al.* (2009) analyzed rainfall details from 30 rain gauge stations in the Indian Himalayas for 80 years (1901-1980) and found an increasing trend between 1901 and 1964 and a decreasing trend between 1965 and 1980. Ranade *et al.* (2008) did not discover a trend of 316 rain gauges at the beginning or end date, duration and cumulative rain of the hydrological rainy season over various Indian basins in 2008.

During the period 1954-2003, Pal and Al-Tabbaa (2010) observed declining trends in spring and monsoon rainfall and rising trends in autumn and winter rainfall across India. In the meantime, a monthly, seasonal and annual rain study conducted by Subash *et al.* (2010) of 5 Central North East India meteorological sub-divisions showed a significant decreasing trend of 4.6 mm/yr for Jharkhand and 3.2 mm/day for Central North East India throughout 1889-2008. In the recent past in December, all meteorological sub-divisions, except Jharkhand, have shown a great decreasing trend of rain. For the period 1901–2003, Rajeevan *et al.* (2008) analyzed a rainfall series developed using a network of 1476 rain gauge stations. Three sub-divisions (Jharkhand, Chhattisgarh and Kerala) showed a significant decreasing trend in the monsoon season and a significant increasing trend in eight sub-divisions (Gangetic West Bengal, Western Uttar Pradesh, Jammu and Kashmir, Konkan and Goa, Madhya Maharashtra, Rayalseema, Andhra Pradesh Coastal and Karnataka North Interior). The monthly, seasonal and annual precipitation of five Central North East India meteorological sub-divisions showed a significant decreasing trend for Jharkhand, 4.6 mm/yr and for Central North East India, 3.2 mm/day during the period 1889 to 2008. All meteorological sub-divisions, except Jharkhand, showed a significant decrease during December.

Pradeep *et al.* (2011) analyzed and reported that February was the driest month in 1987-2008 and Sept. was the wettest month with a mean rain of 2.3 mm and 175.9 mm, respectively. Their research found that *Kharif* was the wettest season, while *Rabi* was the driest with 537.4 mm and 30.8 mm of normal seasonal rain. The variations over the basins of the Ganges, Brahmaputra and Meghna were studied by Mirza *et al.* (1998) and found that precipitation was by and wide constant in the Ganges basin. A declining trend was seen by one sub-division of the Brahmaputra basin, while another showed a growing trend. For the basin of Meghna, there was a declining trend in one sub-division and a growing trend in another sub-division. A research was done by Nyatuame *et al.* (2014) which revealed that the linear regression analysis was a statistically negligible improvement in the annual mean rain trend. The overall monthly results indicated an associated upward trend in some months and in others downwards. It was jointly reported that a very poor association occurred between rain and monthly rain. During the period from 1901 to 1980, Rao (1993) did not detect any major pattern in monsoon and annual rainfall over the Mahanadi basin. For the Raipur district of Chhattisgarh, Swain *et al.* (2015) conducted analytic tests in 2015 for monthly rain data for 1901-2002, *i.e.* Sen slope and Mann Kendall. For that number, they noticed a downward trend for much of the years.

Singh *et al.* (2005) observed that there was a decreasing trend in annual precipitation over major basins in Central India (Sabarmati, Mahi, Narmada, Tapi, Godavari and Mahanadi) since the 1960s, although there was an increasing trend in the Indus, Ganga, Brahmaputra, Krishna and Cauvery basins. Rao *et al.* (2016) studied Godavari sub-Basin for the time period of 14 years, *i.e.* from 2001 to 2014, from which it was discovered that there are signs of potential negative trends. Shekhar *et al.* (2017) observed a negative pattern in all Western Himalayan ranges other than Shamshawari. The positive trend rate was found in the western and middle parts of the Western Himalayas, while the Japanese and southern parts of the Western Himalayas were dominated by negative trends. Sharma (2017) results of rectilinear regression analysis showed a statistically critical decreasing trend in annual average rain, but along with monthly rain data, decreasing trends were seen every month. Li *et al.*(2018) in the Himalayas, which was supported by four sets, namely interpolated grid data based on gauge observations, reanalysis data and high-resolution simulation by a regional climate model, investigated the abstraction and temporal pattern of rain. They concluded that although datasets in terms of abstraction pattern and temporal variation and modifications could be similar, there is a distinction in absolute values, *i.e.* 497-819 mm/year due to source and technique. In July and August and in the windward slope and high-elevation regions, these variations were notably large. Summer was found to be wetter and winters were drier and trends were not statistically significant. As a result, wetter summer ends in a lot of and greater floods and less accumulation of glaciers ends in hotter and drier winters.

Conclusion:

An essential and significant prerequisite for the planning and control of water supplies is a knowledge of the spatial and temporal distribution and evolving patterns of rainfall. The river-basin precipitation patterns are predicted to show a wide variance. In trend analysis research, the findings depend greatly on the data duration and the stations from which the data is used. Another point is that much of the pattern identification data used applies to the stations that are situated in urban environments; these areas are kind of islands of heat. Therefore, the analysis of trends using this knowledge may not be the right interpretation of the facts and this factor needs to be discussed. In particular, these issues illustrate the importance of identifying a network of baseline stations for studies to detect improvement.

In a major exercise, the Ministry of Environment and Forestry conducted an assessment of the impact of climate change in the 2030s on four main sectors of the Indian economy, namely agriculture, water, natural habitats and biodiversity and health in four climate-sensitive regions of India, namely the Himalayan region, the Western ghats, the coastal areas and the north-eastern region. Integrated nationwide change identification, impact evaluation and adaptation and mitigation programme is required.

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