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Research Article

ANALYSIS OF SPATIAL AND TEMPORAL VARIATION OF RAINFALL IN INDIAN SUB-CONTINENT

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Abstract: The impact of climate change is projected to have its effects both on global and regional basis. The most adversely affected weather parameters due to the changing climate are global temperature and rainfall pattern. The temperature shows an increasing trend whereas the rainfall shows an anomalous trend all over the world. The change in rainfall trend has direct and adverse effects on land and water resources, agricultural practices and thus on total ecosystem. India is also facing the problems developed due to climate change. In the present study, the anomalous behaviour of rainfall due to climate change in the context of Indian subcontinent has been established using 1° x 1° gridded daily rainfall data of India Meteorological Department (IMD) from January 1951 to December 2004. Both, temporal and spatial variation of rainfall have been analysed utilizing statistical tests and presented using ArcGIS 9.1.

Keywords: *Climate change, Temporal and spatial variation of rainfall, IMD, ArcGIS 9.1*

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Introduction

Climate change is a major concern among the scientists and researchers nowadays. It happens due to changes in concentration of the greenhouse gases (CO_2, CH_4, N_2O, and water vapour) which trap infrared radiation from the Earth's surface and thus cause the greenhouse effect. This effect is through a natural phenomenon, which helps to maintain a stable temperature and climate on earth. However increased concentration of greenhouse gases cause to increase the temperature of atmosphere and change the climatic balance. Climate is the average long-term weather patterns usually taken over a 30-year time period for a particular region.

Generally, the change in temperature influences the rainfall which has direct impact on hydrology, land and water resources, agricultural practices and finally on overall ecosystems. It is also recognised that rainfall is one of the key climatic variables that affect both the spatial and temporal patterns on water availability [1]. The changing rainfall pattern and its impact on surface water resources, is an important climate change induced problem facing the world today. So, analysis of rainfall trends is important in studying the impacts of climate change for water resources planning and management [2]. The general conclusion from different climate observations shows that the world's climate has changed during the 20th century. The warming of the climate system is now noticed worldwide and proved by observations that there is an increase in global average air and ocean temperature, accelerated rate of melting of snow, ice resulting into rise of average sea level. The average surface temperature of world's atmosphere has increased about 0.6°C or 1°F [3]. An increasing trend in surface temperature by 0.3°C is noticed by the analysis of 100 years of temperature records of India [4]. Kumar and Jain (2011) [5] found decreasing trend in the annual rainfall and rainy days in 15 basins out of 22 basins in India. Even, consolidation of recent studies that have been carried out on analysis of rainfall which is the key input into the hydrologic system, there is conclusive evidence that rainfall is decreasing in Asia [6-13]. Some investigators [14-16] have reported evidence of trends (possibly due to anthropogenic influences) and long-term variability of climate. The other signals of climate change in India are like change in the spatial pattern of rainfall with respect to normal and occurrence of more intense and frequent extreme temperature, rainfall and cyclone events. India receives about 80 % of its annual rainfall during the south-west monsoon in June, July, August and September months [17]. However, monsoon rainfall is not evenly distributed across the country and the temporal and spatial variations are high. The rainfall of India has shown a dynamic trend since the start of 20th century and has suffered twelve droughts in the years 1900, 1942, 1965, 1966, 1967, 1972, 1973, 1979, 1982, 1983, 1987 and 1993 [18]. Millions of people suffer due to this natural disaster. To control the temporal and spatial effect of drought, one should be aware of upcoming weather conditions. The meteorological department mainly forecasts the weather parameters by the radar or the satellites. The India Meteorological Department forecasts the daily rainfall data in 6h or 12h advance for daily weather report. But there is need of a sequential and long term analysis of forecasted rainfall data to follow the rainfall trend of India. The forecast of rainfall in long-term can help the farmers of India for sowing, irrigation, harvesting and also to take forward steps for drought and flood control.

Materials and Method

The study area is the main island of India; its global position is in the south-east Asia and bounded between 8°4' N latitude to 37°6' N latitude and from 68°7' E longitude to 97°25' E longitude. The data used for the study is the daily 1° x 1° gridded rainfall data of India obtained from India Meteorological Department (IMD). Total 54 years of data, from 1951 to 2004, is used for the study. Data constitutes 357 grids of 1° x 1° size covering the main land of India.

The daily grid data was arranged to generate monthly seasonal (June-September, October-January, February and May) and annual rainfall time series. Statistical analysis of rainfall data for each grid was done by estimating mean, standard deviation, minimum and maximum and slope value.

These estimated parameters showed the temporal variation of rainfall on seasonal and annual basis. The slope values were arranged in ArcGIS to interpolate the spatial variation of rainfall. ArcGIS is the name of a group of geographic information systems software package produced by ESRI. ArcGIS consists of Desktop GIS products, as well as GIS products that run on a server, or on a personal computer. The grid wise rainfall slope values for annual, seasonal and monthly were used to develop the spatial variations. The universal kriging technique was used to interpolate the data and develop smooth-toned figures in ArcGIS 9.1. The results are shown in the Figures [Fig-1 to Fig-3].

Result and Analysis

Seasonal rainfall

[Fig-1] shows that the seasonal (monsoon season) rainfall trends in India. Most parts of West Bengal, Meghalaya, Sikkim are showing the maximum increase in monsoon rainfall since 1951 to 2004. Western parts of West Bengal, Assam, Meghalaya and Uttarakhand also show relative increase in rainfall. Andhra Pradesh, parts of Rajasthan and some parts of north-east India are showing a moderate increase.

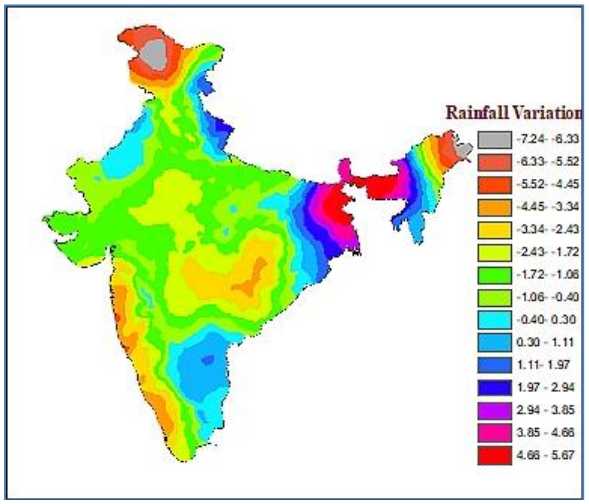

Fig-1 Monsoon rainfall variation

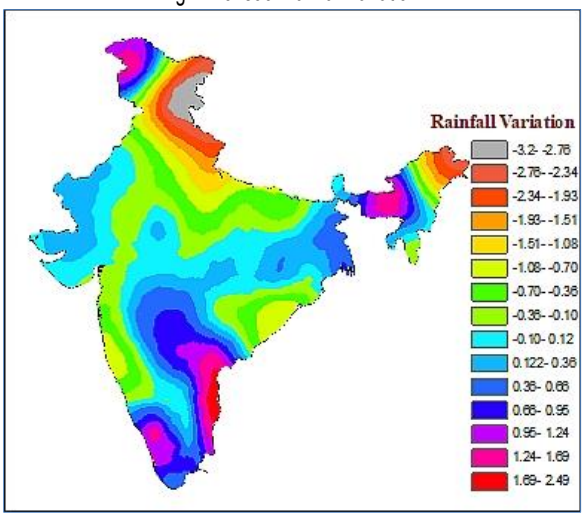

Fig-2 Post-monsoon rainfall variation

However, Jammu and Kashmir and extreme north-east India are show maximum decrease in monsoon rainfall. Andhra Pradesh, Orissa, Madhya Pradesh, west Uttar Pradesh, Chhattisgarh, Karnataka, Kerala, and Maharashtra show relative decrease in rainfall. The rest parts of country like Gujarat, Rajasthan, Delhi and middle Uttar Pradesh are showing moderate decrease in rainfall.

[Fig-2] shows the post-monsoon rainfall patterns. From the figure, it is clear that the range of variation (either increase or decrease) in rainfall during the post-monsoon season is less as compared to monsoon season. The slope range for post monsoon rainfall is -3.2 to 2.49 and for monsoon rainfall it is -7.24 to 5.67. North-east part of Jammu and Kashmir shows the maximum decrease in rainfall than other parts. Himachal Pradesh, Uttarakhand and extreme north-east India also show a comparative decreasing trend. Orissa, parts of Rajasthan, Uttar Pradesh, Bihar and coastal parts of Maharashtra and Karnataka are showing moderate decrease in the post monsoon rainfall. Highest increase in rainfall is marked in coastal regions of Tamil Nadu, Andhra Pradesh, Kerala and north-east part of Jammu and Kashmir and part of Assam and Meghalaya. North-west parts of Rajasthan, Gujarat, Chhattisgarh, Madhya Pradesh, Parts of Andhra Pradesh, Tamil Nadu, Orissa and Bihar show moderate decrease in post-monsoon rainfall.

The pre-monsoon rainfall pattern [Fig-3] shows that during February, March, April and May, there is remarked variation in rainfall between highest and lowest events. The variation ranges -5.2 to +8.5 in terms of slope values in the whole country. Highest increase in rainfall is observed in north-west Jammu and Kashmir. Tripura, Mizoram, Manipur, West Bengal, parts of coastal Orissa and Uttarakhand show moderate increase in rainfall. Rajasthan, Delhi, parts of Gujarat, Chhattisgarh show slightly increasing rainfall trend. North-east part of Jammu and Kashmir and extreme north-east India are showing extremely decreasing rainfall trend during this period. Kerala, central parts of Andhra Pradesh, Maharashtra and Karnataka are having relative decrease in monsoon rainfall. Then, the rest parts of Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh and other parts are having a slight increase in rainfall.

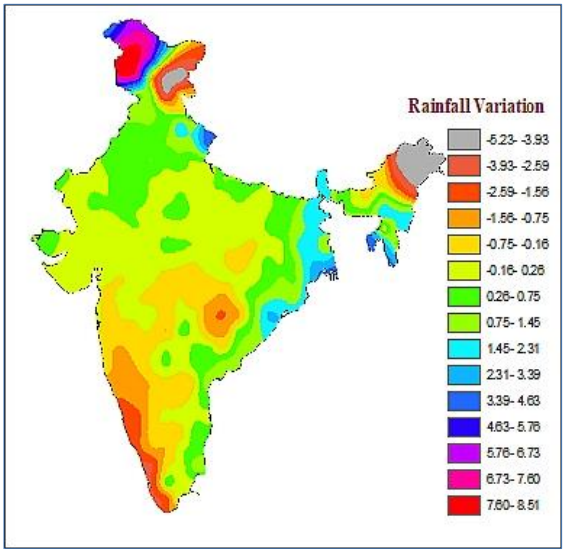

Fig-3 Pre-monsoon rainfall variation

Conclusion

The grid wise (1° x 1°) slope values for seasonal rainfall was used to develop the spatial variability and universal kriging technique was used to interpolate the data and develop smooth-toned figures in ArcGIS 9.1. The results showed increasing annual rainfall trends in eastern parts of country and dominantly decreasing trends in central, North-East Jammu and Kashmir, western Ghats and western parts of the country. Pre-monsoon, monsoon and post monsoon rainfall slope variations ranged from -5.23 to 8.51, -7.24 to 5.67, -3.20 to 2.49, respectively, for the country. Extreme north-east India including Arunachal Pradesh, parts of Assam and Nagaland, Jammu and Kashmir, Rajasthan and Gujarat are the states showing maximum decrease in rainfall. West Bengal is showing persistent increase in rainfall since 1951 except few exceptional years. Thus, the rainfall in India is showing both spatial and temporal variation for seasonal rainfall.

Application of research: The anomalous behaviour of rainfall due to climate change in the context of Indian subcontinent has been established using 1° x 1° gridded daily rainfall data of India Meteorological Department (IMD) from January 1951 to December 2004

Research Category: Agrometeorology

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Institute: Indian Institute of Technology Kharagpur, Kharagpur, 721302, India
Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: India Meteorological Department (IMD) and Indian Sub-Continent

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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