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RESEARCH ARTICLE

Assessment of Spatial and Temporal Variability of Rainfall in the Tunga River Basin

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Abstract

Climate change has caused significant variations in precipitation across the different geographical regions of the world. A better understanding of rainfall trends, distribution, and features is essential for effective water resource management, particularly in areas with high spatiotemporal variability. This study examines the spatiotemporal changes in rainfall patterns of the Tunga River Basin which is located in the Western Ghats region of Karnataka, India. Also, the potential reasons for the rainfall variability in the region were investigated. The Tropical Rainfall Measuring Mission (TRMM) 3B43 monthly precipitation data for 24 years from 1998 to 2021 were used. The study revealed that the high-elevated areas are getting more rainfall compared to the lowlands, which shows the influence of topography on precipitation.

Keywords: IDW; Rainfall; Spatial variability; Temporal variability; TRMM

1 Introduction

Rainfall is one of the key elements in establishing climate, along with temperature. It can have a significant impact on the management of agriculture, ecosystems, and water resources due to its spatial distribution and changing properties [1]. One of the biggest problems of our time is climate change. A long-term shift in the typical weather patterns is referred to as climate change. The impact of climate change on weather and extreme events is becoming more well-recognized. In the 20th century, there has been a dramatic change in the patterns of rainfall over the world [2].

The global variability of precipitation in terms of both space and can be obtained from infrared sensor readings on passive microwave sensors carried on board geostationary satellites by the newly operational radars on board and the polar-orbiting satellites the TRMM satellite and its successors. TRMM was a research satellite that functioned from 1997 to 2015. Its purpose was to improve our understanding of the distribution and variability of precipitation in the tropics as part of the water cycle in today's climate system. As an extension and enhancement of the TRMM data, the Global Precipitation Measurement (GPM) Core Satellite was launched in February 2014.

The major threats to agriculture and food security are changing weather patterns such as less predictable seasons more frequent rainfall events and prolonged droughts (IPCC 2001) [3]. The most important factor that affects Indian agriculture is the monsoon because 70% of it is dependent on the monsoon[4]. Global warming is one of the reasons for the occurrences of heavy rainfall events nowadays (Goswami et al 2006[5]; Turner and Annamalai 2012). Rainfall is the main source of river flow in India. Extreme rainfall variability thus increases the frequency of extreme hydrological events like droughts and floods. The temporal and spatial variability of rainfall is crucial from both scientific and economic viewpoints[6–10].

The study area is located in the Western Ghats of Karnataka and is characterized as one of the biodiversity hotspots in the world. The climate and topography of the region support a wide variety of plants and animal species. But the region is now undergoing rapid transformation. The high deforestation rate, illegal hunting, hydroelectric projects, mining, and extraction of forest resources is altering the region and would seriously affect the variability of rainfall in the study region. Similarly, Agriculture is a major economic activity in the river basin. Rainfall variability directly impacts crop yields and influences decisions related to crop selection, planting times, and irrigation needs. The study helps the farmers to optimize their practices based on the expected rainfall patterns. Further, the health of aquatic ecosystems in the Tunga River basin is closely tied to the availability of water. Variability in rainfall can affect river flow, water levels, and overall ecosystem health. Understanding these variations is vital for preserving biodiversity and maintaining ecological balance in the study area. Understanding the variability in rainfall helps in managing water resources effectively. In this context, this study aims to find out the variability of rainfall in the Tunga River basin, Karnataka using Remote Sensing and GIS techniques to understand the distribution pattern of rainfall within the study basin for sustainable water management.

2 Study Area

Tunga is a river that flows through the state of Karnataka, India. The river originates in the western ghats and flows through two states of Karnataka, Chikmagalur and Shivamogga. Rivers Tunga and Bhadra are the principal tributaries of Krishna in Karnataka along with other tributaries like Ghataprabha, Mala Prabha, and Bhima. Tunga River Basin is located between 13°24′ N to 14°03′ and 75°07′ E to 75°67′ E having an aerial extent of 2722 sq. km. It flows through the state of Karnataka. The study area map is shown in Figure 1.

The river originates in the Western Ghats on Varaha Parvata hill, Ganga Moola. Three important rivers, the Tunga, the Bhadra, and the Nethravathi have their origin here. The river flows through two districts of Karnataka- Chikmagalur and Shivamogga. It has a length of 147 km. The river merges with Bhadra at Koodli, a small village near Shivamogga. From here the river is known as Tungabhadra. The river Tungabhadra flows eastwards and joins the Krishna River in Andhra Pradesh.

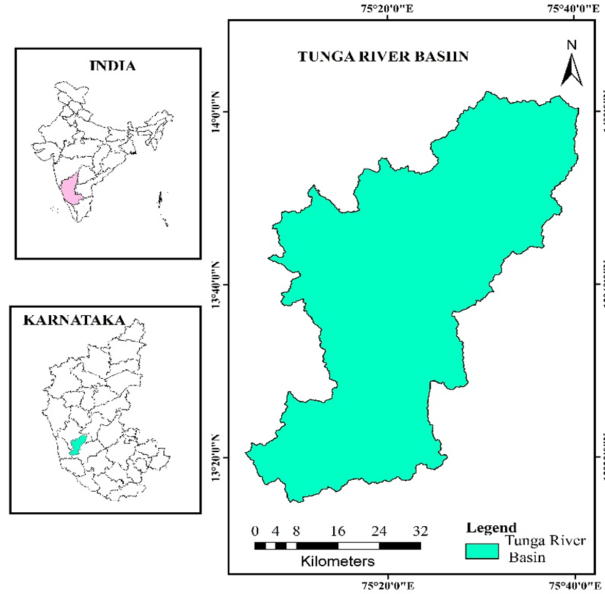

Fig. 1. Location map of Tunga River Basin

3 Data and Methodology

3.1 Data Used

The present study used TRMM 3b43 rainfall data for years from 1998 to 2021 for studying the rainfall variability of the Tunga River basin. The Tropical Rainfall Measuring Mission (TRMM) is a NASA-JAXA collaborative space mission that monitors and studies tropical rainfall. The TRMM spacecraft carried numerous sensors for detecting precipitation, including the Visible Infrared Radiometer (VIRS), TRMM Microwave Imager (TMI), Cloud and Earth Radiant Energy Sensor (CERES), Lightning Imaging Sensor (LIS), and the first spaceborne precipitation radar (PR).

Several precipitation retrieval techniques have been developed based on observations from the TRMM satellite's sensors, including the TMPA (TRMM Multi-satellite Precipitation Analysis). The TMPA algorithm uses satellite-based microwave and infrared sensors, as well as ground rainfall gauge analyses, to generate 3-hourly rainfall estimates with a spatial resolution of $0.25\circ \times 0.25\circ$ and a quasi-global coverage (50∘ N-S). The Level 3 TRMM 3B43 data, also known as the TMPA product, were chosen for our investigation. TRMM 3B43 (v7) data, specifically from 1998 to 2019, were used. For the years 2020 and 2021, GPM data is used.

3.2 Methodology

The spatial variability maps for each month are prepared using the IDW interpolation method using ArcMap 10.5. The spatial variability maps for four seasons- pre-monsoon, monsoon, post-monsoon, and winter were also prepared. Temporal variability patterns of rainfall involve a systematic methodology to discern and analyze the fluctuations in rainfall values over a selected period. Once the data is gathered, a thorough exploratory data analysis is conducted to identify patterns, trends, and potential outliers. A graphical representation of the data is derived to obtain the seasonal, annual, and interannual changes associated with the climate anomaly.

Inverse distance weighted (IDW) interpolation determines cell values which uses a linearly weighted collection of sample points. Weight is inversely proportional to distance. The interpolated surface should represent a locationally dependent variable. IDW uses the measured values around any unmeasured location to forecast a value. The measured values closer to the prediction location have a greater impact on the anticipated value than those farther away. IDW assumes that the local influence at each measured place decreases with distance.

3.3 Digital Elevation Model

The Digital Elevation Model of the Tunga River basin is shown in Figure 2. A representation of the Earth's topographic surface that is devoid of any buildings, trees, or other surface features is called a digital elevation model, or DEM. The highest elevation in the study area is 1508 meters and the lowest elevation is 463 meters. Cartosat-1 generated DEM was downloaded from the Bhuvan portal.

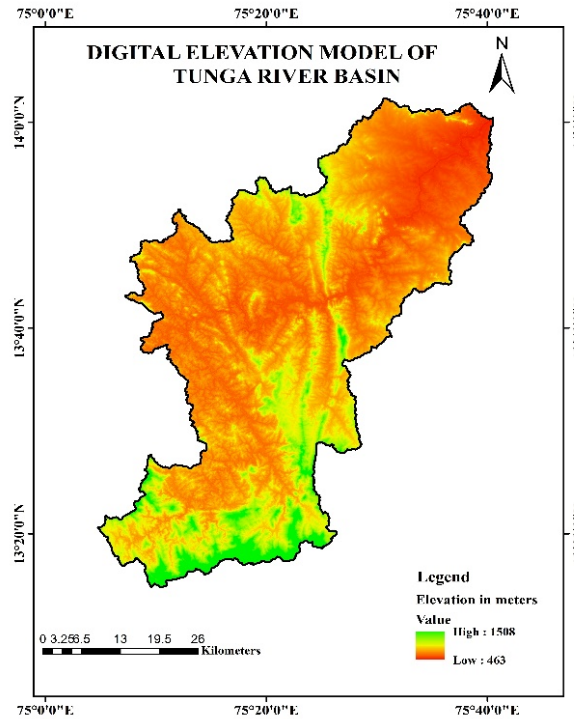

Fig. 2. DEM of Tunga River Basin

4 Results and Discussions[11–25]

4.1 Spatial Variability of Rainfall

The seasonal spatial variability maps showing the variability of rainfall of the Tunga River basin are shown in Figure 3. For this analysis, the entire year's data is categorized into different seasons such as Monsoon, Pre-monsoon, Post- Monsoon, and Winter to explore the variability pattern in different seasons from one place to the other place within the study basin. The study area experienced the highest average rainfall of 0.80 mm/day during the monsoon season from June to September. The post-monsoon season, occurring from October to November witnesses a decline in overall rainfall (>0.2mm). The spatial variability during this period reflects the retreating monsoon, with southwestern areas experiencing residual precipitation. The rainfall is very low throughout the study area in the winter season (>0.1mm). During the pre-monsoon period, there is typically a spatial heterogeneity in rainfall distribution, with southern areas experiencing rainfall of up to 0.2mm/day while northern areas remain relatively dry. The comparison of spatial variability of rainfall with the terrain elevation (Figure 2) shows the high rainfall observed within the study area is characterized in the southern part of the study basin which has the highest elevation of 1508 meters. While low rainfall is observed in the northern eastern parts exhibiting a low elevation of 463 meters. The spatial rainfall variability trend is observed from southwest to northeast. This indicates that the presence of Western Ghats mountains plays a major role in the spatial distribution of rainfall in the area.

4.2 Temporal Variability of Rainfall

The temporal distribution of seasonal rainfall variability in the Tunga River basin, spanning is examined using the rainfall data of TRMM 3B43 for the 23 years from 1998 to 2021. The study revealed distinctive patterns across different seasons and the year.

4.2.1 Intra-annual rainfall variability

The graph showing the intra-annual rainfall variability of the Tunga River basin is given in Figure 4. The monsoon season typically dominates with intense rainfall from June to September. The highest rainfall of 0.8 mm/day/month is observed in July. Rainfall was found to be gradually decreasing in the post-monsoon months from October to December indicating the

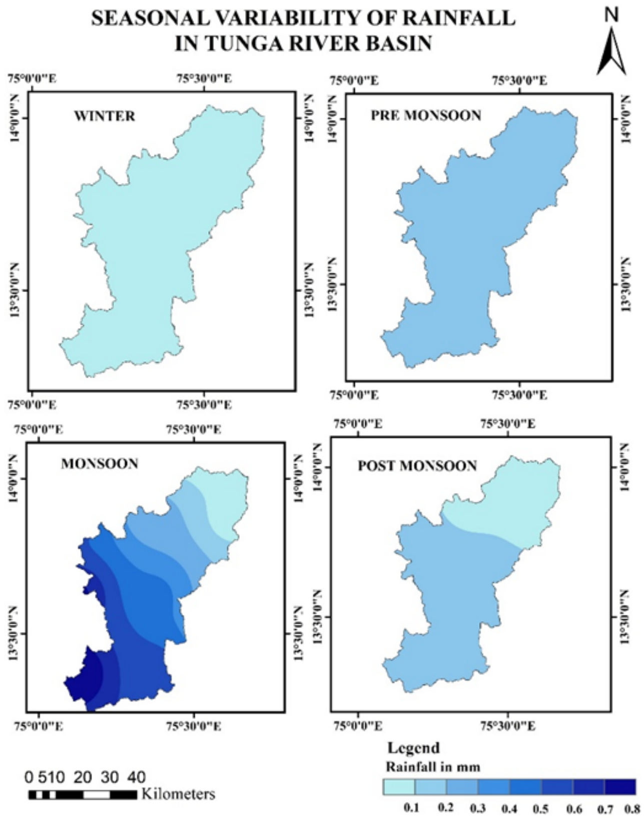

Fig. 3. Spatial variability of seasonal rainfall in the study area

receding phase of monsoon season. The lowest rainfall was observed in January (0.008mm/day/month).

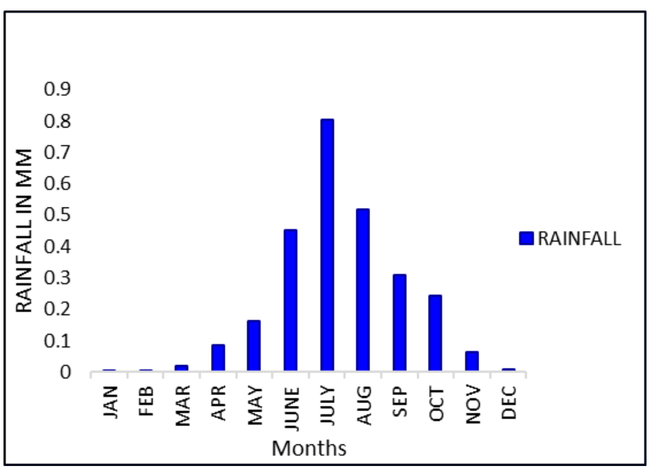

Fig. 4. Intra-annual rainfall variability in the study area

4.2.2 Seasonal variability of rainfall

The seasonal variability of rainfall is shown in the Figure 5. The rainfall variability is characterized by a pronounced increase in rainfall, with high inter-annual variability influenced by monsoonal dynamics in all the years in the study area. During the monsoon season, an average rainfall of 0.5 mm/ day/ season is received for 23 years. The monsoon rainfall has a greater impact on the life of the people of the region due to its significant impact on the water supply and agriculture. The monsoon rainfall shows higher variability as compared to the other seasons of the year. In contrast, the pre-monsoon and post-monsoon seasons exhibit a transitional nature of rainfall. The amount of rainfall received during the winter season remained low throughout the year.

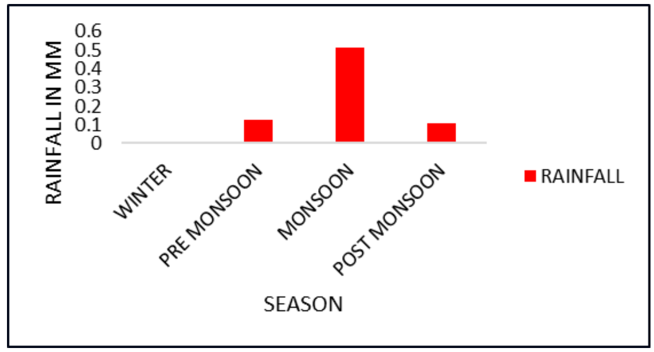

Fig. 5. Temporal variability of seasonal rainfall in the study area

4.2.3 Inter-annual rainfall variability

The inter-annual rainfall variability of the study area is given in Figure 6. The study witnessed notable year-to-year fluctuations in precipitation, showcasing the basin's sensitivity to changing meteorological conditions. From the study, it is observed that the study area received the highest amount of rainfall during the beginning of the study period with an average rainfall of 0.3mm/day/year. In the later years fluctuation in the peaks of rainfall is observed over several years indicating the shifts in climate patterns, impacting the overall water resources in the study area.

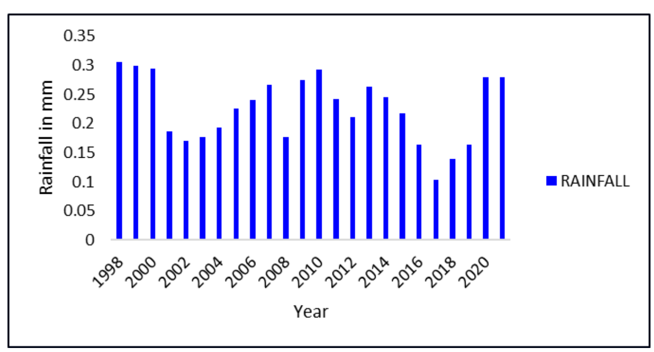

Fig. 6. Inter-annual rainfall variability in the study area

5 Conclusion

Recognizing the potential ramifications of any alterations in the rainfall patterns, this research aimed to comprehensively examine and understand the variability of precipitation in the Tunga River basin in Karnataka, which serves as a critical catchment within the Western Ghats. The study utilized TRMM 3B43 monthly data for a thorough investigation into the patterns and trends of rainfall variability. The study revealed distinct spatial and temporal variations, emphasizing the need for a detailed understanding of these dynamics for effective water resource planning and management. Notably, the southern part of the basin consistently experienced higher rainfall across all seasons, with a spatial trend observed from southwest to northeast. The correlation between spatial variability and terrain elevation highlighted the influence of topography on precipitation, with elevated areas in the southern part receiving more rainfall compared to lower elevation areas in the northern eastern parts. Temporal variability analysis further emphasized the dominance of the monsoon season in terms of rainfall, with July identified as the peak month. The persistence of low rainfall during the winter season throughout the studied years underscores the seasonal variation of precipitation in the Tunga River basin.

The findings of the study not only contribute to the scientific understanding of rainfall variability but also hold practical significance for the states reliant on the Tunga River and its tributaries. The awareness generated through this research assists in informed decision-making in water resource planning, especially in the face of potential modifications to rainfall patterns that could significantly impact the socio-economic and ecological fabric of the region. As climate change continues to pose challenges, this study serves as a foundation for developing adaptive strategies and sustainable management practices in the Tunga River basin.

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