

# Original Research Article **Assessment of Temperature of Ramgarh District, Jharkhand, India – A Case Study of Colafield's Temperature**

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## ABSTRACT

Global interest in climate variability, especially annual temperature changes, necessitates an analysis of spatiotemporal meteorological dynamics, particularly in regions relying on rain-fed coal field agriculture areas. This study examines the impacts of temperature trends and climate change in Jharkhand's Ramgarh district, India. Six sub-divisions, such as Ramgarh, Gola, Chitarpur, Mandu, Patratu, and Dulmi, are under-examined, exploring long-term temperature changes from 1981 to 2022. Leveraging the Mann–Kendall test and Sen's slope Test, a 42-year data set analysis uncovers a decrease in average and maximum temperatures, contrasting an increasing minimum temperature trend. Applying Sen's slope for each temperature category Maximum, Minimum, and Average at Six sub-divisions of the Ramgarh district where Mandu has the highest increasing slope of 0.01 was observed in minimum temperature. However, Gola's maximum and average temperature observed the highest decreasing slope among all stations. Similar patterns were found at other stations. Hence, our study suggests that additional attention should be given to the variability of temperature, and it is imperative to consider the increasing temperature trend to mitigate its effects on human well-being.

*Keywords: Mann–Kendall, Sen's slope, Spatiotemporal, Temperature, Trend.*

## 1. INTRODUCTION

Climate change, one of the most pressing concerns of our era, has starkly manifested through escalating ocean levels, melting polar ice caps, rampant wildfires, and extreme dry seasons observable globally [3]. Indeed, rising temperatures, particularly in urban regions, predominantly affect residents' health, economy, recreational activities, and overall well-being [4]. For an agricultural nation like India, the ramifications of climate change, including altering the intensity and frequency of climate extremes, are deeply felt [6]. These climatic variations and their effects on physical and biological systems have been thoroughly examined by the Intergovernmental Panel on Climate Change [9].

Understanding regional temperature variations is crucial as the global community grapples with climate change, particularly in economically significant regions [12, 13]. Within this global context, the Ramgarh district in Jharkhand, India, a significant coal-producing area with an influential role in the India's economy, comes into sharp focus [1, 2, 12]. Urbanization dynamics, such as population in-migration from rural to urban areas and significant industrial activity like coal production, might be contributing to local climate change effects, necessitating a thorough investigation of temperature trends in this district [12]. The juxtaposition of industrial activity and its potential climatic implications warrants a comprehensive study of temperature trends in this region.

While previous studies have illuminated aspects of regional and global climate change, there's a distinct lack of research conducted at a district level, especially in regions comparable to Ramgarh. Previous research on climate change and its influence on temperature variability has primarily focused on global or larger regional scales [8]. For instance, Kumar et al. (2023) Tirkey et al. (2018) conducted a broader analysis of climate change impacts in Jharkhand and India, but a detailed study focusing on the effects in coal-producing districts like Ramgarh is yet to be done [7, 16]. Likewise, studies like Pandey et al. (2015) and Pandey et al. (2016), which analyzed temperature trends in the agrarian and habitat context, provide a relevant foundation but leave a gap for district-specific investigations of the Ramgarh district of Jharkhand [11, 12]. Few have investigated the intricate climate dynamics at the district level, especially in areas like Ramgarh, where significant industrial activity, such as coal production, might be affecting local temperature patterns.

This study, therefore, bridges this gap in the existing literature, providing a granular view of temperature trends in the Ramgarh district, employing sophisticated statistical methods, including the Mann-Kendall test and Sen's slope test. The study focuses on three key temperature measures: average, minimum, and maximum temperatures, thus providing a holistic understanding of the temperature dynamics in the region. The study aims to accomplish two primary objectives. First, it seeks to identify and analyze the trend in temperature variation in the Ramgarh district over a defined study period. Second, the study will explore the potential correlation between these temperature trends and broader climate change patterns.

The outcomes of this study bear substantial significance. This study will contribute to the growing body of knowledge on the localized impacts of climate change and provide policymakers with evidence-based insights for crafting climate-sensitive policies in the coal-producing regions of India. As such, this research serves as a vital step towards understanding and addressing the intricate tapestry of climate change impacts on a regional scale.

## 2. MATERIAL AND METHODS

### 2.1 DESCRIPTION OF STUDY AREA

Ramgarh is the solitary regulatory district of Jharkhand, India, having longitude  $23^{\circ}63'$  and Latitude  $85^{\circ}52'$  [2]. Ramgarh area comprises of six squares specifically – Ramgarh, Gola, Chitarpur, Mandu, Patratu, and Dulmi. It stands firm on the main Foothold in the mining area of Jharkhand [1,2]. It is restricted in the N-W through the Hazaribagh region, in the N-E through the Bokaro, in the E through the Purulia space of WB state and in the S through the Ranchi regions. The region is part of the Chotanagpur Plateau with a Huge topographic feature of space. The study area falls in the Damodar Basin.

#### LOCATION MAP OF THE STUDY AREA

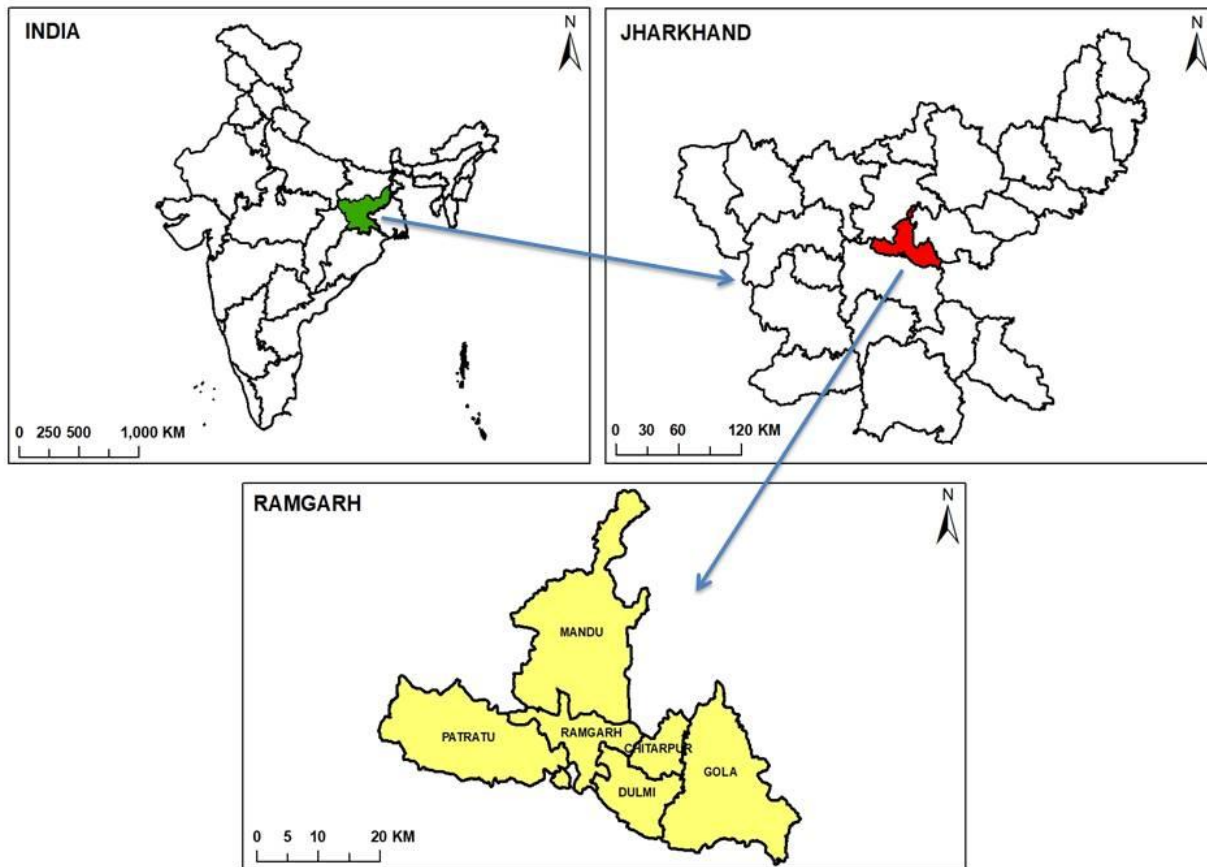


Figure. 1 Location map of Study Area.

## 2.2 METHODS

### 2.2.1 MANN-KENDALL TEST (MK)

The Mann-Kendall (MK) test, crafted by statisticians Henry B. Mann and Donald R. Kendall, is a widely recognized non-parametric technique for spotting trends in time series datasets [5, 17]. Its non-parametric nature means it doesn't assume any specific data distribution, making it versatile for various applications. The MK test primarily identifies consistent upward or downward trends over time, especially those that don't change steadily.

Every pair of data points in the time series is analyzed to conduct the MK test. The later data point's value is compared to the earlier one. These pairwise comparisons lead to the S-statistic, which nears zero if there's no discernible trend. A positive S-statistic indicates a rising trend, while a negative one points to a declining trend.

In the MK test, the null hypothesis ( $H_0$ ) suggests no trend exists, while the alternative hypothesis ( $H_a$ ) suggests a trend, be it upward or downward. The test yields a Z-score, measured against a critical value from a standard normal distribution to decide on the validity of the null hypothesis. Key benefits of the MK test include its resilience to anomalies, not needing normally distributed data, ability to work with gaps in data, and managing tied data points. Yet, a limitation is its assumption that data points are independent. This may not hold true for time series data with autocorrelation.

The Mann-Kendall statistics (S) is given in equation (i).

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sgn}(x_j - x_i) \quad (\text{i})$$

Where,

$x_j$  and  $x_i$  are the annual values at different time  $j$  and  $i$ , respectively and 'N' is the dataset length.

$$\text{sgn}(x_j - x_i) = \begin{cases} 1 & ; \text{if } x_j - x_i > 0 \\ 0 & ; \text{if } x_j - x_i = 0 \\ -1 & ; \text{if } x_j - x_i < 0 \end{cases} \quad (\text{ii})$$

If the datasets show a positive value of S, the trend will increase, whereas the negative values show a decreasing trend. The more significant value indicates the Trend is more reliable in its direction, and the smaller values indicate that the Trend is less reliable.

Under the assumptions that data are dependent or independent, the variance of the S statistics is provided in equation (iii)

$$\text{var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^n t_i(t_i-1)(2t_i+5)}{18} \quad (\text{iii})$$

Where  $n$  represents the total number of tied rank groups and  $t_i$  is the number of data points in the  $i^{\text{th}}$  tied group, and  $\Sigma$  shows the summation over all tied groups.

After obtaining the data variance, the standard normal distribution Z-Statistics is calculated using equation (iv)

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{var}(S)}} & ; \text{if } S > 0 \\ 0 & ; \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{var}(S)}} & ; \text{if } S < 0 \end{cases} \quad (\text{iv})$$

Further, with a two-tailed significance level at  $\alpha = 0.05$ , the calculated standard Z value is compared to the standard normal distribution table. If the calculated Z is greater than  $z \alpha/2$ , the null hypothesis ( $H_0$ ) of no trend is rejected, and the trend is statistically significant; otherwise, the  $H_0$  hypothesis is accepted, which indicates that the trend is not statistically significant.

### 2.2.2 SEN'S SLOPE TEST

Sen, (1968) provided a method to calculate the magnitude of the slope of the trend in hydro meteorological data series [11]. The non-parametric, linear slope method performs effectively on monotonic data. Despite linear regression, it is unaffected by missing data, outliers, or large data errors. So, the linear slopes  $T_i$  and all data sets are determined by using equation (v).

$$T_i = \frac{x_j - x_k}{j - k} \text{ for } i = 1, 2, 3 \dots n, j > k \quad (\text{v})$$

Where  $x_j$  and  $x_k$  are data values at time  $j$  and  $k$  ( $j > k$ ). On the other hand, the median of these N values of  $T_i$  is implies to the slope of trend, which is calculated using equation (vi)

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & \text{if } N \text{ is odd} \\ \frac{1}{2} \left( T_{\frac{N}{2}} + T_{\frac{N+2}{2}} \right) & \text{if } N \text{ is even} \end{cases} \quad (\text{vi})$$

An increase in trend is depicted if  $Q_i$  show positive value; conversely, a negative value shows that the trend in the time series is declining

## 3. RESULTS AND DISCUSSION

The Mann-Kendall (MK) Trend Test and Sen's Slope estimator were employed in tandem with descriptive statistics to determine the temperature trend. The MK trend test parameters such as the MK statistic (s), Kendall's tau, test statistic (Z), and P-value were calculated using R Studio. Sen's slope (Q) also facilitated the graph representation of the Sen's slope test. Descriptive statistics encompassed parameters like minimum, maximum and average temperature, facilitating trend detection in climate change.

Ramgarh station has a decreasing trend for the maximum temperature, supported by a Z Value of -1.572, which is statistically significant with a p-value of 0.08, falling below the 0.05 significance threshold (Table 1). This led to rejecting the null hypothesis in favour of the alternative for this station (Johnson & Levine, 2008). The minimum temperature trend, characterized by a Z Value of 1.739, is statistically significant ( $p=0.043$ ). A similar significance is observed in the average temperature trend, as depicted by a Z Value of -0.227 and a p-value of 0.039.

For Patratu station, also presented in Table 1, results revealed a mildly significant decreasing trend for the maximum temperature, indicated by a Z Value of -1.697 and a p-value of 0.09. Although the p-value exceeds the 0.05 threshold, it resulted in the null hypothesis rejection for the Mandu station. Chitarpur station station has the highest decreasing trend for the maximum temperature, supported by a Z Value of -2.161, which is statistically significant with a p-value of 0.032, falling below the 0.05 significance threshold. This led to rejecting the null hypothesis in favor of the alternative for this station. Furthermore,

**Table 1 encompass Sen's slope tests for all the six station between 1981 and 2022.**

Station (↓)	Parameters (↓)	Minimum Temperature	Maximum Temperature	Average Temperature
Patratu	Z	1.811	-1.697	-0.427
	P Value	0.07	0.09	0.669

	Mann-Kendall Stat (S)	145	-136	-35
	Kendall's Tau	0.207	-0.194	-0.05
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.008	-0.015	-0.004
	Var (s)	6322.333	6324	6325
	Trend	Increasing	Decreasing	Decreasing
Dulmi	Z	1.661	-2.257	-1.051
	P Value	0.048	0.036	0.062
	Mann-Kendall Stat (S)	112	-153	-76
	Kendall's Tau	0.146	-0.253	-0.217
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.007	-0.015	-0.005
	Var (s)	6332.34	6225.6	6313.58
	Trend	Increasing	Decreasing	Decreasing
Mandu	Z	1.679	-1.873	-0.197
	P Value	0.048	0.057	0.039
	Mann-Kendall Stat (S)	147	-134	-48
	Kendall's Tau	0.314	-0.168	-0.32
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.01	-0.012	-0.003
	Var (s)	6372.333	6334	6327
	Trend	Increasing	Decreasing	Decreasing
Gola	Z	1.345	-2.1127	-1.031
	P Value	0.178	0.035	0.302
	Mann-Kendall Stat (S)	108	-169	-83
	Kendall's Tau	0.154	-0.241	-0.118
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.006	-0.018	-0.008
	Var (s)	6322	6323	6323
	Trend	Increasing	Decreasing	Decreasing
Ramgarh	Z	1.739	-1.572	-0.227
	P Value	0.043	0.08	0.039
	Mann-Kendall Stat (S)	142	-129	-43
	Kendall's Tau	0.238	-0.176	-0.25
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.008	-0.015	-0.004
	Var (s)	6372.333	6334	6327
	Trend	Increasing	Decreasing	Decreasing
Chitarpur	Z	1.32	-2.161	-0.982
	P Value	0.037	0.032	0.053
	Mann-Kendall Stat (S)	119	-147	-79
	Kendall's Tau	0.168	-0.201	-0.086
	Alpha	0.05	0.05	0.05
	Sen's Slope (Q)	0.009	-0.016	-0.006

Var (s)	6349.42	6251.67	6326.81
Trend	Increasing	Decreasing	Decreasing

Positive and negative signs corresponded with ascending and descending trends, respectively, while a null slope underscored a static dataset throughout the assessment duration. When the derived p-value remained under the 0.05 significance level, this signified robust statistical significance. The interplay between the Sen's slope estimate and the MK statistic (Z) was evident in Figure 2, 4 and 6, revealing an augmenting trend from 1981 to 2022 for the Ramgarh sub-divisional block station. Such trends were consistent for the Dulmi station as per Table 1.

The spatial representation of Kendall's tau and test statistic (Z) for minimum, maximum, and average temperature, using inverse distance weighted interpolation, is illustrated in Figures 2 to 7, offering a visual representation of the inter-station variabilities.

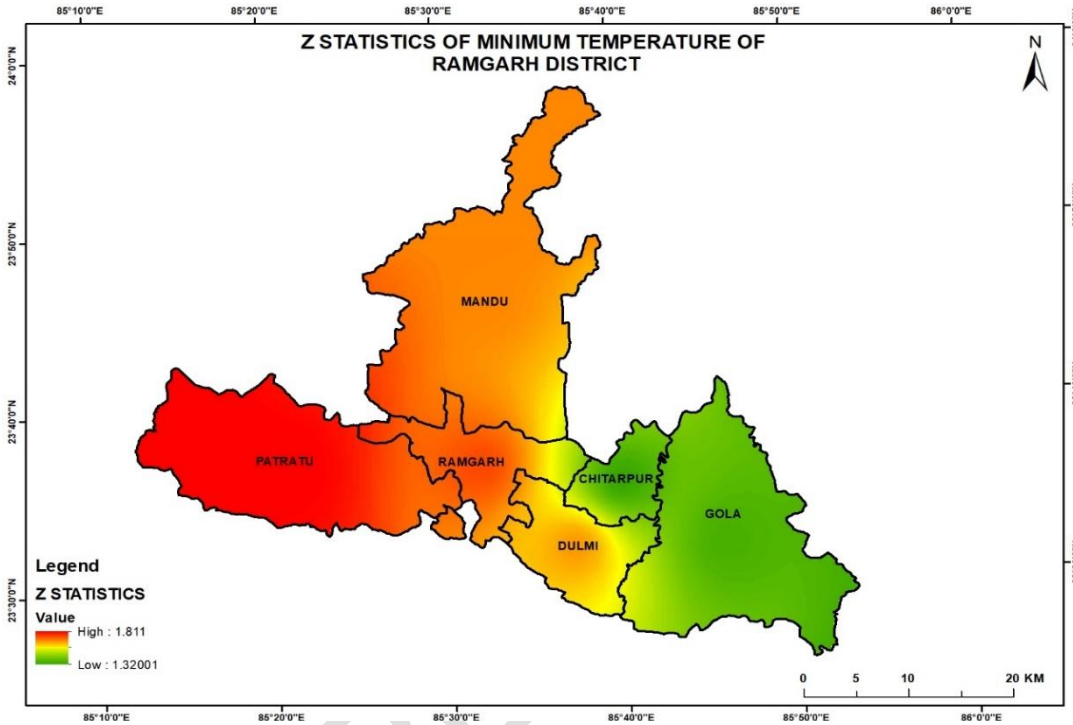


Figure. 2. Z Statistics of minimum temperature of Ramgarh District.

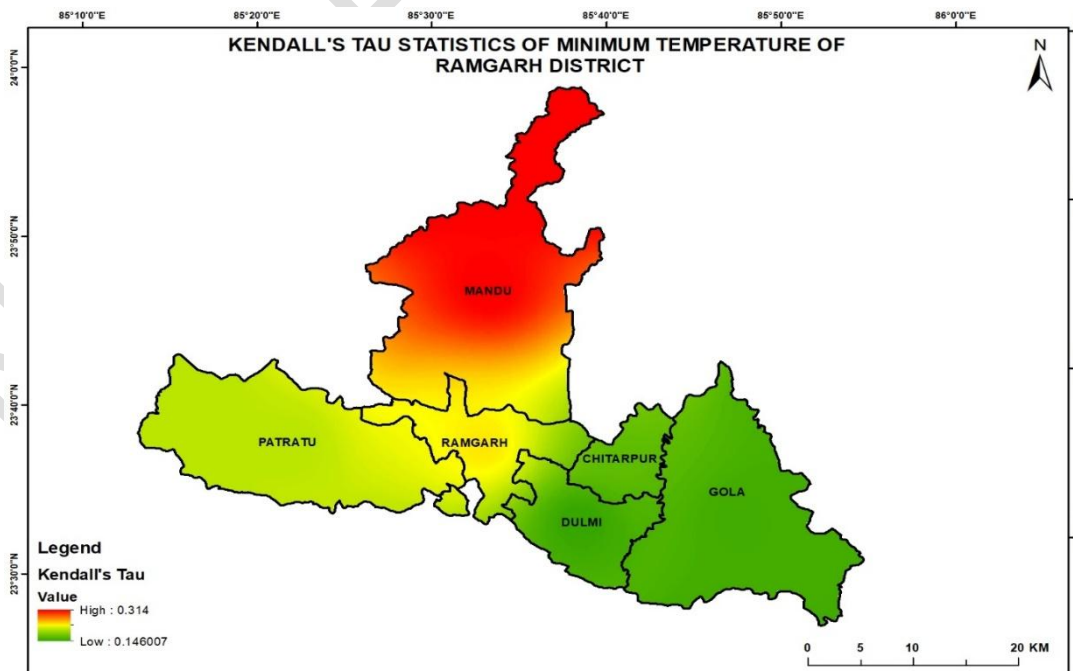


Figure. 3 Kendall's tau Statistics of minimum temperature of Ramgarh District.

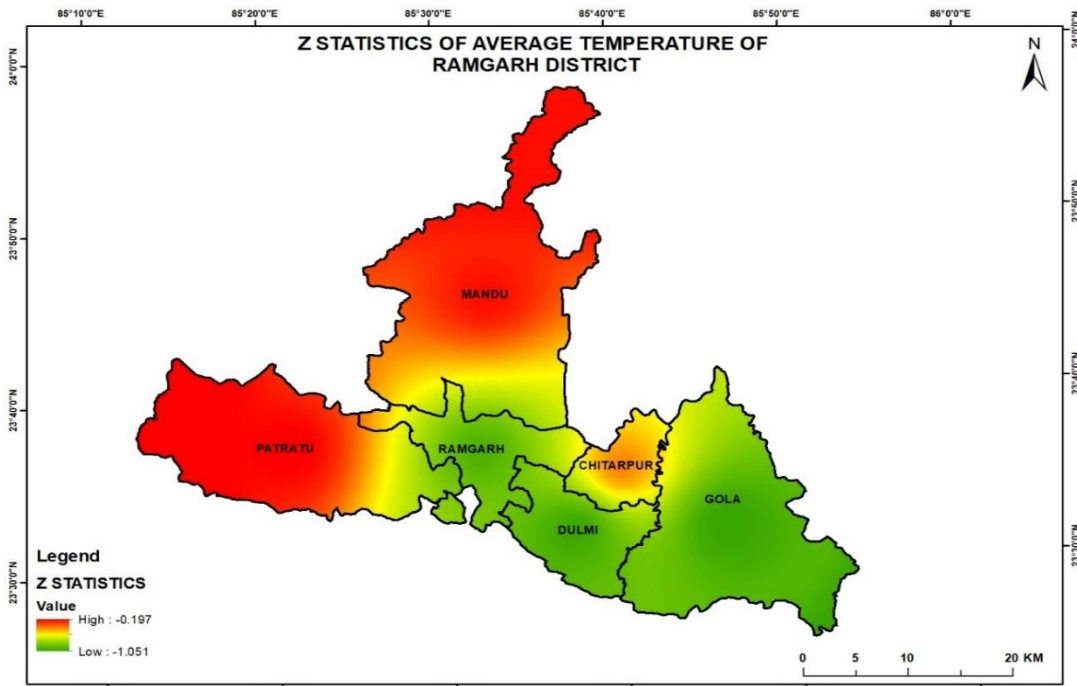


Figure. 4 Z Statistics of average temperature of Ramgarh District.

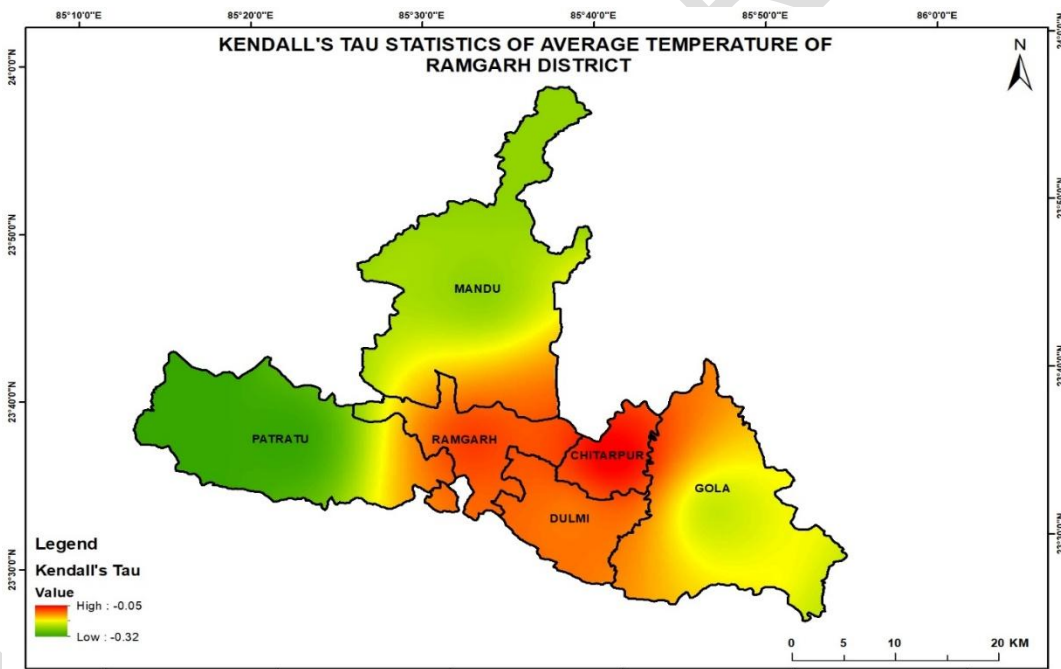


Figure. 5 Kendall's tau Statistics of average temperature of Ramgarh District.

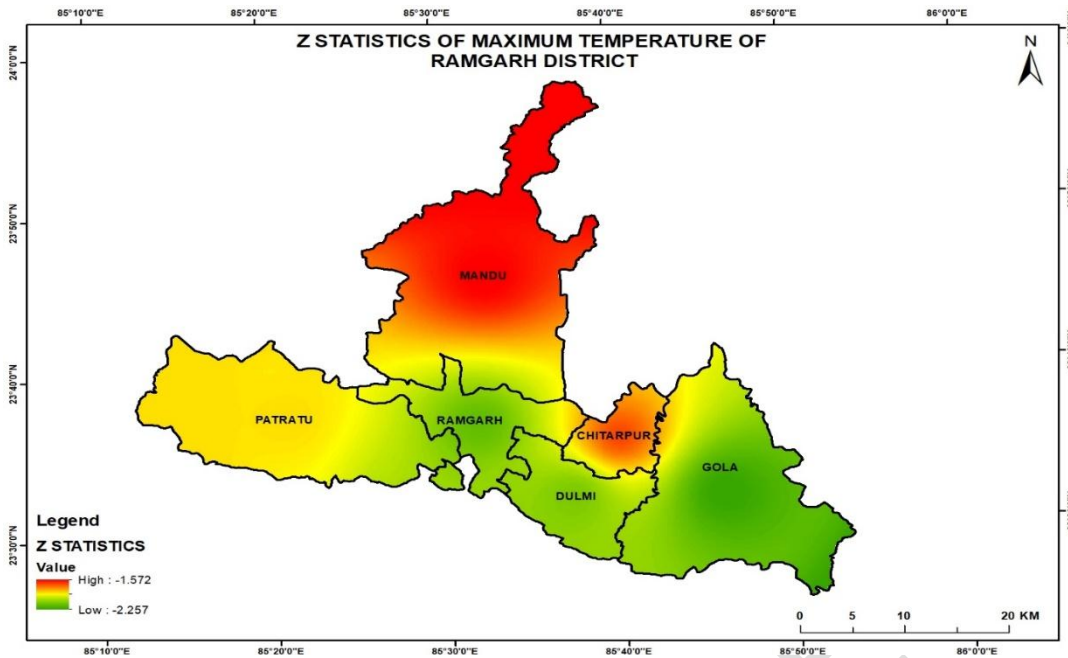


Figure. 6 Z Statistics of maximum temperature of Ramgarh District.

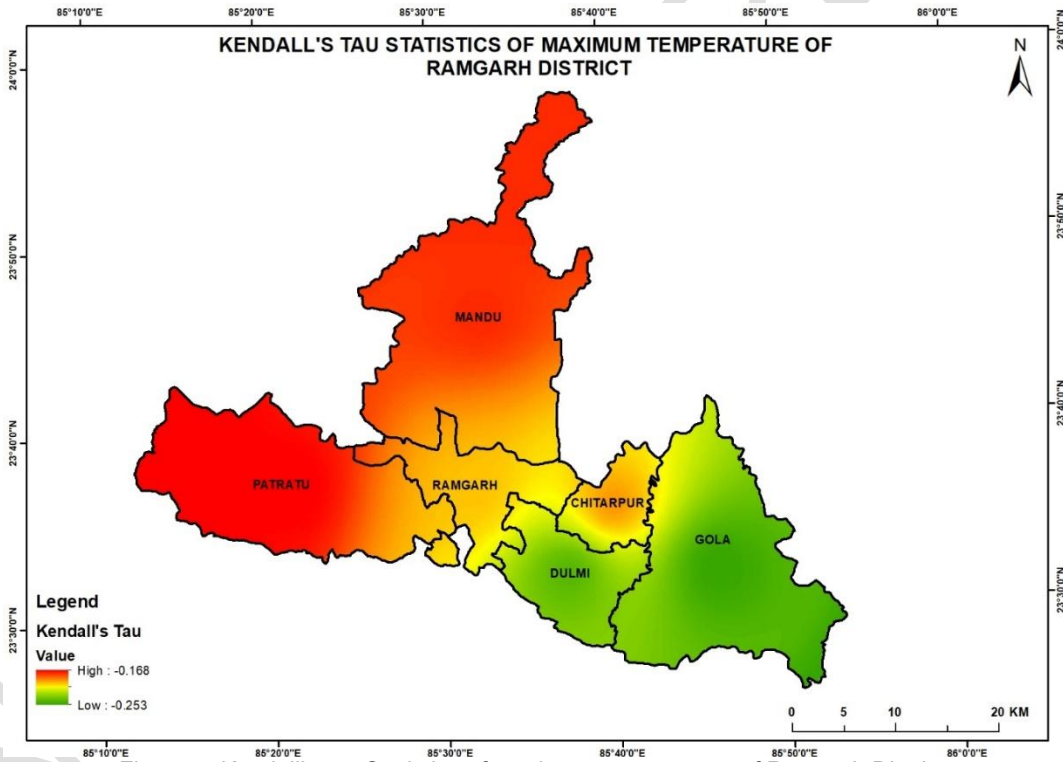


Figure. 7 Kendall's tau Statistics of maximum temperature of Ramgarh District.

#### 4. CONCLUSION

Ramgarh District is vulnerable to environmental inconstancy, and change is seen in the study area and likewise experiences something very similar. The impacts of environmental fluctuation intensify existing social and monetary encounters across the study area. This results in people here mainly relying upon resources sensitive to climate vacillation and deluge takes care of agribusiness. There is a rise in minimum temperature increases within the study area and a decrease in maximum temperature, while a drop in the average temperature is observed. The study result could influence environmental change, which can prompt climate limits in the study area. From the examination, it will generally be contemplated that the example investigation of yearly temperature for the sub-divisional station shows a +ve pattern and genuine importance. Also, the examination showed that the Mann-Kendall design test and Sen's Slope test reveal an affinity for minimum temperature increase in the assessment locale. Therefore, this study recommends that the alterability of temperature needs a further noticing strategy, and there is a need to consider the growing temperature example to restrict its impacts on human prosperity.

## ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by the authors.

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