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Impact Assessment of Mining Activities on Surface and Sub-Surface Water Condition of Ramgarh, Jharkhand, India using Geospatial Techniques

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Abstract

This work illustrates the impact of excessive mining on the precipitation trends and ground water condition of the Ramgarh district over a period of 12 years (2007-2018). The Landsat 8 and Landsat TM- 5 data is processed under Arc-GIS in order to compare the LULC maps. Out of 7 classified classes, the Results obtained indicate the expansion of the mining area, barren land, settlement, and water body by 10.95%, 10.07%, 3.44%, and 0.43%, while a reduction in the forest, fallow, and crop land by 11.24%, 11.31%, and 2.34% respectively. The TRMM 3B43 data is used to trace out the annual precipitation values of 5 selected raster location points through Arc GIS. The annual precipitation under the mining regions (lower Mandu, Ramgarh, Bhurkunda) shows a decreasing trend. The Mann-Kendall test and Sen's slope estimator method is used in order to evaluate the ground water pattern in the pre- and post-monsoonal conditions. The Mandu block, the densest mining region of the district with the positive Z values of 1.714 and 0.137 in the pre- and post- monsoon period shows a decrease in the ground water level at the rates of 0.103 m/year and 0.017 m/year, respectively. The continuous rise in the mining activities has created an alarming shift of weather pattern and deteriorated ground water table in Ramgarh.

1. Introduction

The mining activities disturb the equilibrium of the ecosystem, which causes an adverse effect on the precipitation trends [3]. The high insolation coverage due to heavy deforestation causes a significant thermal rise in the area. This phenomenon further results in the reduction of the moisture content, which ultimately affects the cloud formation process [3, 4]. A huge decrease in the green cover creates an imbalance in the evapotranspiration rate, which directly affects the local precipitation trend [1-3]. The changing hydrological behavior and its frequent alarming trends are one of the major aspects, where a quick and innovative approach is required.

The extensive mining operations make an aggravation in the sub-surface seepage framework. These disturbances incorporate a condition that brings down the ground water table of the area. The insoluble coal dust released from the mines starts to settle down at the base of the local repositories (lakes, wells, ponds, etc.), which disrupts the percolation capacity, and ultimately reduces the ground water level of the area [3, 4]. A deep excavation generally disturbs the natural subsurface arrangements, which changes the relocation of groundwater streams [4].

The organic aerosols released from the coal mines have been found to have a significant impact on the cloud formation and the condensation processes [7]. The study based on the interactions between the cloud formation and the aerosol emission in the warm season of central east China has concluded that the aerosols (black carbons) are responsible for the enhancement of atmospheric stability, which further results in the depression of upward motion of evaporation and

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consequently affects the precipitation process [10].

The mining industry is a noteworthy financial movement, which contributes fundamentally to the economy of India. India has the 5th biggest coal reserves in the world. The states like Jharkhand, Odisha, Madhya Pradesh (M.P), Chhattisgarh, West Bengal (W.B), Telangana, and Maharashtra are having the abundant coal beds in their vicinity. They share about 98.26% of the total known coal reserves in India. Ramgarh is one of the major coal abundant districts of Jharkhand that has been chosen for the case study analysis.

This work briefly investigates the impact of expanding the mining activities over the changing rainfall and ground water trends of Ramgarh. The objectives of this work include (1) Quantification of the topographic variations observed by comparing the LULC maps of the study period; (2) A comparative study of the rainfall trend through the TRMM maps with a special focus on the mining prone areas; (3) The ground water trend analysis and the study of the variations observed in the water table using the Mann-Kendall test and Sen's slope estimations.

2. Materials and methods

2.1. Studied Area

Ramgarh was carved out of the erstwhile district of Hazaribagh on 12th September 2007. The district is situated between the 23˚ 25' 30" N - 23˚ 58' 00"N latitude and the 85˚ 12' 00" E - 85˚ 53' 00" E longitude, having an area of 1343.68 km². It is a part of Chotanagpur Plateau that comes under the zone of Damodar Basin/Rift. Due to the varied hydro-geological characteristics, the ground water potential differs from one region to another. The area is mostly covered under the red soil, which provides a suitable condition for the growth of rice, wheat, pulse, oilseed, and maize. There is a huge temperature difference in this area. It has been recorded up to 40˚ C (104˚ F) during summers and 10˚ C (50˚ F) during the winters. The Ramgarh district entails six blocks, namely Gola, Ramgarh, Mandu, Chitarpur, Patratu, and Dulmi (District survey report of stone district-Ramgarh, 2018).

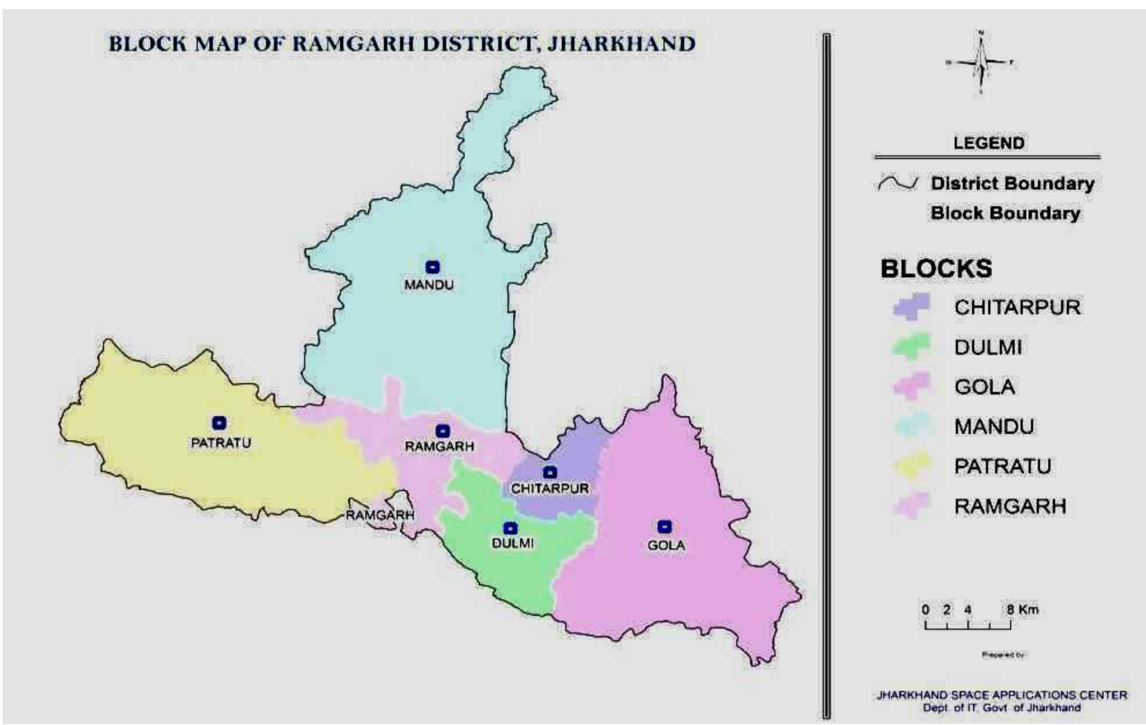

Figure 1. An adminstrative map of the Ramgarh district (Source: www.mapsofindia.com)

2.2 Data collection

Land use/cover: For the LULC classification, the Landsat satellite data was downloaded from the official website (earthexplorer.usgs.gov) of the United States Geological Survey (USGS). Each satellite image represents the dry season. The Landsat 8 and Landsat TM-5 data of the base year (2007) and the end year (2018) was used for the analysis.

Precipitation data: The TRMM 3B43 dataset was used for the rainfall trend analysis. The monthly rainfall datasets were collected from the website of https://giovanni.gsfc.nasa.gov for the period of 2007-2018. The 3B43 dataset is the monthly dataset. The product was generated using the adjusted TRMM microwave-infrared precipitation rate (mm/h) and the Root-Mean-Square precipitation-error estimates. It provides an accurate precipitation estimation in a latitude band covering 500 N to 500 S under the growth of the TRMM section from all the universal datasets like high-quality microwave data, infrared data, etc.

Ground water data: The pre-monsoonal (June) and post-monsoonal (October) ground water data (2007-2018) for Ramgarh was used for the trend analysis. The data was obtained from the official portal of Central Groundwater Board.

2.3 Classification and evaluation of land use/cover

In order to evaluate and classify the land use pattern through LULC, the supervised classification methodology with the maximum likelihood algorithm was used. The maximum likelihood algorithm (MLC) is a standout amongst the most well-known directed grouping strategies utilized with remote sensing system techniques. This strategy depends on the likelihood that a pixel has a place with a specific class. The essential hypothesis accepts that these probabilities are equivalent for all classes and that the info groups have typical disseminations [8]. In any case, this technique requires a prolonged stretch of time of calculation, depends vigorously on an ordinary circulation of the information in each info bands, and tends to over-group marks with generally expansive qualities in the covariance framework.

The land use/cover was analyzed by classifying the area into 7 classes, namely barren land, fallow land, crop land, forest cover, mining area, settlement area, and water body. The obtained maps of 2007 and 2018 were compared according to the percentage change observed in their land use area for the detailed analysis.

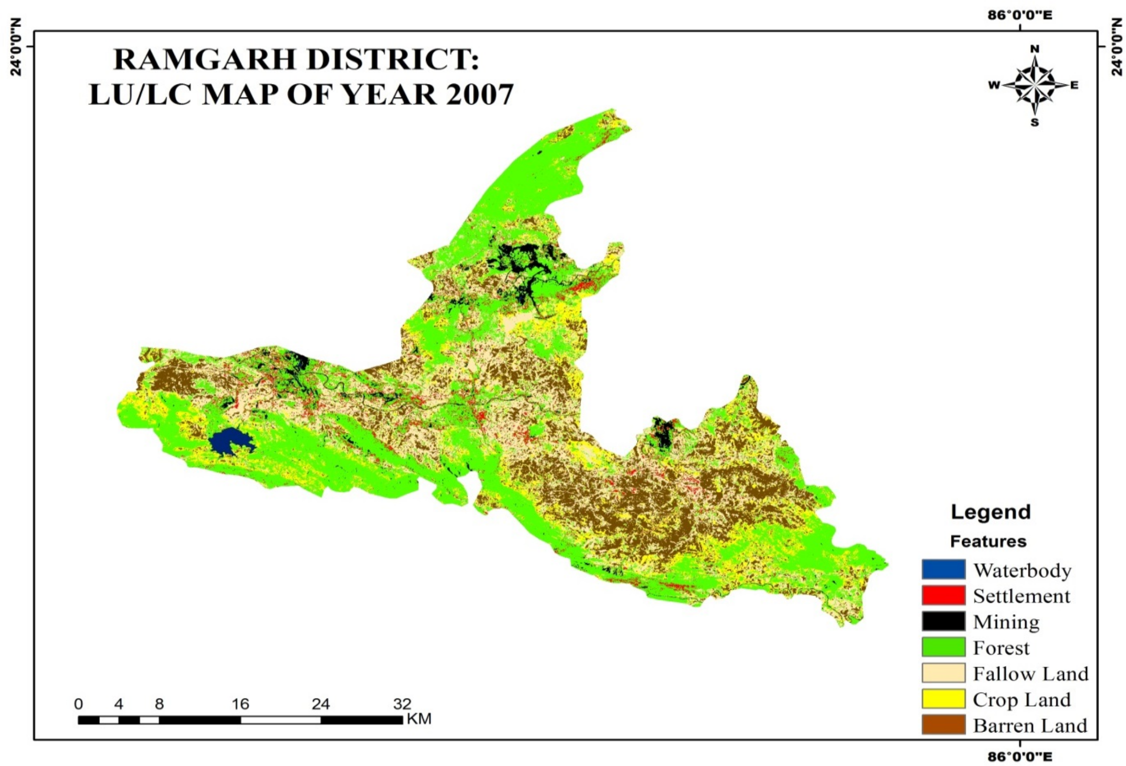

Figure 2. Land use/cover map of year 2007.

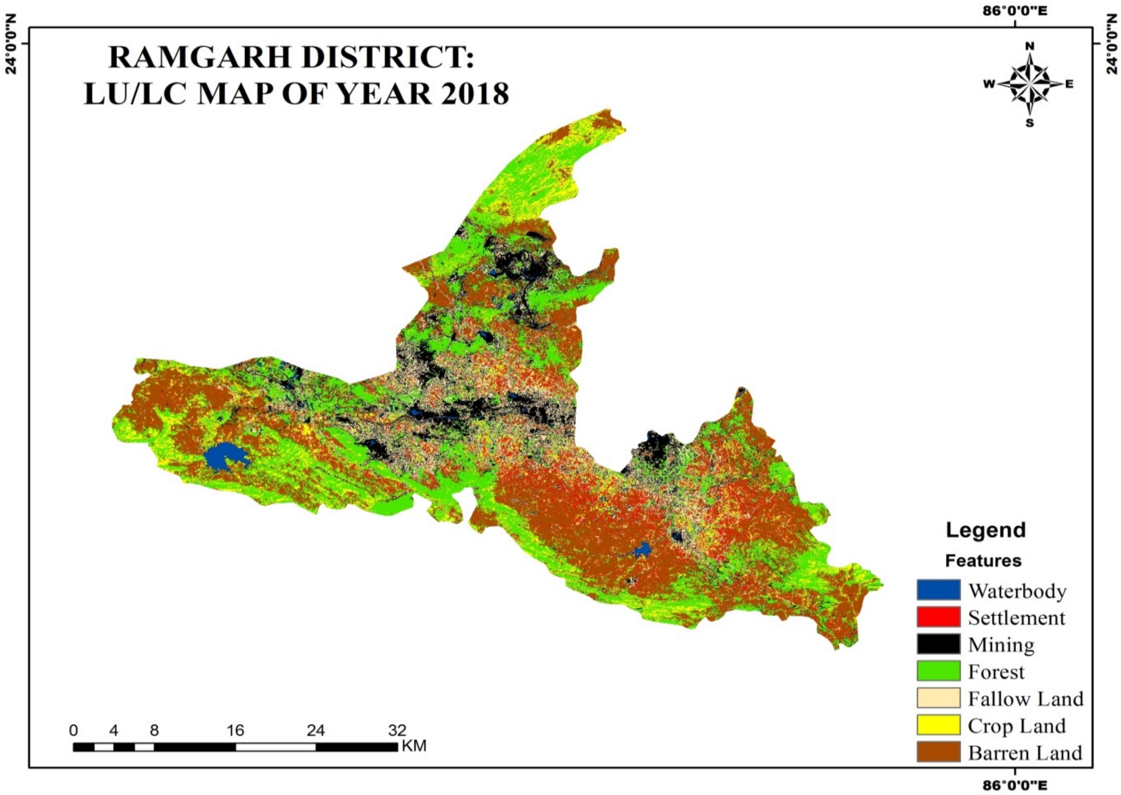

Figure 3. Land use/cover map of year 2018.

2.4 Rainfall trend analysis using TRMM 3B43 data

The rainfall trend analysis of Ramgarh was carried out using the TRMM 3B43 annual accumulated rainfall datasets (processed by the monthly dataset values). The datasets were recorded for the 7 raster location points (Mandu (upper and lower regions), Patratu, Gola, Dhulmi, Chitarpur, and Ramgarh) of the district, under which every block was covered individually for the analysis. The datasets were processed in order to obtain the precipitation maps under Arc-GIS. These precipitation maps were further classified under the different rainfall intensity zones mentioned in Table 1.

Table 1. Zone classification of precipitation map.

Zone	Precipitation zone
Red	Lowest rainfall
Yellow	Low rainfall
Green	Moderate rainfall
Sky blue	High rainfall
Navy blue	Highest rainfall

2.5. Ground water trend analysis

Mann-Kendall Test: The Mann-Kendall test is a non-parametric strategy utilized for pattern investigation of time arrangement information .The Significant preferred standpoint of this test is that it is free from the factual conveyances that are required for the parametric techniques [5] [6][9]. The null hypothesis (H0) for the Mann-Kendall test is that there is no pattern or sequential connection amongst the broke down populace against the elective speculation (H1) that accepts the expanding or diminishing monotonous pattern. The Mann-Kendall statistic (S) is given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (X_j - X_i) \quad (1)$$

where (S) is the Mann-Kendall's measurement, and (sgn) is the signum work. The above pattern test is done for a period arrangement X_i that is positioned from i = 1, 2, …n-1 and X_j , which is again positioned from j = i+1, 2,…,n. For each one of the evidence points, X_i is taken as a kind of perspective point that is differentiated, and the remainder data focuses on X_j so that:

$$sgn(X_j - X_i) = \begin{Bmatrix} 1\ if\ (X_j - X_i) > 0 \\ 0\ if\ (X_j - X_i) = 0 \\ -1\ if\ (X_j - X_i) < 0 \end{Bmatrix} \quad (2)$$

On the off-chance that n < 10, at that point estimation of |S| is contrasted straightforwardly with the hypothetical dissemination of S inferred by Mann and Kendall. At a particular likelihood level, [H0] is dismissed for [H1] if the total estimation of S rises to or surpasses a pre-defined esteem$S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S that has the likelihood not exactly α/2 to show up if there should be an occurrence of no pattern. A progressive estimation of (S) shows a rising pattern, and the adverse esteem demonstrates a descending pattern [7] [10]. For n = 10, the measurement S is coarsely circulated with the mean value of E(s) = 0 and difference (Var. (s)). The change measurement is specified as:

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18} \quad (3)$$

Here, t_i is assumed as the quantity of estimation for test I. In this strategy, the nearness of a factually huge pattern is assessed utilizing the Z_C esteem.

$$Z_C = \{\frac{S-1}{\sqrt{Var\ (S)}}\}\ \text{if S} > 0$$

$$Z_C = 0\ \text{if S} = 0 \quad (4)$$

$$Z_C = \{\frac{S+1}{\sqrt{Var\ (S)}}\}\ \text{if S} < 0$$

A positive estimation of Z_C shows an expanding pattern, and a negative esteem demonstrates a diminishing pattern. The measurement Z_C is typically conveyed. In order to examine the escalating and the diminishing monotonous pattern, a two-followed investigation at α dimension of criticalness was utilized. The invalid or null theory of (H0) is excluded if the outright estimation of Z_C is more noteworthy in comparison with the $Z_{(1-\alpha/2)}$, where the $Z_{(1-\alpha/2)})$ value is attained from the ordinary dispersion tables. In this examination, (H0) that is the null hypothesis denotes that there is a non-pattern scenario regarding the time arrangement of the groundwater level, where α is the dimension of immensity for the trial. For this assessment, α and $Z_{(1-\alpha/2)}$ were taken as 5% and ±1.96, separately. A positive estimation of Z_C demonstrates an expanding pattern, and a negative esteem shows a diminishing pattern. The measurement Z_C is typically dispersed.

Sen's Slope Estimator Test: The genuine slant in time arrangement information (change per unit time) is evaluated through the strategy depicted by Sen (1968) assuming the event that the pattern is straight. The extent of pattern is anticipated by the Sen's slope estimator value (Q_i).

$$(Q_i) = \frac{X_j - X_k}{j-k} \quad \text{for i = 1, 2,…, N} \quad (5)$$

X_j and X_k are the data values with times j and k (here it is assumed that j > k), respectively. The median obtained from the calculation of these N values is represented as the Sen's estimator (Q_i). The value of Q_{med}= $Q_{(N+1/_2)}$ when N is odd, and Q_{med}= $Q_{N/_2}$ + $Q_{((N+2/_2)/2)}$ if N is even. The positive value is obtained for the (Q_i) point toward the rising trend whereas the negative value of (Q_i) shows a decreasing trend in the given time series.

3. Results and discussion

3.1. Land use/cover status

The topographical variation witnessed during the study period of Ramgarh was evaluated by comparing the land use/cover (LULC) maps of 2007 and 2018. The area was divided into seven different classes: barren land, crop land, fallow land, forest, mining area, settlement, and water body. The detailed evaluation of each class is recorded properly. The drastic change in the land use pattern under these 12 years (2007-2018) can be clearly observed from Figures 2 and 3. The retrieved map of the year 2007 shows more green spots (forest cover) and less black spots (mining area) in comparison with the map of the year 2018. The expanding mining region in the black spot and the deteriorating forest cover in the green spot can be clearly seen under the map of the year 2018.The fluctuations observed in the land use pattern under the different classes from 2007 to 2018 are detailed under Table 2.

Table 2. Data showing area differences occurring under following categories of land use/cover from 2007-2018.

Topographical features	2007 Area		2018 Area	
Class	(in Km²)	(in %)	(in Km²)	(in %)
Barren land	233.36	17.37	368.75	27.44
Crop land	179.75	13.38	148.26	11.03
Fallow land	308.92	23.0	156.92	11.67
Forest	519.21	38.64	368.19	27.40
Mining area	35.41	2.64	182.55	13.58
Settlement	58.40	4.35	104.57	7.78
Water body	8.63	0.64	14.43	1.07
Total area	1343.68	100	1343.68	100

The important facts revealed under the analysis are as follow:

- The mining area has enormously increased from 2.64% to 13.58% in just 12 years with an expansion rate of approx. 12.26 km²/year.
- A net increase of 10.95% in the mining area has critically affected the agricultural and forest cover of the Ramgarh district.
- The area under the barren land has been increased with 135.39 km² over these 12 years.
- Area under forest, crop land, and fallow land has been drastically decreased with the percentages of 11.24%, 11.31%, 2.34%, respectively.
- A minor increase in the water body and settlement areas has been observed with a percentage value of 0.43 and 3.44, respectively.

3.2. Precipitation trend analysis

The precipitation trend of the studied area was evaluated by processing the 3B43 TRMM data under Arc GIS. The raster to point conversion of the image was used to obtain the annual rainfall values of the seven selected location points of the district. The rainfall values were evaluated and compared graphically. The yearly rainfall map of 2007-2018 was prepared in Arc GIS, shown under Figures 4-15. These maps were used for the detailed investigations.

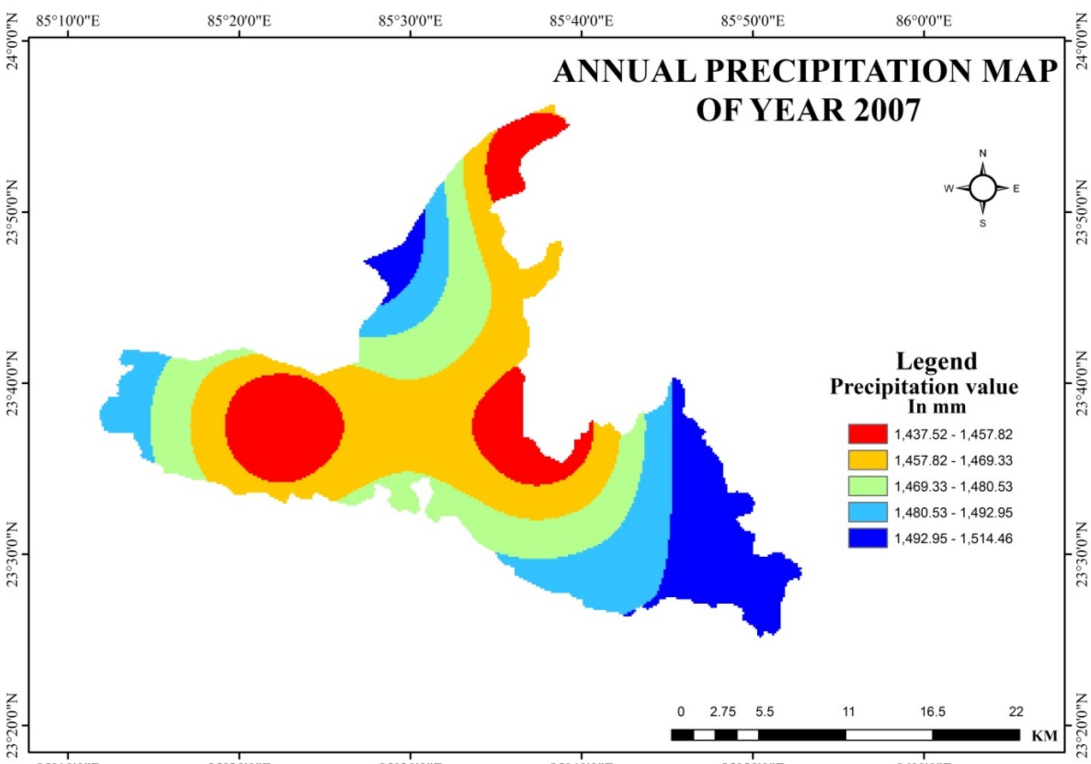

Figure 4. Annual precipitation map of Ramgarh district of year 2007.

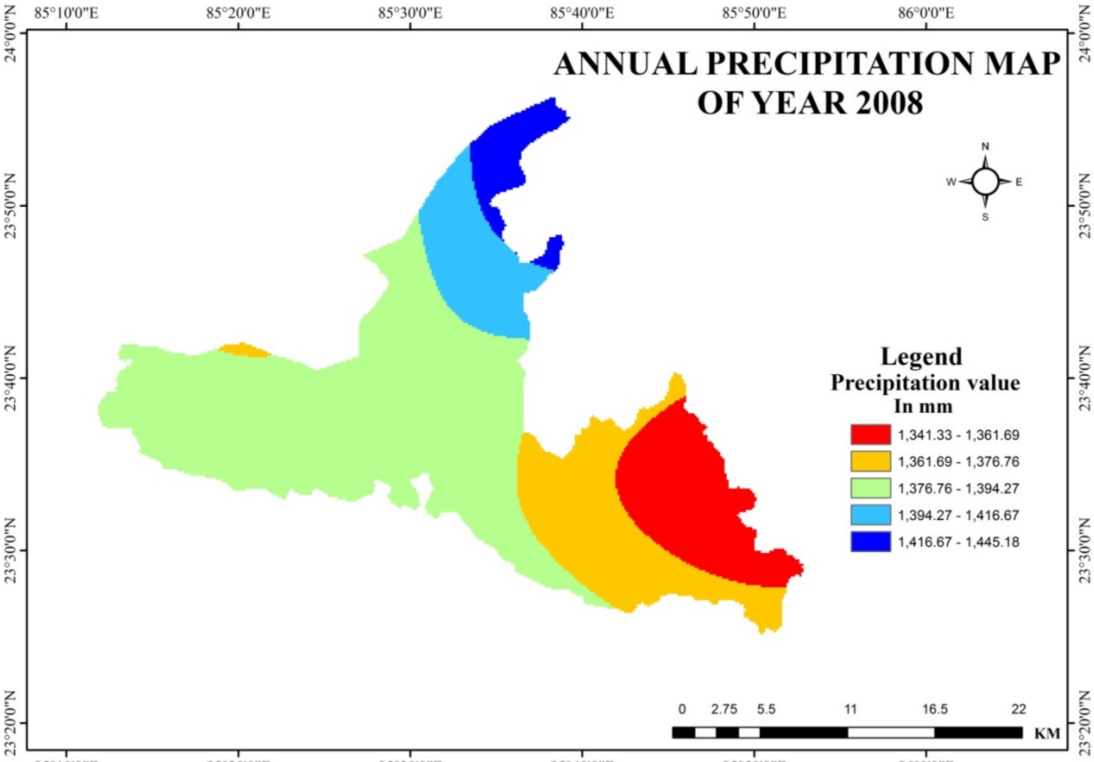

Figure 5. Annual precipitation map of Ramgarh district of year 2008.

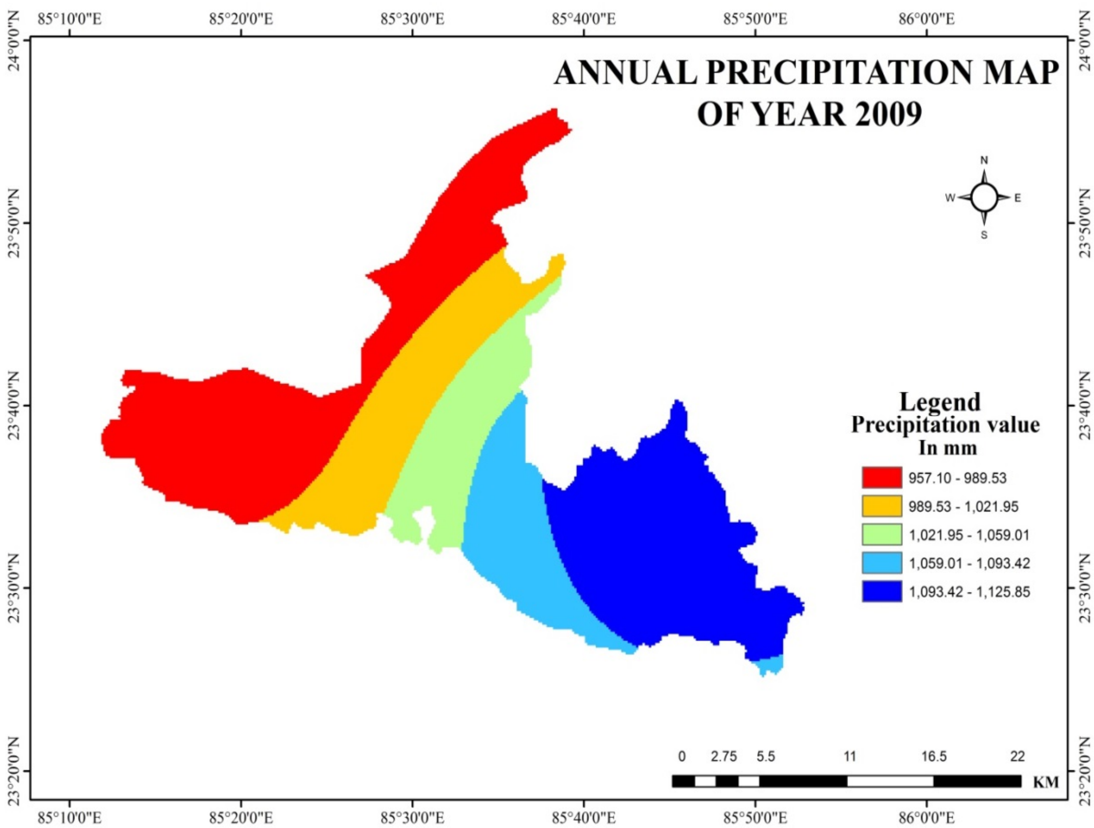

Figure 6. Annual precipitation map of Ramgarh district of year 2009.

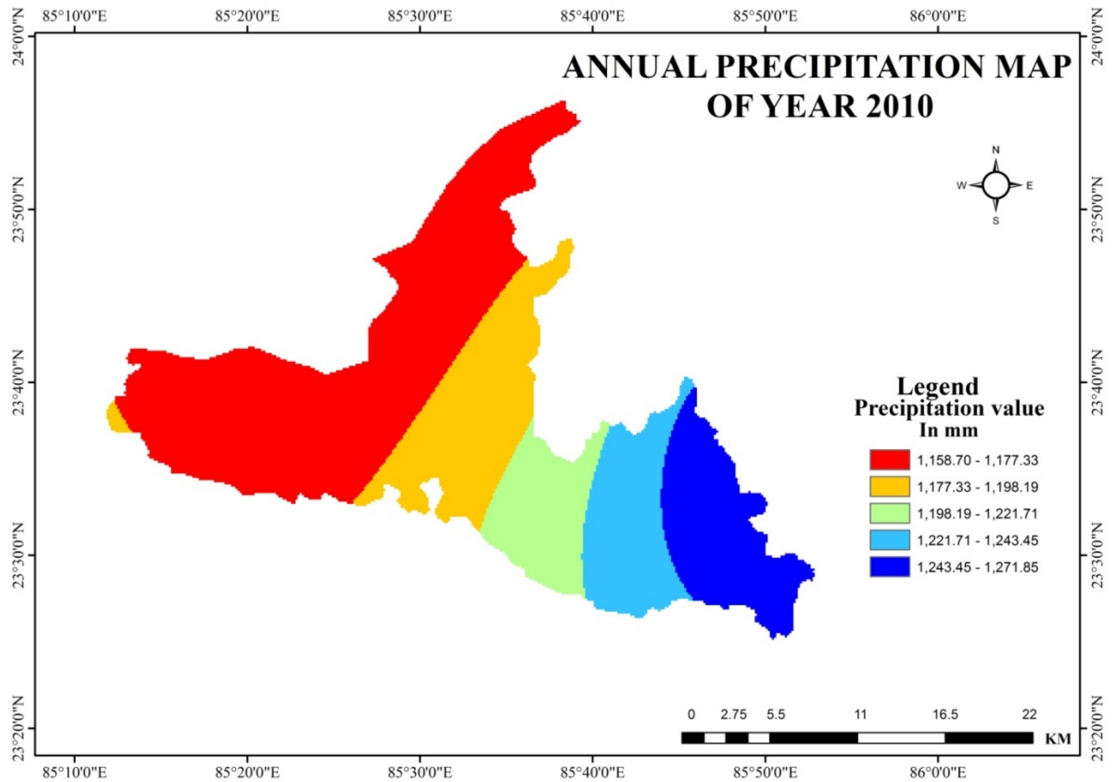

Figure 7. Annual precipitation map of Ramgarh district of year 2010.

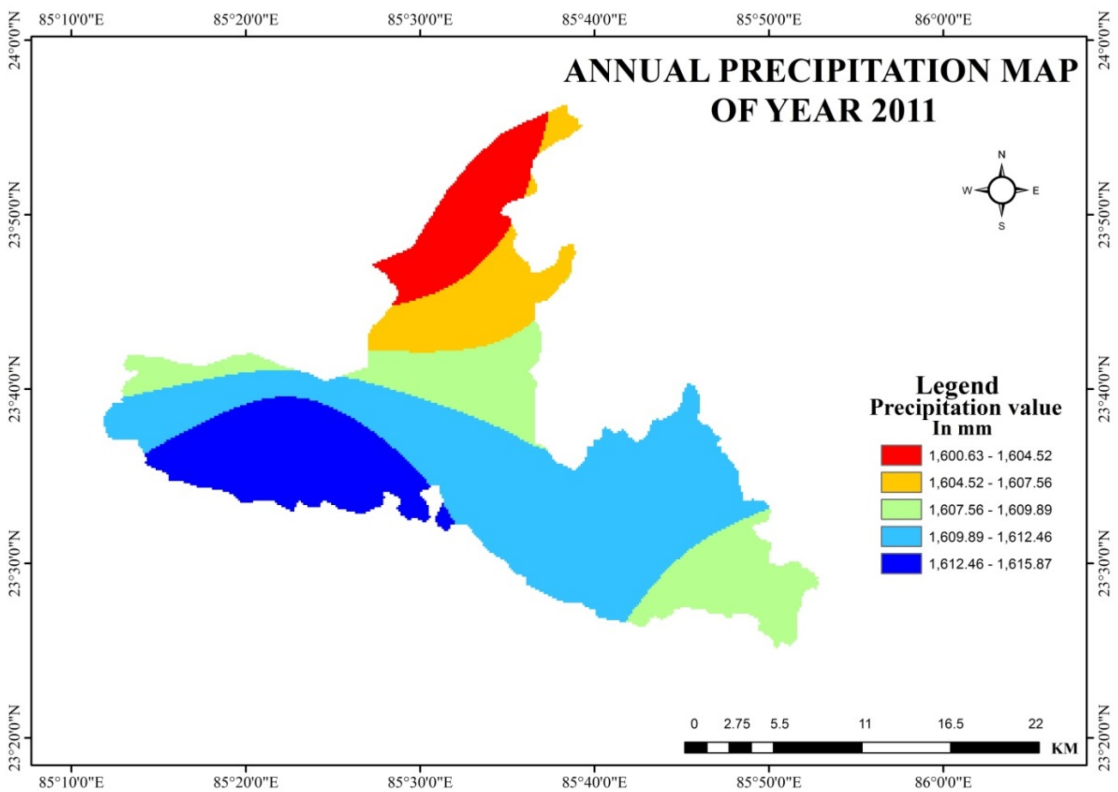

Figure 8. Annual precipitation map of Ramgarh district of year 2011.

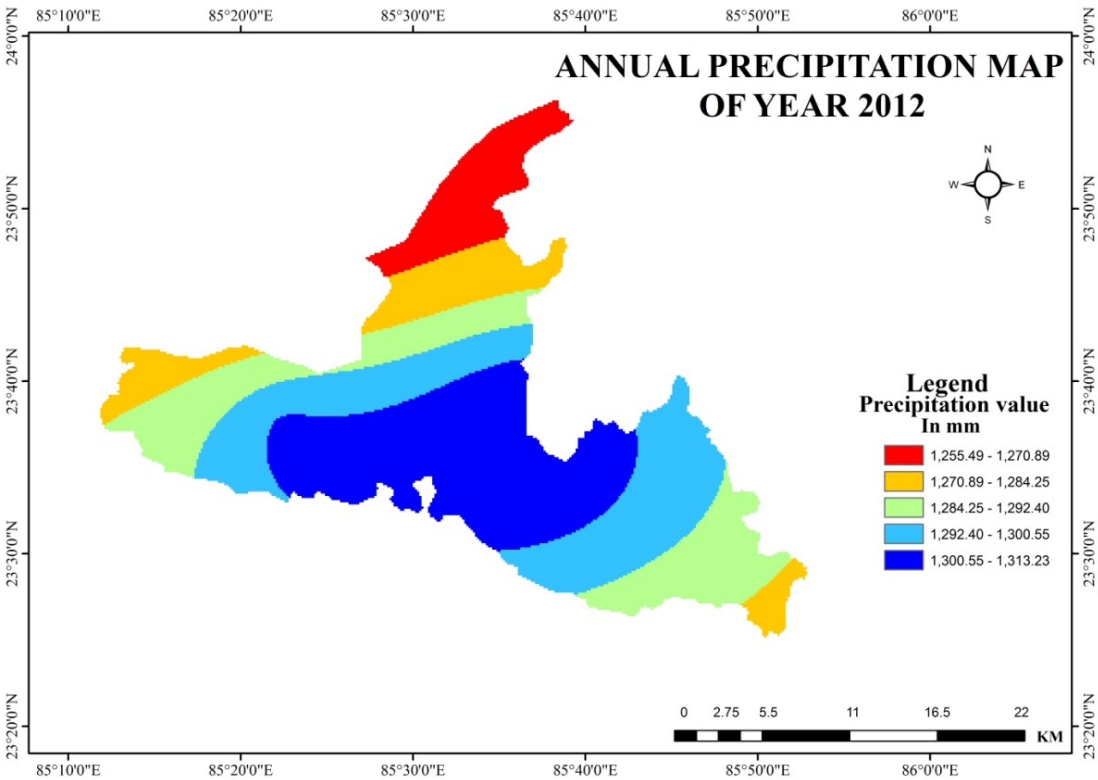

Figure 9. Annual precipitation map of Ramgarh district of year 2012.

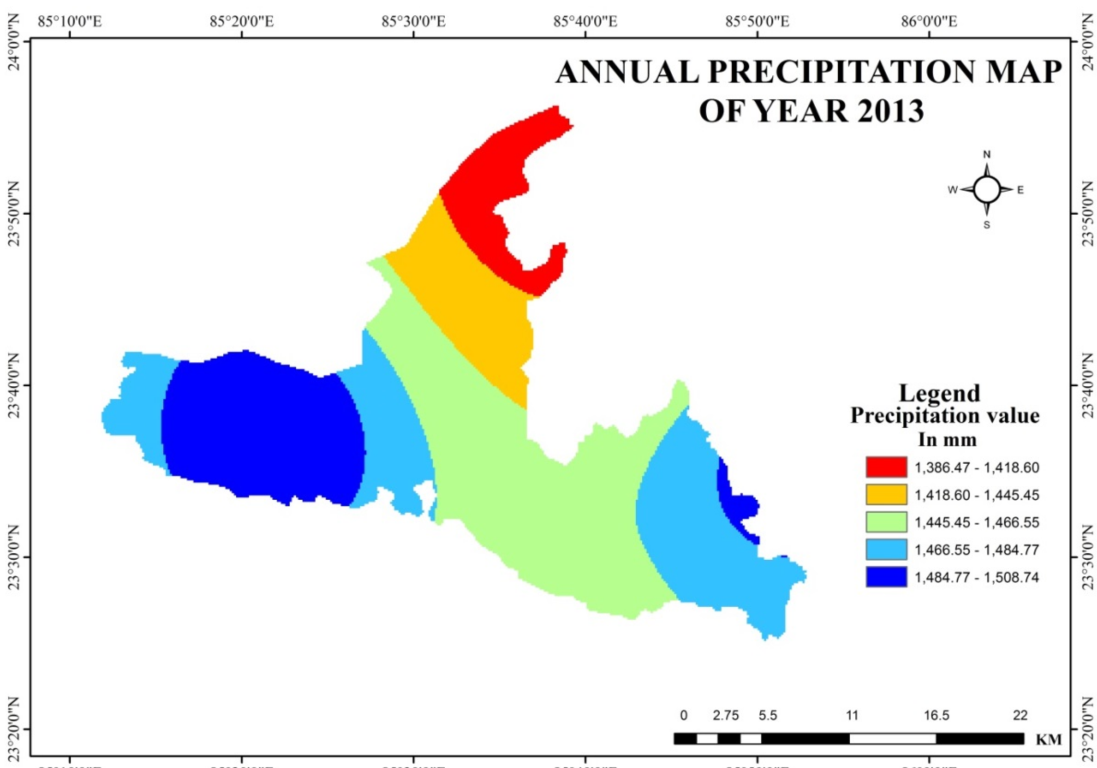

Figure 10. Annual precipitation map of Ramgarh district of year 2013.

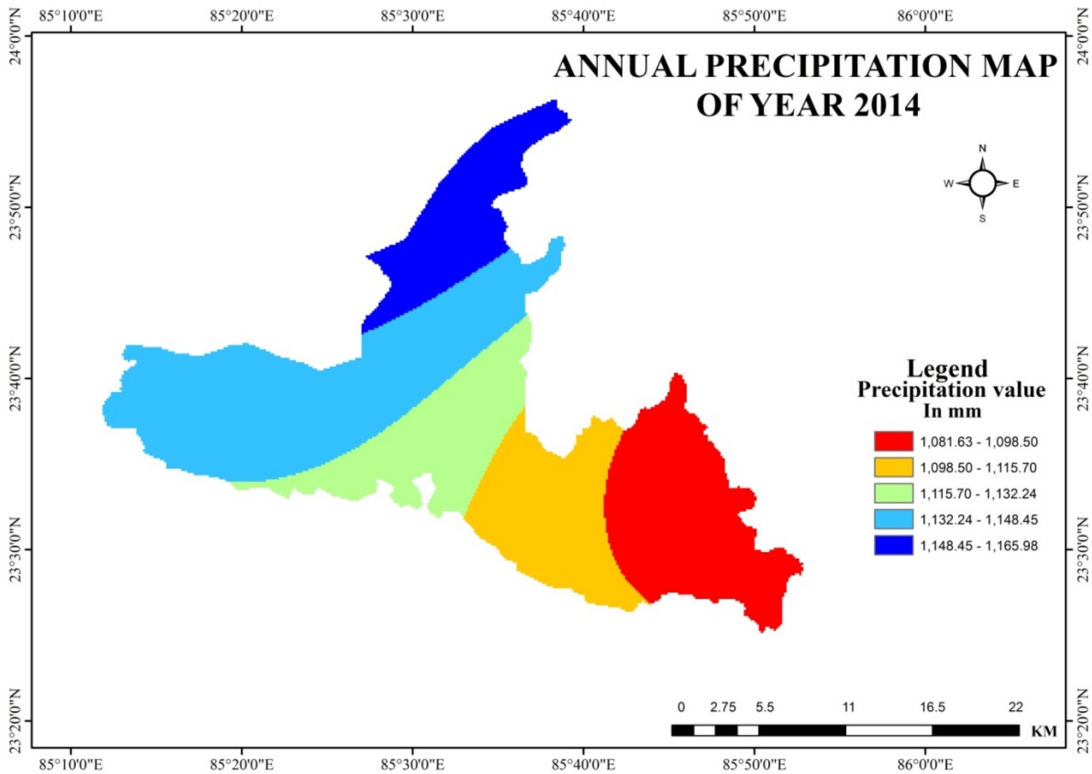

Figure 11. Annual precipitation map of Ramgarh district of year 2014.

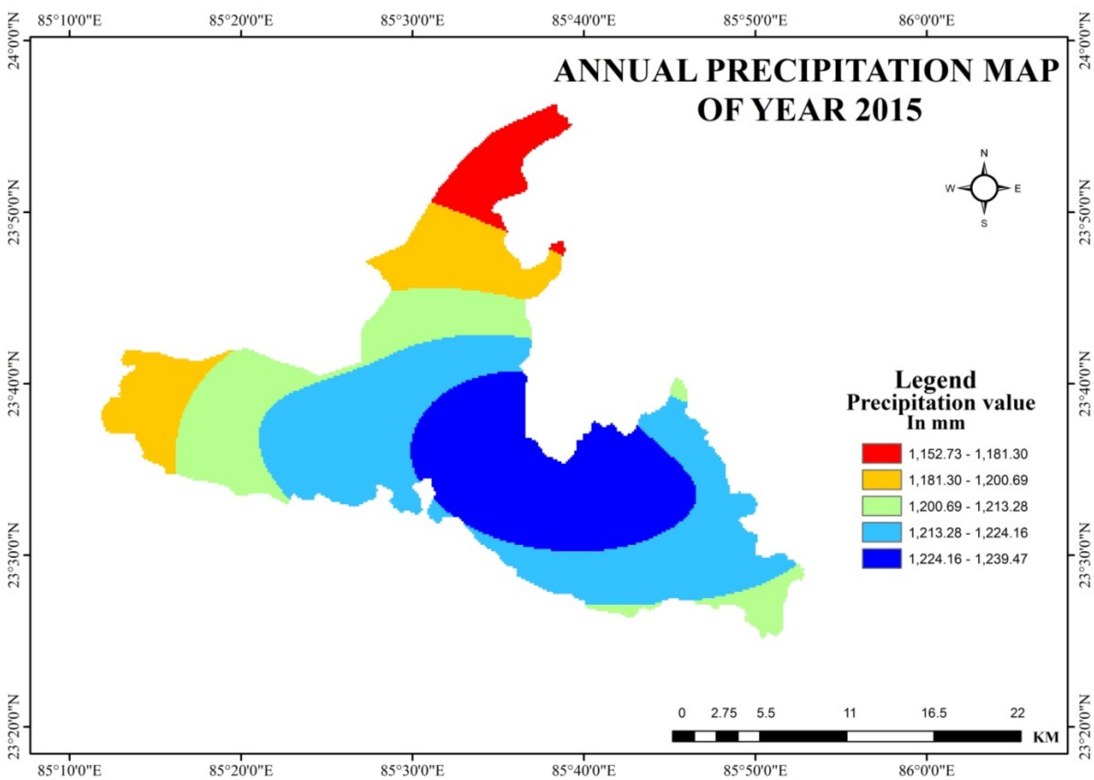

Figure 12. Annual precipitation map of Ramgarh district of year 2015.

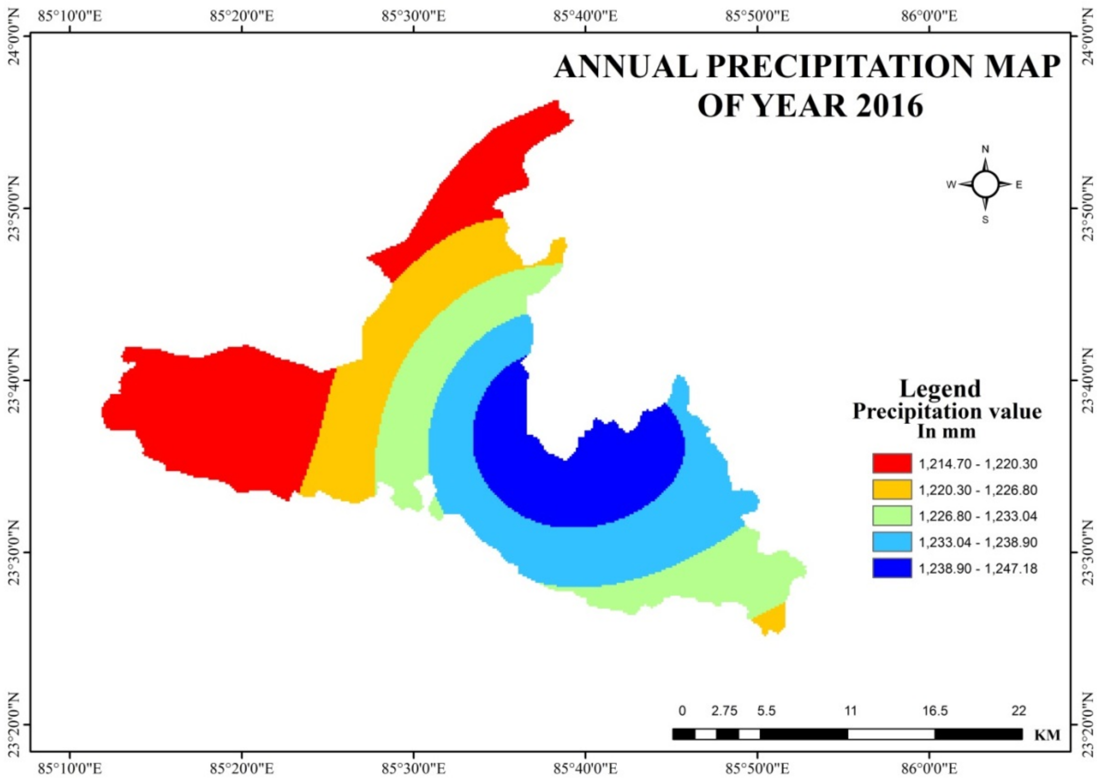

Figure 13. Annual precipitation map of Ramgarh district of year 2016.

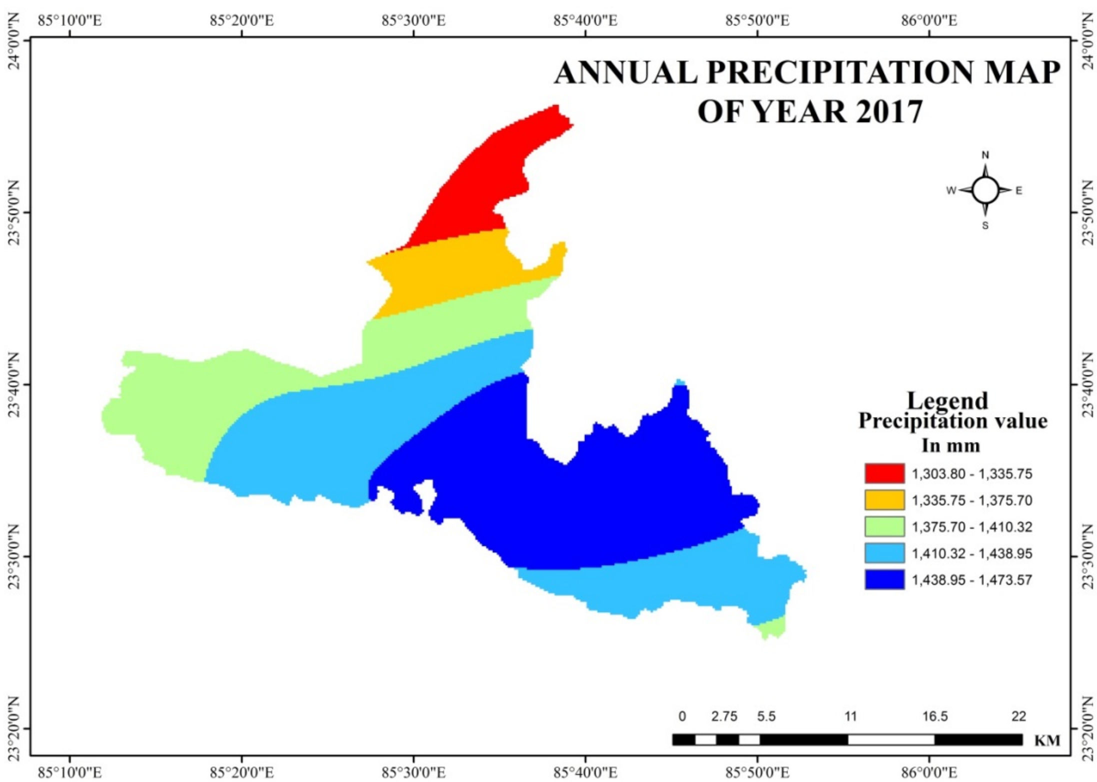

Figure 14. Annual precipitation map of Ramgarh district of year 2017.

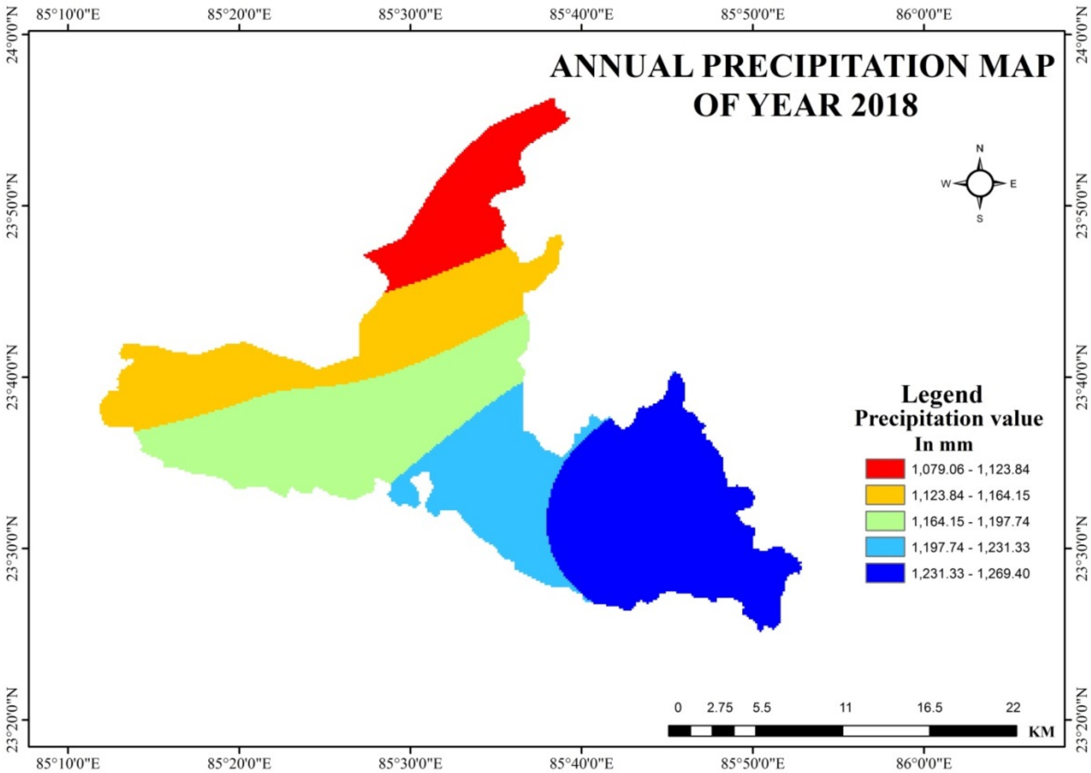

Figure 15. Annual precipitation map of Ramgarh district of year 2018.

The yearly rectified TRMM image shows that there is a continuous average to low rate of the rainfall occurring specially in the regions where mining activities exist. The mines are mainly situated in the lower mandu, ramgarh, and bhurkunda blocks of the district. Through the rainfall maps, it was observed that the mining areas were recorded with lesser rainfall values in contrast to the other regions of the district. The annual average precipitation data obtained for the selected location points is shown in Table 3.

Table 3. Average Annual precipitation data obtained from TRMM raster to point calculation.

Year	Annual precipitation in mm						
	Mandu (Upper region)	Mandu (Lower region)	Bhurkunda	Ramgarh	Chitarpur	Dulmi	Gola
2007	1437.281	1589.904	1437.362	1435.905	1535.483	1548.361	1618.71
2008	1447.005	1350.916	1383.103	1375.270	1329.247	1410.727	1409.68
2009	972.513	923.719	972.494	1093.716	1136.317	1207.509	1183.13
2010	1168.004	1152.096	1165.472	1202.304	1291.963	1205.503	1304.23
2011	1608.545	1542.375	1651.321	1603.518	1612.697	1704.795	1682.76
2012	1260.167	1233.11	1302.343	1314.293	1287.573	1351.938	1372.44
2013	1381.329	1452.355	1508.859	1446.810	1505.739	1495.275	1559.44
2014	1161.208	1174.979	1138.178	1110.919	1071.927	1119.55	1116.07
2015	1161.269	1172.568	1217.614	1240.433	1216.81	1315.033	1338.99
2016	1215.495	1209.585	1216.774	1248.847	1234.079	1264.026	1227.08
2017	1306.568	1273.912	1427.047	1475.755	1449.366	1582.551	1560.69
2018	1090.7	1049.464	1177.505	1218.14	1285.08	1336.172	1396.66
Average (excluding 2008 and 2014)	1260.187	1259.909	1307.679	1327.972	1355.511	1401.116	1424.413

Some interesting key results found from the analysis are as follow:

- The Lower Mandu, Ramgarh, and Bhurkunda blocks that are the prime mining areas of the district have constantly been seen under the least rainfall zones (red and yellow zones).
- The rainfall map of the years 2008 and 2014 shows an exception in the trend by recording the higher rainfall values under the Mandu, Ramgarh, and bhurkunda blocks (i.e. sky blue and navy blue zone).
- After analyzing the precipitation values, it was found that the mining active regions show a relatively lesser rainfall values (except in the year 2008 and 2014) in comparison with the non-mining areas under each individual year.
- The differences in the decadal average precipitation between the mining (Mandu with the value of 1260.187 mm/y) and non-mining zones (Gola with 1424.413 mm/y) can be clearly seen in the above tabular data.

3.3 Analysis of groundwater trend using non-parametric test

The results obtained from the Mann-Kendall test were utilized in order to set up the patterns according to the periodic arrangements of the pre- and post-monsoonal groundwater levels of the area. This test relates the comparative magnitudes of data rather than the data values itself. The statistics of this test is not required to be checked for any further precision. If the value of Z is negative and the value of Z– statistics is greater than the z–value analogous to 5% level of significance, then the trend obtained is found to be negative. Likewise, if the Z value is positive corresponding to 5% level of significance, then the trend is observed as an increasing one. The Mann-Kendall test delivers a kind of trend statistic (Z) that indicates the monotonous rising (positive z) or falling (negative Z) trend. If the P value is < 0.05, then it tells that there is (monotonic) trend, and if τ is +ve, it shows an increasing trend and vice versa. A p value > 0.05, shows a non-monotonic trend. For evaluation of the groundwater trend using the pre- and post-monsoonal data of the different blocks of Ramgarh, the Mann-Kendall test and the Sen's slope estimation were conducted. The deviations observed in the values of z, s, p, τ, and Qi for the pre- and the post-monsoon water levels of each block of Ramgarh are detailed in Tables 4 and 5.

Table 4. Blockwise details of Mann-Kendall's Statistic and Sen's slope estimator for pre-monsoon and the post-monsoon groundwater levels.

Block	Pre-monsoon			Post-monsoon		
	Z	Sen's slope Qi (m/year)	Trend	Z	Sen's slope Qi (m/year)	Trend
Gola	-1.099	-0.1058	↓	-0.7543	-0.0875	↓
Mandu	1.7143	0.1025	↑	0.13747	0.01738	↑
Patratu	-1.3029	-0.1813	↓	-1.3747	-0.16388	↓
Ramgarh	-1.44	-0.17321	↓	-1.5772	-0.2316	↓

(*The Statistical significant value at 5% level of significance, ↑ means an increasing trend and ↓ means a decreasing trend.)

Table 5. Parameters evaluated to analyze variation in groundwater level trend using Mann-kendall and Sen's slope estimator.

Block	Pre-monsoon			Post-monsoon		
	S-value	p- value	τ-value	S-value	p-value	τ-value
Gola	-17.0	0.27	-0.26	-12	0.45	-0.18
Mandu	26.0	0.086	0.39	3.0	0.89	0.04
Patratu	-20.0	0.19	-0.30	-21.0	0.16	-0.32
Ramgarh	-22.0	0.14	-0.33	-24.0	0.11	-0.36

From the non-parametric evaluations, it has been found that:

- The negative value of τ observed in Gola, Patratu, and Ramgarh has generated a decreasing ground water trend with a value of -0.26, -0.30, and -0.33. The ground water level has deteriorated sharply under these areas.

- The positive τ value of the Mandu block in its pre-monsoon period as 0.39 and post-monsoon period as 0.04 specifies an increase in the groundwater level.
- The Z value for Gola, Patratu and Ramgarh in the pre-monsoon season as -1.997, -1.303, and -1.44 and in the post-monsoon season as -0.754, -1.375, and -1.577 also indicates a decreasing ground water trend.
- The Mandu block with its positive Z values of 1.714 and 0.138 in its pre-monsoon and post- monsoon period only shows an increasing trend scenario.

4. Conclusions

The case study of Ramgarh revealed some of the interesting evidences that explained the role of expanding mining activities and its direct or indirect influences over the hydrological conditions. The study period observed a drastic change in its land use pattern. The alarming growth of the mining areas with the rate of 12.26 km² per year is a huge matter of concern. The decreasing rainfall values under the mining zones (Lower Mandu, Ramgarh, Bhurkunda) are the clear indication that may establish a possible relationship between these two factors. The non-parametric test (Mann-Kendall test and the Sen's slope estimator) also observed a negative trend in the ground water level under the mining prone areas of the district. The continuous reduction in forest cover, fallow land, and crop land was somehow seen as the factor responsible for the degraded ground water capacity in this area.

Hence, a comprehensive conclusion can be inferred from the results obtained that the mining operation can have a possible impact over the rainfall and the ground water patterns. The gradual expansion of mining might be one of the reasons behind the changing precipitation and ground water trends in these areas. In order to resolve such issues, a proper blue print was prepared by the joint consent of the environmentalists and the government must be required to balance the environment and the economy side by side.

Some suggestive measures that may be taken to counter the risk in the future are as follow:

- Afforestation practices in the dump sites of the mines.
- Lack of metrological data has always been a concern for the impactful research, and hence, proper steps regarding the data storage should be taken.
- Strict legal provisions regarding the emissions of pollutants should be implemented on the local mining industries.
- Revision and strengthening of the carbon credit policy is a requirement of the hour.
- More research work should be carried out in order to study the severe mining impacts on the hydrological parameter using the accurate data.

The issue of mining hazard and its correlation with the hydrological cycle was tried to rise under this article. There are very few research works in this field, and hence, some more relevant studies and stronger evidences are required for the accurate and better understanding of such relationships in the future.

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ارزیابی تأثیر فعالیتهای معدنی بر وضعیت آبهای سطحی و زیر سطحی رامگار، جارکند، هند با استفاده از تکنیکهای Geospatial

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چکیده:

این پژوهش تأثیر معادنکاری گسترده بر روند بارندگی و وضعیت آبهای زیرزمینی منطقه رامگار را در یک دوره ۱۲ ساله (۲۰۰۷-۲۰۱۸) نشان می‌دهد. داده‌های Landsat 8 و Landsat TM-5 به منظور مقایسه نقشه‌های LULC، تحت Arc-GIS پردازش شدند. از بین ۷ کلاس طبقه بندی، نتایج بدست آمده نشان دهنده آ است که مناطق معدنی، زمین‌های بایر و شهرک‌ها به ترتیب به میزان ۱۰/۹۵ ٪، ۱۰/۰۷ ٪ و ۳/۴۴٪ گسترش یافته است در حالی که در پی این روند میزان آبهای زیرزمنی، جنگل‌ها و زمین‌های کشاورزی به ترتیب به میزان ۱۱/۲۴ ٪، ۱۱/۳۱ ٪ و ۲/۳۴ ٪ کاهش یافته است. داده‌های TRMM 3B43 برای ردیابی مقادیر بارندگی سالانه ۵ نقطه مکانی انتخاب شده از طریق Arc GIS استفاده شد. میزان بارندگی سالانه در مناطق معدنی (ماندو پایین، رامگارا، بهورکوندا) روند کاهشی را نشان می‌دهد. برای ارزیابی الگوی آبهای زیرزمینی در شرایط قبل و بعد از باران‌های موسمی از روش Man-Kendall و روش تخمین شیب سن استفاده شد. بلوک ماندو، متراکم ترین منطقه معدنی منطقه با مقادیر Z مثبت به اندازه‌ی ۱/۷۱۴ و ۰/۱۳۷ در دوره قبل و بعد از موسم بارندگی، سطح آب زیرزمینی را با نرخ ۰/۱۰۳ متر در سال و ۰/۰۱۷ متر در سال کاهش می‌دهد. افزایش مداوم فعالیتهای معدنی باعث تغییر هشداردهنده الگوی آب و هوا و خرابی سطح آبهای زیرزمینی در رامگار شده است.

کلمات کلیدی: کاربری/پوشش زمین (LULC)، Arc-GIS، TRMM 3B43، آزمون Man-Kendall، برآورد کننده شیب سن.