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Assessment of Microclimatic Variations and Environmental Impact of Mining Activities Using Temperature, and Rainfall Patterns from Various Mining Regions of Odisha

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Abstract: In spite of the fact that it has good benefits on the economy, the mining industry is frequently associated with serious environmental problems. The purpose of this study is to investigate the impact that mining activities on local microclimatic conditions, specifically temperature and rainfall, over a period of twenty years (2003-2022) in four different mining regions of India. These regions are Sukinda (chromite mining), Balaram OCP (coal mining),), Joda (iron ore mining), and Danagadi (industrial area. Microsoft Excel and RStudio were utilized to collect and analyze meteorological data, which included monthly averages of maximum and lowest temperatures as well as total, and seasonal rainfall. ArcGIS 10.4 was utilized in order to map the locations that were under investigation. The findings demonstrate that, there have been considerable alterations to the ecosystem, with a discernible increase in both highest and lowest temperatures across all four areas. For Sukinda, the biggest increase in maximum temperature was reported to be 2^0C, while the temperature at the lowest point climbed by 2.5^0C. The patterns of rainfall displayed a significant amount of variation, with an overall rise in total rainfall in Sukinda area and decline in rest three sampling locations. This result can be attributed to factors such as deforestation, air pollution, and anthropogenic activities. The research reveals the significant influence that mining activities play in modifying the microclimates of the surrounding areas, highlighting the importance of implementing sustainable mining methods in order to reduce the negative impacts on the environment. The results of this study offer important insights that may be used for climatological, environmental, & impact assessments. These findings also contribute to the creation of policies for the sustainable management of resources in mining zones.

Keywords: Mining activity, Climate change, Temperature, Rainfall

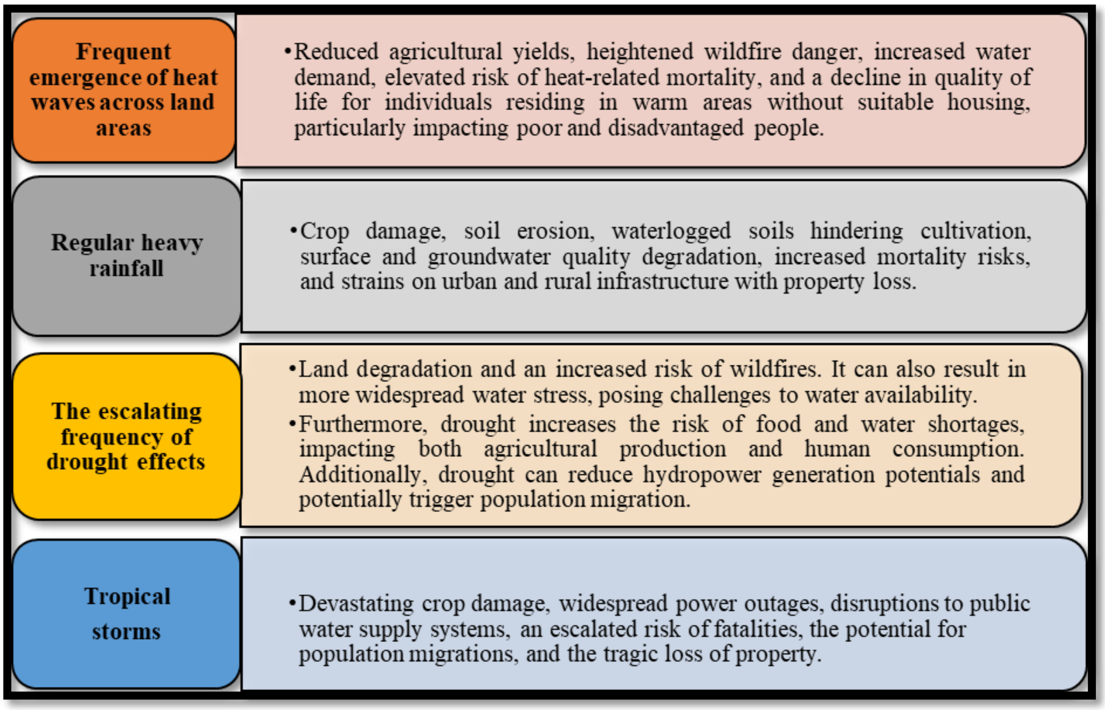
Introduction

Since the inception of mankind, mining, which is the process of extracting different geological elements and other precious minerals from the earth, has been an essential component of human development. Mining has been the driving force behind both technological improvements and economic expansion (Zhironkin & Szurgacz, 2021).Surface &underground mining, and placer mining are all examples of different sorts of mining procedures. Each of these mining methods has its own set of uses and environmental considerations that are specifically related to it (Marjoribanks, 2010).The mining industry is extremely broad all over the world, with large operations taking place in nations such as China, the United States of America, Australia, and India (Humphreys, 2015). In terms of the production of coal, iron ore, gold, and various other critical minerals, these countries are at the forefront. The global need for minerals is continuously increasing, which is being pushed by the process of industrialization, urbanization, and the technological revolution(Dold, 2020).

The mining industry is frequently linked to major environmental problems, despite the fact that it has positive economic effects(Scanes, 2018). Mining operations frequently result in a number of negative repercussions, including soil erosion, water contamination, and air pollution(Sankhla et al., 2016). In addition, mining activities are a contributor to the modification of local climates, which in turn influences the microclimatic conditions that are present, such as the patterns of temperature and rainfall. There is the potential for these changes to have a domino impact on agricultural practices, water supplies, and weather patterns in the region.

The air temperature in a mine depends on various factors, likethe temperature, and depth of exploitation of the associated primary rock, but also the temperature of the atmospheric air, the amount of extraction, ventilation's intensity, or machine's power, and the device working in the mining excavations (Pherson, 2012; Xie, 2012; Han et al., 2019). Therefore, it is very much crucial to identify the amount of heat generated by them, and heat sources. There is a great significance, where accurate determination of heat balances of mining areas, for both existing and planned, is concerned (Danko &Bahrami, 2008; Chu, 2015). Due to mining industries and its operations, there will certainly be impacts on the peripheral zone, where the incremental concentration somehow exceeds the background concentration, several research articles suggest (Agbaire & Esiefarienrhe, 2009; Dash & Dash, 2017; Kumar et al., 2018; Dash & Dash, 2018).

Therefore, it is very important to identify the heat sources and the amount of heat produced by them. Accurate determination of the heat balance of both existing and planned mining areas is very important.In addition to this, it has been experienced that, increasing urbanization as well as industrialization and related anthropogenic activities are the major reasons which lead to different air & gaseous emissions and deteriorated in air quality (Jones, 1991; Dash & Dash, 2015). Temperature has a vital role, where air pollution results from contamination of ambient air by chemical species in such concentrations, and after the existence of such contaminants for some period it would be harmful to general health (Canziani et al., 2007; Dash & Dash, 2015;Dash et al., 2018). Air pollution including greenhouse gases, and major air pollutants that lead to climate change and climatological conditions (Dash & Dash, 2015; Mishra et al., 2021).



Frequent emergence of heat waves across land areas	•Reduced agricultural yields, heightened wildfire danger, increased water demand, elevated risk of heat-related mortality, and a decline in quality of life for individuals residing in warm areas without suitable housing, particularly impacting poor and disadvantaged people.
Regular heavy rainfall	•Crop damage, soil erosion, waterlogged soils hindering cultivation, surface and groundwater quality degradation, increased mortality risks, and strains on urban and rural infrastructure with property loss.
The escalating frequency of drought effects	•Land degradation and an increased risk of wildfires. It can also result in more widespread water stress, posing challenges to water availability. •Furthermore, drought increases the risk of food and water shortages, impacting both agricultural production and human consumption. Additionally, drought can reduce hydropower generation potentials and potentially trigger population migration.
Tropical storms	•Devastating crop damage, widespread power outages, disruptions to public water supply systems, an escalated risk of fatalities, the potential for population migrations, and the tragic loss of property.

Source: IPCC – 2013

The water scarcity will increase in some of the locations because of the warming of temperature, complicating site rehabilitation , disrupting water-dependent operations, and there will be chance of bringing direct conflict between companies with communities over water resources.However, in the Arctic and sub-Arctic regions, warmer temperatures will open up exploration for new mineral-rich areas and reduce the cost of heating(Kivinen et al., 2017; IPCC, 2013; IPCC, 2018).

There are significant environmental repercussions associated with mining in India, a nation that is home to a wide range of climate zones and abundant mineral resources (Jain et al., 2007; Jain & Kumar, 2012). To gain a better knowledge of the overarching environmental implications, it is essential to conduct an analysis of the microclimatic variations that occur in mining zones, specifically changes in temperature & patterns of rainfall. Through the comparison of these variances with places that are not affected by mining, the purpose of this study is to provide insights into the magnitude of environmental changes using the temperature & rainfall data that are caused by mining activities and to inform practices that are sustainable for mining.

Materials & Methods

Study Area Details

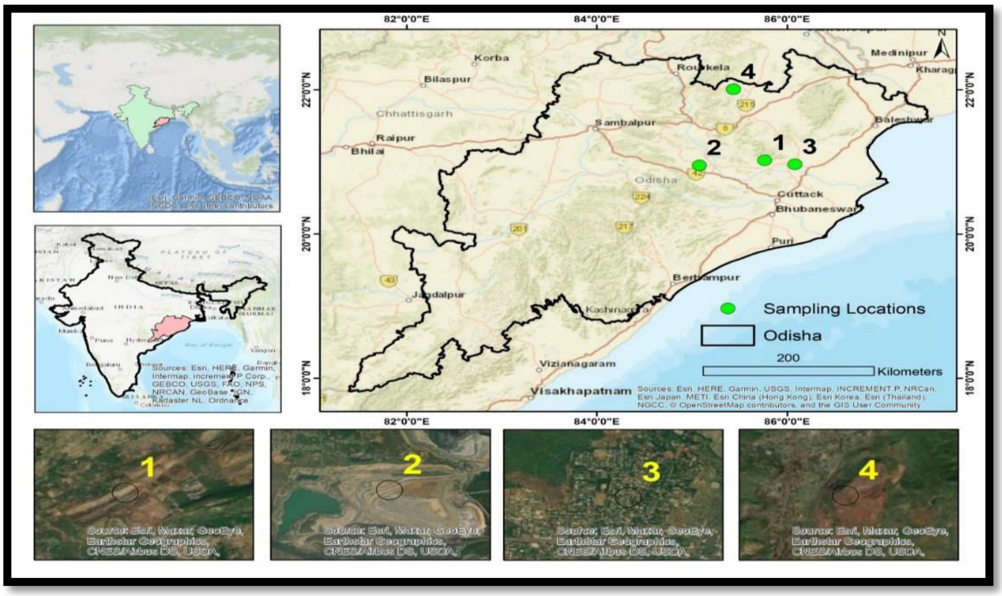


Figure 1.Sampling locations of the study area

The details of four sampling sites with location are shown in Fig.1 and given in Table 1.

Table 1:Details of sampling location

Sampling Sites	Location	District	Details of sampling site
SL-1	Sukinda	Jajpur	Chromite Mining Area, 12 number of mines operated in this region, spread over 50km^2.
SL-2	Balaram OCP	Angul	Coal mining area located in the south-central part of Talcher coalfield in Brahmani valley to the north of Mahanadi River. about 201 sq.km has been explored out of 1860 sq.km.
SL-3	Danagadi	Jajpur	No mining area present in the peripheral region of this village but industries like Tata Steel, Jindal Stainless Steel and Neelachal Ispat Nigam Ltd. etc. are present with 5km.
SL-4	Joda	Keonjhar	One of the largest Iron Ore Mining of the country, encompassing around 671 hectares. Surrounded by number of mines in this region.

Data Collection and analysis

Over the course of the past two decades, beginning in 2003 and continuing through 2022, rainfall and temperature data have been collected at four different sample locations within the study area. The weather information for SL-1 was gathered from Sukinda Chromite Mines, which is owned and operated by Tata Steel. The Balaram OCP Coal Mining of Mahanadi Coalfields Limited (MCL) provided the information that was used for the SL-2 study. Similarly, data were gathered from Danagadi, Jajpur, Tata Steel for SL-3. The data for SL-4 collected from the Iron Ore Mining operations of Tata Steel, which were located in the Joda region. The purpose of compiling these data sets was to create a comparative data set that represented all of the sampling locations within the study area. In order to analyze, raw data have been collected from the above four locations, and monthly averages have been calculated. The analysis was done based on monthly average data using Microsoft Excel. The software RStudio was utilized in order to carry out the statistical analysis. For the preparation of the maps of the study area, the software ArcGIS 10.4 was used.

Result & Discussion

The current study presents meteorological data such as a maximum temperature, minimum temperature, and rainfall for four locations considering different types of mining activities of the study area had been collected for last twenty years starting from 2003 to 2022 i.e., for last twenty years. There are monthly averages for maximum and minimum temperatures (in°C), and total rainfall (in mm) that are included in the data. This study can provide useful information that can be used for describing climatology, environmental conditions, and the rate of change of climatic parameters with time. This result depicts the analysis to gain an understanding of the dynamics of the local climate and possibly discover links with other environmental and geological factors.

Stations	**SL-1**			**SL-2**			**SL-3**			**SL-4**		
Parameters	**Temp**		**Rainfall**	**Temp**		**Rainfall**	**Temp**		**Rainfall**	**Temp**		**Rainfall**
Year	**Max**	**Min**	**Total**	**Max**	**Min**	**Total**	**Max**	**Min**	**Total**	**Max**	**Min.**	**Total**
2003	32.3	22.6	534.4	34.2	20.6	1379.3	31.5	21.5	2674.0	33.1	16.2	1389.7
2004	32.5	21.9	1568.7	33.4	19.1	1254.7	32.5	21.9	1754.0	32.4	15.8	1199.8
2005	31.3	21.3	1398.8	33.4	22.5	1607.0	31.3	21.3	2432.0	31.6	15.6	1247.6

2006	33.7	22.2	1362.3	33.4	20.8	1204.2	31.9	22.0	2121.0	30.1	15.1	1457.3
2007	32.6	19.1	1211.3	33.5	21.0	1132.0	32.0	23.0	2115.0	31.3	14.6	2170.2
2008	33.9	20.3	1289.1	32.8	20.9	1779.3	33.1	22.7	1732.0	32.2	14.2	1344.4
2009	33.9	23.3	1274.4	30.0	22.0	1760.0	33.7	22.6	1745.0	31.6	14.8	1048.1
2010	31.1	22.3	1090.1	33.8	19.9	1451.4	32.4	22.7	1936.0	31.4	15.5	919.0
2011	32.2	21.6	1085.6	33.0	19.4	1797.0	32.0	22.1	2505.0	31.4	14.6	1652.2
2012	33.1	24.0	830.0	33.5	22.0	2050.0	32.8	21.7	1760.5	30.3	14.4	1063.0
2013	31.1	22.3	1673.3	33.1	20.3	1777.0	32.7	21.8	2685.0	30.8	16.4	1537.0
2014	31.0	22.4	1421.3	32.5	20.8	1818.0	33.4	21.6	1971.0	30.3	17.7	1233.4
2015	31.0	22.5	1191.9	33.9	21.3	1595.0	33.4	22.1	1663.0	33.9	18.6	1027.6
2016	31.1	22.4	1492.5	34.1	19.6	1346.0	34.0	21.8	1503.0	34.2	18.6	1082.3
2017	31.2	22.6	2061.8	34.4	21.0	1420.0	31.5	22.6	1662.2	34.1	18.6	1168.9
2018	32.6	19.0	1665.8	34.2	19.0	1312.0	31.6	22.9	1956.0	34.3	18.3	1327.9
2019	32.9	19.5	1446.2	34.9	19.8	989.0	30.7	22.8	1792.4	34.7	18.5	1021.7
2020	32.8	19.2	1702.9	34.8	19.5	1405.0	32.4	22.2	1592.3	35.1	18.4	1433.5
2021	31.1	22.3	1124.3	35.6	20.1	979.0	30.5	21.7	1433.0	34.5	19.7	1705.2
2022	34.3	25.1	1240.8	34.6	20.7	1172.0	33.4	22.1	1370.4	35.3	18.9	1182.2
Max.	**34.3**	**25.1**	**2061.8**	**35.6**	**22.5**	**2050.0**	**34.0**	**23.0**	**2685.0**	**35.3**	**19.7**	**2170.2**
Min.	**31.0**	**19.0**	**534.4**	**30.0**	**19.0**	**979.0**	**30.5**	**21.3**	**1370.4**	**30.1**	**14.2**	**919.0**
Avg.	**32.3**	**21.8**	**1333.3**	**33.6**	**20.5**	**1461.4**	**32.3**	**22.2**	**1920.1**	**32.6**	**16.7**	**1310.6**

Table 2:Station wise average of Temperature & Rainfall data from 2003 to 2022.

After careful analysis of the available data, it is observed that both the highest and lowest temperatures is experienced a seasonal shift throughout the course of the years starting from 2003 to 2022. The collected data shows the temperatureincreased from 32.3^{0}C to 34.3^{0}C in SL-1, 34.2^{0}C to 34.6^{0}C in SL-2, 31.5^{0}C to 33.4^{0}C in SL-3, and 33.1^{0}C to 35.3^{0}C in SL-4 from 2003 to 2022 at the highest point (Table2). Based on the monitored values, when the last twenty years data were compared, it has been found that the highest temperature increased by 2^{0}C from 2003 to 2022 in SL-1, increased by0.4^{0}C in SL-2, increased by 1.9 ^{0}C in SL – 3, and increased by 2.2^{0}C in SL-4 (shown in Fig. 2). The observed results implicate that, the mining activities have influenced to the peripheral environment, which leads to rise in temperature in the study areas. The results showthat there is an increase in atmospheric temperature since 2003 to 2022.The maximum highest temperature observed in SL- 2 i.e., 35.6^{0}C (during 2021) followed by SL-4 i.e., 35.3 ^{0}C (during 2022), and SL-1 i.e., 34.3 ^{0}C (during 2022). It may be because of, increasing concentrations of greenhouse gases,climate change, and increase in anthropogenic activities due to mining.

A comparison of the temperature data with that of other sites across the world that are used for chromite mining reveals that Sukinda experiences temperature ranges that are comparable to those found in other significant chromite mining areas (Mishra et al., 2016; Beukes et al., 2017; Nanda et al.,2022). Within the context of the development of standardized procedures for chromite extraction, this highlights the significance of taking temperature differences into consideration (Hillier et al., 2003;Grieco et al., 2018).

Figure 2. Variation of Maximum Temperature station wise

Simultaneously, where the lowest temperature recorded is concerned, during last twenty years, the same trend has been experienced, where the temperature increased from 22.6^{0}C to 25.1^{0}C in SL-1, 20.6^{0}C to 20.7^{0}C in SL-2, 21.5^{0}C to 22.1^{0}C in SL-3, and 16.2^{0}C to 18.9^{0}C in SL-4 at the lowest point, with a rising of temperature 2.5^{0}C, 0.1^{0}C, 0.6^{0}C, and 2.7^{0}C in SL- 1, SL-2, SL-3, and SL-4an respectively. The variation of minimum temperature is shown in Fig. 3.

The results implicated that, increase in temperature trend is comparatively same in both highest and lowest point. It shows, due to mining activities, there is an impact on the local atmospheric conditions, which later leads to climate change. Not only there is impact on the temperature, but other adverse impacts can result from mining activities such as soil erosion, pollution,habitat destruction, deforestation, andconflict between human being &wildlife, which ultimately lead to the loss of biodiversity. All these factors are also responsible in forming a vicious circle for further increase in temperature leading to climate change.

The pattern of total rainfall, with significant precipitation occurring between different years starting from 2003 to 2022 indicates the increase in rainfall in the SL-1 from 534.4 mm to 1240.8 mm, and decrease in rainfall from 1379.3 mm to 1172.0 mm in SL-2, 1389.7 mm to 1182.2 mm in SL-3, and 2674.0 mm to 1370 mm. The observed values indicates that, except increase of maximum rainfall by 706.4 mm in SL – 1 , there is decrease of rainfall by 207.3 mm, 207.5mm, and 1304 mm in SL-2, SL-3, and SL-4 respectively.

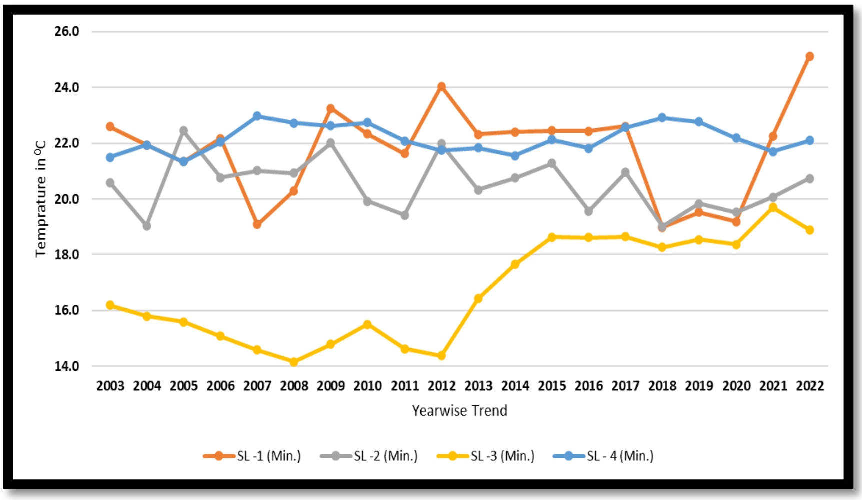


Figure 3. Variation of Minimum Temperature station wise

The increase in total rainfall indicates that both mining activities and deforestation prior to start of mining activities, have a direct impact on the weather condition in the study area (shown in Fig. 4). As the temperature increases, the capacity of air to absorb water increases, which also triggers heavy rainfall due to upward movement and resulting cooling of warm, humid air. Whereas the most common cause of reduced rainfall is low-humidity air. Low rainfall can have multiple causes. One reason could be lack of moisture in the air, which can be caused by a prolonged drought or changes in climatic pattern.

If analysis with all four sampling locations from 2003 to 2022 are done, then overall trend of increase in temperature by 1.6^{0}C at the highest point. The increasing trend of average temperature is shown in Fig. 5.

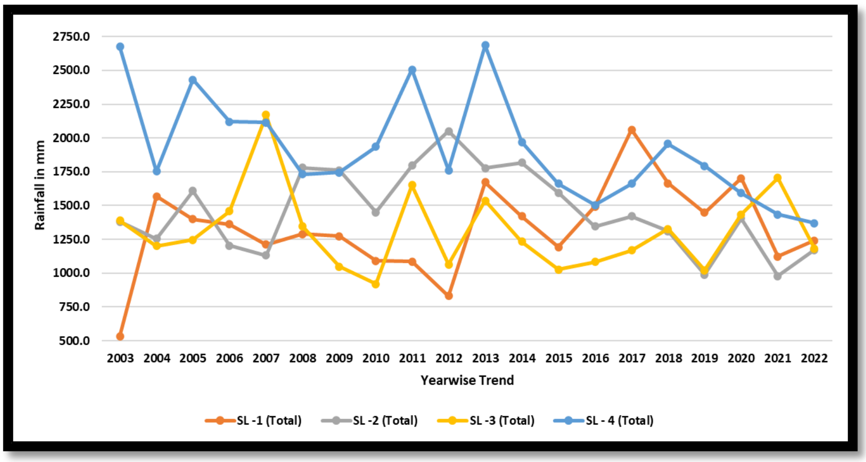


Figure 4.Variation of Total Rainfall Station wise

Simultaneously, the trend of temperature increased by 1.1 ^{0}C at the lowest point, which is shown in Fig. 6. The rising of temperature both in highest and lowest point indicates that, the impact of mining activities has a major influence on temperature pattern which ultimately lead to climate change.

On world prospective, rise of temperature just for one degree celsius would also escalates extreme heat waves, which would become more continual and enduring. In turn, the rising in temperature, which especially affect members of the most vulnerable populations of flora and fauna and increase the risk of heat-related illnesses.

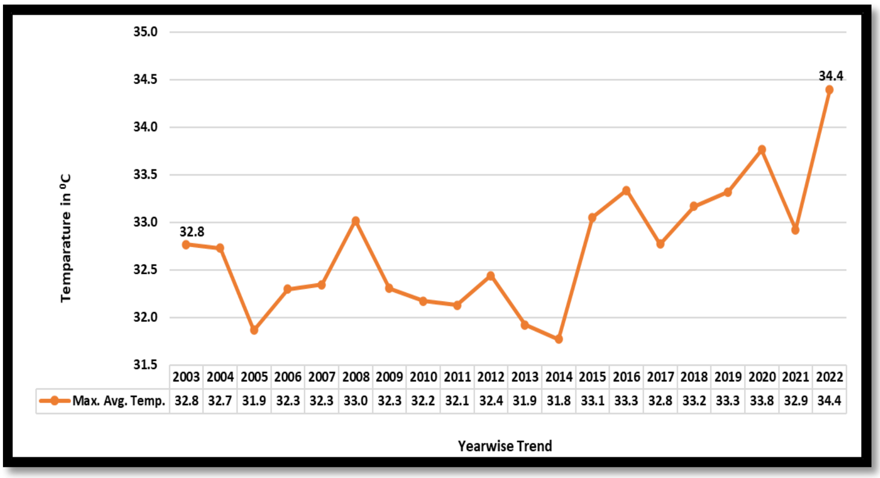


Figure 5.Variation of Temperature (Maximum Avg.)

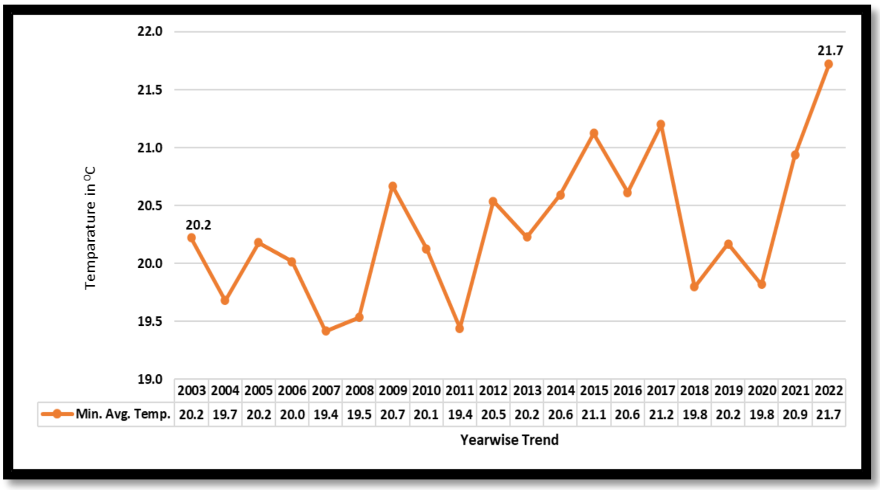


Figure 6.Variation of Temperature (Minimum Avg)

In a similar way, when we are analysing the total average rainfall of all four sampling locations. then the trend of rainfall declined by 253 mm, which shown in Fig. 7. During 2003 the average rainfall recorded as 1494.4 mm and during 2022 it was recorded as 1241.4 mm

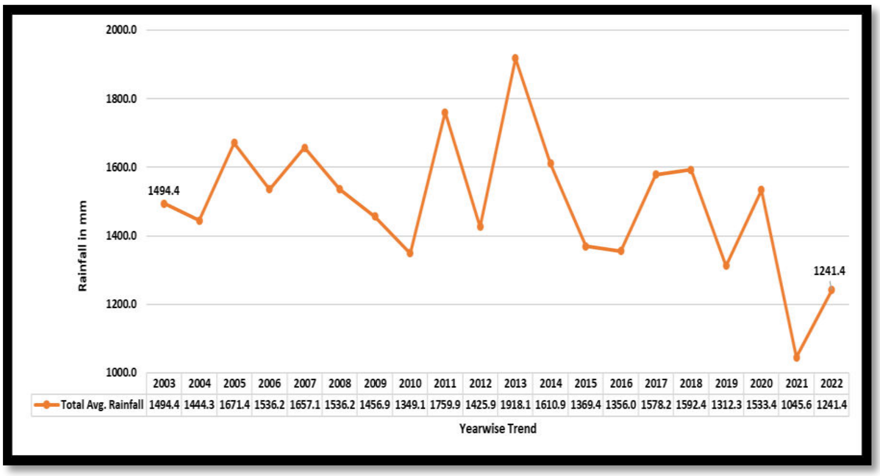


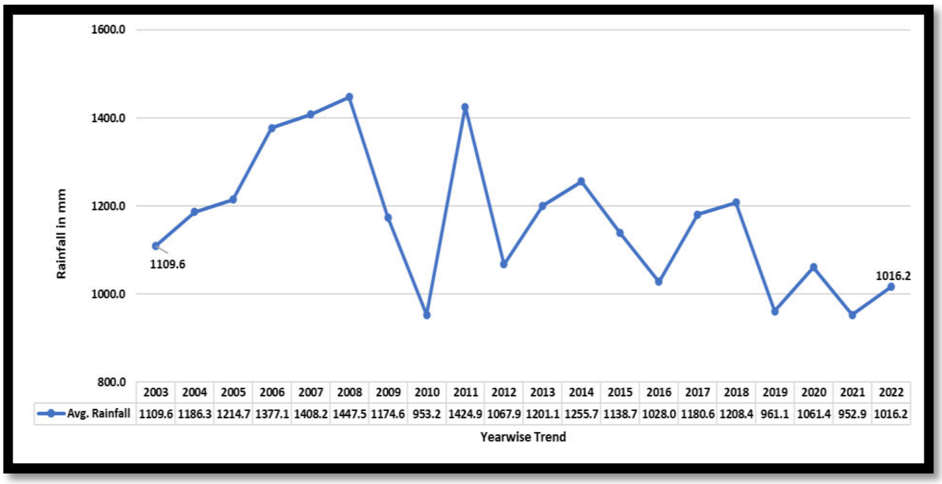
Figure 7.Variation of Rainfall (Total Avg.)

To get a better clarity, we have gone through the total rainfall of all four sampling locations during monsoon on yearly basis. It has been found that the trend of total average rainfall during monsoon is declining from 1109.6 mm during 2003 and 1016.2 mm during 2022 with a difference of 93.4 mm (shown in Fig. 8). If we go through the maximum total rainfall during monsoon season, then it is being observed that the highest rainfall recorded in SL- 3 during 2011 i.e., 2029 mm followed by SL-4 during 2007 i.e., 1775.3 mm, and then in SL-2 during 2012 i.e., 1692 mm. Similarly, the minimum total rainfall recorded as 2029 mm in SL-3 (during 2011), followed by 1775.3 mm in SL-4 (during 2007), and then 1692 mm in SL-2 (during 2012). Similarly, the minimum total; rainfall recorded as 412.5 mm in SL- 1 (during 2003), followed by 626.9 mm in SL- 4 (during 219), and 671 mm in SL- 2 (during 2009). The average data during monsoon recorded are shown in

Table 3.

Table 3:Station wise variation of Rainfall during Monsoon period from 2003 to 2022

Year/Station	**Sukinda (SL-1)**	**Balaram OCP (SL-2)**	**Danagadi (SL- 3)**	**Joda (SL-4)**	**Total Avg. Rainfall (Monsoon)**
2003	412.5	1017.0	1811.0	1198.0	1109.6
2004	1312.9	1082.3	1381.0	969.0	1186.3
2005	1077.5	1357.5	1543.0	880.8	1214.7
2006	1206.9	1105.2	1990.0	1206.2	1377.1
2007	1002.4	1050.0	1805.0	1775.3	1408.2
2008	1248.7	1686.3	1715.0	1139.9	1447.5
2009	1075.0	1466.0	1320.0	837.6	1174.6
2010	714.1	1021.0	1331.0	746.6	953.2
2011	867.7	1443.0	2029.0	1359.9	1424.9
2012	573.4	1692.0	1135.5	870.5	1067.9
2013	1041.3	1242.0	1534.0	987.0	1201.1
2014	1067.7	1430.0	1468.0	1057.1	1255.7
2015	941.1	1370.0	1389.0	854.6	1138.7
2016	1127.1	1012.0	1213.0	759.9	1028.0
2017	1435.8	1236.0	1123.2	927.2	1180.6
2018	1422.0	978.0	1452.0	981.8	1208.4
2019	1134.6	671.0	1412.0	626.9	961.1
2020	1401.6	919.0	962.3	962.7	1061.4
2021	1100.0	783.0	935.1	993.4	952.9
2022	1094.1	942.0	1022.9	1005.9	1016.2
Max.	**1435.8**	**1692.0**	**2029.0**	**1775.3**	**1447.5**
Min.	**412.5**	**671.0**	**935.1**	**626.9**	**952.9**
Avg.	**1062.8**	**1175.2**	**1428.6**	**1007.0**	**1168.4**



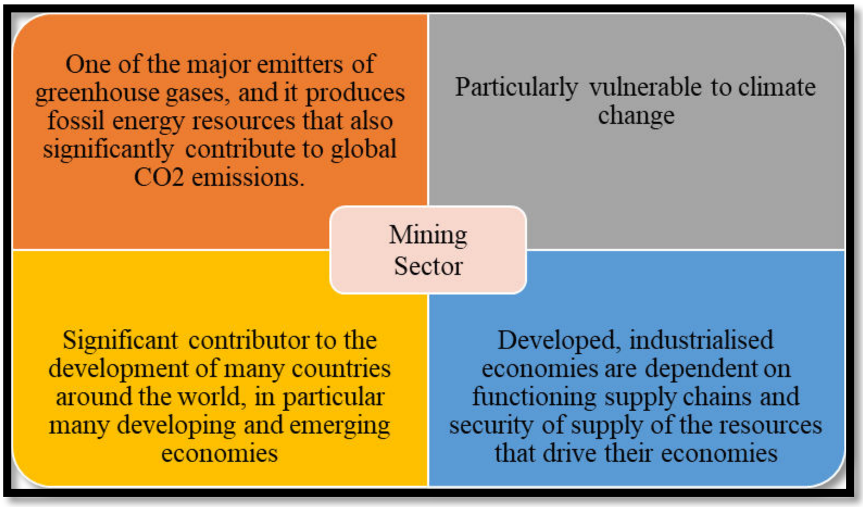
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avg. Rainfall	1109.6	1186.3	1214.7	1377.1	1408.2	1447.5	1174.6	953.2	1424.9	1067.9	1201.1	1255.7	1138.7	1028.0	1180.6	1208.4	961.1	1061.4	952.9	1016.2

Figure 8.Variation of Rainfall in Monsoon Period (Total Avg.)

The rainfall data indicate that, there is a significant amount of variance in the patterns of precipitation in this region, which is supported by previous study (Patra et al., 2012). The region is characterized by seasonal patterns (different wet and dry seasons). The amount of precipitation that falls on an annual basis fluctuates from year to year, with some years also experiencing more precipitation than the average (Swain et al., 2018). The study of rainfall pattern in Sukinda in comparison to Odisha state of Eastern India highlights the importance of adopting flexible approaches to water management (Mohapatra & Mohanty, 2005). For mining operations to be sustainable, it is essential to address the impact of mining activity on the climatic parameters.

Foreign policy makers should pay more attention to the relationship between mining and climate change based on the findings of different reports, as there are many reasons behind it. There might have associated negative impacts on environments due to exploration in mines, construction, and operation&maintenance activitiesincluding erosion, deforestation, alteration of soil profiles, contamination of wetlands & streams, and also there is an increase in dust emissions , and noise level,which results change in the trend of temperature as well as rainfall in the respective areas.

Several studies have indicated that, mining activities as well as supporting services such as raw material transportation, crushing, grinding, beneficiation and processing of iron ore have impacts on the air, water, soil and biodiversity of the surrounding environment (Dash & Dash, 2018; Mishra et al., 2019). High rate of energy consumption and international trade of products of these sectorswill increase the greenhouse gas emission and energy regulation (Marshall et al.,2018; Kharyutkina et al.,2022). It is well understood thatmaximum mining companies often operate in remote areas and also in the most politically and socially challenging parts of the world. In these specific areas, industry remains an important driver where the economic growth, and social development are utmost concern. Furthermore,there is a threat to the profitability and viability of specific sectors, and climate change could have significant consequences for development in countries. (Gao et al., 2019; Wongbusarakum et al., 2021). Mining



operation must be carried out by taking care of the surrounded green environment, because mining has a direct impact on the nearby vegetation and green cover (Dash & Dash, 2018).

The increase in temperature has a great impact on air pollution in the mining activities. The air pollutants are classified as primary or secondary pollutants (CPCB, 2006; Tian et al., 2013; Xiao et al., 2018; Dash et al., 2017). Some studies resembled that about 50% of the global population will be living in urban areas by 2030. India recorded within 10 of the world's 20 most populated cities as per the report by WHO (2016). Due to the emissions of $PM_{2.5}$, India was ranked the 5th most polluted country by WHO (2019). It is an alarming situation for India, where air pollution is highly concerned during this urbanisation and industrialisation scenario (Maji et al., 2015; Dash et al., 2018).

The extent for which mining avoids reducing the resilience of host communities to climate change, and even strengthens that resilience, will directly affect the reputation of industry, access to project financing , and social license (Fazey et al., 2007; Cinner et al., 2018;Dash et al., 2020). Proactive approach should be undertaken by all mining industry pertaining to climate adaptation for the following reasons:

» Both water and energy, may face greater constraints, as far as supply of critical inputs to mining operation is concerned (Dash et al., 2016; Kunz et al., 2017) .

» Due to rising in temperature, health and safety of employees will be put at risk by increases in communicable diseases. In addition to this, exposure to heat-related illnesses and the likelihood of accidents related to rising temperatures (Goltz & Barnwal, 2019).The impact of frequent emergence of heat waves across land areas heat wave and regular heavy rainfall shown in the below chart for a boarder view.

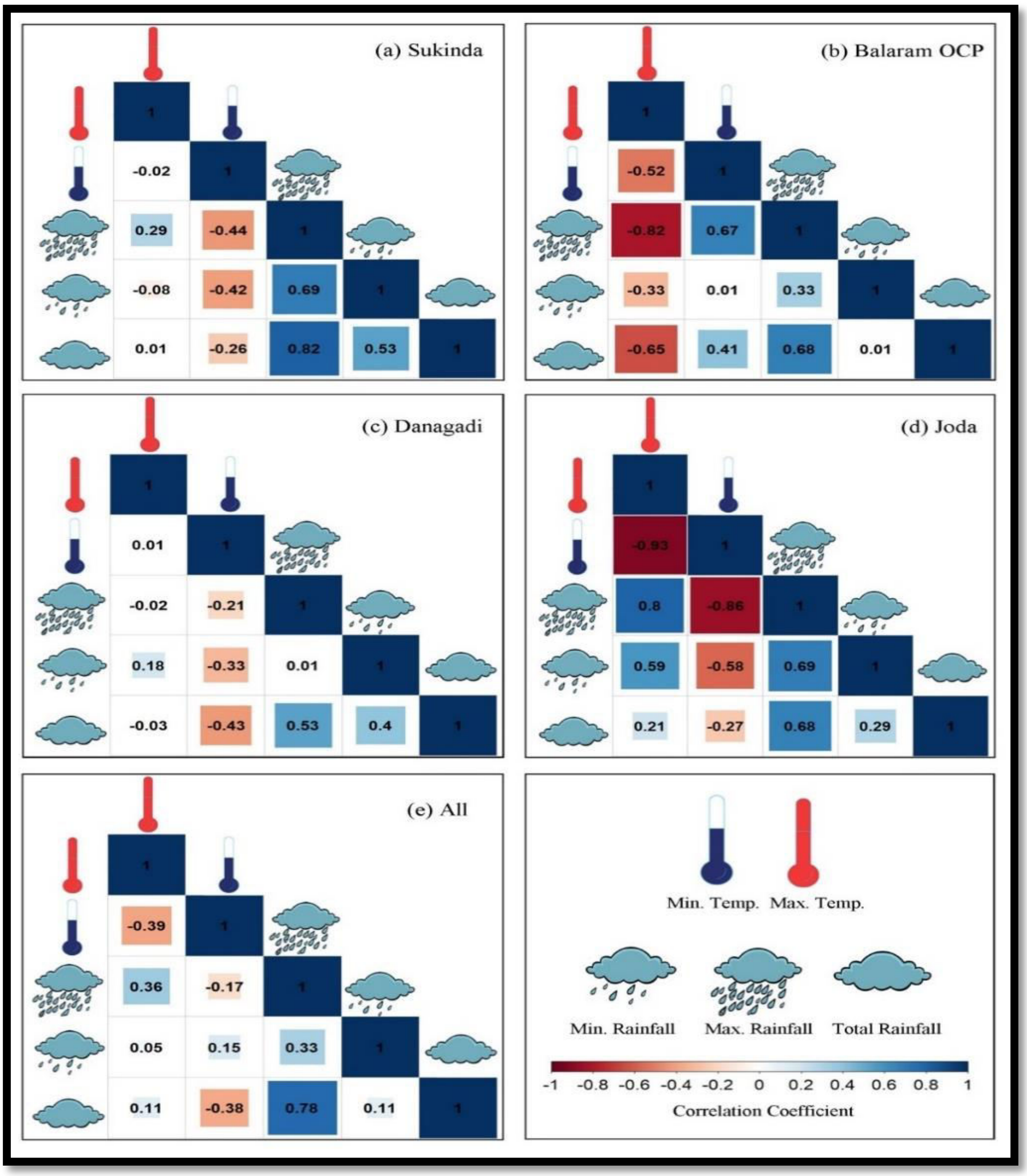


Figure 9. Corr-plot for SL-1:(a) Sukinda, SL-2: (b) Balaram OCP, SL-3:(c) Danagadi, and SL-4:(d) Joda, presenting the relation between temperature and rainfall.

The maximum temperature at SL-1 was shown to have a positive correlation with the maximum rainfall, whereas the minimum temperature was found to have a negative correlation with rainfall. At the SL-2, the maximum temperature has a negative correlation with rainfall, whereas the minimum temperature has a positive correlation with rainfall. When the temperature and rainfall were measured at SL-3, there was no significant link identified between the two variables. There is a positive correlation between the maximum temperature and the rainfall at SL - 4, while there is a negative correlation between the minimum temperature and the maximum temperature (shown in Fig. 9). There was a consistent pattern that was seen in every place, which was that as the maximum rainfall was higher, the total rainfall was also higher. It can be observed that the temperature is positively or negatively related with the rainfall in all of the mining areas. On the other hand, in SL-3 which was not a mining site, there was no significant correlation between the temperature and the rainfall. The effect of mining on the local environment is depicted by the fact that it causes fluctuations in the temperature and the amount of rainfall that occurs.

Conclusion

The meteorological data collected from mining areas have highlighted the dynamic character of the climatic parameters that influence mining and vice versa. In order to standardize mining techniques on a global scale, a systematic approach that takes into consideration the differences in climatic parameters of different regions are required. This study makes some contribution to the development of strategies that are both sustainable and flexible for the mining of different minerals on a global scale.

Odisha state has experienced severe catastrophic meteorologicalevents andis susceptible to climate variability pertaining to its position near the seacoast. From the study of the above data, it is evident that, the fluctuations or variations in climatic parameters is a recurring phenomenon in the sampling locations. The effects of climate variability worsen the existing economic, and social encounters across the region as people here rely primarily on resources that are vulnerable to rain-fed agriculture, and climate variability.Both rainfall and temperature are the most determining climatic parameters of this region, as more than 80% of agriculture is dependent on rainfall.

Under climate change adaption strategy, all the respective stakeholders including the people who matter for mining as well as who makes policy related to mining should take into consideration effect of the rainfall variability in particular and temperature variability in general. Sustainable mining adhering the mitigationmeasures to climate change will go a long way in continuing mining activity with minimum effect to the climate and people living around the mining area.

From the analysis of weather data from the four sampling locations, it is observed that there is increase in maximum temperature by 1.6^{0}C, and increase in minimum temperatureby 1.1^{0}C, and decrease in rainfall by 253 mm in the last 20 years. It may be concluded that mining activities play a significant role in influencing the climatic parameters. It is also observed that the pattern of rainfall during the monsoon period, which used to be extended till the month of September at the beginning of the study period, has shown reduction in the duration of monsoon rain. This change in the pattern and distribution of rainfall during the monsoon period will definitely lead to less infiltration, more drainage loss, flood, and extended drying period.

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