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An Exploration the impacts of Industrialisation and Environment in Nagpur, Maharashtra

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Abstract - Industrialization is a government plan to diversify and empower a region's economy based on its resources. The resource base of a region must be studied & developed before its industrial potential may be used. Groundwater levels and groundwater extraction are investigated to see if they are affected by climate variability. The primary goal of the industrial & impact of Environment report was to document the state of the environment in Nagpur. This will provide a rational framework for planners, policymakers, and citizens to make decisions that are conducive to environmental conservation. The analysis begins by mapping the industrial landscape of Nagpur, highlighting key sectors and their contributions to economic growth. Special attention is paid to the types of industries, their scale, and the associated resource consumption and waste generation. Subsequently, the study delves into the environmental repercussions of this industrial surge, exploring issues such as air and water pollution, deforestation, and biodiversity loss. the study investigates the environmental policies and regulations in place, assessing their effectiveness in mitigating the adverse impacts of industrialization.

Keywords - Industrialization, Groundwater, environment, climate, Nagpur, air and water pollution

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INTRODUCTION

The term "industrialization" refers to the economic shift that occurred as societies shifted their focus from primary (agricultural) to secondary (manufacturing) industries. Agriculture, livestock, fishing, and forestry might all be important to the pre-transformed society's way of life. Depending on technical progress, an industrialized economy will either have a high or low degree of processing of raw materials obtained from primary production. The amount of value added by the skilled or unskilled labor & materials used in such processing varies. The market worth of finished products is multiplied many times over by the time they have undergone processing and value addition. As a result, secondary economic activities outperform main ones. Therefore, in theory, an industrialized economy is a means by which poverty can be alleviated, as it is capable of supporting a larger population thanks to its higher per capita income.

Since 1947, when the government intervened through planned development, industrialization in India has gained traction and accelerated. Looking at the state level, we see that industrial resources are spread out over the territory. Most of Rajasthan and a sizable chunk of Gujarat, in addition to some western regions of Punjab & Haryana, make up the country's northwestern semi-arid and arid region. The western Thar desert & semi-desert of Bangar are particularly important to the state of Rajasthan's economic growth. Droughts and other instances of rainfall scarcity have hampered agricultural progress. The pastures have supported a considerable number of cattle & sheep despite their carrying capacity. As a result, the number of animals has been roughly the same as, if not greater than, the human population. It has been necessary to resort regularly to the practice of forced livestock movement during famine years. Sedimentary minerals & lignite make up the bulk of the mineral richness in this once-submerged region. Traditional forms of industry include wool processing, salt production, jewelry making, textile dying, etc.

Positive Impacts of Industrialization in Nagpur

- **Economic Growth:** Industrialization has contributed to economic growth and development in Nagpur, leading to increased employment opportunities, higher income levels, and improved living standards for many residents.
- **Infrastructure Development:** The growth of industries has led to improved infrastructure, including better roads, transportation

networks, and utilities, which can enhance the overall quality of life in the region.

Negative Impacts of Industrialization in Nagpur

- **Air Pollution:** Industrial activities in Nagpur have led to increased air pollution due to emissions from factories, vehicles, and other sources. The city has often experienced poor air quality, with particulate matter and pollutants like sulfur dioxide and nitrogen oxides exceeding safe levels. This has adverse effects on respiratory health and the overall well-being of the population.
- **Water Pollution:** Industrial effluents and untreated sewage often find their way into water bodies in and around Nagpur, leading to water pollution. This contamination can harm aquatic ecosystems, affect drinking water quality, and impact the health of both humans and wildlife.
- **Deforestation and Habitat Destruction:** The expansion of industries has sometimes resulted in deforestation and the destruction of natural habitats, which can have severe consequences for local biodiversity. Nagpur's surrounding areas are rich in flora and fauna, and industrialization can threaten these ecosystems.
- **Resource Depletion:** Industrialization requires significant natural resource consumption, leading to resource depletion. This can include the extraction of minerals, water resources, and energy, which may lead to long-term environmental challenges.
- **Waste Generation:** Increased industrialization generates more waste and solid waste disposal issues. The improper disposal of industrial and hazardous waste can have detrimental effects on soil quality and groundwater.
- **Noise Pollution:** Industrial areas are often associated with high noise levels, which can disturb the peace and quiet of nearby residential areas, affecting the mental and physical health of residents.

NAGPUR REGION'S ENVIRONMENT SITUATION

The Nagpur region is situated in the eastern section of Maharashtra, in the middle of India, on the Maharashtra plateau, between the Wainganga & Wardha river basins. The area of the Nagpur region is 50666 square kilometers. Lows of 5.6°C and highs of 48°C are typical for the area. We get around 1235 mm of rain on average. Coal, limestone, manganese, iron, and other minor minerals abound in the area, as do perennial rivers, rich soil, groundwater, forests, & minerals. The locations with these resources tend to have a higher concentration of industrial development. Approximately 26.01 percent, or 1,334 hectares, of the land area in the area is covered by forests.

Table 1: The average forest covers by district

Nagpur	13.68%	Wardha	4.40%
Bhandara	10.00%	Chandrapur	5.26%
Gadchiroli	41 .89%	Gondia	22.37%

Since 1984, Nagpur has been home to the Maharashtra Pollution Control Board's regional office.

This region encompasses 63 talukas, with a municipal corporation in Nagpur and 30 municipal councils. The talukas are as follows: 14 in the Nagpur district, 8 in the Wardha district, 7 in Bhandara, 14 in Chandrapur, 12 in Gadchiroli, and 8 in Gondia. There are municipal councils in Nagpur-10, Wardha-6, Chandrapur-7, Bhandara-3, Gadchiroli-2, Gondia -2.

NAGPUR CITY

Due to its abundance of mandarin oranges, Nagpur has earned the nickname "The Orange City of India." According to the Regional Meterological Center (2011), the zero mile stone is situated in the middle of Nagpur city, close to the Gowari Smarak (Memorial), which represents the geographical center of the country. From the Yadavas to the Khiljis, the Gonds, and finally the British, the city of Nagpur has been under the dominion of many dynasties. Nevertheless, in 1703, the prince of the Gond tribe "Bhakt Buland" placed the foundation stone of the present-day city of Nagpur. Since the Middle Ages, it has served as the administrative center of Central India (Census, 2011). Nagpur was a part of the Central Provinces at independence, but it was combined with the Marathi-speaking Maharashtra state in 1960 as part of a linguistic reformation that was taking place at the time. Nagpur, in Maharashtra's Vidarbha region, is one of the fastest-growing cities in India. The winter sessions of the State Assembly are held there, making it a significant political and administrative hub. There are a number of government offices and research institutions based there, as well as the Indian Air Force's Maintenance Command. In the Vidarbha area, Nagpur is also a major center for industry. Butibori is the biggest industrial estate in the area, which is around 25 to 30 km from Nagpur city. Other industrial zones in the neighborhood of Nagpur include Kalmeshwar, Kamptee, Hingna, Wadi, Khapri, and Butibori. The Maharashtra government has launched a plan to transform Nagpur's current airport into MIHAN, or Multimodal International Hub Airport at Nagpur, in addition to establishing a Special Economic Zone (SEZ) and related infrastructure. A multi-faceted, interdisciplinary, world-class initiative, MIHAN is now under development. here: http://smartcities.gov.in/.

With an average yearly rainfall of 1018 mm with summer temperatures reaching 48ºC and winter temperatures dropping to 10–12ºC, the city has hot, dry, tropical weather typical of tropical savannah climates (Aw in Köppen climatic classification). The city is experiencing a spatial expansion in administrative boundaries as a result of recent socio-economic developments, population growth, & urbanization. As a result, the natural landscape that was once on the outskirts of the city is now within its borders. Lakes, urban forests, playgrounds, gardens, parks, and other public and managed green spaces in Nagpur are under extreme threat of destruction and degradation as a result of the city's fast urban transformation. Air & water pollution, loss of green space, more frequent flash floods as a result of greater development, the rise of urban heat islands, and other problems are all results of urban expansion & changes it brings to land use [3]. The five types of urban green spaces were used to create a thematic map of Nagpur city in a recent study. The map was created using ground truth points collected during field visits. In Figure 2, we can see how the ground truth points are distributed over Nagpur city.

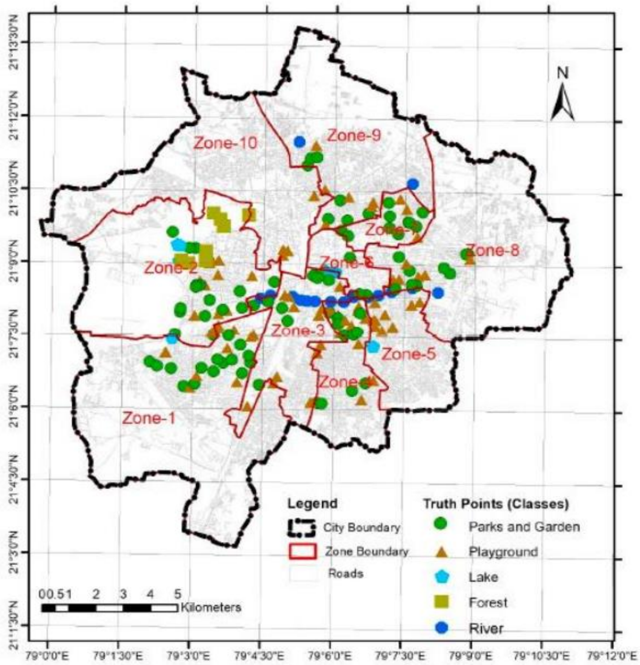


Figure 1: Ground truth point distribution reference map

POPULATION

The current projection for Nagpur's population in 2020 is 2,893,455. Nagpur had a population of 472,859 in 1950. There has been a yearly change of 1.57%, or 216,735 new residents, in Nagpur since 2015. United Nations World Urbanization Prospects, most recently revised, is the source for these population estimates & predictions. The population of Nagpur and its surrounding suburbs are usually included in these figures, which are for the urban agglomeration of Nagpur (https://worldpopulationreview.com/world-cities/nagpur-population/). It ranks third in the state & thirteenth in the nation in terms of population. More than 3.6 million people call the greater metropolitan area home, according to estimates. The precise figures, however, will be revealed in the subsequent census. Among the Indian cities, this one has a stellar reputation for cleanliness. It ranks high among the most liveable cities because of its excellent public transportation system, plenty of parks, and healthcare facilities. With an area of slightly more than eighty-four miles, the population density in Nagpur is thirty thousand inhabitants per square mile. Looking into the demographics of Nagpur's population in greater detail reveals that men outnumber females. With a population of over 10%, the city is home to a sizable youth population. There are about 859,000 residents living in slums — or more than 35% of the population. Males have a greater literacy rate than females, contributing to the nearly 92% literacy rate.

NAGPUR ESR 2019-20

The Nagpur Municipal Corporation has been entrusting the preparation of the Environmental Status Report to CSIR-NEERI since 2016. The following environmental metrics are the main emphasis of the 2019–20 ESR:

- Urban green spaces: a participatory solution to the demand-supply gap
- Water environment: river & lake freshwater quality, benthic environment, metagenomics, microbial diversity, groundwater quality, aquifer mapping of Nagpur city
- Solid waste
- The cost of ecological damage caused by solid waste
- The air environment

CLIMATE CHANGE NEEDS UNDERSTANDING

The most complicated issue that mankind has encountered so far in the 21st century is climate change. In order to reach the sustainable development goals proposed by the UN, it is crucial to solve the climate change conundrum, which is inextricably linked to the socioeconomic development of each given area. As a result of human activities, particularly those associated with the industrial revolution, the concentration of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), or nitrous oxide (N_2O) is increasing. Carbon dioxide & other greenhouse gas emissions are directly attributable to human activities, such as burning fossil fuels & altering land use. According to the IPCC (2018), the levels of carbon dioxide in the atmosphere are at their highest point in at least the last 700,000 years, and by 2050, the average surface temperature is projected to increase by more than 1.5 ºC. Greenhouse gas emissions from human activities are largely responsible for the climatic changes that have been observed over the past fifty years (Hayhoe et al., 2007). The number of academics & climate researchers who think we have entered a new weather system characterized by more frequent and intense extreme weather events is growing (Secretariat, 2008). Because greenhouse gases stay in the air for so long, the effects of climate change are not immediately noticeable. People in the next century would feel the effects of today's greenhouse gas emissions. Anthropogenic forcing will persist for ages to come, regardless of if the growth in greenhouse gasses were to stabilize. Tackling climate change is unique & challenging compared to other policy concerns since its effects will not be realized during our lifetime. Climate change is a worldwide climatological phenomenon; furthermore, the atmosphere of Earth does not distinguish greenhouse gas emissions according to city, district, state, or country.

CLIMATE CHANGE INDICATORS

Temperature

The most notable climatic changes affecting Nagpur city, according to weather & geography records, are likely to be an increase in the average yearly temperature and precipitation. Summers are typically hot & dry, with an average temperature of 33.3 ºC and a high in the mid-40s; however, being exposed to extremely high temperatures can cause serious health problems or even death. This is particularly the case if the general population is unprepared for such a scenario. Both the frequency and severity of these disasters are increasing on a global scale. From 2000 onwards, the world has experienced fifteen out of the sixteen warmest years ever recorded (US EPA, 2016). Heat exhaustion, strokes, cramps, etc. are just some of the many health complications that can arise from being in an extremely hot environment, along with fatalities. People who are already at a high risk of heat-related illnesses include the elderly, those with certain disabilities, those living in poverty or social isolation, children, & homeless (Center for Disease Control and Prevention, 2012). Heat events can have different impacts on humans, as seen in Fig 3.

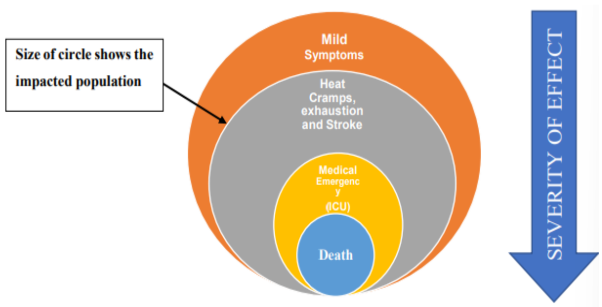


Figure 2: The effects of heat waves divided by population & intensity (CDC, 2012)

Annual Average Temperature

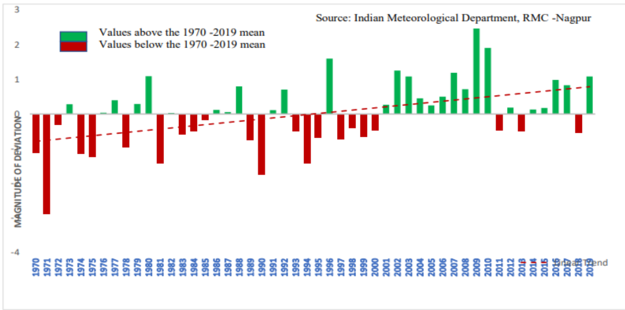


Figure 3: Temperature on an annualized basis, as compared to the mean from 1970 to 2019.

Figure 3 shows that there were 16 (in green) instances of above-average surface temperatures between 2000 and 2019, compared to 8 (in green) instances between 1980 and 2000. Over the past 20 years, a pattern has emerged in which the average yearly temperature (the sum of the daily mean temperatures) has been steadily rising above the 50-year mean.

Extreme Heat Events

Extreme heat occurrences are defined by the Hoosier Resilience Index (Cains, Websters, 2019) as days with highs of 32.22 ºC or higher and nights with lows of 20 ºC or above. Particularly for vulnerable groups, rising average & overnight temperatures pose serious health risks to humans. When calculating the Heat Events, we have taken the Nagpur conditions into account for the base temperature. For this exercise, the base temperatures used were the average maximum & minimum temperatures of Nagpur city from 1970 to 2019. According to Cain, Websters, (2019), the overall count of extreme heat events can be determined by adding up the number of high heat days, high heat nights, and high heat days and nights combined.

High Heat Days (HD): TMAX >= 33 ºC and TMIN < 20 ºC

High Heat Nights (HN): TMAX < 33 ºC and TMIN > 20 ºC

High Heat Days and Nights (HDHN): TMAX >= 33 ºC and TMIN >= 20 ºC

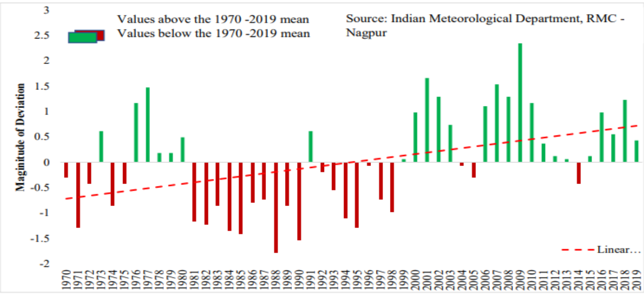


Figure 4: Extreme Heat Events Deviation, comparison with the 1970-2019 mean

Compared to the period from 1980 to 2000, there were 18 (in green) occurrences where the extreme events were above average from 2000 to 2019, as shown in figure 5. According to the Hoosier Resilience Index, there has been a noticeable upward trend in the frequency of high heat occurrences.

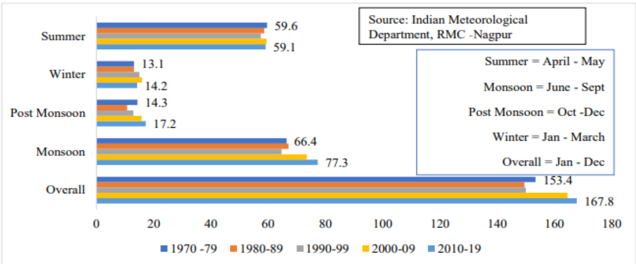


Figure 5: Time series analysis of extreme heat events

A comparison of the frequency of high heat days & nights (HDHN) in Nagpur over a decade is displayed in Figure 6. Contrary to the 1970–1979 decade, the incidence of HDHN has been on the rise in the recent two decades, with a 14.4 unit increase for the 2010–2019 decade, according to the study. Looking at the seasonal occurrence of HDHN reveals that it increases by 10.9 units during the monsoon season.

Precipitation

Among the many important climate factors, precipitation stands out. In order to grasp the breadth and depth of climate change, researchers frequently examine changes in the frequency & intensity of rainfall. This is particularly the case for India, whose agrarian economy is highly reliant on the south-west monsoon. Knowing the spatio-temporal dynamics of this variable is crucial for providing credible inputs to policymakers. A whopping 71% of Indians find work in agriculture, making it the country's economic backbone (Duhan & Pandey, 2013). Furthermore, according to Joshi et al. (2016), India is among the nations that are most at risk of flooding & drought. For this reason, comprehending the effects of climate change requires knowledge of how the pattern of precipitation across Nagpur has changed.

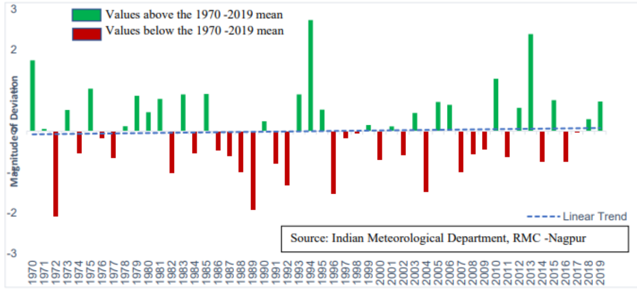


Figure 6: Variation in annual rainfall from 1970 to 2019

The yearly rainfall over Nagpur City has remained relatively constant from 1970 to 2019, as shown in Figure 7. The overall trend, shown in blue, is rather near to the mean. This indicates that for the past fifty years, there has been no change in the total annual rainfall for Nagpur. To learn whether there have been shifts in the seasonal distribution of rainfall over Nagpur, the study delves further into the pattern of rainfall throughout the year.

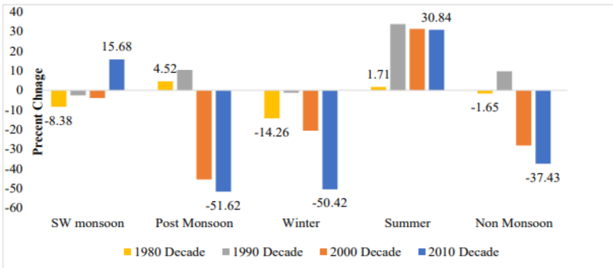


Figure 7: Analysing the Decadal Percent Change in Rainfall from 1970–1979 Base Decade

The south-west monsoon has grown in intensity by 15.68 units between 2010 and 2019, as shown in Figure 8, when compared to the baseline decade of 1970–79. But compared to the baseline decade, significant decrease in the amount of rain that falls throughout the post-monsoon & winter seasons, which are responsible for watering the rabi crops. The non-monsoon period (Oct-May) also had a decline of 37.43%.

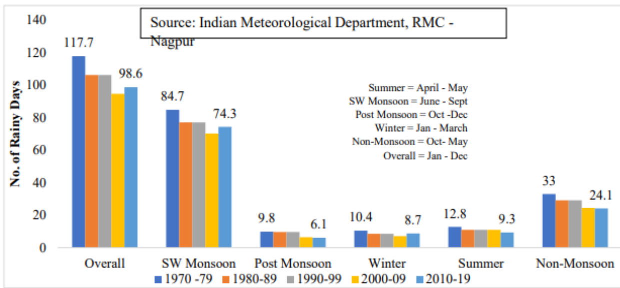
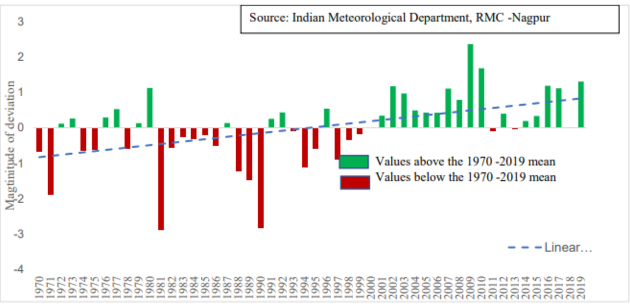


Figure 8: Rainfall data from 1970 to 2019 compared across decades

Figure 9 shows the total & seasonal rainfall compared over a decade. From 1970 to 2019, the study shows that the number of rainy days decreases over time. There was a 19.1 unit drop between the baseline decade & 2010–19 period. The Southwest monsoon season shows similar trends, with a decline of 10.4 units.

Effect on Energy consumption

Energy consumption in buildings is on the rise due to rising global temperatures & demand for more comfortable interior environments (Bhatnagar, 2018). Because of its extreme summer heat & monsoon humidity, this is particularly the case in Nagpur.



Condition	Calculation Formulae
$T_{MIN} < T_{BASE}$	$D_C = (T_{MAX} + T_{MIN})/2 - T_{BASE}$
$T_{MIN} >= T_{BASE}$	$D_C = (T_{MAX} - T_{BASE})/2 - (T_{BASE} - T_{MIN})/4$
$(T_{MAX} + T_{MIN})/2 > T_{BASE}$	$D_C = (T_{MAX} - T_{BASE})/4$
$T_{MAX} < T_{BASE}$	$D_C = 0$

D_C = the cooling degree days
T_{MIN} = daily minimum temperature
T_{MAX} = daily maximum temperature
T_{BASE} = base temperature

Figure 9: The anomaly of cooling degree days from 1970 to 2019

The term "degree-days" is used to measure the amount of energy needed to heat or cool a structure. According to Shanmuga Priya et al. (2011), this approach is based on the premise that a building's energy consumption is directly proportional to the deviation of the daily mean temperature from a base temperature. The temperature at which India is measured is 18 ºC. The calculation of cooling degree-days for Nagpur is taken into account in the study. According to Shanmuga Priya et al. (2011), the following formulas were used for the estimate:

The cooling degree days anomaly across the annual mean for 1970-2019 is shown in Figure 10. From 1970 to 2019, the cooling degree-day trend increased, according to the study. Looking at a two-decade comparison, we can see that there were 16 (in green) cases where cooling degree-days were higher than average from 2000-2019, and 5 (in green) from 1980-1999.

Effects on Regional Agriculture Productivity

Agriculture and food security are among the areas that will feel the effects of climate change the most. Because seasonal rainfall is crucial to India's agricultural sector & economy, climate variability—the difference between the world's average temperatures and precipitation patterns—could have a profound impact on India's farming practices. So, the purpose of the research is to figure out if there's a connection between temperature, rainfall, & crop productivity. The Government of Maharashtra's Department of Agriculture was the source of the agricultural production data. According to the study, there is a weak upward trend in temperature for Kharif Cotton at a 95% confidence level ($r^2 = 0.393$, $p<0.1$), and rainfall is responsible for 34.1% of the variation in wheat output.

Table 2: Coefficient of Pearson's correlation and p-value for Yield vs Rainfall and Yield vs Temperature

Food Crops		K.H. Cotton	K.H. Rice	RB Wheat
Yield Vs Rainfall	Slope	-0.548	-0.527	-7.853
	R-square	0.026	0.013	0.341
	P-Value	0.552	0.682	0.017
Yield Vs Temperature	Slope	971.69	-225.92	457.57
	R-square	0.393	0.011	0.051
	P-Value	0.009	0.700	0.166

Note: Legend: Yield = Crop Yield, Green = positive trend, Red = negative trend, Blue = Statistically Significant

Effect on Ground Water Level

According to Manzar (2013), the Central Groundwater Board (CGWB) estimates that Nagpur's urban & rural groundwater availability is 6498.86 ham/year. The purpose of this research was to determine whether there is a relationship between the yearly rainfall pattern, temperature, & GWL in the city of Nagpur. The GSDA in Nagpur, which has three monitoring wells in and around the city, was used to get the readings of the groundwater levels (both urban & rural). In order to deduce the trend, the study also looked at the groundwater extraction behavior during the non-monsoon season.

Table 3: Coefficient of Pearson's correlation & p-value for GWL vs Rainfall GWL vs Temperature and GWL versus Evaporation rate

Monitoring Well sites		Bahadura (R)	Bokhara (U)	Makardhokara (U)
GWL Vs Rainfall	Slope	-0.0042	-0.00152	-0.00123
	R-square	0.151	0.031	0.078
	P-Value	0.03388	0.34893	0.13541
GWL Vs Temperature	Slope	-0.0362	0.162	0.0669
	R-square	0.0023	0.0662	0.0116
	P-Value	0.8023	0.532	0.57115
GWL Vs Evaporation rate	Slope	-0.01346	0.03008	0.18054
	R-square	0.001	0.028	0.182
	P-Value	0.9	0.54942	0.02659

Note: Legend: GWL = Ground water level, Green = positive trend, Red = negative trend, Blue = Statistically Significant ($p < 0.1$)

For GWL at Bahadura (R), as shown in table 3, out of all the parameters studied, rainfall demonstrates a weak negative trend with 90% confidence level ($r^2 = 0.151$, $p<0.1$), while the remaining parameters indicate a non-significant weak negative trend. A weak negative trend is observed for rainfall at the

GWL at Bokhara (U), whereas a weak positive trend is observed for temperature & evaporation rate. Neither trend is statistically significant. A low positive trend with 90% confidence level (r^2 = 0.182, $p<0.05$) is observed in the evaporation rate at the final site at Makardhokara (U).

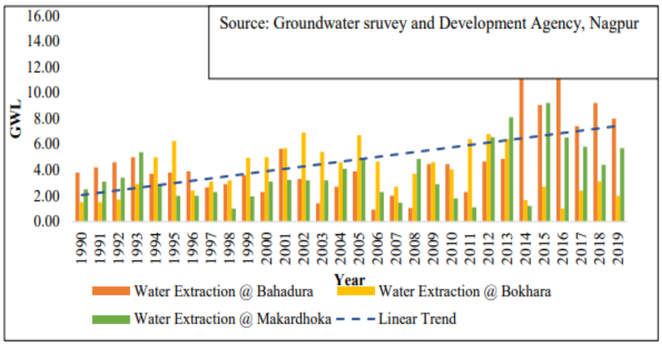


Figure 10: Groundwater level fluctuation during the lean period (January-May)

From 1990 to 2019, groundwater extraction increased throughout the lean period (January to May), as seen in Figure 11. In order to comprehend the extent of extraction in the Nagpur area, the GWL in January & pre-monsoon monitoring in May were examined. From 1990 to 2019, the data reveals a weakly positive trend (R^2 =0.274) in the extraction at Bahadura (R).

CONCLUSION

The major negative effects of industrialization on the environment have begun to spread across the globe. Humans' insatiable hunger and greed have led to the establishment of enormous polluting industries. We need unprecedented levels of cooperation on a global and local level to tackle the global challenge that is climate change. Groundwater levels and groundwater extraction are investigated to see if they are affected by climate variability. In addition, industrialization has its own set of environmental problems. More people may need air conditioning in Nagpur during the hot and humid monsoon season if the city's average temperature continues to climb. Nagpur's climate is going to get hotter with more frequent and intense heat waves, which means that keeping indoor temperatures comfortable will demand a lot of water and energy. This research effort to map out the mining and manufacturing sectors' contributions to the growth of the Nagpur area and its surrounding desert, with a particular emphasis on the region's environmental impacts.

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