ENVIRONMENTAL CARRYING CAPACITY OF AN INDUSTRIAL PARK

A DISSERTATION

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Requirements for the award of the degree

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In

WATER RESOURCES DEVELOPMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this Dissertation entitled, **"Environmental Carrying Capacity of an Industrial Park"** in partial fulfillment of the requirement for the award of the degree of Master of Technology in **Water Resources Development**, submitted to the **Department of Water Resources Development and Management, Indian Institute of Technology Roorkee**, is an authentic record of my own work carried out during the period of June, 2018 to May, 2019 under the supervision and guidance of **Dr. Surendra Kumar Mishra, Professor,** Department of Water Resources Development and Management, IIT Roorkee and Dr. **U.C. Chaube,** Professor Emeritus Shri Vaishnav Vidyapeeth University, Indore (M.P).

The matter presented in this Dissertation report has not been submitted by me for the award of any other degree.

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CERTIFICATE

This is to certify that the above declaration made by the candidate is correct to the best of our knowledge.

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(Yogesh Kumar Meena)

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ABSTRACT

Environmental Carrying capacity refers to the capacity of the environment in a specified region to sustain biotic and abiotic things beyond which the concern for their sustenance shall arise. It depends on a large number of factors including soil cover, water quality, air quality, social factors and so on. It also concerns with steep growth of human population in the region along with other living organisms. In this study, carrying capacity is evaluated for five categories: Meteorology, Land Use/Land Cover, Soil Pollution, Air Pollution, Terrain roughness, Demographic Profile.

An industrial park is a portion of a city that is zoned for industrial use rather than residential or commercial needs. Industrial parks may contain oil refineries, ports, warehouses, distribution center, factories, and so on. In this study, land use/land cover change is shown to have occurred in Singrauli coal field due to rapid expansion of mining and industrial activity during the period 1985-2019. Environmental degradation is the exhaustion of the world's natural resources: land, air, water, soil, etc. It occurs due to over-exploitation of natural resources. Individuals dispose off wastes that pollute the environment at rates exceeding their rate of decomposition or dissipation and are overusing the renewable resources such as agricultural soils, forest trees, ocean fisheries, etc. at rates exceeding their natural abilities to renew themselves. Information from numerous sources have been used to estimate the carrying capacity at appropriate scales. The carrying capacity results are mostly based on the threshold concentrations of the environment. In other words, carrying capacity is determined from the emission that causes the environmental conditions not exceeding the threshold levels.

Singrauli is the 50th district of Madhya Pradesh State of India with its headquarter at Waidhan. It has been formed after disintegrating it from Sidhi district. Singrauli has emerged as an energy hub of the country, especially for thermal electric power and coal, and therefore, it is also locally called as “URJANCHAL”. The total installed capacity of all power plants in Singaruli is about 10% of the total installed capacity of the country.

SO_2 level for the study area is above 700 ppm which is 8 times of the limit specified and NO_2 level measured was 687.2 mg/Nm^3 which is 8.59 times of the limits specified by CPCB, which indicate

that the air carrying capacity of the region is already exhausted (http://cpcb.nic.in/automatic-monitoring-data/).

While the water quality is within desirable limits, indicating that the quality of water is not yet deteriorated to its fullest extent, and thus, the water quality carrying capacity is not exhausted. The data of groundwater table when analyzed indicate its over-exploitation, and consequently, the groundwater availability has declined. Highest depletion of groundwater is experienced in Mara village where the groundwater level has decreased by 10.43 meters from its ground level. There has been a significant reduction in agricultural land due to industrialization and urbanization in the last two decades, and thus, there is a stress on agricultural land. On the other hand, a significant increase in Coal Mines and Built-up area has been observed. Since the major population of Singrauli region depends on agriculture, the future is not green enough. The drainage density of region in 2014 was 0.52km/km^2 (up to order 3) while in 2017, it reduced to 0.06km/km^2, indicating that the conversion or burial of drains has taken place in the region due to industrialization and urbanization.

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CHAPTER 1
INTRODUCTION

The knowledge of carrying capacity helps in management of environmental practices being or to be followed in the area of concern. Carrying capacity is a broad concept varying with stakeholders, such as from person to person, institution to institution, and region to region. For example, if one NGO related to environment and another related to Private owned industry performs an assessment for the carrying capacity of a lake or a dam, it is quite likely that NGO would see the distortion in quality of resources whereas the other would see in terms of maximum over-exploitation of the water resources.

1.1 CARRYING CAPACITY

Miler et al. (2002) defined Environmental Carrying Capacity as the size of population that can thrive for an indefinite period of time without causing any harm to the environment. It is a measurable term in which both biotic and abiotic things are considered as measurable variables. Carrying capacity plays an important role in designing a blueprint of development in a sustainable manner without compromising environmental resources. It will be very helpful in decision-making process of large projects. Assessment of carrying capacity is very complex and time-consuming as it is purely based on (a) individual's perception which is a subjective term that varies from project to project and (b) a clear understanding of the variables affecting the carrying capacity of the project.

The following research gaps can be identified from the literature survey:

- The environmental carrying capacity is not assessed in finer context for the specified area. It is usually considered an assessment of regional environmental resources. The aspects of environmental carrying capacity are however much wider as it also includes the aspects of resources, environment, recycling economy, sustainable development degree, etc.
- Singrauli has been declared as power hub of India, emphasizing that the region has a large number of thermal power plants as well as coal mines degrading the quality of the resources

of the region in various aspects that are yet to be explored, and degradation of resources yet to be quantified (BK Misra et al. 1993).

- Studies have been carried out on water, air, and other ecological parameters in terms of environmental quality degradation, but the quantity of degradation is not much studied to date (PK Rai et al. 2010).

In the last few decades, environmental deterioration has taken place severely in many parts of the Singrauli region. Therefore, there is an urgent need of environmental carrying capacity assessment which would act as an indicator for alarming environmental deterioration. In this study, an attempt has been made to consider and analyze various factors that impact the environment directly or indirectly, such as socio-economic, air, water, etc.

The study area covers the Singrauli region involving the area around Rihand reservoir as well as industries such as Coal Mines, Thermal Power Plants, and major and minor industries in the surrounding area. It shall include the following disciplines: Land Use Land Cover, Meteorology, Socio-Economic, Water quality, and Air Quality.

1.2 OBJECTIVES

The study is carried out with the following objectives:

- To assess the environmental carrying capacity of Singrauli region.
- To study the impact on LULC and drainage density of the Singrauli region over the years.
- To suggest appropriate preventive measures for a sustainable environment in the Singrauli region.

1.3 ORGANIZATION OF DISSERTATION

The chapter consists of five chapters which describe their respective subject matter.

Chapter 1: Introduction

It describes the historical background of the environmental carrying capacity, its evolution, and its need, and finally sets the objectives of the study.

Chapter 2: Literature review

It reviews the literature on carrying capacity considering different aspects.

Chapter 3: Study Area

It describes the study area, its location, geographical area, meteorological parameters, air quality, and water quality, etc.

Chapter 4: Materials and methodology

It primarily describes the data collected for the study.

Chapter 5: Results and discussion

It analyses the data and discusses the results with respect to LULC change, drainage density change, groundwater level change, etc.

Chapter 6: Summary and Conclusions

It summarizes the study and derives conclusions and finally provides recommendations for future work.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

2.1.1 Carrying Capacity

Paehlke et al. (1999) assessed the carrying capacity of California, which is concerned with the steep growth in the human population along with other living organisms. When a specific community or species increases rapidly, it tends to diminish other population that leads to overexploitation of resources and creates an imbalance in the ecological cycle causing reduced resources for mankind.

Dashefsky et al. (1993) stated that when population growth is rapid, it results in differences created between the existing production and replenishment of resources. It further leads to several environmental related problems.

Joel E. Cohen et al. (1995) conducted a study on "how many people on the earth can support" stated that the carrying capacity is connected with the human population. Carrying capacity can be explained in different ways with respect to different variables, such as social, economic and environmental. These are the basic and broad areas of environmental carrying capacity. Variables can include supplies, materials and basic amenities in close correlation with environmental factors like climate, temperature, wind speed, etc. The demographic profile of the area (marriage, death rate, birth rate, migration, etc.) plays a crucial role in determining the carrying capacity of the area. In today scenario, it is nearly impossible to access the natural variables as, in the progressive world, the development costs our natural resources and the constraints have unpredictable consequences.

Eliabeth A Viau (1999) elaborated the carrying capacity with respect to both human beings and animals. The environmental territory is very important maintaining the ecological hierarchy and ecological cycle of animals. Elizabeth defined the ecological food chain of animals and summarizes it into nature to kill or get killed. This is the result of the competition between the animals to survive.

Van Gilas et al. (2004) suggested some additional measures to improve the existing models. The previous models were based on the “standing stock“type models which assumed that the resources are not replenished after the consumption. The current population does not consider the demographic profile of the area. Without modification, the models are not accurate because it considered the nature and ecology of nature as predictable in nature which actually is not predictable in nature.

Squires et al. (2004) carried out a study on Land Capability assessment and estimation of the pastoral potential of semiarid rangeland in South Australia. He as such carried out the carrying capacity using Environmental Resource Assessment and Management System (ERAMS). It is a computer-aided program (CAD) developed to carry out the potential and present pastoral productivity of arid and semiarid regions. This model is based on soil water availability and determines land sustainability. The same method can be used to carry out the productivity of the land in the industrial area.

Pulastu et al. (2003) carried out a study on carrying capacity of rainbow trout in Kessikkopru Dam Lake. Phosphorus budget model was used for determining the productivity of the lake using Phosphorus as a major variable affecting the productivity of the lake. While considering these variables, certain assumptions are included, and therefore, these models are not accurate enough. Similarly, in carrying out the carrying capacity analysis of reservoir, the productivity of the reservoir can be considered as the reservoir carrying capacity variable.

Matsuda et al. (2006) stated that the carrying capacity cannot be managed by specific guidelines and protocols. The carrying capacity is subjective in nature, not objective, so there is no specific protocol to evaluate it. It depends on the nature of the project and environmental conditions in the area. Carrying capacity must be understood first. It is also defined as “Amount of change than a function over an acceptable limit,” It is a subject-specific concept; each case requires its own subject-specific decision-making models that also involve the potential effect on stakeholders. He gave a definition of decision makers as “have to incorporate uncertainty and unpredictability in management into the decision-making process”.

Manning et al. (2004) studied how a tourist in a particular area can affect the carrying capacity of National Parks, with the development and increase in accessibility to these parks. The study states that with the increase of encroachment of human into national parks and expansion of urban agglomerations, the congestion and precisely interference in national parks will only increase.

Miller et al. (2002) defined carrying capacity as “the number of individuals of a given species that can be sustained indefinitely in a given space, area or volume”. It means that the carrying capacity of the area can also be defined by considering the population as a resource variable in a particular area. In an example, at the micro level in sewage treatment plant, bacteria first eat the organic matter if food is less, then endogenous respiration starts it means resources are less and population is more so they try to kill each other and on macro level a country where shortage of water exists, people fight with each other for water that is the typical case of resource shortage and overexploitation of resources.

Miller found four major reasons affecting carrying capacity:

- Competition between and within the species
- Migration and immigration
- Catastrophic conditions directly or indirectly created by humans.
- Extra burden on resources by uncontrolled expansion of population and overexploitation of resources

Swenson et al. (1998) dealt with the polar bear population expansion. He explains “how the polar bears in Sweden population start growing in a suitable environment that is almost near extinction have affected the carrying capacity of that area because they are the important part of the food chain and food web.

Zawartz et al. (1995) studied “carrying capacity in respect of overwintering birds, largely based on the availability of food to migratory birds. The study reveals how many days a migratory bird except the breeding season can sustain in the region. The study used the Daily Ration Model (DRM) and Spatial Depletion Model (SDM), where DRM deals with daily food availability and SDM is used when the food density patches are treated individually. Both DRM and SDM exhibited similar results but DRM proved better than SDM.

Singer et al. (2001) studied about "Role of patch Size, Disease, and Movement in Rapid Extinction of Bighorn Sheep", largely with the growth of migratory sheep's and large patch sizes improves the carrying capacity

2.1.2 Land Use / Land Cover

Viswakarma et al. (2016) analyzed the landscape changing pattern using Landsat data 1991, 2000 and 2014. Deforestation rate in 2000-2014 was more than that in 1991-2000. There is significant increase seen in the mines in 2000-2014 and forest patches have either converted into agriculture or barren land. In all these studies it was observed that the progress of mining activities have caused forest loss and many transformations in LULC patterns. This study focuses on the impact of mining on forests and LULC pattern using satellite remote sensing data and GIS. It analyzed the spatial-temporal changes related to mines and its expansion over the years 1976, 2002, 2010 and 2015 along with simultaneous forest loss.

Ahmed et al. (2017) observed that the forests are at present facing threat because of various reasons. One such reason is the blooming of the mining industry. It has many adverse impacts on the forest environment, water resources and wildlife habitat. Evaluation of such impacts time to time and controlling the negative aspects to promote sustainable living would benefit the nation and the people. This study attempted to evaluate the spatial and temporal expansion of mines near Singrauli district (Uttar Pradesh and Madhya Pradesh border) since 1976. Amidst the dry tropical forests, the mines are prevalent since the 1980s and are now a threat to the health of these forests. Satellite remote sensing data have the potential to observe large areas at regular intervals. Further, in the GIS domain, the area statistic can be computed for quantifying the actual loss or gain in various LULC classes. The temporal datasets for the present case were from Landsat (1976, 2002, 2010 and 2015). After the image processing and classification, the expansion of mines and transformation of various LULC classes were observed. The loss of forests and conversion to other land use was analyzed between different time periods. It was observed that the annual increase in the mines area is 4.25 times higher than that in the period (2010-2015) to (1976-2002). Continuous losses in the annual forest cover were due to an increase in the mining area between the study periods (1976-2015).

Dhar et al. (1985) stated that with rapid industrialization the consumption of coal resources increases exponentially. In comparison to coal production, much less attention is paid to the ecological aspects of the coal mining industry. This is perhaps because the disastrous effect caused by newly modified environments due to mining in a particular area is not immediate, but effects are visible after a period of time. Hence, with the adoption of advanced technology for higher production, India is gradually heading towards irreversible environmental damage brought about by land degradation, deforestation, water pollution, air pollution, and noise pollution. As a part of an exercise to study the impact of large scale open-cast mining operations, Singrauli Coalfield is an excellent example. This study attempted to cover various sources of water pollution in Singrauli opencast coal mine at one place and the measurement of chemical parameters of water to assess the water quality degradation in and around the mine.

CHAPTER 3
STUDY AREA AND DATA AVAILABILITY

Singrauli is the 50th district of Madhya Pradesh, which is separated from the direct district of Madhya Pradesh. It is a district of Sonbhadra district in Uttar Pradesh. Historically Singrauli, Rewa was an area of Baghel Mandal state. Singrauli is known as the hub of industrialization for the present era. It is known as “Urgjanchal” due to mineral resources and thermal power plants. There is a large area of natural and mineral resources which is essential for modern industries.

Archaeological evidences from the area indicate the city to be of ancient origin. For a very long period of its known history, it was lost in a land time, settled between forests and inaccessible terrain. Painted rock shelters from Chitrangi go back in the 7th-8th century. Rock Caves of Mada Rock Cat Caves have been the largest of the single rock and are dedicated to various deities. Some of the rock caves are also rich sources of knowledge about our cultural heritage, like Madha, which is famous for being the place of Lord Rama and Sita's marriage. Other rock caves like Ganesh Mada, Ravana Mada, etc. are very important from the scope of the scriptures that have been declared as protected monuments by the state government.

In modern times, the city has become an important center of coal mining and power industry. With the onset of industrialization, many new projects were started in the region. One such project was the Rihand Dam which was constructed inaugurated in 1962. The dam has completely changed the look of the city. Singrauli became the 50th district of Madhya Pradesh on 24th May 2008. With its headquarters in Baidhan, it was formed after dividing it directly from the district. With three districts Singrauli, Devsar, and Chitrangi, it is one of the fastest growing economic areas in Madhya Pradesh.

3.1 LOCATION AND ADMINISTRATIVE DIVISIONS

Singrauli district is located on the border of the eastern part of Madhya Pradesh. The district is having its boundary with U.P. and Jharkhand states. Its location made its position important in terms of the intrastate transportation system. It is a newly formed district which came into existence in the year 2008. This district is also known as the power zone of the state. Because it has enormous coal reserve and power generating Industries which makes this place most important in terms of non-renewable energy resources. It has its own pros and cons of its location like Naxalism is one problem which provoked with its location on borderline as well as its mineral resources. The administrative profile of the Singrauli district which is shown in table 3.1, includes the geographical coordinates and district- administration related information.

Table 3. 1 Administrative profile of Area

Location	Latitude – 24.32	Longitude – 82.69
District Area (in Hectares)	567486	
No of Blocks	Waidhan	
	Deosar	
	Chitrangi	
Year of Formation	24th May 2008	
Adjacent District	In West Sidhi district of M.P.; In north and east Mirzapur, Sonbhadra district of U.P.; In South Sarguja and Koriya district of Chhattisgarh	

3.2 GEOGRAPHY AND TOPOGRAPHY:

The topography of Singrauli is mountainous in nature, having seasonal and perennial rivers like Gopad, Son, etc. A large area of Singrauli district falls under forest cover and typical slopes which make the area a rough terrain. In table 3.2 the geographical profile of Singrauli is shown, which includes water bodies, dams, hills, and existing mountains.

Table 3. 2 Geographical Profile of Singrauli

Name of rivers and lakes:	Son river, Mahaan river, Kachani river, Mahaan river, Mayaar river, Gohwaiya river, Rihand River, Kanchan, Chalki, Kanjas, Silhor, Bijul, Kamjhawan, bukuru, Juri, Kahkan, Badhaniaya Nala Gopad river
No. of dams, embankments:	Obra dam, Badwani dam Rihand dam Kaachan dam Tippa Jharia dam.

Hills	Silyari, Chhuiya, Kharawan, Vihara, Teldah,Tarkedei , Chela Pahar, Chhuiya, Uska, Chokra, Burma Pahar,
Name of existing mountains:	Rock cut caves (Moda caves); Painted rock shelters (Ranimachi, Dholagiri and Goura rocks in Chitrangi block). Rakashganda fall, Neelkanth river, and Kudargarh fall.

3.3 THERMAL AND HYDROPOWER PLANTS IN SINGRAULI REGION

Table 3.3 indicates the thermal power plants existing in the Singrauli region and these are combinedly generating more than 15000 MW which is the 7.82% of the total coal-based electricity production of the country. The thermal based electricity production is 54.60 % of the total electricity production in the country (powermin.nic.in), and therefore, this region is treated as a power hub of the country.

Table 3. 3 Thermal Power Plants in Singrauli (M.P) and Saunbhadra (U.P)

S.No	Name	Company	Capacity
1.	Vindhyachal Super Thermal Power Station	NTPC	4760 MW
2.	Shaktinagar N.T.P.C. Thermal Power Plant	NTPC	1000(2*500)
3.	UPRVUNL Anpara Thermal Power Plant	UPRVUNL	3,830
4.	Renusagar Thermal Power Plant	HINDALCO	801.57
5.	Reliance Sasan Ultra Mega Power Project	Reliance	3960
6.	Anpara ‘C’ Lanco Thermal Power Station	LANCO	1200
7.	Essar Power Mahan Thermal Power Plant	ESSAR	1,200
8.	Obra Power Plant	UPVUNL	722
9.	J P Niegre,	JAYPEE	1320
10.	Rihand NTPC	NTPC	3000

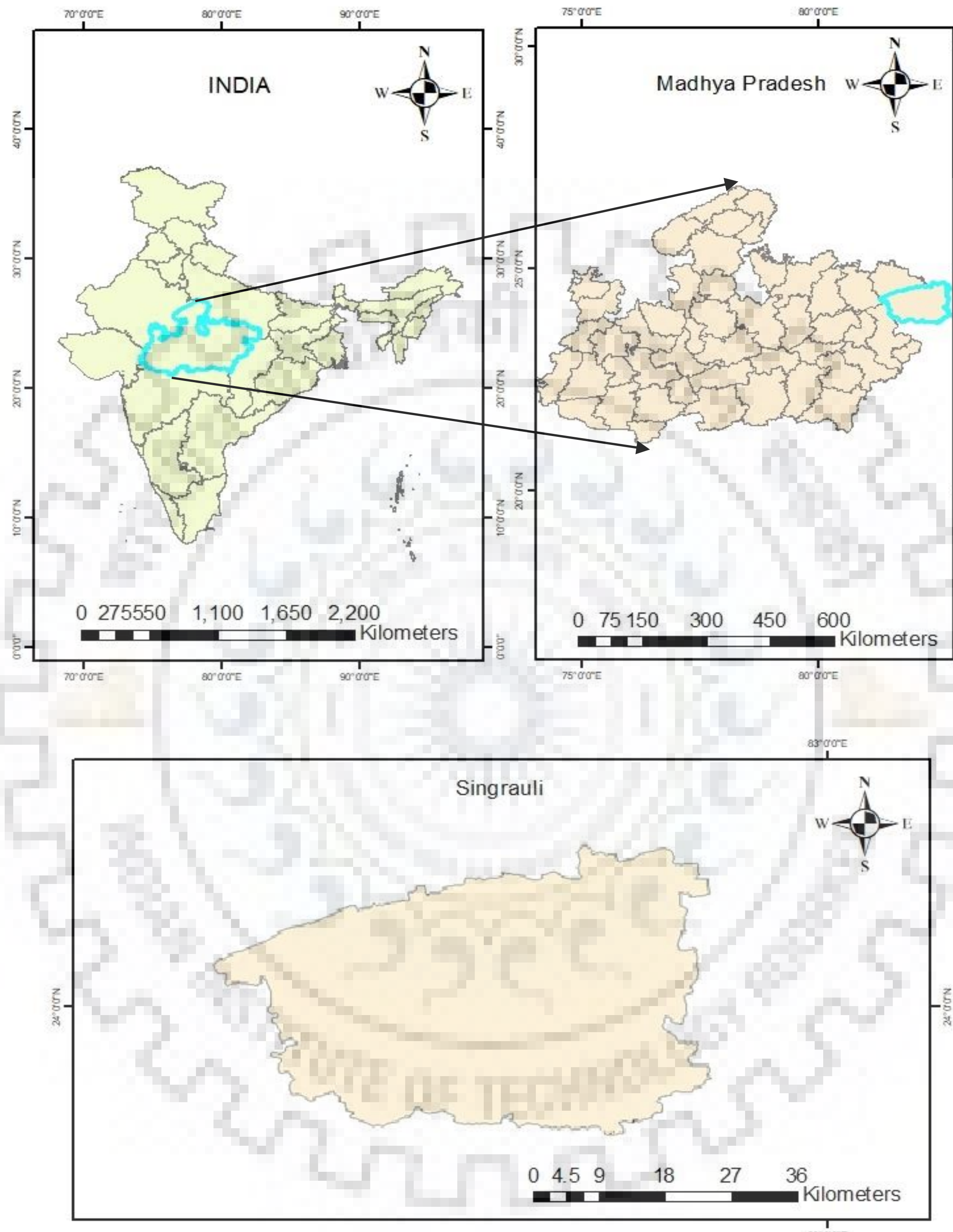


Figure 3. 1 Singrauli Map

3.4 DATA AVAILABILITY

3.4.1 Meteorology

The meteorological data like temperature (maximum and minimum) precipitation, relative humidity and wind velocity have been taken from https://globalweatherweatheronline.com for one location in the study area, i.e. Singrauli (M.P). The Singrauli region experiences semi-arid climate, the region experiences hot summer as wells winters, and in pre-monsoon period the area experiences water shortage and dryness throughout the year except during monsoon season.

Table 3.4 shows meteorological parameters like temperature, rainfall, wind speed, and relative humidity.

Table 3.4 Meteorological parameters

Parameter	Temperature (in ºC)		Rainfall (mm)	Wind (Km/h)	Relative Humidity
	Maximum (daily)	Minimum (daily)			
Yearly average	33.77	18.35	2.58	2.00	0.49
Maximum (yearly)	52.85	32.04	143.05	5.49	0.96
Minimum (yearly)	6.18	-0.84	0.00	0.45	0.06
Maximum variation (average)	2.85	3.49	3.38	0.38	0.12

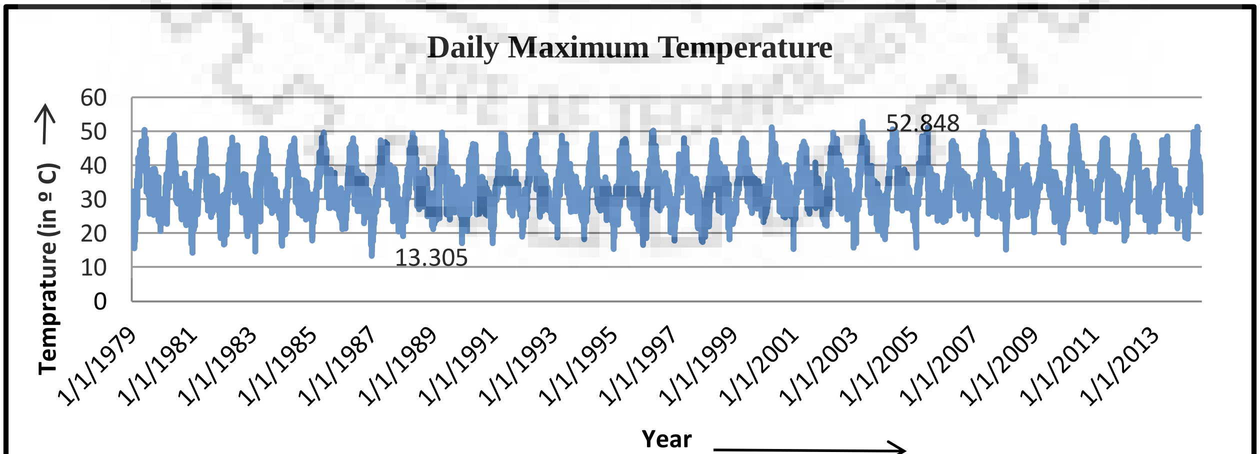


Figure 3. 2 Daily maximum temperature

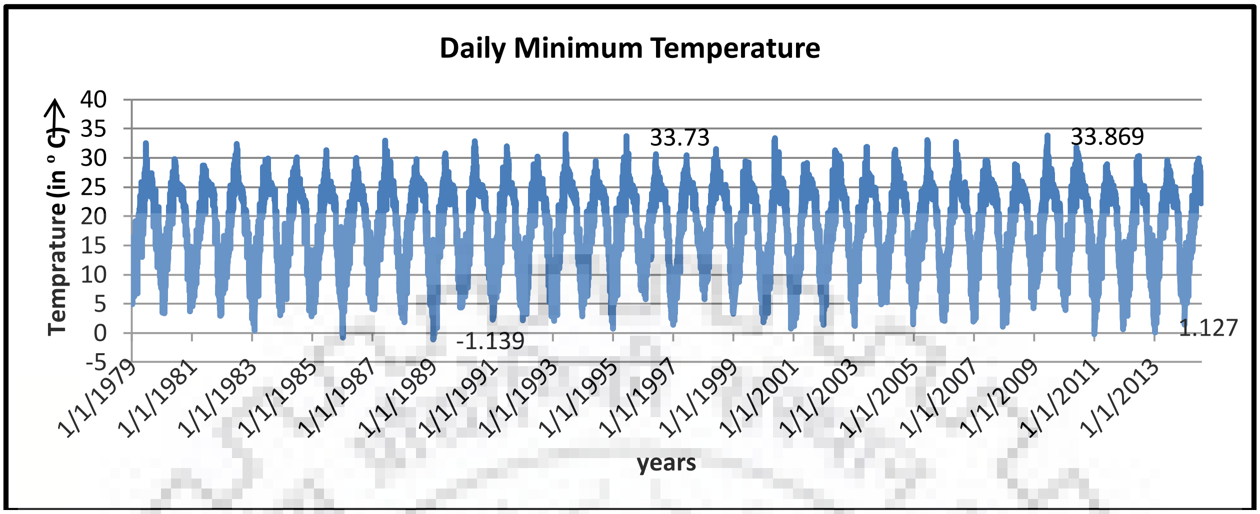


Figure 3. 3 Daily Minimum Temperature

Figures 3.2 and 3.3 show daily maximum and minimum temperature variation from the year 1979 to 2014. A trend can be observed during January; the temperature is comparatively lower while moving towards June an increasing trend in temperature is observed and the lower temperature will move towards December. The temperature affects the dispersion of air pollutants in the environment.

3.4.2 Windrose Diagram

The wind rose diagram (Figure 3.4) indicates the wind incidence frequency in a particular direction. For each site having different rose Diagrams for each and every place that indicate time variation of wind speed in different directions. The wind rose diagrams are widely applicable in fields such as environmental impact assessment, industrial emission measurements, oceanography, wind energy, agriculture engineering, ambient air monitoring, air quality measurements, indoor air quality testing, air dispersion modeling (Lira et al. 2012), noise impact modeling and soil impact modeling (India Meteorological Department, 2014). The wind rose diagram shows the wind flow in a particular direction in the year and the intensity of the wind. Fig. 3.5 shows the number of days in a year in which the direction of the wind is specified. Figure 3.6 shows cumulative hours in particular wind velocity.

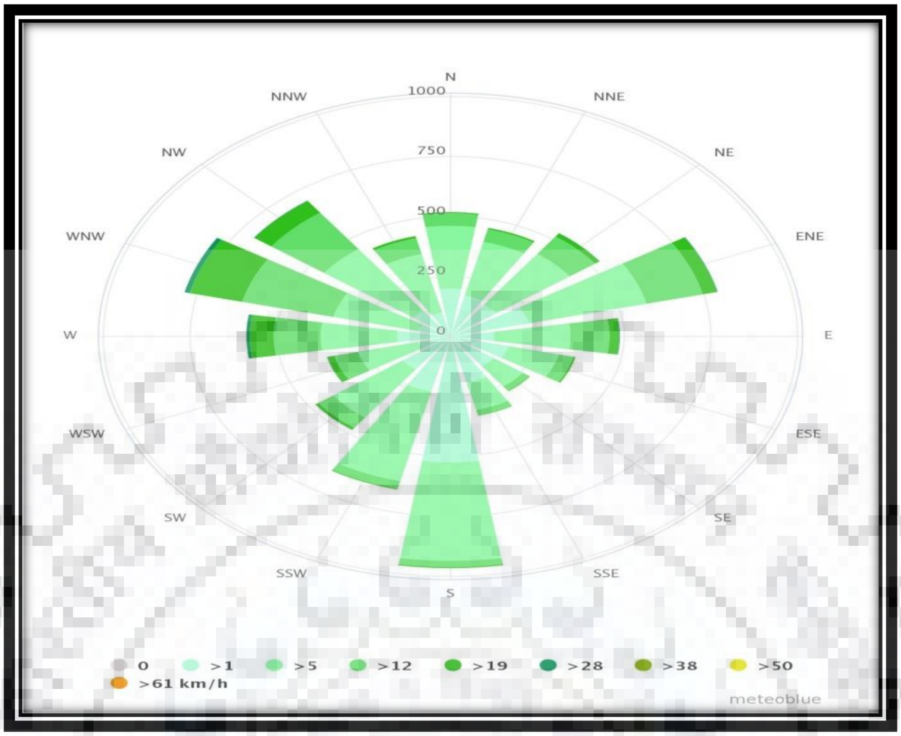


Figure 3. 4 Wind Rose Diagram

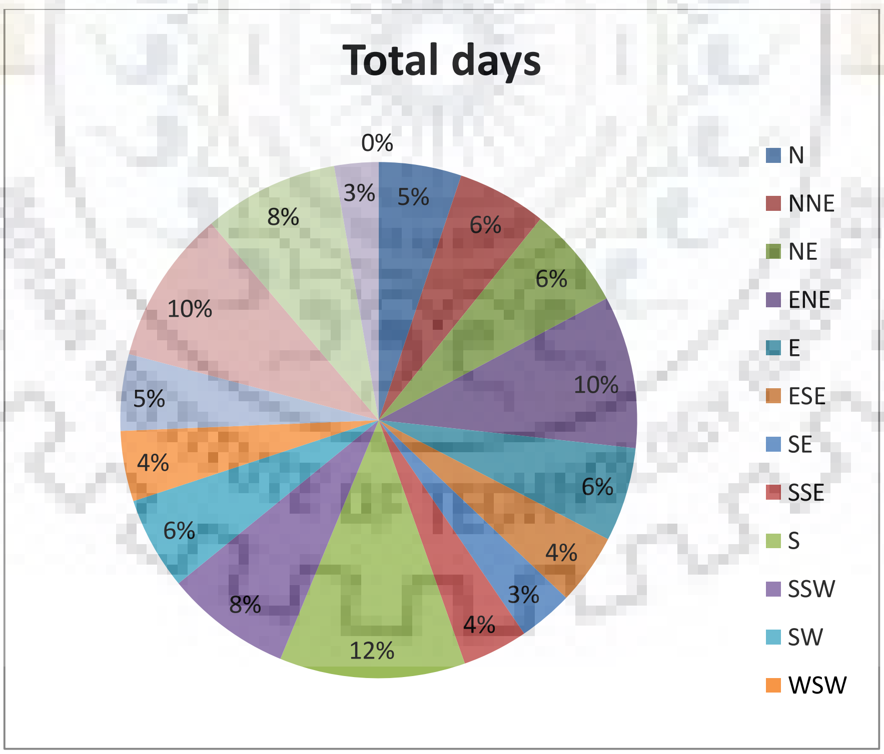
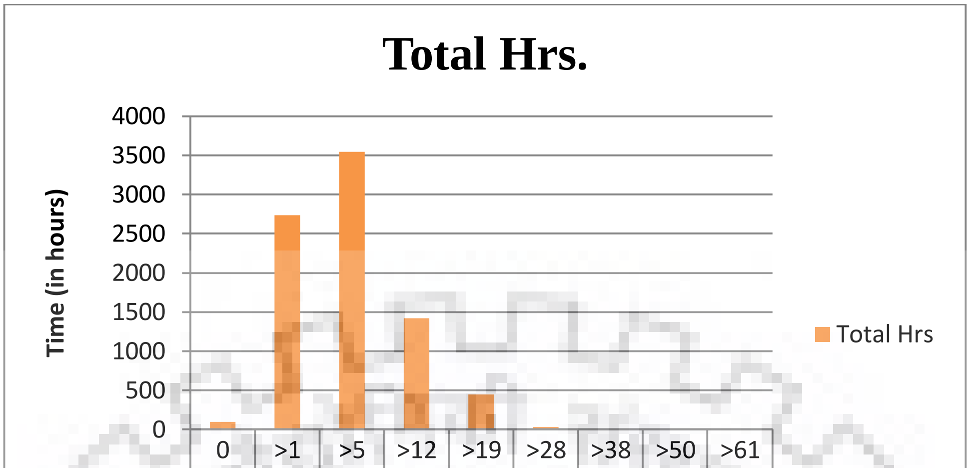


Figure 3. 5 Day wise distribution of wind direction in a year



	0	>1	>5	>12	>19	>28	>38	>50	>61
Total Hrs	94	2735	3544	1423	447	34	0	0	0

Figure 3. 6 Total times in hours versus wind speed

3.5 GROUND WATER LEVEL

The groundwater table is an important indicator to show the decrement in water availability of the particular region. The decline in water level can be an indicator of, for example, increase in population, increase in industries, drought, etc.

3.5.1 Location of Sample Wells

The data has been obtained from India-WRIS for Singrauli district by identifying the locations of dug wells which provide the data for the ground water table (Fig. 3.7).

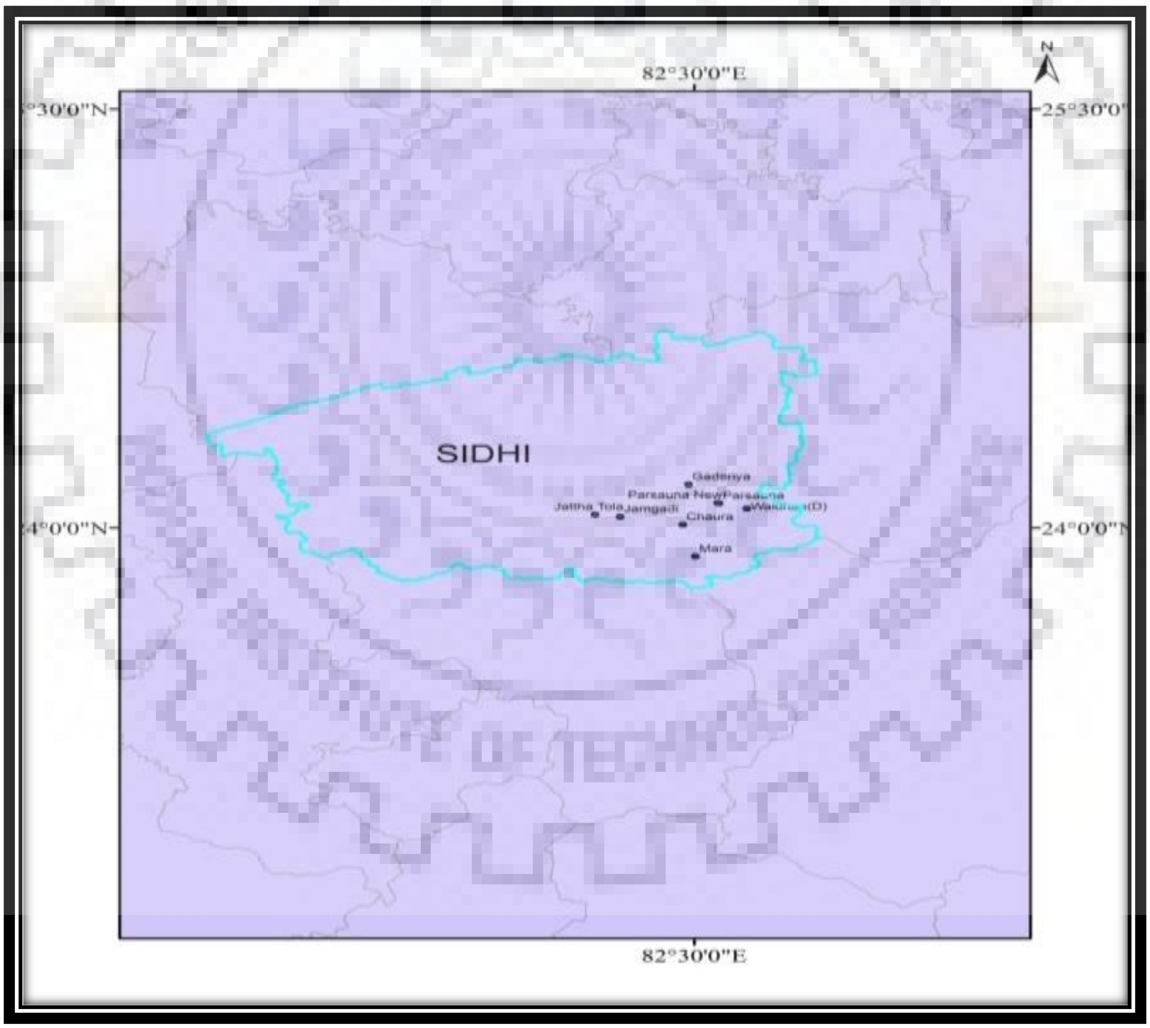


Figure 3. 7 Location of dug and borewells

The data were collected for four seasons

- Monsoon
- Post-Monsoon Rabi (POMRB)
- Post-Monsoon Kharif (POMKH)
- Pre Monsoon (PREMON)

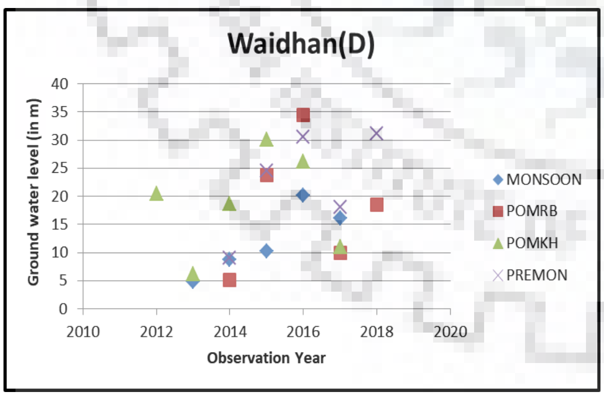
Table 3. 5 Depletion of Groundwater Level at different locations

Village NAME	MONSOON		POMRB		POMKH		PREMON	
	YEAR	VALUE	YEAR	VALUE	YEAR	VALUE	YEAR	VALUE
CHAURA	**2015**	**4.9**	**2016**	**10.13**	**2015**	**6.53**	**2018**	**11.75**
GADERIYA	**2014**	**4.1**	**2015**	**4.11**	**2014**	**4.35**	**2015**	**4.6**
JAMGADI	**2015**	**5.8**	**2016**	**6.92**	**2015**	**6.32**	**2016**	**7**
JATTHA TOLA	**2015**	**6.3**	**2016**	**6.55**	**2015**	**6.45**	**2016**	**6.85**
MARA	**2008**	**10.43**	**2010**	**11.25**	**2010**	**10.79**	**2000**	**12.93**
PARSAUNA	**2011**	**8.5**	**2009**	**8.5**	**2008**	**8.5**	**2009**	**8.5**
PARSAUNA NEW	**2015**	**6.1**	**2016**	**8**	**2017**	**8.9**	**2015**	**9.29**

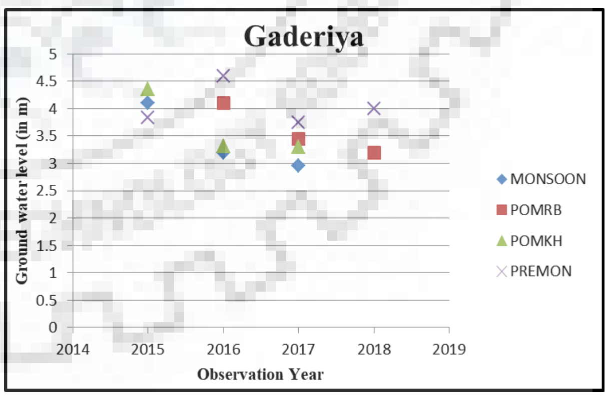
Note – All Values are in a meter

3.5.2 Ground Water Level Data of Different Sites

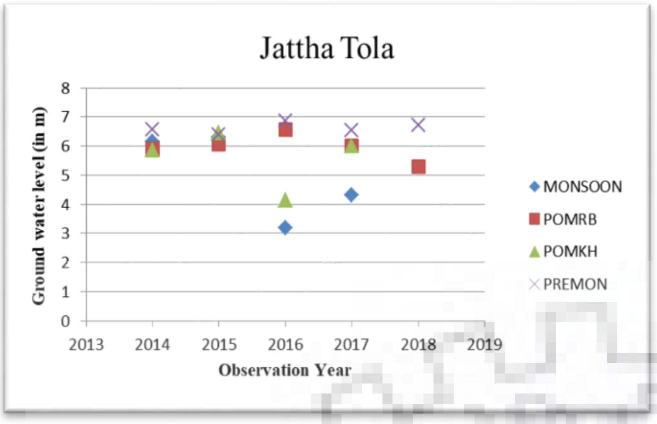
The data collected from six locations from India-WRIS site for the sites, **Chaura, Gaderiya**, Jamgadi, **Jattha Tola, Mara, Parsauna, and Parsauna New** are shown in Figure 3.8. This figure shows a change in ground water level with time at different locations. These graphs help describe the trend line of groundwater declination.



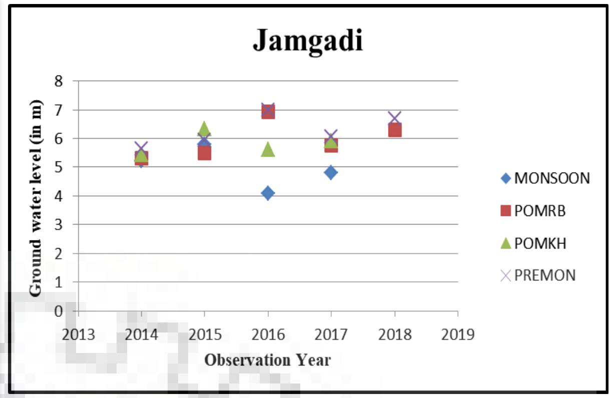
(a)



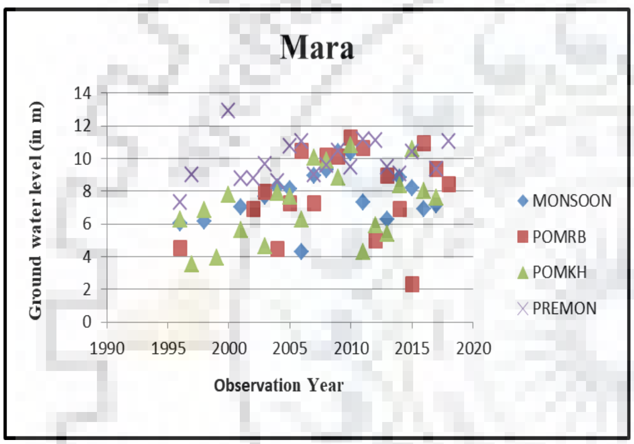
(b)



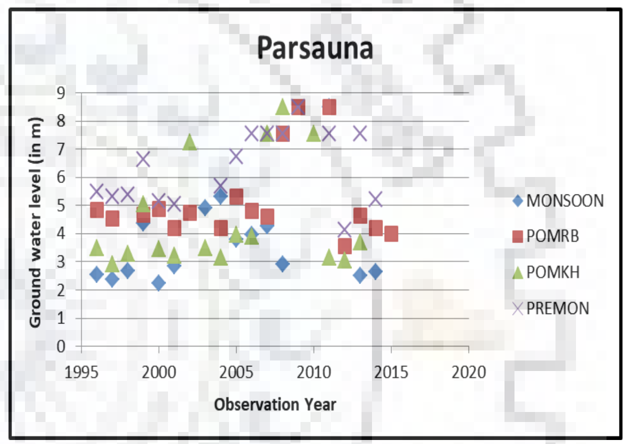
(c)



(d)



(e)



(f)

Figure 3. 8 GWL Scatter chart of (a) Waidhan (b) Gaderiya (c) jattha tola (d) Jamgadi (e) Mara (f) Parsauna

3.6 WATER QUALITY

3.6.1 Water Quality Standards as Per CPCB

(a) Drinking water standards

Different water quality standards have been mentioned by the Central Pollution Control Board (CPCB) with the context of the Indian environment and geography. Some of these are shown in Table 3.6.

Table 3. 6 CPCB Guidelines for Drinking water

Designated best use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20C 2mg/l or less
Outdoor bathing (Organized)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Propagation of Wildlife and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25C micromhos/cm Max.2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

3.6.2 Groundwater Quality

Groundwater quality plays is an important carrying capacity indicator because the area is having Ash ponds, Coal Mines and many heavy Mineral based industries. The effluent from industries is either dumped into river or reservoir while the ash which is the by-product of the thermal power plant fuel and grade coal stored in dumping yards which are located near the reservoir, as seen in the LULC, there were traces of water which finally seeps into the ground and meet the groundwater table, and therefore, heavy metals must be tested. Thus, it is an important indicator to assess the carrying capacity of the area.

From the literature and groundwater data from INDIA-WRIS indicates that most villages in the nearby area of Singrauli area use either hand pumps or wells to meet their domestic as well as agricultural needs. The groundwater and surface water quality data were taken from the Sasan Power plant environment compliance report and these have been given in Tables 3.7 & 3.8 respectively. Groundwater quality parameters and their respective values for April 2018 have been shown in Table 3.9. The values of the parameters appear to have exceeded the prescribed limit in the study area and hence need attention.

Table 3. 7 Sampling location of groundwater quality

Location	Location name
GW1	Siddhi Khurd Village
GW2	Sasan Village
GW3	Harrahwa Village
PW1	Service Building
PW2	Township Canteen
PW3	Poorvanchal Canteen

Table 3. 8 Sampling location of surface water quality

Location	Location name
SW1	Harrahwa Village
SW2	Mayar River
SW3	Rihand River

Table 3. 9 Ground water quality parameters for April 2018

GROUND WATER QUALITY							
April 2018							
Parameters	**IS:10500**	**Monitoring Location**					
		GW1	**GW2**	**GW3**	**PW1**	**PW2**	**PW3**
pH	6.5-8.5	7.31	6.73	7.16	7.09	6.89	7.1
Color (Hazen Units)	15	2.8	3.4	1.81	BDL	BDL	BDL
Odor	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
Turbidity (NTU)	5	BDL	BDL	BDL	BDL	BDL	BDL
TDS (mg/l)	2000	330	340	367	135	160	162
Total Alkalinity (mg/l)	600	144	128	112	68	52	48

Total Hardness as CaCO3(mg/l)	600	148	136	132	88	68	60
Calcium as Ca(mg/l)	200	41.6	38.4	40	20.8	17.6	12.8
Magnesium as Mg(mg/l)	100	10.69	9.72	7.77	8.74	5.83	6.8
Free Residual Chlorine(mg/l)	1	BDL	BDL	BDL	BDL	BDL	BDL
Total Ammonia (mg/l)	0.5	BDL	BDL	BDL	BDL	BDL	BDL
Boron (mg/l)	1	BDL	BDL	BDL	BDL	BDL	BDL
Chloride as Cl (mg/l)	1000	18	32	24	28	16	20
Sulphate as SO4 (mg/l)	400	24.6	31.6	16.2	12.1	25.2	18.5
Fluoride as F (mg/l)	1.5	BDL	BDL	BDL	BDL	BDL	BDL
Nitrate as NO3 (mg/l)	45	10.1	20.3	11.1	5.99	2.5	BDL
Phenolic Compound (mg/l)	0.002	BDL	BDL	BDL	BDL	BDL	BDL
Mineral Oil (mg/l)	0.5	BDL	BDL	BDL	BDL	BDL	BDL
Sulphide as H_2S (mg/l)	0.05	BDL	BDL	BDL	BDL	BDL	BDL
Anionic detergent (mg/l)	1	BDL	BDL	BDL	BDL	BDL	BDL
Total Coli form (MPN/100ml)	detected in 100ml sample	Absent	Absent	Absent	Absent	Absent	Absent
E. Coli (No’s/100ml)	detected in 100ml sample	Absent	Absent	Absent	Absent	Absent	Absent

3.6.3 Surface Water Quality

The surface water quality is also a carrying capacity indicator for qualitative analysis. The Singrauli region has one of the eighty-eight industrial clusters of India and CPCB considered it as the fourth most polluted cluster in India. The region has many industries in the region, which also indicates the region having a high population density. The industrial effluent and domestic effluent are the major sources of surface water pollution. To determine, the carrying capacity, the analysis of surface water quality can be an important indicator. The surface water collected from the three locations Harrahwa Village, Mayar River, and Rihand River for the month of April 2018 and June 2018 have been analyzed and the values are shown in Tables 3.10 (a) & (b) respectively. The values show great variation from the codal values given by CPCB.

Table 3. 10 Surface water quality parameters for (a) April 2018 (b) June 2018

(a)

SURFACE WATER QUALITY				
Month -April 2018				
Parameters	**IS:2296 Class 'C' Limits**	**Monitoring Location**		
		SW1	**SW2**	**SW3**
pH	6.5-8.5	7.06	8.4	7.42
Color (Hazen)	300	130	172	155
Total Dissolved Solids (mg/L)	1500	346	352	270
Dissolved Oxygen (mg/L)	4	5	4.9	4.8
BOD (mg/L)	3	1.5	1.4	1.35
Chloride (mg/L)	600	48	38	34
Cyanide (mg/L)	0.05	BDL	BDL	BDL
Fluoride (mg/L)	1.5	0.37	0.42	0.35
Sulphate (mg/L)	400	41.5	29.1	27.1
Phenolic Compound (mg/L)	0.005	BDL	BDL	BDL
Anionic detergent (mg/L)	1	BDL	BDL	BDL
Oil and Grease (mg/L)	0.1	BDL	BDL	BDL
Nitrate (mg/L)	50	16.8	12	19.1
Arsenic (mg/L)	0.2	BDL	BDL	BDL
Copper (mg/L)	1.5	0.152	0.05	BDL
Iron (mg/L)	50	3.69	7.45	1.3
Zinc (mg/L)	15	BDL	BDL	BDL
Cadmium (mg/L)	0.01	BDL	BDL	BDL
Chromium as Cr6+ (mg/L)	0.05	BDL	BDL	BDL
Selenium (mg/L)	0.05	BDL	BDL	BDL
Lead (mg/L)	0.1	BDL	BDL	BDL
Mercury (mg/L)	0.001	BDL	BDL	BDL

(b)

SURFACE WATER QUALITY				
Month -June 2018				
Parameters	**IS:2296 Class 'C' Limits**	**Monitoring Location**		
		SW1	**SW2**	**SW3**
pH	6.5-8.5	7.25	7.56	7.4
Color (Hazen)	300	138	164	142
Total Dissolved Solids (mg/L)	1500	455	440	420
Dissolved Oxygen (mg/L)	4	5	5.1	5.2

BOD (mg/L)	3	1.56	1.15	1.6
Chloride (mg/L)	600	64	50	60
Cyanide (mg/L)	0.05	BDL	BDL	BDL
Fluoride (mg/L)	1.5	0.38	0.42	0.55
Sulphate (mg/L)	400	46	27	32
Phenolic Compound (mg/L)	0.005	BDL	BDL	BDL
Anionic detergent (mg/L)	1	BDL	BDL	BDL
Oil and Grease (mg/L)	0.1	BDL	BDL	BDL
Nitrate (mg/L)	50	20	22	20
Arsenic (mg/L)	0.2	BDL	BDL	BDL
Copper (mg/L)	1.5	0.2	0.061	BDL
Iron (mg/L)	50	2.6	1.12	1.37
Zinc (mg/L)	15	BDL	BDL	BDL
Cadmium (mg/L)	0.01	BDL	BDL	BDL
Chromium as Cr6+ (mg/L)	0.05	BDL	BDL	BDL
Selenium (mg/L)	0.05	BDL	BDL	BDL
Lead (mg/L)	0.1	BDL	BDL	BDL
Mercury (mg/L)	0.001	BDL	BDL	BDL

3.7 AIR POLLUTANTS

There are ten thermal power plants operating with a capacity of **17963.57 MW.** Since India is the developing country and the demand for energy is high, we try to exploit our natural resources that directly or indirectly affect the Earth carrying capacity of resources. Air is one of the important resources of the environment and essential for survival. The thermal power plants reduce the carrying capacity of air by distorting the air quality by their gas emissions which are generally high. In this study, DSPIR model was used that gives us a clear picture of the impacts of industries such as thermal power plants, coal mines, etc. that can pollute the air. The parameters taken in the model study are compounds of NO_2, SO_X, $PM_{2.5}$, etc. as shown in Table 3.12.

Table 3. 11 DPSIR Model variables

Driver	Thermal Power Plants, Coal Mines, Ash Ponds, Mineral Based Industries
Pressure	NO_2 , SO_X , $PM_{2.5}$, PM_{10} , O_3, Benzene ,CO , NH_2
State	Air
Impact	Health problems , Socio –Economic condition , Ecological Imbalance
Response	Yet to be suggested

3.7.1 Analysis of Air Quality Data

Ambient Air quality monitoring data of Singrauli region obtained from the CPCB site and parameters reported are PM_{10}, $PM_{2.5}$, NO_2, NH_3, CO, Benzene, Ozone. Average, maximum and minimum values for these parameters for a period of Jan 2018 to Oct 2018 have been given in Tables 3.12, 3.13 and 3.14 respectively.

Table 3. 12 (a) Average of Pollutants in Singrauli District from Jan 2018- Oct 2018

Month/Pollutant	NO_2	NH_3	CO	Ozone	SO_2	Benzene	$PM_{2.5}$	PM_{10}
Jan	44.16	44.16	1.25	18.66	18.59	0.86	152.91	268.76
Feb	41.26	17.75	0.94	20.39	19.88	0.52	93.44	222.24
Mar	37.74	37.74	0.97	27.30	19.39	0.44	89.30	257.38
April	36.52	36.52	1.34	11.93	20.81	0.31	86.19	253.03
May	35.52	35.35	1.35	37.57	19.86	0.17	76.72	241.44
June	21.31	21.31	0.82	38.54	13.84	0.06	67.21	134.16
July	16.86	16.86	0.96	17.20	16.66	0.05	72.80	68.19
August	15.42	15.42	0.58	12.56	12.96	0.03	28.41	61.79
Sep	18.63	18.63	0.66	32.33	12.94	0.04	41.41	107.03
Oct	34.72	34.72	1.01	38.43	19.84	0.10	92.74	250.75

Table 3.13 Maximum of Pollutants in Singrauli District from Jan 2018- Oct 2018

Month/Pollutant	NO_2	NH_3	CO	Ozone	SO_2	Benzene	$PM_{2.5}$	PM_{10}
Jan	63.98	31.02	2.12	29.36	44.98	1.68	584.9	654.39
Feb	59.68	21.43	1.35	29.1	61.58	0.78	140.88	303.48
Mar	51.6	18.69	2.03	44.74	36.74	0.63	133.97	513.84
April	73.04	25.69	2.21	35.28	64.42	0.62	177.06	404.28
May	53.97	24.13	2.14	60.76	48.28	0.31	139.83	363.6
June	43.33	31.62	2.58	58.4	33.43	0.13	289.37	261.11
July	30.91	16.48	1.56	31.61	45.29	0.12	985	323.17
August	26.68	17.75	0.86	22.4	32.77	0.08	55.29	168.49
Sep	35.47	22.06	0.99	69.03	27.28	0.1	84.44	243.75
Oct	50.86	24.06	1.38	54.33	43.1	0.16	139.78	369.91

Table 3.14 Minimum of pollutants in Singrauli district from Jan 2018-Oct 2018

Month/Pollutant	NO_2	NH_3	CO	Ozone	SO_2	Benzene	$PM_{2.5}$	PM_{10}
Jan	31.72	13.63	0.68	10.62	7.49	0.32	56.9	208.69
Feb	27.58	14.46	0.63	8	8.9	0.28	57.85	93.58
Mar	20.55	12.66	0.46	9.88	11.34	0.19	49.1	140.91
April	18.5	17.65	0.27	4.26	5.82	0.13	46.24	106.48
May	17.31	15.71	0.92	8.43	9.86	0.03	30.35	89.5
June	11.26	12.86	0.42	18.28	5.38	0	21.35	35.62
July	5.7	8.13	0.3	5.97	2.51	0	7.17	13.48
August	5.28	10.16	0.36	7.7	4.15	0	7.03	13.52
Sep	4.96	7.46	0.41	10.16	6.84	0	11.32	15.15
Oct	24.92	17	0.59	27.08	9.98	0.02	28.77	61.26

Note – All values are in micrograms per cubic meter (µg/m^3), All except Ozone (8 hrs.) and CO (8 hrs.) are 24 hrs. average.

Table 3.15 Values Specified by CPCB

Parameter/time	NH_3 *µg/m³*	CO *µg/m³*	Ozone *µg/m³*	SO_2 *µg/m³*	Benzene *µg/m³*	$PM_{2.5}$ *µg/m³*	PM_{10} *µg/m³*	NO_2 *µg/m³*
24 Hrs. average	100			80		60	100	80
Annual	400			50	5	40	60	40
8 Hrs. average		2	100					
1 Hrs. average		4	180					

3.7.2 Air Pollutant from Sasan Power and Stack Emission

Ambient Air quality (PM_{10}, $PM_{2.5}$, NO_2, CO, SO_2) monitoring data of Singrauli nearby SASAN thermal Power plant were obtained from Sasan site for the period April 2018 to July 2018. The data were collected from five different locations: Construction offices, Permanent Store, Tiyara Town Ship, Siddhi Khurd Village, Sasan Village. The data were used to analyze the air quality of Singauli region and nearby villages as shown in Table 3.16. Location of air quality sampling is shown in Table 3.17.

Table 3.16 Ambient Air Quality from Sasan Thermal Power Plant

		Locations and Concentrations (in µg/m³)									
		AAQ1		AAQ2		AAQ3		AAQ4		AAQ5	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
April ,2018	**PM10**	50.2	55.3	48.2	54.3	51.6	55.9	51.48	54.48	43.3	52.7
	PM2.5	23.9	28.1	25.1	28.5	25.5	31.5	27.4	29.4	18.2	26.2
	SO2	12.2	15.5	12.25	16.8	13.2	16.3	13.8	16.4	10.5	17.5
	NO2	18.2	25.3	21.7	26.3	24.5	27.5	21.3	25.4	21.5	24.3
	CO	0.56	0.69	0.58	0.84	0.5	0.65	0.53	0.69	0.59	0.89
May ,2018	**PM10**	52.2	56.2	48.2	52.4	51.2	58.7	52.3	56.3	46.6	52.4
	PM2.5	24.7	27.3	25.4	29.3	26.8	33.4	27.2	31.6	18.3	27.5
	SO2	12.2	14.7	13.25	17.2	13.45	17.1	13.8	16.5	10.5	18.3
	NO2	22.2	26.6	21.7	28.3	24.5	27.3	21.3	25.4	21.6	27.3
	CO	0.56	0.69	0.58	0.82	0.56	0.68	0.57	0.68	0.72	0.86
June, 2018	**PM10**	50.8	55.2	47.1	50.9	52.2	56.2	52.43	54.3	45.2	56.7
	PM2.5	25.7	28.8	25.4	28.5	25.4	32.4	28.6	30.4	18.3	27.5
	SO2	12.9	15.3	13.25	17.3	14.8	16.5	13.8	16.4	10.5	19.4
	NO2	22.5	27.2	21.7	28.3	24.8	28.5	21.3	25.4	21.6	27.3
	CO	0.58	0.68	0.58	0.68	0.58	0.68	0.62	0.68	0.72	0.86
July, 2018	**PM10**	46.4	54.2	45.9	50.1	48.2	53.9	50.13	54	42.45	50.4
	PM2.5	26.6	34.9	23.7	28.5	23.7	27.7	26.3	29.1	16.6	25.8
	SO2	13.5	17.4	10.35	14.4	11.9	13.6	10.3	13.5	7.6	16.5
	NO2	22.3	26.7	20.1	26.6	23.2	26.9	19.7	23.8	20.1	25.3
	CO	0.68	0.78	0.5	0.62	0.5	0.6	0.54	0.6	0.64	0.76

Table 3.17 Locations of air quality sampling

ABBREVIATION	
AAQ	Ambient Air Quality
SAMPLE LOCATION	
Code	**Location**
AAQ1	Construction office
AAQ2	Permanent Store
AAQ3	Tiyara Town Ship
AAQ4	Siddhi Khurd Village
AAQ5	Sasan Village

3.7.3 Stack Emission from Sasan Power Plant

Table 3.18 indicates that the concentration of four effluent gases from stacks of Sasan power plant. The data was taken from the Environment Compliance report of Sasan power plants, which consist of six units.

Table 3.18 Ambient Air Quality from Stacks of Sasan Thermal Power Plant

Months	Pollutants	Locations and Concentrations (in mg/Nm^3)					
		Unit # 1	Unit # 2	Unit # 3	Unit # 4	Unit # 5	Unit # 6
April, 2018	PM	48.5	38.2	44.3	48.3	48.7	44.6
	SO2	676.3	716.4	553.7	712.4	725.3	661.6
	NOx	239	271	251.5	235.5	259.4	242.5
	CO	1.7	2.6	1.5	1.8	1.6	2.7
	Exit Velocity(m/s)	25.2	25	25.2	25.3	25.4	25.7
May, 2018	PM	49.3	36.8	41.9	48.6	40.3	45.5
	SO2	678.5	712.3	556.5	714.5	721.2	662.5
	NOx	241	218	245.7	237.5	257.6	239.3
	CO	1.8	2.3	1.7	1.7	1.7	2.8
	Exit Velocity(m/s)	25.3	25.6	25.7	25.4	25.5	25.1
June, 2018	PM	38.7	34.8	38.75	42.5	48.6	47.2
	SO2	667.5	710.3	522.6	695.3	705.5	659.3
	NOx	238	265	248.5	238.5	256.2	242.7
	CO	1.7	2.4	1.3	1.8	1.8	2.6
	Mercury	BDL	BDL	BDL	BDL	BDL	BDL
	Exit Velocity(m/s)	25.2	25.3	25.5	25.8	25.6	25.2
July, 2018	PM	43.5	40.2	45.6	46.3	41.2	41.2
	SO2	759.3	703.5	708.5	687.2	757.2	757.2
	NOx	236	273	239.3	236.5	249.3	251
	CO	1.6	2.2	1.4	1.6	2.8	2.8
	Exit Velocity(m/s)	25.3	25.4	25.3	25.4	25.4	25.4

3.8 Demographic Profile

In the present modern world, urbanization and industrialization are unavoidable and trends reveal that these bring substantial negative consequences to the environment. The carrying capacity actually refers to the imbalance between demand and supply of resources. The chain may be artificial or natural. This section deals with the inclusion of demographic profile, socio-economic status, reproductive health issues, health practices, and its indicators. Not all aspects are included in this study because the assessment has limitations with respect to the existing datasets.

3.8.1 Population Data

It is observed that the total change in population in Singrauli tehsil is about 23.8%, and in the district, it is about 28% which is mainly due to migration to Singrauli district. While the urban population increased by 18.9%, the decadal growth rate was more than the District growth rate, i.e. 17.9%. The decadal Growth of the rural population was comparatively less than the district decadal growth population.

On a block level, the total no. of inhabited villages was 204 out of 727 with the highest no. of villages 73 had a population between 1000-1999, with a total population of 10194 persons. Baidhan block has Scheduled Caste and Scheduled Tribe population as 296940 with 14.9% SC and 26.25 % ST population, both accounts for around 41.15 % of the total block population. In the town of Singrauli Municipal Cooperation, the total population was around 21925 with 13.41 % ST and 9.95 % SC and total accounts 23.36%.

The literacy rate of Singrauli district in total is 60.41% while the male literacy rate is 70.13 % and the female literacy rate is 48.53% and the gap in literacy rate between male and female is 22.81 %. The literacy rate of Singrauli Tehsil is 64.79 %. The male literacy rate is 76% while the female literacy rate is 52.51% and the gap in literacy rate between male and female is 23.6 percent. The gap in male and female literacy rates in a rural area is 27.19% and in an urban area, it is 18.2%.

CHAPTER 4
METHODOLOGY

4.1 ENVIRONMENTAL CARRYING CAPACITY

The environmental carrying capacity is an important indicator of regional sustainable development. This chapter discusses various features of various methods of environmental carrying capacity in practice and its current/future trends. In the rapid economic expansion, the development that took place in 20^{th} and 21^{st}-century is appreciable, but the cost of this development is unplanned, and therefore, these days we see various consequences of this development in the forms of global warming, ozone layer depletion, which are a few of several serious consequences. The environmental/ecological carrying capacity as such reflects the maximum population with a certain living standard and the intensity of social and economic activities that are sustained by the ecosystem in a specific country or a region.

4.1.1 Evaluation Index System Method

Carrying capacity index system is generally composed of various natural as well as human-made endowments like the self-sustaining capacity of the environment, time of replenishment of resources, productivity level and standard of living of the people of a particular region. For different components of nature, different indices are developed by various agencies, for example, for water quality, water quality index is developed; for air, various air quality indices like national Ambient air quality index, Oak Ridge Air quality index, revised air quality index, etc.; and to overcome the deviations subjected to different components of air quality, different weighting methods are adopted like Analytical Hierarchy process. Literature suggested a variety of hybrid models like sustainability-oriented and systematic PSR model, DPSIR models or GRA-TOPSIS models, which when combined with GIS yield better and more accurate results, like GIS-DSS (Decision making Support system), GIS fuzzy set, GIS-enabled remote sensing.

4.1.2 System dynamics Method

Ecological carrying capacity estimation involves various aspects and thus is complex in nature. Overlapping of data and their temporal variations are the major problems. In reference to ECC to simplify the evaluation of carrying capacity, System Dynamics is used to carry out the carrying capacity analysis. There exist various models that are used in system dynamics for calculating the carrying capacity. System dynamics can be further classified as follows:

(i) Feedback Loops

I. Open Loop Impression of the world

It is linear in nature. It is a bit conservative in nature and slightly away from reality in some cases. For example, electricity is the major problem for societal development but once electricity generation starts, the problem is resolved. This is the linear approach with which open loop impression deals with.

II. Closed Loop Impression

This approach is comparatively more realistic in nature. Its problems which need certain actions when resolved create more problems in the future. This approach is a closed loop having no end and no beginning.

Figure 4. 1 Open Loop Impression of World

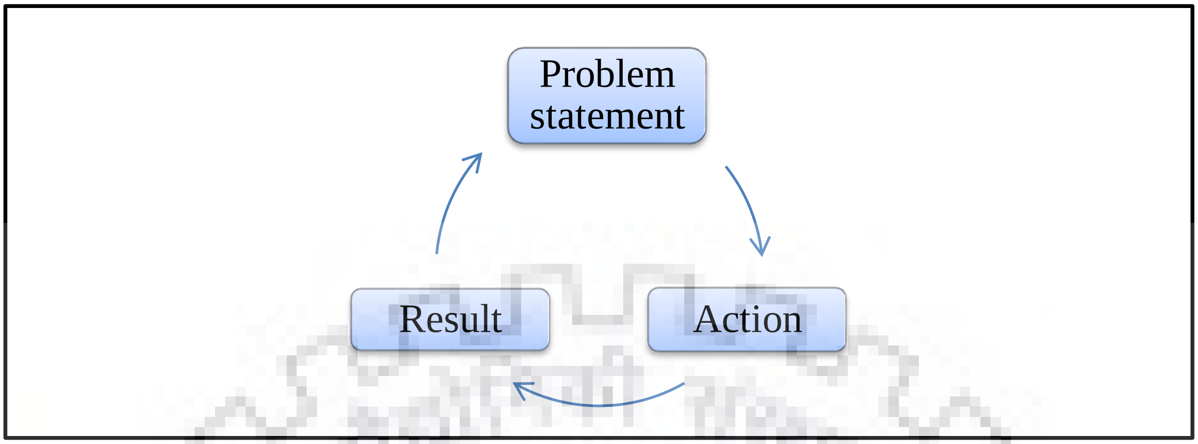


Figure 4. 2 Closed Loop Impression of World

Generally, we face a close loop of the problem in day to day life. Singrauli is suffering from the concept of system dynamics. The carrying capacity can be calculated using the closed loop dynamics.

4.1.2 Decision- Making optimization models

Decision-making optimization models are analyzed by considering various constraints and resources (Rardin et al. 2006). The optimized path is suggested to carry out the carrying capacity analysis and resources evaluation in a sustainable manner. For determination of industrial pattern, Multi-object programming consisting of fuzzy linear programming and uncertain linear programming models are used. While going for the optimization models one must have a clear idea about the spatial heterogeneity and combination of temporal-spatial heterogeneity to select the best model for the particular region. The factors affecting such studies can be divided into two parts:

a. **Uncontrollable factor** – while decision maker took some decision these factors are not in control of decision maker for example – environmental factors like rain, temperature, climate, etc.
b. **Controllable factor** – the factors which a designer can manipulate are also the design variables. Auxiliary variables which depend on the design variable are taken into account.

The approaches are classified into two categories –

a. **Deterministic Decision-making approach** – if uncontrolled variables are not involved in decision making then the approach is deterministic in nature.
b. **Stochastic or probabilistic approach** - if uncontrolled variables are involved in the decision-making process then the nature of the analysis is probabilistic in nature and to analyze such models a well-sounded knowledge of various probability distribution models are required. But due to the complexity of the project and involvement of various variables deterministic approaches are adopted.

The estimation of environmental carrying capacity is probabilistic in nature. Various steps involved in decision-making are as follows -

(i) **Get precise information about the problem and the factors affecting that problem and data related information** – collect numerical as well as quantitative data with uncontrollable and controllable factors.

(ii) **Construct a mathematical model for the problems** – construct a mathematical model helps encapsulate various parameters including performance parameter as a decision making parameter. It creates a mathematical function for the problems statement and sometimes some variables are also ignored to reduce the complexity of the function.

(iii) **Solve the model** – solve the model to get a decisive solution. These days there are various mathematical models available. Some models have good and efficient algorithms to solve but for some models, there are not good algorithms yet available to find a better solution then with the help of approximate solution the solutions can found out.

(iv) **Implementation of the model** – At the end of the solution, the result has to be implemented in practical life, and therefore, the practical feasibility of the solution must be checked. If, for some reason, the solution is not implemented then approximate modifications are incorporated to obtain more practical solutions.

4.2 LAND USE/LAND COVER

Singrauli is a region in which both public, as well as the private sector, have ventured. Thermal power industry and coal mining have grown and have been spreading widely. A rapid increase in population creates a huge demand for power in terms of electricity that tends to increase the capacity of thermal power plants. But the thermal power plants and coal mining industry invade upon forest and agricultural lands. Generally, it is observed that industrialization does have a negative impact on the environment in terms of air, water, and pollution. Mineral mining is one of the major reasons for land degradation. Thus it is an important task to regulate the coal and other mineral minings in a particular area to create an approach for its development in a sustainable manner.

Zubair et al. (2006) defined that the land use/land cover of a particular region is derived from the social, economic and environmental condition by considering the temporal and spatial references. This information also assists the dynamics of land use resulting from changing demands of an increasing population.

4.2.1 Methodology

The steps followed for making the land use/land cover maps have been shown through the flow chart in Fig. 4.3.

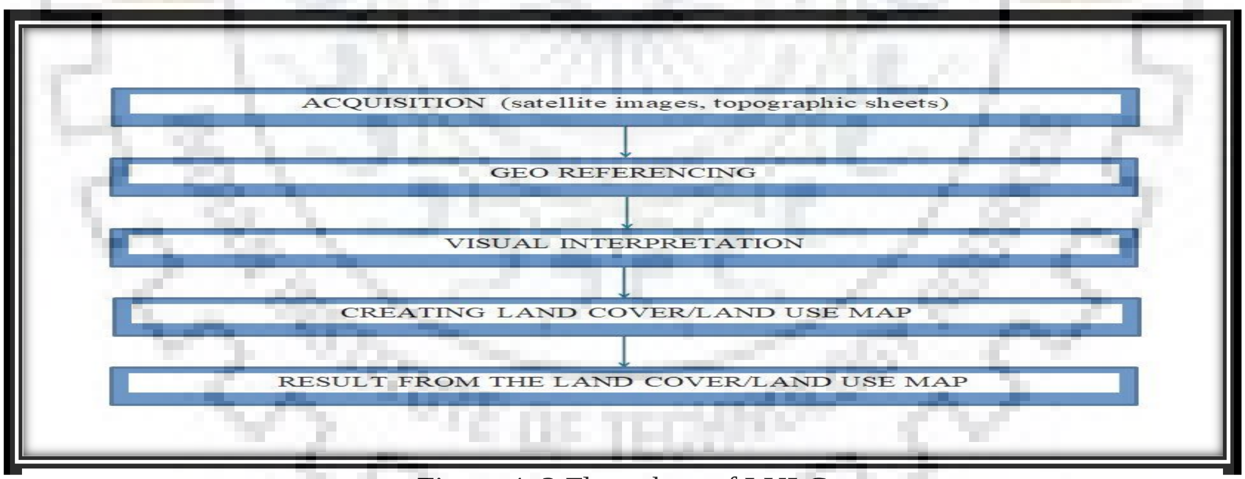


Figure 4. 3 Flow chart of LULC

4.2.2 Data Availability

For this study, the data were acquired from USGS earth explorer from LANDSAT for Singrauli district M.P. These images are multispectral and multi-temporal in nature. The thematic mapper is

30m in resolution. All images are bought to Universal Transverse Mercator (UTM) projection in zone 44N. The following software's were used in the study:

a) ERDAS – The software was used for geo-referencing, mosaicking and unsupervised and supervised classification of images.
b) ARC–MAP – the software was used for compositing the bands and raster calculation and to create a land use /land cover pattern.

A list of imageries collected for LULC maps preparation is shown in Table 4.1 along with their source, scale, satellite and year of production.

Table 4. 1 Data Acquisition Details

S. No	**Dataset**	**Image production Year**	**Scale**	**Source**
1	Landsat 4-5	1980	60 m*60m	United States Geological Survey https://earthexplorer.usgs.gov
1	Landsat - 7	2005	30m*30m	United States Geological Survey https://earthexplorer.usgs.gov
2	Landsat - 8	2019	30m*30m	United States Geological Survey https://earthexplorer.usgs.gov

LULC maps were created for the years 2005 and 2019 using ARC Map and ERDAS, as shown in Figure 5.9 and 5.10

4.3 DRAINAGE DENSITY AND STREAM LENGTH

Streams carry water from various sources to rivers, estuaries, and reservoirs. These are the habitats for various aquatic plants and "Hotspot" for the ecosystem. Habitat quality and potential for nutrient retention in headwater streams can be highly sensitive to changes in watershed land use (Meyer et al. 2007). The Stream Burial term is a relative term. Stream Burial can be by culvert, pipes, concrete lining and simply paved over or urbanization. Industrialization and urbanization have extreme effects on streams. Stream Burial causes destruction of natural streams that feed the downstream habitat and is the reason for downstream habitat destruction.

Stream burial results in the destruction of natural stream channels and contributes to downstream habitat degradation, aquatic habitat fragmentation, enhanced transport of water and toxic contaminants, and reduction of ecosystem services such as nutrient and sediment retention (Paul and Meyer 2001; Walsh et al. 2005). Because they constitute the largest fraction of stream length and are the most eco-nominally feasible to bury, the smallest streams are among those most affected by urbanization.

4.4 AIR QUALITY INDICES

Air quality indices are an innovate attempt to assess the air quality into an understandable form. Various indicators of air quality are encapsulated into a single factor. There are various indices available to calculate the air quality, a few are listed below.

4.4.1 Oak Ridge Air Quality Index

Oak Ridge National Laboratory published the ORAQI in 1971. It was based on the 24-hour average concentrations of the following five pollutants: SO_2, NO2, PM_{10}, $PM_{2.5}$, CO, Photochemical oxidant. Note – these data were not available in this study, and therefore, their value was considered to be 0. Air Quality Index is calculated as follows:

$$\textbf{AQI} = [5.7 \sum (\frac{Ci}{Cs})]^{1.37} \quad \text{.....(i)}$$

Where, C_i = value of air quality parameters PM_{10}, $PM_{2.5}$, NO2 and SO_2; Cs = standard or prescribed limit for air quality parameter; and

$$\frac{Ci}{Cs} = L_i$$

L_i is the ratio of the value of observed air quality parameters to the standard air quality parameters.

4.4.2 National Ambient Air Quality Index

Air Quality Index (AQI) is a tool for effective communication of air quality status to people in the terms which cane be easily understood. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and color. There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). AQ sub-index and health breakpoints are evolved for eight pollutants, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH3, and Pb, for which short-term (up to 24-hours) National Ambient Air Quality Standards are prescribed.

The Sub-indices are based on the individual pollutants' concentration of 24 hrs. Average (except 8 hrs. average concentrations of CO and O_3) and health breakpoint concentration range, the Worst Sub Index is AQI of that area is defined as:

$$\textbf{AQI} = \frac{(I_{obs}-I_{min})*(AQI_{max}-AQI_{min})}{(I_{max}-I_{min})} + AQI_{min} \quad \text{...(ii)}$$

where

I_{obs} = observed 24-hour average concentration in µg/m3

I_{max} = maximum concentration of AQI category that contains I_{obs}

I_{min} = minimum concentration of AQI category that contains I_{obs}

AQI_{max} = maximum AQI value for a category that corresponds to I_{obs}

AQI_{min} = minimum AQI value for a category that corresponds to I_{obs}

4.4.3 Revised Air Quality Index (RAQI)

This term accounts for the individual contribution of each sub-index pollutant to the RAQI by factoring the pollutant's daily concentration into their yearly averages, and reduces AQI's ambiguity and eclipse where levels of pollutants are more serious than indicated by the index value (**Cheng et al., 2004**):

$$\textbf{RAQI} = \boldsymbol{Max[I_{1,}I_{2\ldots}I_n] * \frac{AVG_{daily}\sum_{j=1}^{n}[I_j]}{AVG_{annual}\,[AVG_{daily}\sum_{j=1}^{n}[I_j]]} * \frac{AVG_{annual}\,[Entropy\ Max[I_{1,}I_{2\ldots}I_n]}{Entropy\ daily[max[I_{1,}I_{2\ldots}I_n]]}} \quad \textbf{.........(iii)}$$

$$\text{I} = \boldsymbol{\frac{I_H-I_L}{BP_H-BP_L} * (C - BP_L + I_L)}$$

Where C denotes the daily reference concentration, BP_H is the highest breakpoint of the pollutant that is greater than or equal to C, BP_L is the lowest breakpoint that is less than or equal to C, I_H and I_L are indices values corresponding to BP_H and BP_L, respectively. The second term on RHS establishes the background arithmetic mean index, in which the numerator is the sum of daily arithmetic averages of all sub-indices (I_1… I_n), and the denominator is the yearly average of the sum of daily average for these pollutants.

The third term of RHS in Eq. (iii) represents the background arithmetic mean entropy index in which the numerator is the yearly average of the average daily entropy, and the denominator is the entropy function of the sub-index pollutants. The entropy function defined as the log10 of the maximum function. The concept of entropy is applied not only to the physical quality of thermal energy but also to information technology (information entropy) as a measure of “useful” ability. In addition, the entropy function has been used in atmospheric energy balance models.

CHAPTER 5

RESULTS AND DISCUSSION

This study attempts to assess the carrying capacity of the environment of Singrauli region based on the indices of meteorological, surface and groundwater quality, air quality, land use change, etc. To this end, the values of various indices developed for different aspects have been compared with values already prescribed by the Government of India.

The meteorological parameters involve rainfall, relative humidity, wind movements, and so on. The declination in levels of groundwater in the Singrauli area was obtained and analyzed. The quality parameters for the same were also analyzed, and inferences are drawn. The extent of air pollution in the study area was high enough compared to the standard limits of CPCB. The change in land use indicated a change in the extent of coal mines, a decrease in vegetation, an increase in built-up area and a decrease in agriculture land. The drainage density estimate shows the blockage of drainage for various lengths of different order streams in the mapped area. Lastly, this chapter deals with terrain roughness, demographic profile and Air Quality Indices.

5.1 METEOROLOGICAL

Table 3.4 (also shown below as Table 5.1) shows different meteorological parameters and their variation in average, maximum and minimum terms. Further, this table has been used to analyze each parameter.

Table 5.1 Meteorological results

Parameter	Temperature (in ºC)		Rainfall (mm)	Wind (Km/h)	Relative Humidity
	Maximum (daily)	Minimum (daily)			
Yearly average	33.77	18.35	2.58	2.00	0.49
Maximum (yearly)	52.85	32.04	143.05	5.49	0.96
Minimum (yearly)	6.18	-0.84	0.00	0.45	0.06
Maximum variation (avg)	2.85	3.49	3.38	0.38	0.12

The data collected shows the daily variation in temperature, rainfall, wind speed, and Relative Humidity.

(a) Maximum Daily Temperature

- The Average maximum temperature of the region is 33.7743 ºC with a variation of 2.89423 ºC
- The maximum observed till 2014 was 52.848 ºC, and minimum is till 2014 was 6.175 ºC

(b) Minimum Daily Temperature

- The Average maximum temperature of the region is 18.349716ºC with a variation of 3.487054ºC
- The maximum temperature observed till 2014 was 32.036ºC

(c) Daily Rainfall

- The average rainfall of the Singrauli region in 2.59 mm. with a variation of 3.38 mm.
- The maximum rainfall recorded till 2014 on a single day was 143.05091 mm.

(d) Wind

- The average wind speed is 1.997 m/s. with a variation of 0.383 m/s.
- The maximum wind observed until 2014 was 5.493676 m/s.
- The minimum wind observed until 2014 was 0.44941 m/s.

(e) Relative Humidity

- The average R.H speed is 49.16 %. with a variation of 11.76%
- The maximum R.H observed until 2014 was 96.13 %.
- The minimum R.H observed till 2014 was 6.25%

6. Wind rose Diagram

- The maximum speed has been obtained in the South direction with a maximum wind speed greater than 28 Km/h
- The direction of air flow for most of the time is towards the south direction in the Singrauli region.
    - Most of the time wind speed is between 5-12 Km/h. Thus, the findings suggest that people habituating in the south direction tend to get affected the most by air pollution.

The meteorological data (precipitation, relative humidity, temperature, and wind speed) and air pollutants data (Sulfur Dioxide, PM_{10}, $PM_{2.5}$, and NO_2) of Singrauli region (M.P) from 1-Jan -2018 to 31- Dec-2019 was acquired from nasa.larc.gov and cpcb.nic.in respectively. The meteorological and air pollution data were used for regression analysis.

Figures 5.1 (a) & (c), Figures 5.2 (a) & (c), Figures 5.4 (a) through (d) indicate that the precipitation and relative humidity directly affect $PM_{2.5}$ and PM_{10} and NO_2. While there is no direct relation seen between the temperature and air pollutants in the region.

Figure 5.1 indicates the relationship between $PM_{2.5}$ and meteorological properties, such as $PM_{2.5}$ vs. Precipitation (Figure 5.1–a) and $PM_{2.5}$ vs. relative humidity (Figure 5.1–c) are 0.29 and 0.33 respectively. These figures show a significant impact of Precipitation and Relative humidity on $PM_{2.5}$. Similarly, Figure 5.2 shows the relationship between PM_{10} and Precipitation (Figure 5.2 – a) and relative humidity (Figure 5.2 - c). There is however no significant relationship existing between SO_2 and meteorological parameters (Figure 5.3). All the four meteorological parameters are related to NO_2. NO_2 and Relative humidity (Figure 5.4 - a) are significantly correlated with each (r^2 =0.41).

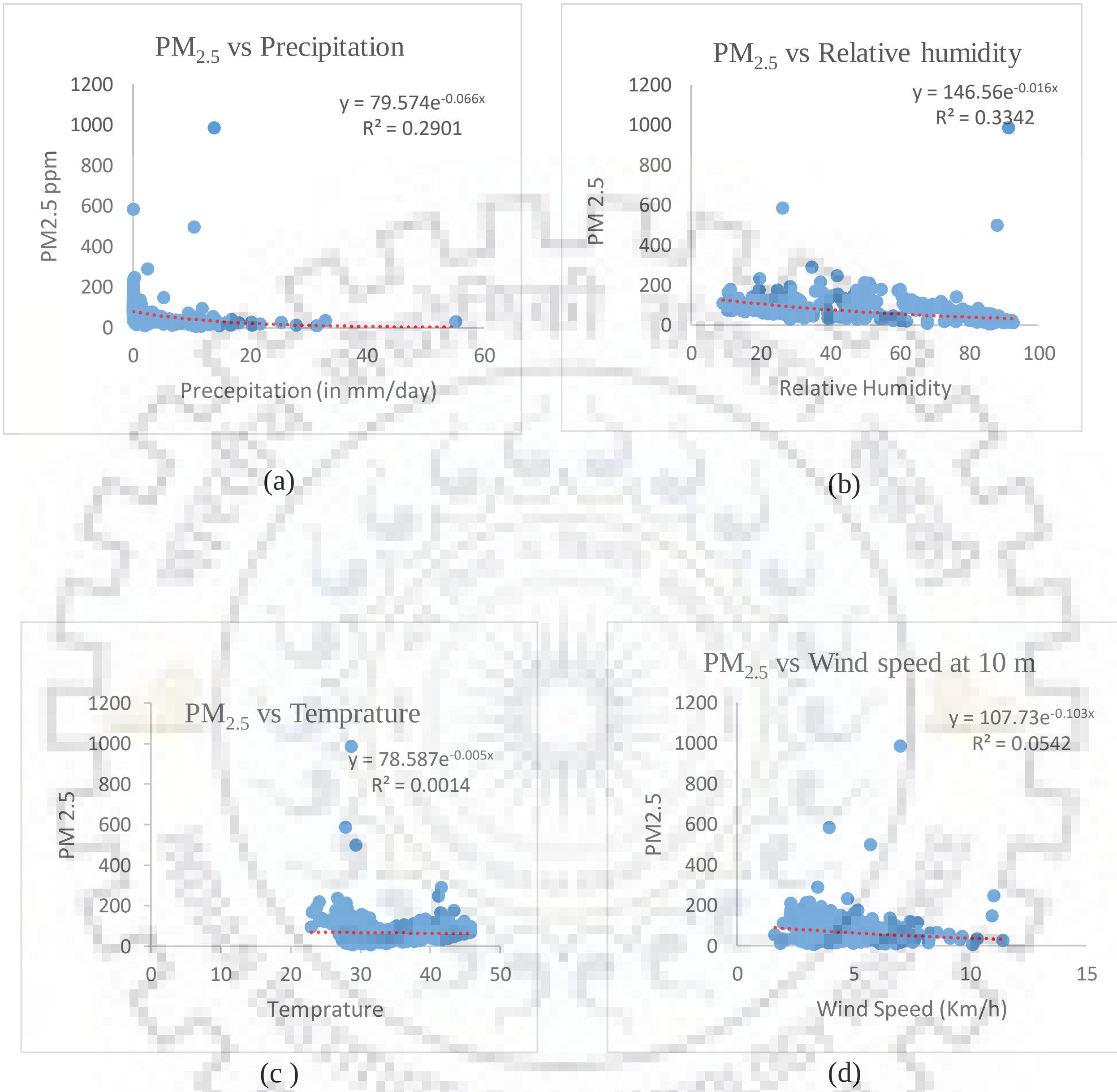


Figure 5. 1 Scatter diagram between PM2.5 vs. (a) Precipitation, (b) Temperature, (c) Relative humidity, (d) wind speed

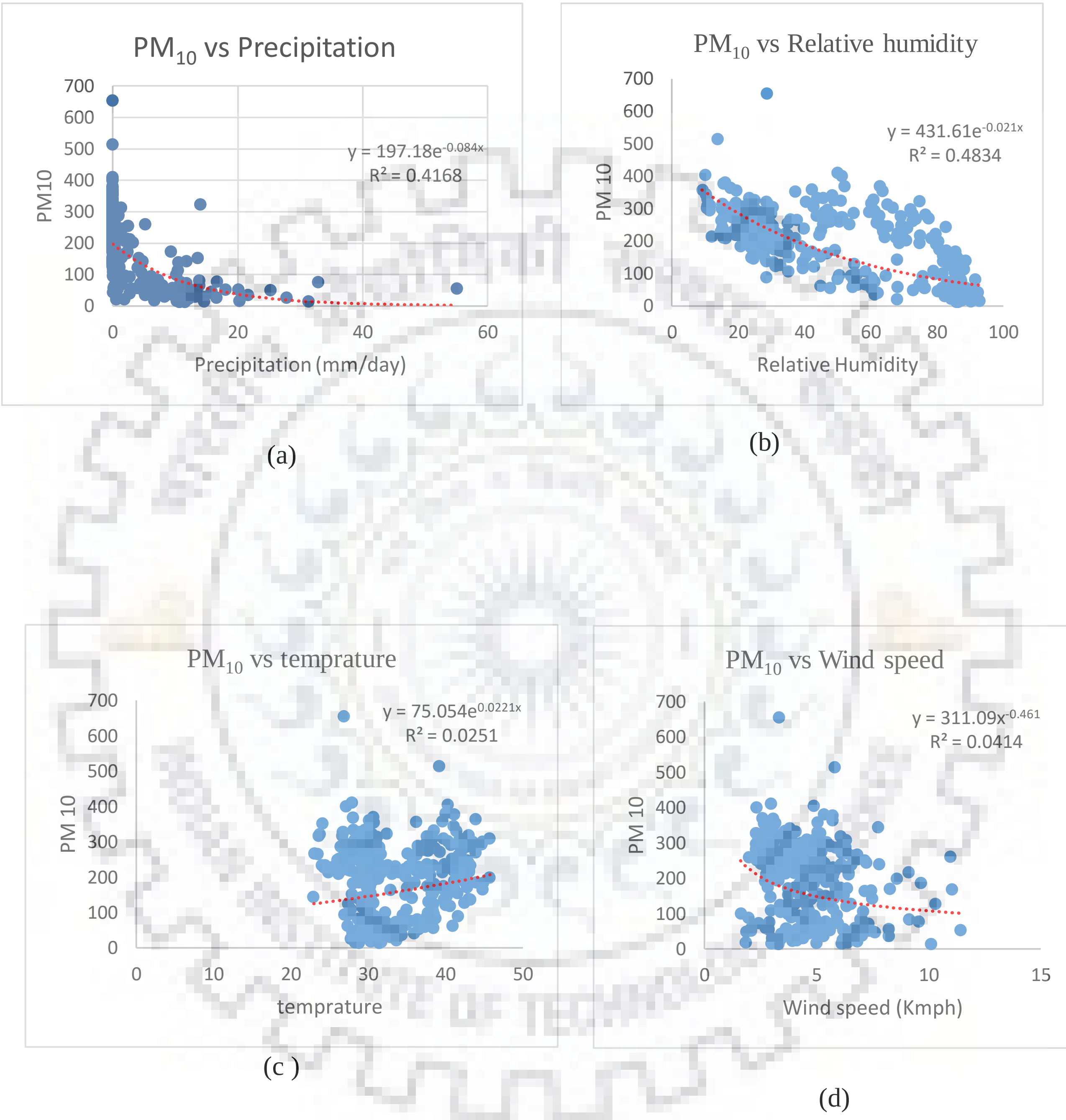


Figure 5.2 Scatter diagram between PM10 (a) Precipitation, (b) Relative humidity, (c) Mean temperature, (d) wind speed

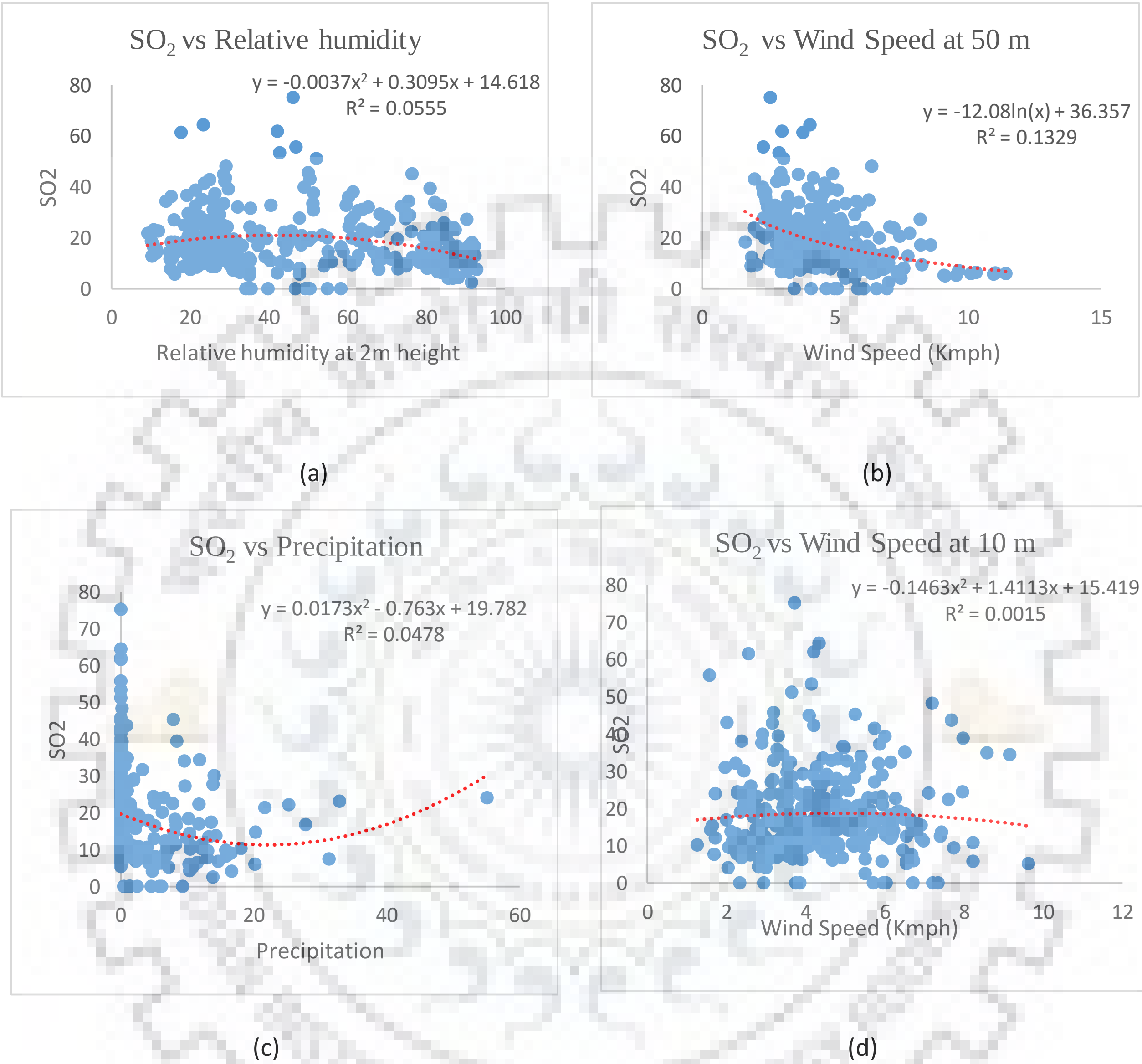


Figure 5.3 Scatter diagram between SO2 vs (a) Relative humidity (b) wind speed, (c) Precipitation, (d) Mean temperature.

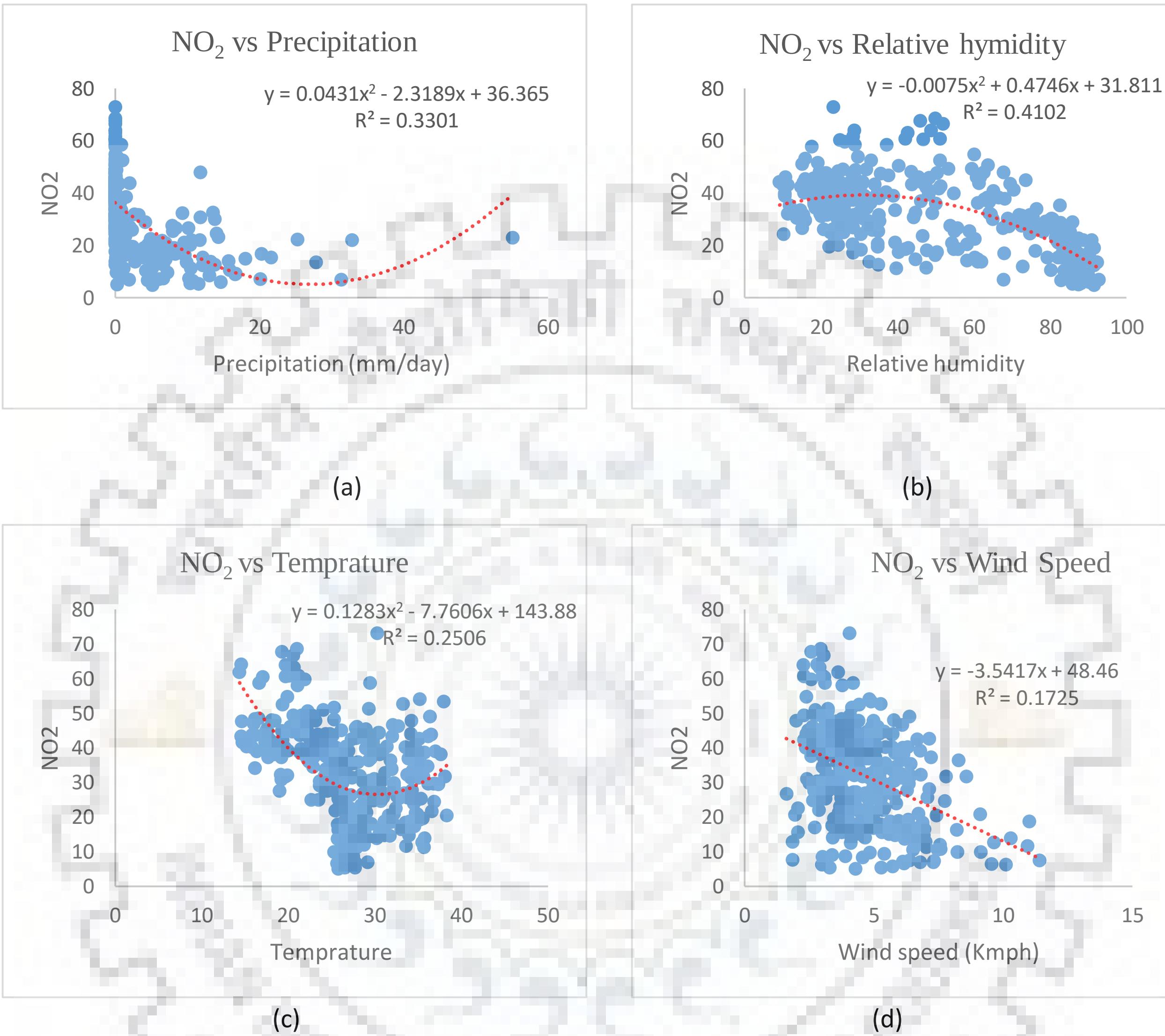


Figure 5.4 Scatter diagram between NO2 vs (a) Precipitation, (b Relative humidity, (c Mean temperature, (d) wind speed

5.2 GROUNDWATER LEVEL

The data (Table 5.2) were collected for the following four seasons: Monsoon, Post-Monsoon Rabi (POMRB), Post-Monsoon Kharif (POMKH), and Pre Monsoon (PREMON).

Table 5.2 Maximum depletion values at a different location

Village NAME	MONSOON		POMRB		POMKH		PREMON	
	YEAR	VALUE	YEAR	VALUE	YEAR	VALUE	YEAR	VALUE
CHAURA	2015	4.9	2016	10.13	2015	6.53	2018	11.75
GADERIYA	2014	4.1	2015	4.11	2014	4.35	2015	4.6
JAMGADI	2015	5.8	2016	6.92	2015	6.32	2016	7
JATTHA TOLA	2015	6.3	2016	6.55	2015	6.45	2016	6.85
MARA	2008	10.43	2010	11.25	2010	10.79	2000	12.93
PARSAUNA	2011	8.5	2009	8.5	2008	8.5	2009	8.5
PARSAUNA NEW	2015	6.1	2016	8	2017	8.9	2015	9.29

Note – All Values are in meter.

The following can be observed from the table:

- Mara which is nearest to Rihand Reservoir experienced the maximum depletion of 12.93 m (Pre-Monsoon) from Ground Level in the year 2000.
- In Monsoon, depletion of water level ranged from 4.1 in Gaderiya to 10.43 m in Mara village.
- Groundwater levels are highest in Mara Village for the Monsoon, Post Monsoon Rabi, Post monsoon Kharif and pre-monsoon seasons.
- In Post-Monsoon rabi season, depletion of water level ranged from 4.1 in Gaderiya to 11.25 m in Mara village.
- In Post-Monsoon Kharif season, depletion of water level ranged from 4.1 in Gaderiya to 11.25 m in Mara village.
- In Pre-Monsoon, Gaderiya and Mara showed 181.09 % difference in depletion, which is maximum.

Table 5.2 and Figure 3.8 show that there is an over-exploitation of groundwater resources and as a consequence of it, the groundwater carrying capacity has been deteriorated. The highest depletion of groundwater was experienced in Mara village where the groundwater level decreased by 10.43 meters from its ground level. This village is very close to the reservoir and still have inadequate water supply scheme, ultimately resulting in overuse of groundwater.

5.3 WATER QUALITY

Most villages in Singrauli region use groundwater for their daily requirements. The major population exploits groundwater using hand pumps or dug wells. Table 5.3 shows groundwater and surface water quality. As seen, all the parameters are under desirable limits. Since the major part of the population is using groundwater for their daily use without any treatment, it has played a major role in human health.

Table 5.3 (a) Groundwater quality

parameters	limits	April		June	
		max	**Min**	**Max**	**Min**
Ph	6.5-8.5	7.31	6.73	7.51	6.9
Colour (Hazen Units)	15	3.4	1.81	2.1	1
Odour	Agreeable	0	0	0	0
Turbidity (NTU)	5	0	0	0.16	0.16
TDS (mg/l)	2000	367	135	312	72
Total Alkalinity (mg/l)	600	144	48	136	28
Total Hardness as CaCO3(mg/l)	600	148	60	172	48
Calcium as Ca(mg/l)	200	41.6	12.8	43.2	9.6
Magnesium as Mg(mg/l)	100	10.69	5.83	18.46	4.86
Chloride as Cl (mg/l)	1000	32	16	42	14
Sulphate as SO4 (mg/l)	400	31.6	12.1	28	10
Fluoride as F (mg/l)	1.5	0	0	0	0
Nitrate as NO3 (mg/l)	45	20.3	2.5	22	2.98

Table 5. 4 (b) Surface water quality

Parameters	**Limits**	April		June	
		max	min	Max	min
pH	6.5-8.5	8.4	7.06	7.56	7.25
Colour (Hazen)	300	172	130	164	138
Total Dissolved Solids (mg/L)	1500	352	270	455	420
Dissolved Oxygen (mg/L)	4	5	4.8	5.2	5
BOD (mg/L)	3	1.5	1.35	1.6	1.15
Chloride (mg/L)	600	48	34	64	50
Fluoride (mg/L)	1.5	0.42	0.35	0.55	0.38
Sulphate (mg/L)	400	41.5	27.1	46	27
Nitrate (mg/L)	50	19.1	12	22	20
Arsenic (mg/L)	0.2	0	0	0	0

Parameters	Limits	April		June	
		max	min	Max	min
Copper (mg/L)	1.5	0.152	0.05	0.2	0.061
Iron (mg/L)	50	7.45	1.3	2.6	1.12

5.4 AIR POLLUTION

The Ambient Air quality has been analyzed using the data collected from CPCB air quality monitoring station and EIA report published by Sasan power plant lying within the study area. Table 5.4 shows the National Ambient air quality standard 2009 notified by CPCB.

Table 5.5 Air quality standard by CPCB

Parameter/time	NH_3 *μg/m³*	CO *μg/m³*	Ozone *μg/m³*	SO_2 *μg/m³*	Benzene *μg/m³*	$PM_{2.5}$ *μg/m³*	PM_{10} *μg/m³*	NO_2 *μg/m³*
24 Hrs. average	100			80		60	100	80
Annual	400			50	5	40	60	40
8 Hrs. average		2	100					
1 Hrs. average		4	180					

From Table 5.5 (a), it can be seen that the Singrauli district is under severe threat to air pollution as its limits are crossed most of the times for $PM_{2.5}$ and PM_{10}. From the above Tables 5.4 (a), it is clear that $PM_{2.5}$ and PM_{10} are the air pollutants of concern in Singrauli as $PM_{2.5}$ is 16.41 times the specified limit while PM10 is 6.54 times the specified limit.

Table 5.6 (a) Data from CPCB

parameters	Maximum		Minimum	
	Value (*μg/m³*)	**Month**	Value (*μg/m³*)	**Month**
NO_2	73.04	April	26.68	August
NH_3	31.62	June	16.48	July
CO	2.58	June	0.86	August
Ozone	69.03	Sep	22.4	Sep
SO_2	64.42	April	27.28	April
Benzene	1.68	Jan	0.08	Jan
$PM_{2.5}$	985	July	55.29	August
PM_{10}	654.39	Jan	168.49	August

The analysis of data (Table 5.5b) used by Sasan EIA Report indicates the following:

- The air quality was analyzed for five parameters: Particulate matter 10 and 2.5, Sulfur Dioxide, Nitrogen dioxide, and Carbon Monoxide observed at four locations Permanent Store, Tiyara Town Ship, Siddhi Khurd Village, Sasan Village. The report indicates that all parameters are within permissible limits for all five villages.
- Stack monitoring indicated SO_2, NO_x was more than the permissible limits during month April 2018 to July 2018. (Table 5.7 b)

Table 5.7 (b) Data from SASAN EIA report

Month	Pollutant	Limit ((in mg/Nm^3) (24 Hrs)	Max and Min concentration (in mg/Nm^3)	
			Maximum	Minimum
April, 2018	SO_2	80	725.3	553.7
	NO_2	80	271	239
May, 2018	SO_2	80	721.2	556
	NO_2	80	257.6	218
June, 2018	SO_2	80	710	522.6
	NO_2	80	265	238
July, 2018	SO_2	80	759.3	687.2
	NO_2	80	273	236

It is thus clear that SO_2 and NO_2 are the air pollutants of concern in Singrauli. The highest values of SO_2 was in July (about 9.59 times the specified limit) and the highest NO_2 concentration was observed in July having value 687.2 mg/Nm^3 which is 8.59 times the limit specified by CPCB.

5.4.3 Air Quality Indices

5.5.3.1 Oak Air Quality Index

Oak air quality index and air quality limits are shown in Table 5.8 & 5.9 respectively. The given data shows that the air quality in the Singrauli region falls under the category of "Severe air pollution". Also, it can be inferred that the air carrying capacity of the Singrauli region is way past its maximum potential.

Table 5. 8 Oak Air Quality Index

Month	NO_2	CO	$PM_{2.5}$	PM_{10}	SO_2	Sum L_i	Sum L_i *5.7 = X	$X^{3.7}$	Integer value
Jan	1.10	0.63	3.82	4.48	2.69	12.72	72.52	353.89	353
Month	NO_2	CO	$PM_{2.5}$	PM_{10}	SO_2	Sum L_i	Sum L_i *5.7 = X	$X^{3.7}$	Integer value
Feb	1.03	0.47	2.34	3.70	2.52	10.06	57.34	256.47	256
Mar	0.94	0.49	2.23	4.29	2.58	10.53	60.03	273.15	273
April	0.91	0.67	2.15	4.22	2.40	10.36	59.03	266.89	266
May	0.89	0.68	1.92	4.02	2.52	10.02	57.14	255.27	255
June	0.53	0.41	1.68	2.24	3.61	8.47	48.27	202.61	202
July	0.42	0.48	1.82	1.14	3.00	6.86	39.10	151.80	151
August	0.39	0.29	0.71	1.03	3.86	6.28	35.77	134.37	134
Sep	0.47	0.33	1.04	1.78	3.86	7.48	42.63	170.88	170
Oct	0.87	0.50	2.32	4.18	2.52	10.39	59.22	268.06	268

Table 5. 9 Oak Air Quality Limits

INDEX VALUE	AIR QUALITY
0-25	Clean Air
26-50	Light Air Pollution
51-75	Moderate air pollution
76-100	Heavy Air Pollution
Greater than 100	Severe Air pollution

5.5.3.2 National Ambient Air Quality Index

Air quality index values for Singrauli district are shown in Table 5.10, and Table 5.11 shows the air quality limits. AQI based on CPCB has also represented in graph form in Fig. 5.5.

Table 5. 10 AQI values of Singrauli District

month/AQI	AQI		
	Min	Max	Average
Jan	172	680	325
Feb	96	316	211
Mar	127	505	207
April	104	368	203
May	90	317	194

June	36	430	124
July	21	965	143
August	18	146	62
Sep	21	196	105
Oct	61	325	209

Table 5. 11 NAQI Limits

(0–50)	Good	Minimal Impact
(51–100)	Satisfactory	Minor breathing discomfort to sensitive people
(101–200)	Moderate	Breathing discomfort to the people with lung, heart disease, children and older adults
(201–300)	Poor	Breathing discomfort to people on prolonged exposure
(301–400)	Very Poor	Respiratory illness to the people on prolonged exposure
(>401)	Severe	Respiratory effects even on healthy people

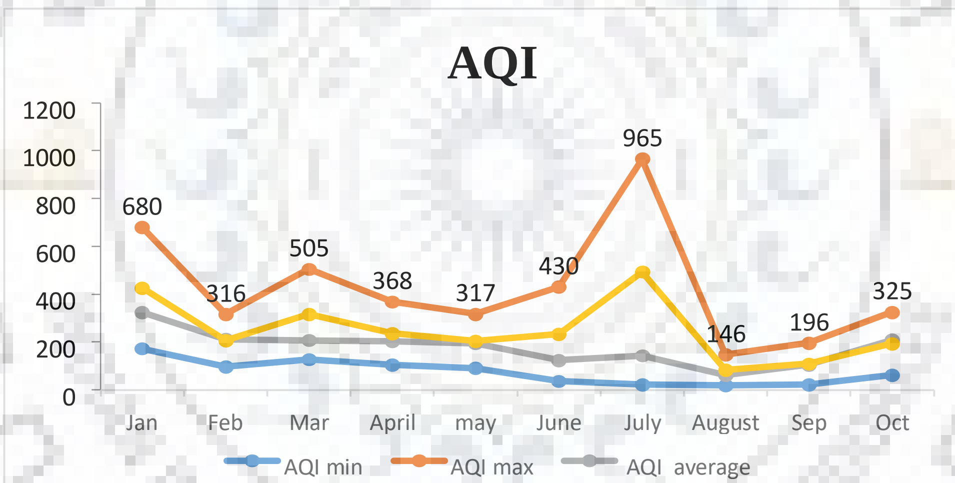


Figure 5. 5 AQI based on CPCB

The above Figure 5.5 depicts that air quality in Singrauli region lies in the very severe zone for the major part of the year and reaches its maximum value in the month of July 2018.

5.5.4 Revised Air Quality Index

Table 5.2 and Fig. 5.3 show the values of the revised air quality index for different months and different parameters.

Table 5. 12 RAQI

POLLUTANTS/ MONTHS	Jan	feb	march	April	may	June	July	August	Sept	oct
Carbon monoxide	13.2	10.6	11.8	15.1	15.3	9.1	11.1	6.7	7.5	11.3
Nitrogen dioxide (NO2)	41.8	38.8	35.6	35.1	37.6	41.5	36.2	35.1	32.4	41.6
Ozone	2.6	2.6	2.6	2.5	2.7	2.7	2.6	2.6	2.7	2.7
PM10	81.5	83.3	75.9	98.5	92.8	39.7	7.0	3.9	26.2	97.4
PM2.5 - Local Conditions	201.6	97.6	95.4	93.8	88.9	84.0	86.9	231.2	263.2	389.6
Sulfur dioxide	26.6	28.4	27.7	29.7	28.4	19.8	23.8	18.5	18.5	28.3
Max I	201.6	97.6	95.4	98.5	92.8	84.0	86.9	231.2	263.2	389.6
Sum	367.2	261.2	249.0	274.7	265.6	196.7	167.6	297.9	350.5	570.9
	2.3	2.0	2.0	2.0	2.0	1.9	1.9	2.4	2.4	2.6
RAQI	120.8	48.2	45.1	51.1	47.1	32.3	28.3	109.6	143.4	323.0

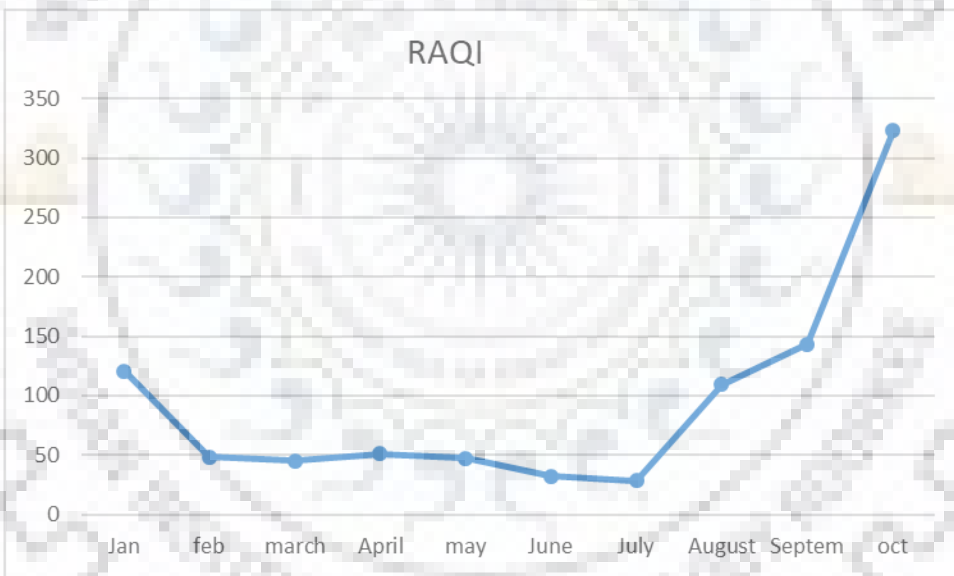


Figure 5. 6 RAQI Graph

It can be observed that

- Oak air Quality Index shows the air to be in **Severe** state at most of the times
- National Ambient Air Quality Index is the highest seen in July, showing **severe** state.

- RAQI (an improved AQI) indicates January and June–July to be the most critical months in terms of pollution. Notably, RAQI is a better indicator of air pollution than other AQIs.

The air quality is one of the most important indicators in carrying capacity estimation. The Singrauli region has more than ten coal-based thermal power plants. The data (Table 5.5 a & b) clearly indicate that the air carrying capacity of the Singrauli region is already exhausted because of the continuous emission of gases from the thermal power plants. The AQI indicates that the air quality of the Singrauli region is **severe** most of the time. Thus, the air carrying capacity of the region is already exhausted and it needs urgent action to check its further deterioration.

5.6 LAND USE / LAND COVER

As the urbanization is increasing at an unmatchable pace, the other land uses and the land cover class areas have reduced. The area-wise cover for each class calculated for the years 1980, 2005 & 2019 is shown in Table 5.14, and net change for each class is shown in Table 5.6.

Table 5.16 Areal change of LULC from 1980-2019

Legend	1980		2005		2019	
	Area	% Area	Area	% Area	Area	% Area
Water Body	384.95	13.28	330.71	11.41	352.57	12.16
Coal Stocks	1.45	0.05	2.70	0.09	4.28	0.15
Forest Cover	1187.95	40.98	1132.42	39.07	1027.00	35.43
Coal Mines	17.08	0.59	116.76	4.03	152.84	5.27
Agricultural Field	792.18	27.32	999.98	34.50	809.75	27.94
Barren Land	447.67	15.44	260.30	8.98	442.95	15.28
Dry Ash Pond	0.00	0.00	14.05	0.48	10.68	0.37
Urban /Built up area	67.91	2.34	41.60	1.44	98.45	3.40

Table5.17 Net percentage change in LULC classes

NET % CHANGE		
LEGEND	**1980-2005**	**2005-2019**
Water Body	-14.1	6.6
Coal Stocks	86.0	58.7
Forest Cover	-4.7	-9.3
Coal Mines	583.5	30.9

NET % CHANGE		
LEGEND	**1980-2005**	**2005-2019**
Agricultural Field	26.2	-19.0
Barren Land	-41.9	70.2
Dry Ash Pond	100.0	-24.0
Built up area	-38.7	136.7

5.6.1 Change in Land Use/Land Cover

The percent net change for each land cover class for the year 1980-2005 and 2011-2016 is given in Table 5.15 and in Figures 5.10 and 5.11. It can be seen that, during 1980-2005, the agriculture area considerably increased by 26.24 %, the barren land is decreased by 41.86%, which is primarily due to the conversion of the area from barren to either agricultural or coal mines. It shows a very significant decrease in the built-up area due to the expansion of coal mines by 583.5 %. While in 2005-2019, there is a decrease in the agricultural area by 19%, during the second term, the forest cover decreased by 9.30%. There is an increase in barren land compared to the 1st period. The built-up area increased by 136.65% in the second period. The following observations can be made:

- From LULC, the maximum change occurred in the urban and Built-up areas.
- Change in a water body is not too much; the minor change is due to seasonal variations.
- There is a decrease in Dense Forest by 9.31%.
- Coal Mines are increased by 30.91% in the second term, due to setting up of new thermal power plants and increment in their capacity.
- The Coal Mines of Singrauli is the source of fuel to a thermal power station located in other districts.
- Barren Land increased by 70.16% as some portion of Coal Mines was converted into Barren Land
- In the 2nd period, the agriculture land is around 809.747 Km^2. It indicates that a large portion of Singrauli region depends on agriculture.
- Since the image was taken in Monsoon, the ash pond (dry) was measured less due to its being submerged in water.

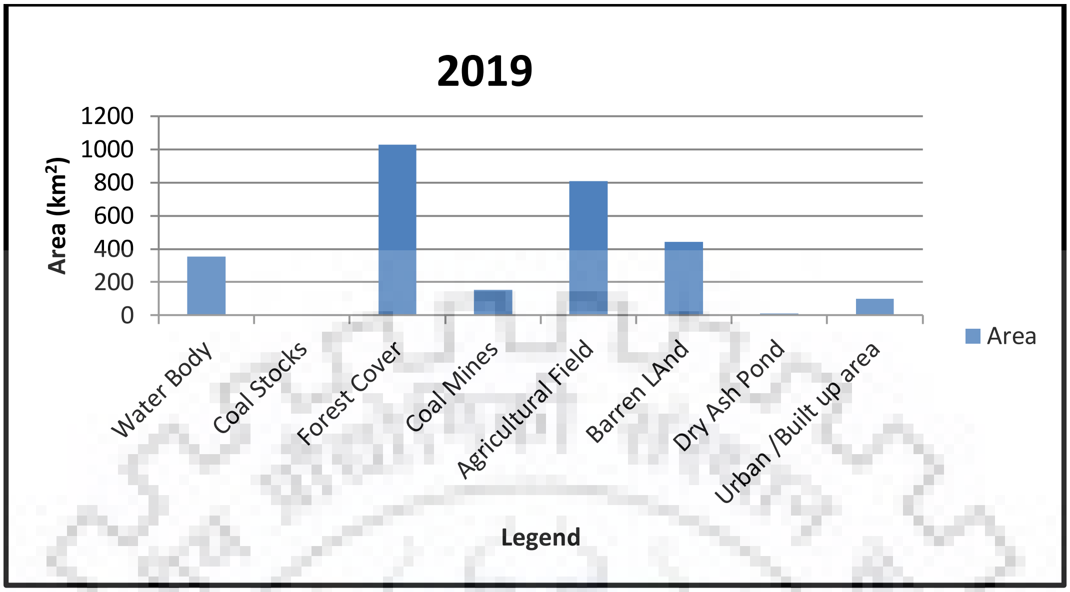


Figure 5. 7 2019 LULC Classification

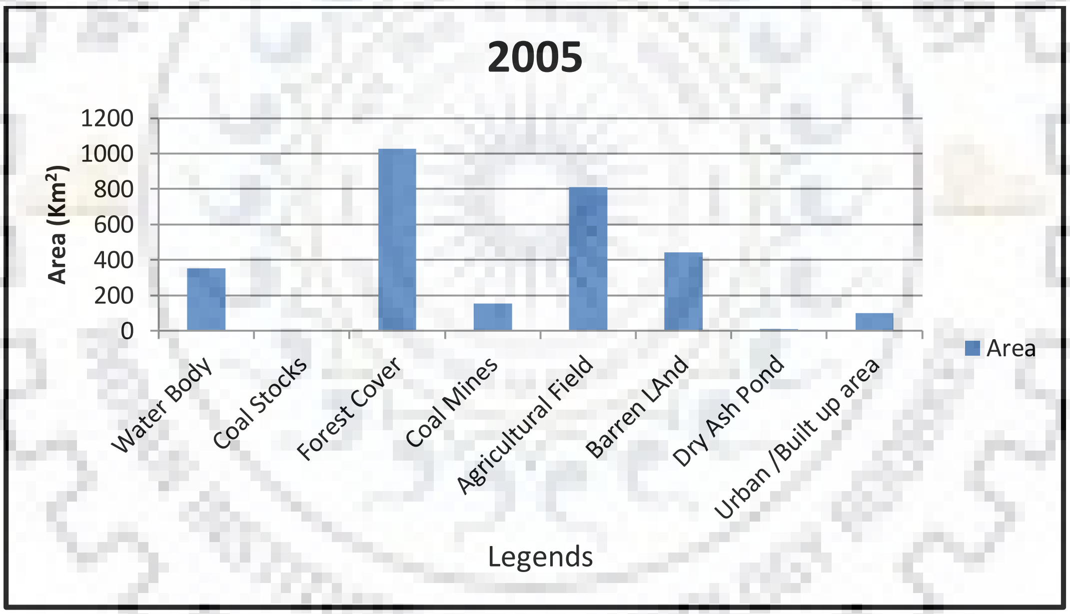


Figure 5. 8 2005 LULC Classification

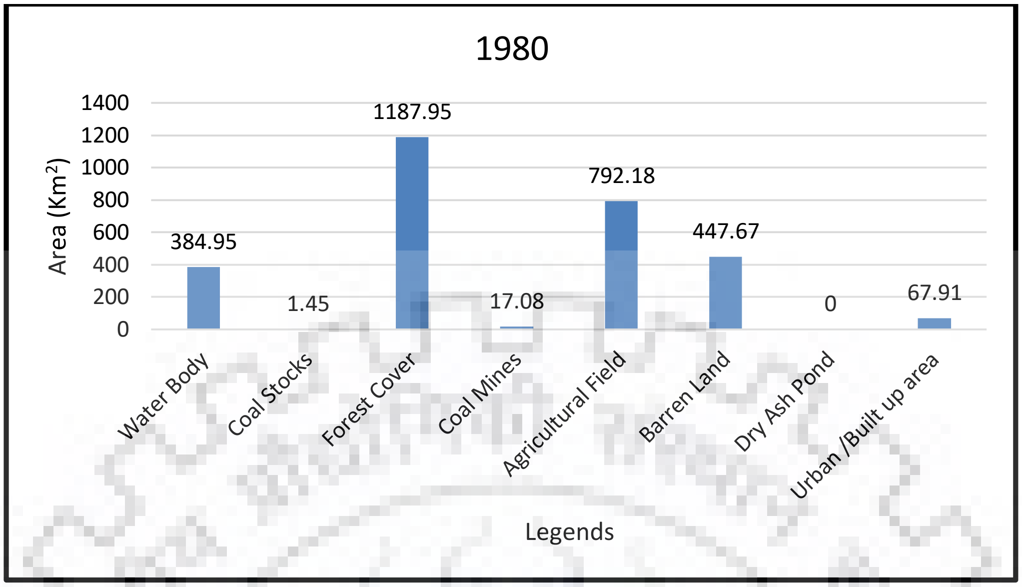


Figure 5. 9 1980 LULC Classification

5.6.2 LULC of Singrauli Region 2030

Table 5.16 shows the extrapolated parameters of Singrauli district in 2030. It can be seen that the Land Carrying capacity of the Singrauli area is decreased as shown in table 5.16. Rapid industrialization and urbanization have decreased the forest cover and agriculture land and simultaneously the Coal Mines increment was seen in the land use matrix. The Rapid industrialization also leads to the migration of people from other places to Singrauli due to substantial increment in jobs. All these lead to exhaustion of land carrying capacity of the area. The increase in the built-up area also indicates that the Singrauli region is leading towards the exhaustion of flora and fauna of the region. The considerable decrease in agriculture is also a big concern for the region as a large segment of the population depends on it. It can be easily inferred that the land carrying capacity of Singrauli in on the verge of exhaustion, and therefore, there is an urgent requirement of proper land management in the region.

Table 5.18 LULC for Singrauli in 2030

Legend	Area (Km^2)	Percentage Area
Water Body	327.675	-10.955
Coal Stocks	4.837	0.1467
Forest Cover	1003.907	33.563
Coal Mines	197.109	6.589
Agricultural Field	906.605	-30.310
Barren Land	355.29	11.88
Dry Ash Pond	8.065	0.2696
Urban /Built up area	187.59	6.27165

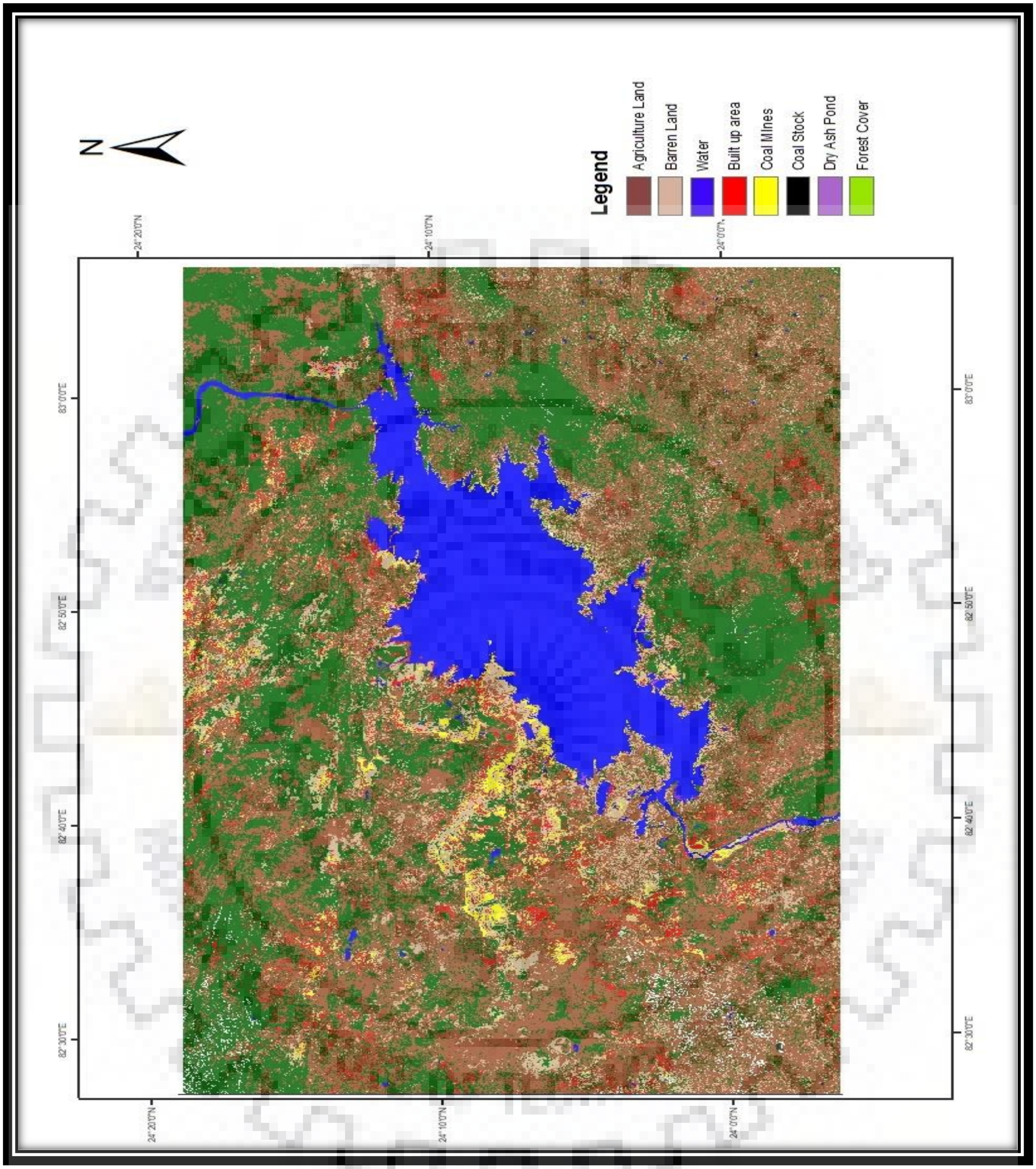


Figure 5. 10 LULC of Singrauli Region in the year 2005

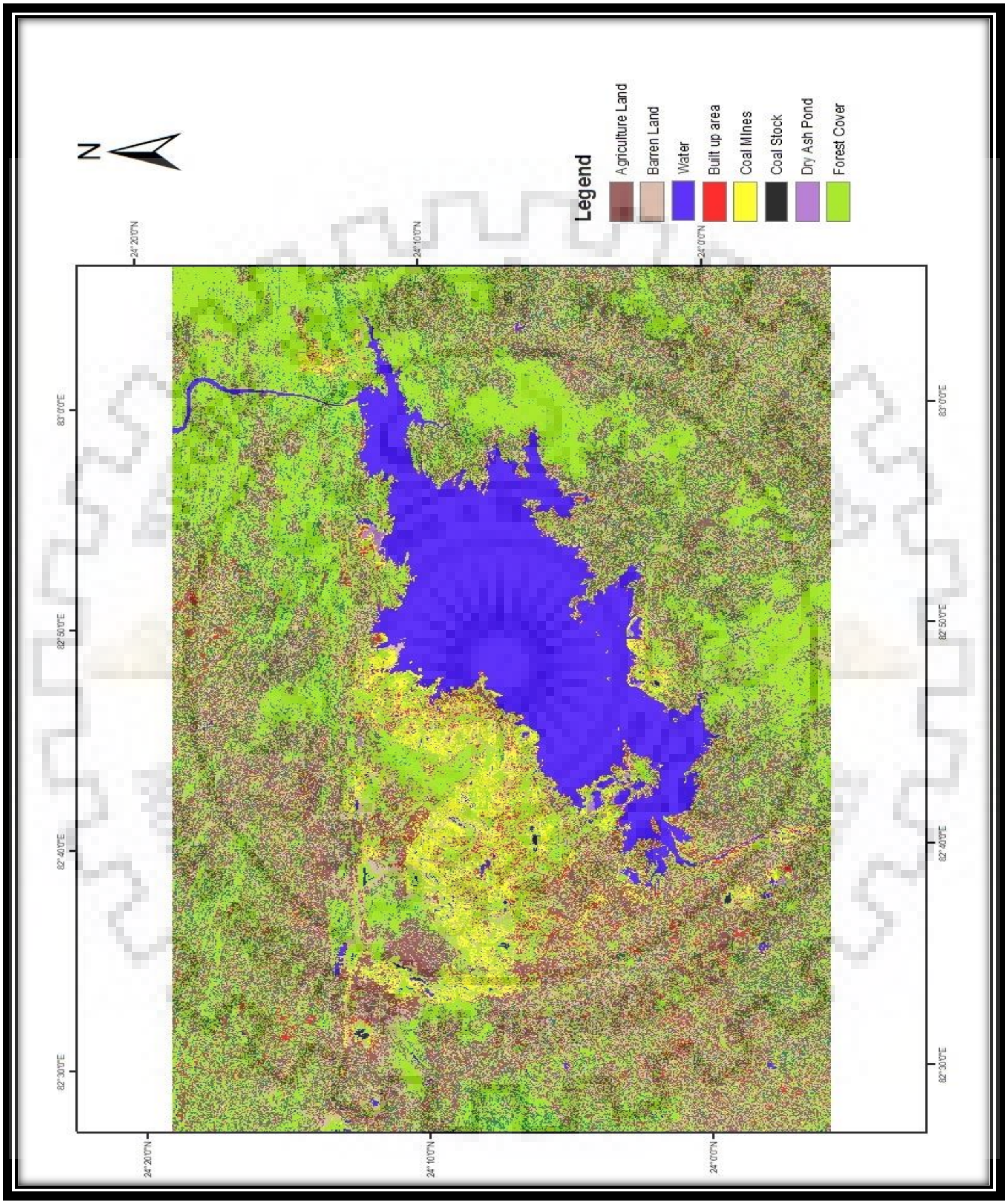


Figure 5.11 LULC of Singrauli Region in the year 2019

5.7 DRAINAGE DENSITY

The natural drains follow a specific path as per the elevations and terrain of the land. The drains flow with gravity and hence contour maps play an important role in the formation of drainage density map. Fig. 5.5 shows the contour map of the study area and Table 5.17 shows the SRTM DEM data used for the preparation of contour maps and drainage density map. Table 5.9 shows stream order length generated and Fig. 5.6 shows the stream length distribution.

Table 5. 19 SRTM DEM details

SITE	https://dwtkns.com/srtm30m/
DEM RESOLUTION	30 m
DATE	Not specified
NO OF TILES	4

Table 5.20 Stream Order and Length

Stream order	Length (in m)	Length (in Km)
1	922654.58	922.65
2	1347657.99	1347.66
3	1584684.32	1584.68
4	1681001.41	1681.00
5	1747658.42	1747.66
6	1783810.46	1783.81
7	1822392.64	1822.39

Table 5.20 indicates the length of the stream along with orders. Order 1 streams are the lowest rank streams while order 7 streams have the highest order of streams..

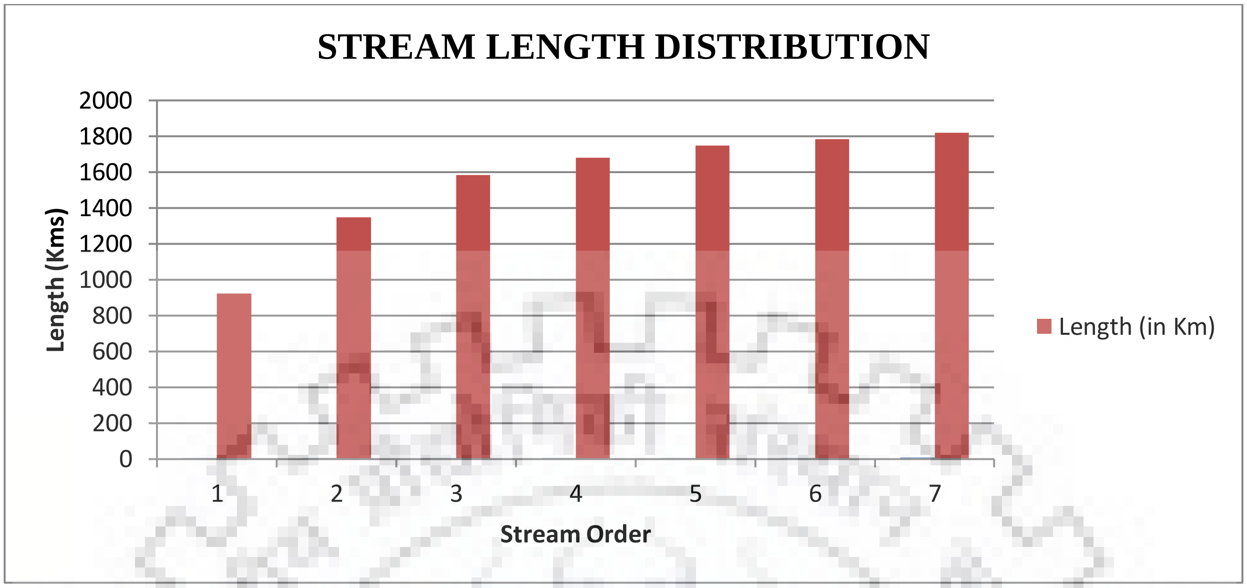


Figure 5. 12 Stream Length Distribution

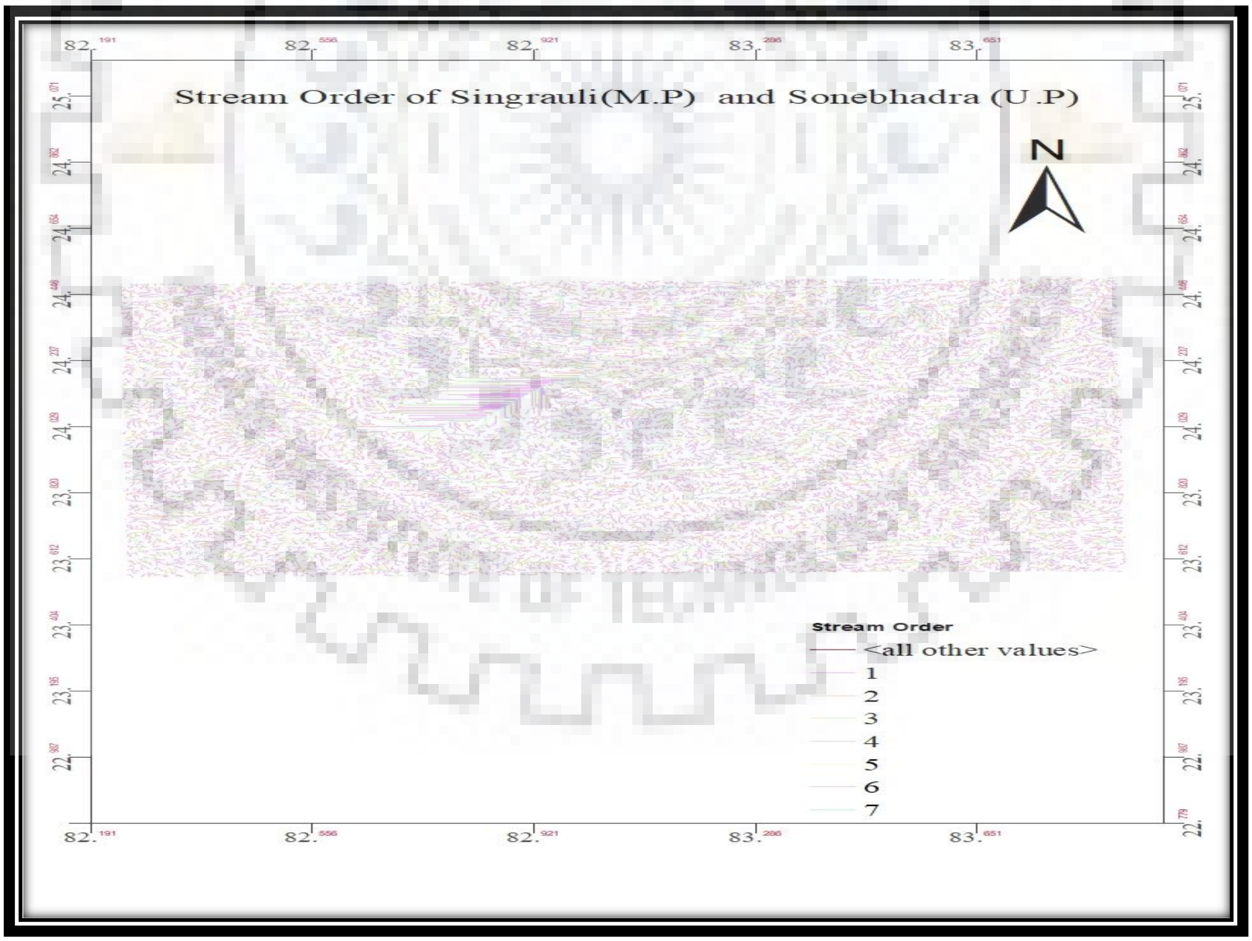


Figure 5. 13 Stream Order

From the above, the following observations can be made:

- For Singrauli region, stream density = 0.61112 / Km, where

$$\textbf{\textit{Stream Density}} = \frac{\textbf{Stream Length}}{\textbf{Area}}$$

- The total sum of drainage streams is around 10889.85 Kms
- Stream of highest order 7 having have Length = 1822.34 Kms, and lowest stream having stream length = 922.654 KMs

The density of the region in 2014 was 0.52/km (up to order 3) while in 2017, it reduced to 0.06/km (Bijendra et al. 2017), which indicates that the conversion or burial of drains has taken place due to industrialization and urbanization. It also indicates that the water carrying capacity is reduced, and simultaneously, the land carrying of the region is getting exhausted.

CHAPTER 6
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY AND CONCLUSIONS

6.1.1 Meteorological

The meteorological parameters like temperature, rainfall, wind speed, and relative humidity indirectly affect the environmental carrying capacity. Various meteorological parameters (temperature, wind speed, and relative humidity) which are crucial for environmental carrying capacity study were analyzed for trends. The average maximum temperature of the region is 33.77 ºC with a variation of 2.89 ºC and the maximum temperature observed till 2014 was 52.85 ºC. The minimum temperature observed till 2014 was 6.18ºC while the average minimum temperature in the region is 18.35ºC with a variation of 3.49ºC. The average daily rainfall of the Singrauli region is 2.59 mm with a variation of 3.38 mm and maximum rainfall recorded till 2014 on a single day was 143 mm. The average wind speed is 1.997 m/s. with a variation of 0.383 m/s with maximum wind observed till 2014 was 5.49 m/s while minimum wind observed till 2014 was 0.451 m/s. The average R.H. is 49.16% with a variation of 11.76% and maximum R.H. observed till 2014 was 96.13%. The maximum speed has been obtained in the South direction with a maximum wind speed greater than 28 Km/h. The findings suggest that people habituating in the south direction tend to get affected the most by air pollution. Thus, the meteorological conditions play a crucial role in ambient air pollution, by affecting both, directly and indirectly, the emissions, transport, formation, and deposition of air pollutants.

6.1.2 Water Quality

The quality of ground and surface water is within desirable limits, and therefore, fit for industrial and domestic uses, for no toxic or cacogenic mineral is found. Thus, the water carrying capacity of Singrauli region is not yet exhausted, The groundwater pH varies from 6.73 -7.51 which lies within the acceptable limit varying from 6.5 – 8.5, color varies from 1-3.4 on Hazen scale observed within desirable limit (15 Hazen units) while TDS varies from 72-367 mg/l which also lies within the permissible limits 1500 mg/l. These results indicate that all the parameters are within desirable limits. The water quality standards conform to the standard prescribed by the concerned authorities. The results obtained for surface water show that pH varies from 7.06 -8.4 which lies within the acceptable limit varying from 6.5 – 8.5, color from 130-172and is observed under the desirable limit (300 Hazen unit), TDS varies from 70-455 mg/l which was also under desirable limits 1500 mg/l. These results indicate that all the surface water quality parameters are within limits. Although water carrying capacity is not yet exhausted, certain remedial measures are required to check the percolation of heavy metals from Ash ponds.

6.1.3 Ambient Air Quality

The study reveals that Singrauli district is under **severe** threat due to air pollution as $PM_{2.5}$ and PM_{10} limits have been crossed most of the times. For Singrauli city, $PM_{2.5}$ level seems to be highest in July while PM_{10} is recorded highest in January. The minor relief could be from the fact that SO_2, NH_3, NO_2, Ozone are within limits. Heavy industries and thermal power plants are the major source of air pollution ($PM_{2.5}$, PM_{10}, SO_2) in the area. The EIA report by Sasan power plant shows that the concentration of SO_2 ranges from 522.6 -725.3 Ng/m^3 although the permissible limits are 80 Ng/m^3, which is almost nine times the limits specified by CPCB, while NO_2 ranges from 218-273 ng/m^3 which is also much higher than desired limits (80 Ng/m^3), almost three times the specified limit. Fly ash and coal dust are the major concerns in the area. Rapid industrialization increases traffic pollution. Traffic congestion or traffic jam saw in the area also increase pollution in the area. The air carrying capacity of the region is already exhausted and reached the critical limits, and therefore, urgent and necessary actions should be taken to check the pollution.

The National ambient air quality index (AQI) has an average value ranging from 62-325, the lower limit being in August while the upper in January. Similarly, the range for Maximum AQI is 146-965 in August and July respectively, and the Minimum AQI range is 18 (August) – 172 (January). According to the Oak air Quality Index, the Air is in **severe** state most of the times. The National Ambient Air Quality Index of CPCB is highest in July, which is in a **severe** state. The revised AQI reveals that PM_{10} level is maximum in April, $PM_{2.5}$ in October, NO_2 in January while Carbon Monoxide in May. According to RAQI, January, and June –July is the most critical months in terms of pollution. On the whole, the major concern in the Singrauli region is ambient air quality. The region has already exhausted its air carrying capacity and reached a **severely critical level**. Certain measures are urgently required to check the air pollution in the region.

6.1.4 Land Use Land Cover

Considerable land use/land cover changes have taken place in and around Singrauli region during 1980-2019. Forest has a reported loss of 160.95 Km^2 areas with 55.95 Km^2 in 1980-2005 and 105.42 Km^2 in 2005-2019. The change is primarily due to the expansion of mining activities and power Industries in the region and as a result of expansion, the forest gets degraded and converted into barren land. The agriculture land has increased by 207.8 Km^2 due to the conversion of barren land into agriculture land in the year 1980-2005 but there is a significant decrease in agriculture land by 190.23 Km^2 in 2005 – 2019 due to the conversion of agriculture land into uncultivated and barren land because of decline in rainfall and groundwater level. The change in a water body is not too much; the minor change is due to seasonal variations. A significant increase in coal mines has been observed, the increment is estimated to be 135.76 Km^2 from the year 1980 -2019 while a change of 99.68 Km^2 in the year 1980-2005 and increment of 36.08 Km^2 in 2005-2019 which indicates a significant increment in the coal demand of Singrauli and nearby regions for industrial purpose. The major increment in the built-up area has been registered as 56.85 Km^2 in 2005-2019 which reveals the rapid industrialization in the area. The major contributor to this increment is a migration of the working class towards Singrauli which has also resulted in an increase of demand for residential complex and associated services in the area. The number of ash ponds has also increased in the periphery of rihand reservoir which combined amounts to 10.68 Km2 of area. These Ash ponds used to dispose of the huge quantity of ash generated from the thermal power plants which pollute the groundwater quality and water of Rihand reservoir. This has resulted in a drastic change in the land cover dynamics of the fragile ecosystem. Thus, due to industrialization and urbanization in the last two decades, a significant reduction in agricultural land while a significant increase in Coal Mines and Built up area has been observed. Since the major portion of Singrauli region depends on agriculture, conservation of agricultural land should be a major concern in the future.

6.1.5 Drainage Density

Drainage density of Singrauli region has decreased with time, indicating its blockage with time. The Drainage density also affects the inflow of water into the Rihand dam from nearby areas. The total sum of drainage streams is around 10889.9 km. Stream Density in the area is 0.6111 km/km^2.

The major reason is the conversion of land into agricultural or built up area which includes industries too. Thus, the density of region in 2014 was 0.52 km/km^2 (up to order 3) while in 2017 it reduced to 0.06 km/km^2, indicating the conversion or burial of drains due to industrialization and urbanization.

6.2 RECOMMENDATION AND SUGGESTION

1. Establishment of Dynamic Monitoring Mechanism

Based on Ambient air quality and Land use Pattern it has been observed that there is an urgent need of a mechanism for quantitative assessment and takes necessary steps to check the deterioration of the environment. Therefore, dynamic monitoring mechanism for all 88 industrial clusters notified by GOI is recommended.

2. **Upgradation of Singrauli Industrial area**

Singrauli required certain upgradations because air pollutants (Table 5.5a,b) are much more than the desirable limits. In industrial development especially the Power sector in Singrauli region must be focused on the upgradation of industries. The economic development density and economic efficiency for the Singrauli region should be improved.

3. **Moderate Development Area**

Demographic of Singrauli district indicates that the region has seen rapid industrialization in the last two decades as it has created jobs. For a sustainable environment, it is necessary that the area experiences a moderate development only as people are largely dependent on agriculture and there has been a reduction in agriculture in the last few decades, which is a major concern.

4. Reservoir and River-side Protection of Area

Land use indicates that the ash dumping ponds have increased nearby Rihand reservoir. The ash pond pollutes the reservoir indirectly as these affect groundwater as well as the reservoir water quality that will be harmful to the aquatic ecology. Eco-Tourism should be promoted and developed.

5. Future expansion of Industries in Singrauli Region

The National Ambient Air Quality index (NAQI) is above 900 which is nine-time the permissible limit and the concentration of SO_2 in the region is 725.3 mg/Nm^3 which is much higher than the acceptable limit of 80 mg/Nm^3. As per the data and the corresponding indices, the air quality in the region lies in the very severe zone. Further establishment of new industries will worsen the air quality and it is not recommended to allow construction of such thermal power plants in the region. It is highly recommended that the thermal power plants in the Singrauli region upgrade their existing technology so as to meet the emission standard laid down by the CPCB.

Inferences drawn from the study of similar studies in the past and patterns of change in Land Use indicate that there is a significant increase in the coal mining industry in last two decades which causes a reduction in the forest and agricultural areas. Coal reserves in nearby or other areas should be quantified. The cost-benefit analysis on the basis of availability, mining, and transportation should be done and compared with overall environmental costs. A simultaneous approach of a shift towards alternate energy sources should be pursued however any new activity in the coal mining in the Singrauli region should be checked and the future allocations should be made after critical assessment for EIA and Demographic sustainability. There is a need for integrated energy planning to examine the solutions available and to pick the energy pathway that is most sustainable. As Demographic profile of Singrauli indicates that the major portion of the population belongs to the tribal or rural population so it is important to declare some of the forest areas as permanently off limits to mining. Thus, there is a need for urgent remedial measures to mitigate the negative environmental and health impacts due to the existing mining and power industries in the Singrauli region.

CHAPTER 7
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APPENDIX

METEOROLOGICAL DATA

Table A-1 Average of Daily Climatological Parameters

Year/Parameter	AVERAGE OF DAILY CLIMATOLOGICAL PARAMETERS				
	Max Temp (ºC)	**Min Temp (ºC)**	**Precipitation (mm)**	**Wind (kmph)**	**R.H (in %)**
1979	34.32	18.74	1.13	2.09	43%
1980	33.51	18.50	3.00	2.06	48%
1981	32.96	17.78	3.05	2.06	51%
1982	32.80	19.00	2.39	1.90	51%
1983	32.33	16.57	1.88	1.96	48%
1984	32.77	17.94	2.08	2.15	48%
1985	33.86	17.67	1.71	2.11	47%
1986	33.14	17.94	1.87	2.06	49%
1987	33.80	18.64	2.01	1.98	46%
1988	34.31	18.49	3.03	2.04	49%
1989	33.32	17.54	3.45	2.07	48%
1990	32.63	19.40	4.51	2.08	54%
1991	34.33	18.20	2.68	2.09	50%
1992	34.34	18.02	1.76	2.07	47%
1993	33.90	18.61	2.76	2.05	50%
1994	33.45	18.44	2.98	1.94	52%
1995	33.39	19.37	2.78	2.03	50%
1996	33.58	18.50	2.68	1.99	51%
1997	32.34	18.77	3.75	2.04	54%
1998	33.21	20.05	3.51	2.02	55%
1999	34.20	18.29	2.41	2.03	49%
2000	34.66	17.31	2.11	2.07	46%
2001	34.26	17.70	2.35	1.98	48%
2002	34.87	18.57	2.27	2.07	45%
2003	33.95	18.91	3.96	1.86	50%
2004	34.65	18.45	1.62	1.97	47%
2005	34.07	18.18	1.80	1.96	47%
2006	34.46	19.19	1.93	2.02	48%
2007	34.11	19.14	2.97	2.04	50%
2008	33.92	18.35	3.27	1.97	51%
2009	34.77	19.29	2.47	2.02	47%

2010	35.23	19.64	2.59	1.92	49%
2011	33.72	16.92	4.43	1.77	54%
2012	33.87	17.15	2.14	1.86	48%
2013	33.67	17.85	1.61	1.78	50%
2014	33.18	17.51	2.12	1.82	51%
Average	**33.77**	**18.35**	**2.58**	**2.00**	**49%**

Table A-2 Maximum of Daily Climatological Parameters

Year/Parameter	MAXIMUM OF DAILY CLIMATOLOGICAL PARAMETERS				
	Max Temp	**Min Temp**	**Precipitation**	**Wind**	**R.H**
1979	50.49	32.46	71.93	4.52	93%
1980	48.84	29.78	118.47	5.35	94%
1981	47.80	28.73	101.03	4.77	95%
1982	48.09	32.42	63.59	3.83	95%
1983	48.09	32.42	63.59	4.02	95%
1984	47.97	30.09	49.51	4.77	94%
1985	49.71	31.29	29.32	3.89	90%
1986	47.99	29.98	42.14	3.53	92%
1987	47.38	32.91	85.20	5.49	96%
1988	49.39	29.75	88.41	4.06	94%
1989	49.60	30.81	59.85	5.05	94%
1990	46.34	32.89	116.46	4.14	95%
1991	49.24	32.01	75.07	4.04	95%
1992	49.16	30.24	99.85	5.07	95%
1993	48.63	34.04	72.44	4.41	93%
1994	49.30	29.47	41.02	4.09	94%
1995	47.72	33.73	60.55	4.51	94%
1996	50.15	30.66	69.36	3.70	91%
1997	48.01	30.40	130.86	4.66	94%
1998	47.40	31.49	69.76	4.52	94%
1999	47.87	31.49	69.76	4.52	94%
2000	51.24	33.34	143.21	4.47	96%
2001	46.95	29.12	33.03	3.77	92%
2002	49.61	31.34	48.20	4.52	93%
2003	52.85	31.85	94.31	4.08	95%
2004	50.52	31.40	45.37	4.39	93%
2005	51.11	33.07	63.56	4.42	93%
2006	47.14	32.73	90.18	4.41	95%
2007	49.82	29.55	109.63	4.80	95%
2008	49.33	28.95	133.89	4.85	94%

2009	51.26	33.87	98.57	4.03	95%
2010	51.52	31.82	105.73	4.45	91%
2011	48.00	28.90	102.50	3.98	95%
2012	48.71	30.35	96.49	4.50	94%
2013	48.48	29.58	67.30	5.34	95%
2014	51.37	29.86	140.95	5.34	95%
Maximum	**52.85**	**32.04**	**143.05**	**5.49**	**96%**

Table A-3 Minimum of daily Climatological Parameters.

Year/Parameter	**MINIMUM OF DAILY CLIMATELOGICAL PARAMETERS**				
	Max Temp	**Min Temp**	**Precipitation**	**Wind**	**R.H**
1979	15.51	4.86	0.00	0.84	8%
1980	16.89	3.36	0.00	0.96	6%
1981	14.18	2.90	0.00	0.91	11%
1982	16.63	5.55	0.00	0.66	11%
1983	6.40	0.46	0.00	0.60	11%
1984	16.34	2.82	0.00	0.98	6%
1985	17.73	3.46	0.00	0.75	11%
1986	13.31	-0.84	0.00	0.84	10%
1987	17.67	3.23	0.00	0.90	12%
1988	19.14	1.84	0.00	0.97	9%
1989	17.13	-1.14	0.00	0.85	7%
1990	20.65	5.37	0.00	0.45	11%
1991	19.01	2.63	0.00	0.80	9%
1992	21.87	2.87	0.00	0.96	12%
1993	18.79	2.09	0.00	0.83	12%
1994	18.18	1.94	0.00	0.94	13%
1995	15.37	4.73	0.00	0.66	9%
1996	18.65	2.41	0.00	0.73	7%
1997	17.49	2.10	0.00	0.84	10%
1998	18.26	3.29	0.00	0.84	12%
1999	6.58	3.28	0.00	0.64	6%
2000	24.67	0.73	0.00	0.75	8%
2001	23.60	1.14	0.00	0.91	8%
2002	22.23	3.55	0.00	0.80	7%
2003	17.04	1.18	0.00	0.71	9%
2004	18.26	1.46	0.00	0.64	11%
2005	15.76	2.21	0.00	0.82	7%
2006	23.64	2.00	0.00	0.99	12%
2007	19.64	1.04	0.00	0.72	11%
2008	15.20	1.71	0.00	0.81	9%

2009	17.31	6.46	0.00	0.88	6%
2010	21.04	3.95	0.00	0.58	9%
2011	20.53	0.59	0.00	0.85	13%
2012	19.07	1.47	0.00	0.64	12%
2013	21.32	0.11	0.00	0.63	9%
2014	6.18	0.11	0.00	0.63	9%
MINIMUM	**6.18**	**-0.84**	**0.00**	0.45	6%