COMPENDIUM ON WORK OF INTERNS

SUPREME AUDIT INSTITUTION OF INDIA
लोकहितार्थ सत्यनिष्ठा
Dedicated to Truth in Public Interest

Occasional Research Paper Series # 4

INTERNS, iCED

Compendium Report 2022

International Centre for Environment Audit and Sustainable Development, Jaipur

About the Research Papers

These Research Papers are a part of our endeavor to improve accountability and inculcate professional excellence in the areas of environment and sustainable development. We have initiated from the year 2022 an Occasional Research Paper Series featuring different emerging areas of environmental audit and sustainable development. These papers are based on the case studies conducted by interns during the last five years.

Feedback

We strive for constant improvement and encourage our readers to provide their valuable feedback/suggestions. Please send us suggestions, comments, and questions about this compendium series to iced@cag.gov.in.

Disclaimer

Copyright

Foreword

Public Sector Institutions (including Central and State Governments) are undergoing various sectoral and structural reforms. These paradigm shifts in governance strategy, structures, policies and processes have a direct impact on audit policies, processes and methodologies. In this changed scenario, public auditors need to upgrade their skills continuously. The audit of environment and sustainable development issues is an emerging area of activity for the Supreme Audit Institutions. Given its cross-cutting, dynamic and multi-disciplinary nature, capacity building and inputs informed by research becomes an essential pre-requisite for human resource management and reporting on public accountability in these areas.

International Centre for Environment Audit and Sustainable Development has been set up by the Comptroller and Auditor General of India with an aim to improve accountability and governance in the areas of audit of the environment and sustainable development. Strategic objectives of iCED include inter-alia, the sharing of knowledge related to the environment among government agencies and public auditors and undertaking research in the environment and sustainable development area. In this direction, iCED, apropos of the policy guidance of the O/o the Comptroller and Auditor General of India to encourage internships, provides opportunities to research interns from Universities and institutions to research at iCED for short durations and provide research inputs in the selected areas of engagements.

This compendium presents the results of efforts and studies undertaken by interns at iCED since the commencement of this scheme in the year 2018. As a new initiative, iCED is commencing an Occasional Research Paper Series to act as a springboard for ideas and facilitate both young and experienced voices to conduct a constructive discourse. In this first such paper, we are showcasing the efforts made by selected Interns to present their ideas.

I hope this compendium will serve as a repository of reference material for auditors working in the field of audit of environment and sustainable development, and also enable them to include new tools, methodologies and approaches, especially in areas covered here such as waste management, disaster management, eco-tourism, biodiversity etc. I would particularly like to highlight the compendium on GIS and Remote Sensing, which maps a synergy between environmental audit methodologies and harnessing the power of advanced technology in audit impact assessment. I trust that this compendium will enhance our understanding about the environment and provide a fresh audit perspective for the audit of environment and sustainability-related issues.

As the contributors are young students, sharing their ideas with audit professionals, can also be a mode of outreach which can enliven the discourse on an audit of the environment.

It is also worth stressing that the value of these inputs is to bring a spirit of zestful inquiry from young voices to our structured processes.

We at iCED would be delighted to receive your feedback and valuable insights into this compendium.

04 August, 2022 **(Sayantani Jafa)**

Jaipur Additional Deputy CAG and Director General, iCED

Introduction

The subject of environment and sustainability are recent entrants in the domain of public discourse, especially after the United Nations Conference on Human Environment held in 1972 at Stockholm. As per UNEP's report "Making Peace with Nature" (2021), the three critical issues affecting the environment and sustainability are Climate Change, Loss of Biodiversity and Pollution. Driven by decades of relentless and unsustainable consumption and production, these crises are amplifying deep inequalities and threatening our collective future.

In view of unparalleled scale and pace of change affecting the planet earth, it is emphasized that transformative changes are required in our ways and means of living. Our growing concern for the environment and sustainability has also been accompanied by more concerted efforts for environmental conservation and sustainable use of natural resources. Increase in the number of global covenants, Acts and Rules framed by national governments and the initiatives taken by local-level agencies have gained momentum. Environment Audit and audit of sustainable development issues are growing as a major area of activity for the Supreme Audit Institutions (SAIs) around the globe.

Given its nascent and dynamic nature, the subject of environment and sustainability is evolving with new research taking place all the time. While some areas are not supported by policy framework, in some others, the policy has been questioned and is still being debated. Many issues that appear intractable currently have empirical solutions and reflect a lack of consensus among stakeholders. It is quite challenging for the auditors to arrive at definite conclusions and recommendations. A well informed research input, therefore, is a *sine qua non* for the development of the subject and its increased understanding. It is therefore imperative that research should continuously inform our audit process and design.

In line with its vision to be a global Centre of Excellence in the area of environment and sustainable development; iCED undertakes various activities such as training and workshops, knowledge sharing, information hub and research, supporting audit, etc. In the initial years, focus was largely towards capacity building, knowledge sharing and allied works. Of late, in-house research activities have gained momentum at iCED through the engagement of interns, young professionals and research associates.

A total of 13 interns have been engaged at iCED since the beginning of the internship scheme (2017-18). The broad areas covered by the interns in their study are; Use of Geospatial

Technology in Audit, Marine-nature based tourism, Plastic waste, Non-Timber Forest Produce (NTFPs), E-Waste, Disaster preparedness, Air pollution, Pollution caused by dust, Invasive alien species, Hazardous waste and Change in the urban landscape.

This compendium is a compilation of twelve case studies conducted by interns during the last five years at iCED. Besides being a repository of domain information in respective thematic areas, this compendium also captures the tools, methodologies and analytical rigour used to study various environmental and sustainability-related issues for ready reference and use by auditors.

Volume -1 covers the theme **Eco-Tourism and Disaster Preparedness;** which is based on three case studies. Two studies focus on the impact of tourism and violations of the shack policy in Goa respectively using the process of Regulatory Impact Assessment to analyse the problem and constructing recommendations. These studies are: "Tourism a Bane or a Boon? A case study of the impact of marine nature-based tourism in Goa" by Ms. Trinayani Sen and "A research aimed at enhancing evaluation in Audits by integrating it with Regulatory Impact Assessment" by Mr. Saurabh Suman completed during the period April-May 2018. The study on "Disaster preparedness in Andaman and Nicobar Islands" conducted by Ms. Ankita Singh during July-September 2020 is based on the 2004 tsunami affecting the Andaman & Nicobar island with a focus on mapping vulnerabilities using GIS techniques, map studies and other vulnerability frameworks for disaster mitigation and adaptation.

Volume -2 on the theme **Use of recent Technologies for study of Environmental Issues and Audit** is based on inputs drawn from the work of three interns. These studies are "A case study on changing of land and land cover analysis over iCED campus for the period 2009-2018", "A comparative study of change in urban landscapes covering five Indian cities (Delhi, Bengaluru, Kolkata, Pune and Indore) using QGIS" and "Industrial hazardous waste management in Rajasthan and Gujarat using GIS Technique" by Mr. Sangam Yadav, Mr. Nishant Kumar Upadhyay and Ms. Simran Jatwani respectively. This volume of the compendium showcase use of new tools for studying land use change and land cover analysis, the impact of urbanization on vegetation, water bodies, etc, using Remote Sensing Data with QGIS in selected sites and for ascertaining locational compliance in respect of Hazardous waste disposal sites using Google earth tool.

Under Volume 3, **Waste Management** encompassing the issue of plastic waste, e-waste and hazardous waste are covered. It is based on the following studies: "The assessment of plastic waste in Jaipur city with focus on the role of Municipal Corporation in plastic waste management", "Assessment of E-waste in regard to management policy in Jaipur city", "Plastic waste management with a focus on role of circular economy and other management techniques: A Review" and "Industrial hazardous waste management in Rajasthan and Gujarat" completed by Mr. Manikant Barik, Mr. Sungrongti, Mr. Prateek Kumar and Ms. Simran Jatwani respectively during 2018-19 to 2020-21. The studies provide inputs and perspectives such as the circular economy approach, which is becoming critical from a sustainability point of view, and also aid in framing audit questions in these areas.

Volume 4 on the theme of **Air Pollution** comprises the work of Mr. Swapnil Das, covering the city of Delhi with focus on vehicular pollution, conducted during the year 2020.

Volume 5 of the compendium titled **Forest/Biodiversity** has two studies. One of the study is regarding the impact of Alien Invasive Species on some native animal species; conducted by Ms Nilisha Sinha in 2021. It underlines the impact of two invasive species *Prosopis juliflora* and *Acacia tortilis* on some native animal species in Rajasthan such as Spiny-tailed Lizard, Blue Bulls, Great Indian Bustard and Bengal Tiger. The other study illustrates the use of system dynamics modelling for generating models to assess the value of Non-Timber Forest Products and aid in improved decision making towards promotion of sustainable development goals. It was conducted by Mr Hari Haran Kannan during 2020.

It may be appreciated that the case studies incorporated in this compendium have been done by the interns within a very limited time period of their engagement at iCED and may not be expected as professional research papers. Yet, these may serve as a good source of information in selective areas and also provide many new inputs/ perspectives/ tools and approaches which can be suitably adopted during various stages of audits, covering the subject of environment and sustainability.

(**Pushkar Kumar)**
Director (Training and Research)
iCED, Jaipur

Contents

THEME – 1.1: IMPACT OF TOURISM IN GOA

1.1.1 Introduction:

According to UNWTO, "Tourism is a social, cultural and economic phenomenon which entails movement of people to countries or places outside their usual environment for personal or business/professional purposes" (UNWTO, 2007). As a country, India has a lot to offer in terms of tourism.

Goa, with its 100 km (approx.) long coastline, is a major tourist destination in India and tourism is an important lifeline for the State of Goa as the Goan economy receives a significant boost from that particular industry. Goa has different kinds of tour packages for its tourists, from coastal tourism, partying and nightlife, marine tourism, nature-based tourism, cultural and heritage tourism, health and wellness tourism to spiritual tourism. However, the rapid development and promotion of tourism, especially marine tourism, over the last few decades have led to widespread exploitation of the natural wealth of this state. The Goa tourism policy, formulated to promote tourism in the state, does not account for the environmental and sustainability issues that are a consequence of such unregulated tourism activities.

1.1.2 Literature Review:

A Performance Audit of the promotion of tourism in Goa was conducted by the field office of the Comptroller and Auditor General (C&AG) of India in 2012. Based on the audit report, interns from iCED conducted two studies. The rationale behind choosing the research topics came from the audit report for the State of Goa, especially violations of shack policy and issues in the regulation of water sports etc. The audit report also talks about the need for Sustainable tourism in the state. The audit attempted to assess the impacts of tourism on the environment. The audit report in Chapter-II highlighted the stagnating tourist arrivals from 2009 onwards. The impact of marine nature-based tourism on the marine ecosystem, which is a crucial aspect of tourism in Goa, is attempted in the studies undertaken by two interns of iCED. The first study conducted by Ms. Trinyani Sen aimed to assess the impact of tourism on the natural resources and the marine ecosystem and devise necessary regulatory mechanisms for the same.

The shacks are dependent on the tourists for their existence, and it is the flow of the tourists which influences their behaviour. Other things of importance highlighted by the report were the inadequacy and poor maintenance of amenities at tourist places like parking lots, toilets and changing rooms. In paragraph 2.1.9.2 of the report, findings regarding the cleanliness of beaches and beach inspections have been published. This is followed by paragraph 2.1.9.3 (Regulation of Beach Shacks), paragraph 2.1.13.1 (Lack of Sewage Network in Coastal Belts), paragraph 2.1.13.2 (Lack of Solid Waste Management in Coastal Belt), paragraph 2.1.13.5 (Violation of coastal regulation zone), paragraph 2.1.13.7 (Lack of Community Participation for the planning of projects) and paragraph 2.1.15 (Recommendations). The second study conducted by Mr. Saurabh Suman is focused on the two most relevant regulations which govern the behaviour of the shacks under the Coastal Regulation Zone Notification, 2011 (CRZ Notification, 2011) and the Shack Policy by the Department of Tourism, Goa.

1.1.3 Methodology:

Two studies were undertaken by interns. The first study attempts to analyse the problem of the negligence of marine life for the promotion of tourism activities, identify the key causal factors for the same and devise relevant regulatory mechanisms. The focus of the study was mainly on marine nature-based tourism activities such as dolphin watching, picnic boat cruises and diving activities. The components of the marine ecosystem considered for this study were the coral reefs and the marine mammals present in that area. The other study probed the question 'Why do the shack owners violate the regulations?' These violations are the problem and this exercise aims to go beyond the problems encounter and look into the causes that lead to the problems.

Both studies demonstrate the use of the process of Regulatory Impact Assessment (RIA) an increasingly accepted process in the Organisation for Economic Co-operation and Development (OECD) nations, of the developed countries, often helps in exploring these causes, establishing a relationship among them, and therefore in helping make precise recommendations and how can it be useful to the auditor fraternity in carrying out a deeper analysis, and in making more informed recommendations.

1.1.4 Study-1: Tourism- A Bane Or A Boon? (A case study of the impact of marine nature-based tourism in Goa)

The report outlines the impact of marine nature-based tourism activities on the marine ecosystem of Goa. This research has been conducted through the process of a Regulatory Impact Assessment, taking negligence towards marine ecosystem as the central problem behaviour. Various causal factors have been identified, that are instrumental in causing the problem behaviour and the links between them have been established. Following this different tools from a regulatory toolkit have been used to try and solve the problem behaviour effectively and efficiently. Finally, an operationalization procedure for a feasible solution has been briefly described. This study is aimed to provide auditors with an insight into the process of RIA with a case study to supplement the general template. Some aspects of RIA, however, are beyond the scope of this study.

1.1.4.1 Identifying and Defining the Problem Behaviour:

To understand the problem behaviour two major marine nature-based tourism activities- Dolphin watching tours and diving tours (Scuba diving and snorkelling) were chosen for study using RIA. The problems associated with them were as follows:

Dolphin Watching tours:

The increasing volume of dolphin tours with the increase in the number of tourists is a major cause of stress for the Indian Ocean Humpback dolphins (Genus: Sousa). The boat tours, that have become very popular in the last decade, were causing degradation of the dolphins' natural habitat which may be the cause for a decrease in their numbers over the years. Studies report that the dolphin sighting rates have fallen from 0.236 groups/km in 2001-02 (Sutaria and Jefferson, 2004) to 0.151 groups per km in 2016 (Hemalatha, 2018). Hundreds of boats take tourists for dolphin sighting tours daily during the 6-month tourist season in Goa. These boats use techniques such as Path cutting (boats being driven perpendicular to the dolphin's path of travel), chasing (closely pursuing dolphins) and circling (Arc like movement of boats aimed at restricting the movement of dolphins) after spotting a pod of dolphins. Along with this, the sound produced by the boat engines acts as a deterrent for dolphins (WWF, 2016). According to a study conducted by WWF in 2016 50 percent of the boat trips cut the dolphin's path of travel, 28.57 percent circle the dolphins and 10.71 percent of boats chase them (Ganesan, 2016). These techniques used by the boat operators adversely affect the essential socialising, mating and hunting activities of the dolphins. It also causes them a great deal of energy loss due to the continuous path change that they have to undertake to escape the boats. It may also be a reason for increasing dolphin mortality along the coast (Field interaction). Tourist actions such as creating noise by playing loud music, littering, dancing and consumption of alcohol on the boats also contribute to the negligent behaviour on part of the tourists.

Coral Reefs and other marine life around Grande Island:

Sites around Grande Island are used for recreational diving in Goa due to the presence of coral reefs and other marine life. The subtidal area surrounding the island is a high-biodiversity site comprising natural ecological habitats, seaweeds, submerged rocks encrusted with sponges, corals, sandy bottoms and more than 85 species of fish thus making it a hotspot for marine nature-based tourism. (Fernandes, 2016). Apart from diving, these sites are also used by operators for picnics, swimming, snorkelling and fishing activities (WWF, 2016). However, due to several factors such as port activity, unregulated tourism, fishing and so on, the marine ecosystem is facing a lot of stress. Studies have reported the presence of debris, damage to corals in terms of breakage and bleaching and algal growth. Boat operators who are not aware of the importance of corals, carelessly throw their anchors causing severe damage to the corals.

Tourists and boat operators also throw garbage into the sea which increases the levels of marine pollution and damages the eco-fragile flora and fauna around the island.


The problem behaviour for this RIA can be defined as negligence towards the marine ecosystem and across actions of all the different stakeholders. This is because the degradation (or loss) of the habit of the dolphins and the damaging of corals is occurring due to the negligent behaviour of the system as a whole.

Stakeholders:

For this study, several stakeholders involved in the marine nature-based tourism activities conducted in Goa were identified. This includes boat operators, tourists, dive tour operators, government departments and NGOs working in this sector, to name a few. However, the focus of this study has been on the three main stakeholders. Firstly, the Government of Goa and its different departments are involved in marine nature-based tourism and marine conservation. This mainly includes the Department of Tourism, the Department of Forests, the Goa Coastal Zone Management Authority and the Captain of Ports Department. The reason for focussing on this group of stakeholders is the fact that the onus for protection as well as the power lies in their hands. The second category of stakeholders includes different kinds of boat operators involved in marine nature-based tourism activities. This includes dolphin boat tour operators, dive tour operators and picnic boat operators that also offer nature-based tourism products. These boat operators are directly interacting with the marine ecosystem through the tours carried out by the, thus they are very important stakeholders in this particular problem. The third group of stakeholders considered for this study are the tourists who visit Goa and are also responsible for facilitating the problem behaviour through their perception, level of awareness and behaviour. Since tourists are crucial for fostering tourism in Goa it is important to consider them while analysing the problem as well as devising solutions that will make them aware and yet not compromise on their experience.

Causal Analysis

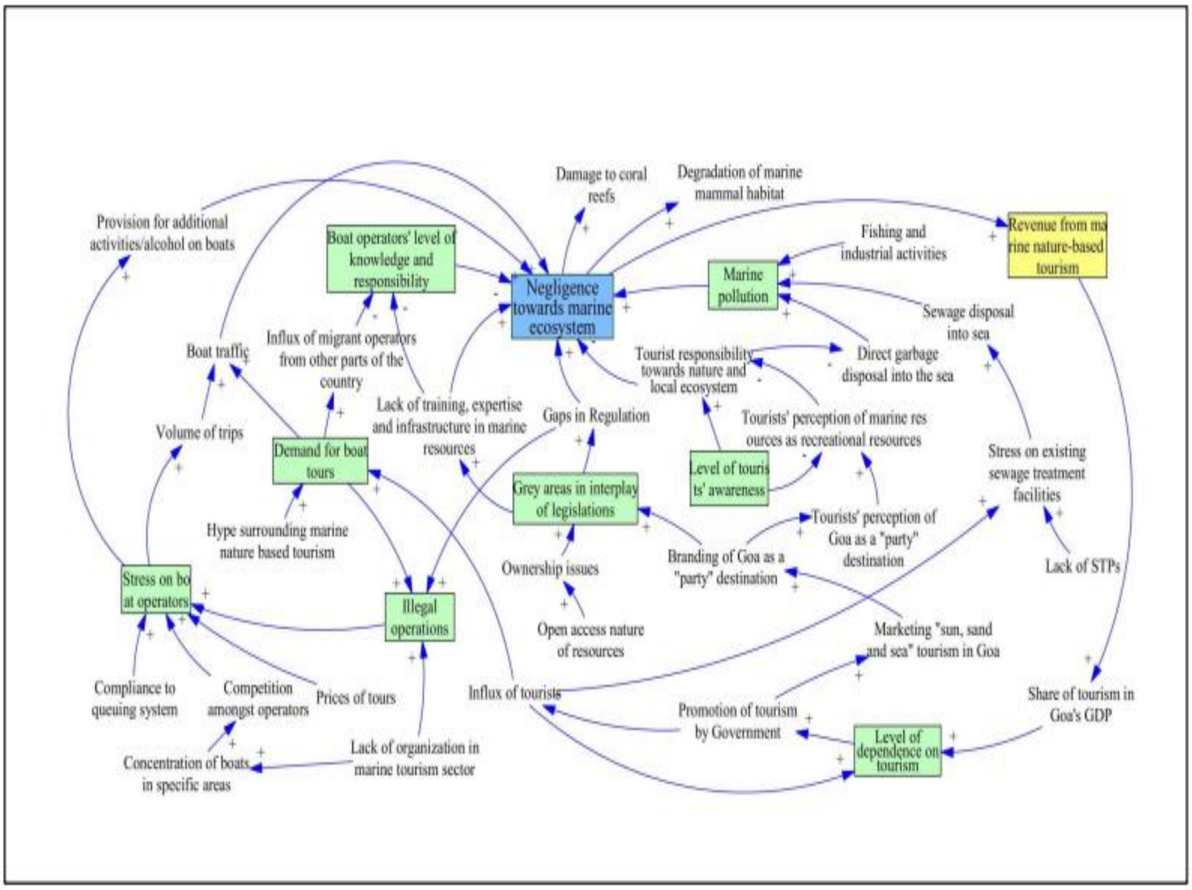


Diagram - 1

For this study, a causal analysis of the factors responsible for the negligence towards marine life was conducted with the help of literature and a comprehensive field study. A preliminary round of causal factors was identified from the literature review conducted. This was followed by a visit to the research sites in Goa and an interaction with several stakeholders. These interactions helped to bring out a lot of causal stories from which layers of causal factors were identified. These factors have been collected and represented above (Diagram-1) in the form of a Causal Loop Diagram (CLD).

The central variable of the CLD is the problem behaviour the negligence towards the marine ecosystem of Goa (variable in the blue box). The variables that have been linked to this central variable, with the help of loops, are the causal factors for this problem behaviour. The inter-linkages are explained in succeeding paragraphs:

- **Explanation of the relationship between negligence towards marine ecosystem and revenue from marine nature-based tourism**: It may seem odd that a positive relationship has been established between negligence and revenue, but the reason lies in the fact that all of the stakeholders are neglecting the marine ecosystem and carrying on with activities that are causing harm to it because these activities are also increasing their revenue. Each of the stakeholders, due to various causal factors, is promoting negligence towards marine life and in that process are gaining a higher revenue from the activities so conducted. Thus a higher level of negligence towards the marine ecosystem will correspond to higher revenue from marine nature-based tourism.
- **Level of dependence on tourism**: Tourism contributes a significant chunk to the GDP of Goa and provides employment to approximately 16-17 per cent of the total workforce of the state (Dept. of Tourism, Govt. of Goa, 2015). The reduced level of responsibility among tourists is also responsible for an increasing level of marine pollution due to the direct disposal of plastics, alcohol bottles and other garbage into the sea.
- **Stress on boat operators**: The Policy for Regulation of Water-sports in Goa issued by the Dept. of Tourism calls for a queue system to be followed by all water sports. Boat operators are majorly concentrated around a few particular jetties in Goa one of them being the Sinquerim jetty. Due to a large number of boat operators, compliance to the queue system often leads to a lower number of rides and hence lower income for individual operators. Thus it creates increased stress on them as boat tours are their means of livelihood. Other reasons are competition amongst operators, prices of tours as low as Rs.300 (for dolphin sighting) making them quite an attraction for tourists. **Illegal operations**: Lack of organization in the marine nature-based tourism sector is responsible for the increase in illegal (unregistered and unlicensed) tourism activities, which create stress on the boat operators and negligence of the marine ecosystem through increasing boat traffic and additional activities on-board. These operations often also pose a threat to the tourists they are catering to, in terms of their safety and security.
- **Demand for boat tours**: An increasing demand for boat tours is beneficial for the tourism industry and the operators and yet detrimental to the ecosystem due to its unregulated nature.

- **Grey areas in the interplay of legislation**: There are several prevalent legislation for the protection of the marine ecosystem. The open-access nature of these resources has led to a perception that everybody has the right to exploit them. It is from this nature of the resource that ownership issues have stemmed. For example, Grande island which is the site for most of the diving activities in Goa has become almost a no-man's land because of counterclaims from the Government of Goa, the Indian Navy and a private party (a Goan family) over the ownership of the island. These confusions regarding the ownership of resources lead to confusion regarding the responsibility of protecting the resources. The grey areas are also caused due to the focus of the Government, especially the Department of Tourism on promoting "sun and sand" tourism in the State which has led to it being branded as a party destination, thus shifting the focus from the extremely sensitive marine ecosystem of the State, marine nature-based tourism activities and much-needed regulation and conservation in this sector.
- **Level of tourists' awareness**: A low level of tourist awareness directly leads to an increased level of negligence on their part as it reduces their responsibility towards the ecosystem. Also, a lower level of tourist awareness when coupled with a perception of Goa as a "party" destination leads to an increased level of tourist perception that these marine resources are purely for their recreation. This reduces the tourists' responsibility towards the marine ecosystem hence facilitating negligence. The level of tourists' awareness also affects levels of marine pollution as tourists are major stakeholders in that problem.
- **Boat operators' level of knowledge and responsibility**: Boat operators act as an interface between the tourists and the marine ecosystem. Thus their level of knowledge and awareness and sense of responsibility towards the marine ecosystem plays a very important role in moulding the nature of these trips. If they have lower levels of knowledge and responsibility, then that directly leads to negligence of the marine ecosystem.
- **Marine pollution**: With a growing influx of tourists into Goa, there are more and more shacks, hotels and restaurants coming up. This is creating increased stress on the existing sewage treatment facilities of Goa. This increasing stress coupled with the lack of Sewage Treatment Plants leads to sewage disposal into the sea which is one of the major reasons for increasing marine pollution. The tourists are also responsible for

direct garbage disposal into the sea which is instrumental in increasing marine pollution levels and hence facilitating negligence towards the marine ecosystem.

1.1.4.2 Ideating Solutions:

Now that all the causal factors have been listed and represented in the form of a CLD, identification of all the possible solutions or policy interventions that can be used to achieve the regulatory objective.

1.1.4.3 Causal loop diagram with solutions

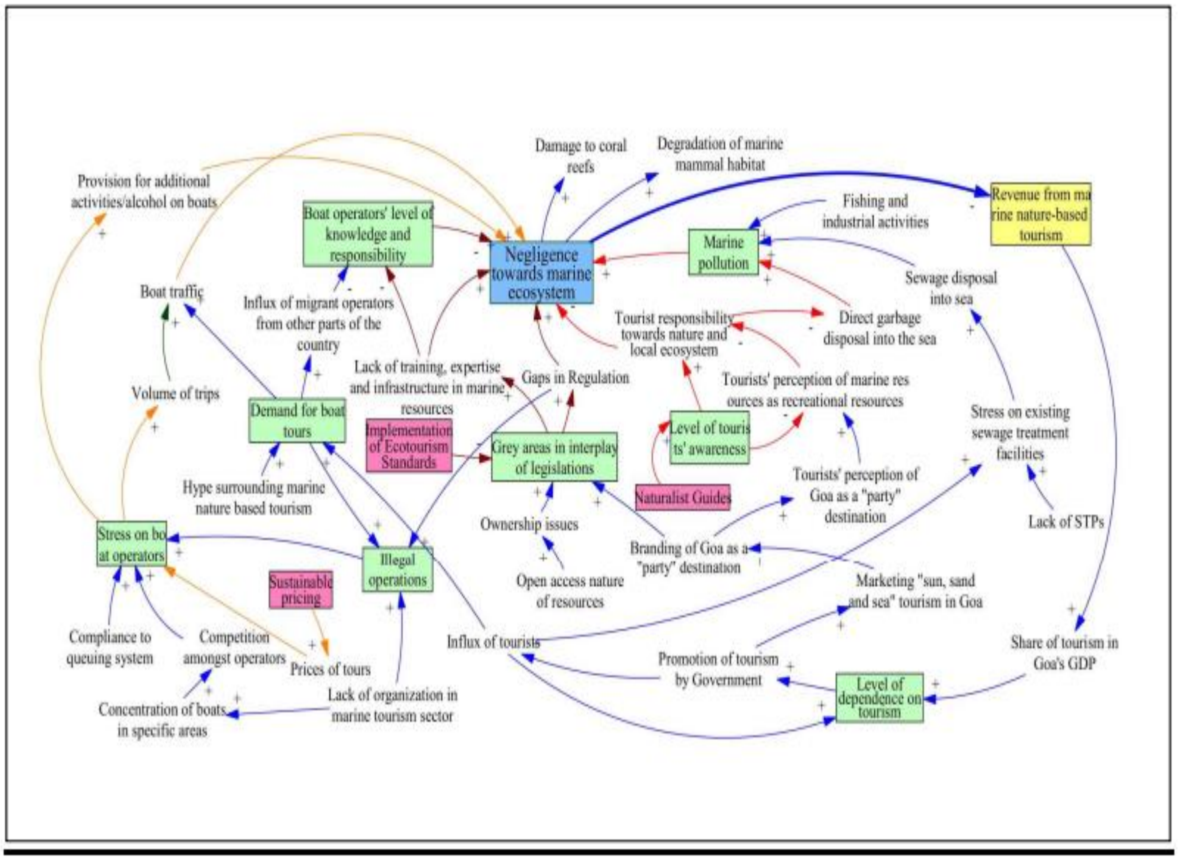


Diagram - 2

Explanation of the relationship between negligence towards the marine ecosystem and revenue from marine nature-based tourism: The previous section defined the relationship between these two variables and the importance of such a relationship. Now, the idea is to implement solutions that will reduce the negligence towards the marine ecosystem and at the same time increase revenue from marine nature-based tourism.

• **Sustainable pricing/tariff setting**: Prices for boat tours in Goa are inexplicably low. The sustainable tariff system will also, simultaneously, increase the revenue from marine nature-based tourism thus achieving the desired objective. (Refer to orange arrows in the CLD for tracing the impact of sustainable pricing on the problem behaviour). Thus the tariff for these boat tours should be set in a way that does not create stress on the boat operators and provides a meaningful and worthy experience to the tourists.

Implementation of Ecotourism Guidelines: Implementation of ecotourism guidelines is extremely necessary for developing Ecotourism. The tourism master plan prepared by the Department of Tourism focuses on Nature-based and Ecotourism but does not include marine nature-based tourism in that category. Nor does it set guidelines to be followed by operators providing the ecotourism package in Goa. This necessitates the development of Eco tourism as a product and enactment of binding guidelines for all operators involved in this sector of tourism. Implementation of the guidelines will also improve the boat operators' level of knowledge and responsibility as following these guidelines and subsequent training for understanding the marine ecosystem will be binding on all the operators. This will thus lead to reduced negligence on their part. It will also be instrumental in ensuring the sustainability of tourism in the state and help increase the revenue earned from this sector of tourism. (Refer to maroon arrows in the CLD for tracing the impact of the implementation of ecotourism guidelines on the problem behaviour).

• **Naturalist Guides:** Naturalist guides are individuals who are educated and trained in the ecology, features, history, environmental interpretation, problems and conservation of the local ecosystem along with being trained to deal with emergency situations on board. (Refer to red arrows in the CLD for tracing the impact naturalist guides on the problem behaviour).

• In a similar way **Mooring Buoys** will reduce negligence by reducing the problem of carelessly dropped anchors, Social Scores will reduce negligence by self-regulation of the boat operators, Capacity Building of Boat Operators will improve boat operators' knowledge and responsibility and hence reduce negligence on their part and Redistribution of boats along the coast of Goa will reduce competition amongst boat operators and hence the stress on them, thus reducing the negligence on their part through the loop. All of these instruments will also be instrumental in increasing revenue from marine nature-based tourism, over time.

• **Regulations and penalty:** is a form of direct regulation or command and control that will regulate the problem behaviour using the force of law. Rigorous patrolling and monitoring by the marine police will be required for implementing this system. The success of this tool will depend on the marine patrolling and penalising system.

- **Alternative Regulatory Mixes**: In this case, the two feasible alternative mixes are: (a) Regulatory Mix 1 i.e. Regulations and penalty + Redistribution of boats using a levy + Mooring Buoys and (b) Regulatory Mix 2 i.e. Ecotourism Guidelines + Social Score based incentive system + Naturalist Guides + Capacity building of boat operators + Sustainable tariff system + Mooring Buoys.

Regulatory Mix 2 involves a combination of informational, economic, legal and structural tools which are used based on the sensitivity of the stakeholders' behaviour. Thus there is a scope for a long-term behaviour change. This regulatory mix impacts long-term behaviour change and a step toward the implementation of sustainable tourism in the State of Goa.

1.1.4.4 Prototyping:

In the case of this study, a preliminary qualitative analysis from the researcher's point of view declares Regulatory Mix 2 to be the most effective and efficient solution. The study provides the following set of guidelines that can be followed for prototyping the recommended solution.

- The most effective and efficient solution based on this study is a combination of Ecotourism Guidelines + Social Score based incentive system + Naturalist Guides + Capacity building of boat operators + Sustainable tariff system + Mooring Buoys, to be used for modifying the problem behaviour.

- The implementation process will be a sequential process starting with the implementation of the Ecotourism Guidelines. For this, the first requirement would be to set up a competent authority such as the Ecotourism Board. Once these guidelines have been formulated and implemented they will be binding on all the boat operators involved in marine nature-based tourism. The boat operators will be trained and then certified by the board as Ecotourism operators. The certification process will give the dues recognition to the operators and bring about an organization in this sector.

- **The Eco tourism board** will implement the social score based incentive system for the boat operators to incentivise them into improving their behaviour. Various incentives can be provided to them for motivating them to improve their social score.

- **Naturalist Guides** would be a mandatory part of every Eco-boat tour. They will be providing interpretation sessions to the tourists as well as acting as a monitoring and feedback mechanism.

They will be reporting to the Eco tourism Board on a regular basis regarding their observations on the boat tours.

- **Capacity building** of boat operators will be done by the Ecotourism Board with the help of local NGOs and conservationists to improve the knowledge of the boat operators. Volunteer Vacation programmes and involvement of local communities can also + .0 be used for this purpose.

- **A sustainable demand-based pricing system** can be devised for the boat tours and implemented by the Department of Tourism as discussed in earlier sections.

- **Mooring buoys** can be installed around Grande Island to avoid damage to corals by carelessly dropping anchors.

- **Periodic evaluation of the social scores**, ranking and certification scheme to be done with the help of third-party audits.

1.1.5 Study - 2: Coastal Regulation Zone (CRZ) And Shack Policy

Identifying the regulations

The two most relevant regulations which govern the behaviour of the shacks under the Coastal Regulation Zone (CRZ) Notification, 2011 and the Shack Policy by the Department of Tourism, Goa.

1.1.5.1 Provisions in CRZ Notification for the State of GOA

Section V of the notification gave outlines for areas requiring special consideration. Sub Section 3 of the aforementioned section states the provisions for the state of Goa.

Section 3. CRZ of Goa - Because of the peculiar circumstances of the State Goa including history and other developments, the specific activities shall be regulated and various measures shall be undertaken as follows:

(i) The Government of Goa shall notify the fishing villages wherein all foreshore facilities required for fishing and fishery allied activities such as traditional fish processing yards, boat building or repair yards, net mending yards, ice plants, ice storage, auction hall, jetties may be permitted by Gram Panchayat in the CRZ area;

(ii) Reconstruction, repair works of the structures of local communities including fishermen community shall be permissible in CRZ;

(iii) Purely temporary and seasonal structures customarily put up between September to May;

(iv) The Eco-sensitive low-lying areas which are influenced by tidal action known as Khazan lands shall be mapped;

(v) The mangroves along such Khazan land shall be protected and a management plan for the Khazan land prepared and no developmental activities shall be permitted on the Khazan land;

(vi) Sand dunes, beach stretches along the bays and creeks shall be surveyed and mapped. No activity be permitted on such sand dune areas;

(vii) the beaches such as Mandrem, Morjim, Galgiba and Agonda have been designated as turtle nesting sites and protected under the Wildlife Protection Act, 1972 and these areas shall be surveyed and a management plan prepared for the protection of these turtle nesting sites;

(viii) No developmental activities shall be permitted in the turtle breeding areas referred to in subparagraph (vii). The notification gives a specific mention to ‘purely temporary and seasonal structures customarily put up between September to May’ in clause (iii) for Goa. (CRZ Notification, 2011).

This clause was a new addition to the 2011 notification. The notification cited guidelines regarding activities that can or cannot be carried out in coastal zones. However, it did identify and specify the authority that it has delegated the task of looking after adherence to these regulations. The authority identified was the Coastal Zone Management Authority (CZMA). Goa Coastal Zone Management Authority (GCZMA) is responsible for the governance of the coastal zone; it has outsourced the governance of the shacks to the Department of Tourism, which has framed regulations under the shack policy.

1.1.5.2 Impact of CRZ:

The CRZ was implemented in the year 1991, which barred the local fishermen, toddy tappers, and farmers from construction, drawl water and also imposed a lot of restrictions. As a result, numerous people from the coastal community were displaced. The implementation of the notification created a lot of dissent among the people, and the anguish from never being consulted in the matter stayed on. Slowly, with so many restrictions imposed on them, the locals started selling off the land to outsiders at a good price. The outsiders who purchased the land started tourism activities. The local people who were selling off their land started getting into businesses like taxi operators, or guest houses, and again got dependent on the tourists for their livelihood. The fishermen who no longer could sustain their traditional livelihood, and could not function well within the restrictions of the Coastal Regulations, also migrated to other occupations. Nonetheless, the CRZ gained a lot of criticism, and the government earned a bad reputation as well. The major complaint was that the people were not consulted while framing regulations for them. Eventually, the increasing number of shacks invited another form of regulation, the Shack Policy.

1.1.5.3 Shack Policy:

This is a time-bound tourism policy for the erection of temporary seasonal structures, beach shacks, huts and others. The policy laid down terms and conditions for the construction of temporary structures. The policy also laid down several guidelines regarding the activities of shacks and the materials to be used for construction. The main features of the policy are as under:

- The policy was initially started for a period from 2016-2019,
- the approach used in regulating the coastal zone, and in implementing the guidelines of the coastal regulations were those of command and control in nature,
- the shack owners were allotted licenses for the building of shacks for 3 years,
- the structure is permitted temporary and has to be dismantled by the end of the season (10th June) and
- imposing penalties and cancelling the licence on the offender were the tools to stop the violations.

The CAG in its Audit found that there were huge numbers of violations in the implementation of the policy, which indicated the failure of the then solutions and instruments in curbing the problem behaviour.

To study the impact, various stakeholders, local residents and shack owners were consulted. Tourists and organisations working towards making shacks more compliant with regulations, like the Centre for Responsible Tourism, interacted.

Impact of Shack Policy:

The shack owners are the ones who are subject to regulation under the Shack Policy. The policy came as a tool to look after the implementation of the CRZ notification to ensure compliance among the Shacks. The Department of Tourism of the State government looks after the policy and the stakeholders.

The Shacks were a mod of self-employment. The policy restricted the people who run the shack business from having any other occupation or source of income other than the shacks. Such a regulation becomes binding in nature, as the shacks by nature are temporary and function only for half of the year. Putting up a shack every season and dismantling it involves a lot of costs and imposes a burden on the shack owner to run the business for a limited period. A lottery system for the allotment of the shacks and increase in the licences fee from time to time, construction cost of shacks, raw material for business and other miscellaneous expenditures put the shack holders in trouble. Also, with the consequent years, and newer standards being imposed by the authority, like the sewage of garbage disposal, their capital requirements were increasing amidst all this insecurity. The decision to start a lottery system created uncertainty that shack owners did not know if they will have a shack for the coming year or not. This insecurity led them to adopt other means for securing themselves, which somewhere led to the violations of rules/regulations/guidelines. A large number of subletting shacks to outsiders or foreigners can be understood in this context.

The policy also generates conflicts among the shack holders and other local youths who run their small businesses on the beaches. For instance, the policy has a provision for the allotment of deck beds on the beach to the unemployed youth. The deck beds are allotted to the shacks holders also. Due to this, the youth either have to offer highly competitive prices or have to offer services which otherwise would not be allowed to shack holders, which again makes their survival difficult. The excessive penalising nature of the policy, like many fines and forfeiture of the security deposit, also has created a dissent against the governing authorities. There was already discontent towards the coastal regulation notification, as it has caused a lot of discomfort to the people. The Shack Policy is like a layer to the CRZ notification which by way of its stringent rules further restricts the stakeholders. Even though the shack policy has the intent of promoting livelihood and giving an opportunity to the unemployed, the self-contradictory nature of restrictions in the policy gives way to violations as unintended consequences. The policy seeks to implement the guidelines of notification by commanding the shack owners and holding them responsible for the beach, rather than assisting, inviting cooperation, and providing training and information to preserve the ecosystem.

1.1.5.4 Problem analysis:

The problem is that despite regulations in place, the shack owners do what is prohibited, therefore violating the regulations. These violations were further explored in detail, concerning the literature available, and also based on interactions held with the stakeholders in the field. To ascertain the causes of these violations, they were categorised into six types:

i. Violation of permissible noise limit.

ii. Violation of sewage disposal norms.

iii. Violation of garbage disposal norms.

iv. Violation of guidelines for shack construction.

v. Violations about encroachment.

vi. Violation of initiating operation without obtaining all licenses.

Different causes which lead to these violations were identified which have been explained in the causal loop diagram.

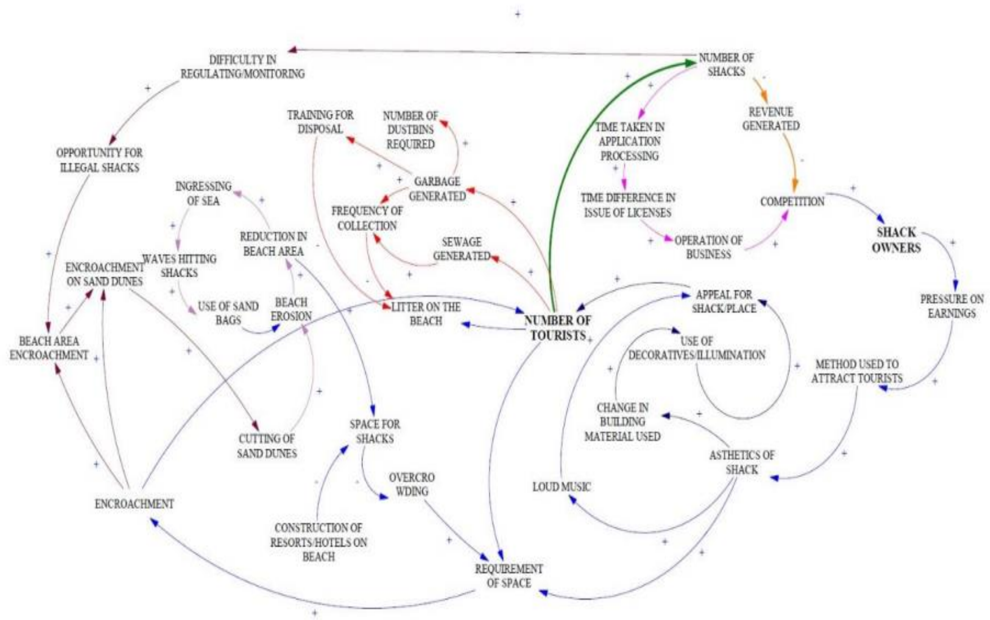


Diagram – 3

Problem Analysis represented in Causal Loop Diagram

In this case study, the primary stakeholders are the Shack Owners. The shack business is contingent on the tourists and their number. Thus, these two are the crux on which the understanding of the whole issue has to be built. To arrive at a CLD, causal factors and causal stories have to be collected by referring to literature from various sources. These can be journal papers, newspapers, books, and also by conducting small field studies through methods like interviews, observations, group discussions, or interactions. Once the factors have been identified, then the next step is to look for variables. Variables are those, that increase or decrease (variance) which can cause an increase or decrease in the problem behaviours. This helps in establishing relationships among different variables and the problem behaviour. The loops in the diagram are indicated by arrows, which carry a polarity sign of negative (-) and positive (+). A negative polarity indicates an indirect relation and a positive polarity indicates a direct relationship. This polarity in relationships helps in figuring out reinforcing or balancing loops. Reinforcing loops are those in which the causal factors/variables work towards making the behaviour stronger. Whereas, a balancing loop is indicative of controlling or establishing a balance in the phenomenon. In the CLD, the existing regulatory solutions which influence the system have to be embedded.

In fact, it is the volume of tourist inflow that affects the shack holders' business in the area. A bold line of a different colour connects the number of tourists to the number of shacks with a direct relationship. With an increase in the number of tourists, the number of shacks increases, but an inverse relationship with the revenue. The more number of shacks holders, the more divided the revenue generated for each shack. This intensifies the competition, and thus incentivises commencing business without obtaining licenses. The shack owners also resort to different methods to attract tourists and thus slip into violations. They deploy loudspeakers, use decorative and illuminations which are not permissible. They also use non-approved and non-eco-friendly materials for construction, like concrete or tiles. The shack holders also encroach beach area often the sand dunes. They build on the area which is supposed to be left empty between the shacks and dunes. With the cutting of sand dunes comes another grave issue of beach erosion, which further causes a reduction in the beach area. This results in the sea moving inwards, causing the waves to hit the shacks during high tides. To avoid this, many of the shacks use sandbags, which are again obtained by cutting sand from the beaches. This causes further erosion, and then a reduction in space eventually.

This rise in the number of unauthorised shacks also leads to increased generation of garbage and sewage and ultimately results in the littering of the beach, as there is no other place to store or dispose of waste. This also leads to other issues like incineration of waste on beaches, or construction of soak pits for disposal of sewage.

1.1.5.5 Analysis of the Economic Tool Penalty Solution

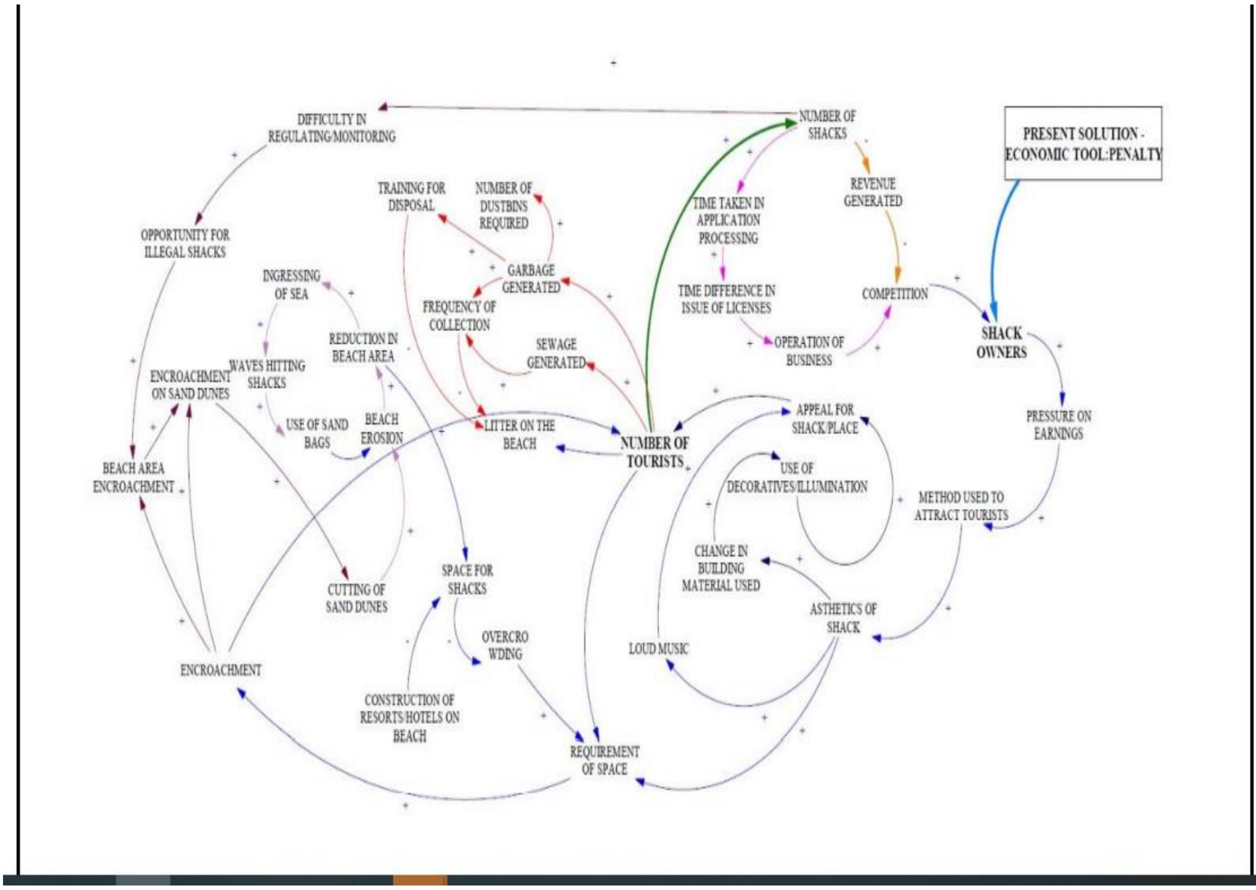


Diagram - 4

In the diagram, the tool used by shack policy for the implementation of the CRZ Notification has been embedded in the area it targets in the problem analysis. Fig.: Causal Loop Diagram with Present Solution Embedded. As the policy targets, it can be seen that the tool, that is the economic tool of penalty has its focus on the Shack Owners. However, the whole loop revolves around the number of tourists, which in turn affects a variety of activities. Therefore, the pivot of the loop is not the shack owners, but, the number of tourists. The policy can regulate the shack owners, but, the nature of the violations that exist is contingent not on the shack owners but, on the tourists. It therefore urges, to take steps towards the regulation of the tourists as well as curb the violations as well on the beaches.

1.1.5.6 Shortcomings of the solution:

The regulation is focused at a point in the loop which is not causing but responding to the effects of the other causes. Thereby, the falling failure of the tool is evident from the large number of violations that exist.

- The shack policy uses the tool of penalty extensively. In the policy, features of forfeiture of the security deposit, and cancellation of license lastly have been cited as the control mechanisms. The issue that arises here is that fixing a penalty for violations at all stages ultimately converts it to a premium. The penalty becomes a fee to perform the prohibited action, thereby reducing its effectiveness.
- Also, in the presence of regulations, a violator always carries a personal risk and cost and benefit analysis before committing to the violation. If the benefits of violating the norm are greater than the penalty imposed by the regulation, it becomes an obvious choice to violate.
- Also, provisions of lottery to fill in the number of shacks to be allotted create further complications which have been explained in the impact earlier. The provision of various licenses also creates a lag. The applicant has to run to different places to obtain licenses from so many authorities. This causes a delay for him in commencing the business while the tourist season has already started.
- Also, some clauses in the policy prohibit the use of materials in the construction of shacks, like tiles, or reusable materials. This further complicates the issue.
- During the field visit, the interaction with the owners revealed that working and maintaining things on sand is difficult.
- Also, if they don't cover the floor with these tiles, there are chances of sand in the food, which is again a health hazard and would jeopardise their license from the FSSAI (Food Safety and Standards Authority of India). This would also cause a reduction in customer numbers for them rendering them helpless.
- There are also guidelines about how the materials used in the shack are not to be disposed of. However, guidelines regarding the disposal remain unclear. This is reflected in the use of palm leaves. Though directed at using palm leaves for the roof, there is no support for disposing of the leaves after the season is over and the shacks have been dismantled. The residue of leaves from all the shacks is huge. Due to a lack of collection or disposal mechanisms, the leaves are either left or burnt on the beach, which causes littering again.

- The policy misses out on strengthening the mechanisms for aiding what is prohibited. It rather relies on imposing the responsibility of maintenance of the beach on the shack owners by way of penalties.
- There is no mechanism to monitor the timely collection of garbage, or sewage. There is a provision which again mandates the shack owner to maintain a register, but amidst all the irregularity this again proves to be ineffective.
- Also, the records go unexamined, and the inspection of the cleanliness of the beaches is also not so frequent. The policy does not focus on making the other mechanisms to support the preservation of beaches, like holding the beach cleaning contractors accountable. Resorting to only one type of tool aimed at a stakeholder who is not in control of the situation and is only an actor, leads to the ineffectiveness of the regulation.

The Auditors can seek a remedy to this by taking a more diverse approach and by employing a mix of tools, using Instrumentation.

Prototyping:

The problem analysis in the previous section helps us in understanding the degree of complexity of the issue. This understanding can be enhanced by a review of data collected from the field and by doing a stakeholder analysis.

Stakeholder analysis: To conduct a stakeholder analysis, the stakeholders were distinctly identified, and interactions with them were carried out on an individual basis. The classification was done based on the motto of the research, the literature studied, and also the basis of ground revelations. The identified stakeholders for this research were: A. Shack Owners B. Local Residents C. Tourists D. Government Departments.

Solution Proposed:

A stakeholder analysis, a problem analysis, and an analysis of the present solution give us an idea about how can we shape our approach to the solution. It is clear by now, that the tool which has to be designed needs to target not only the shack owners but also the tourists who are pivotal in causing other processes as well. In order to satisfy the general purpose of the regulation, that is, the preservation of the beaches, a mix of various tools can be adopted.

A regulatory mix of Transactional Tools, Economic Tools, Authorisation Tools, and Informational Tools is advisable for the formulation of a final tool for regulation. The target of the regulation here is the shack owners, as well as the tourists, and also the party which is directly responsible for beach cleaning and garbage collection. A combination of economic tools and informational tools can be formulated for bringing a change in the attitude of the tourist. From the economic tools, charges or levies could be adopted. The reason for adopting economic tools and informational tools is based on the interactions held with the tourist as a stakeholder, it was realised that their behaviour is sensitive to information as well as money, imposed as a fine or a penalty. A combination of transactional, informational and authorisation tools are targeted for the shack owners and the contractors. The provision of licensing which is already there serves as an authorisation tool. The amalgamation of informational and transactional tools is aimed at ensuring accountability. Measures such as performance indicators or credit ratings from the informational regulatory tools could be used to further enhance provisions of contract disqualification from the transactional tools.

Therefore, the mix of the solution proposed is: For Tourists: Sign Boards/Displays (Informational Tool) + Penalty (Economic Tool).

For Shack Owners and Contractors: Licensing (Authorisation Tool) + Performance Indicators/Credit Ratings (Informational Tool) + Contract Disqualification (Transactional Tool).

1.1.5.3 Operationalisation of the Solution

For Tourists:

In order to raise awareness about the value of beach ecology and need for the conservation, a wide movement of spreading awareness has to be initiated by the Department of Tourism, Goa Government for tourists following steps may also be adopted by the Department:

- Banners/posters/slogans and signboards may be put up at regular intervals on the beaches.
- Information about marine life affected by the litter could also be put up on the beaches to increase awareness about their existence and their sensitivity towards them.
- There can be designated entry and exit gates for the tourist to the beaches. This could help in keeping a check on the goods being carried by the tourists to the beach.
- A security amount can be taken in advance from the tourist against the violation of the rules framed by the department to protract the environment.

- In case of broken rules intentionally or negligence, a heavy penalty can be charged to the tourist.

For Shack Owners and Beach Contractors:

Licensing as a tool is already in use by the authority. Some more measures can adopt as detailed below:

- Performance indicator converted to scores for each shacks owner can be displayed by the authority.
- An arrangement can be made so that tourists can easily assess the performance indicator of shack owners. This would move the tourists to the better-performing shack owners.
- These performance indicators can also use as a basis for the issuance of licenses on a priority basis in the next season.
- For the beach contractor, parameters could be developed to issue credit ratings to the contractor, on the basis of consultations with local people, or the panchayat and the shack owners.

1.1.6 Conclusion:

This research having two studies, suggests a way in which a Regulatory Impact Analysis could be integrated with an Audit exercise to enhance the recommendations and its projected effectiveness. This could serve as a case study on what could be the approach for carrying out an RIA. Cost-Benefit Analysis is a major part of an RIA. The research has been able to explore the key causes for the violations to exist, and on being complemented with data from the field, a robust quantitative Cost-Benefit Analysis could be undertaken. Though, a qualitative cost-benefit analysis of the solutions can always be done to gauge the fulfilment of the aims. The Chapter-II of the CAG State Audit Report of 2012 recommended the promotion of tourism with special packages to capitalize on the advantages of visiting Goa during the monsoon. On similar lines, the state of Goa has to renovate the image Goa has formed as a tourist destination. It is essential to redistribute the tourist population that visits Goa so that the ecology of a particular place does not bear a special burden. Also, community participation is essential to make any vision for the place or state succeed. As was envisioned in the State policy, benefits from tourism should accrue to the locals.

THEME – 1.2: TSUNAMI DISASTER PREPAREDNESS

1.2.1 Introduction:

In 2004, tsunami fourteen regions of the Andaman and Nicobar Islands were affected.[i] This ocean earthquake goes down in history as the deadliest of all time. The official death toll was 1,310, with about 5,600 missing and monetary loss in Andaman was exceeded Rs1,000 cr. [ii] The Great Nicobar and Car Nicobar Islands were the worst hit among all the islands because of their proximity to the quake and relatively flat terrain. The Chowra Island lost two-thirds of its population of 1,500. Entire islands were submerged, and Trinket Island was divided in two[iii]. Ninety seven per cent of mangrove cover in the Nicobar Islands was razed[iv]. Until the 2004 tsunami, India's vulnerability to tsunami-caused destruction was estimated as very low, the effort was made to set up an advance warning and international networking system and tsunami vulnerability was not the part of the study[v].

The second theme of the chapter-1 is based on earthquake/tsunami disaster preparedness. A study conducted by Ms. Ankita Singh, intern, iCED on the 2004 tsunami in the regions of Andaman and Nicobar Islands. The study is focused on the impact, mapping and prevention measures of tsunamis.

Study Area

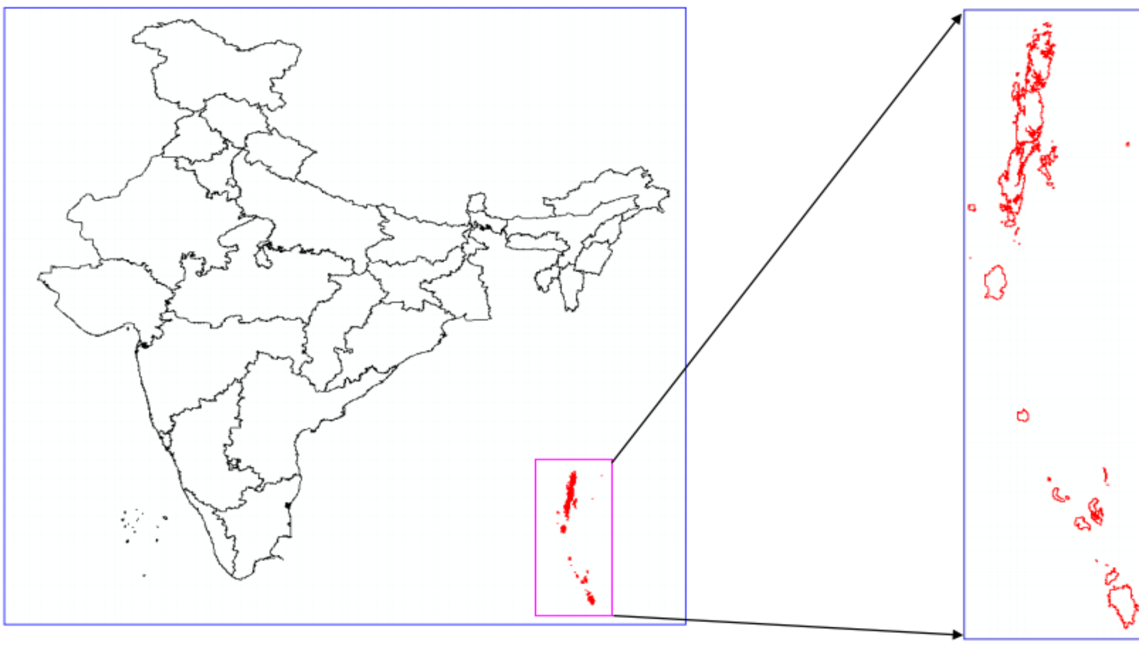


Diagram - 5

The Andaman Islands are an Indian archipelago in the Bay of Bengal. These roughly 300 islands are known for their palm-lined, white-sand beaches, mangroves and tropical rainforests.

Disaster preparedness includes organizational activities which ensure that the system, procedure and resources required to confront a natural disaster are available to provide timely assistance. Below are the levels of disaster management categorized as L0, L1, L2, and L3:

L0

- Planing stage where plans at all level from the Central to the State.
- Mock drill is carried out.

L1

- At the District level, the disaster can be managed.
- If needed, the Centre and State are required to prepared for assistance.

L2

- Disaster that required the active participation of the State and mobilisation of resources at the State level.

L3

- At this stage, the Central Government assistance is required where the State Government may not have the adequate capacity to deal with the disaster.

1.2.2 Risk Assessment and Its Component

Risk can alter very quickly as a result of evolving hazards, exposure, and vulnerability. Some unprecedented changes like unplanned development, high population growth or global climate change are increasing coastal hazards. These changes are placing communities at increasing risk from coastal hazards such as severe storms, tsunamis leading to coastal erosion, flooding and environmental degradation.

Risk= Hazard*Vulnerability*Exposure

- **TSUNAMI RISK**

  Risk is defined as the combination of the severity(s) and frequency (f) or return period of a hazard, further splits the consequences into two factors-exposure(E) of the numbers of people and assets exposed, and their vulnerability(V) to damage (UNISDR, 2015a).

$$R = s * f * E * V$$

- **HAZARDS**

  Hazards may be natural and anthropogenic in origin. It is a phenomenon or human activity that may cause property damage, social and economic disruption, loss of livelihood, injury and other health impacts and environmental degradation. Episodic hazards include severe storms, earthquakes, tsunamis and oil spills, all of which have limited predictability and may result in major disasters (Hettiarachchi, S.S.L; Samarawickrama, S.P; Wijeratne 2011). This hazard may result in or increase chronic conditions like shoreline erosion, flooding, sedimentation, sea-level rise and coastal environmental and resource degradation.

- **EXPOSURE**

  It refers to the human life, infrastructure, ecosystem and other tangible human assets potentially affected by the hazard.

- **VULNERABILITY**

  Vulnerability can be a difficult theory to understand because it tends to mean different things to different people and because it is often described using a variety of terms including ‘susceptibility’, ‘instability’, ‘feebleness’, ‘scarcity’ or ‘lack of capacity’.

Vulnerability can relate to several numbers of factors, including:

- **Physical factor** – poor construction or building design, unregulated land use planning.
- **Social factor** – discrimination by gender, inequalities, physiological factor, etc.
- **Economic factor** – vulnerable rural livelihood, poverty etc.
- **Environmental factors-** environment degradation, climate change, etc.

Diagram - 6

1.2.3 The Potential impact of Tsunami:

Vulnerability alludes to the possible impacts of the tsunami. These impacts can be divided into different types, based on what aspects are being focused on.

Disaster effects are categorized into tangible and intangible effects and direct and indirect effects. The impact can be defined as the effect of the disaster on people, infrastructure and society.

Direct losses refer to physical or structural impacts such as loss of livelihood, destruction of buildings, movable-immovable property etc. Indirect losses are not immediate losses; these are secondary results of the initial destruction such as economic loss.

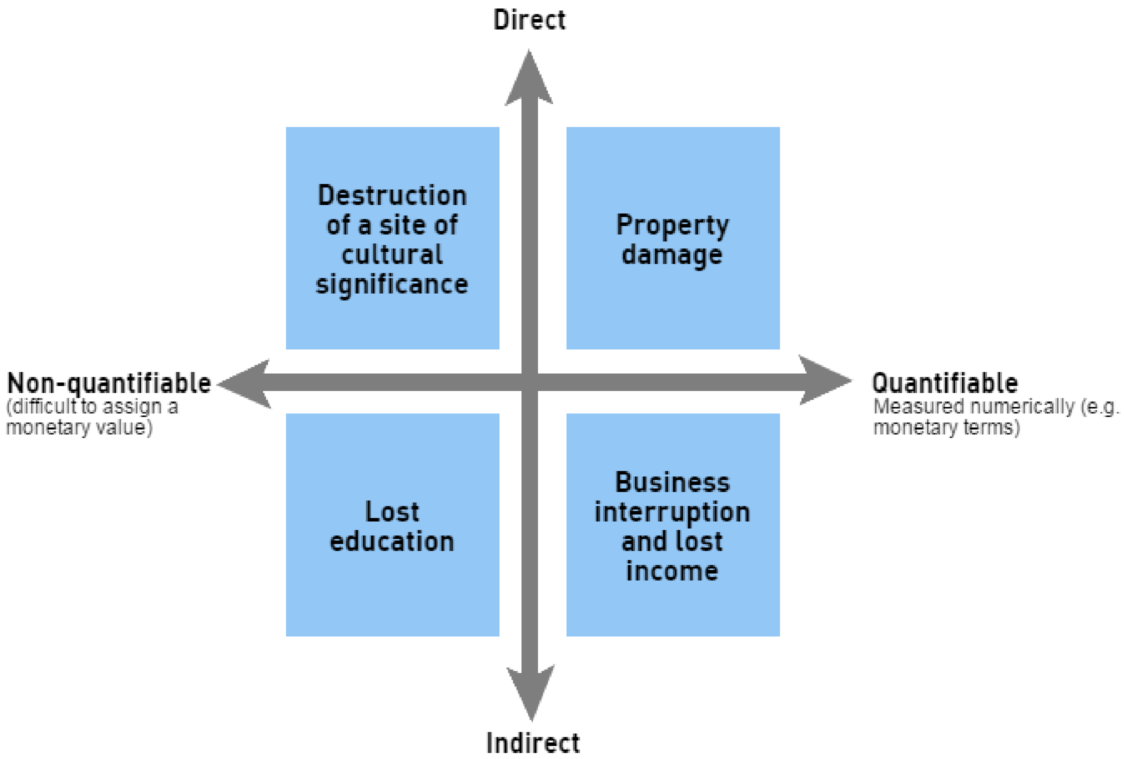


Diagram - 7

Potential direct impacts of tsunami:

Damage caused by the tsunami is also categorized into damages due to debris impact, inundation, contaminants through flowing water, wave-front or surge.

- **Inundation:** It can cause the drowning of people and animals. It can disrupt the life marine habitats (mangroves, coral reefs, and lagoons), damage cropland and yield, disturbance of forest and wetlands, loss of protected areas, etc. It can also lead to slope instability due to saturation of the soil, damage to electrical and mechanical equipments and destruction of communication systems and infrastructure.

- **Sharp Drift:** Loss of livelihood, damage to structures i.e. due to hydrodynamic force structures getting washed away. Port and harbours, walls, fences, roads, railways, and oil and water pipelines get damaged. Spillage of oil, scouring of embankments or bridge foundation, loss of coastline and dunes due to erosion and destruction of rafts and fishes.

- **Debris:** Human beings and animals can get injured or killed by debris. Burial of roads and rail tracks by sediments and debris.
- **Contaminants:** Contaminated water can cause serious health issues and infectious diseases. It can cause eutrophication, salinization and contamination of the near shore environment.

Potential indirect impact of the tsunami:

Disaster damages cause a secondary impact on the community, infrastructure and economy of the area.

- **Societal impact:** Societal impact: Disaster leads to an increase in poverty, debts, food prices and cost of medical treatment and care. It can impact individual jobs and individual reduction of earnings and income. Scarcity of essential items, reduction in land prices and extra cost of relocation and temporary accommodation are also societal impacts.
- **Cost generated due to infrastructure losses:** Disaster disrupts road networks, and pipelines and increases water and sanitation operating costs. After the tsunami, lots of waste are generated in the form of debris, demolition waste and sewage waste. A certain amount of cost is required to manage those wastes.
- **Economic loss:** Loss of revenue to federal region and local government. Disruption in Business, loss of crops and loss of production and services. Less revenue generation because of a decrease in tourism and fewer businesses due to bankruptcies. The cost involved in the renovation of affected structures. A decline in GDP, decrease in exports and increase in inflation.

Intangible impacts of tsunami

- Social conflict and health effects.
- Loss of heritage
- Environment degradation
- Decrease in air and water quality
- Loss of biodiversity and soil erosion
- Stress, trauma and depression
- backwardness from unaffected parts of tsunami

Estimating the likelihood of Tsunami Impact:

Two approaches that are widely used for expressing the potential for tsunami impact:

- Scenario-based Tsunami Hazard Analysis (STHA)
- Probabilistic Tsunami Hazard Analysis (PTHA)

1.2.4 Scenario-based Tsunami Hazard Analysis (STHA)

STHA describes the effect of a particular tsunami scenario or group of tsunami scenarios on a coast of interest. STHA is limited in that it essentially addresses only one question: what is the potential impact of a particular suite of scenarios (and sometimes only one scenario) on a particular coast?

It is of limited usefulness for broader policy and planning decisions because it contains little or no information about the likelihood of a tsunami event. It is less suitable for a situation in which the coast of interest may be affected by a number of very different scenarios of varying likelihood or if the relative hazard due to many scenarios needs to be evaluated over a broad geographical region or where there is an interest (example, for building codes) in tsunami effects expected at various return periods. Also, STHA typically requires high-resolution bathymetric and topographic data for the shore of interest (Ioc 2009).

1.2.5 Probabilistic Tsunami Hazard Analysis (PTHA):

Probabilistic Tsunami Hazard Analysis (PTHA) is at an early stage of development. In contrast to STHA, PTHA attempts to consider a large class of tsunami scenarios, essentially all those which might cause a significant impact and is often based on more than one geological framework (Ioc 2009).

PTHA produces a very information-rich result, which can be used to express hazards in many different ways. For example, maps of tsunami exceedance height for various return periods, or disaggregated hazard maps showing the relative contributions of different sources to the hazard at a particular site. These products can be used to answer a variety of questions about the tsunami hazard of interest to emergency managers and coastal planners (Ioc 2009).

PTHA is restricted to the ability to address site-specific mitigation measures, such as the identification of evacuation areas and routes. Also, because this approach requires a much more complete characterization of potential tsunami sources than STHA, its results are more sensitive to uncertainties in the specification of those tsunami sources (Ioc 2009).

Several developmental ranges of maps are studied. The low-hazard and high-hazard maps for Andaman and Nicobar Islands are very similar characters, with maximum hazard along the east coast, and hence the whole island is near the disaster occurrence zone, both the maps show very little variability.

Since both high-hazard and low-hazard cases for Andaman and Nicobar Island are dominated by the events in North Sumatra and the Nicobar Islands, it shows that the Indian Ocean Tsunami was a worst-case scenario.

1.2.5.1 Vulnerability Framework:

The double structure of vulnerability

According to Bohle (2001), vulnerability is seen as having two sides i.e. an internal side and an external side. The external side is related to the exposure to risks and shocks and is influenced by Political

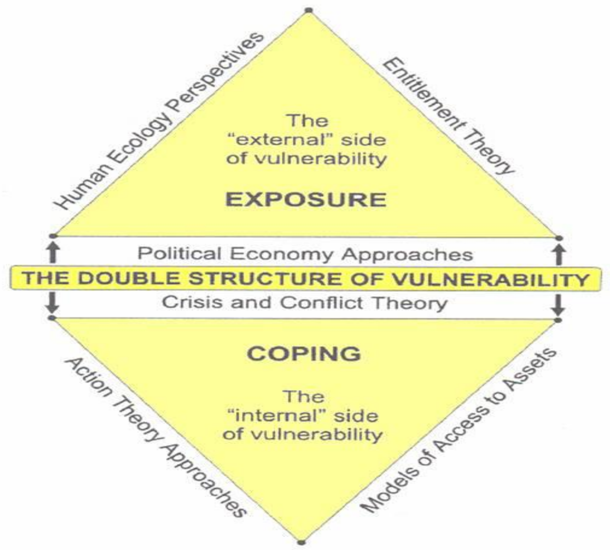


Diagram - 8

Economic approaches (social inequalities etc.), Human Ecology Perspectives (population dynamics and capacities to manage the environment) and the Entitlement Theory (relates vulnerability to the incapacity of people to obtain assets via legitimate economic means). The internal side relates to the capacity to anticipate, cope with, resist and recover from the impact of a hazard and is influenced by the Crisis and Conflict Theory (control of resources, capacities to manage crisis etc.), Action Theory Approaches (how people act and react freely etc.) and Models of Access to Assets (mitigation of vulnerability via access to assets).

Pelling model

In the framework for vulnerability proposed by Pelling (2003) human vulnerability is defined by: exposure, resistance and resilience. Exposure is related to the location and characteristics of the hazard; resistance is related to the economical, psychological, and physical health, as well as the capacity of individuals or communities to withstand the impact of the event and is related to livelihoods; resilience is defined as the ability to cope with or adapt to the hazard stress through preparedness and spontaneous adaptations once the event has manifested itself.

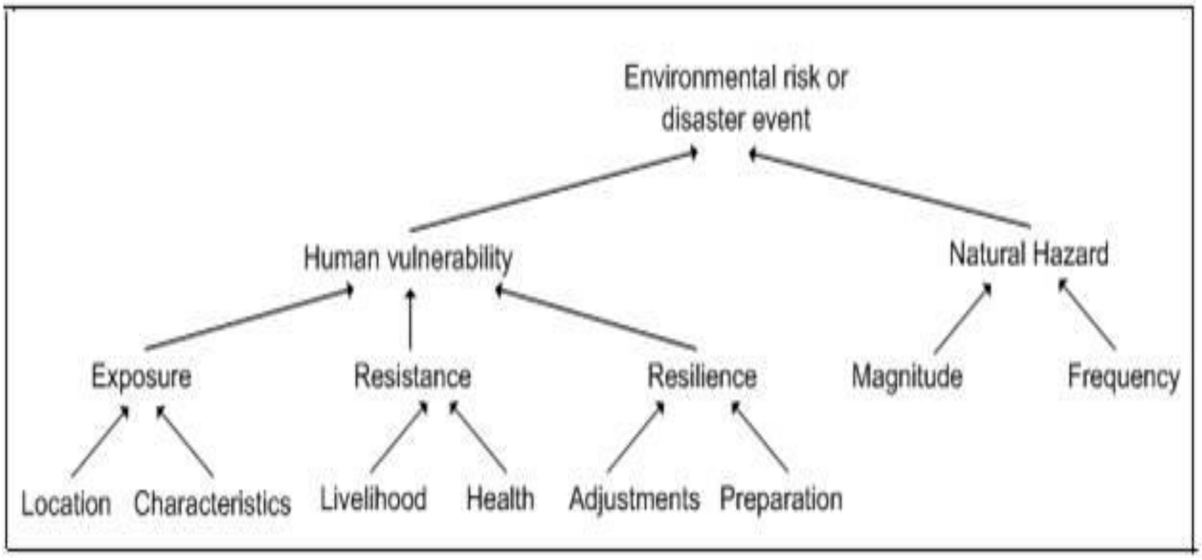


Diagram - 9: Exposure, resistance, resilience model (Pelling 2003)

Simplified approach to vulnerability

A simplified approach focuses attention on critical parameters of interest identified. The critical parameters applicable to the Andaman and Nicobar Islands were:

- Land use/ Land cover
- Exposure to the hazard
- Distance from the sea
- Elevation
- Capacity to evacuate (within the broader framework of awareness, preparedness, early warning, response and safe evacuation)
- Impact on livelihood

Based on the description of the above points vulnerability mapping is done, defining areas into four different zones i.e. very high vulnerable, high vulnerable, medium vulnerable and low vulnerable.

1.2.6 Vulnerability mapping based on land use/land cover

Data processing: Raster data of Path/row 134/51 and 134/52 from the USGS Earth Explorer site are obtained. After clipping the obtained data, mosaic both the raster files using ArcGIS for obtaining Andaman and Nicobar Island raster file. After that supervised classification of land use is done by maximum likelihood classification in Arcmap10.8.

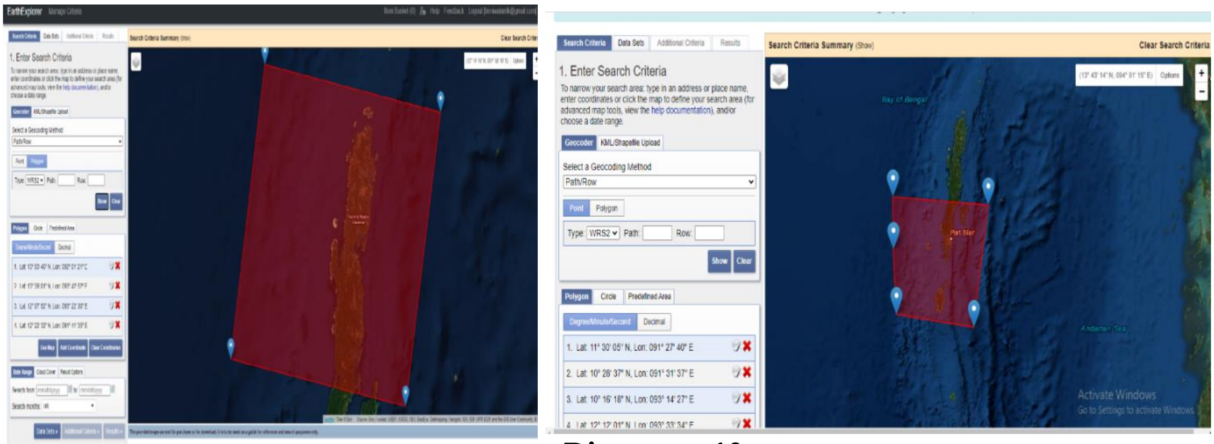
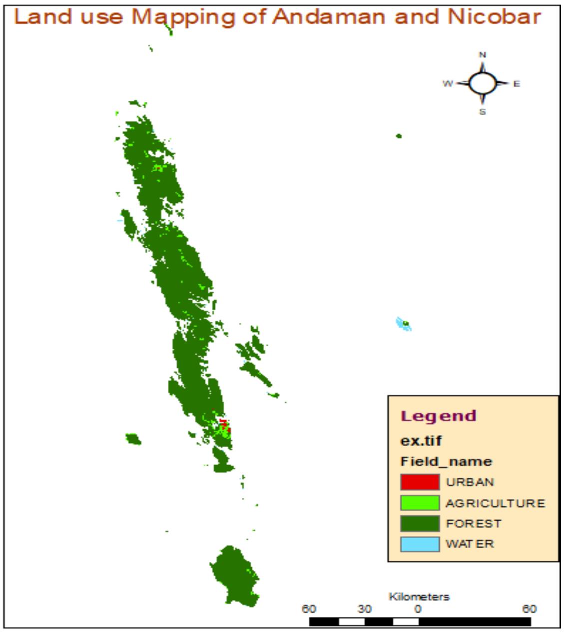


Diagram - 10

Result: Mapping describes the vulnerability of areas based on its use. The settlement has the highest vulnerability because it can endanger people's life, health and livelihood. As the disaster has a huge impact on people's lives, it also affects the economy and agriculture is one of the main professions on which the livelihood of a small town is dependent. That's why urban areas are very high vulnerable and agriculture is highly vulnerable. The Forest area is medium vulnerable and waterfalls under low vulnerability as shown in the map below:

Land use classes	Colored	Score
Urban		Very High Vulnerability
Agriculture		High Vulnerability
Forest		Medium Vulnerability
Water		Low Vulnerability

1.2.7 Vulnerability mapping based on elevation



Data processing: Topographic elevation is a primary condition to assess the tsunami vulnerability of a region. Digital Elevation Model (DEM) from shuttle Radar Topography Mission (SRTM) is used to obtain the topographic elevation of the study area. The elevations were classified into four groups by using reclassify tool in Arc Map 10.8.

Diagram - 11

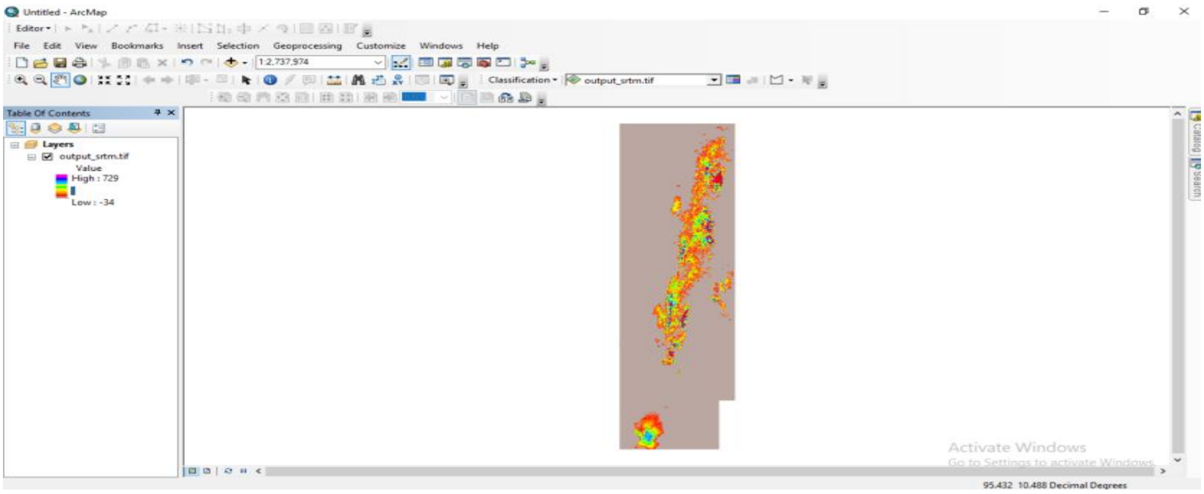


Diagram - 12

Result: Vulnerability mapping based on elevation shows the vulnerable area based on its slope. If the slope of the area is less than that area is very high vulnerable. And high slope area is less vulnerable.

1.2.8 Prevention Measures:

In coastal zone management when planning for a tsunami and other coastal hazards that accompany high waves and high inundation can prevent by adopting many prevention measures. These include early warning systems, regulatory interventions in the form of extending existing setback defence lines, and physical interventions such as the protection of structures and utilizing the full potential of coastal ecosystems. These should be supplemented with public awareness of disaster preparedness and efficient evacuation procedures incorporating planned evacuation routes. (Hettiarachchi, S.S.L; Samarawickrama, S.P;Wijeratne 2011).

Prevention measures are broadly classified into three categories, which include mitigation of hazard impact, mitigation of exposure and vulnerability to the tsunami, and successful response and rescue.

➢ **Mitigation of tsunami impact**

- Dense mangroves in coastal areas help to absorb the impact of tsunamis i.e. effective use of the natural coastal ecosystem.
- Tsunami breakwater, dikes and revetments are some artificial measures.
- Hybrid of natural and artificial measures.

➢ **Mitigation of exposure and vulnerability to the tsunami**

- Techno–legal regime

Slope		score
0 - 5		Very High Vulnerability
5 - 11		High Vulnerability
11 - 19		Medium Vulnerability
19 - 69		Low Vulnerability

- Hazard resilient infrastructure and lifeline buildings.
- Construction of saline embankments.
- Lay down all-weather link roads.
- Land use planning

➢ **Promote successful response and rescue**

- Capacity building
- Frequent mock drill
- Efficient early warning system and public warning system

- Awareness among local people
- Evacuation routes and structures

Some examples of well-integrated hybrid products of natural and artificial systems for physical intervention on the coastline are:

- Tsunami breakwaters and coral reefs reduce the impact of tsunami waves prior reaching to the shoreline.
- Tsunami dikes and sand dunes protect coastal zones by preventing tsunami waves' inland movement.
- Tsunami dikes, revetments and mangrove forests reduce the impact of severe tsunami waves.

Hazard, vulnerability and risk maps play a vital role in risk management. In view of the benefits of risk management measures, it is important to upgrade these maps regularly. These maps can be used for the production of disaster preparedness or management maps. (Hettiarachchi, S.S.L; Samarawickrama, S.P;Wijeratne 2011).

1.2.9 Mangroves of Andaman and Nicobar Island:

Andaman and Nicobar Islands are the major hotspots of coral reefs in India (Mondal, 2011). Approximately 34 true mangrove species associated with 15 genera, 10 orders and 12 families are found here (Dam Roy et al., 2009). A 2020 study, which assessed the impact of coastal upliftment on the Northern Andaman mangroves based on satellite data analysis from 2003 to 2019, reports a loss of 6,500 hectares of mangroves. Superseding initial reports that documented 60-70 per cent mangrove cover loss in the Nicobar Island, a 2018 study revealed that 97 per cent of mangrove cover of the islands was razed due to the 2004 event. Studies have found that the Diglipur region in the Andaman and Nicobar Islands is most vulnerable. Both natural and man-made impacts are high in Diglipur. There are two major degradation hotspots identified for 2030 and 2050, and these are Mayabunder and Diglipur regions. The major threats to these regions are population growth and the influence of climate change[vi].

1.2.10 Techno-legal regime of Tsunami:

Since the earthquake shaking of 2004 in Port Blair was not very high (shaking intensity was VI-VII), houses that were sensibly built on a regular grid and reasonably good soil fared quite adequately and suffered only non-structural damage and some minor structural damage. Buildings which were complex with a lot of architectural gymnastics and no clear load path were punished severely and many such houses collapsed or suffered heavy structural damage and needed to be torn down. The topography of Port Blair is fairly undulating and the sliding of the plinth was observed in many buildings. Foundation failures due to erosion and excessive settlements were also observed. Shore-front building on Car Nicobar Island was inundated by the waves, but the frame resisted the wave effects. There was the failure of many important government buildings, some of which had been completed less than 5 years before the earthquake. The passenger terminal building at the Haddo Wharf is a case in point[vii].

1.2.11 Capacity Building:

With a view to create disaster awareness amongst the stakeholders, The Directorate of Disaster Management in coordination with the Department of Education, Health, A&N Police Fire Services and National Disaster Response Force (NDRF) has conducted Disaster Management Exhibition and Mock Drills to generate adequate and appropriate awareness amongst the children and youths on the basics of disaster management so that they can respond to any disaster, the Directorate of Disaster Management, A&N Administration, in coordination with Indian National Centre for Ocean Information Services (INCOIS), Hyderabad organized a day-long workshop in 2013 for capacity building of all Disaster Management Functionaries of this Union Territory.

The Andaman and Nicobar Islands fall under Zone V, which is an area most vulnerable to earthquakes. After the tsunami, in December 2004, the Government of India has taken into the notice of the destruction caused during that time. A nationwide campaign was thus started on disaster preparedness through training on Disaster Risk Reduction (DRR) and subsequent Mock Drills. One such programmes was conducted in the Nancowrie Sub-division as a collaborative effort between the A&N Administration and Tata Institute of Social Sciences (TISS). TISS provided the necessary expertise in developing disaster preparedness among the government departments and the community. Following the training sessions, two Mock Drills were conducted in the villages of Kamorta and Pilpillow on the 14th and 16th of January 2012.

1.2.12 Early Warning System:

The Early Tsunami Warning System installed at Rangachang in Andaman and Nicobar Islands can predict a tsunami immediately after an earthquake. The system can predict tsunamis within 3 minutes after the occurrence of the initial tremors and send alerts. The system would assess the impact of waves during the earthquake for the possibility of triggering a tsunami and send alerts[viii].

The Indian National Institute of Ocean Information Services (INCOIS) is planning to set up 35 seismic stations on the Andaman and Nicobar Islands in the next two years to improve tsunami warning systems. Strong Motion Sensors with Global Positioning Systems (GPS) have been installed at 28 locations on the islands.

1.2.13 Planning:

Pre-disaster recovery planning is an opportunity for communities to consider how they will manage important recovery issues, like how to keep the government and essential services up and running, where to locate temporary housing, how and where they will rebuild, and how to re-establish essential economic activity. Communities can, and should, take steps before being impacted by a disaster to ensure that the aftermath will not become a disastrous and chaotic situation in itself. For sustaining multiple uses of the coastal zone and long-term stability, these options reflect a strategic approach and give due consideration to the threats and risks of hazards.

Within the prevailing legal and institutional frameworks, policy and management options should be formulated on a sound scientific basis. Here participation of stakeholders has been given the highest priority. Extreme care has to be exercised when obtaining the active participation of stakeholders who have witnessed the disaster and suffered heavily in loss of lives, property and livelihoods from one of the most severe natural disasters to have affected the region. Most of them require a long period to recover completely from their traumatic experiences. (Hettiarachchi, S.S.L; Samarawickrama, S.P;Wijeratne 2011).

Identifying possible courses of action on the shoreline is done by proper strategy:

- Maintenance of existing defence line.
- Apply a strategic approach to deal with the disaster.
- Setback of the defence line

In order to implement the policy options, below mentioned management options may be appropriate for the coastal area:

- Reinstate the previous condition
- Modify the existing design
- Develop new design

After the prevention, planning and preparedness phase, mitigation options should be developed within the framework of policy and management options, giving due consideration to stakeholder consultations.

1.2.14 Tsunami Resilient Building:

Tourism and activities performed at the coast play a vital role in generating the economy of Andaman and Nicobar. So, it is difficult to terminate or shift all the activities on the coast to an area that is completely free from potential tsunami hazards. Vertical evacuation structures, such as safe evacuation centres are too far to reach on foot. Therefore, the development of design guidelines and construction manuals for tsunami-resistant infrastructure is required for the benefit of the public.

Points may include in design guidelines:

- Detailed design information on hydraulic and structural loads and geotechnical issues.
- Guidelines include useful advice on location, layout, orientation, structural configuration and other relevant information.

Guidelines could be developed from the experience of different countries' damage assessments. Such assessments may be analysed in the context of the hydraulic regime generated by the tsunami at that location. In particular, local effects which can enhance the impact of tsunamis have to be taken into consideration. It is important that damage assessment should cover a variety of infrastructure that was destroyed or damaged, or that survived with fewer impacts.

1.2.15 Conclusion:

This report has described in detail and presented the results of vulnerability mapping of Andaman and Nicobar Island. The paper focuses on the Potential Impact of tsunami, hazard, vulnerability and capacity analysis followed by risk management measures.

Impacts of the tsunami are classified into different types based on what aspects are being focused on. Direct losses refer to physical or structural impacts such as loss of livelihood, and destruction of buildings cause by tsunamis or cyclones or earthquakes. Indirect losses are not immediate losses; these are secondary results of the initial destruction such as economic loss.

Hazard analysis comprises both probabilistic and scenario-based hazard analysis. Being influenced by events in North Sumatra and the Nicobar Islands it is determined through probabilistic analysis that low hazard and high hazard maps of Andaman and Nicobar Islands are similar. The scenario-based analysis deals with a particular scenario or group of scenarios.

In terms of hazard impacts, the IOT represented a worst-case scenario which may be used for long-term strategic urban development planning, in particular to identify locations for critical infrastructure and installations. The multi-scenario modelling carried out for this study may be used for such an exercise, with the adoption of weightage factors (Hettiarachchi, S.S.L; Samarawickrama, S.P;Wijeratne 2011).

This report consists of three vulnerability frameworks out of three simplified approaches to vulnerability applied to Andaman and Nicobar Islands. According to Bohle, Vulnerability is defined in two parts that are internal and external vulnerability. Pelling model has classified human vulnerability into exposure, resistance and resilience. It was evident that the simplified approach provides an effective vulnerability analysis on which risk assessment can be undertaken with confidence.

This paper described a multi-criteria analysis of tsunami vulnerability at a regional scale using geospatial variables within a GIS. Vulnerability mapping based on land use and elevation of Andaman and Nicobar Island is undertaken using GIS. Overlying the land-use classification on the tsunami vulnerability map showed that the urbanized area is particularly at risk of the tsunami were to strike the study area. GIS analyses can be useful in a wide range of disaster assessments through the use of spatial functionalities such as topographic operation, buffer creation, raster reclassification and also intersection operations. Such approaches can aid in regional planning for the management and mitigation of natural disasters, including tsunamis. However, such analysis can be limited by the availability of data necessary for estimating the risk of natural hazards.

Tsunami risk management has been focused on a three-pronged strategic approach and identifies the importance of operating within a multi-hazard coastal protection plan. Such an approach considers measures to:

- Mitigation of tsunami impact
- Mitigation of exposure and vulnerability to the hazard
- Promote successful evacuation from the hazard

The report has also focused on the evaluation of the resilience of coastal communities, which is considered one of the most important goals in risk management.

THEME 2.1: APPLICATIONS OF GEOGRAPHICAL INFORMATION SCIENCE & REMOTE SENSING IN ENVIRONMENTAL AUDITING & PLANNING

2.1.1 Introduction

A Geographic Information System (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can help individuals and organizations better understand spatial patterns and relationships by relating seemingly unrelated data.

Many different types of information can be compared and contrasted using GIS. The system can include data about people, such as population, income, or education level. It can include information about the landscape, such as the location of streams, different kinds of vegetation, different kinds of soil, groundwater, air quality status, forest fires etc.

A research paper on the subject is contributed by Mr. Sangam Yadav, intern iCED with a case study on "changing of land and land cover analysis over iCED campus during the period 2009-18".

2.1.2 Water Pollution

Knowledge of water quality parameters is essential to interpret water quality and for making accurate predictions of the water quality of a particular area. GIS and Remote Sensing have been used extensively to assess water quality worldwide. The kriging method can be used to predict the spatial distribution of some groundwater quality parameters.

Remote Sensing-GIS in Monitoring Water Quality in Malaysia

Malaysia has used remote sensing techniques because of the limit of the field cost, to improve the information contents, to produce the digital map, and to monitor the large-scale monitoring of water quality that will offer a significant source of information. A study was done in Malaysia on Penang Island by MatJafri et al., (2001), using a satellite scene from Malaysian Tiungsat-1 for water quality mapping around the island.

The objectives of the study were to determine the total suspended solids and to produce a water quality map. The best Tiungsat-1 image available for the study area did not have the coincident data of the total suspended solids. To overcome this problem, they correlated the Tiungsat- 1 image with the Landsat TM images that have the corresponding sea-truth data. From the analysis, the Landsat TM image produced the highest correlation with the Tiungsat- 1 image.

Another example is a prediction of groundwater potential zone in Langat Basin using an integration of remote sensing and GIS (Khairul et al., 2000). The purpose of the study was to predict the groundwater potential zone through the various thematic maps from remote sensing and GIS technique. From the results, it was revealed that almost all of the Langat basin is an alluvial plain which has a high potential for groundwater occurrence.

In a steep mountainous area underlain by granite with low lineament density, the groundwater potential is very low. Satellite data has been proven to be very informative and useful in detecting surface features and characteristics such as lineaments and land use. Integrated assessment of thematic maps using a model based on GIS techniques is the most suitable method for groundwater potential prediction zoning.

Advantages of Remote Sensing in Monitoring Water Quality

One major advantage of remote sensing observations over traditional measurements for water quality monitoring provides both spatial and temporal information on surface water characteristics (Lindell et al., 1999). With present advanced satellite sensors, a large number

of water quality information about chlorophyll-a, suspended sediment, yellow substance, turbidity, wave height, color index and surface water temperature can be observed regularly (Zhang et al., 2002). Besides, the remote sensing technique has been widely used for water quality studies in coastal and inland lakes (Koponen et al., 2002).

Remotely sensed data have the potential to provide knowledge of broad-scale changes, the link between offshore and near-shore waters, and the ability to obtain a long-term, near-daily view of the region of interest indicating seasonal and inter-annual variability.

RS and GIS represent an additional source of information for hydrogeological maps production where the application of RS in the field of water resources management includes:

- Hydrogeological mapping.

- Identification of areas affected by salinization.

- Determination of Biomass.

- Land use and crop classification.

- Environmental monitoring.

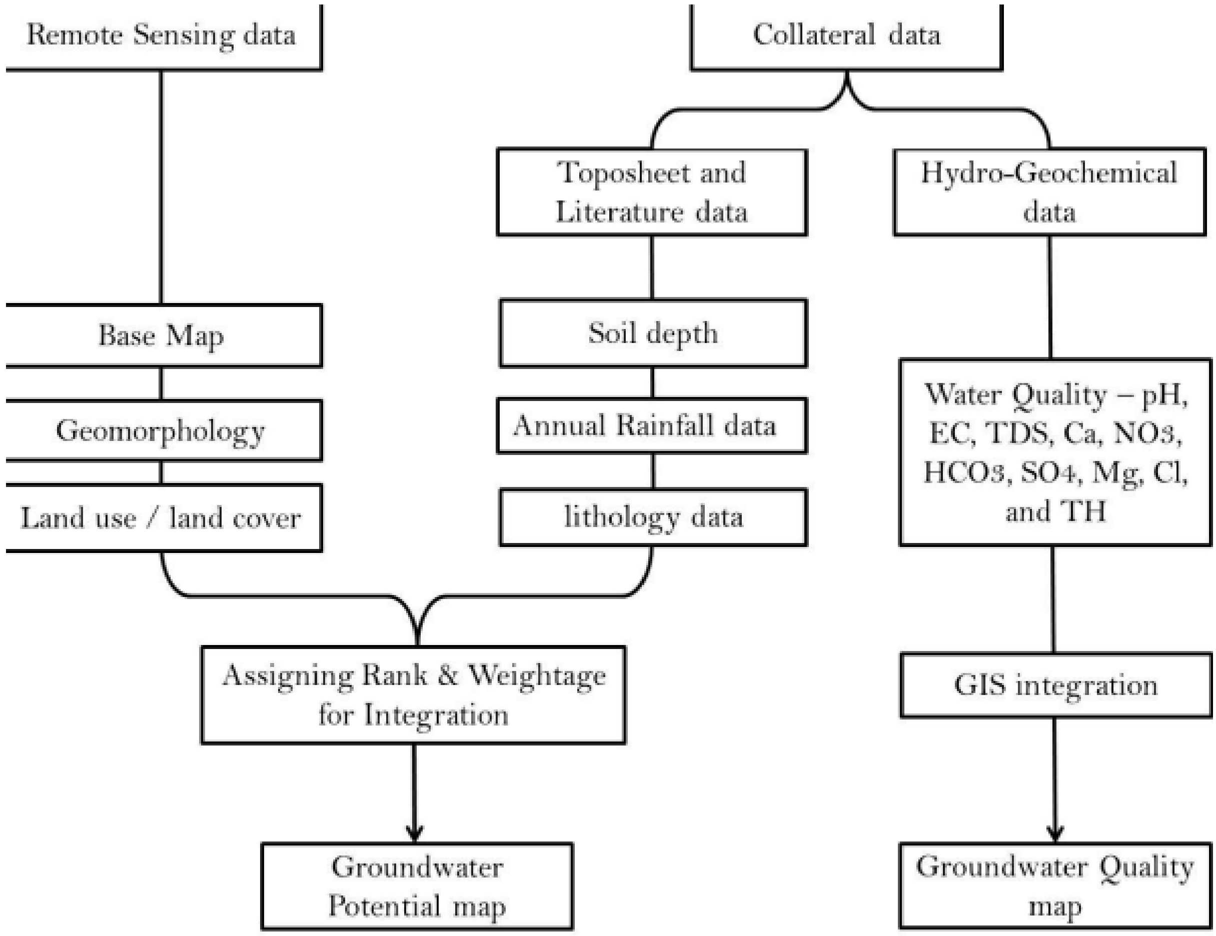
Groundwater Quality Mapping using Remote Sensing & GIS

It is very essential to start investigations oriented towards groundwater quantification and qualification which is a basic requirement to form plans for its exploitation, management and conservation.

Test drilling and stratigraphy analysis are the most reliable and standard methods for determining the location and thickness of aquifers and other subsurface formations, quality of groundwater, physical/ hydraulic characteristics of aquifers, etc., in a basin. In the era of information technology, modern technologies such as remote sensing (RS) and geographic information systems (GIS), coupled with geophysical surveys are very helpful for the evaluation of groundwater resources in a basin. The RS technology, with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has emerged as a powerful tool for the assessment, monitoring and management of groundwater resources. The hydro-geologic interpretation of satellite data has been proved to be a valuable survey tool in areas of the world where little geologic and cartographic information exists or is not accurate as well as in inaccessible regions of the world.

Since remote sensors cannot detect groundwater directly, the occurrence of groundwater is judged from different surface features derived from satellite imagery such as geomorphology, soil, land use/land cover, topographic slope, surface water bodies, etc., which act as indicators of groundwater existence. In addition, surface geophysical techniques are non-invasive and relatively less time-consuming and offer cost-effective alternatives for obtaining information about subsurface formations and groundwater.

The following schematic diagram shows the methodology of analysis of the quality of groundwater.



Methods

Sample collection: water quality monitoring stations should be identified and water samples may be collected in the middle month of four seasons namely post-monsoon (January – March), summer (April –June), pre-monsoon (July – September) and monsoon (October – December) of the year.

Parameters under monitoring: The groundwater samples must be analysed for parameters which include pH, EC, TDS, TA, TH, Ca (II), Mg (II), Na, K, fluorides, sulphates and chlorides using standard protocols and the quality of the data was ensured through careful standardization.

Water Quality Index (WQI) The water quality index (WQI) of groundwater is calculated using the weighted Arithmetic Index method and quality rating/sub-index (Qi) corresponding to the parameter Pi is a number reflecting the relative value of this parameter.

TDS, pH, chlorides, fluorides, total hardness, total alkalinity, calcium and magnesium are recognized as preliminary indication of the quality and it is used in calculating WQI for public water supply.

2.1.2.1 Groundwater mapping in Egypt using RS and GIS (a case study)

1. Eastern Desert

Omran performed an interpretation approach that integrates data obtained from RS, geophysics and other hydrogeological phenomena through GIS, to characterize groundwater resources for the identification of candidate well locations in the Sohag region. Groundwater potential zones have been demarcated by integration of aquifer thickness derived from surface electrical resistivity survey and drilling data with the different thematic layers; hydro geomorphology,

Table 1- Weightage of different parameter for groundwater prospects

S. no.	Criteria	Classes	Weight
1	Hydro geomorphology	Nile flood plain	5
		Transverse channels	3
		Low land desert areas	2
		Limestone plateau	1
2	Slope (degree)	0–0.5	5
		0.6–2.0	4
		2.1–5.0	3
		5.1–10.0	2
		>10.0	1
3	Surface lineament	Present	2
		Absent	1
4	Subsurface lineament	Present	2
		Absent	1
5	Drainage	High possibility for floods (A)	3
		Moderate possibility for floods (B)	2
		Low possibility for floods (C)	1
6	Depth to water bearing zone	>25 m	3
		6.0–25.0 m	2
		<6.0 m	1
7	Aquifer thickness	>35 m	5
		26.0–35.0 m	4
		16.0–25.0 m	3
		6.0–15.0 m	2

lineaments, slope, drainage and depth to an aquifer, using a model developed through a GIS technique. The weights for each parameter are shown in Table-1. The groundwater potential zone map generated (Fig. 1) through this model was verified with the yield data to ascertain the validity of the model developed. Total weights of final integrated grids were derived as a sum of the weights assigned to the different layers based on suitability.

Weightage of different parameters for groundwater prospects

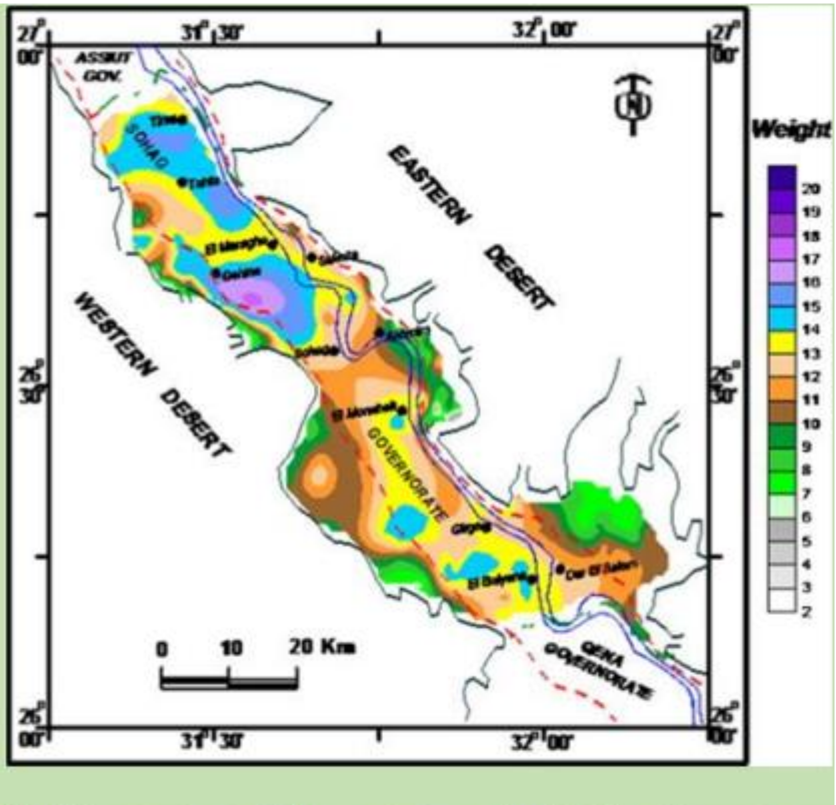


Fig 1- Groundwater potentiality map, Quaternary Aquifer, Sohag Governorate area.

Abdalla determined the most important contributing parameters that indicate the groundwater potential in Wadi El Laquita in the Central Eastern Desert and its surroundings as one of the most promising areas for agricultural development in Egypt. To delineate the location of the groundwater prospect zones, different thematic maps were prepared from topographic and geological maps. These maps were based on determining the most important contributing parameters that control groundwater storage. These parameters include the following:

(1) Slope, which controls the runoff of water or remains on the ground surface for a time long enough to infiltrate (Sl),

(2) Stream network, which influences the distribution of runoff and groundwater recharge (Dr),

(3) Lineament, which enhances significantly the permeability by inducing secondary porosity and hence vertical water percolation to recharge the aquifers (Lin),

(4) Lithology or rock type, which determines the soil and exposed rocks infiltration capabilities and governs the flow and storage of water (Geo) and

(5) Topographical map layers (top).

The thematic map of each parameter was produced using GIS and RS. These input layers were combined using the Raster Calculate Module in a GIS model to produce the final groundwater prospective zones of the investigated area (Fig 2).

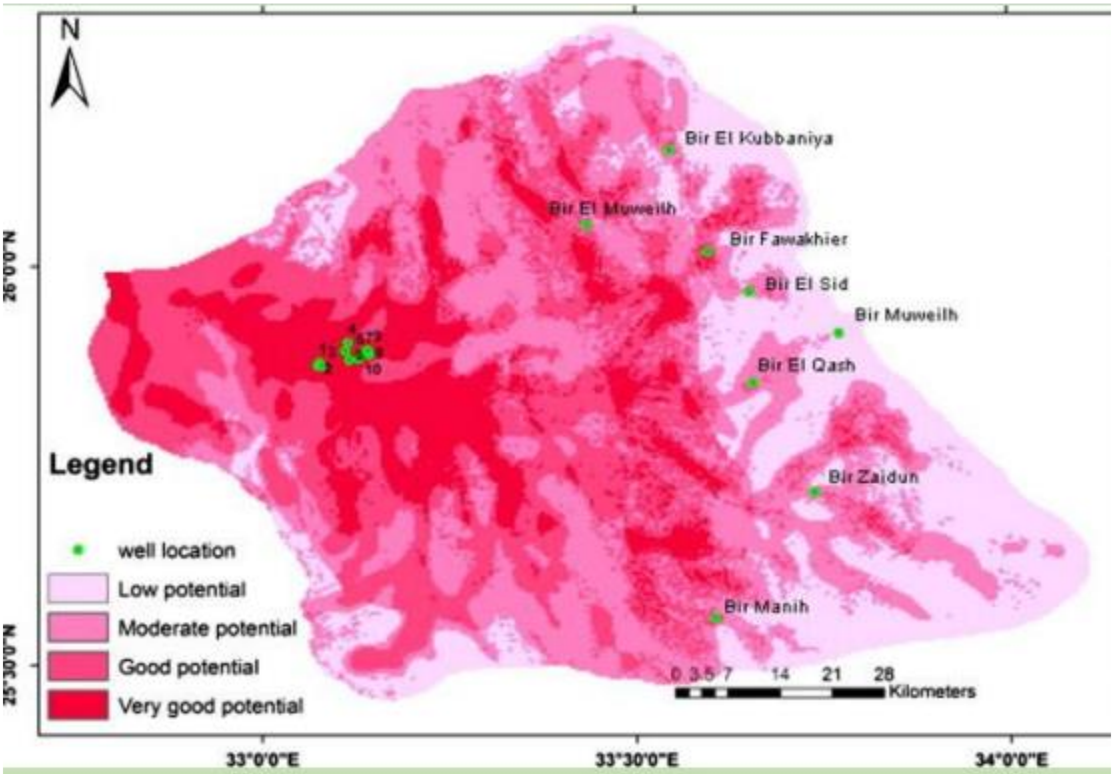


Figure 2-. Groundwater prospect map of the Central Eastern Desert

The groundwater prospect map (Fig-2) was mathematically calculated using ARC GIS raster analysis as follows:

GWP=∑Wi∗CVi

Where the GWP = groundwater potential, Wi = map weight, CVi = capability value (weight of inter-map class).

GWP=∑(Dr,Lin,SI,Geo,top)

Where Dr = stream network classes, Lin = lineaments density classes, Sl = slope classes, Geo = lithology classes, top = topography/elevation classes.

Gheith and Sultan constructed an integrated hydrology model that represents a first-order estimate for groundwater from sparse storm events over the Red Sea hills. Watersheds and stream networks were identified from digital terrain models verified by comparison with co-registered Landsat scenes and geologic maps. Amer et al. Assessed quality, quantity and potential uses for groundwater in the Central Eastern Desert of Egypt as a case study for groundwater utilization in arid regions. Field studies and RS data were combined with IS-based modelling to estimate the groundwater budget of sedimentary sub-basins, and use these estimates to suggest locations for new wells. Stable isotopic composition and major ion hydrochemistry of groundwater were used to evaluate the source of water in different aquifer types and propose management policies for groundwater use.

2. A joint project between the Government of the Arab Republic of Egypt and the United Nations Development Program (UNDP) and UNESCO was launched under the title: “Capacity Building of The Egyptian Geological and Mining Authority (EGSMA) and The National Authority for Remote Sensing and Space Sciences (NARSS) for the sustainable development of the South Valley and Sinai”. One of the main outputs of this joint project was the production of an atlas of water resources in the Sinai Peninsula with a scale of 1:450,000.

Elewa and Qaddah integrated Enhanced Thematic Mapper Plus (ETM+) images, GIS, a waters modelling system (WMS) and weighted spatial probable modelling (WSPM) to identify the groundwater potential areas in the Sinai Peninsula, Egypt. Validation using measured well yield data was performed to check the WSPM results. Eight related thematic layers (rainfall amount, net Groundwater recharge, lithology, lineament density, terrain slope, drainage density, depth to water, and water quality) were built in a GIS and assigned appropriate rankings. The WSPM was checked and validated by comparison with the published hydrogeological map of North Sinai in 1992 and actual borehole yield data and it was found that it correlates well with the previously published data and maps. The resulting groundwater potentiality map of Sinai indicates that the different geographic locations are suitable for groundwater storage with different magnitudes and potentialities, but the overall groundwater potential is of the moderate Class.

Sultan et al. integrated optical and radar RS and geophysical data for exploring groundwater in El Qaa Plain, South Sinai, Egypt. The hydrological analyses of the Digital Elevation Model (DEM) extracted the drainage networks pattern, determined the flow direction of the main

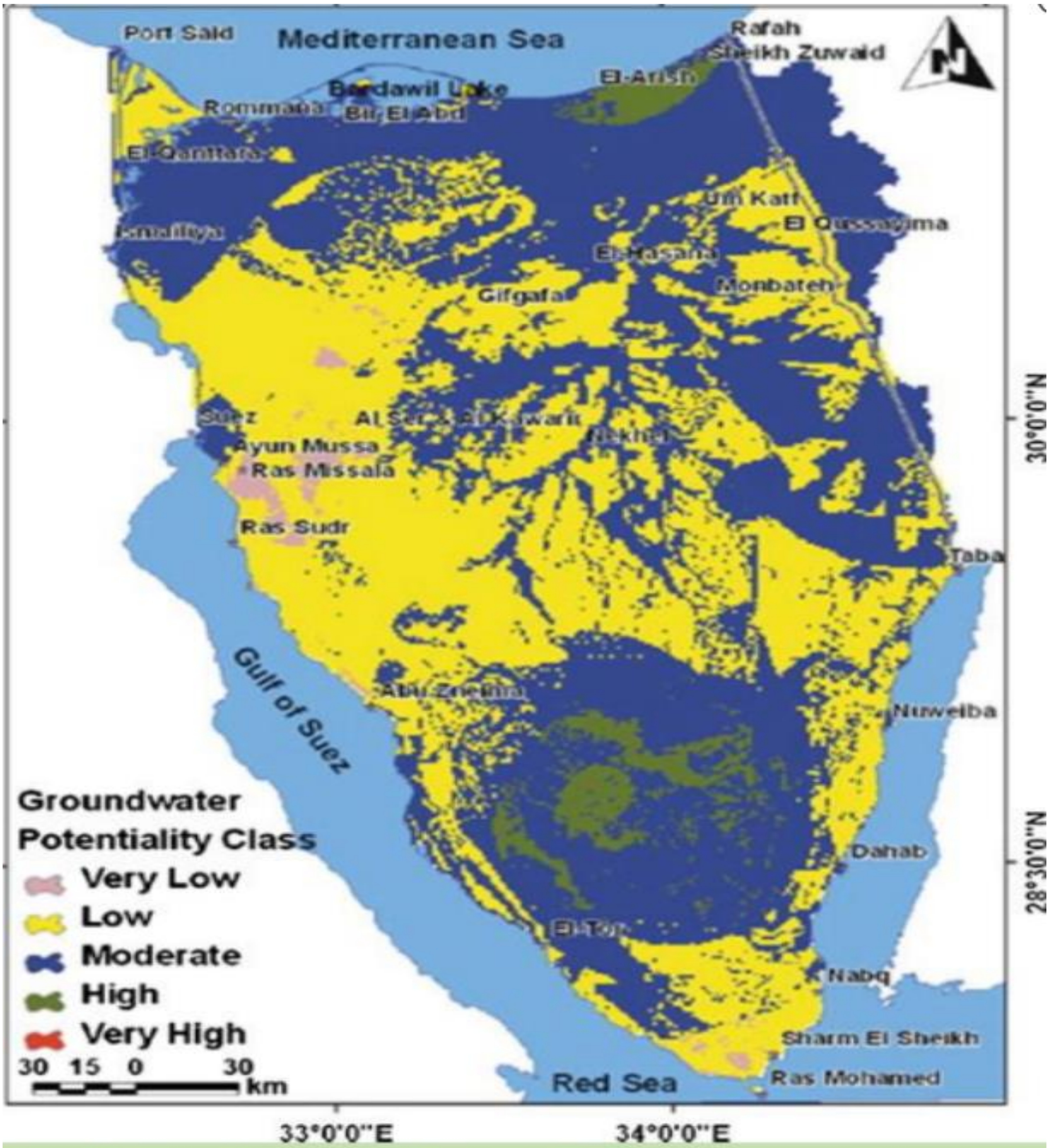


Figure 3. Groundwater potentiality map of Sinai.

channels and find the relationship between paleo channels and structural elements. The water table maps constructed from interpreted geo-electrical data indicated that the elevation of the water table decreases from the east and north to the west.

Milewski et al. developed an interactive data language (IDL)-based computer program, the RS data extraction model (RESDEM) for integrated processing and analysis of a suite of RS data sets. RESDEDRSDENrts, calibrates, and georeferenced scenes, and subsets global data sets to extract and verify precipitation over areas and periods of interest.

Western Desert

Robinson used SIR-C and Radar sat radar data to map structural and fluvial features in southwest Egypt to identify new groundwater resources in fractured rock aquifer settings.

The interpretation of one Radar sat image and five high-resolution SIR-C radar scenes combined with Digital Elevation Models (DEM) analysis showed that NE and ENE drainage directions prevail in south-western Egypt and culminate in the Kharga Depression. Radar data are ideal for mapping paleochannels since some are sand-covered (L-band can penetrate to at least 2 m beneath the sand in arid areas). The regionally extensive faults (Fig. 3) drain numerous wades and extend for tens of kilometres in length, so may constitute important water carrying conduits.

Radar waves are uniquely able to penetrate beneath the desert sand in the eastern Sahara to reveal groundwater related to near-surface features, that is; courses of ancient rivers, streams, faults and fractures. The depth of near-surface imaging for the data sets used is on the order of half a meter. Three new areas have been identified as promising sites for agricultural development.

Koch et al. used optical and radar RS techniques, supported by limited ground surveys to locate potential areas for accumulating groundwater in El-Gallaba plain, west of Aswan City. These techniques were a combination of multispectral, thermal and microwave data (ASTER and PALSAR) and supported by ground measurements (Ground Penetration Radar (GPR), field spectroradiometry and magnetometry).

The infrared bands of the ASTER image were used to calculate the Land Surface Temperature (LST) in El-Gallaba plain where the resulting LST map revealed two broad strips of thermal cooling anomalies arranged in a linear fashion and diagonally crossing the alluvial basin of the study area. The areas were further explored with radar data to better understand the nature of these LST anomalies. Radar ALOS/PALSAR data (HH) were used to determine the range of backscatter coefficient values of the sediments along with the thermal anomalies and their surroundings.

A number of 12 GPR profiles across the LST anomalies confirmed that the near-surface sediments (up to 17 m depth) consist of thin horizontal layers of sandstone with very low gravel content. A set of spectral signatures were acquired at the investigated sites (LST anomalies sites and surroundings) where the results indicated that the silt and clay content is low as they generally do not exceed 1 percent.

Nile Delta and Nile Valley

The hydrogeological map of the Nile Delta was completed in the period 1989–1992 and produced by RIGW within the framework of the main project entitled: "Development and management of groundwater resources in the Nile Valley and Delta". This project was an Egyptian – Dutch bilateral project.

Dawoud et al. developed a GIS-based model to simulate the water resources in the Western Nile Delta. This model has provided a useful tool to evaluate the water resources status and to test the proposed management alternatives in the Western Nile Delta region. The model consisted of a multi-layer aquifer system. GIS was used to manage the spatially distributed input parameters such as the time-invariant spatial data and outputs of the model. The model was calibrated against the available average annual groundwater heads of about 60 observed wells during the period from 1990 to 2002. The calibrated model has been used to test two management alternatives.

Concluding remarks and recommendations

From the previously mentioned studies related to the use of RS and GIS in groundwater mapping, it could be concluded that groundwater mapping is one of the main tools for efficient and controlled development of groundwater resources. These maps can be used by engineers, planners and decision-makers to allocate, develop and manage groundwater within a national water policy. Integrated RS and GIS techniques prove to be rather satisfactory options for groundwater mapping in different regions of Egypt.

From these studies, the following concluding remarks could be highlighted:

- Integrated RS data and GIS are useful in delineating favourable areas for well establishment using various geo-informative thematic maps.
- Modelling approach is applied to integrate the physical and geologic factors governing groundwater potentiality in a map form showing spatial data for areas with different responses to groundwater potentiality in the Sinai Peninsula.

- Interpretation of Radar sat images and high-resolution SIR-C radar scenes combined with DEM analysis shows that NE and ENE drainage directions prevail in south-western Egypt and culminate in the Kharga Depression. These results will be helpful in strategic planning for ground-water exploration and drilling programs.
- Information has been extracted on lithology, geological structures, landforms, land use/land cover, soil characteristics, and slope of the terrain and studying all these in an integrated way in a GIS environment to generate village-wise groundwater prospect zones.
- Much more RS and GIS-based groundwater research with field investigations may be tried to effectively exploit the current and expand the potential of the technologies.

2.1.3 Air Pollution

Air Pollution Monitoring using Remote Sensing

Importance of satellite imagery in monitoring air quality

- Satellite remote sensing provides a complete and synoptic view of large areas in one image on a systematic basis due to the good temporal resolution of various satellite sensors.

- Satellite remote sensing technology can monitor many pollutants simultaneously.

- It can monitor in real-time and provides continuously rapid monitoring.

- The different sensors used in mapping air pollution are –

• Landsat TM/ETM+

• MODIS AOT

• ASTER data

• Resource sat

Types of monitoring techniques used to map air pollutants Aerosols

• Aerosol thickness is monitored by four different methods-

➢ Ocean method

➢ Brightness method

➢ Contrast – reduction method

➢ Dark vegetation method

Black particle measurement-

➢ Black particles have a very high negative correlation (-0.97) with the temperature of the atmosphere.

➢ One theory regarding pollution is the more pollution build-up in the atmosphere, the more interception the pollution particle has with the sunlight, and the atmosphere will have a lower temperature.

➢ The reduction in temperature is usually in 0.5C range, which is hard to detect.

➢ A very high spatial resolution is needed to accurately measure black particles.

Land use / Land-cover change-

➢ Two images from the same sensor are compared on different dates.

➢ Interval between the dates must be short.

➢ Images must be captured at low elevation angles to reduce the effect of electromagnetic radiation.

➢ By comparing the two images, a third image was created with Ground instruments for supporting Remote Sensing Measurements

- Automatic Sun- Photometer (AERONET).

- Handheld Sen- Photometer.

- PM10 devices.

Fig- CIMEL Sun Photometer

Land Use and Land Cover Analysis

Land Use & Land Cover Change Detection with Remote Sensing data

An increasingly common application of remotely sensed data is for change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh,1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Change detection is useful in such diverse applications as land use change analysis, monitoring shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes (Singh, 1989).

Macleod and Congalton (1998) list four aspects of change detection which are important when monitoring natural resources:

• Detecting that changes have occurred

• Identifying the nature of the change

• Measuring the areal extent of the change

• Assessing the spatial pattern of the change

The basic premise of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computing power.

Coppin & Bauer (1996) summarize eleven different change detection Algorithms that were found to be documented in the literature. These include:

• Mono temporal change delineation

• Delta or post-classification comparison

• Multidimensional temporal feature space analysis

• Composite analysis

• Image differencing

• Image rationing

• Multi temporal linear data transformation

• change vector analysis

• Image regression

• Multi temporal biomass index

• Background subtraction

The scientific literature reveals that digital change detection is a difficult task to perform accurately and unfortunately, many of the studies concerned with a comparative evaluation of these applications have not supported their conclusions with quantitative analysis (Singh, 1989). Digital change detection is affected by spatial, spectral, temporal, and thematic constraints. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the change. Even in the same environment, different approaches may yield different change maps. The selection of the appropriate method, therefore, takes on considerable significance.

Not all detectable changes, however, are equally important to the resource manager. On the other hand, it is also probable that some changes of interest will not be captured very well, or at all by any given system. Figure 2.5 illustrates LULC change detection capabilities of satellite data.

According to recent research by Coppin & Bauer (1996), image differencing appears to perform generally better than other method of change detection; and such monitoring techniques based on multispectral satellite data have demonstrated potential as a means to detect, identify, and map changes in forest cover. Image differencing is probably the most widely applied change detection algorithm for a variety of geographical environments (Singh, 1989). It involves subtracting one date of imagery from a second date that has been precisely registered to the first. The vegetation index (VI) differencing is one of the most popular changes detection algorithms. The fundamentals for this technique rely on the idea that if VIs are correlated to biomass, then the decrease of vegetation can be detected by a difference of VI images (one before and other after the land cover change). In this method, the first step is to calculate a differencing image by subtracting two co-registered images, followed by the application of a threshold to distinguish significant spectral differences as areas of land cover change.

Four types of VI can be tested: (1) Normalised Difference Vegetation Index (NDVI) one of the most common indices used in remote sensing studies, (2) the Atmospherically Resistant Vegetation Index (ARVI), which accounts for the atmospheric influence in the sensor output, (3) the Soil Adjusted Vegetation Index (SAVI) (Huete, 1988) that accounts for the background effect, and (4) the Modified Soil Adjusted Vegetation Index (MSAVI2), which is an improvement of SAVI.

Change Vector Analysis (CVA) is another well-accepted change detection technique. The change vector of a pixel is defined as the vector difference between the multi-band digital vectors of the pixel on two different dates. When a forest suffers a change, its spectral characteristics also change. The vector describing this change is known as the pixel change vector and describes the intensity and the direction of the change that occurred between the first and the second date. The CVA is applied to two co-registered bands of an image, on two different dates. With this method, two images are computed: one image for the vector intensity and another for the vector direction. The first image contains change information, while the second contains information on the type of change. CVA can be applied to two different spectral data sets: original TM bands and the components of the Tasseled Cap transformation, brightness (B), greenness (G) and wetness (W).

Principal Components Analysis (PCA) is another technique available. PCA is one of the most popular multivariate analysis techniques for data reduction. The PCA transformation leads to the description of multidimensional data in which axis variables are uncorrelated. In the transformed data, the first variable or component (PC1) contains the higher variance present in the data while the subsequent variables contain decreasing proportions of data scatter.

PCA can be performed on original or standardised data, the former uses the covariance matrix, and the latter uses the correlation matrix.

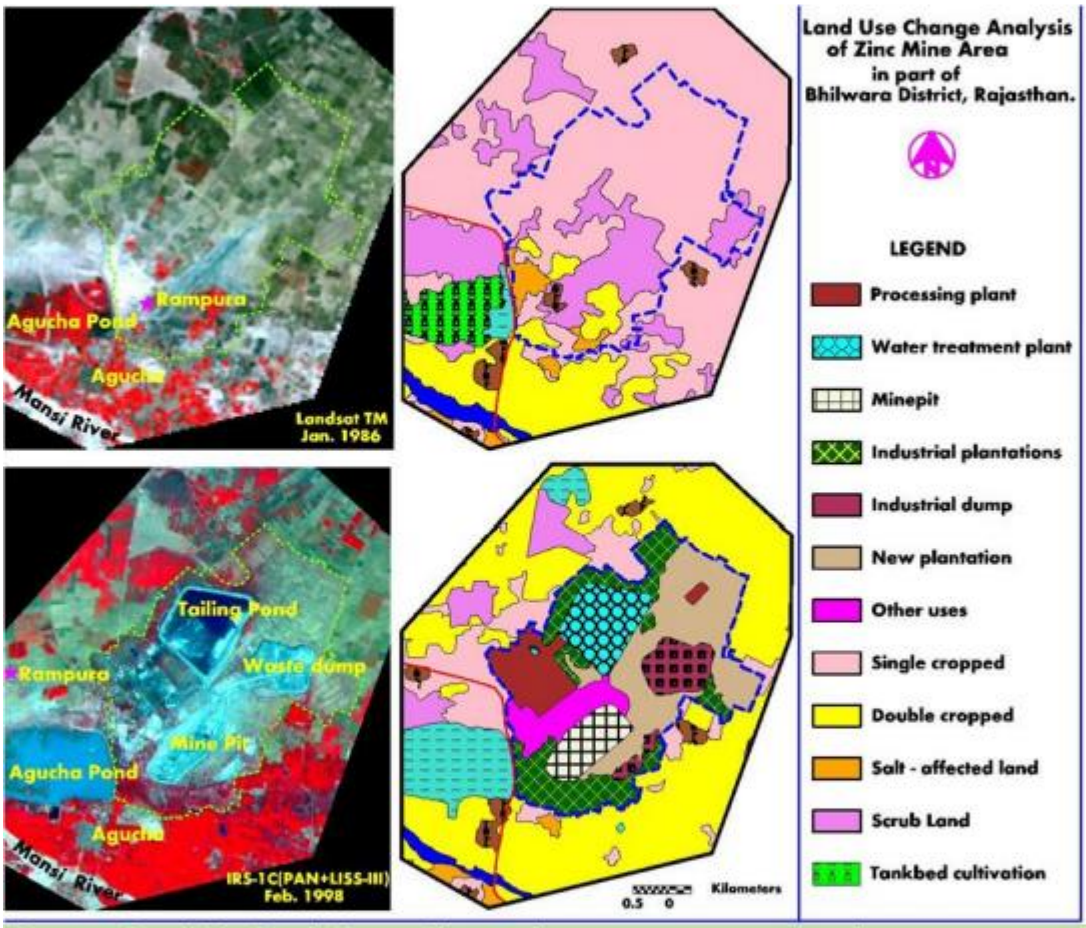


Figure - Land Use/Land Cover Change detection using post-classification comparison technique

Conclusions

Earth observations have the potential to respond to the growing and urgent demand for timely and accurate land cover information over large areas. In the recent past, land cover mapping from satellites has come of age. Through research on various issues regarding data pre-processing, classification and accuracy assessment, new and unique data/land cover products are being generated which could not be produced by earlier techniques. The techniques of LULC analysis will help in finding out the different changes in land this will help in the audit of land-related issues where monitoring of earth crust is required as well as other important aspects like climate change, pollution level can also be studied.

2.1.4 Mapping of Degraded Lands Using Remote Sensing and GIS Techniques

Introduction

Remote sensing and GIS are effective technologies for detecting, assessing, mapping, and monitoring land degradation. The application of remotely sensed data in mapping degraded lands space borne sensors started with the launch of the first Earth Resources Technology Satellite ERTS-1 / Landsat-1. However, the satellites Landsat-TM, SPOT and Indian Remote Sensing Satellites with a better spatial and spectral resolution, enabled to map and monitor degraded lands more efficiently. GIS proved to be an effective tool in handling spatial data available at different scales, voluminous point data such as soil information, rainfall, temperature etc. and socioeconomic data and to perform integrated analysis of data on various resources of any region and arrive at optimum solutions for various problems.

IRS-LISS-III Satellite data was used for qualitative assessment of areas, being subject to soil erosion. Based on the length and degree of slope from SRTM, lausesuse/land and soil characteristics as revealed by Rabi, Kharif and Zaid seasons satellite data and other related ancillary data, three soil erosion classes namely Sheet Erosion, Gullied, and Stony Waste could be mapped.

Assessment of Soil Erosion

FCCs obtained from LISS III sensor (with 24 m spatial resolution)) can be used for evathe luation of delineation of eroded areas. Based on soil, slope, land use/land cover, current soil erosion status can be mapped. Visual interpretation involves identification and delineation of degraded lands that are manifested on False Colour Composite (FCC).

The False Color Composites are analyzed initially with the help of topographical maps, published reports and other available ancillary data; broad categories of degraded lands can be delineated.

Based on length and degree of slope from SRTM, land use /cover and soil characteristics can be revealed by IRS-LISS-III data and other related ancillary data. The extent and geographical distribution of degraded lands like sheet erosiand on, gullied and stony waste areas can be used as an input for future planning reclamation conservation program. IRS P-6 LISS-III remotely sensed satellite digital data can be used to classify the different land use/land covers, and Shuttle

Radar Topographic Mission (SRTM) digital elevation model (DEM) data may also be used to draw the classified slope maps.

Remote Sensing of Ecology, Biodiversity and Conservation (EBC)

Advanced Instruments in Remote Sensing of EBC

Based on their existing applications and future potential contributions to EBC, there are five types of Instruments: high spatial resolution, hyperspectral, thermal infrared, small-satellite constellation, and LIDAR sensors. In order to avoid overlapping between high spatial resolution and hyperspectral sensors, the hyperspectral sensors mainly refer to sensors with medium spatial resolution, such as Hyperion with 30 m spatial resolution.

High Spatial Resolution

High spatial resolution, also called ‘fine spatial resolution’, is less than 10 m and ranges from 0.5–10 m in the commercial domain for environmental research. IKONOS, QuickBird, OrbView-3 and SPOT-5 are the commonly used systems (for the high-spatial resolution optical sensors). The benefit of high spatial resolution imagery is that it greatly increases the accuracy of identification and characterization of small objects at spatial scales which were previously only available from airborne platforms. For example, Gillespie et al. provided several examples of accurately identifying plant species based on the high spatial resolution imagery. Turner et al. have pointed out it is applicable and feasible to directly identify certain species and species assemblages at the scale of high spatial resolution [3]. In addition, high spatial resolution imagery can be employed to assess the accuracy of remote sensing pre-cuts derived from moderate or coarse spatial resolution imagery.

Hyperspectral

Hyperspectral data can collect ample spectral information across a continuous spectrum generally with 100 or more contiguous spectral bands. It is different from multispectral sensors which detect relatively few discrete bands. Hundreds of spectral bands with 10–20 nm spectral bandwidths offer new possibilities to detect subtle differences between objects of interest. The best example is to discriminate fine-scale, species-specific land cover, such as vegetation categories or soil types, which make a remarkable contribution to the study of biodiversity patterns.

The Hyperion sensor, an upgrade from the LEWIS Hyperspectral Imaging Instrument (HSI), records visible light and other reflected electromagnetic energy in 220 spectral bands from 0.4 to 2.5 μm at a 30 m resolution Hyperion characteristics.

The recent applications of Hyperion hyperspectral imagery mainly include ecology and biodiversity in forest, grassland, agriculture, and vegetation, fragmented ecosystem and ecosystem succession, coastal environment, etc. For example, vegetation types and densities were classified in support of wildfire management, that is, fire propagation simulation models and fire risk assessment were based on a Hyperion classification map with 93 percent accuracy.

Thermal Remote Sensing

Thermal remote sensing detects the energy emitted from the Earth's surface in the thermal infrared (TIR, 3 μm to 15 μm), which can be radiated by all bodies above absolute zero. Theoretically, TIR sensors measure the surface temperature and thermal properties of targets, which are essential for developing a better understanding, and more robust models, of land surface energy balance interactions. Moreover, TIR remote sensing is capable of uncovering the principles of ecological patterns of structure and function due to the development of ecological thermodynamics. A thermal grey level image is generated based on relative radiant temperatures (a thermogram), and light tones correspond to warmer temperatures and dark tones to cooler temperatures. TIR remote sensing plays an important role in the observation of Earth surface characteristics and is very useful for research regarding the analysis of biophysical Earth processes, in particular landscape characterization and measurement of land surface processes. The well-known sensors with TIR bands include the Advanced Very High Resolution Radiometer (AVHRR) on board the Polar Orbiting Environmental Satellites (POES), the Landsat Thematic Mapper (TM) and ETM+, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on the Terra Earth-observing satellite platform.

LIDAR

Light Detection and Ranging (LIDAR), also called Laser altimetry, is an active remote sensing technology that utilizes a laser to illuminate a target object and a photodiode to register the backscatter radiation. The current LIDAR remote sensing can be categorized into two general groups: non-scanning LIDARs and scanning LIDARs. The non-scanning LIDARs record pulsed ranging that measures the travel time between the transmitted and received signal backscattered from the object surface, and the scanning LIDARs register continuous-wave ranging that is produced in a transmitted sinusoidal signal and carried out by modulating the laser light intensity. According to the characteristics of LIDAR technology, it has been proven to provide horizontal and vertical information at high spatial resolutions and vertical accuracies.

2.1.5 Application of GIS and RS in Forest management and forest monitoring

A review of forestry applications in GIS reveals an extensive range of activities. Geographic Information Systems for forest management may be characterized by two broad and related categories: 1. resource inventory and monitoring; 2. analysis, modelling, and forecasting to support decision making.

With these two types of broad activities as a guide, this paper is organized into two parts – resource assessment (including inventory and monitoring) and resource management (including the full range of analysis and modelling concerning the evaluation and testing of specific interventions).

Resource Assessment

Resource assessment activities include: 1) inventorying forest resources available for harvest, fuel, food, recreation, or conservation purposes, along with related data such as topography, soils, roads, and hydrology, and 2) monitoring changes that occur to these resources over time, and 3) evaluating potential land productivity for forest types given certain biophysical and climatic factors. It is in forest resource assessment that other technologies related to GIS, remote sensing, and global positioning systems, make direct and substantial contributions.

Inventory

The acquisition of basic inventory data is fundamental to timber management as well as efforts to conserve certain forest ecosystems. Data include soil type, species type, size, class/stand structure, crown closure, density, and the boundaries of management units (e.g., stands). Once data are entered in a GIS, maps can be displayed showing general species distributions.

Monitoring

While an initial inventory of forest resources stored in a GIS is an important step, changes occur that need to be monitored and recorded. For example, silvicultural activities to manage timber involve complex and specific interventions to control stand structure, stand density, species composition, length of harvest rotation, and maintain site quality. Other changes may result from sudden, discrete events or disturbances, such as massive deforestation or pestilence that initiate new development patterns in the affected areas.

Suitability and Productivity Assessment

Another factor in resource assessment includes efforts to identify biophysical and climatic factors suitable for the regeneration of tree species. This can be important for establishing tree plantations, afforestation programs, re-establishing endemic species following severe over-utilization and timber harvesting. The information obtained from assessing the potential productivity of a site can be used to manage it for optimal harvest.

Timber Harvesting

GIS has now made it possible to incorporate spatial components into harvest planning and simulation models. In some cases, the modelling capabilities of a particular GIS may be used directly to aid decisions about timber harvesting; in other cases, an external model is linked to a GIS database. These models are typically called Decision Support Systems (DSS) or Spatial Decision Support Systems (SDSS).

Fuel Wood Supplies

The availability of fuelwood supplies for local use is an important forest management issue in many parts of the world. GIS can contribute to assessments of fuelwood supply and demand and offers the potential to predict future needs.

As part of the land resource mapping project in Nepal, fuelwood sufficiency for the 75 districts in the country was evaluated and mapped using GIS. This was part of a larger resource Application of GIS in Forestry. Fuelwood production was estimated using yield data for each forest type included in the inventory: shrub, grassland, and four forest maturity classes. To calculate fuelwood supplies, the yields were multiplied by area data for each land use category. To calculate fuelwood demand, estimates for each district were supplied by the domestic energy model of the Water and Energy Secretariat. Surplus and deficit figures were calculated and each district was assigned a surplus, sufficiency, or deficit rating. The fuelwood assessment was also combined with the fodder and food assessments to create an overall evaluation of resource poverty.

Fire Management

The effect of fire on forest resources is another important management concern. Management activities include fire prevention, wildlife control, prescribed burning, and post-fire recovery actions. The modelling capabilities of GIS have been quite effective in this context. Forest fire managers have used GIS for fuel mapping, weather condition mapping, and fire danger rating (Holder et al. 1990). Several examples illustrate a range of fire applications.

Conclusion

The range of applications reviewed in this paper is a clear testament to the significant value of forests and the potential of GIS to aid in their management. Despite the diversity of applications, however, several broad conclusions can be reached about the role of GIS in forestry:

1. GIS applications can strongly benefit from remote sensing and image processing technologies. Forests are complex assemblages of species that lend themselves well to broad level inventory through remote sensing. However, the need for strong ground truth remains paramount and satellite positioning systems (such as GPS) will likely play an important role in augmenting traditional forest survey activities.

2. Simulation modelling has been applied in forestry to a degree that is substantially higher than in many other disciplines. Simulation of process modelling is one of the more challenging areas of GIS applications and it is likely that this activity will increase as the research and tools to support this kind of application become more prevalent.

Satellite image processing and analyzing

The processing and analysis of satellite imagery can be summarized by the following procedure:
i.Geo-referencing Spatial Data Geo-referencing is the conversion of spatial information from an existing format (collected data and tested samples) into a digital format and data structure compatible with a GIS. Geo-referenced data to be encoded include hard copy paper maps and tables of attributes electron files of maps and associated attribute data, scanned aerial photographs and digital satellite remotely sensed data (form GPS device). The traditional digitizing of points is based on the use of Cartesian coordinates such as UTM coordinates.
ii. Analyzing Spatial Data -The satellite image for AL-Daura site is analyzed by using software (EARDAS 10) to get the reflectance of geo-referenced data (soil samples locations) depending on the results of radiometer measurements for soil samples in the field. Data not in image form are difficult to reduce or associate with specific ground elements unless simultaneous bore-sighted photography is available.

iii. Classification Process -Multispectral classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, the pixel will be assigned to the class that corresponds to that criterion. This process is also referred to as image segmentation. Depending on the type of information, extracted from the original data, classes can be associated with known features on the ground or can simply represent areas that look different to the computer.

The classification process breaks down into two parts: supervised and unsupervised. In supervised classification, the analyst designates a set of “training areas” in the image, each of which is a known surface material that represents a desired spectral class. The classification algorithm computes, the average spectral pattern for each training class, and then assigns the remaining image cells to the most similar class. In unsupervised classification, the algorithm derives its own set of spectral classes from an arbitrary sample of the image cells before making the class assignments.

iv. Organization Spatial Data -The organization of spatial data components includes those functions needed to store and retrieve data from the database. The methods used to implement these functions determine how efficiently the system performs all operations on the data; each variable is archived in a computer-compatible digital format as a geographically referenced plane (often called a GIS layer). Each layer contains features with similar attributes, like a type of pollutant and concentration of pollutant that are located in the same geographic extent.

2.1.6 Climate Change Analysis and Adaptation: Role of Remote Sensing and Geographical Information System

Role of Remote Sensing and Geographical Information System

Ice/Glacier Monitoring

Satellite images of the ice sheets can track their growth and recession over the years. Use of RS and GIS in glacier monitoring and provision of global glacier inventory by Global Land Ice Measurements from Space (GLIMS). RS and GIS tools are potentially useful for monitoring glaciers, particularly in the advancement and recession mapping, measurement of mass balance, glacier inventory, glacier hazard monitoring, snow depth measurement, among others. As glaciers partially regulate atmospheric properties, sea level variations, surface and regional hydrology and topographic evolution (Bishop et al., 2004), information about them is very crucial for adaptation, and this can best be ensured by using RS and GIS.

A study stated that GLIMS’ glaciers monitoring involves the creation of a global glacier database of images such as ASTER, Landsat, Synthetic Aperture Radar (SAR), air photos, maps and derived data, and the analyses producing information are performed using a variety of methods including both automatic algorithms and manual interpretation in a distributed environment. Bishop et al. (2004) had earlier reported the applicability and potential of RS/GIS in glacier monitoring by GLIMS. Field and satellite investigations were reported to have indicated many small glaciers and glaciers in temperate regions down-wasting and retreating. They concluded that RS/GIS and field investigations are vital for producing baseline information on glacier changes and improving our understanding of the complex linkages between atmospheric, lithospheric, and glaciological processes.

Vegetation Change Monitoring

RS is one of the widely used approaches for providing scientific evidence of vegetation change (Omuto, 2010). For example, Chen and Rao (2008) monitored vegetation using multi-temporal Landsat TM/ETM data in an ecotone between grassland and cropland in northeast China between 1988 and 2001. Classification and change detection carried out showed accelerated land degradation of the grassland around the salt-affected soil near the water bodies due to variation in water sizes as a result of both climate change and anthropogenic activities.

Omuto (2010) while tracing the footprint of vegetation dynamics modelled a relationship between Advanced Very High-Resolution Radiometer (AVHRR) / Moderate Imaging Spectroradiometer (MODIS) NDVI and rainfall using regression analysis. Results showed a high correlation between rainfall and NDVI which proved that vegetation trend monitoring with RS and GIS can give an accurate indication of climate change. Li et al. (2008) assessed land-use/landcover change patterns in the Lake Qinghai watershed between 1977 and 2004 by combining Landsat MSS, TM and ETM data. Shrinkage in lake level and grassland degradation were discovered in the study area, with the first being attributed to climate change and the latter to anthropogenic disturbance.

Carbon Trace/Accounting

Studies have demonstrated the efficacy of RS and GIS in carbon accounting. Using a combination of field measurements, airborne Light Detection and Ranging (LiDAR) and satellite data.

Atmospheric Dynamics

Hecker and Gieske (2004) listed a range of applications of satellite data in the monitoring of atmospheric dynamics. RS can be used for the determination of the atmospheric radiances, emissivity and surface temperature. Burrows et al. (1998) measured the absorption cross-sections of NO2 using the global ozone monitoring experiment (GOME) flight model (FM)

Terrestrial Temperature Monitoring

Evapotranspiration (ET) is an important part of the planet's hydrological cycle, and it is likely to change in a warming world as it is highly increased by high temperatures (Michon, 2008b). Accurate ET estimation enables improvements in weather and climate forecasts, flood and drought forecasts, predictions of agricultural productivity, and assessment of climate change impacts (Sun et al., 2012). Hecker and Gieske (2004) posited that satellite data can be used for the determination of surface emissivity and temperature, rock emissivity mapping and thermal hotspot detection such as forest fires or underground coal fires, or volcanic activity. Bradley et al. (2002) modelled spatial and temporal road thermal climatology in rural and urban areas of west midlands UK using satellite land cover classification, field analysis of urban canyon characteristics, physical variables of albedo, emissivity and surface roughness within a GIS environment.

Erosion Monitoring and Control

Soil becomes a carbon source as the rate of organic matter decomposition increases through erosion (Bridges and Oldeman, 1999). Water erosion is the most significant type of soil degradation in all continents, except in western Asia and Africa where water and wind erosion are almost of equal significance (Sentis, 1997; Bridges and Oldeman, 1999). Santillan et al. (2010) integrated RS, GIS and hydrologic models to predict land cover change impacts on surface runoff and sediment yield in a watershed of the inilippines. The method quantifiably predicted the potential hydrologic implications useful for planners and decision makers as a tool for evaluating proposed land cover rehabilitation strategies in minimizing runoff and sediment yield during rainfall events in the ecosystem.

Ocean and Coastal Monitoring

Climate variability modifies both oceanic and terrestrial surface CO2 flux with resultant strong impacts on the land surface temperature and soil moisture (Okajima and Kawamiya, 2011). Sea surface temperature (SST), El Nino, sea level, biomass, precipitation, surface wind and sea surface height relative to the ocean geoid are important features that determine global weather conditions (Janssen, 2004; Issar and Zohar, 2007). These can be captured very easily by satellites in space (Janssen, 2004). Several studies have demonstrated the applicability of RS and GIS in this regard. For example, Kavak and Karadogan (2011) investigated the relationship between phytoplankton chlorophyll and sea surface temperature of the Black Sea, using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. The study discovered a high correlation between sea surface temperature and chlorophyll at the same time, and it concluded that the information could be useful in connection with studies of global changes in temperature and what effect they could have on the total abundance of marine life.

Biodiversity Conservation

Palminteri et al. (2012) used airborne waveform light detection and ranging (LiDAR) data in combination with detailed field data on a population of bald-faced Saki monkeys (Pitheciairrorata) to assess the canopy structure in describing parameters of preferred forest types in the south eastern Peruvian Amazon. Results provide novel insights into the relationship between vegetation structure and habitat use by a tropical arboreal vertebrate, highlighting the capability of RS in predicting habitat occupancy and selection by forest canopy species.

Remote sensing tools to predict bird richness in the city of Jerusalem. Bird richness was sampled in 40 1-ha sites over a range of urban environments in 329 surveys. NDVI and the percentage cover of the built-up area were strongly negatively correlated with each other and were both very successful in explaining the number of bird species in the study sites. It was suggested that remote sensing approaches may provide planners and conservation biologists with an efficient and cost-effective method to study and estimate biodiversity across urban environments that range between densely built-up areas, residential neighbourhoods, urban parks and the peri-urban environment.

Drought and Desertification

Advancements in RS technology and the GIS help in real-time monitoring, early warning and quick damage assessment of both drought and flood disasters (Jeyaseelan, 2003). Laughlin and Clark (2000) submitted that data from NOAA Advanced Very High-Resolution Radiometer (AVHRR), Landsat, SPOT and Radar Sat are used operationally in the assessment of drought, frost impact on crop production and flooding in Australia. Kogan (2000) tested the new numerical method of drought detection and impact assessment from NOAA operational environmental satellites and validated the outcome against conventional data in 25 countries, including all major agricultural producers. The study discovered that drought can be detected 4-6 weeks earlier than before and delineated more accurately, and its impact on grain production can be diagnosed far in advance of harvest, which is the most vital need for global food security and trade.

Flood Monitoring

Sanyal and Lu (2004) submitted that the conventional means of recording hydrological parameters of a flood often fail to record an extreme event, thus RS and GIS become the key tool for delineation of flood zones and preparation of flood hazard maps for vulnerable areas. Islam and Sado (2000) developed flood hazard maps for Bangladesh using RS data for the historical event of the 1988 flood with data on elevation height and geological and physiographic divisions. Abas et al. (2009) successfully demonstrated the potential of using GIS for flood disaster Management find Allahabad Sadar Sub-District (India). The flood-prone areas were identified and various thematic maps including a road network map, drinking water sources map, land use map, population density map, ward boundaries and location of slums were generated and stored for management and decision making.

Agriculture

Many studies have used remote sensing and geographical information system (GIS) based modelling to predict the distribution of forest species and shifts as effects of climate change. Such groups of species might not shift rather changes will occur only. In some selected species, which will complete with associates and form communities later.

Climate change, being a spatial-temporal phenomenon, has a direct linkage with agricultural patterns and processes. Knowing and mapping the altered distribution of precipitation and temperature could gather place-specific and tailor made responses from agriculture. Such attributes along with biophysical parameters are easier to collect using remote sensing data and model GIS.

These data sets become handier to the decision- or policy-makers to devise alternatives for the area. Combination of computable general equilibrium (CGE) model with a GIS model to analyse the impact of climate change impacts on agriculture.

Conclusion

GIS/ RS can play an important role in the audit of different fields that Land and land cover analysis, forest fires, soil erosion, emissions to air, mining, water related issues.

Different methods are used while observing the satellite images that help to obtain a clear picture of the current and past scenarios of the samples collected.

Land and land cover analysis can be easily done by comparing raster images of the different periods and a correlation curve as well as a variance curve over a period, which easily helps to get vegetation cover over any sample taken as an area of interest.

NDVI images help a lot for getting vegetation covers over an area as well as Index stack images from Land Sat help to figure out changes in the land pattern as well as any growth in the sample whether it is related to vegetation growth or any human construction over a period. Land Sat images also help in monitoring forest fires, changes ~~that occur~~ due to human interference, soil erosion over a period, changes in the land pattern due to mining etc.

Water related issues can also be figured out using GIS data which can help in identifying the stretch of water bodies, changes over a period in these water bodies, number of algae and chlorophyll amount in the water sample, Remote sensing devices can also be used to measure the transparency and depth of the water bodies etc.

GIS/RS can be used as a modern tool for better audit and planning which will be more efficient and effective as well as accurate proofs can be given with errors. Best suggestions can be given after a better study of the samples through GIS and RS as the results and outputs are non-biased and give correct results.

GIS/RS plays an important role in environmental auditing, auditing of the following fields can be covered easily with the use of GIS/RS –

• Waste management

• Emission to air

• Ground and groundwater protection

• Surface water management

• Environment emergencies

• Protection of environmentally sensitive areas.

• Local issues related to environment.

• Land use and Land cover analysis.

• Forest fires.

• Soil Erosion and Mining

2.1.7 Changing of land and land cover analysis over iCED campus during the period 2009-18 (A Case Study at Page 72)

2.1.7.1 Introduction Land and Land Cover Analysis

The Indian experience in use of satellite data for LULC analysis is mentioned in the Manual on National land Use Mapping at 1:250000 scale using IRS-P6 AWiFS data (NRSA, 2004). The work was carried out by National Remote Sensing Centre (erstwhile NRSA). Department of Space, Government of India, in collaboration with various central and state government organisations. Realizing the need for up-to-date nationwide LULC maps by several departments in the country, as a prelude, a LULC classification system with 24 categories up to Level- II, suitable for mapping on a 1:250,000 scale, was developed by NRSC by taking into consideration the existing land use classification adopted by NATMO, CAZRI, Ministry of Agriculture, Revenue Department, AIS & LUS, etc., and the details obtainable from satellite imagery. After discussions with nearly 40 user, departments/institutions in the country a 22-fold classification system was finalized and adopted for Nationwide LULC Analysis.

Land Use Land Cover Change

Changes in land use and land cover impact both environmental quality and the quality of life, two aspects that impact human wellbeing. Changes in habitat, water and air quality and the quality of life are some of the environmental, social and economic concerns associated with land use and land cover changes.

Habitat: Land use by humans leads to changes in land cover that can negatively impact biodiversity. Conversion of natural wood- and grass-lands to more developed uses decreases the amount of habitat available. The pattern of human land use also tends to result in a patchy landscape and fragmenting habitats.

Some species of plants and animals do better in patchy, fragmented environments, while others need large, uninterrupted areas.

Water Quality: Changes in land use can affect the volume, timing and quality of runoff water. More developed land uses have higher proportion of impervious surface (areas where water cannot soak into the ground, such as roadways, parking lots, and building roofs). As the number of impervious surface increases, rainstorm runoff increases in volume, increasing the risk of flooding and increasing the number of pollutants carried into streams and lakes. Human use of land also disturbs natural land cover, increasing the potential for soil erosion into streams and lakes.

Quality of Life (aesthetics, recreation, congestion): Land use and land cover changes can affect the quality of life when those changes impact landscapes that have aesthetic value (scenic views), or when the quality and quantity of the landscapes are reduced in areas that are attractive for recreational activities. Also, changes in Land Use and Land Cover can affect traffic patterns that can have positive or negative effects on congestion.

Air Quality: The pattern of land use in a region can affect its air quality. If residential areas are located far from shopping and work centres, automobile use and emissions will be higher. If forests or other natural areas that purify air are developed, local air quality can worsen. Changes in vegetative cover can also lead to local changes in climate.

Global Carbon Cycles: More-natural landscapes can capture and store carbon in the soil, decreasing the amount of carbon dioxide in the atmosphere. If vegetation is cut and/or the soil is disturbed, stored soil carbon can be released back into the atmosphere. Several studies have examined the social and economic factors that drive Land Use and Land Cover change. These include:

Population Growth or Decline: As a region's population grows, the new residents need housing, as well as places to work and shop. In a region with a declining population, there will be less new construction of homes and businesses.

Economic Growth: A booming regional economy will result in the construction of new commercial and industrial buildings to house that activity. As the economy grows, the new jobs created will attract workers, leading to population growth, leading to construction of new homes and places to shop. As incomes rise, households may choose to build new larger homes on larger lots, leaving smaller, older houses vacant.

Demographics: The average number of people living in a household has been decreasing over time. Therefore, more housing units are needed to house the same number of people. The number of retired households is increasing, and these households tend to have few members.

Agricultural and forest products: A change in the price of agricultural or forest products can affect landowners' decisions on whether to keep the land for those uses. Policies aimed at supporting agricultural prices provide an incentive to keep landform farming.

Regional and local planning and policies: Regions can influence the rate at which land use and land cover change through a variety of means.

Land Use & Land Cover Change Detection with Remote Sensing data

An increasingly common application of remotely sensed data is for change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Change detection is useful in such diverse applications as land use change analysis, monitoring shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes (Singh, 1989). Macleod and Congalton (1998) list four aspects of change detection which are important when monitoring natural resources:

- Detecting that changes have occurred
- Identifying the nature of the change
- Measuring the areal extent of the change
- Assessing the spatial pattern of the change

The basic premise of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computing power. A wide variety of digital change detection techniques have been developed over the last two decades. Eleven different change detection These include:

- Mono temporal change delineation
- Delta or post-classification comparison
- Multidimensional temporal feature space analysis
- Composite analysis
- Image differencing

- Image rationing
- Multi temporal linear data transformation
- change vector analysis
- Image regression
- Multi temporal biomass index

Different Images of ICED campus, comparing different images as well as ResouceSat data for datasheets of ICED.

Image of 2013

Image of July 2018

ResourceSat-1 LISS-III

ResourceSat-1 LISS-3 Sensor

The LISS-III camera is identical to the LISS-IIIflown in IRS-1C/1D spacecraft except that thespatial resolution of SWIR band (B5) is also 23.5 m(same as that of B2, B3, B4).

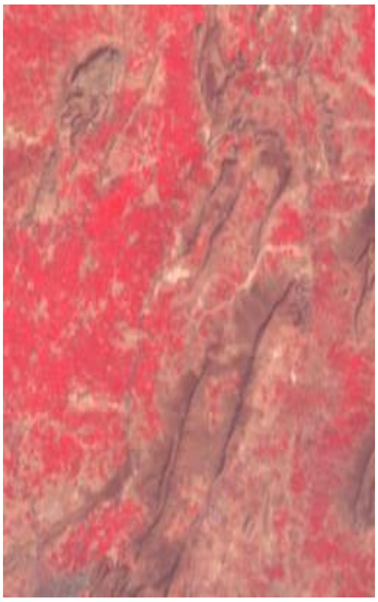
LISS-III covers a swathof 141 Km in all the 4 bands.The LISS-III is a multi-spectral camera operating infour spectral bands, three in the visible and near infraredand one in the SWIR region, as in the case ofIRS-1C/1D.

The new feature in IRS-P6 LISS-IIIcamera is the SWIR band (1.55 to 1.7 microns),which provides data with a spatial resolution of 23.5m unlike in IRS-1C/1D (where the spatial resolutionis 70.5 m).

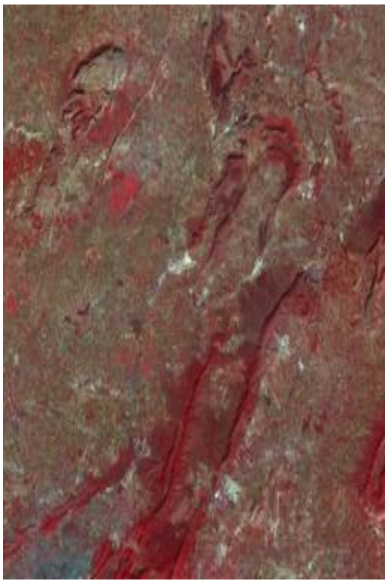
The LISS-III Camera operates in fourspectral bands in the VNIR and SWIR range. Eachband consists of a separate lens assembly and a lineararray CCD. Each lens assembly is realised with 8refractive lens elements (a combination of convex andconcave lenses), an interference filter and a neutraldensity filter.

The VNIR bands (B2, B3, B4) use6,000 element CCDs each with pixel size of 10microns x 7 microns. The SWIR band (B5) uses a6,000 element Indium Gallium Arsenide CCD withpixel size of 13 micron x 13 micron. This SWIR CCDis a new device employing CMOS readout techniquefor each pixel, thereby improving noise performance.The major specifications of LISS-III camera are givenin Table

IGFOV	23.5 m
Spectral Bands	B2 0.52 - 0.59(Microns) B3 0.62 - 0.68 B4 0.77 - 0.86 B5 1.55 - 1.70
Swath	141 Km
Average Saturation	B2 27.8 radiance B3 28.4 (mw/cm2/sr/micron) B4 32.0 B5 7.64
Integration time	3.32 msec
Quantization	7 bits SWIR band has 10 bit quantisation, selected 7 bits out of 10 bits will be transmitted by the data handling system
No. of gains	4 (for visible and NIR bands)



Dated 13 Jan. 2013 *Dated 07 March 2011* *Dated 02 Dec. 2011*



Dated- 15 Dec, 2013 Dated- 23 Oct, 2014 Dated- 28 Oct, 2015 Resourcesat-1 AWiFS

ResourceSat-1 AWiFS Sensor

The AWiFS camera provides enhanced capabilities compared to the WiFS camera on-board IRS-1C/1D, in terms of spatial resolution (56 m Vs 188m), radiometric resolution (10 bits Vs 7 bits) and Spectral bands (4 Vs 2) with the additional feature of on-board detector calibration using LEDs. The spectral bands of AWiFS are same as LISS-III.

The AWiFS camera is realized in two electro-optic modules viz.,. AWiFS-A and AWiFS-B, each containing four band assemblies. A combined swath of 740 Km is realized by mounting the two modules on the Deck, with their optical axes tilted by 11.94 deg away from the + yaw axis in opposite direction. With this mounting, a side lap of 128 pixels i.e., about 7.2kKm, is available in the combined swath.

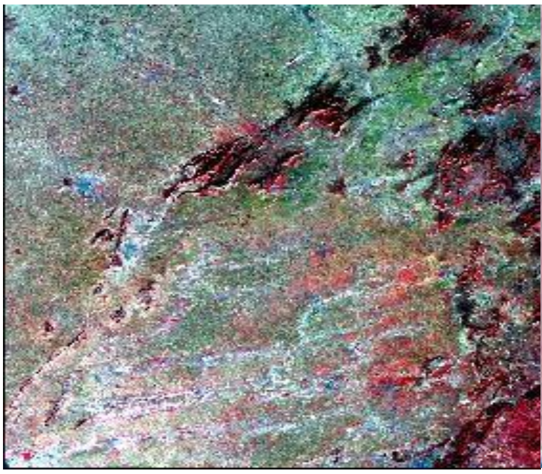
Major specifications of AWiFS sensor.

IGFOV	56 m (nadir) 70 m (at field edge)
Spectral Bands	B2, B3, B4 and B5
Swath	740 km (combined) 370 km each head
Saturation radiance (mw/cm 2 /sr/micron)	B2 - 53 B3 - 47 B4 - 31.5 B5 - 4.64
Integration time	9.96 msec
Quantization	10 bits
No. of gains	16

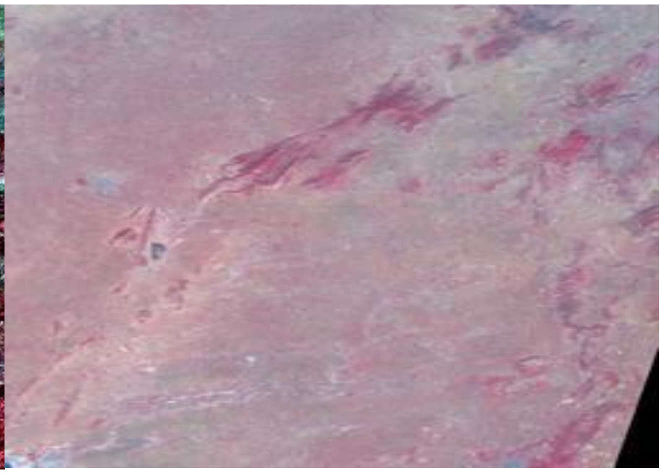
AWiFS camera is as flown in Resourcesat-1.AWiFS operates in four spectral bands identical to LISS-III, providing a spatial resolution of 56 m .The AWiFS camera is split into two electro-optical modules viz, AWiFS-A and AWiFS-B which provides a combined swath of 740 Km. The AWiFS camera provides 12 bit radiometery through Multi Linear Gain(MLG) technique. Data is transmitted in 10bits and restored to 12 bits on ground, through decoding algorithms. The onboard calibration scheme is through LED as in Resourcesat-1.

Major specifications of AWiFS sensor.

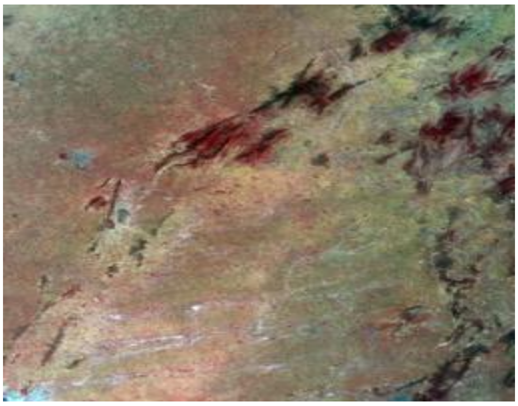
IGFOV	56 m (nadir) 70 m (at field edge)
Spectral Bands	B2, B3, B4 and B5
Swath	740 km (combined) 370 km each head
Saturation radiance (mw/cm 2 /sr/micron)	B2 - 53 B3 - 47 B4 - 31.5 B5 – 7.5
Integration time	9.96 msec
Quantization	12 bits
No. of gains	08



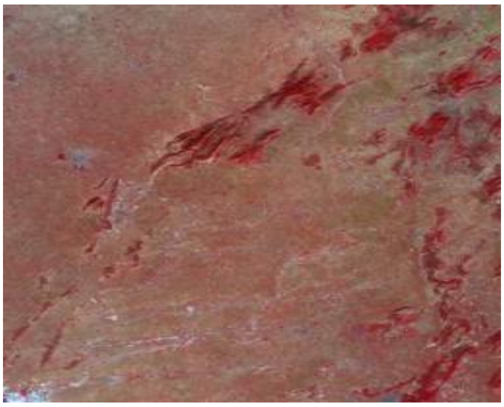
21 Nov 2013



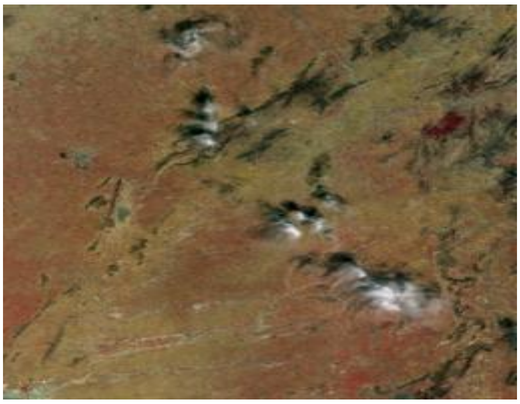
21 oct 2014



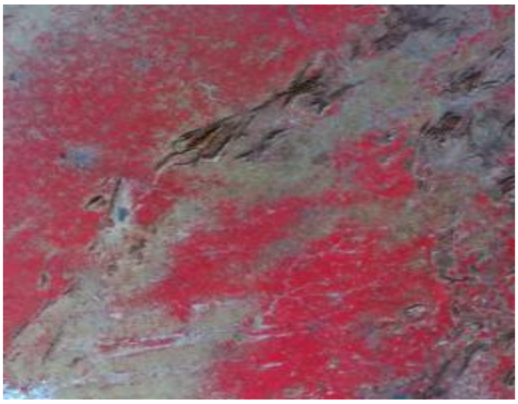
18 April 2015



27 Jan 2016



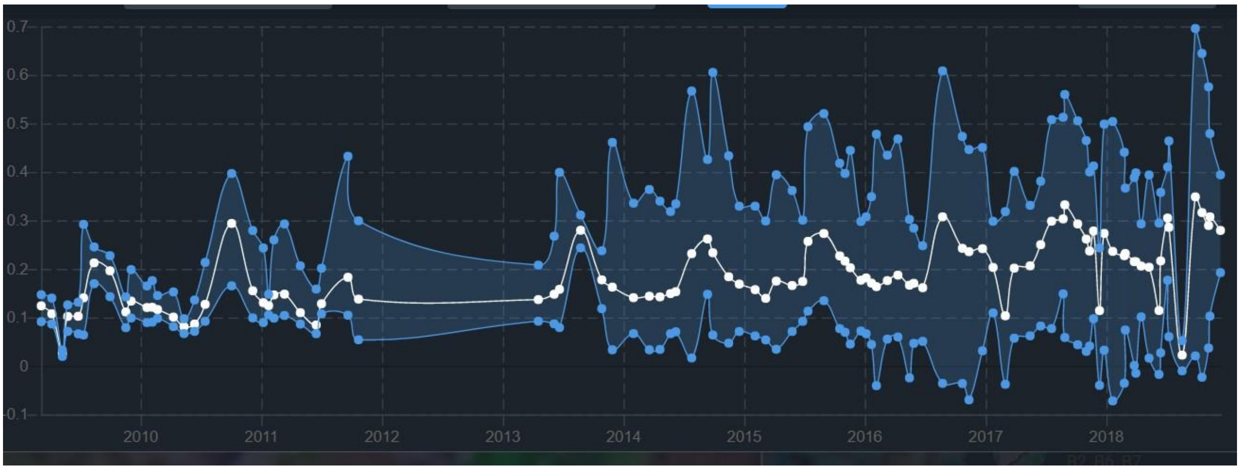
08 April 2016



21 Oct. 2016

2.1.7.2 Summary

The pattern and spatial changes over the iCED campus were observed by comparing different combination of bands and images processed on different dates. Data from Landsat- 8 and Senital- 2 satellites were used to figure out different changes in Land cover over iCED Campus.

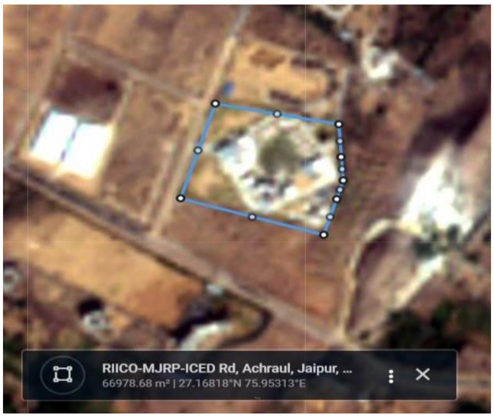


More frequent dates were also available for comparison, but to facilitate the study, more time was taken to readily understand the sample collected. The study found that over time, vegetation density on the iCED campus has greatly improved from barren land. In NDVI images it can be seen that it was barren land and no vegetation found in the sample area but over the time it changed and in the year 2018 we can observe the green bands in NDVI images which is a significant improvement. Statistical data is also attached at the end which shows linear variance in the NDVI from the year 2014 onwards. Vegetation in the sample area has positively improved from 2013 onwards and a linear pattern has been formed. The Below graphs show the changes in NDVI of the ICED campus from the Year 2009 onwards which starts improving from the year 2013, after the establishment of the iCED campus, and gradually improved after 2018 and shows a significant improvement after 2015 in vegetation growth. Points on the graph in white color are the dates of passing satellite over the sample that shows the level of NDVI over that period.

Natural Color (Sample as the iCED campus in below images with selected Area of Interest)

The "natural color" band combination. As the visible bands are used in this combination, ground features appear in colors similar to their appearance in the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are gray, and shorelines are white. This band combination provides the most water penetration, superior sediment and bathymetric information.

26 Nov 2018



6 Jan 2016

26 Mar 2014

18 Apr 2013

Natural colour band combination here shows gradual improvement over the campus. Green colour depicts the vegetation.

Color Infra-Red (Vegetation):

The standard "false color" composite. Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light brown. Ice, snow and clouds are white or light cyan. Coniferous trees will appear darker red than hardwoods. This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth. Generally, deep red hues indicate broadleaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas. Densely populated urban areas are shown in light blue.

26 Nov. 2018

6 Jan 2016

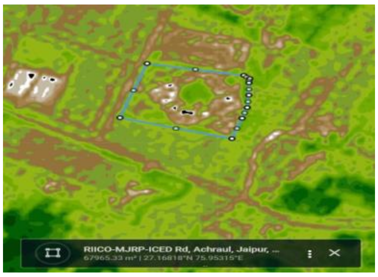
26 Mar 2014

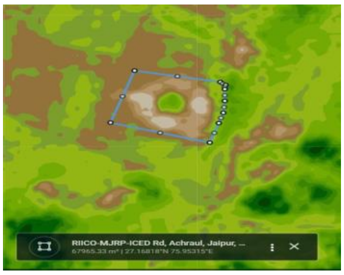
18 Apr 2013

With changing time red colors starts appearing after the year 2014 and good shades of red color can be seen around the campus in the year 2018. Vegetation is shown in red color, which is improving over the sample area.

NDVI (Normalized Differential Vegetation Index)

The Normalized Differential Vegetation Index is often used to monitor drought, monitor and predict agricultural production, assist in predicting hazardous fire zones and map desert encroachment. The NDVI is a standardized vegetation index which allows us to generate an image showing the relative biomass. The chlorophyll absorption in Red band and relatively high reflectance of vegetation in Near Infrared band (NIR) are used for calculating NDVI.





26 Nov 2018

6 Jan 2016

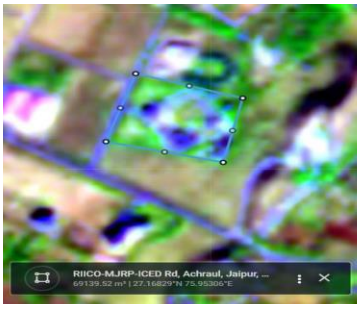
26 Mar 2014

18 Apr 2013

NDVI (Normalized Differential Vegetation Index) Images clearly show the changes in vegetation cover over the sample area. Brown depicts barren land, with changing time sample area improved a lot in vegetation from 2013 to 2018.

Agriculture:

This band combination is useful for monitoring crops. In the image, bright green represents vigorous, healthy vegetation while non-crops, such as mature trees, appear in a dull green. Coniferous forests appear as a dark, rich green while deciduous forests appear as a bright green. Sparsely vegetated and bare areas appear brown.



26 Nov 2018

6 Jan 2016

26 Mar 2014

18 Apr 2013

LAND/WATER (Red, SWIR1, Red):

This band combination is good for picking out the land from water. In this false color image, land appears in shades of orange and green, ice stands out as a vibrant magenta color and water appears in shades of blue.

26 Nov 2018

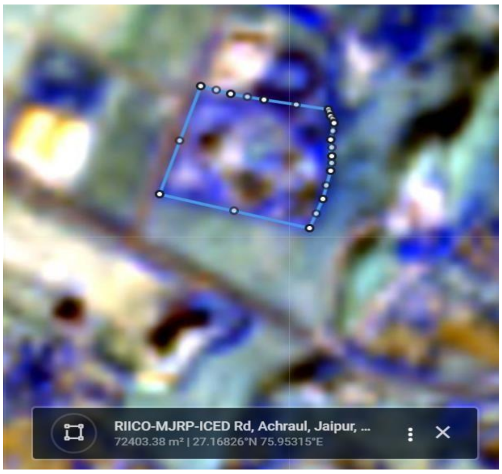
6 Jan 2016

26 Mar 2014

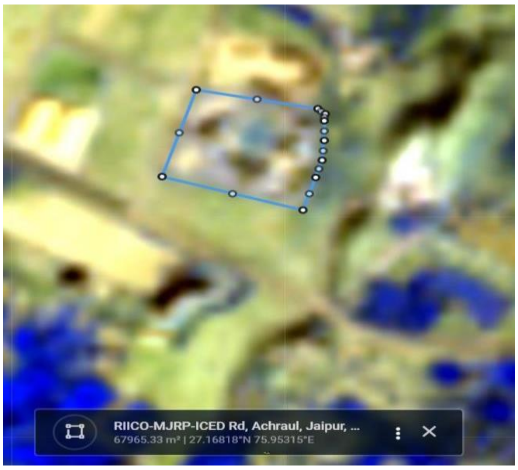
18 Apr 2013

Atmospheric Penetration

This combination involves no visible bands. It provides the best atmospheric penetration. Coastlines and shores are well defined. It may be used to find textural and moisture characteristics of soils. Vegetation appears blue. This band combination can be useful for geological studies.



26 Nov 2018



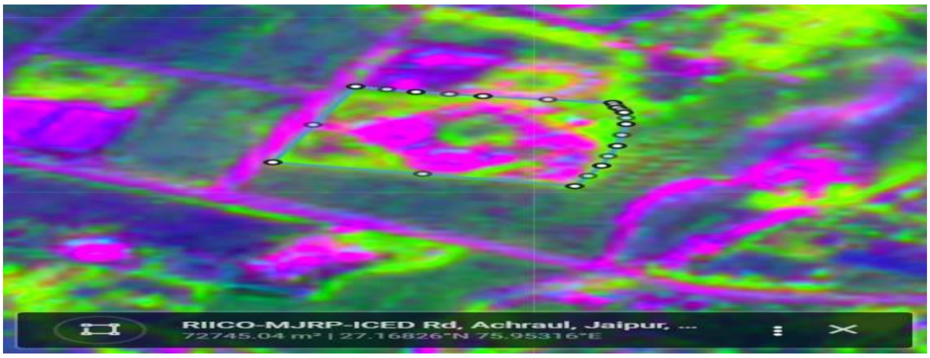
6 Jan 2016

26 Mar 2014

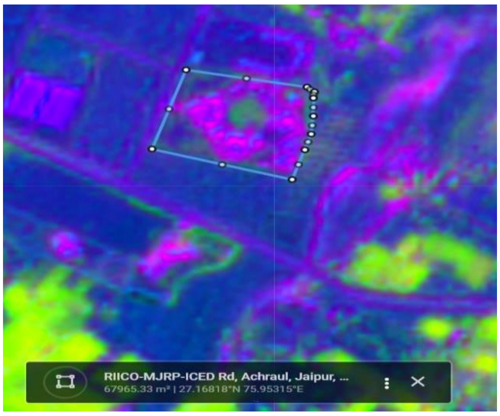
18 Apr 2013

Index Stack

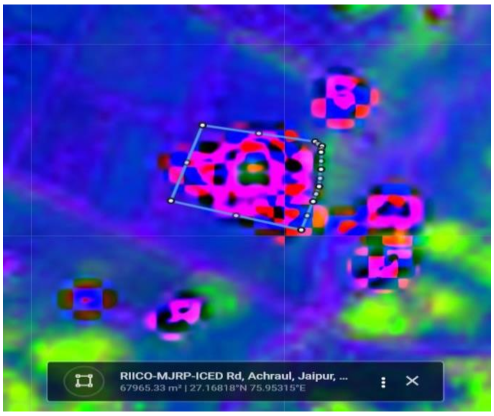
It becomes readily apparent in this image stack that particular colors can be equated to different landscape features. For example, vegetation is displayed here as green, water as purple, snow/ice as magenta, and soil, rocks, and barren land as blue. Clouds also appear as a mixture of purple and magenta, so in this case, these indices alone are not sufficient for differentiating clouds from water and snow/ice



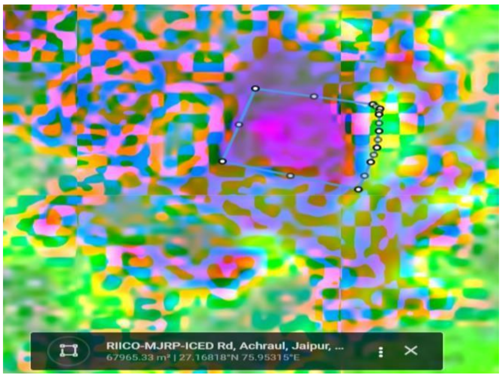
26 Nov 2018



6 Jan 2016



26 Mar 2014



18 Apr 2013

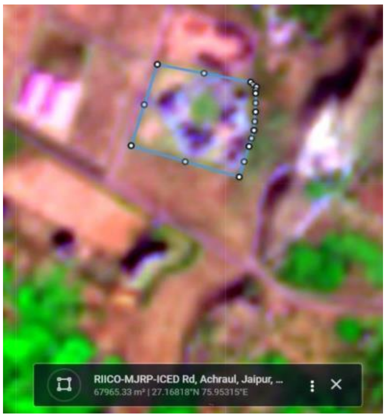
Vegetation displayed here as green which has improved after 2016 onwards and a good cover of vegetation pattern can be seen. Soil, rocks and barren land can be seen in blue.

Purple color can be seen over the campus due to water droplets over the surface.

Atmospheric Removal

This combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke. Healthy vegetation will be a bright green and can saturate in seasons of heavy growth, grasslands will appear green. Pink areas represent barren soil, and orange and brown color represent sparsely vegetated areas. Dry vegetation will be orange and water will be blue. Sand, soil and minerals are highlighted in a multitude of colors. This band combination provides striking imagery for desert regions. It is useful for geological, agricultural and wetland studies. If there were any fires in this image they would appear red. This combination is used in the fire management applications for the post-fire analysis of burned and non-burned forested areas. Urban areas appear in varying shades of magenta. Grasslands appear light green.

26 Nov 2018



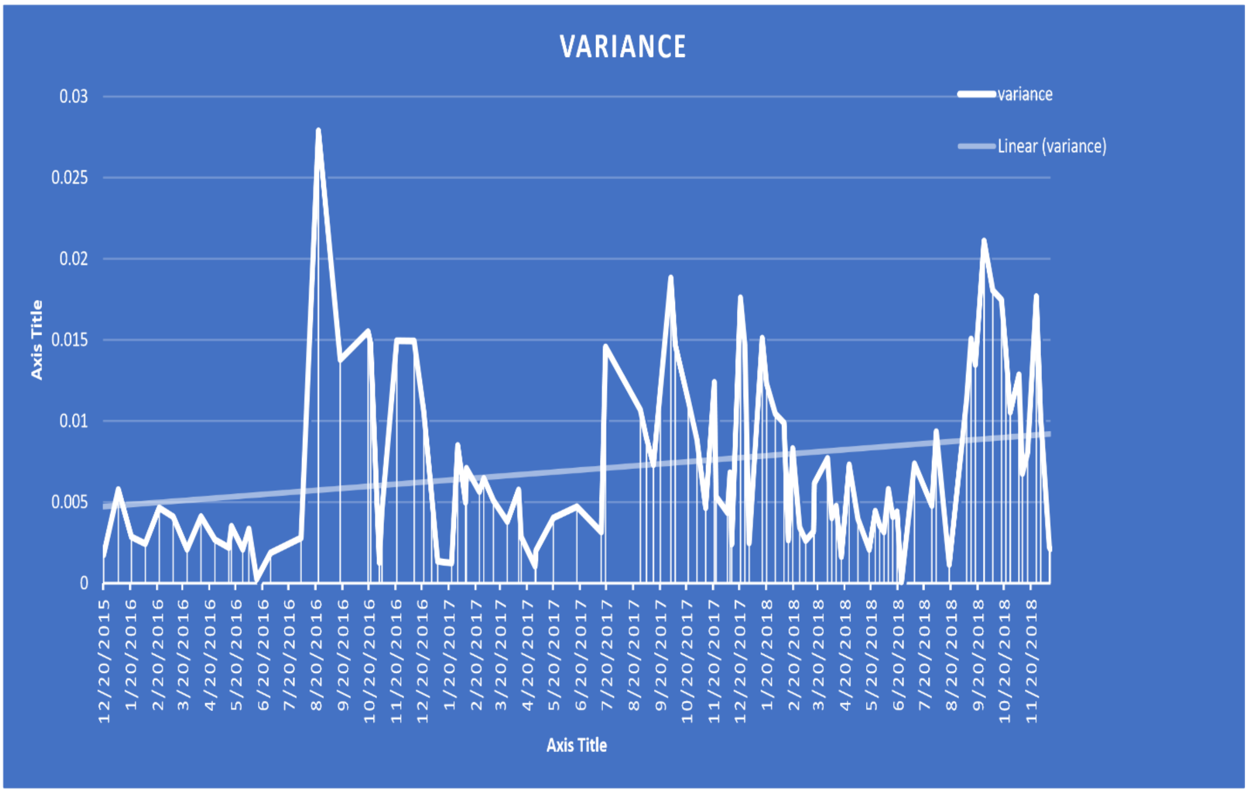
6 Jan 2016

26 Mar 2014

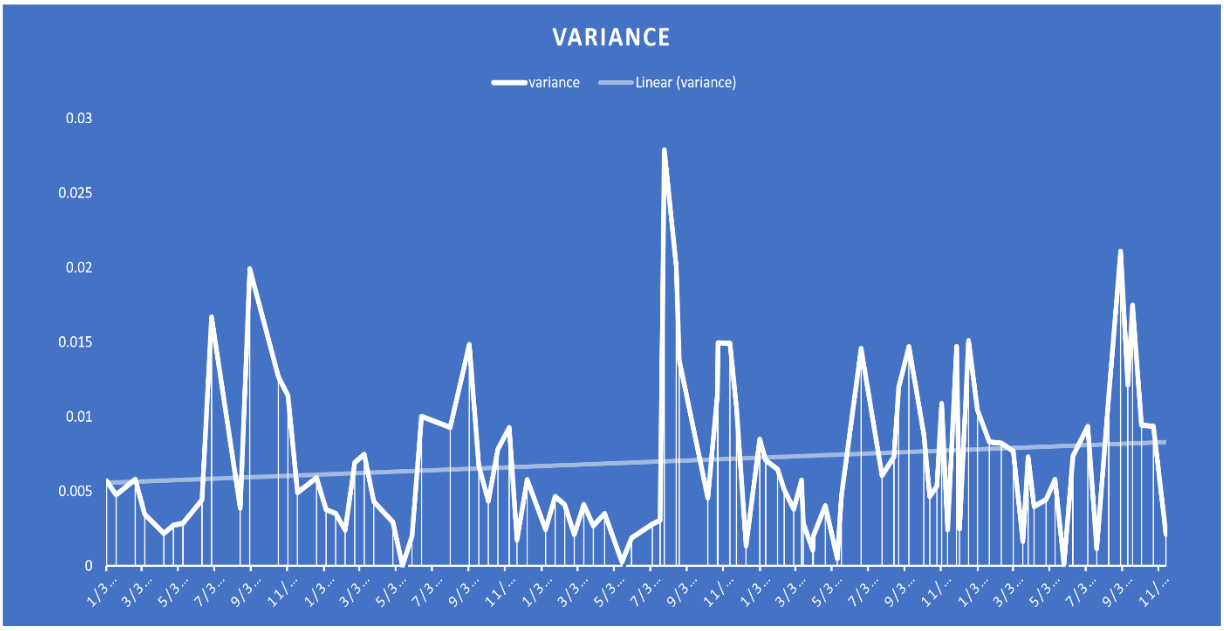
18 Apr 2013

NDVI Variance Graph (2015-18):

Below graph is showing the variance over the period from 2015 to 2018. The graph shows a linear curve growing upwards after 2015 onwards which shows the vegetation over the period is improved after 2015.

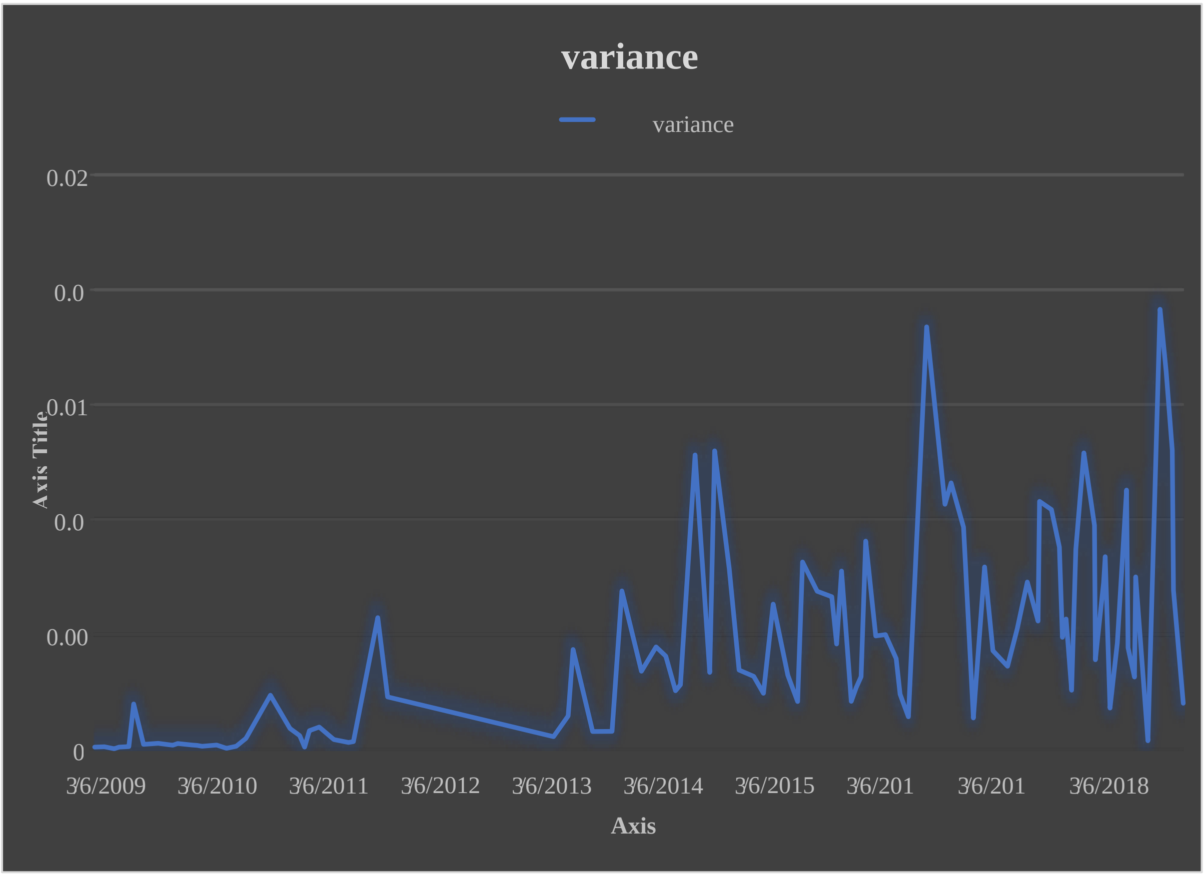


NDVI Variance Graph (2014-18):



NDVI Graph for variance (2009-18):

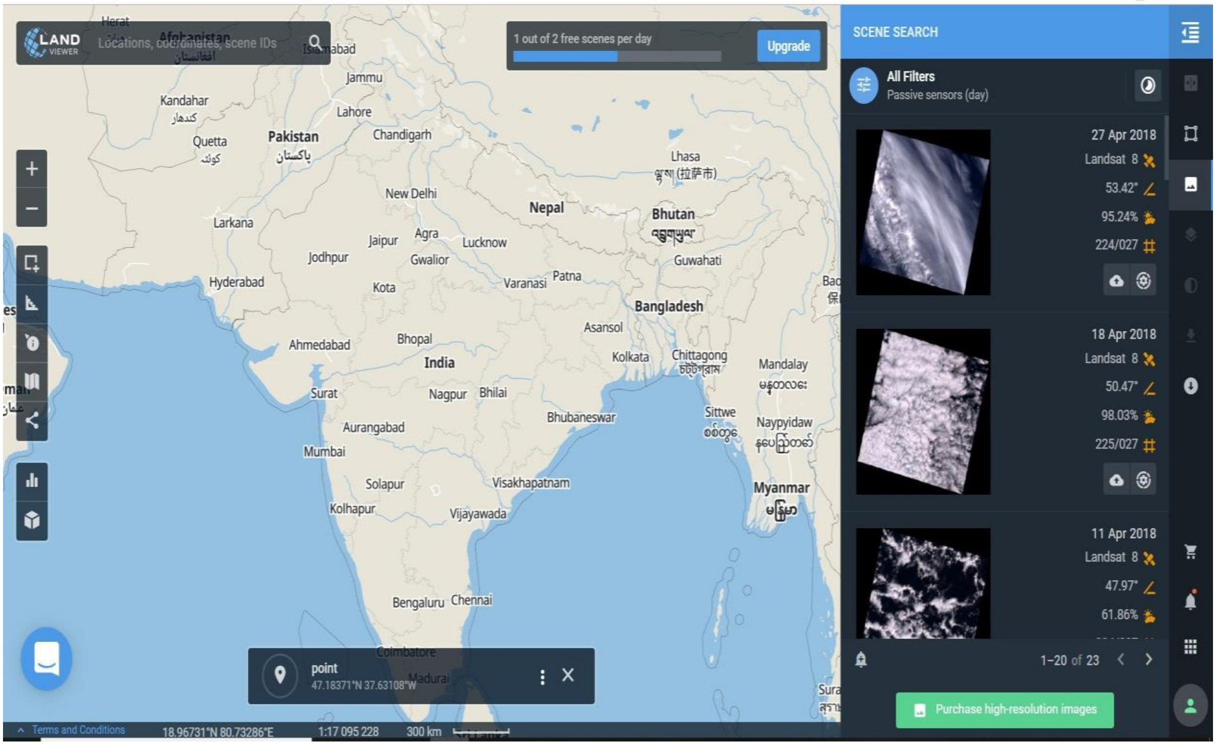
The graph shows the vegetation changes over 10 years over the iCED campus. It easily illustrates that the sample area (iCED campus) has improved a lot in vegetation cover from barren land in 2009 and became a green campus in 2018. From the graph, it can be seen that the campus attains maximum vegetation in 2017 and august 2018. The ups and downs in the graph show the changes in vegetation.



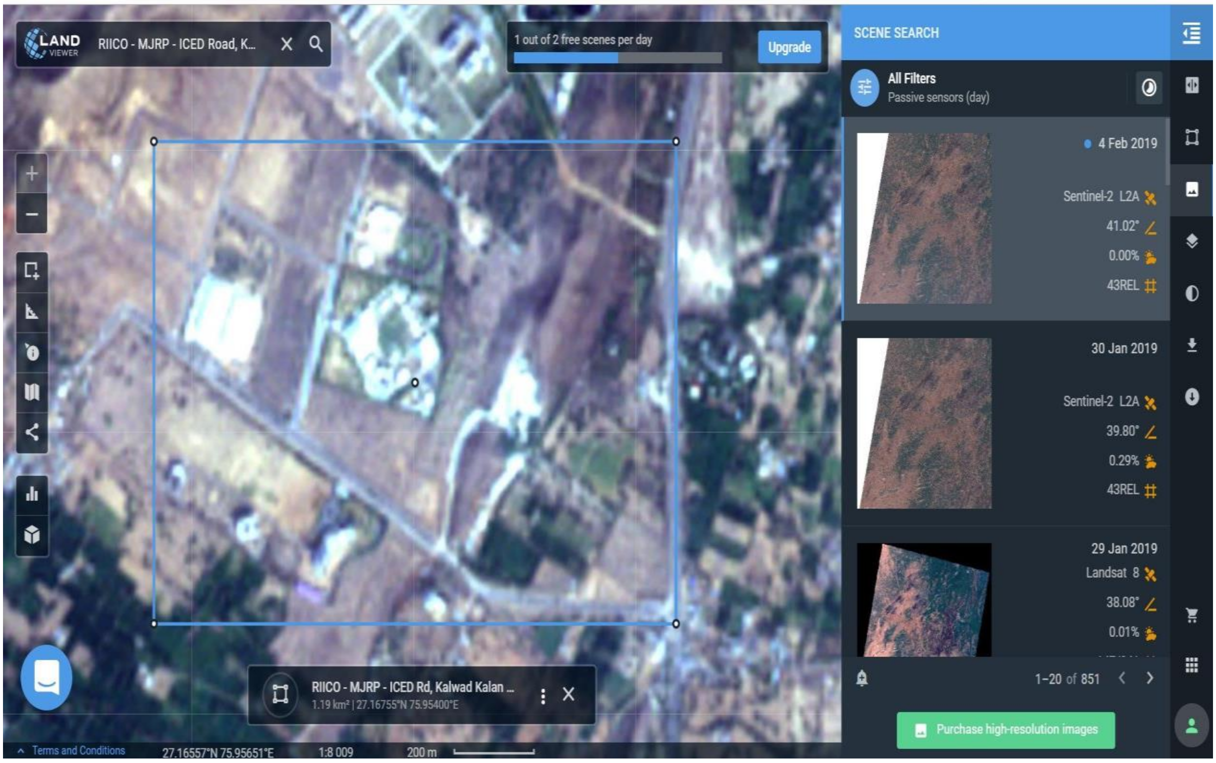
Tools Used

Arc GIS, Bhuvan, EOS Land Viewer, MS- Excel

Typical View of EOS LandViewer Platform.



2.1.7.3 Methods for Changing Observation on EOS Land Viewer (https://eos.com/landviewer/)



- Open https://eos.com/landviewer/ and search the preferred location to know the changes.

- Select the Area of interest to observe the changes.

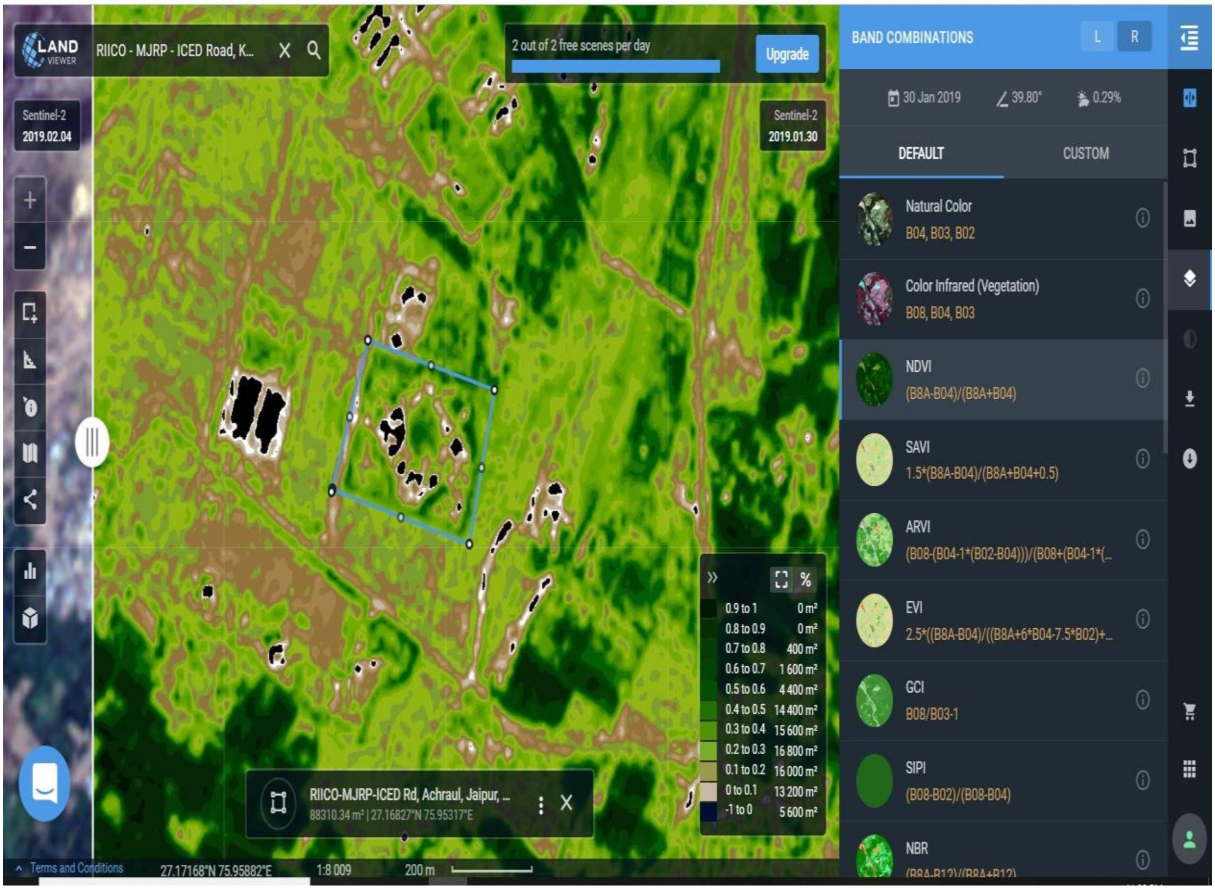
- After the selection of area of interest, select the different band combinations to observe the periodical changes.

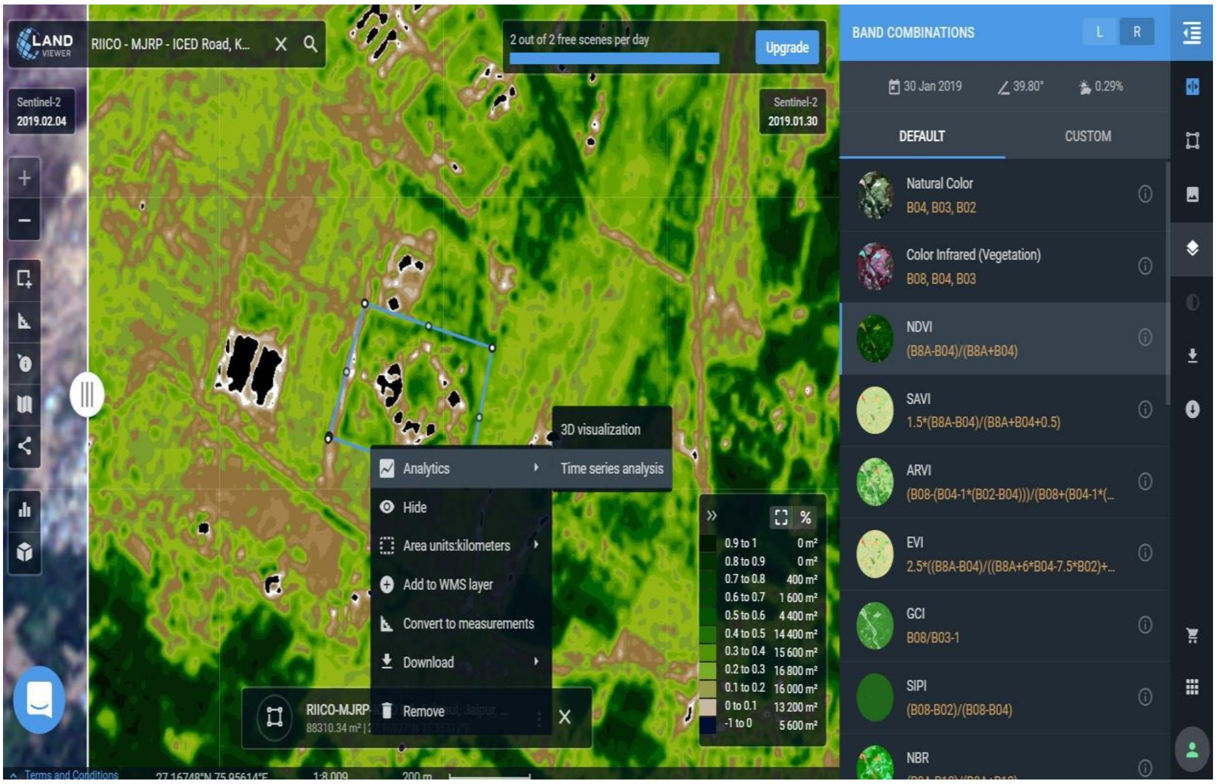
- Different dates and comparisons of bands can be done and customization of bands can also be done through custom options available.

- Different specifications of bands are mentioned in the reports as well on the application too.

- Analytics can also be done using analytics option and selecting time series analysis.

- Time series analysis will give data about the changes over period on a specific area of interest.





2.1.7.4 Conclusion

From the study it is seen that data from different satellites like Land Sat, Resource Sat, Scat Sat etc. play a very important role in observing changes over a sample and it can help in the audit of different projects which may be related to vegetation cover, water bodies, changes in land patterns, urban distribution, forest fires, mining etc. Different bands and images can be used to cover all measures to observe the changes in patterns.

The study found that over time, vegetation density on the iCED campus has greatly improved from barren land. In NDVI images it can be seen that it was barren land and no vegetation was found in the sample area but over time it changed and in the year 2018 we can observe the green bands in NDVI images which is a significant improvement. Statistical data shows the linear variance in the NDVI from the year 2014 onwards. Vegetation in the sample area has positively improved from 2013 onwards and a linear pattern has been formed.

Changes in NDVI and Index Stack show that vegetation over the sample has gradually improved from 2015 onwards. The land was full of rocks, sand and was barren as no presence of vegetation was found in the images. With changing period, the campus has improved in vegetation cover, especially after 2015 onwards and has attained a good vegetation cover in 2018.

THEME 2.2: A COMPARATIVE STUDY OF CHANGE IN URBAN LANDSCAPES COVERING FIVE INDIAN CITIES (DELHI, BENGALURU, KOLKATA, PUNE AND INDORE) BY USING SATELLITE IMAGES AND QGIS TOOL

2.2.1 Introduction

"Ultimately, we need to recognize that while humans continue to build urban landscapes, we share these spaces with other species."

- David Suzuki

From the podium of Habitat III Conference 2016, the United Nations Chief called "New Vision for Urbanization." So, why do we need a new vision? Is the old vision unable to solve the urban problems?

The world is urbanizing at a very high rate. The urban population of the world has grown from 751 million in 1950 to 4.2 billion in 2018[1]. According to the United Nations (UN) Population Division, one-third of the world population was urbanized in 1950, which will increase to two-thirds of the world population in 2050. Figure 1 and figure 2 show percentage of urbanization and city population at various locations, as per the world map for the years 1970 and 2018[2].

With more than 80 per cent of global GDP generated in cities, urbanization can contribute to sustainable growth if managed well by increasing productivity, allowing innovation and new ideas to emerge. However, unprecedented speed and scale of urbanization also put forward many challenges, including those related to meet the accelerated demand for affordable housing, well-connected transport systems, and other infrastructure, basic services, as well as jobs. This may also lead to conflicts resulting in the forced displacement of people living in urban areas.

During the evolution of a city, its physical form and land use patterns can be locked for generations, leading to unsustainable sprawl. The expansion of urban land consumption may outpace the population growth which may further expand unsustainable sprawl. Such sprawl puts pressure on land and natural resources, resulting in undesirable outcomes; cities consume two-thirds of global energy consumption and account for more than 70 per cent of greenhouse gas emissions. Hence, it is important to study the pattern and rate of urbanization to have a clear view of how to use our cities for the betterment of their residents. In this study, an attempt has been made by Mr. Nishant Kumar Upadhyay, intern to analyze the use of land in the selected

[1] https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
[2] https://population.un.org/wup/Maps/

locations in five cities for urbanization during the period from 1980/1989/1991 to 2020/2021 using QGIS and NASA database.

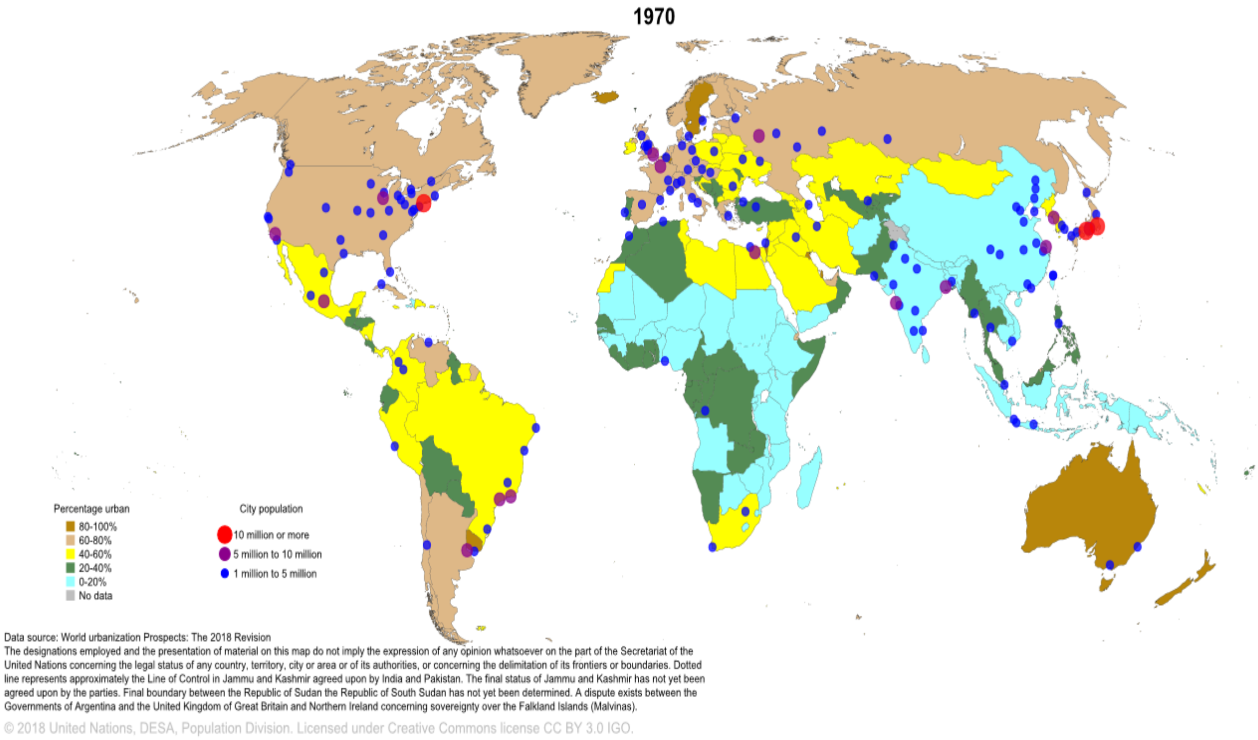


Figure 1: World Urban Population, 1970

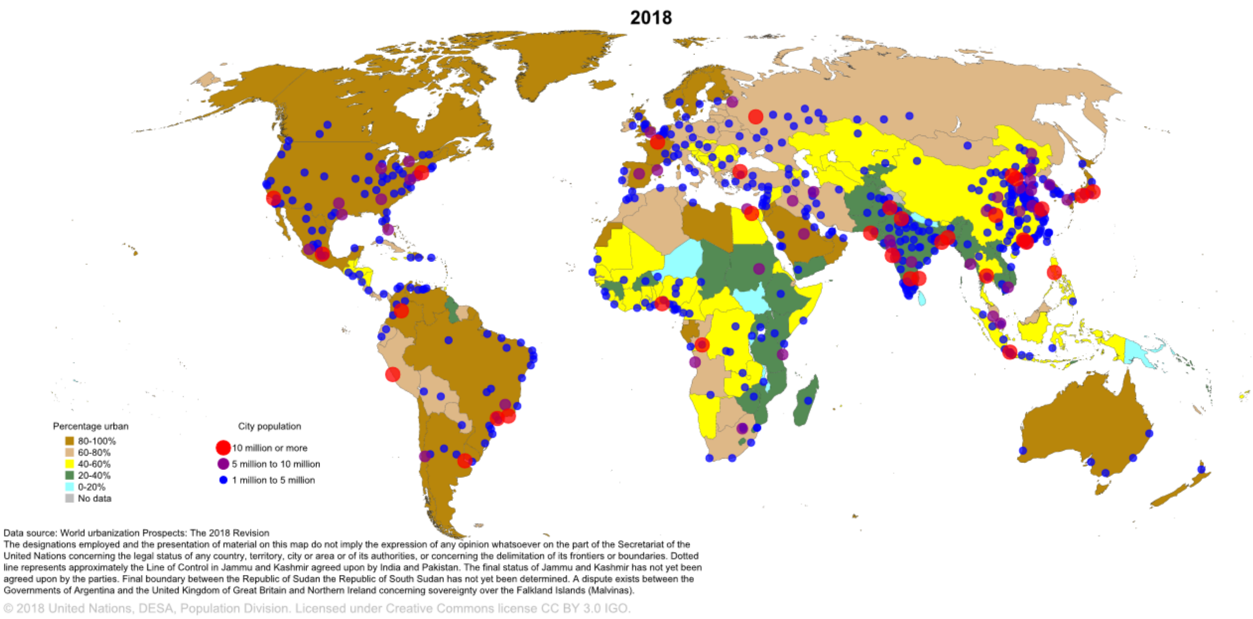


Figure 1: World Urban Population, 2018

Indian scenario

Developing economies such as India have a very high rate of growth in urban population. As per census 2011 data of the Ministry of Home Affairs (above), the urban population has

Population Census 2001 and 2011

	Persons in million numbers				Decadal growth in population %
	2001	2011		1991-2001	2001-2011
Total	1029	1210		21.5	17.6
Rural	743	833		18.1	12.2
Urban	286 27.81%	377 31.16%		31.5	31.8 +0.3%

Figure 2

increased by 31.8per cent in the period 2001 to 2011. There has been an increase of 91.0 million persons in the urban population from 2001 to 2011. The number of million-plus cities/urban agglomeration (UA) has also increased from 35 in Census 2001 to 53 in Census 2011 [3] as of 2020 India has a population of around 1380 million, 34.9 per cent of which is urban population[4].

With increased urbanization emerges new challenges for humans. Challenges such as climate change, unsustainable housing pattern, water pollution, floods, traffic management and waste management have become a daily affair in today's urban cities.

2.2.2 Objective & Scope

The main objective is to study the change in urban landscape from the period 1980/1989/1991 to 2020/2021 at selective locations in Delhi, Bengaluru, Kolkata, Indore and Pune, using Land Use Land Cover (LULC). An effort has been made to study the vegetation spread or green area in these cities based on Normalized Difference Vegetation Index (NDVI).

It covers five Indian cities, namely; Delhi, Bengaluru, Kolkata, Pune and Indore selected on the basis of previous performance in different sustainability indexes, population and other extreme climatic frequencies in these cities.

This study has focused on municipal administered boundaries of the cities of Delhi, Bengaluru, Kolkata, Pune and Indore as given below in figure 3. The maps have been taken from

[3] https://mohua.gov.in/cms/urban-growth.php
[4] https://hbs.unctad.org/total-and-urban-population/

https://www.diva-gis.org/gdata[5]. The city boundaries have been checked and corrected according to Indian municipality limits and as per the extant rules.

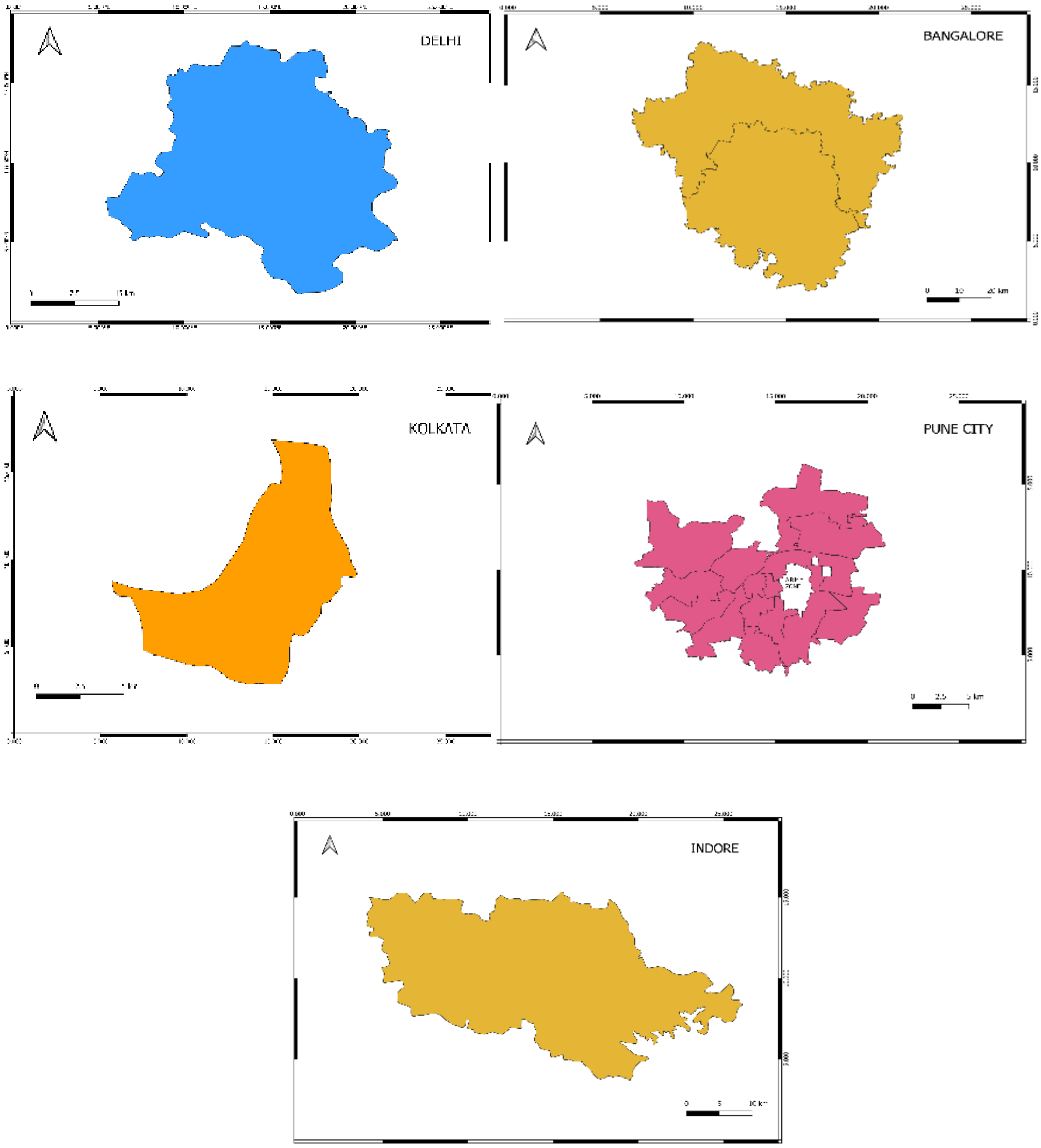


Figure 3: Site Maps of Selected Cities

Sample Selection

Landsat satellite images have been used to analyze the urban LULC pattern of the five cities. The area of the cities has been measured through the municipal boundaries of the given maps (figure 3) and measured through QGIS and shape files of the administration. The source of

[5] This website has all the shape files (.shp) that are used to make maps, with the help of QGIS (Quantum Geographic Information System) version 3.16.

Administrative boundary used in the calculation of the area of the cities is https://gadm.org/ or https://www.diva-gis.org/gdata. QGIS software has been used to calculate the area of the administrative vector shape files taken from the source mentioned above.

CITY	AREA (in sq. Km)
DELHI	1502
BENGALURU	4496
KOLKATA	91
PUNE	251
INDORE	1025

2.2.3 Methodology

What is GIS and how it has been used in this study?

Geographic Information System (GIS) can be defined by the two components of its name. The first one is geographic and another one is information. This involves analysis, interpretation and mapping of different types of data or information of any geographical region. Figure 4 gives

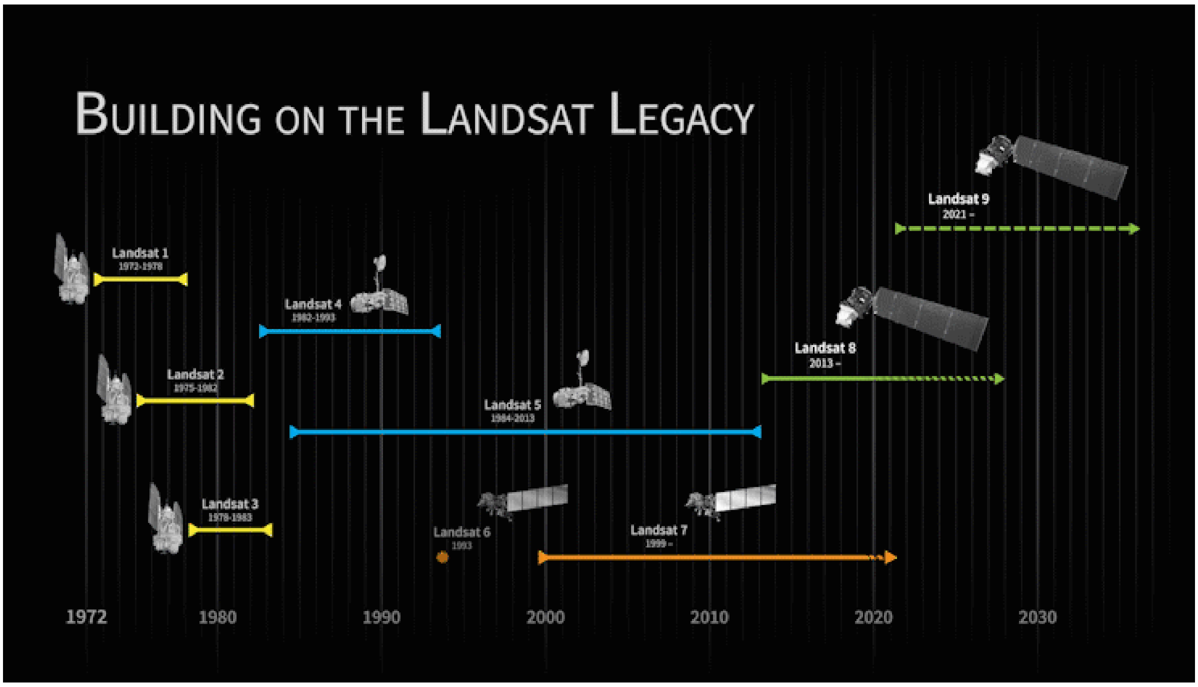


Figure 4: LANDSAT Legacy

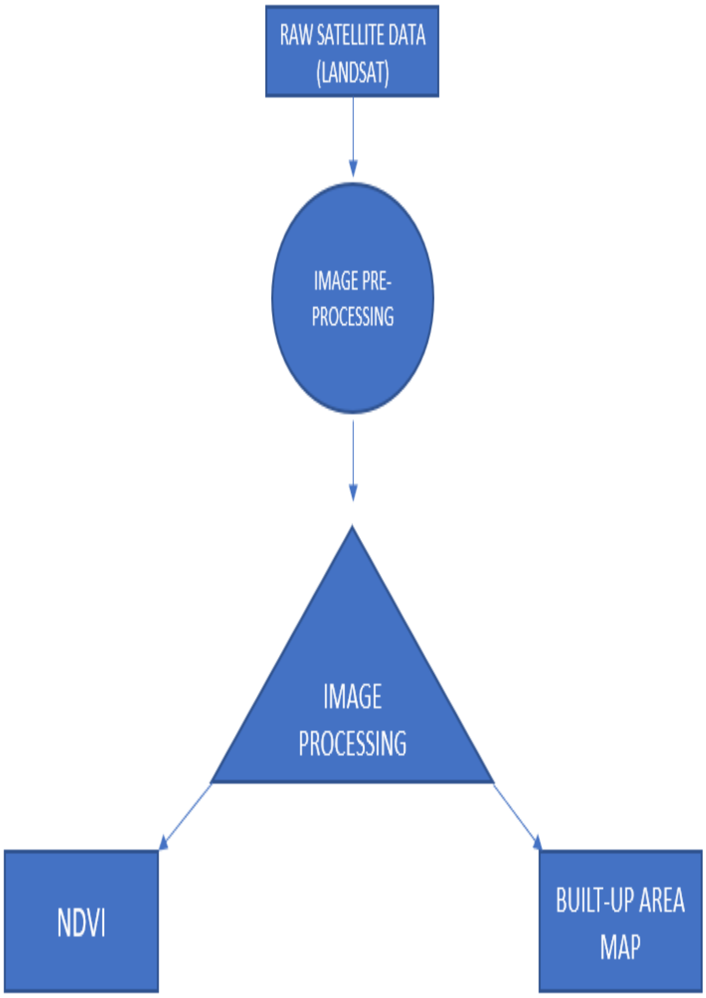
the information about various Landsat satellites which can be used for accessing images about various time zones.

In this study, GIS has been used to map the changing pattern of urbanization, LULC and NDVI of the selected cities.

Landsat data used:

1980	2000	2021
Landsat 3, 4 and Landsat 5	Landsat 7	Landsat 8

Method used for converting geographical Information from Landsat data into a Map of our interest:



Landsat is a series of satellites which are sent by USGS NASA, the government of United States of America for the purpose of collecting geographical high-resolution data which is used in different developmental, planning and decision-making processes. Landsat is the longest running earth observatory satellite which was started in 1972 as Landsat-1. Now it has the latest launched in 2021 which is more accurate and frequent known as Landsat-9. The above picture talks about the different phases of Landsat satellites. Landsat-1 from 1972 to 1978, Landsat-2 from 1975 to 1982, Landsat-3 from 1978-1983, Landsat-4 from 1982 to 1993, Landsat-5 from 1984 to 2013. Unfortunately, Landsat-6 crashed and some sensors are not placed well which was a reason of failure for Landsat-6. Landsat-7 which was sent in 1999 still working, along with Landsat-8 which was sent in 2013 and Landsat-9 which is in 2021.

Figure 5: Methodology Flow Chart

QGIS version 3.16.11 was used to prepare the data, analyze the images and for mapping the results. Microsoft Excel was used to create tables, graphs and charts. City boundary shapefiles were obtained for the year 1980 from DIVA Administrative boundary https://www.diva-gis.org/gdata and Raster image taken from Landsat 3, 4, and 5. Similarly, for the year 2000, the satellite Raster images were taken from Landsat 7 and Landsat 7 and 8 for the years 2020 & 2021.

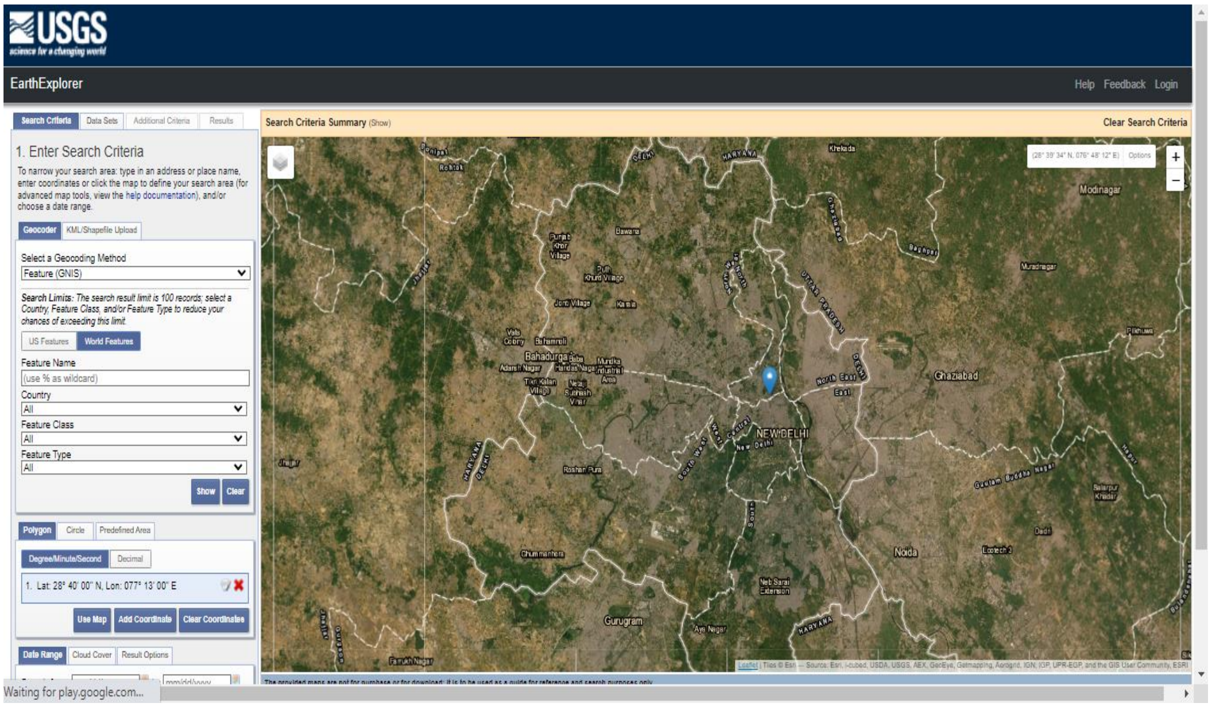


Figure 6: Methodology Step-1

Landsat Data was downloaded from USGS Earth Explorer (NASA): data is available on USGS in real-time data cover (180*185 KM with 30 m resolution), which has several bands according to Landsat data time frame.

Landsat 04, Landsat 05, Landsat 06, Landsat 07 and Landsat 08 images were downloaded from USGS earth explorer for the years 1989, 2000 and 2020 & 2021 as per the required maps, for analysis.

The images were then, imported into a new project file in QGIS 3.16.11. The semi-Automatic Classification plugin was installed using the Manage and Install Plugins option in QGIS. The imported Landsat imagery was then pre-processed.

Step 2- Pre-processing[6] Satellite Imagery using QGIS and Semi-Automatic Classification Plugin

[6] Preprocessing refers to those operations which precede the image analysis and include atmospheric and radiometric corrections.

Atmospheric Correction

Any sensor that records electromagnetic radiation from the earth's surface using visible or near-visible radiation will typically record a mixture of two kinds of energy (Richards, 2005). The value recorded at any pixel location on a remotely sensed image does not represent the true ground-leaving radiance at that point. Part of the brightness is due to the reflectance of the target of interest and the remainder is derived from the brightness of the atmosphere itself. The separation of contributions is not known a priori, so atmospheric correction aims to measure these two components to perform a core analysis on the correct target reflectance or radiance values.[7] **Atmospheric correction was done using the Semi-Automatic Classification Plugin.**

Step 3- Making reflectance on bands and create a virtual band

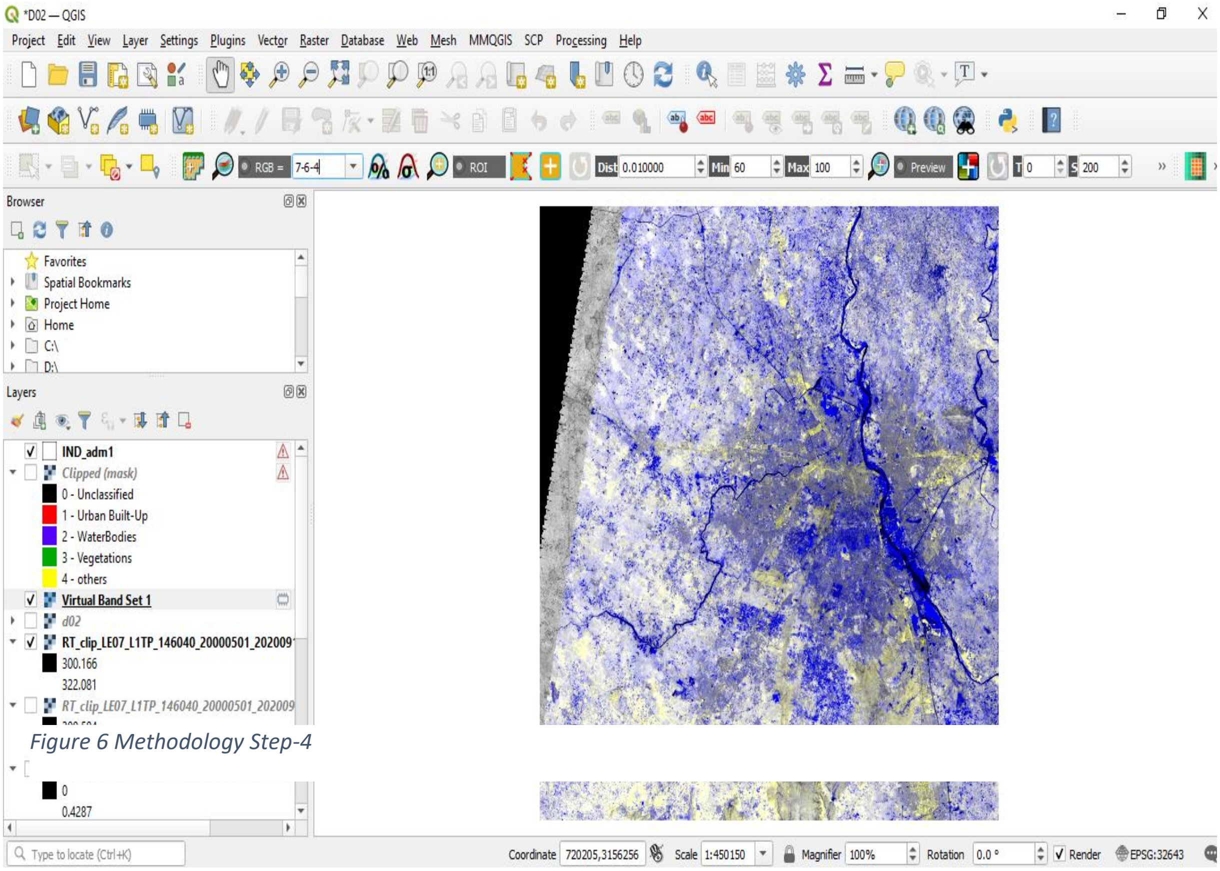


Figure 6 Methodology Step-4

Figure 7 Methodology Step-3

---

[7]ttps://www.researchgate.net/publication/257067491_The_importance_of_considering_atmospheric_correction_in_the_pre-processing_of_satellite_remote_sensing_data_intended_for_the_management_and_detection_of_cultural_sites_a_case_study_of_the_Cyprus_area

Landsat data downloaded from Earth explorer was imported into QGIS software (figure 7) to convert the bands into false-colour composition (FCC). This helps to understand the different land-use patterns like urbanization reflected in gray, vegetation in dark red, water bodies in blue and black and "Others" like barren lands, sands, agricultural lands etc. in yellow and white.

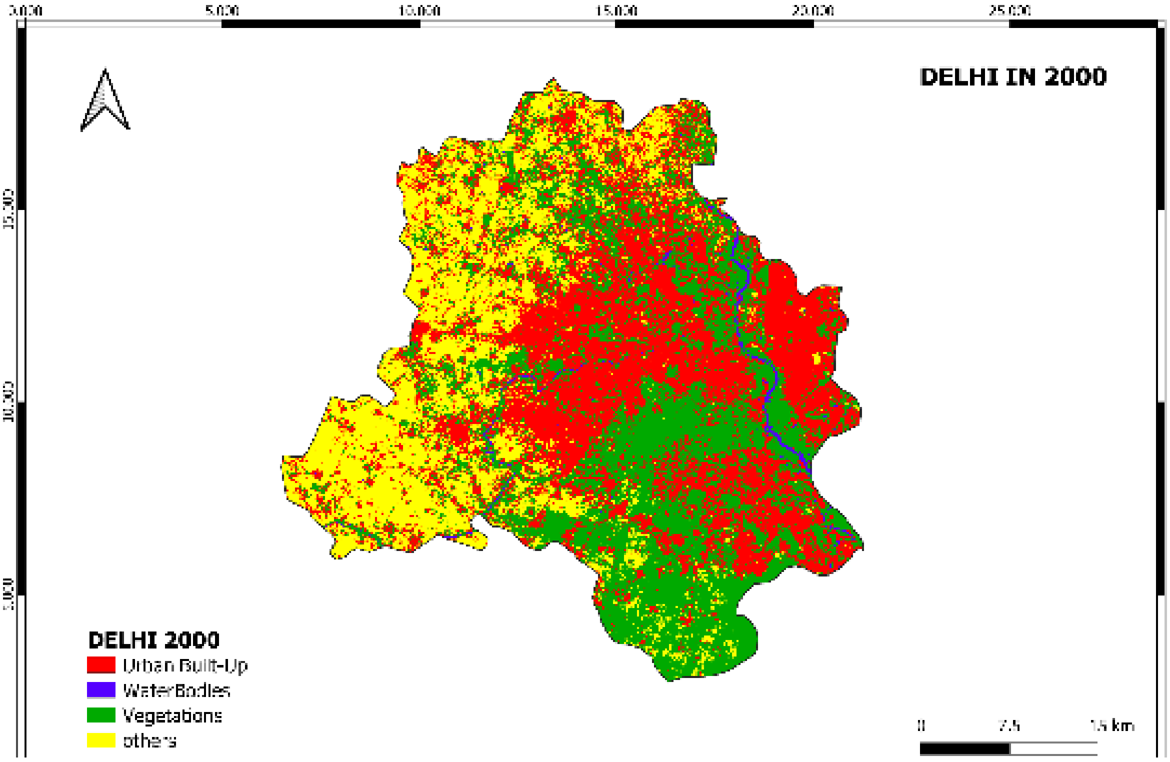


Figure 7 Methodology Step-4

Step 4- Classification of reflectance raster data in our area of study (LULC, NDVI) using QGIS Software

According to research interest and findings, the FCC virtual band was classified into a supervised classification pattern as given in figure 8. The classification of the **urban areas is in red, water bodies in blue, vegetation in green and others in yellow**.

Step 5- Importing of final map in QGIS software

Final import is done by including coordinate values, legend, map title and North arrow for the direction of the map, as shown in figure 9.

NDVI:

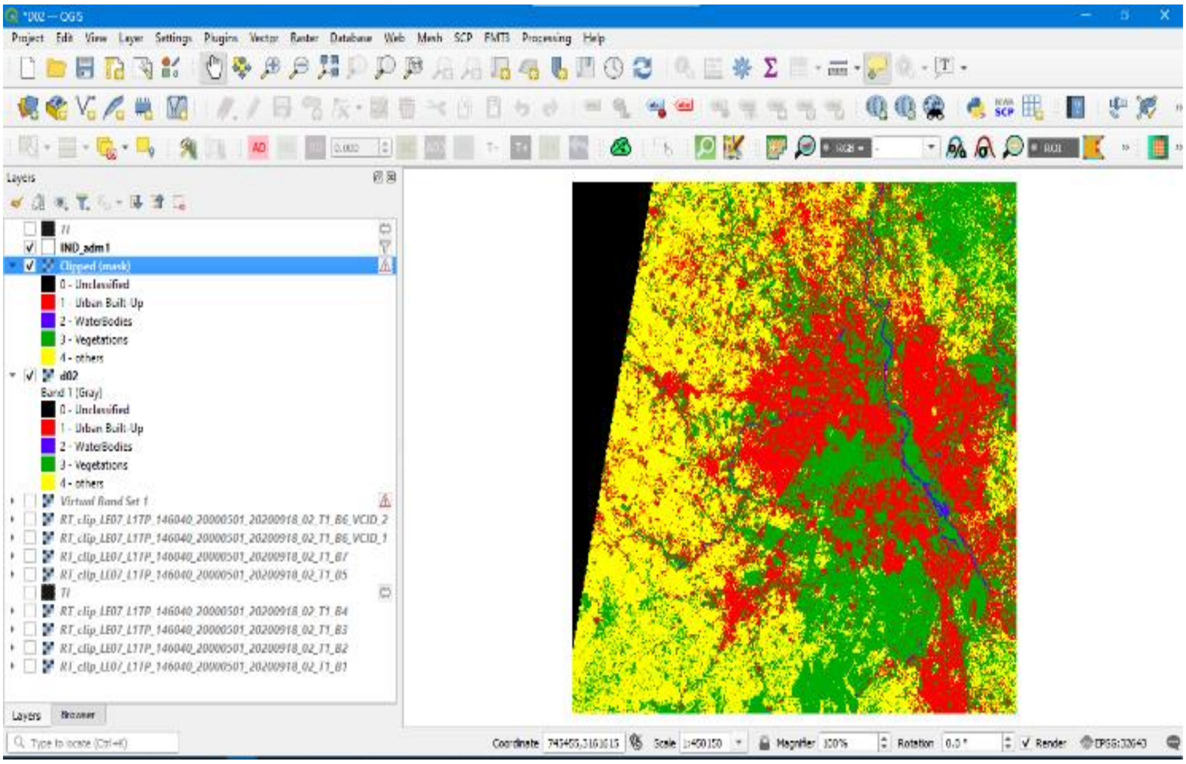


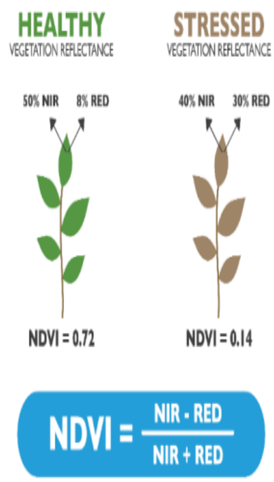
Figure 8 Methodology Step-5

In this study, NDVI has been used to quantify vegetation greenness. This is useful in understanding vegetation density and assessing changes in plant health[8]. NDVI is calculated as a ratio between the red (R) and near-infrared (NIR) values

NDVI= (NIR - R) / (NIR + R)

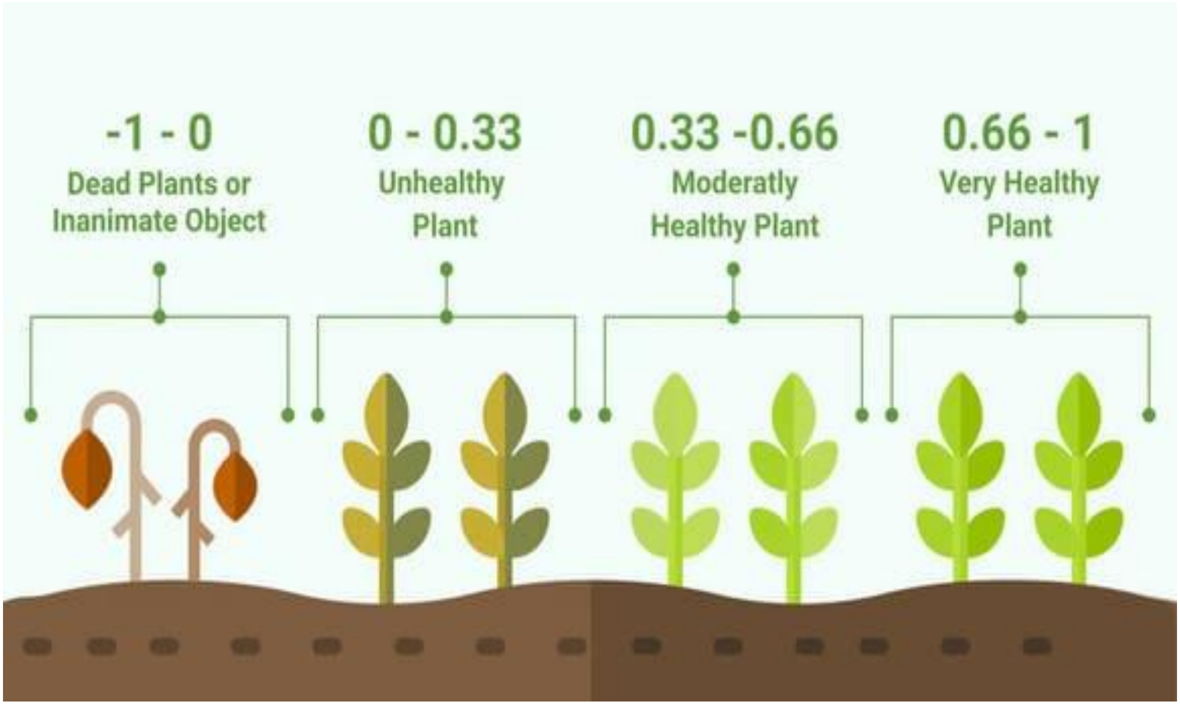
In Landsat 4-7, NDVI = (Band 4 – Band 3) / (Band 4 + Band 3).

In Landsat 8, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).



NDVI values for the five cities have been classified into different categories, ranging from -1 to +1. Negative values represent the water bodies, barren land, urban built-ups and other land use pattern except for healthy plants and the positive value above 0.3 represents healthy plants. It also depicts the density of vegetation. Healthy and densely vegetation is represented by NDVI above 0.6.

[8] https://www.usgs.gov/core-science-systems/nli/landsat/landsat-normalized-difference-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con



2.2.4 Understanding land-use patterns in cities

In urban areas, the presence of vegetation is essential for reducing the effects of environmental pollution and maintaining ecological balance. In the wake of excessive growth of population, the urban vegetation with areas under parkland is diminishing rapidly to provide additional space for various other types of usages. For this purpose, NDVI has also been calculated for these cities.

DELHI:

Understanding the urban pattern

Landsat Data from USGS Earth Explorer (NASA): https://earthexplorer.usgs.gov/ data was downloaded for the city of Delhi. QGIS software was used to highlight different land use patterns in the city. Bands were converted into FCC (false-color composition) to understand the different land use pattern like urbanization looks in gray, vegetation looks in dark red, water bodies in blue and black and others like barren lands, sands, agricultural lands etc. looks in yellow and white. Again, this FCC can be converted into final map of our interest. Maps depicting various land use patterns for the years 1980 and 2020 have been developed using QGIS software.

Landsat data used to make the LULC maps are given as:

YEAR	LANDSAT DATA	Acquired DATE
1980	LM03_L1TP_157040_19800301_20180416_01_T2	01 March 1980
2000	LE07_L1TP_146040_20000501_20200918_02_T1_B1	01 May 2000
2021[9]	LC08_L1TP_146040_20210604_20210614_02_T1_B1	04 June 2021

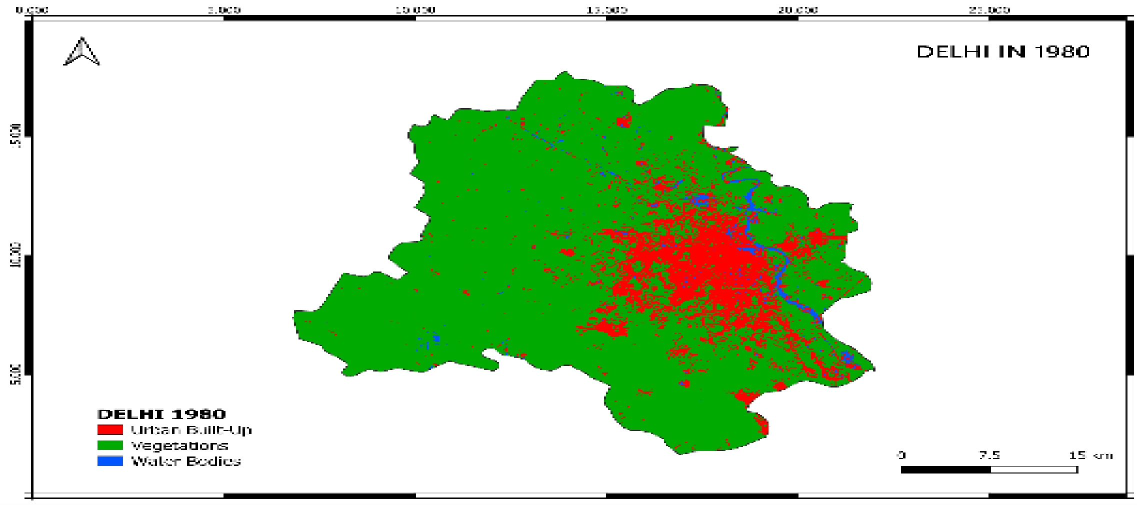


Figure 11: Land use in Delhi 1980

A map for various land uses in Delhi for the year 1980 is given in the figure 11. Urban area in this map is reflected in red, vegetation in green, water bodies in blue and others which comprises agriculture or barren land in yellow color. The urban buildup area in Delhi is seen to be a very limited area and a large area with vegetation cover can be seen on the map with water bodies.

[9] https://www.usgs.gov/faqs/what-naming-convention-landsat-collections-level-1-scenes

Map for land uses in Delhi for the year 2000 is given in the figure 12. It can be seen that the urban area has increased and there is a considerable decrease in the vegetation area. The yellow color denotes land use for others categories including barren lands, sands, agricultural crops, scrubs and some unhealthy vegetation.

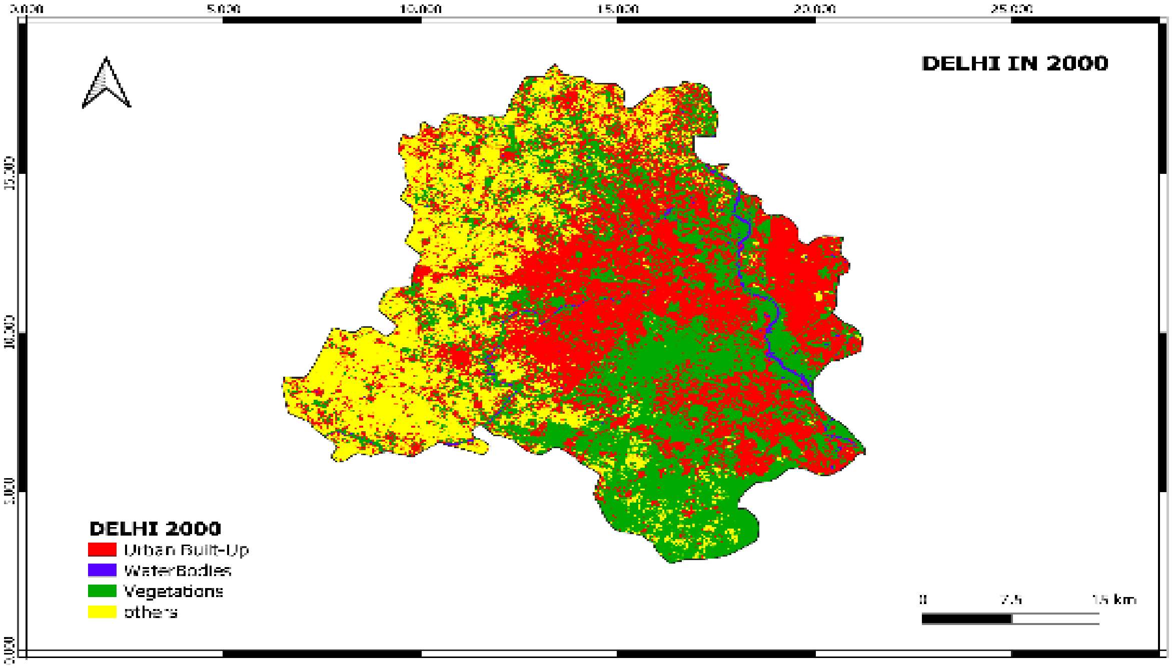


Figure 12 Land use in Delhi 2000

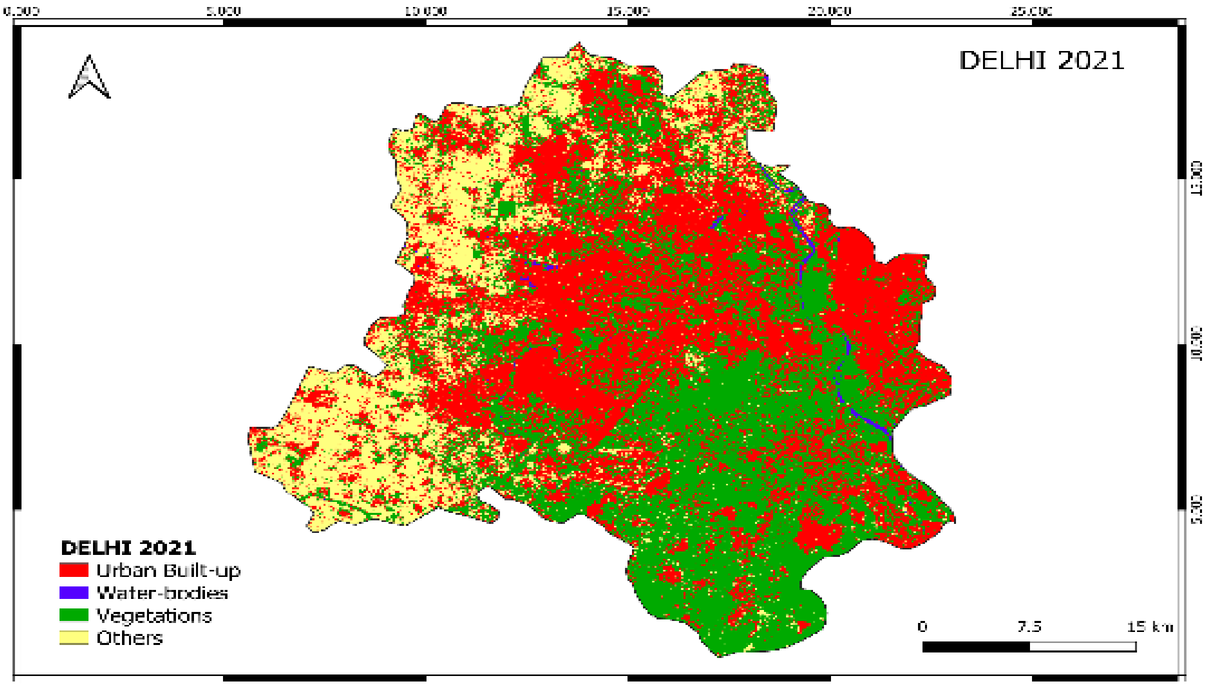


Figure 13 Land use in Delhi 2021

Map for land uses in Delhi for the year 2021 is given in the figure 13. It can be seen that the urban area has increased considerably towards the north and has also occupied land use areas in other category. The map shows that the expansion of urban pattern in Delhi followed urban sprawl and urban agglomeration which is connected via roads and metro transportation. As can be seen in the above image major expansion in 2021 has been in the north, south-west and west side of Delhi.

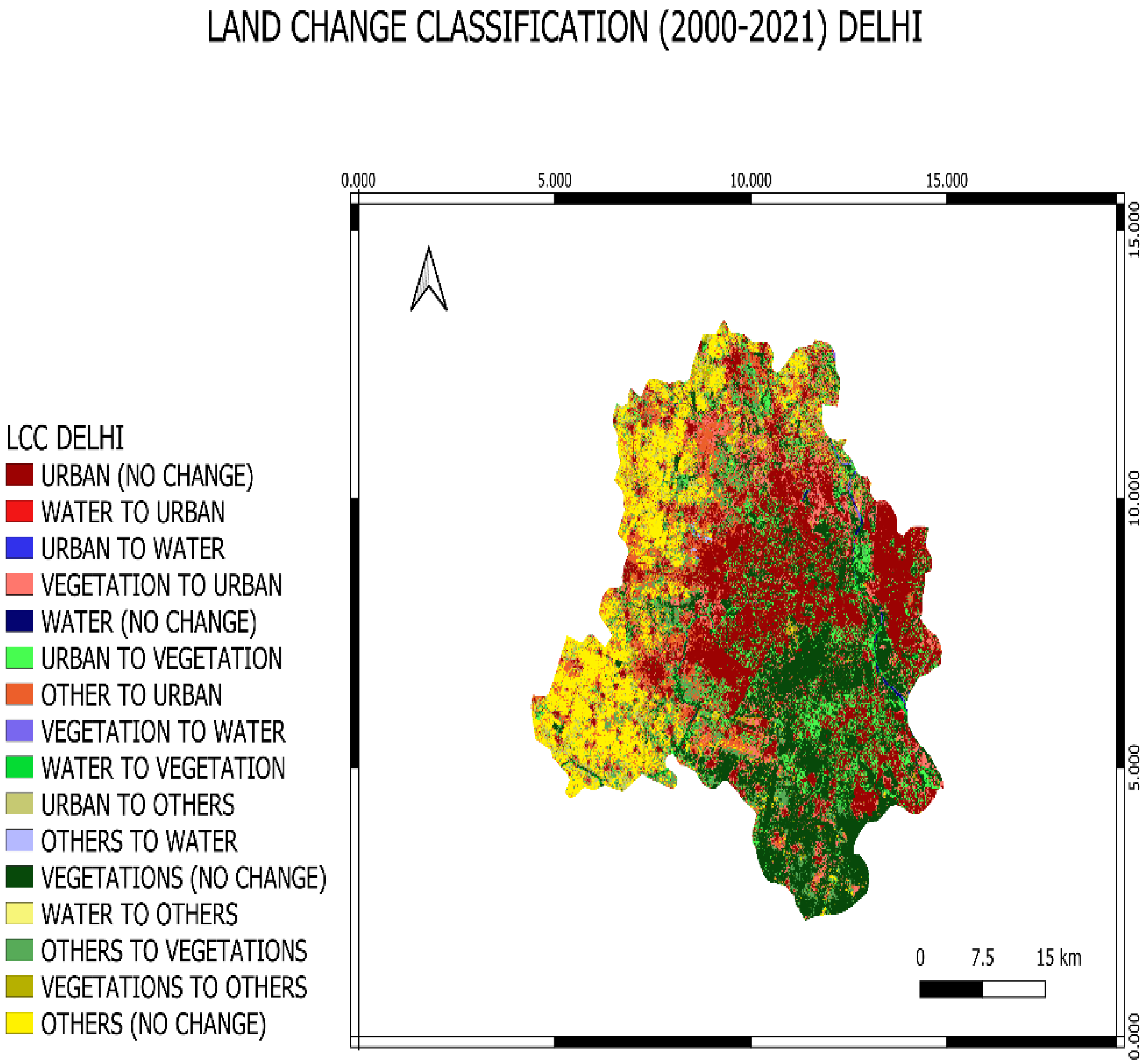


Figure 14: Land change classification in Delhi 2000-2021

For more detailed understanding of urban expansion and changes, the maps for the years 2000 and 2021 have been compared using QGIS software to see the expansion in north, south and south-west from vegetation to urban and others to urban built-ups. Map showing Land Change

Classification between the years 2000 to 2021 is given in figure 14. Changes in land use have been shown in different colors and are shown in the legend. The comparison shows that vegetative land has been converted into other category land use which is Agricultural land and barren land. Patches are showing a change from vegetation to urban area also.

The change in land use pattern in Delhi between the years 2000 and 2021 has been illustrated in the form of a graph (Figure 15). From the graph, it may be inferred that there is a change in areas such as vegetation, water bodies and others such as agricultural and barren land converted into urban space. A total of 115 sq km area has been converted from vegetation to urban area and 116 sq km converted from others to urban space:

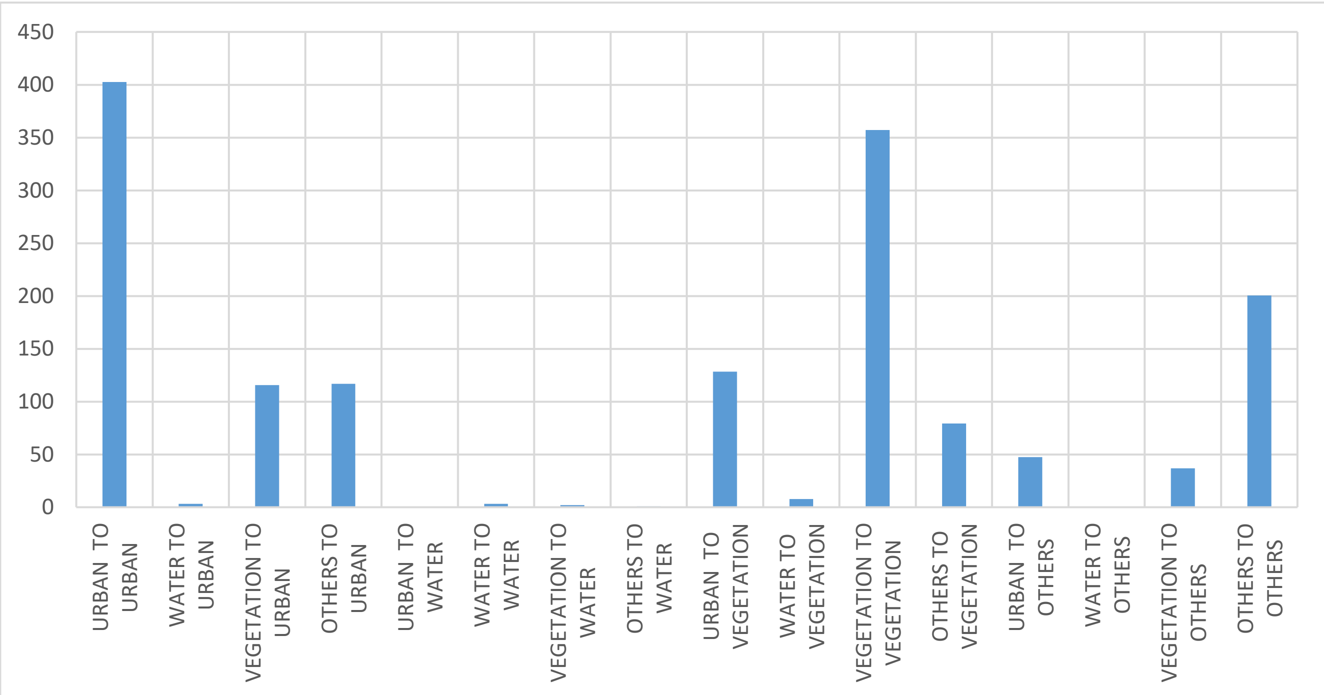


Figure 15: Change in area of land use pattern Delhi 2000-2021

From the above figure 15, it may be concluded that the total amount of land converted into the urban area is 235.33 sq km. Out of the total land converted into urban areas from the year 2000 to 2021, land under ‘different areas’ like agricultural or barren land had the highest proportion, constituting 49 per cent of the total conversion of land into urban areas.

NDVI

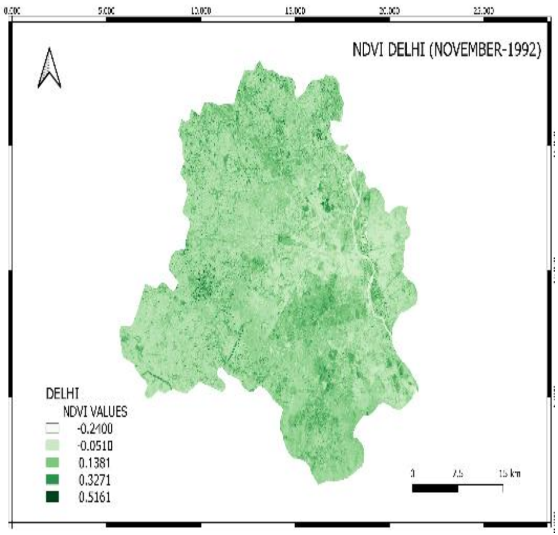
NDVI of Delhi has been classified into five categories. Negative value of NDVI shows the water bodies and built-up areas. Positive value of more than 0.3 shows the vegetation. NDVI ranging from 0.3 to 0.4 has moderate vegetation and above 0.4 means densely and healthy vegetation pattern as depicted below:

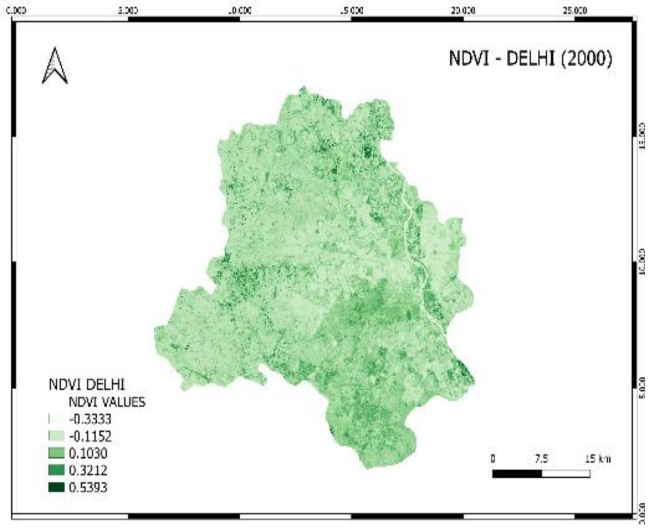
NDVI Values	Meaning
-1	Water bodies
-1 to 0	Urban built-ups
0 to 0.3	Barren land
0.3 to 0.4	Moderate vegetation
0.4 to 1	Healthy or densely vegetation

Landsat data that has been used to analyze the NDVI of Delhi is given below:

Year	Landsat data	Acquired Date
1992	LT05_L1TP_146040_19921111_20200914_02_T1_B3	11 November 1992
2000	LE07_L1TP_146040_20001125_20200917_02_T1_B3	25 November 2000
2020	LC08_L1TP_146040_20201023_20201105_02_T1_B4	23 October 2020

NDVI analysis of Delhi in the years 1992, 2000 and 2020 is shown in figure 16. It can be seen that the highest value of NDVI in the years 1992, 2000 and 2020 is 0.5, 0.5 and 0.40 respectively. There is a decrease in NDVI value, which shows that there has been a reduction in dense and healthy vegetation in Delhi during the period from 2000 to 2020.





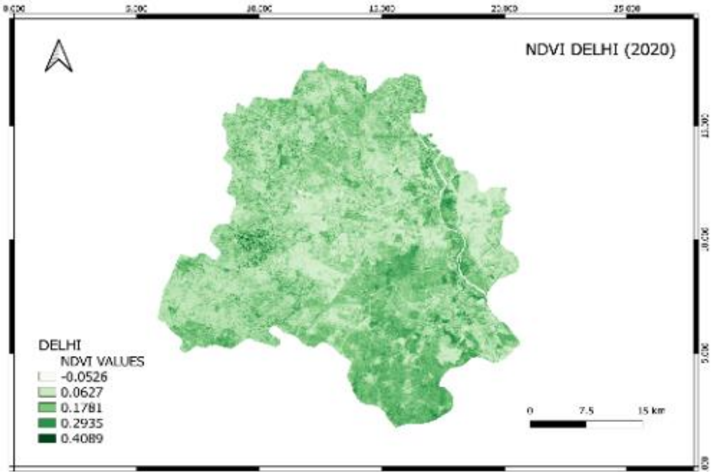


Figure 16: NDVI of Delhi

In Delhi, the green cover has increased as can be seen on the map but the dense forest and healthy vegetation have decreased with the decline in NDVI value, from 0.54 in 2000 to 0.4 in 2020. The dense vegetation may have changed into moderate vegetation and no vegetation. This gives a significant indication of environmental exploitation and deforestation due to urban expansion and other governance issues.

Bengaluru

Understanding the urban pattern

Landsat data used for creating the LULC maps are given as:

Year	Landsat Data	Acquired Date
1991	LT05_L1TP_144051_19910316_20200915_02_T1	16 March 1991
2000	LE07_L1TP_144051_20001026_20200917_02_T1	26 October 2000
2021	LC08_L1TP_144051_20210403_20210409_02_T1	03 April 2021

Bengaluru city has been evolving rapidly in the past few years. Three maps have been made to analyse the growth of urbanization from 1991 to 2021 (figures 17 to 19). Red colour represents urban patterns or build-ups, while green is vegetation, blue for water bodies and yellow for others such as barren land, sand or agricultural lands.

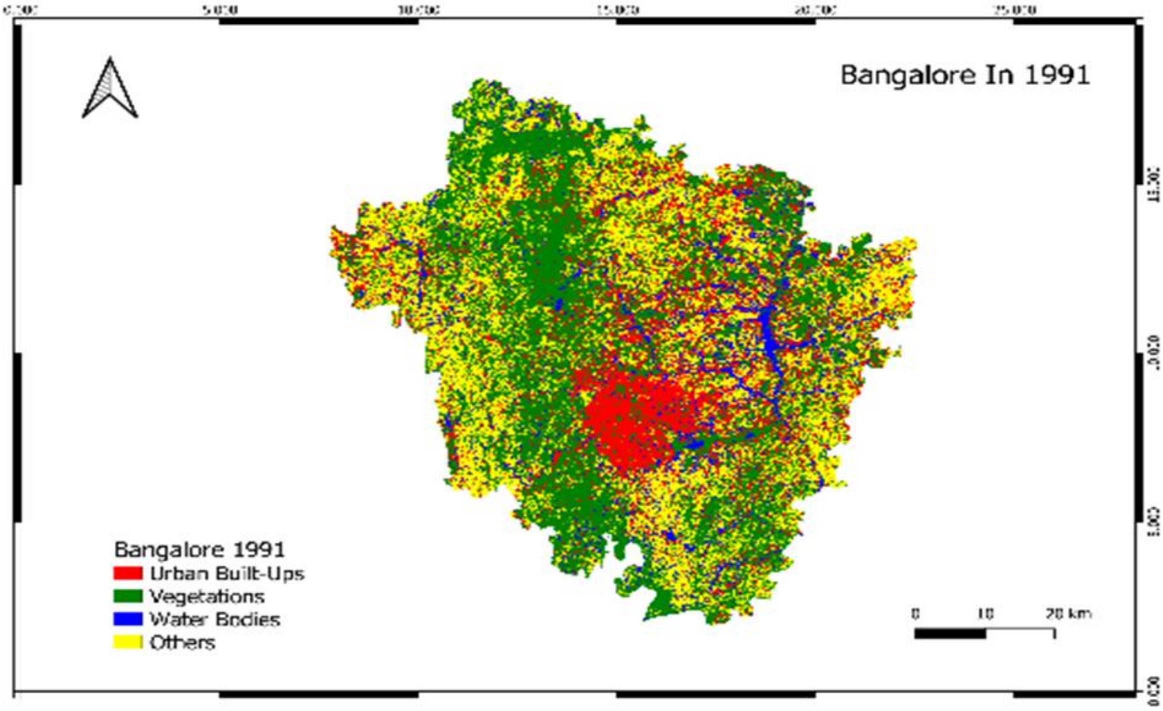


Figure 17: Land use in Bengaluru 1991

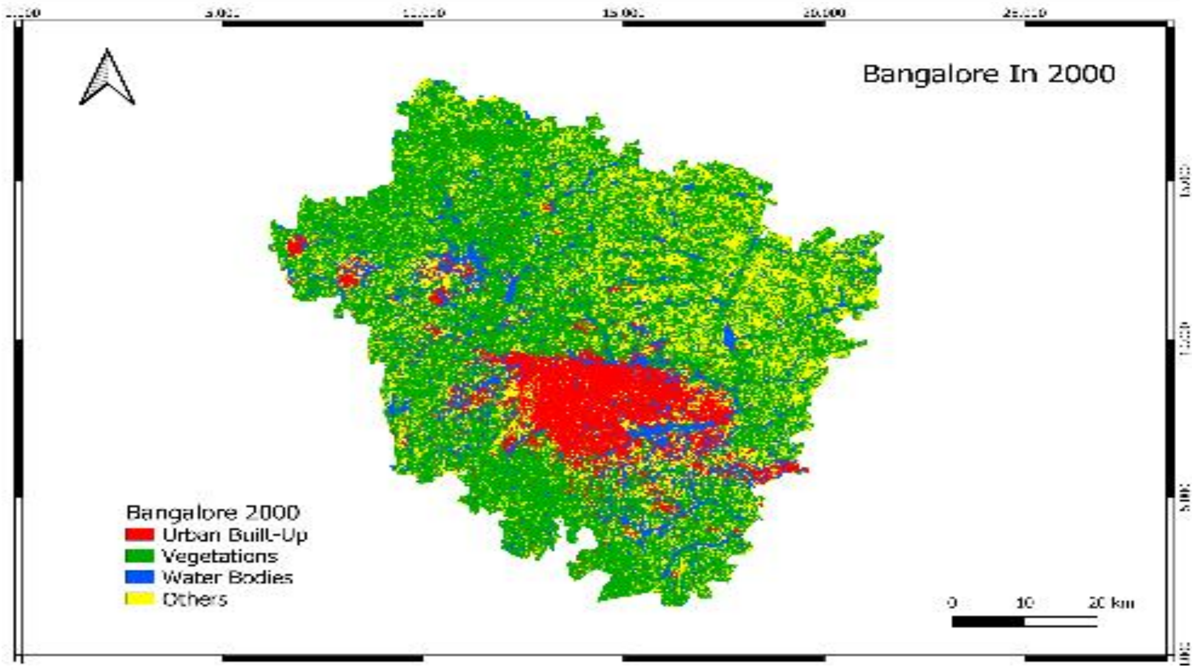


Figure 18: Land use in Bengaluru 2000

It can be seen in figures 17 and 18, that urban expansion in Bengaluru during the period 1991 to 2000 took place primarily in the peripheral parts of the city, showing a scattered pattern. During the period from 2000 to 2021, the pattern of urban expansion was more linear in structure, taking place mainly along the roads/highways connecting the nearby suburbs as seen in figure 18.

Bengaluru had numerous water bodies in the form of small/big lakes, wetlands, ponds etc. A comparison of the maps for the years 1991, 2000 and 2021 reveals that many of these water bodies have disappeared. It is also seen, that during this period a lot of urbanization had occurred near these water bodies which resulted in unprecedented water use and water pollution due to increased anthropological activities. The loss of these water bodies may be attributed to the rapid and dense growth of urban build-up near the waterbodies in Bengaluru.

The 2021 map of Bengaluru reveals that the urban density has increased in all directions,

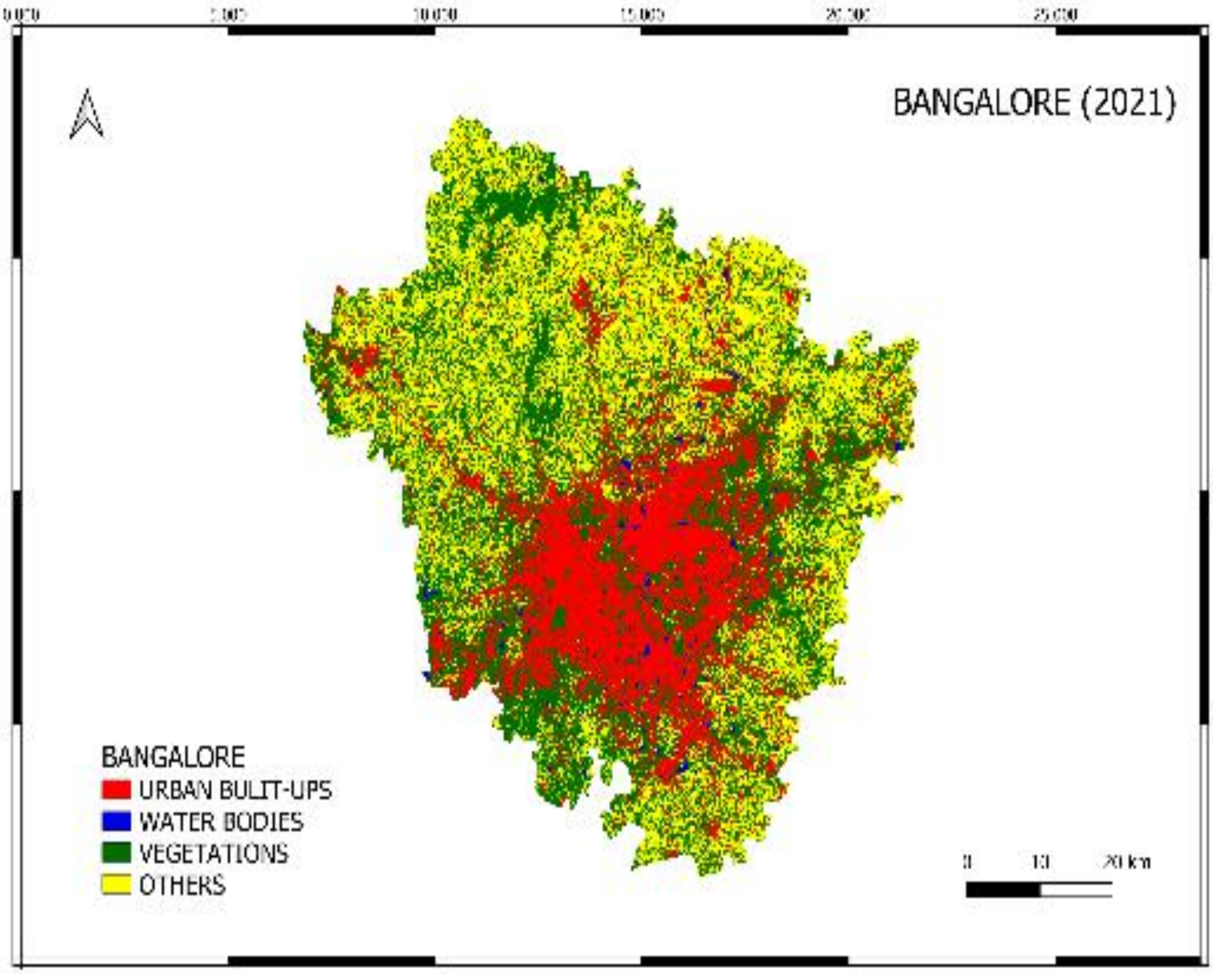


Figure 19: Land use in Bengaluru 2021

especially in the southern part of Bengaluru. Also, the vegetative lands have been converted into agricultural or barren in the past 20 years, if compared to the map of 2000 and 2021.

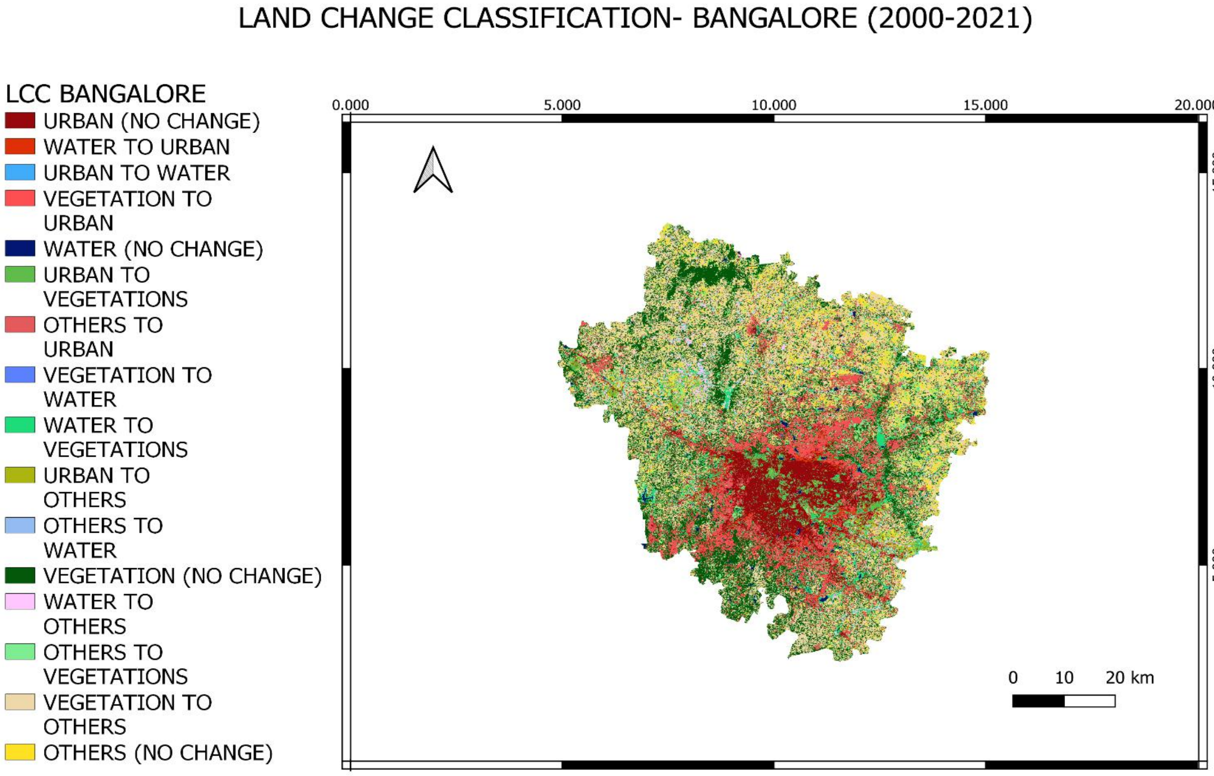


Figure 20 Land Change Classification Bengaluru 2000-2021

Figure 20, shows pattern of change during the period 2000 to 2021, where the dark red color represents the urban area which was there in 2000 and light red (pink) is an expanded region in

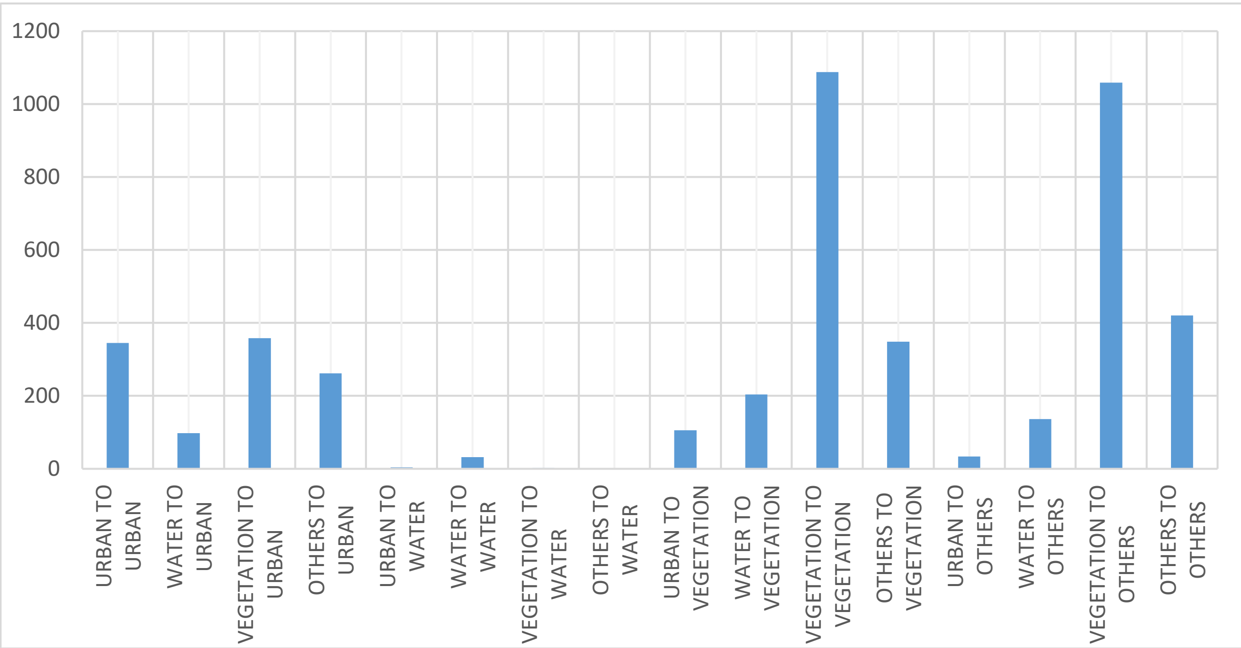


Figure 21 Change in area of Land Use Pattern Bengaluru 2000-2021

the past 20 years.

From figure-21, it may be seen that during the past 20 years more than 1000 sq. km of vegetation land has been converted into other categories (barren, agricultural etc.) and 262 sq. km of other categories of land converted into urban space. Even direct conversion of land under vegetation into urban space is very high (358 Km). Further, 97 sq. km area under water bodies were converted into urban space and 136 sq. km covered underwater were converted into other categories.

NDVI

Landsat data that has been used to analyze the NDVI of Bengaluru is given below:

Year	Landsat Data	Acquired Date
1993	-	-
2000	LE07_L1TP_144051_20001127_20200918_02_T1	27 November 2000
2020	LC08_L1TP_144051_20201110_20210316_02_T1	10 November 2020

In Bengaluru, a decreasing trend in NDVI value from 0.76 in 1993 to 0.56 in 2000 and 0.55 in 2021 is reflected:

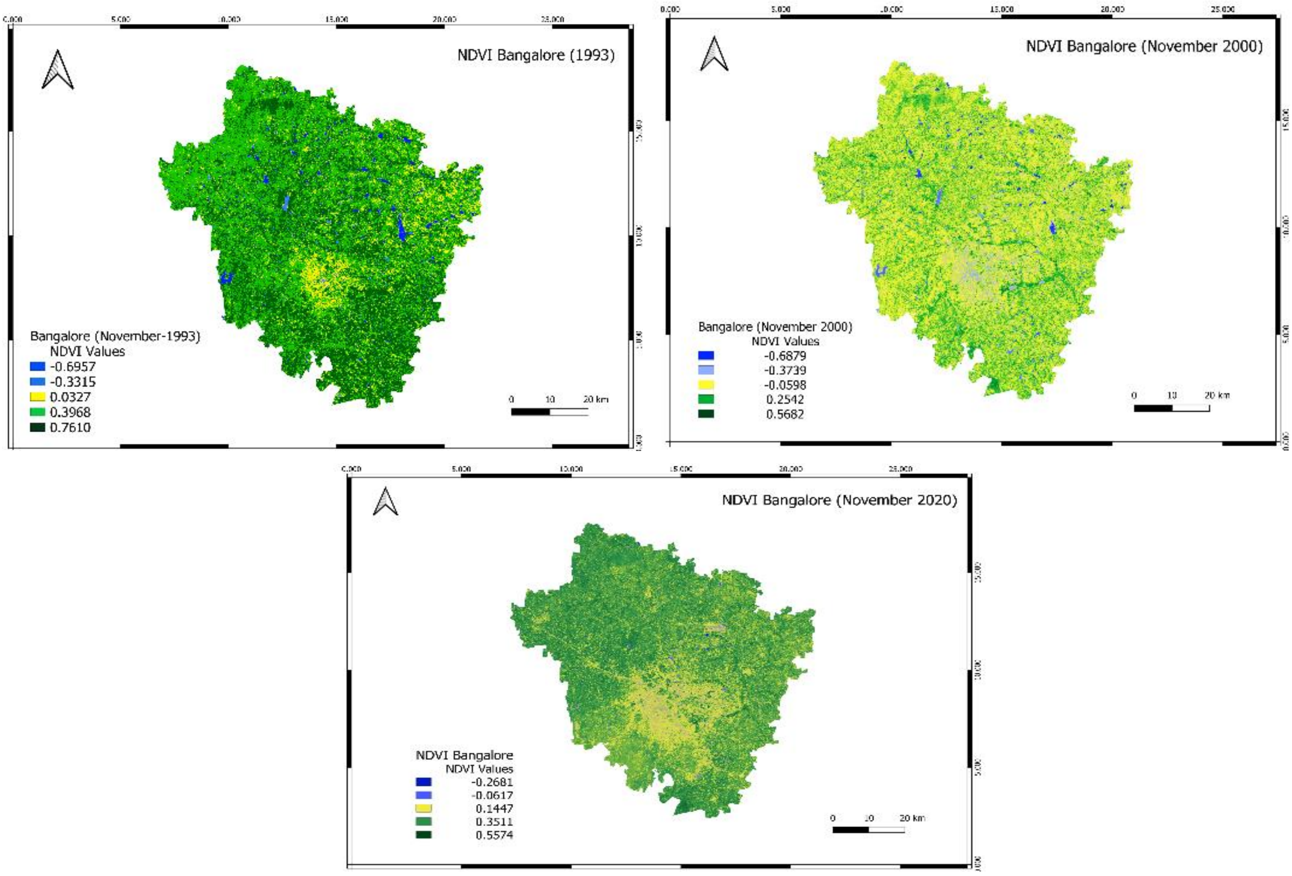


Figure 22 NDVI Bengaluru

The trend of NDVI shows that during the 10 years between the years 1990 to 2000, the rate of decrease in the dense vegetation of Bengaluru is very high, but during the 20 years, from 2000 to 2020 the decreasing rate is low. This implies that in recent years Bengaluru performed well to reduce its deforestation rate. During this period, Bengaluru increased its urban vegetation such as the dense scrubs, plants, trees and gardens which may be called “Urban Forests”.

Kolkata

Understanding the urban pattern

The LULC pattern of Kolkata was studied by using the following Landsat Data-

Year	Landsat Data	Acquired date
1980	LM03_L1TP_148044_19800116_20200906_02_T2	16 January 1980
2000	LE07_L1TP_138044_20001117_20200917_02_T1	17 January 2000
2021	LC08_L1TP_138044_20210204_20210303_02_T1	04 February 2021

The map (figure 23) of 1980 reveals that the city is densely urbanized in 1980. The urban agglomeration pattern in Kolkata is a combined pattern, which means the pattern of Urban sprawl with the infilling pattern. One of the reasons to develop dense Kolkata is better r and a

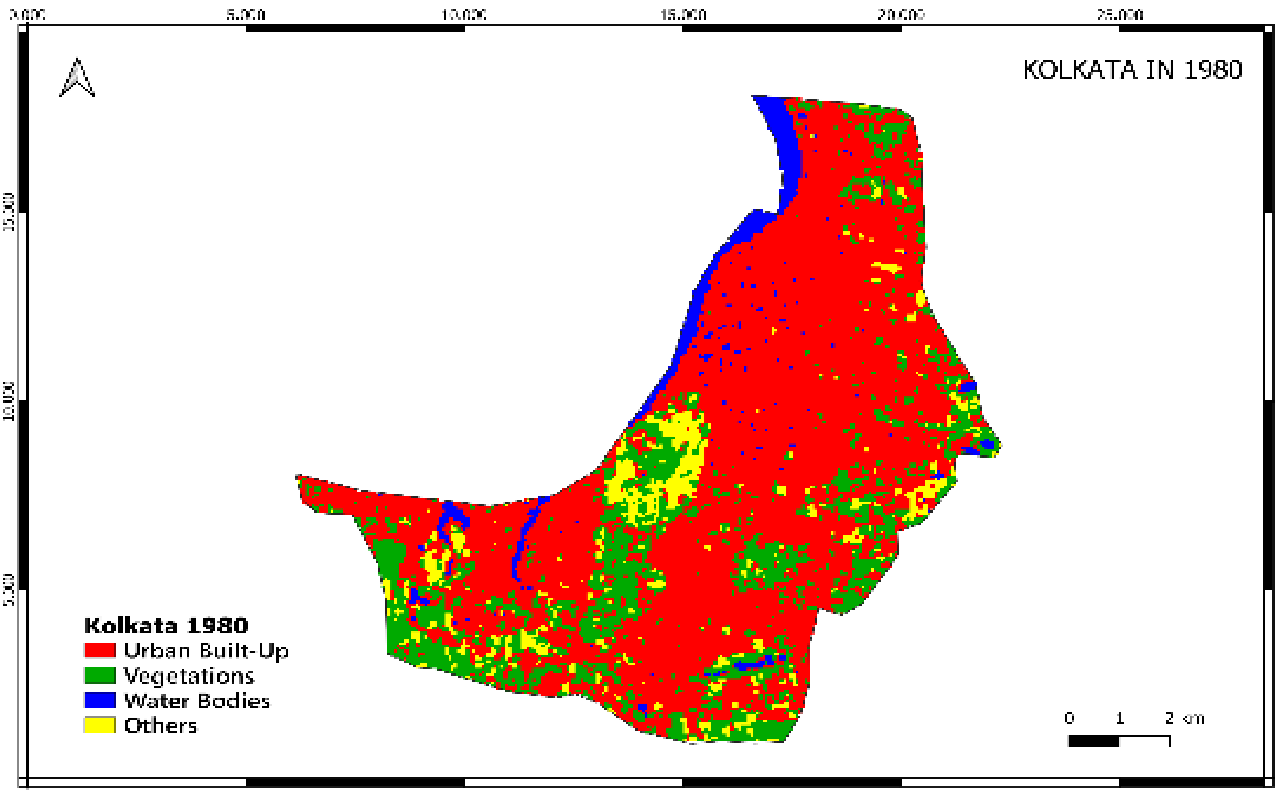


Figure 23: Land use in Kolkata 1980

more affordable transportation system from its early ages, which further helps to connect these sprawl and infillings.

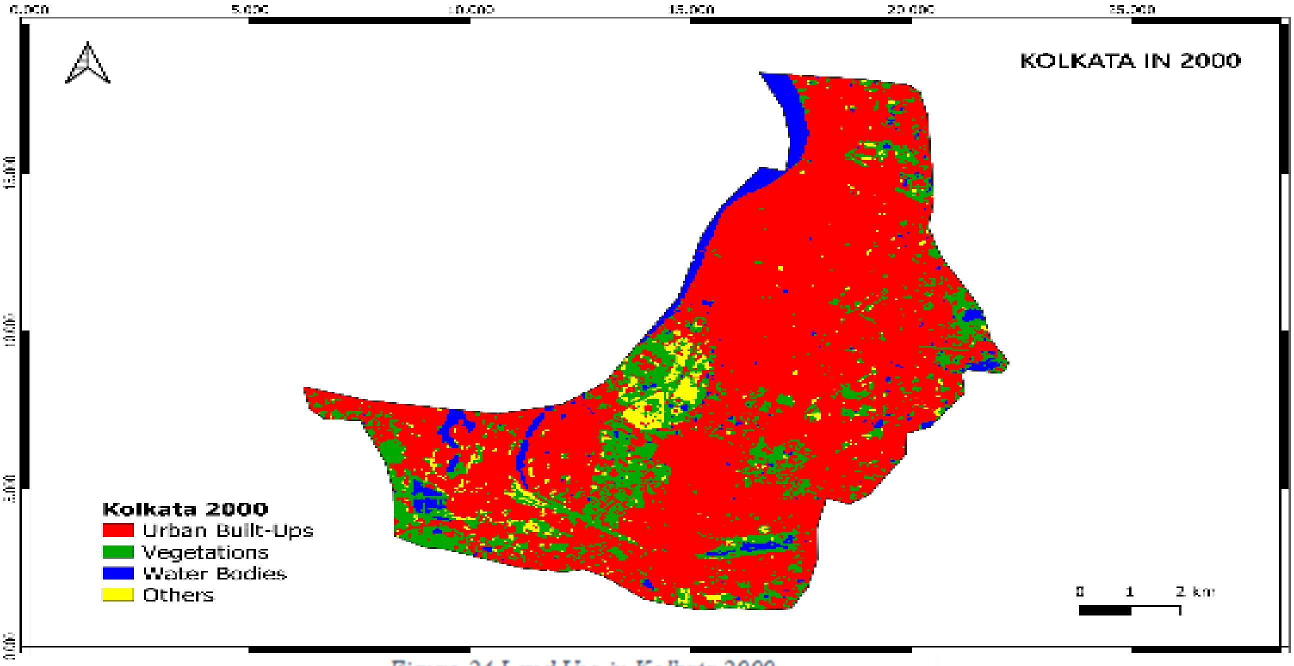


Figure 24 Land Use in Kolkata 2000

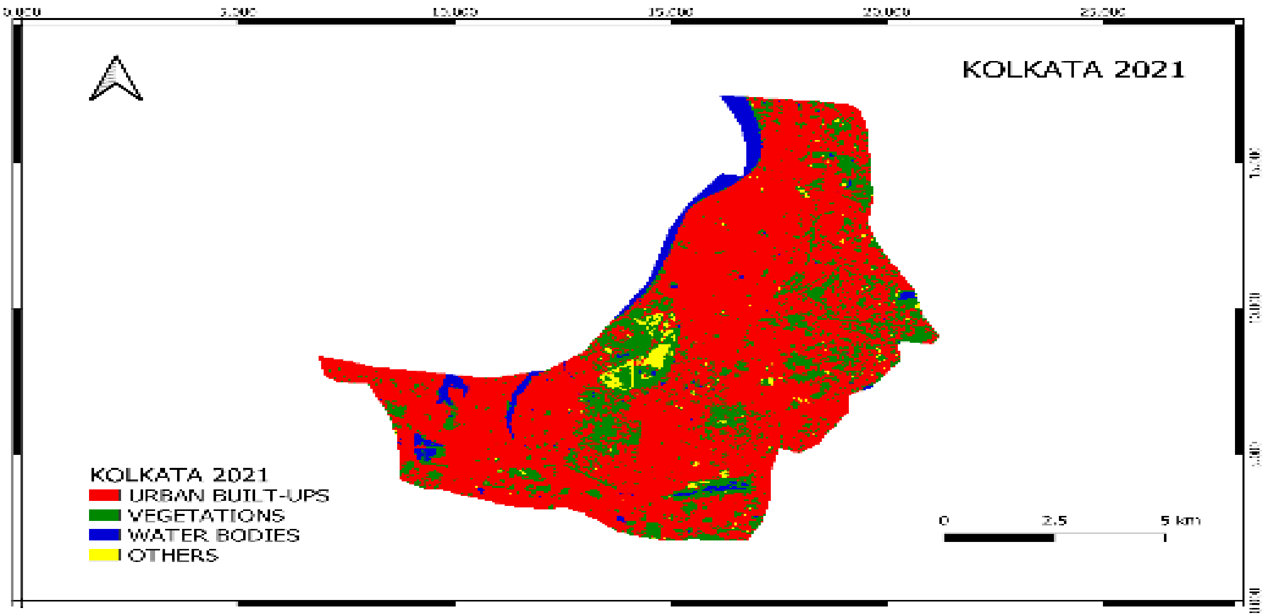


Figure 25: Land use in Kolkata 2021

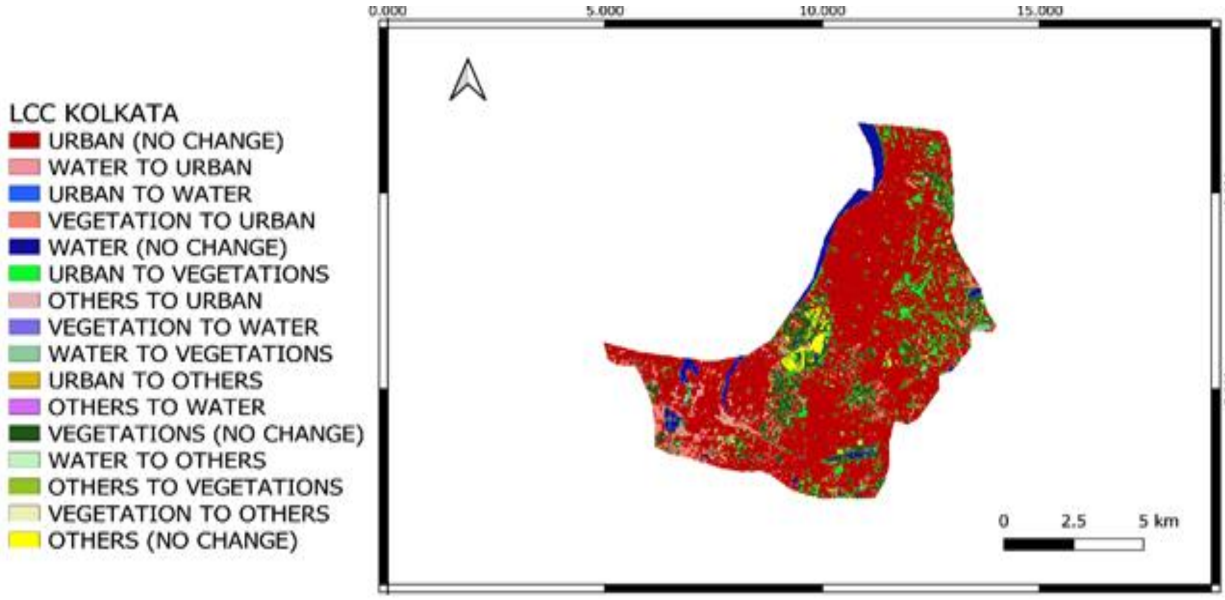


Figure 26: Land Change Classification Kolkata 2000-2021

Here in maps of LULC from 2000 to 2021 (figures 24 & 25), it can be seen that the largest proportion of the area is preoccupied with the urban landscape.

In 2000, urban area comprised 61 sq. km which increased to 69 sq. km in 2021 out of the total area of 91 km demarcated under the city of Kolkata. This means 76per cent of the total area was covered with the urban built-ups and only 10 km of land had vegetation. From the year 1980 to 2000, the position of water bodies improved especially in the south-west part of Kolkata. The map of 2021, shows that there has been an urban build-up in the south-west area. Kolkata maidan area has also witnessed reduced green areas. The north-eastern part of the city shows a loss of area under water bodies however, it also shows some improvement in the growth of vegetation in small patches between the urban sprawls. The light red (pink) color in the above map represents the new urban built-ups, while dark red is old urban space which is already been urbanized since 2000. As can be seen, some parts of the south-west of Kolkata urbanized after 2000. LULC pattern of Kolkata for the period 2000 to 2021 is given on the map (fig 26). The graph shows a change in the area of land use pattern of Kolkata between the period 2000 to 2021. It reveals that 6 sq. km of vegetation land was converted into urban space in the past 20 years. Around 61 sq. km area out of 91 sq. km of Kolkata Municipal was already urbanized in 2000 means that Kolkata was already a dense urban city with little scope for further expansion.

During this period, urbanization also led to a decrease in the area occupied by water bodies and green space available in the city.

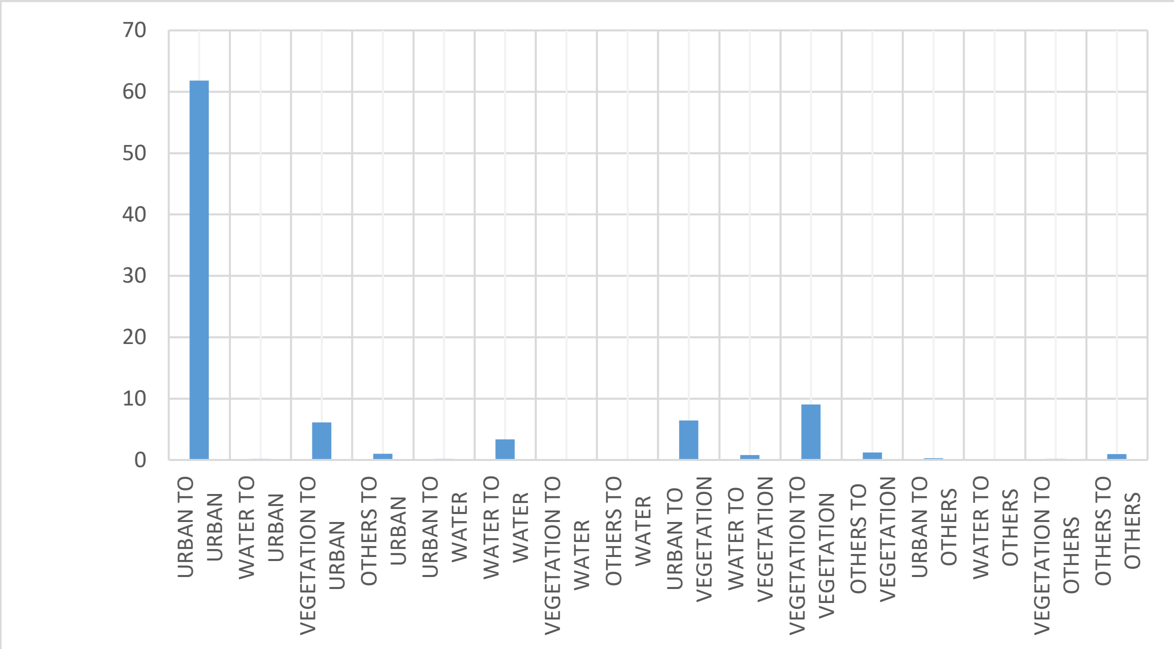


Figure 27: Change in Area of Land Use Pattern Kolkata 2000-2021

NDVI

The following Landsat data has been used to analyze NDVI of Kolkata city:

Year	Landsat Data	Acquired Date
1990	LT05_L1TP_138044_19901114_20200915_02_T1	14 November 1990
2000	LE07_L1TP_138044_20001117_20200917_02_T1	17 November 2000
2020	LC08_L1TP_138044_20201116_20210315_02_T1	16 November 2020

NDVI map of Kolkata is given in figure 28. It shows that the NDVI value is affected at both ends, i.e. at a minimum level and maximum level. The minimum NDVI value has reduced from -0.6 in 1990 to -0.17 in 2020, which means that the water bodies have been affected during this period. For vegetation, the maximum NDVI value in 1990 was reduced from 0.74 to 0.47 in 2000. It indicates that the area under dense vegetation zone in 1990 was reduced in the city from 1990 to 2000. However, little improvement in NDVI with a value increasing to 0.5 can be seen during the period 2000 to 2020 which validates the findings in the LULC pattern discussed earlier.

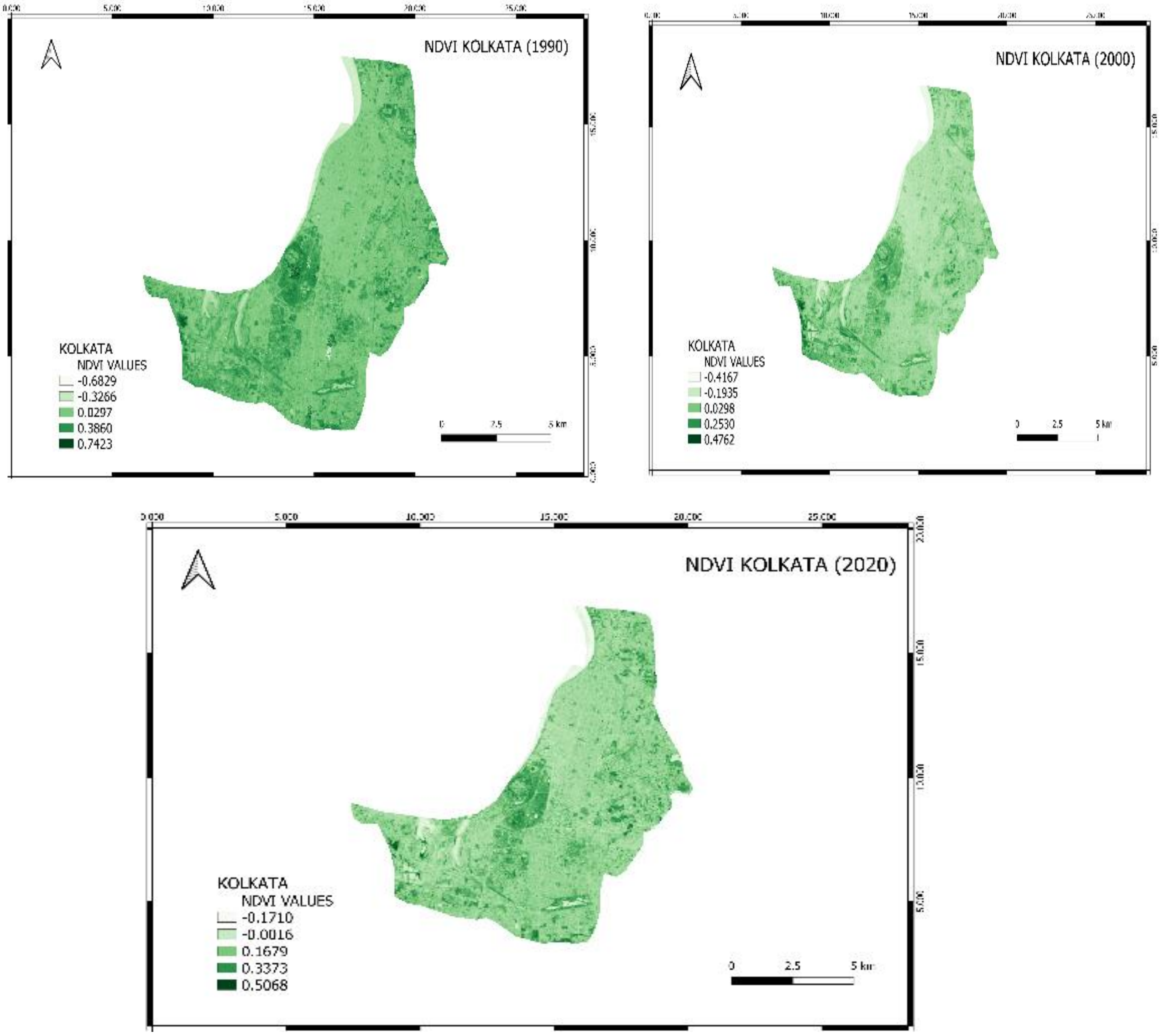


Figure 28 NDVI KOLKATA

Pune

Understanding the urban pattern

Following data was used to study the urban growth in the city of Pune.

Year	Landsat Data	Acquired Date
1989	LT05_L1TP_147047_19891212_20200916_02_T1	12 December 1989
1999	LE07_L1TP_147047_19991114_20200918_02_T1	14 November 1999
2020	LC08_L1TP_147047_20201115_20210315_02_T1	15 November 2020

The land use map of 1989 (fig 29) shows scattered urbanization with a major portion of the land under others category.

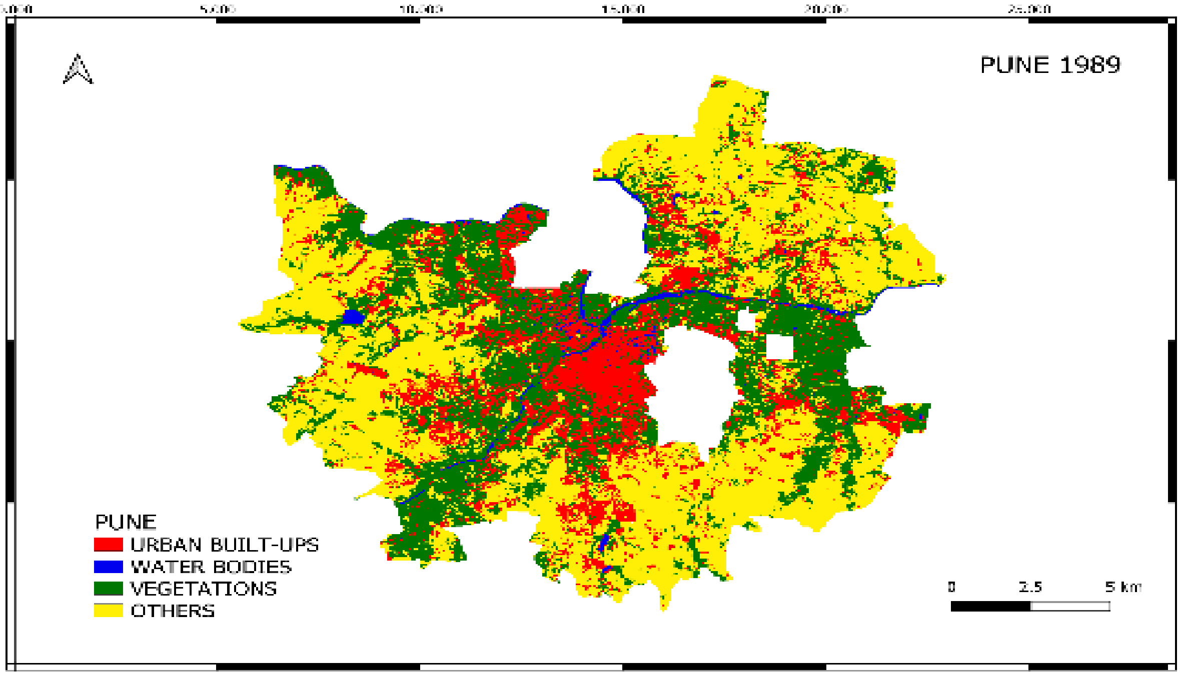


Figure 29: Land Use in Pune 1989

A comparison of the maps of 1999 with 1989 (figure 29 & figure 30), shows that there has been rapid urban growth in south-east and south-west of the city. The urban growth is especially located alongside water bodies and especially the Mula-Mutha river which is passing through the middle of the Pune city.

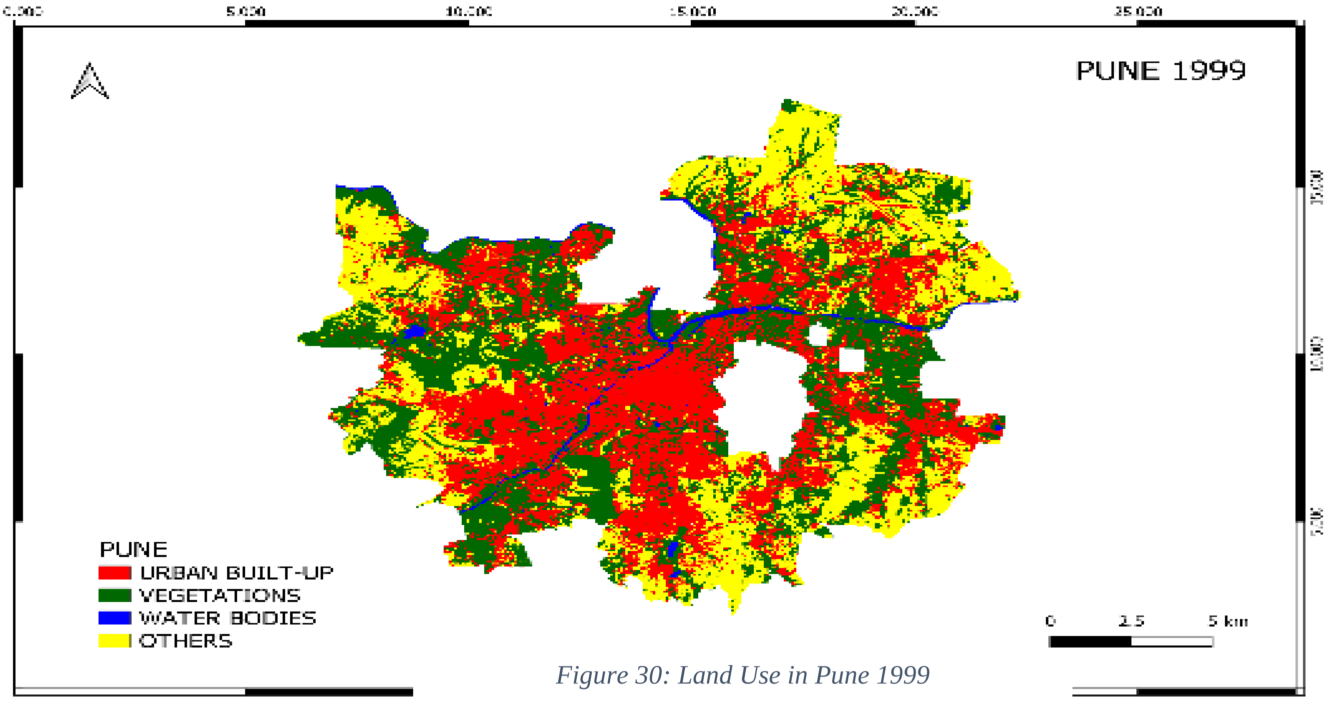


Figure 30: Land Use in Pune 1999

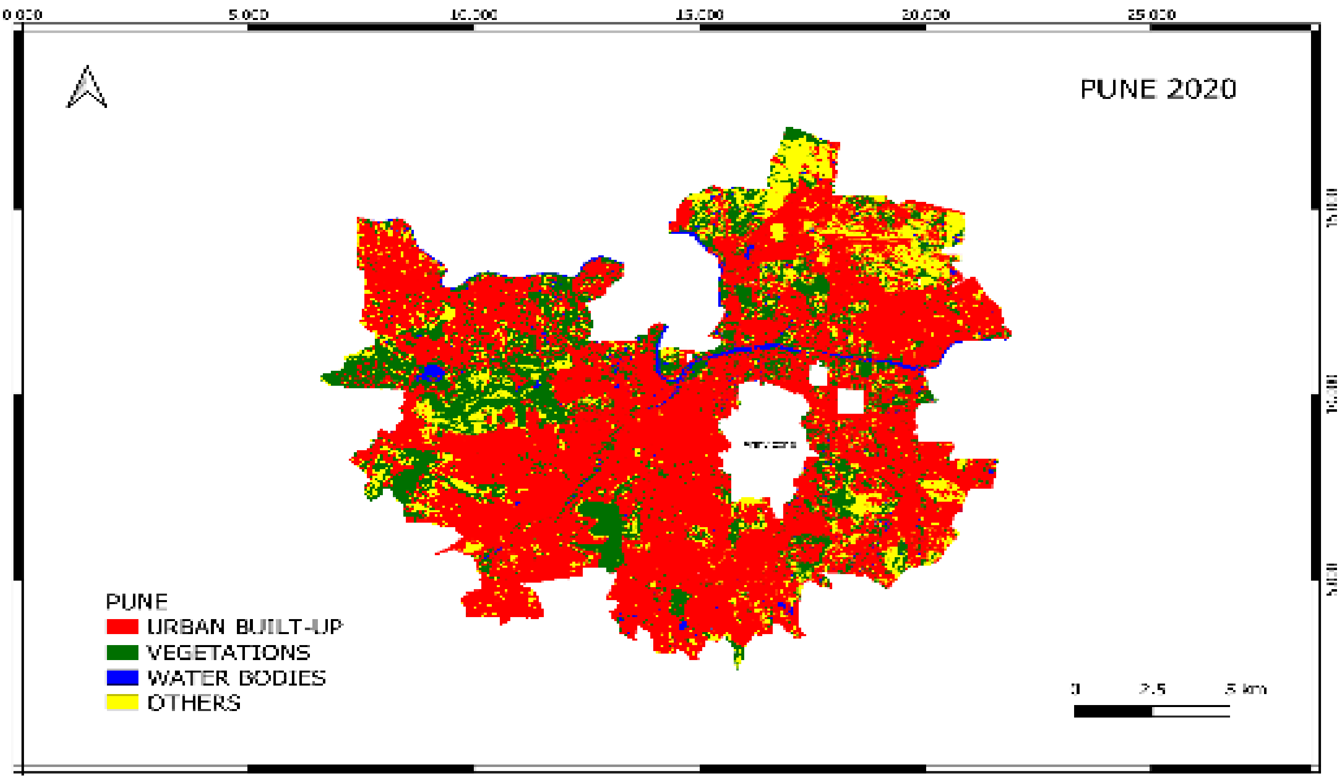


Figure 31: Land Use in Pune 2020

The map for the year 2020 (figure 31) shows a tremendous expansion of urban areas in the city of Pune. It is seen that during the period between 1999 and 2020, urbanization has covered almost all the areas coming under vegetation and other categories. There are signs of degradation of the Mula-Mutha river also along with other water bodies in the region.

In general, the pattern of change from a vegetation area to urban area is interrupted by other areas. However, in this case, many of the areas under vegetation have turned into urban areas directly from vegetation areas.

The LULC pattern of Pune for the period 1999 to 2020 is shown in figure 32. It can be noticed that there is a predominance of colors representing “Vegetation to Urban” and “Others to Urban” change segments. The graphical representation of LULC is also shown in figure 33.

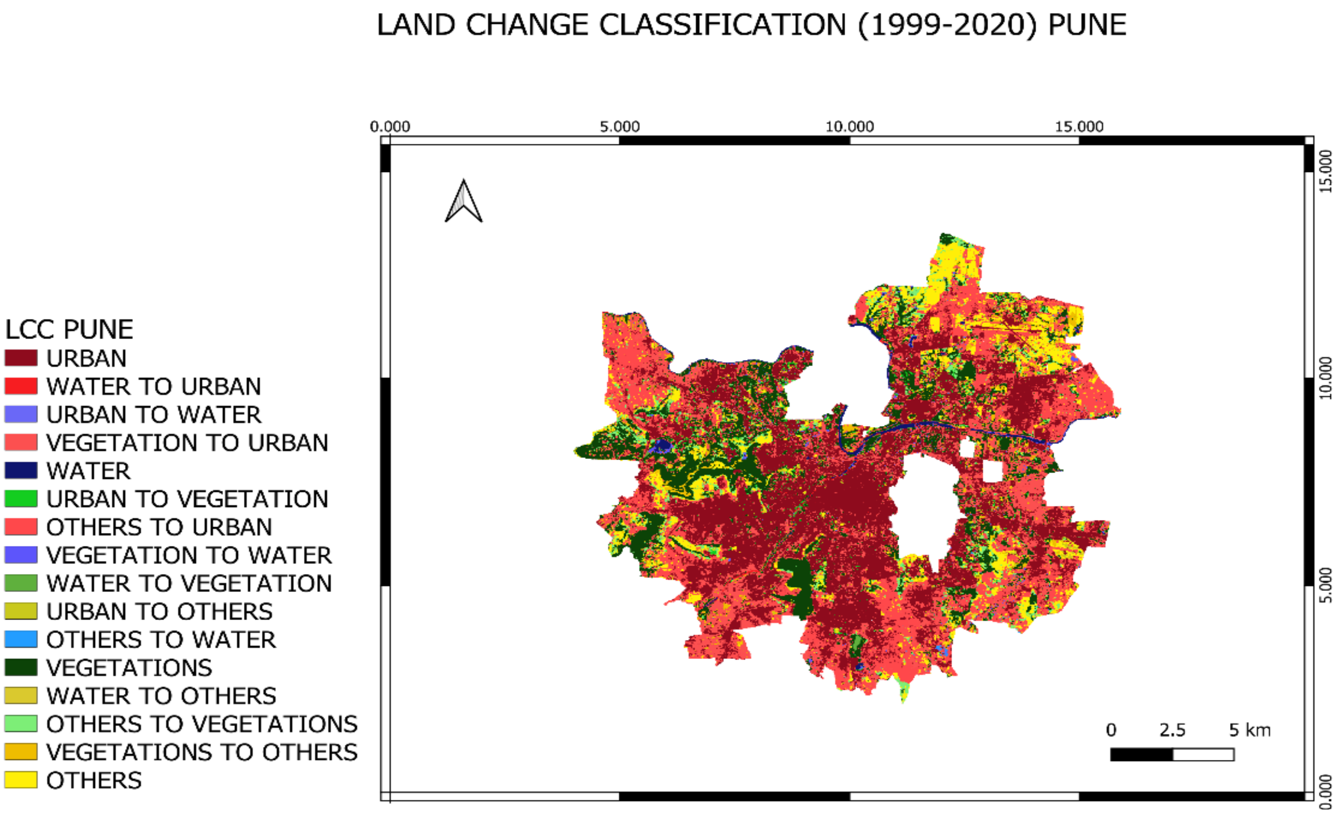


Figure 32: Land Change Classification Pune 1999-2020

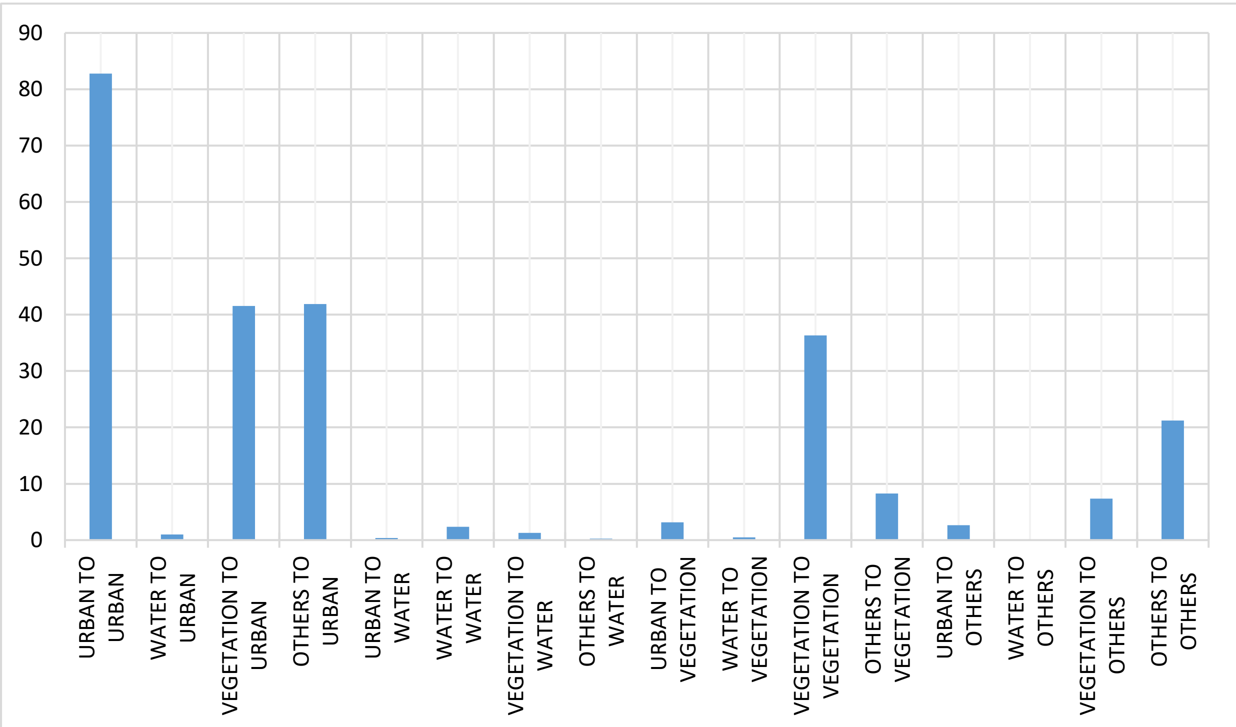


Figure 33: Change in Area of Land Use Pattern Pune 1999- 2020

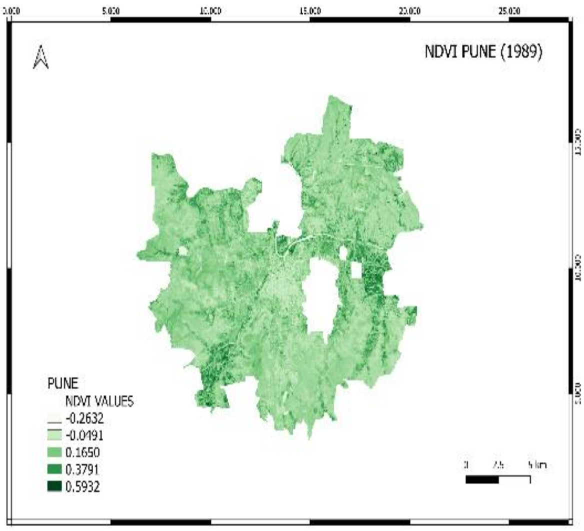
The LULC graph (figure 33), shows that 41.5 km of area under vegetation land had been converted into urban built-ups during the 20 years, while 42 km of the land of agriculture and barren land had converted into Urban built-ups during the same period. There was a total change in urban built-up from 82.79 km in 2000 to 167.25 km in 2020, witnessing growth in urban areas by over 200 per cent in 2the 0 years.

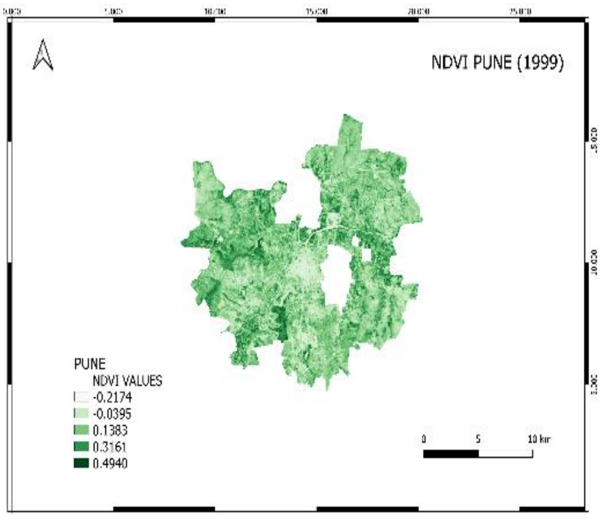
NDVI:

The NDVI for Pune city was studied for the years 1989, 1999 and 2020.

An analysis of NDVI results in Pune shows a decreasing trend from 1989 to 1999 and an increasing trend from 1999 to 2020 indicating that the dense vegetation increased from 1999 to 2020.

The vegetation cover in Pune is impacted largely because of increasing urban agglomeration as more than 41 km of vegetation is directly converted into urban built-ups as shown in figure 34.





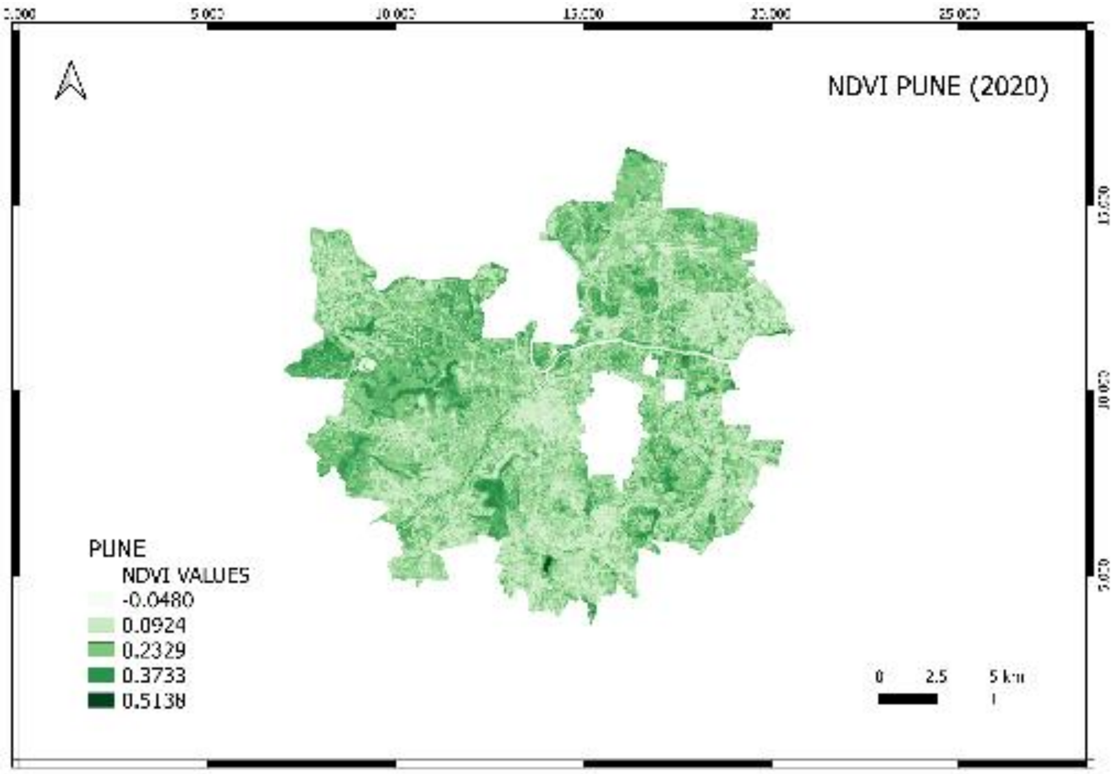


Figure:34 NDVI Pune

Indore

Understanding the urban pattern

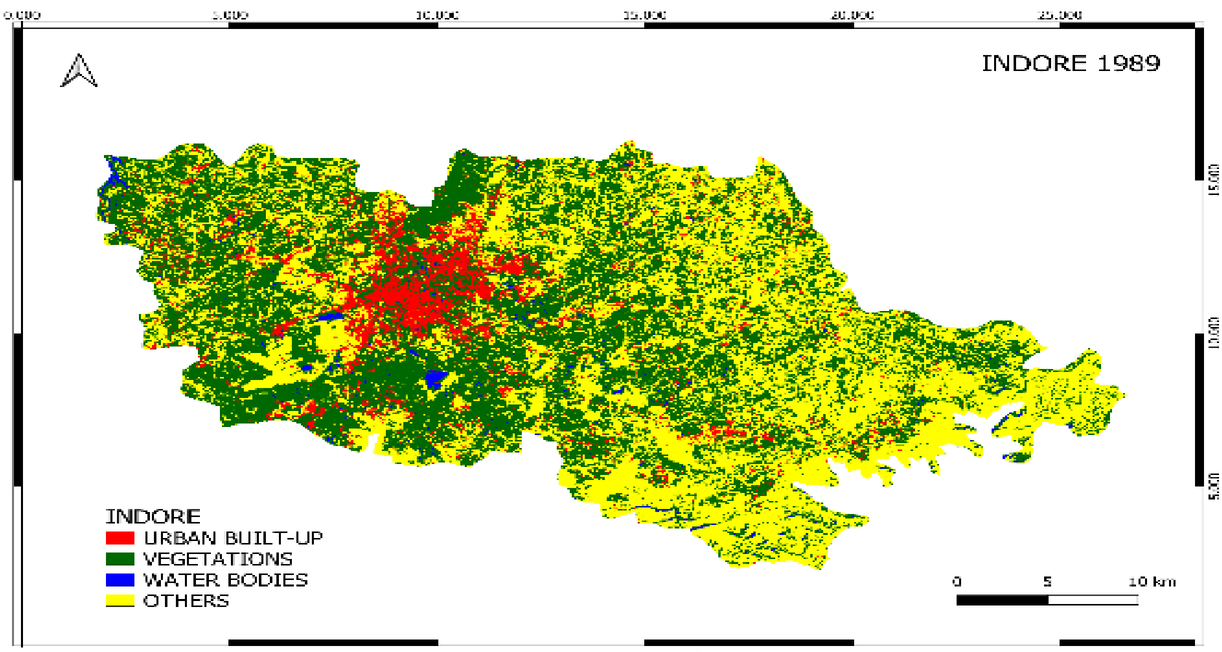


Figure 35: LAND USE IN INDORE 1989

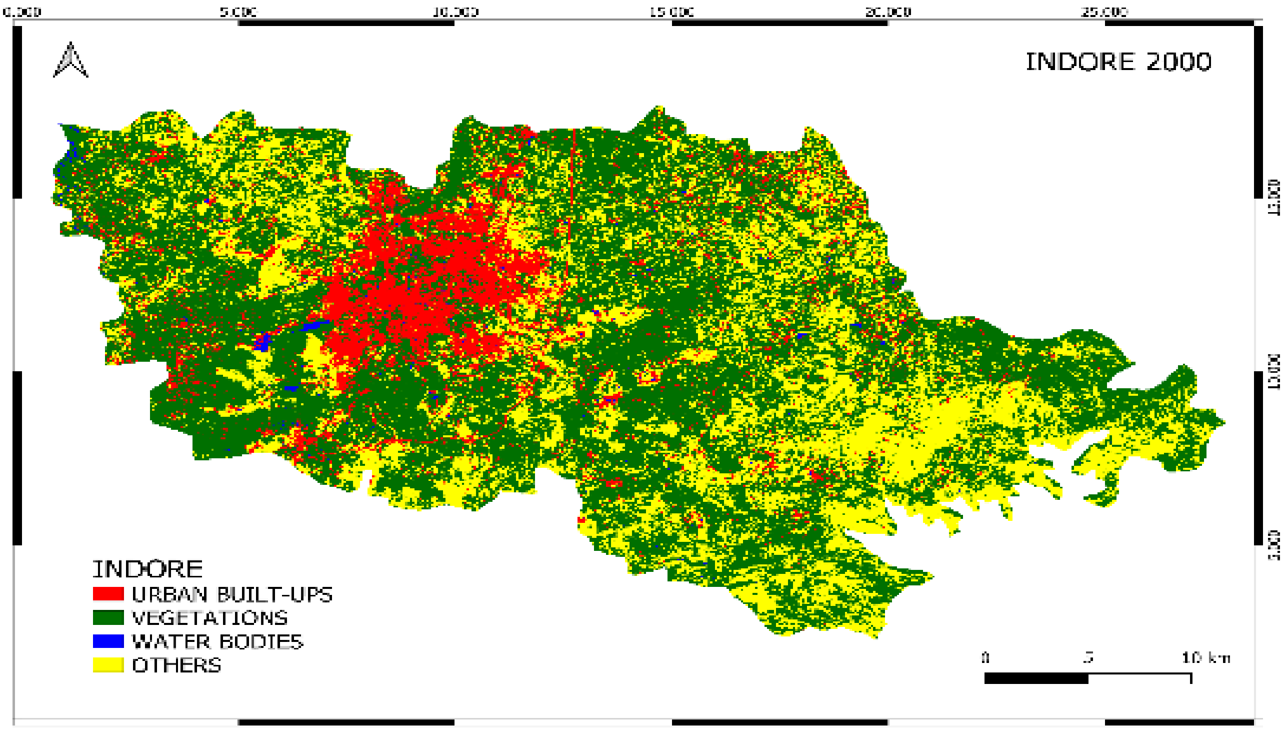


Figure36: LAND USE IN INDORE 2000

The land use map of Indore for the year 1989 (figure 35) shows a major portion of total land under vegetation and others category. Urban areas marked in red color are also seen.

A comparison between the maps for the years 1989 (figure 35) and 2000 (figure 36) shows that there has been an increase in the areas of urban settlements. Also, there is a peculiar pattern of urbanization, in which small urban areas are emerging at various locations of the city. These areas are connected with the main city through roads and habitations can also be seen along those roads.

A comparison of maps for the years 2000 and 2020 reveals the expansion of urban areas in and around the main city of Indore. The land under the “Others” category is also seen to be replaced by vegetation. Also, a few waterbodies are coming into existence by the year 2020.

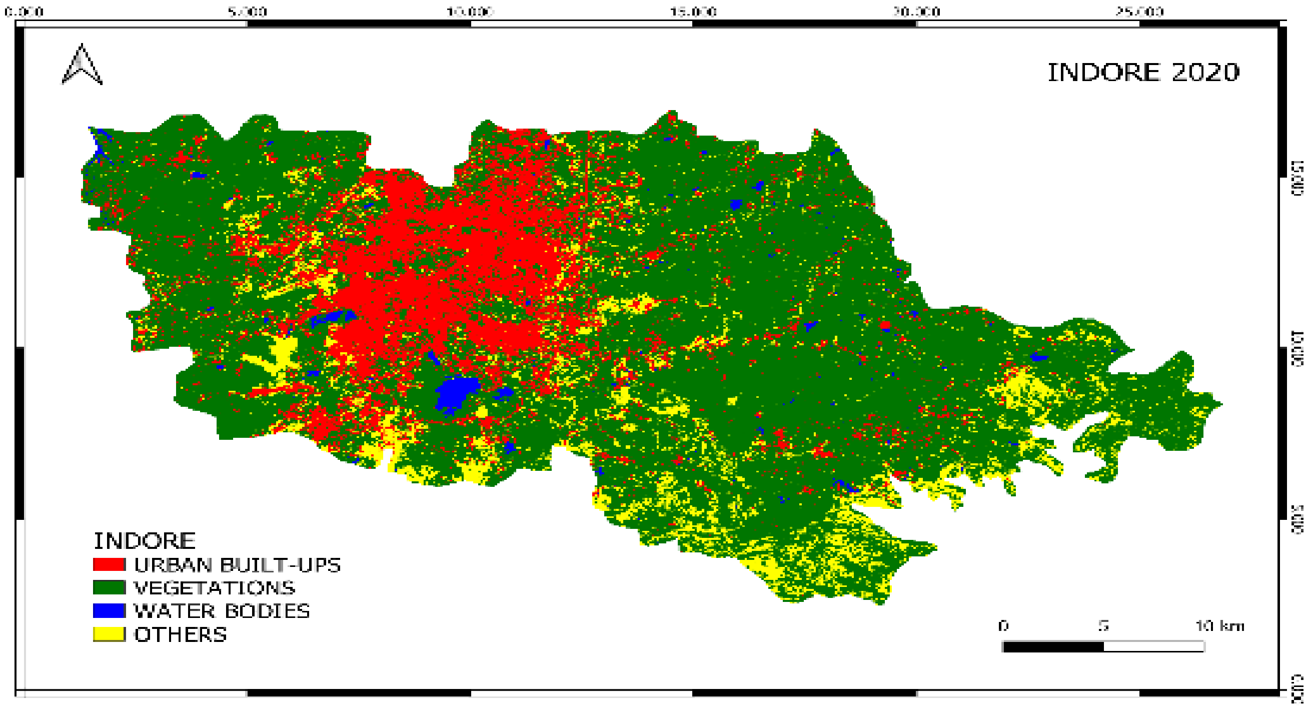


Figure 37: LAND USE IN INDORE 2020

The rate of urbanization in Indore is high, but the proportion of urban built-up in land use is 17per cent of the total area. Even the proportion of land under vegetation, water and agricultural land is still high in the Indore district, which makes Indore a balanced and eco-friendlier urban city.

The LULC pattern map (figure 38) validates the findings given above in color codes. The graphical representation (figure 39) shows that the change from the vegetation area to urban area is 58.6 sq. km. Around 41 sq. km of the “Others” area has also been converted into urban areas. This shows that the total area of Indore city increased from 77.97 sq. km in 2000 to 179.16 sq. km in 2020 which is more than 200 per cent growth of urbanization occurring in between 20-years time period.

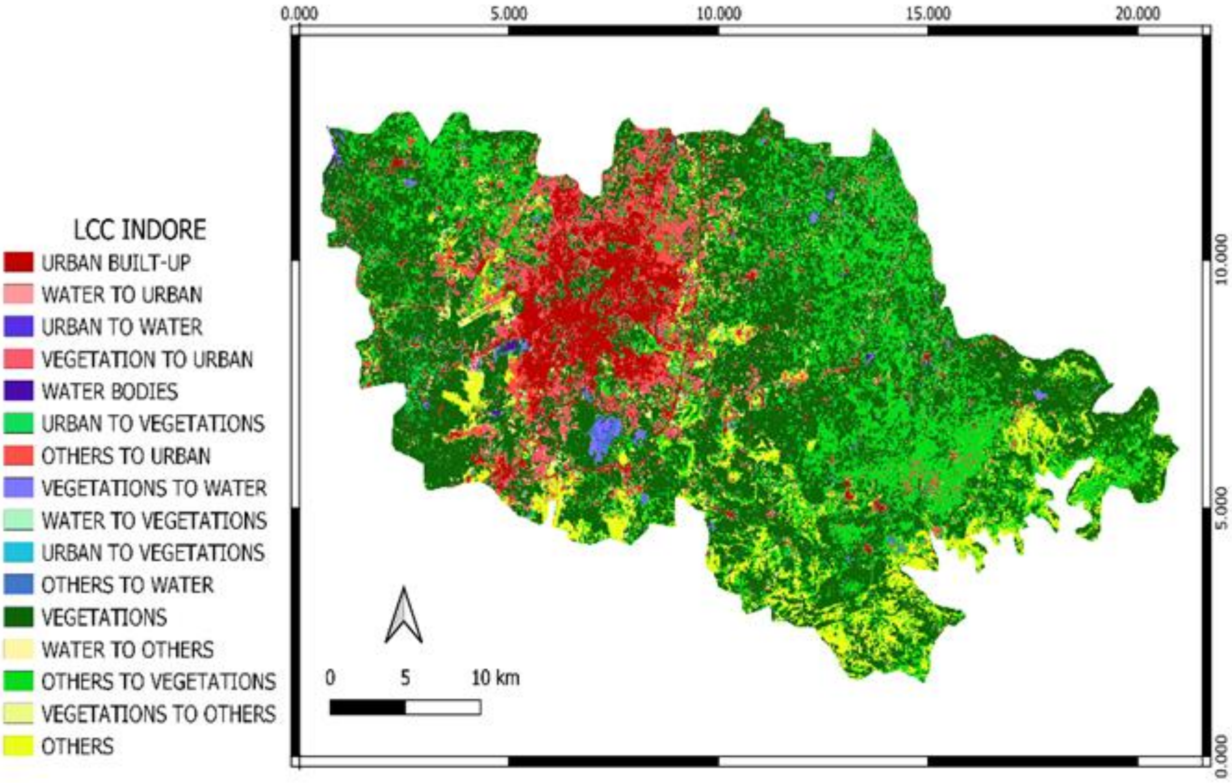


Figure 38: LAND CHANGE CLASSIFICATION INDORE 2000-2020

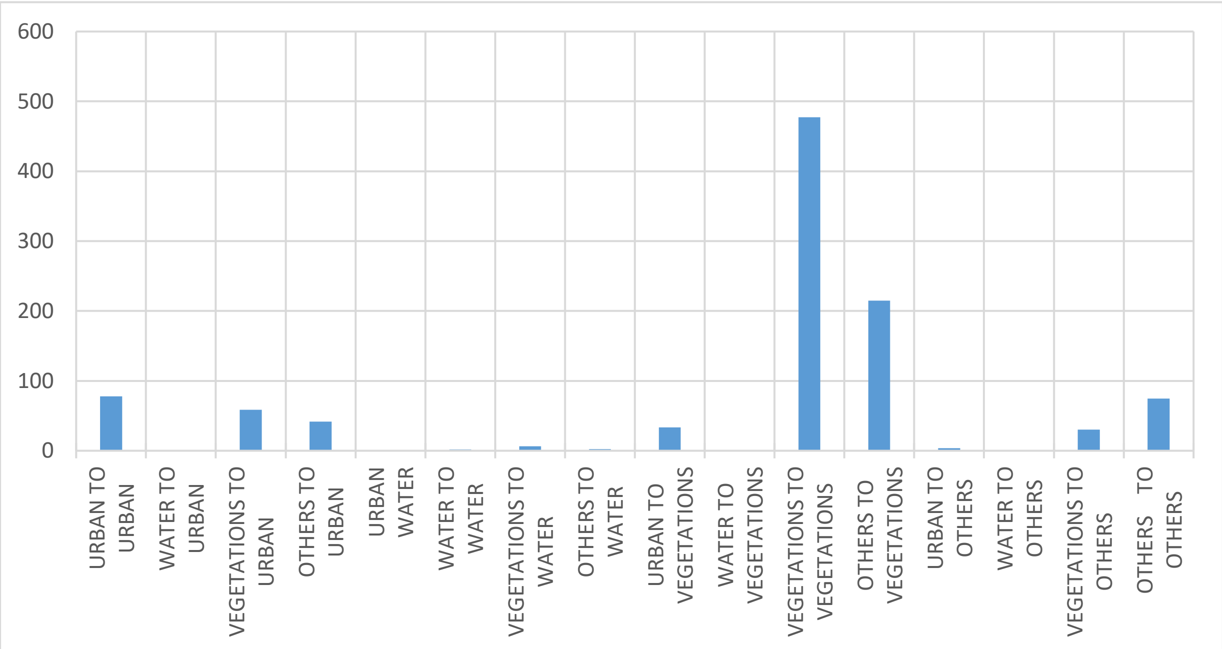


Figure 39: Change in Land Use Pattern Indore 2000-2020

NDVI

Decreasing the trend of NDVI value from 0.712 in 1989 to 0.44 in 2000 (Figure 40), implies the reduced vegetative area and especially the densely vegetation but further in 2020, the value increased to 0.47 which means an improvement of 0.03 in densely vegetation area.

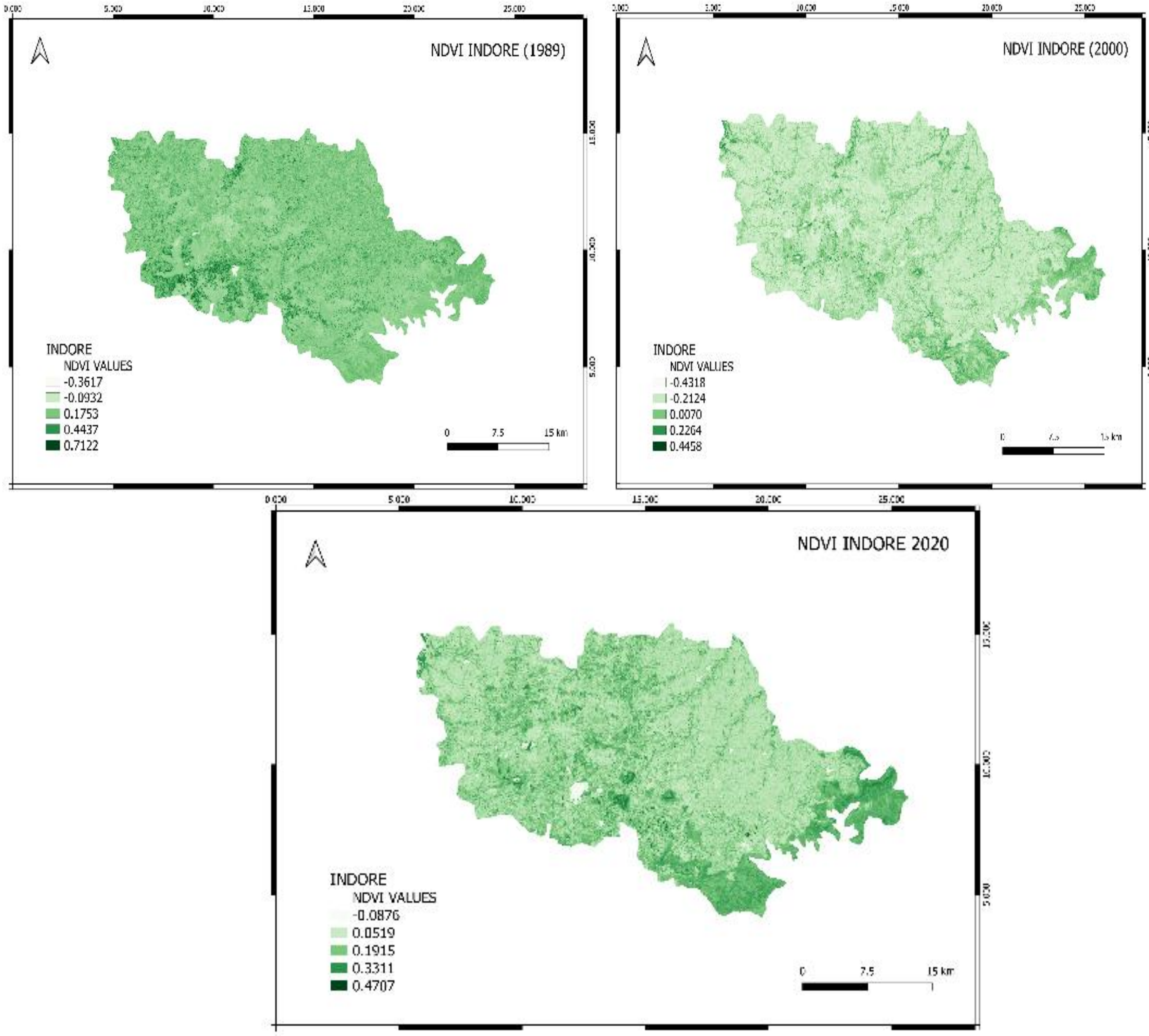


Figure 40: NDVI Indore

Indore has a larger proportion of vegetation area in its total area, which balances the urban emissions and makes it better performing on the scale of sustainability.

2.2.4 Land change classification and comparison

Shapefiles downloaded were used to carry out the study for Delhi, Bengaluru, Kolkata, Pune and Indore using QGIS and an attempt has been made to compare the land change classification of the cities. Graphs obtained from the study have been used. The table below demonstrates the quantification of the qualitative aspect of urbanization using estimation through QGIS software.

- In Column A, the total area (in sq km) calculated using research site maps
- In Column B, the urban area (in sq km) is calculated using data files
- In Column C, the new urban area of the cities between the period 1980/1989/1991 to 2020/2021 is calculated by comparing the maps
- In Column D, the difference between Col C and Col B is divided by 20 years to determine the rate of change in the urban area
- In Column E, percentage of the urban area is calculated based on the formula: Col C/Col A*100

Formulas-

Percentage of Urbanization (per cent) = (Urban area in 2021 / Total area of the city) * 100

Urban area changes rate (sq km/year) = (Urban Area in 2021 – urban Area in 2000) / 20

- In Column F, urban area change pattern, values are already calculated through QGIS software and a Graph of urban area change pattern is generated for each city as provided in previous paragraphs. The findings during the study on urban area change pattern for each city has been summarized in the table.

Table 1

<table>
<tr><th>City</th><th>Total Area (in sq km) A</th><th>Urban Area (In sq km) 2000 B</th><th>New Urban Area (in sq km) 2021 C</th><th>Urban area changes rate (sq km/year) D</th><th>Percentage of the urban area to total Area (in 2021) E</th><th>Urban area Change pattern F</th></tr>
<tr><td>Delhi (Refer Figure 15 for Col F values)</td><td>1502</td><td>402.64</td><td>637.97</td><td>11.76</td><td>42.47</td><td><table><tr><th>FROM</th><th>TO</th><th>CHANGE AREA</th></tr><tr><td>Water</td><td>Urban</td><td>3.13</td></tr><tr><td>Vegetation</td><td>Urban</td><td>115.60</td></tr><tr><td>Others</td><td>urban</td><td>116.77</td></tr></table></td></tr>
</table>

<table>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>Bengaluru (Refer to Figure 21 for Col F values)</td><td>4496</td><td>344.65</td><td>1062.51</td><td>35.92</td><td>23.62</td><td><table><tr><th>FROM</th><th>TO</th><th>CHANGE AREA</th></tr><tr><td>Water</td><td>Urban</td><td>97.54</td></tr><tr><td>Vegetation</td><td>Urban</td><td>358.20</td></tr><tr><td>Others</td><td>urban</td><td>262.12</td></tr></table></td></tr>
<tr><td>Kolkata (Refer to Figure 10 for Col F values)</td><td>91</td><td>61.82</td><td>69.09</td><td>0.36</td><td>75.92</td><td><table><tr><th>FROM</th><th>TO</th><th>CHANGE AREA</th></tr><tr><td>Water</td><td>Urban</td><td>0.15</td></tr><tr><td>Vegetation</td><td>Urban</td><td>6.10</td></tr><tr><td>Others</td><td>urban</td><td>1.02</td></tr></table></td></tr>
<tr><td>Pune (Refer Figure 33 for Col F values)</td><td>251</td><td>82.79</td><td>167.25</td><td>4.25</td><td>66.63</td><td><table><tr><th>FROM</th><th>TO</th><th>CHANGE AREA</th></tr><tr><td>Water</td><td>Urban</td><td>0.99</td></tr><tr><td>Vegetation</td><td>Urban</td><td>41.56</td></tr><tr><td>Others</td><td>urban</td><td>41.91</td></tr></table></td></tr>
<tr><td>Indore (Refer to Figure 11 for Col F values)</td><td>1025</td><td>77.97</td><td>179.16</td><td>5.05</td><td>17.47</td><td><table><tr><th>FROM</th><th>TO</th><th>CHANGE AREA</th></tr><tr><td>Water</td><td>Urban</td><td>1.06</td></tr><tr><td>Vegetation</td><td>Urban</td><td>58.67</td></tr><tr><td>Others</td><td>urban</td><td>41.46</td></tr></table></td></tr>
</table>

S. No.	Summary of Findings		
1.	Percentage of Urbanization (per cent) - (Rank)/Reasons	Kolkata 75.92 - (1)	Kolkata being a Port city has more livelihood opportunities leading to large migration, the area under Kolkata municipality is less compact as compared to other research cities under analysis.
		Pune 66.63 - (2)	Pune has employment opportunities and an increased IT sector supported by better transport facilities and other nearby suburban areas to urbanize at a higher rate.
		Delhi 42.47 - (3)	Delhi, being the capital has a lot of employment opportunities. Better transport facilities, education services and employment opportunities are major causes of migration.

		Bengaluru 23.62 - (4)	Availability and suitable infrastructure, IT hub makes Bengaluru suitable to attract the youth for employment. Added to it are high-quality education and service utility opportunities.
		Indore 17.47 - (5)	Indore has low urban built-up as compared to other cities covered in this study.
2.	Urban Area change rate (Urbanization rate)- (sq km/year) (Rank)/Reason	Bengaluru 35.92- (1)	Bengaluru has the highest urban expansion rate
		Delhi 11.76- (2)	In Delhi, heavy construction and built-up are increasing day by day, which shows a dense and unplanned pattern of growth. Protected regions like Aravali hills and other protected areas are covered. Metro expansion in Delhi is one of the causes of rapid urbanization.
		Indore 5.05- (3)	Indore has a large municipal area and performs well in the area of planning and local governance. Indore was ranked 1st under the municipality performance index and the best city for all time prepared by the Ministry of Urban Affairs.
		Pune 4.25 - (4)	There was a total change in urban built-up from 82.79 km in 2000 to 167.25 km in 2020, witnessing growth in urban areas by over 200 per cent in 20 year time period.
		Kolkata 0.36 - (5)	Kolkata was already urbanized with dense agglomerations even in 1980 and 2000 and has less scope for further urbanization within the demarcated municipal area.
3.	Urban Change Pattern from Water to Urban	Bengaluru 97.54 (1)	A total of 97 sq. km of area under water bodies was converted into an urban pattern. Lakes in Bengaluru have been reduced at a very high rate.

		Delhi 3.13 (2)	Delhi has also shown that some parts of its water bodies have vanished due to the expansion of urban areas.
		Indore 1.06 (3)	The change from water body areas to urban areas in Indore is very less as compared to Bengaluru.
		Pune 0.99 (4)	Pune has shown very less change from water body areas to urban areas.
		Kolkata 0.15 (5)	The water bodies in Kolkata have been least affected by urbanization among the five cities.
4.	Urban Change Pattern from Vegetation to Urban	Bengaluru 358.20 (1)	In Bengaluru, a vegetative area of 358 km has also been used directly in urban built-ups during 20 year time period.
		Delhi 115.60 (2)	An approximate vegetation area of 115.60 km has been changed to an urban area in Delhi from 2000 to 2021.
		Indore 58.67 (3)	Indore has recorded a change in vegetation area of 58.678 km to urban build-up area during the period of 20 years (2000 to 2020.)
		Pune 41.56 (4)	The total change in urban built-ups from 82.79 km in 2000 to 167.25 km in 2020, which is doubled in 20 years. e has experienced a change in vegetation area of 41.56 km into urban build-up area during the period 1999-2020.
		Kolkata 6.10 (5)	Kolkata has shown the lowest change from vegetation to an urban area (6.10 km) during the period 2000 to 2021.
5.	Urban Change Pattern from Others to Urban	Bengaluru 262.12 (1)	In Bengaluru 262 sq. km area of agricultural and other land got converted into the urban built-up area.

		Delhi 116.77(2)	Conversion of agricultural land and other lands into urban areas is also high (116.77 km) in Delhi during the period 2000-2021.
		Pune 41.91(3)	In Pune 41.91 sq. km of agricultural land and other land has been converted into an urban area from 1999 to 2020.
		Indore 41.46 (4)	Indore has shown approximately equal area under agricultural land and other land which has turned into the urban, area during the period 2000- 2020.
		Kolkata 1.02 (5)	The change in Kolkata for "Others to Urban" is the lowest. This may be owed to the fact that Kolkata already has the highest proportion of area under urban build-ups with little scope for conversion of available agriculture and other areas into urban areas.

2.2.5 Conclusion

As far as the proportion of urbanization as a percentage of the total area is concerned, Kolkata has the highest proportion of the urbanized area followed by Pune, Delhi and Bengaluru. Kolkata was already urbanized with dense agglomerations even in 1980 and 2000 and has less scope for further urbanization within the demarcated municipal area. As a result, it has more area converted into urban areas, but the lowest rate of urbanization. Indore has the lowest urban built-up.

The study also considered the rate of urbanization i.e. increase in urban area per sq km per year in the five selected cities during the 20 years. It was found that Bengaluru has the highest urban expansion rate followed by Delhi, Indore, Pune and Kolkata. The pattern of urbanization in Pune and Kolkata indicates area-wise large growth in built-ups, but at a steady pace and at a comparatively slower rate vis a vis other three cities covered in this study.

<u>The inference drawn from the study therefore, indicates that the pattern of urbanization noticed in five selected Indian cities varies in terms of urban built-up areas and the rate of urbanization. It is noticed that the cities with the highest proportion of urban areas also showed a slower rate of urbanization during the 20 years covered in this study.</u>

It is also seen that the vegetation areas are rapidly converting into urban areas. It is observed that a 358 sq km vegetative area has been used directly for urban-built in Bengaluru. The conversion rate is almost twice as high as Delhi and significantly higher than the other selected cities. Conversion of land uses towards urbanization also has an impact on water areas. Data about Bengaluru city showed that 97 sq km of water bodies were converted into urban areas, which was followed by Delhi in terms of conversion of water areas into urban areas. The conversion of water bodies into urban patterns impacts the vegetation /biodiversity in cities. Besides, other agricultural lands, barren lands are converted into urban built-ups. It is noticed that a total of 262 sq km of such area was converted into urban built-up in Bengaluru followed by Delhi with 116 sq km area converted into urban built-up areas.

City-wise findings related to the pattern of urbanization and land-use changes in the five selected Indian cities are described in the following paragraphs:

1. Bengaluru has the highest urbanization rate. The city has also lost most of the areas under water bodies, vegetation and other agricultural areas. During the period of 10 years period between1991 and 2000, the rate of decrease in the dense vegetation of Bengaluru was very high, which slowed down between 2000 and 2020. This implies that in recent years Bengaluru performed well to reduce the deforestation rate. During this period, Bengaluru increased its urban vegetation such as the dense scrubs, plants, trees and gardens which may be referred to as ‘Urban Forests’.

2. As far as urbanisation is concerned, Delhi follows Bengaluru with a high rate of urbanisation. The city is also losing its water areas, vegetation and agricultural sources which are converted into urban built-up areas. In Delhi, the green cover has increased, but the dense forest and healthy vegetation have decreased with the decline in NDVI value, from 0.54 in 2000 to 0.4 in 2020. The dense vegetation may likely have changed into moderate vegetation and no vegetation. This gives a significant indication of environmental exploitation and deforestation due to urban expansion.

3. Indore has the lowest proportion of conversion of land to urban built-ups, but it has a larger municipal area and also conversion of underwater and vegetation areas into urban areas is comparatively higher than Pune and Kolkata. Since Indore has a higher proportion of vegetative area in its total area, it performs better on the sustainability scale.

4. Pune has a larger proportion of the area converted into urban but the rate is stabilized due to scarcity of land and it reflects in other parameters also. The rate of urbanization doubled in 20

years involving a reduction in vegetation area. NDVI results of Pune that the vegetation cover in Pune is impacted largely because of increasing urban agglomeration as more than 41 km of vegetation is directly converted into urban built-ups

5. Kolkata has the highest urban proportion and lowest urbanization rate as it was already an urbanized city and has a less municipal area (covered in the study). In all other parameters also, Kolkata shows lower rates of conversion of land for urban built-ups. Kolkata's minimum NDVI value has reduced from -0.6 in 1990 to -0.17 in 2020, which means that the water bodies have been affected during this period. For vegetation, the maximum NDVI value in 1990 is 0.74, which was reduced to 0.47 in 2000. It indicates that the area under dense vegetation zone in 1990 was reduced in the city from 1990 to 2000. However, little improvement in NDVI with a value increasing to 0.5 can be seen during the period 2000 to 2020.

2.2.6 Recommendations

Possible types of sustainable urbanization and consideration of variables to plan urban structure:

Greenfield urbanization: Urbanization which is proposed to be planned from the scratch and which involves total new planning and infrastructure is known as green-field urbanization. In India Amaravati, the capital of Andhra Pradesh is a green-field project which is very large in scale.

It is required to encourage Green-field urban development with a proper proposed plan and Geographical Information System mapping with the help of modern technology.

Variables important to consider in green-field planning are given below-

- Land acquisition and efficient/smart use of land with advanced technology.
- Consideration of land use proportion to divide the uses of land into multiple subcategories.
- Public services which are a very essential key to making urban space sustainable must be kept in mind. Like water quality and quantity, sustainable transport etc.
- Crisisis and disaster management for the future.
- Decentralized planning from zonal to the master plan for past, present and future.

Brown-field urbanization: Urbanization is planned for the expansion or improvement of the existing urban pattern. In the case of India brown-field urbanization project is for the mega and old cities which are already existed for several decades, but updating these is still a big challenge in India. It is required to encourage brown-field urban development and carefully develop the urban periphery and regulate the plan accordingly.

An example of this is “sponge city” which is a new urban building concept for flood management, ecological infrastructure, and drainage systems. “Sponge city” policies involve nature-based solutions that use natural landscapes to catch, store, and filter water.

Need for regular Impact Assessment: Assessment of urban policy and planning is very important to know about the progress of action taken by authorities:

- Efforts are required for imparting necessary information for sustainable human behaviour regulation for more citizen-centric urban development.
- Public utilities and services must be part of sustainable and green planning.
- Illegal and unlawful urban patterns such as slums are part of urban planning so planning these spaces is very important. Most Indian cities are not planning for slums and do not consider them as part of urban planning leading to unsustainable urbanization.

THEME 2.3: ASSESSING THE LOCATIONAL COMPLIANCE OF COMMON TSDFs SITES IN RAJASTHAN AND GUJARAT USING GOOGLE PRO & GIS TOOL

2.3.1 Objectives

This study aims to assess the **locational compliance** of selective common TSDFs in Gujarat and Rajasthan with the CPCB site selection guidelines using GIS tool, Google Earth Pro.

2.3.2 Methodology adopted for assessing the locational compliance of common TSDFs using Google Pro

- To assess whether the location of the TSDFs site and its distance from highway, river and vegetation is in compliance or not w.r.t the guidelines provided by CPCB with regards to the distance between the TSDF site and various sensitive objects. The same has been calculated using Google Earth Pro.

- In the Google Earth Pro application, the TSDF site was selected as the starting point by entering various sensitive objects as a destination.

Google Earth Pro is a free software that allows visualization, assessment, overlay, and creation of geospatial data. It can be used to review historical and recent imagery of places of interest, including remote areas to assist with environmental planning and rehabilitation planning including;

- To assess areas of ground disturbance
- To view changes in vegetation cover,
- To view changes in landscape
- To find proximity of sensitive areas to proposed activities/projects.
- To measure distances and areas of places of interest, e.g., wetlands,

(**Source**:http://www.integratesustainability.com.au/blog/print.php?id=51)

2.3.3 What are TSDFs sites?

A common waste Treatment, Storage and Disposal Facility (TSDF) for the management of HWs generated from industries is one the useful options for the management of HWs generated from industries. Guidelines issued by the Ministry of Environment and Forests under Hazardous Wastes (Management & Handling) Rules, 2016 promulgated under Environment (Protection) Act, 1986 are available in India for selection of the best site for TSDF.

Treatment facilities use various processes (such as incineration or oxidation) to alter the character or composition of hazardous wastes. Some treatment processes enable waste to be recovered and reused in manufacturing settings, while other treatment processes dramatically reduce the amount of hazardous waste.

Storage facilities temporarily hold hazardous wastes until they are treated or disposed of.

Disposal facilities permanently contain hazardous wastes. The most common type of disposal facility is a landfill, where hazardous wastes are disposed of in carefully constructed units designed to protect groundwater and surface-water resources.

2.3.4 Criteria[10]

Applicability: The criteria apply to owners and operators of facilities that dispose of hazardous waste in landfills. The term 'Hazardous waste landfill' is used to designate a waste disposal unit designed and constructed with the objective of minimum impact on the environment and human health.

The Term encompasses other terms such as "secured landfill", "engineered landfill", "waste mounds" and "waste piles" etc.

Locational criteria: HW landfill shall not be located within a specified distance of the following: lakes, ponds, rivers, wetlands, flood plains, highways, habitations, critical habitat areas, water supply wells, Airports, or coastal zone. If it is essential to establish a landfill within the restricted zone, then appropriate design measures are to be taken and prior permission for the SPCB/PCC should be obtained:

A. **Lake or Pond: No** landfill shall normally be constructed **within 200m** of any lake or pond. Because of concerns regarding runoff of waste contaminated water, a surface water monitoring network with the approval of SPCB/PCC shall be established.

[10] Criteria for Hazardous waste landfills; Technical guidelines, Hazardous Waste Management CPCB Pg 1-5

B. **River:** No landfill shall be constructed **within 100m** of a navigating river or stream.

C. **Flood Plain: No landfill shall be constructed within a 100-year flood plain**. A landfill may be built within the flood plains of secondary streams if an embankment is built along the streamside to avoid flooding of the area. However, landfills must not be built within the flood plains of major rivers unless properly designed protection embankments are constructed around the landfills.

D. **Highways: No landfill shall be constructed within 500m** of the right way of the state or national highways.

E. **Habitation: A landfill site shall be at least 500m from** a notified habitat area. A zone of 500m around a landfill boundary should be declared a no-development buffer zone after the landfill location is finalized.

F. **Public Parks: No landfill shall be constructed within 500m** of a public park.

G. **Critical Habitat Area: No** landfill shall be constructed within critical habitat areas including reserved forest areas. A critical habitat area is defined as the area in which one or more endangered species live. It is sometimes difficult to identify a critical habitat area. If there is any doubt, then the SPCB/PCC shall be consulted for clarification.

H. **Wetlands: No** landfill shall be constructed within wetlands. It is often difficult to identify a wetland area. Maps may be available for some wetlands, but in many cases, such, maps are absent or are incorrect. If there is any doubt, then the SPCB/PCC shall be consulted for clarification.

I. **Airports: No** landfill shall be constructed within a zone around Airports as notified by the regulatory authority or the aviation authority.

J. **Water Supply Well: No** landfill shall be constructed within 500m of any water supply well.

K. **Coastal Regulation Zone: No** landfill shall be sited in a coastal regulation zone.

L. **Ground Water Table Level:** No landfill shall be located in areas where the groundwater table will be less than 2m below the base of the landfill.

M. Other criteria may be decided by the planners in consultation with SPCB/PCC commensurate with specific local requirements such as the presence of monuments, religious structures etc.

Hazardous waste landfills should preferably be located in areas of low population density, low alternative land use value, low groundwater contamination potential and at sites having a high clay content in the subsoil.

A HW landfill is to be selected following the guidelines published by the Ministry of Environment and Forest (MoEF). The step by step procedures are as followed:

i. Earmarking a 'Search area' taking into account the location of the waste generation units and a 'search radius' (typically 5 to 250 km). The search area will be so chosen that it minimizes the number of HW landfills in any region or state.

ii. Identification of a list of potential sites based on:
   (a) Availability of land.
   (b) Collection of preliminary data.
   (c) Restrictions listed in the locational criteria

(iii) Collection of preliminary data as follows:

   a. **Topographic Maps:** A topographic map helps to find sites that are not on natural surface water drains or flood plains. Topographical maps may be procured from the Survey of India.

   b. **Soil Maps:** These maps, primarily meant for agricultural use, show the types of soil near the surface. They are of limited use as they do not show types of soil a few meters below the surface. They may be procured from the Indian Agricultural Research Institute.

   c. **Land Use Plan:** These plans are useful in delineating areas with definite zoning restrictions. There may be restrictions on the use of agricultural land or the use of forest land for landfill purposes. Such maps are available with the Town planning Authority or the municipality.

   d. **Transportation Maps:** These maps, which indicate roads and railways and locations of airports, are used to determine the transportation needs in developing a site.

e. **Water Use Plans:** Such maps are usually not readily available. A Plan indicating the following items should be developed: private and public tube wells indicating the capacity of each well, major and minor drinking water supply line(s), water intake wells located on surface water bodies, and open wells.

f. **Flood plain Maps:** These maps are used to delineate areas that are within a 100-year flood plain. Landfill siting must be avoided within the flood plains of major rivers.

g. **Geologic Maps:** These maps indicate geologic features and bedrock levels. A general idea about soil type can be developed from a geological map. Such maps can be procured from the geological Survey of India.

h. **Aerial Photographs/ Satellite imagery:** Aerial photographs or satellite imageries may not exist for the entire search area. However, such information may prove to be extremely helpful. Surface features such as small lakes, intermittent stream beds and current land use, which may not have been identified in earlier map searches can be easily identified using aerial photographs.

i. **Ground Water Maps:** Groundwater contour maps are available in various regions which indicate the depth of groundwater below the land surface as well as regional groundwater flow patterns. Such maps should be collected from Groundwater Boards or Minor Irrigation Tubewell Corporations.

j. **Rainfall Data:** The monthly rainfall data for the region should be collected from the Indian Meteorological Department.

k. **Wind Map:** The predominant wind direction and velocities should be collected from the Indian Meteorological Department.

l. **Seismic Data:** The seismic activity of a region is an important input in the design of landfills. Seismic coefficients are earmarked for various seismic zones and these can be obtained from the relevant BIS Code or Indian Meteorological Department.

m. **Site Walk Over and Establishment of Ground Truth:** A site reconnaissance will be conducted by a site walk-over as a part of the preliminary data collection. All features observed in various maps will be confirmed. Additional information about the following will be ascertained from nearby inhabitants: (a) flooding during monsoons; (b) soil type; (c) depth to GW table (as observed in open wells or tube wells); (d) quality of groundwater and (e) depth of bedrock.

n. **Preliminary Bore-wells and Geophysical Investigation:** At each site, as a part of preliminary data collection, one to two boreholes will be drilled and samples collected at every 1.5m interval to a depth of 20m below the ground surface. The following information will be obtained: (i) soil type and stratification; (ii) permeability of each strata; (iii) strength and compressibility parameters (optional); (iv) ground water level and quality and (v) depth of bedrock. In addition to preliminary boreholes, geophysical investigations (electrical resistivity/seismic refraction/others) may be undertaken to assess the quality of bedrock at different sites.

i. Selection of two best ranked sites from amongst the list of potential sites on the based ranking system stipulated by the MoEF (1991).

ii. Environmental Impact Assessment for the two sites for the following parameters:

(a) Ground water quality; (b) surface water quality; (c) air quality –gases, dust, litter, odour; (d) land use alteration; (e) drainage alteration; (f) soil erosion; (g) ecological impacts (h) noise; (i) aesthetics – visual, vermin, flies; (j) traffic alteration; and other (k) others.

iii. Assessment of public perception for the two sites.

iv. Selection of the final site.

The above site selection procedure shall not be applicable for the location of facility within industrial areas of State Industrial Development Agencies. However, the EIA requirement will apply.

2.3.5 Common TSDF sites of Gujarat[11]

Gujarat is a major hazardous waste producing State. There are 19,662 hazardous waste generating units in Gujarat, of which only 49.29 per cent units (i.e., 9,693 units) have submitted annual returns. Based on the annual inventory submitted by Gujarat PCB, about 24,85,317 MT of hazardous waste has been generated against the authorized capacity of 1,06,99,830 MT. Of which, 39.55 per cent is land fillable, 6.25 per cent incinerable, 22.27 per cent recyclable and 31.93 per cent utilizable hazardous waste. Gujarat has managed more quantity of HW i.e., 33,14,327 MT against 29,34,447 MT of hazardous waste to be managed (i.e., including previous year's stock and the waste received from other states for recycling/utilization/disposal[12])

The quantity of hazardous waste managed (i.e. recycling/utilization/disposal/storage/sent to other states) in Gujarat in terms of percentage is shown in figure 2.

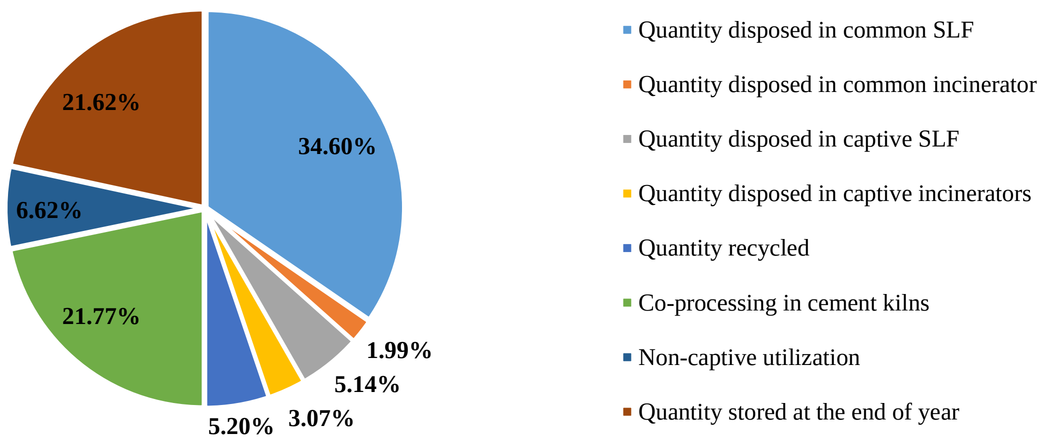


Figure-2: Percentage contribution of hazardous waste managed in Gujarat

---

[11] https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

[12] Hazardous waste management annual inventory report 2019-20 https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

Gujarat has 10 common TSDFs, out of which 3 are integrated (with both secured landfill and incinerator), 4 have only Secured Landfill Facilities (SLF)s and 3 having standalone incinerators facilities[13]. (figure 3)

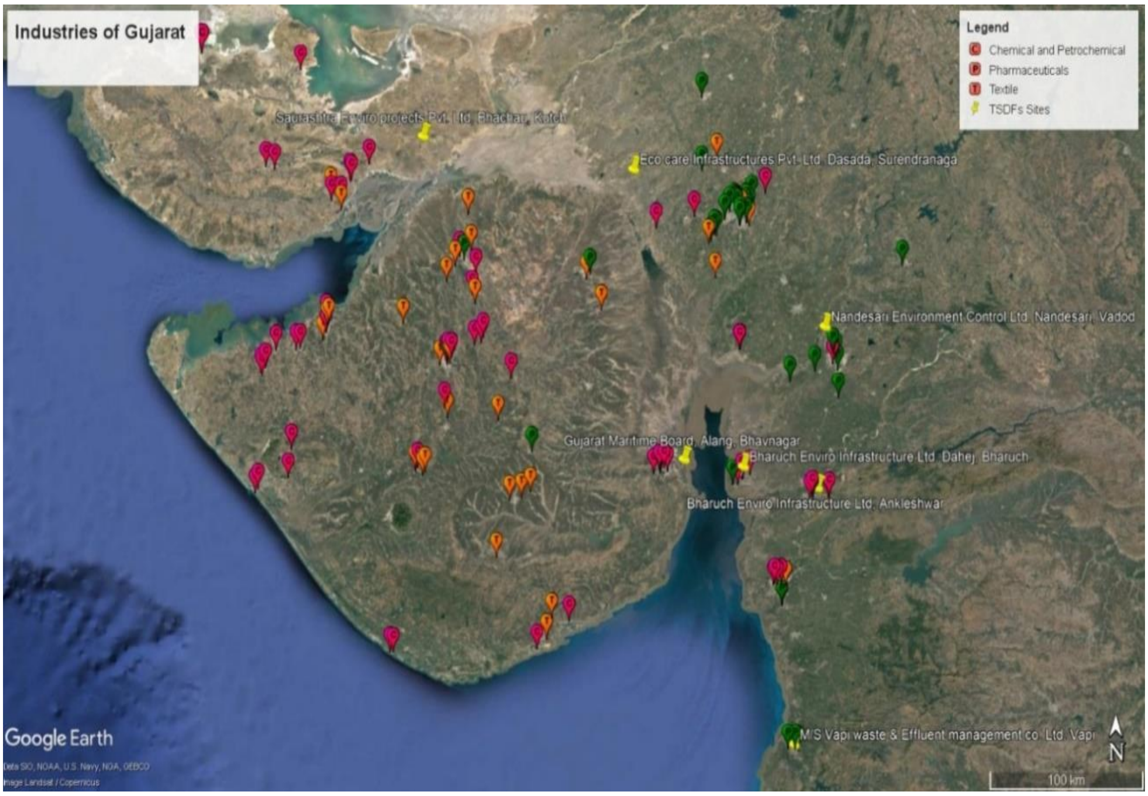


Figure-3 Representation of industrial locations and TSDFs sites of Gujrat

Table 1. Common Hazardous Waste TSDF [Treatment Stabilization Disposal Facilities] in Gujarat as of March -2020

(SOURCE: - https://gpcb.gujarat.gov.in)

Sl. No.	Operator of TSDF	Members	Capacity of TSDF in MT
1.	A1 Firm	1453	34,81,132
2.	A2 Firm		14,00,000
3.	A3 Firm	520	14,00,000
4.	A4 Firm	1650	6,44,000
5.	A5 Firm	157	50,000
6.	A6 Firm	1343	9,31,000
7.	A7 Firm	1755	7,20,000

[13] http://cpcbenvis.nic.in/tsdf.html#

8.	A8 Firm	Capped and Closed	Capped and closed
9.	A9 Firm	Capped and Closed	Capped and closed
10.	A11 Firm	Capped and Closed	Capped and closed
11.	A12 Firm	Closed	Closure u/s 5 of EPA 1986 since November 2011

The locations of the common TSDFs sites in Gujarat have been represented below in the figure. 4 in this with the yellow colored ligand. The map has been prepared with the help of Google Earth Pro.

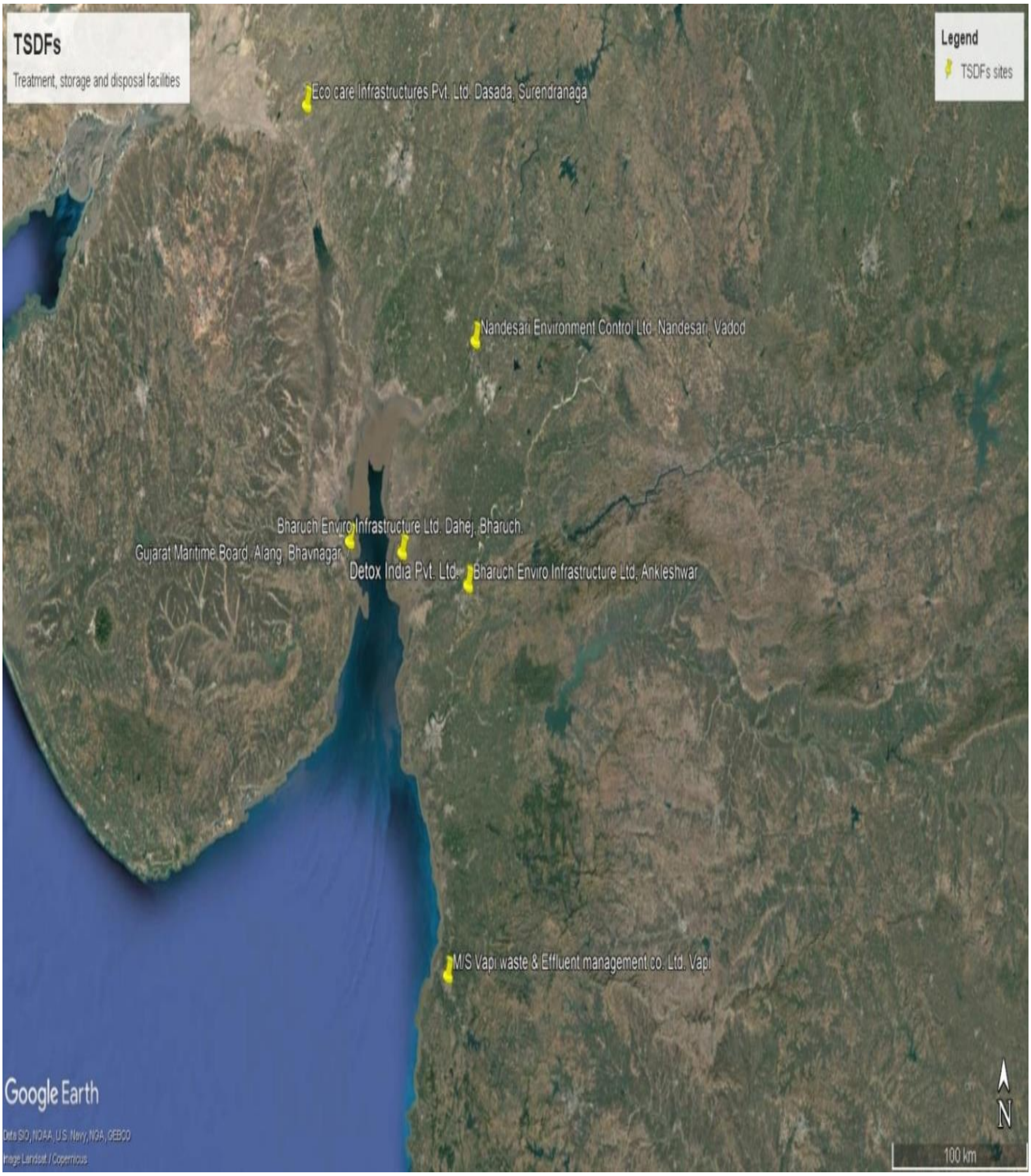


Figure-4 Representation of TSDFs sites in Gujarat

Description of the TSDFs sites

1. **A1 Firm**

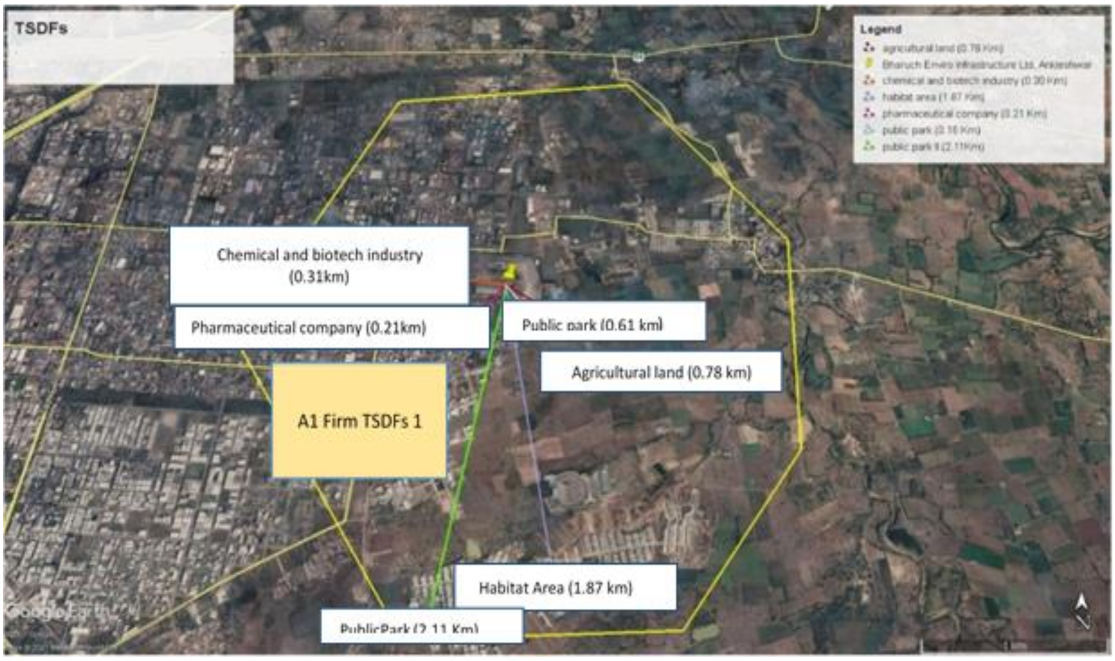


Figure-5 A1 Firm

As per figure 5, public parks, agricultural land and habitat area are away from the location of A1 Firm TSDFs 1 and as per the guidelines given by CPCB.

2. **A2 Firm**

Figure- 6 A2 Firm

In figure 6, Industries are mostly available near the A2 Firm TSDFs 2. The Wetland area is 0.71 Km (More than 500 m) **from this site which is in compliance with CPCB site** selection guidelines.

3. A3 Firm

Figure-7 A3 Firm

Waterbody, forest cover, highway and habitat area are present at 0.32km, 0.71 km, 0.41km and 0.57 km respectively from the A3 Firm TSDFs site**. Distance from the highway is not in-compliance as it should be 500 m away from the site but it is 410 m away**.

Further, TSDFs should be at least 100m away from the water body and also River is 0.32 km away from TSDFs site as shown in fig. 7, which is in compliance, but it is noticed that the river water quality is deteriorating because industries are discharging the treated effluent directly into the river. Therefore, it has been highly polluted by the various industrial clusters present and Gujarat heavy chemical limited is the major contributor to this[14].

---

[14]Earth 5R (2020). Daman ganga: restoration of the river is choked by toxin. Available at:https://earth5r.org/damanganga-restoration-river-choked-toxins/.

4. A4 Firm

Figure-8 A4 Firm

From figure 8, it is clear that TSDFs site is 0.32 km away from the habitat area, which should be at least 500 m away from it, so it is not in compliance with CPCB site selection guidelines. Vegetation is also very close, so flora and fauna will also be adversely affected.

5. A5 Firm

Figure-9 A5 Firm

TSDFs site of Gujarat maritime board is situated nearby areas which are completely barren and also industries and water body are located 6.51 Km, 1.26 km away respectively which is in compliance.

6. A6 Firm

Figure-10 A6 Firm

As shown in figure-10, TSDFs site is 0.36 km, 0.24 km, 0.30km and 0.38 km away from vegetation, forest area, shopping mall and chemical & pharma industry respectively. Close location of industries to TSDFs may reduce the cost of transportation of waste.

7. A7 Firm

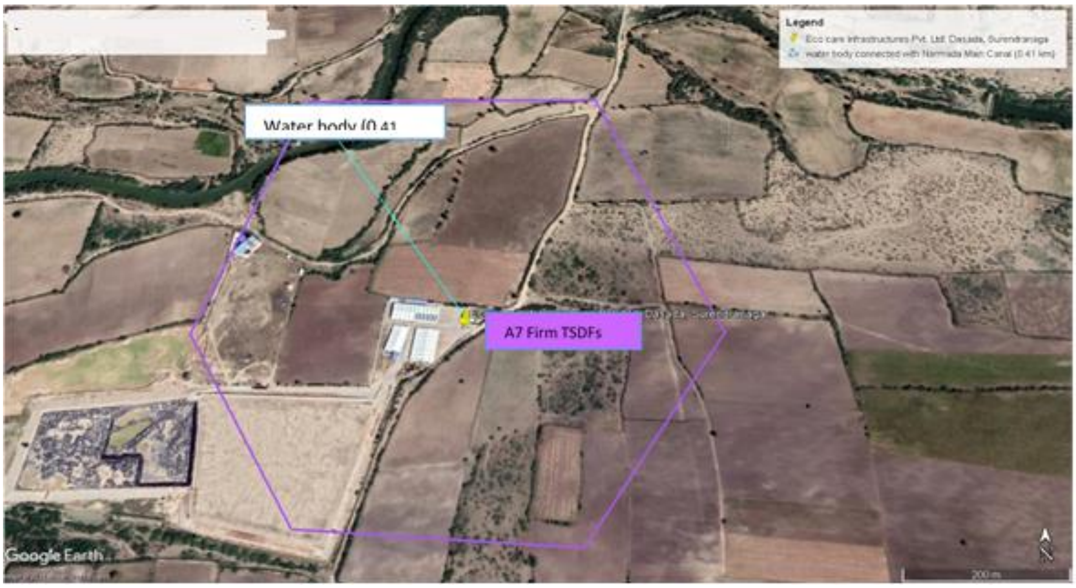


Figure-11 A7 Firm

In figure 11 TSDFs are 0.41 km from the water body, which is connected with the main canal, but it is in compliance with CPCB Guidelines.

2.3.6 Common TSDFs sites of Rajasthan

Rajasthan has 2,094 hazardous waste generating units, out of which 86.44 per cent (i.e. 1810 units) submitted annual returns. About 5,87,554 MT of hazardous waste has been generated against the authorized capacity of 80,92,583 MT[15]. Of this, 30.59 per cent is land fillable, 0.33 per cent incinerable, 13.86 per cent recyclable and 55.22 per cent utilizable hazardous Waste. Rajasthan has managed more quantity of HW, i.e., 9,67,597 MT against the authorized capacity of 9,52,260 MT of hazardous waste to be managed (including previous year’s stock and the quantity of hazardous waste received from other states for disposal in landfill, recycling & utilization).

[15] Based on the annual inventory submitted by Rajasthan PCB https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

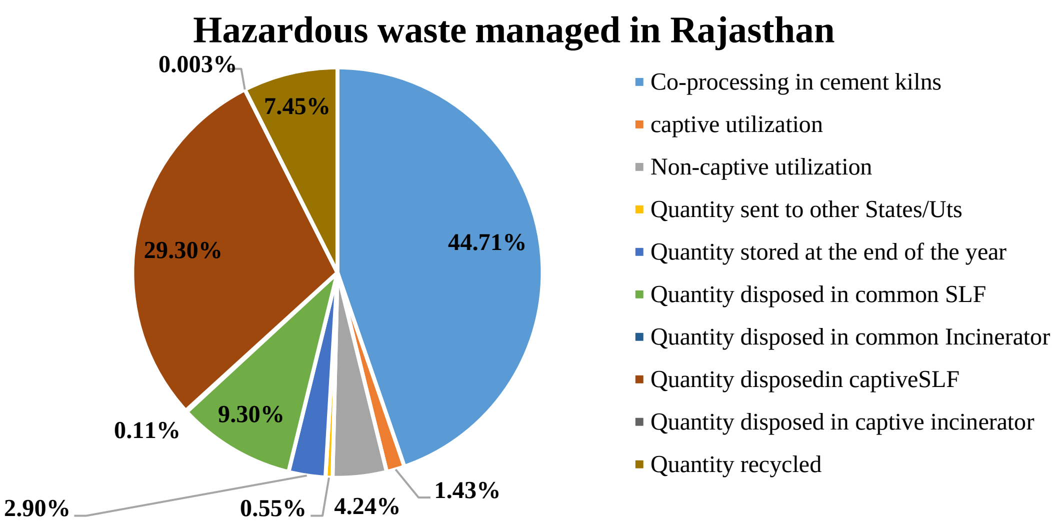


Figure-12: Percentage contribution of hazardous waste managed in Rajasthan

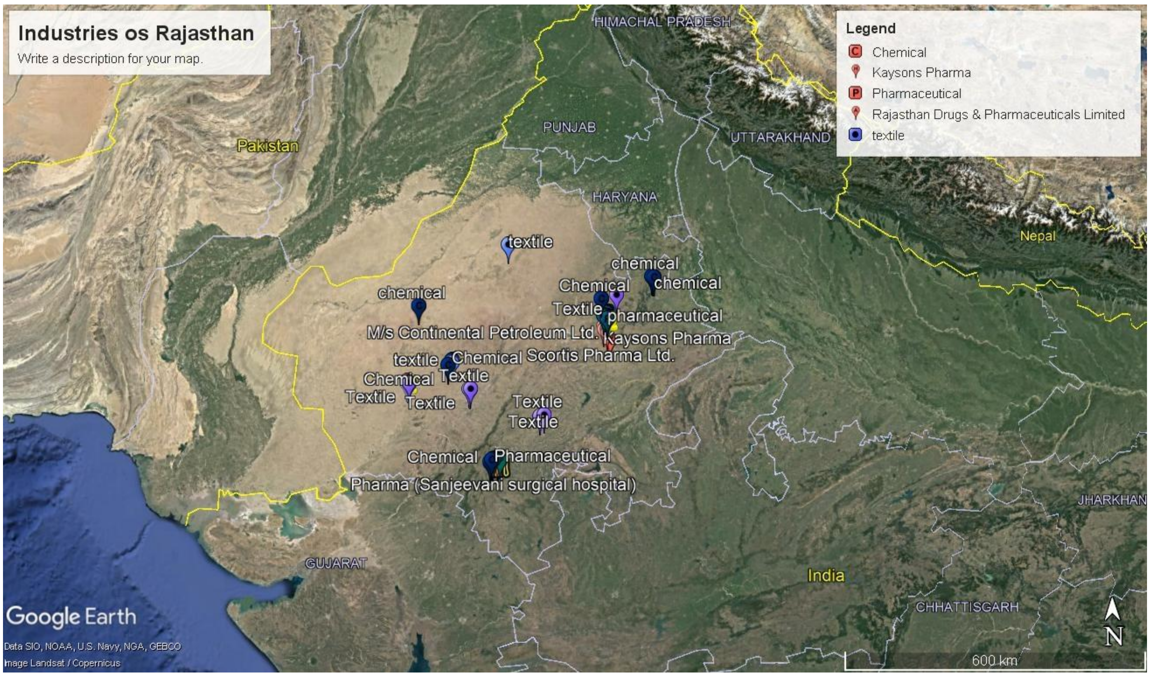


Figure-13: Representation of industrial locations and TSDFs sites of Rajasthan

Rajasthan has 03 common TSDFs (i.e. 02 exclusive SLFs and 01 standalone incinerators). During 2019-20, a total of 1,22,322 MT of hazardous waste has been disposed of.

Table-2 TSDF sites of Rajasthan

Sl. No.	Operator of TSDF	Status
1	B1 Firm	Sanitary Landfill facilities (SLFs)
2	B2 Firm	Sanitary Landfillfacilitiesy (SLFs)
3	B3 Firm	Standalone incinerators

The above three treatment, storage and disposal facility of Rajasthan is represented below:-

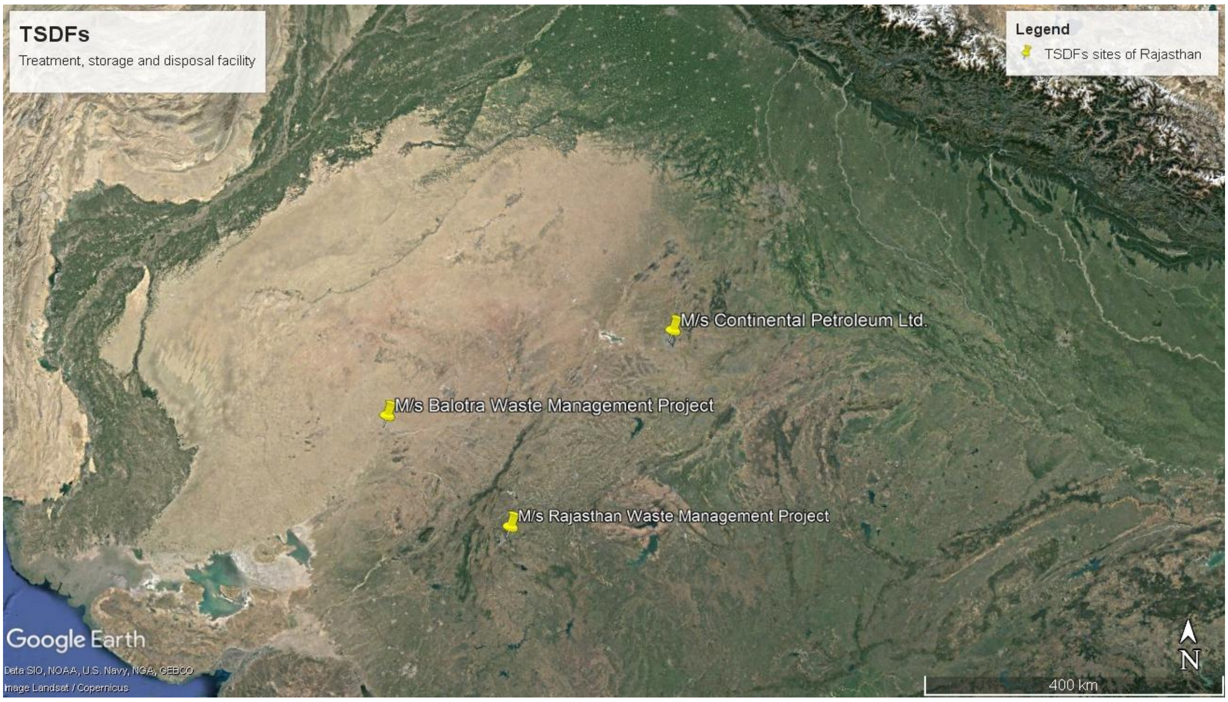


Figure-14 TSDFs sites of Rajasthan

1. **B1 Firm**

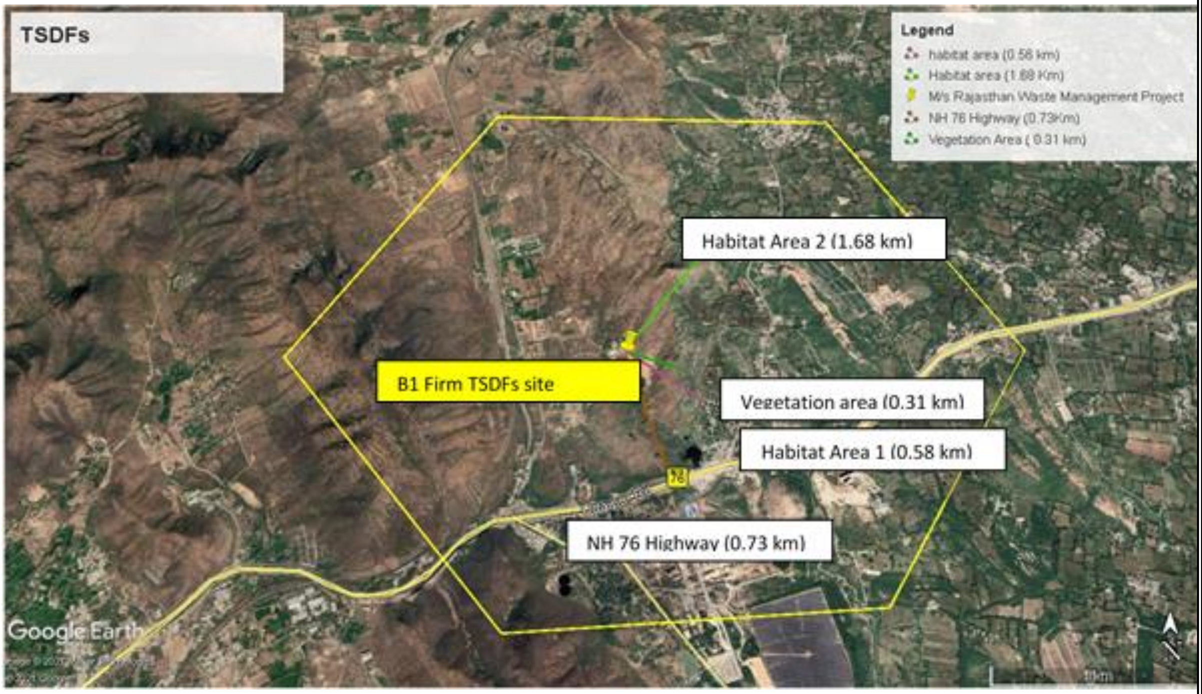


Figure-15 B1 Firm

TSDFs site is 0.73 km, 0.58 km, 0.31 km and 1.68 km away from the highway, habitat area 1, vegetation area and habitat area 2 respectively. According to guidelines given by CPCB the distance of TSDFs is in compliance with the highway.

2. **B2 Firm**

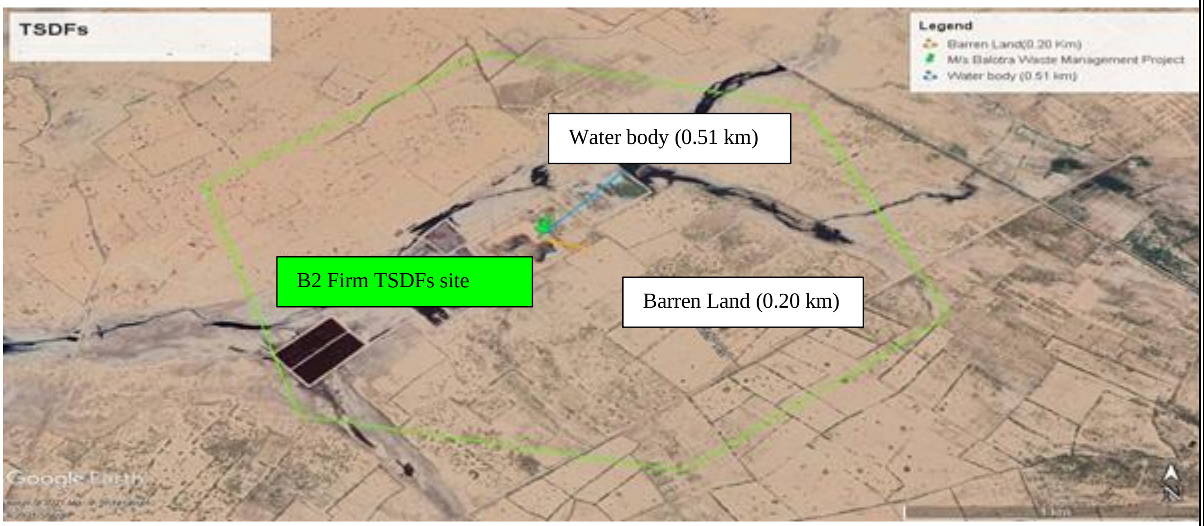


Figure-16 B2 Firm

The area within 3 km is barren and some textile industries are present beyond 3 km. TSDFs site is approximately 0.51 km from the water body, though there is no vegetation or forest or habitat area according to Google Earth pro results. So this site is in compliance with the guidelines of selection.

3. B3 Firm

Figure-17 B3 Firm

TSDFs sites are 0.11 km, 0.021 km, 0.12 km and 0.1 km away from habitat area, vegetation area, road and shopping mart respectively. **This TSDFs site is not in-compliance with the guidelines of CPCB as it should be 500m away from the habitat area and the vegetation area.**

2.3.7 Conclusion

In this study, the common TSDFs were focused and locational compliance was ascertained using the Google Pro tool covering a total of 7 common TSDFs sites from Gujrat and 3 common TSDFs sites from Rajasthan. The distance from habitat area, vegetation, etc. was verified using the Google Earth Pro application (GIS tool) to assess their compliance with CPCB guidelines in terms of location. Two sites of Gujarat and one site from Rajasthan indicate non-compliance with stipulated guidelines based on Google Earth distance estimations. Such cases need to be examined further in detail to assess their implications and associated risks.

The result of the study is given as under:

Table-3 Summary of common TSDFs sites of Gujrat and Rajasthan

(Based on this study which is preliminary and based on distance criteria)

Sl. No.	TSDF site	Compliance (Yes/No)
1	A1 Firm, Gujrat	Yes
2	A2 Firm, Gujrat	Yes
3	A3 Firm, Gujrat	No
4	A4 Firm Gujrat	No
5	A5 Firm, Gujrat	Yes
6	A6 Firm, Gujrat	Yes
7	A7 Firm, Gujrat	Yes
8	B1 Firm, Rajasthan	Yes
9	B2 Firm, Rajasthan	Yes
10	B3 Firm, Rajasthan	No

THEME - 3.1: PLASTIC WASTE (OVERVIEW OF PLASTIC WASTE MANAGEMENT IN JAIPUR CITY & ROLE OF CIRCULAR ECONOMY AND OTHER MANAGEMENT TECHNIQUES)

3.1.1 Introduction

With growing urbanization, India's urban population is expected to grow nearly from 38 crores to 60 crores in 2030[16]. Higher incomes and consumption due to increased urbanization will lead to three times the current waste generation from 62 million tonnes to 165 million tonnes by 2030 and create problems of a high build-up of waste and its impact on our immediate and global environment. As a result, environmental pollution has come to an alarming stage where our environment is experiencing irreparable damage. Solid and liquid wastes, gas particles released from the industries, run-off pesticides and fertilizers from agricultural practices and household sewage from urban regions have come to a point beyond disposal. This is why managing waste properly becomes so important.

World plastic (includes thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings, sealants and not including PP-fibres and PET-, PA- and polyacryl-fibres) production almost reached 359 million tonnes in 2018[17]. Plastic waste primarily originates from three regions i.e. 24 per cent from East Asia and the Pacific, 18.6 per cent from Europe and Central Asia, and 15 per cent from North America [10][18]. Five Asian countries: China, Indonesia, Philippines, Thailand, and Vietnam with ten rivers across Asia and Africa (Indus, Ganges, Amur, Mekong, Pearl, Hai he, Yellow, Yangtze, Nile, and Niger) are responsible for transporting 88 – 95 per cent of the global load into the sea. The top 20 polluting rivers, mainly in Asia, release 67 per cent of all plastic waste into the oceans.

As per the report of the Worldwide Pollution Control Association, 5 trillion plastic bags are used every year. Among all countries, India consumes 50 per cent of single-use plastics. In every household, plastic wastes account for more than 10 per cent of the total waste produced daily. India's annual plastic manufacturing growth is nearly 16 per cent, compared with China

---

[16] Source: Swachh Bharat Mission (Urban) Plastic Waste Management Issues, Solutions and Case Studies (Feb 2019)

[17] Plastics Europe Market Research Group (PEMRG) / Conversio Market & Strategy GmbH

[18] what a waste 2.0, "Tackling Increasing Plastic Waste." http://datatopics.worldbank.org/what-a-waste/tackling_increasing_plastic_waste.html

(10 per cent) and the UK (2.5 per cent) [11][19]. It is estimated that approximately 70 per cent of plastic packaging products are converted into plastic waste in a short span.

In 1950, 2.5 billion of the world's population produced 1.5 million tons of plastic; in 2018, more than 7 billion people of the global population produced over 359 million tons of plastic [12][20]. According to [13][21], 8.3 billion metric tonnes of virgin plastic have been produced from 1950 to 2015.

The life span of plastic products is not the same. It may be less than one year or 15 years or 50 years or more. Thus, from production to waste, different plastic products have different life cycles and this is why the volume of collected waste cannot match, in a single year with the volume of production or consumption. Also, the slow growth in recycling rates and the increase in single-use products will cause more accumulation of plastic waste in our environment.

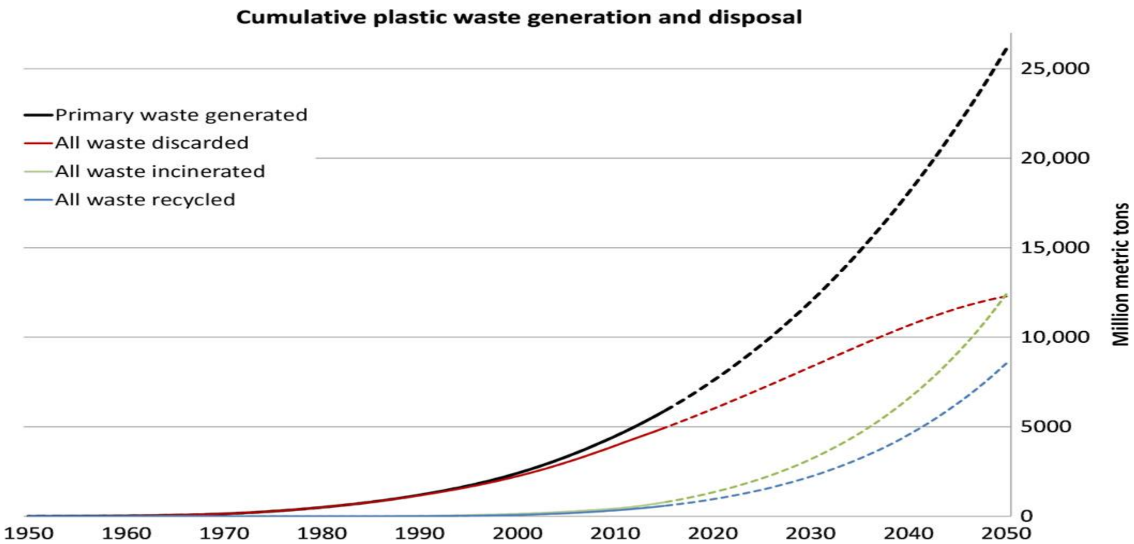


*Figure 12- **Cumulative plastic waste generation and disposal (in million metric tons).** Solid lines show historical data from 1950 to 2015; dashed lines show projections of historical trends to 2050*

Till 2015, approximately 2.5 billion metric tonnes (Mt) of plastic were in use which is 30 per cent of 8.3 billion metric tonnes of virgin plastic ever produced and around 4900 Mt (60 per cent) of all plastics ever produced were discarded and are accumulating in landfills or the natural environment.

---

[19] R. Wei and W. Zimmermann, "Microbial enzymes for the recycling of recalcitrant petroleum-based plastics: how far are we?," *Microbial Biotechnology*, vol. 10, no. 6. John Wiley and Sons Ltd, pp. 1308–1322, Nov. 01, 2017, doi: 10.1111/1751-7915.12710.

[20] "FEATURE: UN's mission to keep plastics out of oceans and marine life | | UN News." https://news.un.org/en/story/2017/04/556132-feature-uns-mission-keep-plastics-out-oceans-and-marine-life

[21] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," *Sci. Adv.*, vol. 3, no. 7, pp. 25–29, 2017, doi: 10.1126/sciadv.1700782.

Seventy per cent of the earth's surface is covered with water of which 88 per cent is polluted by plastic waste. Sea foods are one of the main sources of food in coastal areas. Plastics, if disposed of in the water bodies will result in their consumption and cause biomagnification[22] (or bio amplification) of the toxic compounds present in plastic waste.

Excessive marine pollution has created 500 dead zones in the ocean which is equal in size to the United Kingdom's surface (245,000 km²). This number will double every decade. The lack of oxygen in dead zones causes marine life to migrate to new areas – disrupting the balance of marine life in other parts. 70 per cent of Earth's oxygen is produced by marine plants. 30 per cent of our CO^2 emissions are absorbed by the oceans. Two-thirds of plastic pollution comes from litter being washed down rivers and drains, left on beaches, or dropped in towns or cities. Industry spills, waste being flushed down toilets & badly managed landfill sites near the coast contribute to the problem. [14][23]

Indian perspective:

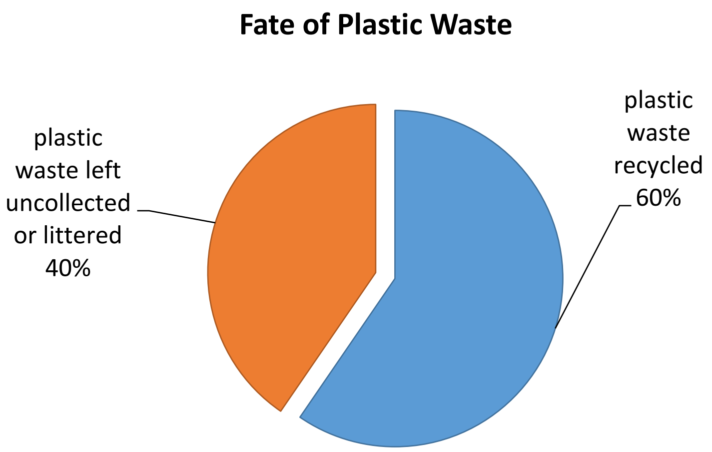


Figure 13- UNIDO Report- Recycling of Plastics in Indian perspective by Dr. Smita Mohanty

[22] Many of the most dangerous toxins settle to the seafloor and then are taken in by organisms that live or feed on bottom sediments. Because these compounds aren't digested, they accumulate within the animals that ingest them, and become more and more concentrated as they pass along the food chain as animals eat and then are eaten in turn. This is bio magnification, and it means that higher-level predators-fish, birds, and marine mammals-build up greater and more dangerous amounts of toxic materials than animals lower on the food chain.

[23] condor ferries, "Plastic in the Ocean Statistics & Facts (2020)." https://www.condorferries.co.uk/plastic-in-the-ocean-statistics (accessed Sep. 19, 2020).

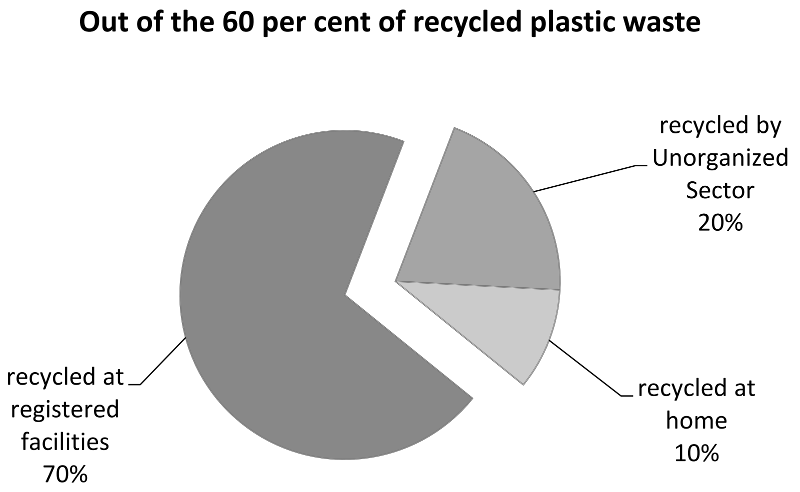


Figure 14- Distribution of recycling sites of plastic waste in India

According to the reports for the year 2017-18, Central Pollution Control Board (CPCB) has estimated that India generates approximately 9.4 Million tonnes per annum of plastic waste, (which amounts to 26,000 tonnes of waste per day), and out of this approximately 5.6 Million tonnes per annum plastic waste is recycled (i.e. 15,600 tonnes of waste per day) and 3.8 Million tonnes per annum plastic waste is left uncollected or littered (9,400 tonnes of waste per day)[24]. Out of the 60 per cent of recycled plastic[25]:

- 70 per cent is recycled at registered facilities
- 20 per cent is recycled by Unorganized Sector
- 10 per cent of the plastic is recycled at home.

There are no comprehensive methods in place for plastic waste management. Additionally, there is a constant increase in plastic waste generation. One of the major reasons is, 50 per cent of plastic is discarded as waste after a single-use. This also adds to an increase in the carbon footprint since the single-use of plastic products increases the demand for virgin plastic products.

3.1.2 Studies

The theme of plastic waste is based on two studies. One study (by Mr. Manikant Barik) is over-viewed of plastic waste management in the Jaipur city while another study of Mr. Prateek Kumar is over-viewed on plastic waste management with a focus on the role of circular economy and other management techniques. Both the studies relied on desk review/literature review. A field visit was undertaken during the study on an overview of plastic waste management in Jaipur city for corroborating the literature view findings.

[24] Source: UNIDO Report- Recycling of Plastics in Indian perspective by Dr. Smita Mohanty
[25] Source: http://cpcb.nic.in/Plastic_waste.php/

3.1.3 Literature Review

The CAG Audit team for the Audit Report No. 2 of 2018 - Local Bodies Government of Rajasthan, following Municipal Corporations (M Corps)/Municipal Councils (MCs)/Municipal Boards (MBs)/ Gram Panchayats (GPs) had teat checked:

Details of test checked ULBs and PRIs

A. ULBs

Sl. No.	Name of					
	District	M Corps	MCs	MBs		
				Type-II	Type-III	Type-IV
1.	Baran	-	Baran	Anta	-	Mangrol
2.	Bharatpur	-	-	-	Nadbai	Nagar
3.	Bikaner	Bikaner	-	-	Nokha	Deshnok
4.	Jaipur	Jaipur	-	-	Sambhar	Viratnagar
5.	Jhalawar	-	Jhalawar	-	Bhawanimandi	Pidawa
6.	Karauli	-	Karauli	-	-	Todabhim
7.	Pali	-	Pali	Sumerpur	Sojatcity	Jaitaran
8.	Udaipur	-	-	-	Fateh Nagar	Salumbar

B. PRIs

Sl. No.	District	PSs	Name of test checked GPs
1.	Baran	Chabra	Bhilwada Neecha, Hanya Heri, Mundakiya and Mundla (4)
2.	Bharatpur	Bayana	Bajna, Kapoora Malooka, Khan Khera, Mahmadpura, Mahrawar, Naroli and Parua (7)
3.	Bikaner	Nokha	Beekasar,Gondusar, Raisar, Somalsar and Soorpura (5)
4.	Jaipur	Shahpura	Bidara, Chharsa, , Manoharpur, Nathawala and Surana (5)
5.	Jhalawar	Khanpur	Jolpa, Khandi, Malan Wasa, Moondla, Piplaj and Soomar (6)
6.	Karoli	Hindaun	Alipura, Dhindora, Khareta, Kherli Goojar, Kotri, Mahoo Ibrahimpur, Pataunda and Todoopura (8)
7.	Pali	Rohat	Diwandi, Gelawas and Singari (3)
8.	Udaipur	Girwa	Barapal, Dodawali, Kanpur, Popalty and Saweena (Rural) (5)

It was observed from the audit report that:

- Directorate of Local Bodies did not assess the quantum of plastic waste being generated in the urban areas of the State during the period from 2012-2017.
- Rajasthan State Pollution Control Board did not have any information regarding the assessment of plastic waste in the entire State.
- As per provisions of Management and Handling (MSW) Rules, 2000 and Rule 11 of Solid Waste Management (SWM) Rules, 2016, the Secretary in-charge of the Department of Urban Development in the State shall prepare policy and solid waste management strategy for the State within a period not later than one year from the date

of notification of these rules but no action plan for effective implementation of Plastic Waste Management & Handling (M&H) Rules was prepared.

- **Segregation** of waste was not being done at the source.
- **Transportation**, the usage of uncovered vehicles and inappropriately designed vehicles caused littering and exposure of waste to open atmosphere resulting in unhygienic and insanitary conditions.
- Neither any retailer/street vendor had registered for selling or providing consumer goods in plastic carry bags nor the ULBs had ensured such registration by the retailer/street vendor even though plastic bags were being used openly.
- None of the 22 tests checked ULBs established mechanism or issued directions for collection, handling, storage, transportation and disposal of plastic waste.
- No Plastic waste collection centre was established either by manufacturers or by concerns in all the tests checked 22 ULBs.
- 22 test checked ULBs and 43 GPs did not ensure that plastic wastes were not burnt in open.
- It was observed that all tests checked 22 ULBs and 43 GPs had neither framed any bye-laws for levy of user charges about plastic waste management nor collected any such user charge as prescribed in the rules ibid.

3.1.4 Field Visits

Field visits were conducted with two clear objectives which emerged corroboration of previous findings with what is actually happening regarding implementation and second to obtain data wherever possible for commenting on the efficiency of implementation.

- A visit to Jaipur Municipal Corporation (JMC) was conducted to ascertain the existence of a mechanism regarding the information on plastic waste generation but no specific information was available in the JMC.
- No segregation of waste at source was observed during the door-to-door collection of waste. Manual segregation by a large number of waste-pickers is being done in an unorganized manner. Further, such waste pickers were neither engaged with the Municipal Corporation nor with the tenderer/organisation/NGO.
- No documentation was maintained for such informal workers who were playing an important role in the collection, segregation and transportation of the plastic waste. The waste pickers were working in insecure conditions and with no safety measures

provided at the site which is very essential as they were handling the waste manually. It appeared that measures to improve working conditions spite pointed out by CAG's Audit in its report no 4 of 2018 in respect of the Government of Karnataka were far from implementation and provisions in respect of waste pickers are yet to be implemented.

- It was observed that waste was being carried to transfer stations in old, poorly maintained vehicles, restricting the efficiency of collection/transportation. The frequency of vehicles was also very low resulting in the transportation of a lesser quantity of waste.
- The city has a total area of 859 bighas for municipal landfill sites (CPCB, 2017-18). The three main sites for landfilling are Mathuradaspura, Sewapura and Langadiawas having an area of 176, 200 and 483 bighas respectively[26]. During the visit to these sites, it was observed that:
    - plastic waste and municipal solid waste were directly disposed of and dumped at these sites.
    - There was no waste inspection before disposing of it at the landfills.
    - Lack of pollution monitoring equipment and improper implementation of safety provisions were visible.
    - With no scientific dumping and without proper reclamation these sites have all the elements of becoming a disaster[27], which happened due to unscientific management of hazardous waste.
    - A guesstimate, billions of plastic carrying bags and biomedical waste were found lying open in these areas.
    - At dump sites, no action was taken for leachate collection and curing the heap of non-recyclable plastic waste, these heaps were directly dumped by dumpers including plastic waste.
    - Waste was not being segregated and processed at any transfer station, due to a lack of sorting and processing facilities.
- At each transfer station, segregated plastic waste was weighed manually to study and find out per day average generation of plastic waste across each transfer station. Thus, accurate measurement of weight of the waste in the city could not possible. With this

---

[26] https://www.slideshare.net/ijtsrd/analytical-research-for-improvement-of-solid-waste-management-in-jaipur-city?from_action=save
[27] https://en.wikipedia.org/wiki/Love_Canal

method, it was estimated that on an average **6163.7 kgs**/day of plastic waste is being generated within the periphery of eight-transfer stations (Recyclable plastic).

3.1.5 Circularity in Plastic Waste Management

Plastic waste is a major part of municipal solid waste and the concept of the waste hierarchy which is used to manage municipal solid waste is very much relevant for managing plastic waste also.

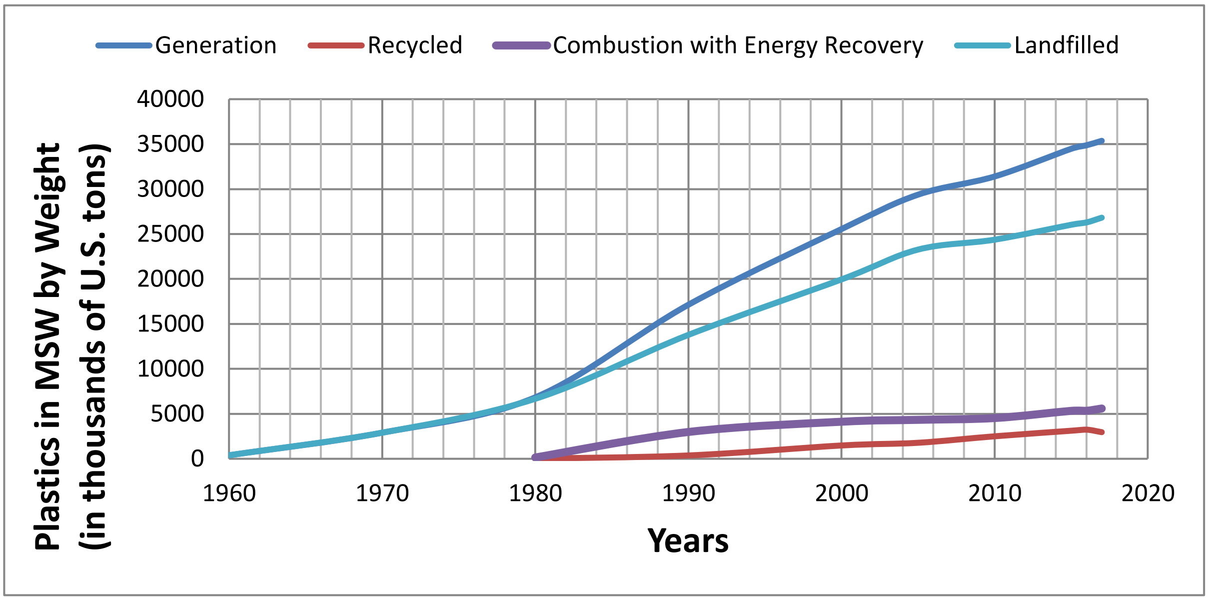


Figure 15- Even developed countries are struggling to cope with plastic waste – Data on plastics in Municipal Solid Waste by weight during the period 1960-2017 (in thousands of US tons)

The waste hierarchy ranks waste management options according to what is best for the environment giving first importance to preventing waste in the first place, and second to reusing the waste that is being created and already present, then recycling, then recovery, and last of all disposal. Recycling therefore, is lower in the hierarchy than prevention and reuse. The same holds for the management of plastic waste also. However, as the world is struggling with plastic waste, recycling has now become an important plan of action for successfully managing plastic waste.

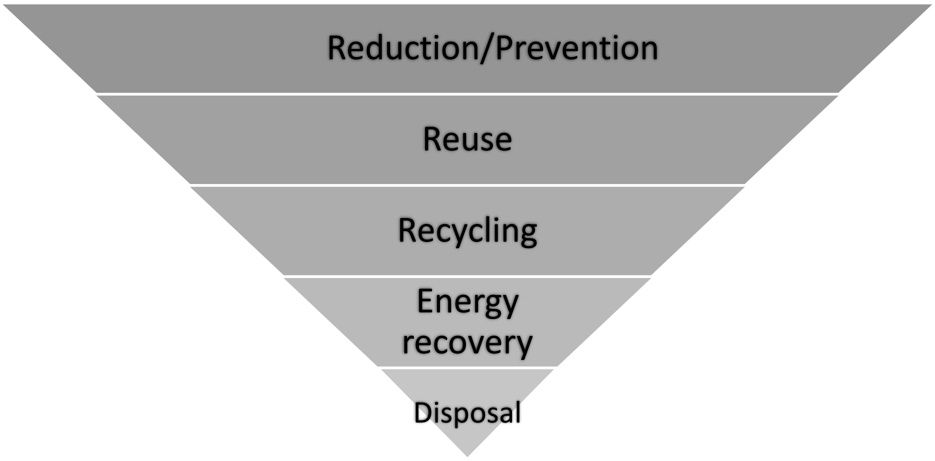


Figure 16-Pictorial representation of waste management hierarchy

3.1.5.1 Reduction/prevention

This is the most preferred option in a waste hierarchy. Before an incident occurs, communities can take steps to reduce the amount and toxicity of incident-generated waste. Communities can limit the possible spread of contamination by sealing access points to the sewer or water system with drain covers. The initial planning and preparation efforts communities take to minimize the amount and toxicity of incident-generated waste have several environmental benefits (e.g., reducing the number of new materials needed to rebuild), as well as economic benefits (e.g., shortening the recovery time-line).

3.1.5.2 Reuse

Reuse refers to materials that can be used again in their original form. These items typically are not removed from the site. Communities should evaluate their reuse program to ensure it can be scaled up to handle incident-generated materials, if necessary. To maximize reuse opportunities for different materials during an incident, a viable reuse infrastructure, such as end markets for salvaged products, should be in place before an incident. In addition, communities should establish and document guidelines in their pre-incident waste management plans for salvaging and reusing various materials. Risk communication should be a part of waste-related community outreach plans to help ensure public acceptance of the salvaged materials.

3.1.5.3 Recycling

Recycling is the process of collecting and processing materials that would otherwise be disposed of as waste and turning them into new products. Items usually are recycled off-site. However, in some circumstances, waste can be recycled on-site. Communities should evaluate their recycling program for everyday wastes to ensure it can be scaled up to handle incident-related wastes, if necessary. To maximize recycling opportunities for different waste streams during an incident, a viable recycling infrastructure, such as recycling facilities and end markets for recycled products, needs to be in place before an incident.

3.1.6 Circular Economy (CE) in Plastic Waste Sector

The world's population is expected to peak at 10bn in 2050. The current 'linear economy' system where everyday products are just made, used and disposed of assumes that raw materials extracted from earth are limitless, but that's not true. Resources with the earth's raw

materials are not limitless. As a result, global labour and raw material costs are on the increase [16][28].

Figure 17- Life cycle of a product when the "Linear Economy" concept employed

On the other hand, in a CE, products and materials keep circulating in a high-value state of use, through supply chains, for as long as possible. As per Dr. HC Walter R. Stahel – "A circular economy is achieved by designing products smartly with their whole life cycle in mind, re-using and repairing to extend their useful life, and then when their life is deemed over, re-manufacturing to create new products from old".

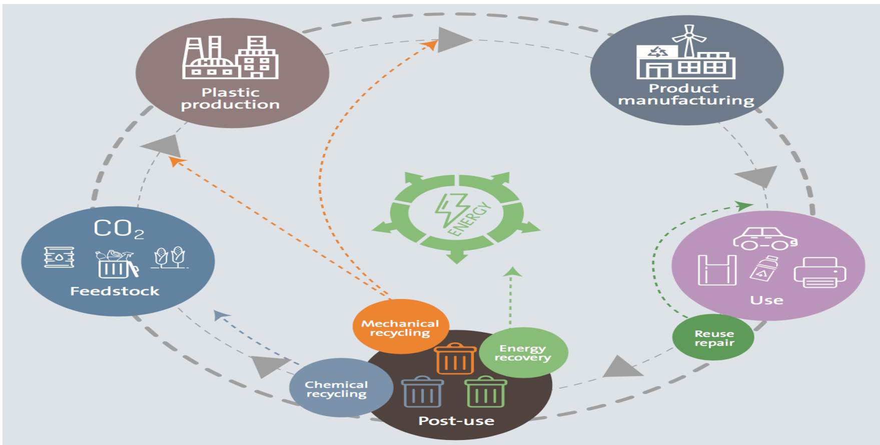


Figure 18- Life cycle of a product when the "Circular Economy" concept employed

Reuse, recycle and recover ensure that resources are used multiple times. This idea of restoration i.e. to keep resources in the loop and to replace the end-of-life concept, put simply,

[28] Zero waste Scotland, "What is the Circular Economy? | Definition | Zero Waste Scotland." https://www.zerowastescotland.org.uk/circular-economy/about

is termed CE. However, the CE concept has deep-rooted origins and cannot be defined in such layman’s language and neither the concept can be awarded to one single date or author.

As of the current scenario, Kenneth Boulding is considered to be a modern-day pioneer. He mentioned in his book: “spaceship economy (or CE) is a prerequisite for the maintenance of the sustainability of human life on Earth” One of the most prominent CE definitions provided goes like “Circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.”[18][29]

Another definition states that “it is an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers.” [19][30]

3.1.6.1 Mimicking Nature for CE

This definition has covered all aspects and caters thought process of every stakeholder. With CE we try to mimic nature’s capability of restoration and regeneration of resources.

[29] The Ellen MacArthur Foundation, “Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition.,” 2012.

[30] J. Kirchherr, D. Reike, and M. Hekkert, “Conceptualizing the circular economy: An analysis of 114 definitions,” *Resour. Conserv. Recycl.*, vol. 127, no. September, pp. 221–232, 2017, doi: 10.1016/j.resconrec.2017.09.005.

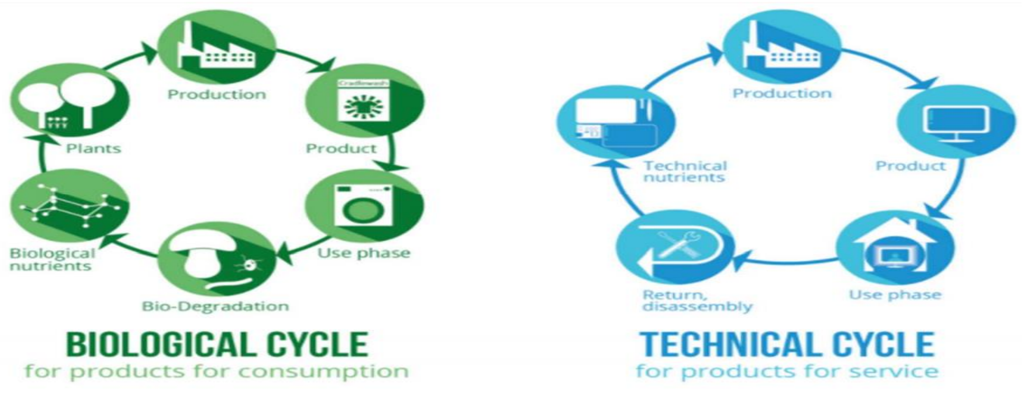


Figure 19- How we can mimic biological cycle in technical cycle and adapt to Circular Economy

If one is able to convert a PET bottle waste once again to a PET bottle which is identical in every respect when compared to the original PET bottle and ensures that no new plastic is entering the system, then only a **true circular economy** can be achieved. However, if we use PET bottle waste say for tiles making or road construction works, then circularity (using resources in loop) of the plastic resource is not happening here as demand for the PET bottle will always be made from virgin plastics and this is an **apparent circular economy.**

CE solutions for plastics include: producing plastics from alternative non-fossil fuel feed stocks; using plastic wastes as a resource; redesigning plastic manufacturing processes and products to enhance longevity, re-usability and waste prevention; collaboration between businesses and consumers to encourage recycling and increase the value of plastic products; encouraging sustainable business models which promote plastic products as services, and encourage sharing and leasing; developing robust information platforms to aid circular solutions, and adopting fiscal and regulatory measures to support the CE[4].

3.1.7 Trending circular economy solutions for the plastic sector:

3.1.7.1 Plastic from alternative feed-stocks

Bio-based plastics can be manufactured from renewable plant materials such as starch, cellulose, oils (e.g. rapeseed oil), lignin (wood), proteins (e.g. maize zein) and polysaccharides (e.g. xylans). Recent technological developments have also proven that it is now possible to utilise organic waste materials and petro plastics (e.g. PET) to produce synthetic bio-based plastics (such as polyhydroxyalkanoates or PHAs)[20]. The current major sources of this starch are maize, potatoes and cassava. Other potential sources include arrowroot, barley, some varieties of liana, millet, oats, rice, sago, sorghum, sweet potato, taro and wheat[20].[31]

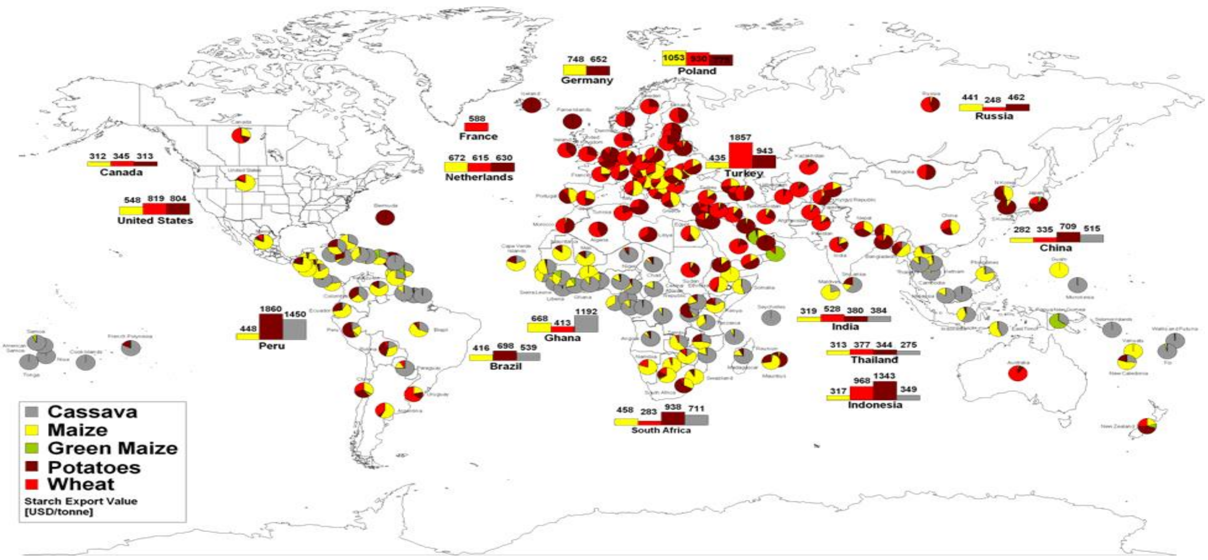


Figure 20- global production of cassava, maize, green maize, potatoes, wheat

Increasing alternative feed-stocks, such as bio-based and renewable content in plastics will reduce dependence on virgin fossil carbon resources and in turn will introduce circularity in the plastic industry. Bio-based plastics act as a carbon stock, and if bio-based products are designed for reuse or recyclability, carbon stock is recycled every time at the end of the product's life[21] [32].

On the other hand, Dow and Thong Guan, one of the world's leading plastic stretch cling film producers, introduced a new range of bio-based polyethene a renewable feedstock from the tall oil residue of paper production, enabling industry to reduce its carbon footprint. Unlike other alternative renewable feedstock, it does not compete with the human food chain, and no extra land is required for its production.

3.1.7.2 Plastic waste as a resource

Ethylene, a **recycled plastic** developed by Eco Birdy, the Antwerp-based company in Belgium. It separates waste based on colors (red, green, yellow, blue, white and clear), which allows for a high degree of control with regards to the resulting products' aesthetics like tables, chairs and containers, all pleasantly colored and with an opalescent finish. The raw materials

31 [20] British Plastics Federation, "Bio-based plastics: Feed stocks, Production and the UK Market." https://www.bpf.co.uk/plastipedia/polymers/biobased_plastics_feedstocks_production_and_the_uk_market.aspx

32 [21] European bioplastics, "Fact sheet July 2020 on mechanical recycling of plastic waste," *European bioplastics*, pp. 1–2, Jul. 2020.

come from used plastic toys, which, instead of becoming waste, are recovered through an awareness campaign conducted in schools aimed at informing children on the issue of plastic waste and possible solutions. Subsequently, containers are provided to schools, and children and their parents are asked to collect used or broken toys that would otherwise be thrown away. The project, which uses waste from across Europe, is co-financed by the EU's Competitiveness of Small and Medium-Sized Enterprises (COSME) programme[23][33].

The company Crafting Plastics!, has developed Nuatan, a patented new-generation plastic that is based on 100 per cent renewable raw materials and is also completely biodegradable. The high-performance material is the result of a long-term interdisciplinary collaboration between Crafting Plastics!, the Slovak University of Technology and Panara, a Slovenian company initially specialised in polyethylene film [24][34]. Since 2006, Panara has been investing in bio-plastics and produces several types based on PHB (polyhydroxybutyrate, a biodegradable plastic made naturally with bacteria), PLA (polylactic acid, a polymer derived from biomasses) or biodegradable and compostable polyester[25][35]. Composed entirely of plant-based biopolymers made of PLA and PHB obtained from natural sources like corn or potato starch, Nuatan can resist temperatures of over 100°C and has a programmable lifespan ranging from one to fifty years, depending on the mixture. When put into an industrial composer, the material biodegrades in water, CO^2 and biomass. The second generation currently being developed will also biodegrade in domestic composts, soil and ocean water. The new material can be injection moulded and 3D printed,[36] or "blown" like traditional plastics[26]. [37]

3.1.7.3 Policy instruments

- In the UK, a group of leading grocery retailers, producers and waste management companies have developed the "Plastics Pact" in a bid to drive down plastic use in Britain[27] [38].

- Bangladesh phased out the use of lightweight plastic bags in 2002[4]

[33]ecobirdy, "ecothylene® – ecoBirdy." https://www.ecobirdy.com/blogs/news/ecothylene® (accessed Sep. 21, 2020).

[34]crafting plastics, "NUATAN." https://www.craftingplastics.com/nuatan

[35] plastech, "Plastic waste as a resource ." https://www.plastech.biz/en/news/Plastic-waste-as-a-resource-14154?p=2

[37] F. Doveil, "Plastic waste as a resource, how design can shape intelligent (re)use – LifeGate." https://www.lifegate.com/plastics-reuse-recycling-design

[38] European Commission, "A European Strategy for Plastics," *Eur. Com.*, no. July, p. 24, 2018, doi: 10.1021/acs.est.7b02368.

- In Scotland, the Scottish Government announced a deposit return scheme (DRS)[28].[39]
- San Francisco, United States, implemented a plastic bag ban that led to a 72 per cent decrease in plastic litter on local beaches from 2010 to 2017 (Mercury News 2018)[10]18.
- In Rwanda and Kenya, plastic bag bans have been implemented effectively with financial and other legal penalties (de Freytas-Tamura 2017)[10]. 18
- In 2018, the European Union launched a strategy called Plastic Waste that aims to make all plastic packaging recyclable by 2030 and to ensure that waste generated on ships is returned to land (EU 2018b)[10].18

3.1.7.4 Sustainable business models

- Loliware creates sturdy single-use straws that are both compostable and straight-up edible using a seaweed-based material.
- We WOOD makes watches. For every watch they sell, they plant a tree.
- Bureo is "untangling the ocean." With an estimate of 640,000 discarded fishing nets polluting the ocean floors and shoals each year (making up approximately 10 per cent of plastic ocean pollution), Bureau has focused its efforts on collecting and reusing that material to create new commodities.
- Another very young and just-getting-going start-up, Solutum is based out of Israel. While not precisely a recycling-focused technology, Solutum's goal is to replace a large variety of plastics with an entirely new material that acts in the same manner, but can also biodegrade quickly.
- Seed Phytonutrients is a young, sustainable, clean hair care start-up. It comes in the first shower-friendly paper bottle, made of 100 per cent post-consumer recycled paper with a thin, post-consumer recycled plastic liner that's 60 per cent less plastic than a traditional bottle. It'll also arrive in recycled and recyclable packaging.

[39] authority of the House of Commons, "Plastic food and drink packaging," 2019, [Online]. Available: https://publications.parliament.uk/pa/cm201719/cmselect/cmenvfru/2080/2080.pdf.

Some practices around the world:

COUNTRY	DURATION	FUNDING	CO-FINANCING	RESULTS
MATERIAL ENGINEERING AND PRODUCT DESIGN				
Burundi	March 2017 – October 2017	US$21,000	US$22.469	• Use of banana bark bag led to avoiding use of estimated 3 million plastic bags • Reforestation of 13,000ha • 150,000 seedlings planted on farmland of beneficiaries • Income generation from producing alternative bags (US$55/Y/household)
India	December 2014 – December 2015	US$45,742	US$82,660	• Collecting waste became a significant source of livelihoods for local communities, allowed for health insurance • Plastic waste used as fuel in furnaces and road construction • Establishment of pilot plastic recovery center • Government Madhya Pradesh introduced policy on plastics, integrating community-led waste collection efforts in the policy framework
Jamaica	January 2009 – March 2010	US$39,200	US$25,793	• Collection of 20 tonnes of recyclable waste • Reuse of recycled material and design of products from recycled materials • Biodiversity protection and coral reef monitoring; protection of 4 species of turtles and corals • Updated Negril Marine Park Zoning Plan and protected area • Protection of 200 ha of marine and coastal area • Gender and youth outreach and awareness raising, 50 women involved in all project activities, 500 households, 2000 students and 30 businesses • Collaboration and partnerships established with 5 local NGOs and the Negril Recycling Center
Sierra Leone	December 2017 – November 2018	US$13,600	US$5,790	• Collecting waste from 1800 households and offices • Creation of sustainable employment for over 400 youth and women and training in waste management • Beautification of Makeni city • Production of 15,000 e-stones used for outdoor paving and made of plastic, rubber and sand
CONSUMER USE AND BEHAVIORS				
Gambia	August 2013 – July 2014	US$20,000	US$20,500	• Sensitisation of 100 women about plastic waste • Increased livelihoods from sale of products made with recycled plastic waste
Ghana	December 2017 – July 2019	US$7,000	US$27,000	• Reduced burning of plastic waste and increased recycling • 5ha land previously filled with litter restored and allocated for eco-farming • Increased livelihoods from sale of products of recycled waste • Reduced environmental pollution • Improved sanitation and health for communities • Reduced urban migration from rural area
Maldives	July 2018 – January 2020	US$38,180	US$28,404	• Sucessful advocacy, awareness raising ad social media campaign to decrease the use of plastic bags • Established partnerships with government and private sector • Introduction of reusable bags to supermarkets and other businesses
WASTE COLLECTION AND RECYCLING				
Afghanistan	March 2017 – March 2019	US$45,000	US$47,180	• Increased awareness among communities and government decision-makers • Innovative waste management model • Conservation of lake ecosystem and biodiversity
Armenia	June 2018 – June 2019	US$49, 200	US$66,000	• Increased environmental awareness and introduction of a recycling culture • Decreased waste to landfill • Contribution to national strategies and policies
Bahamas	January 2015 – December 2015	US$40,000	US$32,885	• Increased collection and recycling of plastic waste • Increased knowledge of the benefits of recycling in community • Decrease in waste at landfill

Source: Plastics and Circular Economy: community solutions by Small Grants Programme (SGP), (a programme of Global Environment Facility (GEF) implemented by the United Nations Development Programme (UNDP))[4].

3.1.8 Sustainable Development and Sustainable Development Goals (SDGs)

Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs[29][40]. The SDGs comprise a global agenda to end poverty, protect the planet, and ensure all people enjoy peace and prosperity [29] 40. The CE has the ability to implement strategies to achieve specific SDGs. According to [30][41], the concept was repeatedly mentioned as a key solution in the Expert Group Meeting[42] and in-depth review of SDG 12 on Sustainable Consumption and Production (SCP) during the 2018 High-Level Political Forum, including in the areas of SCP and climate change, ocean activities, and food waste and loss[31][43]. The CE holds particular promise for achieving multiple SDGs, including SDGs 7 on affordable and clean energy, 8 on decent work and economic growth, 11 on sustainable cities and communities, 12 on responsible consumption and production, 13 on climate change, 14 on life below water, and 15 on life on land [30] 41. Plastic products are not bad however, the way we manage plastic products is bad. As plastics may take more than +400 years to degrade, one way to manage waste is to make new products from them, i.e. recycling or reusing. Upon recycling, refuse or wastes are transformed into new products, reducing the need to extract raw natural resources and thereby protecting natural habitats for the future.

When recycled materials are used to produce new products in the manufacturing process rather than raw materials, we save considerable energy (energy required to extract, refine, transport and process raw materials). – Addressing SDGs 7, 8, 11 to 15. Recycling introduces regional growth by generating employment within the region. According to a [32][44], a recycling plant producing about 50,000 metric tons of recycled plastic, generates more employment than

[40] [29] UNDP, "Sustainable Development Goals : A call for global partnership and cooperation," *GAIA - Ecol. Perspect. Sci. Soc.*, vol. 28, no. 2, pp. 73–73, Jan. 2019, doi: 10.14512/gaia.28.2.1.

[41] [30] United Nations General Assembly, "'Circular Economy for the SDGs: From Concept to Practice,'" pp. 1–2, 2018, [On-line]. Available: https://www.un.org/en/ga/second/73/jm_conceptnote.pdf.

[42] The Division for Sustainable Development Goals (DSDG) convened a two-day expert group meeting on sustainable consumption and production (EGM) , as part of its substantive preparations for the High-level Political Forum on Sustainable Development (HLPF) 2018[31].
Sustainable Development Goal (SDG) 12 on sustainable consumption and production, encompass the aim of implementing of the 10-year framework of programmes on SCP (10YFP), the sustainable management and efficient use of natural resources, the reduction of global food waste and waste generation, the environmentally sound management of chemicals and all wastes throughout their life cycle, sustainable practices and integration of sustainability information into companies' reporting cycles, and support for developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production.

[43] [31] U. N. D. for S. D. D. of E. and S. Affairs and Sustainable, "An expert group meeting in preparation for HLPF 2018: Transformation towards sustainable and resilient societies," *Div. Sustain. Dev. Goals (DSDG), UNDP*, vol. 15, no. 3, p. 210, Aug. 2018, [On-line]. Available: https://sustainabledevelopment.un.org/content/documents/19990EGMSDG12advanceuneditedoutcomeFORWEB9July2018.pdf.

[44] [32] W.D'ambrières, "Plastics recycling worldwide: Current overview and desirable changes," *F. Actions Sci. Rep.*, vol. 2019, no. Special Issue, pp. 12–21, 2019, Accessed: Aug. 18, 2020. [Online]. Available: https://journals.openedition.org/factsreports/5102.

compared to situations like those generated by sending an equivalent amount of waste to a landfill or incinerating it, or manufacturing an equivalent quantity of virgin resins by the petrochemical industry. – Addressing SDGs 8, 13 to 15. As recycling reduces the need for extracting, refining, transporting and processing raw materials, there is a considerable decrease in air and water pollution. Greenhouse gas emissions cause climate change and since recycling saves energy, it also reduces greenhouse gas emissions, therefore, indirectly tackling climate change. Upon recycling refuse or wastes, the amount of rubbish sent to landfill sites reduces, hence the quantity of methane (a powerful greenhouse gas) coming out of these landfills decreases. – Addressing SDGs 7, 11 to 15.

3.1.9 Impact of various efforts in reducing plastic waste

A study has been conducted by W. W. Y. Lau *et al.*, "Evaluating scenarios toward zero plastic pollution" [15][45] which has developed five scenarios to estimate reductions in plastic pollution over the period 2016 to 2040. Scenarios modelled include:

3.1.9.1 Business as Usual (BAU): (a baseline from which to compare alternative intervention strategies)

Annual plastic pollution rates in aquatic and terrestrial environments decreased by only 6.6 per cent and 7.7 per cent by 2040, respectively (Fig. 10A). This result confirms that current commitments coupled with appropriate policies can reduce plastic waste input into the environment.

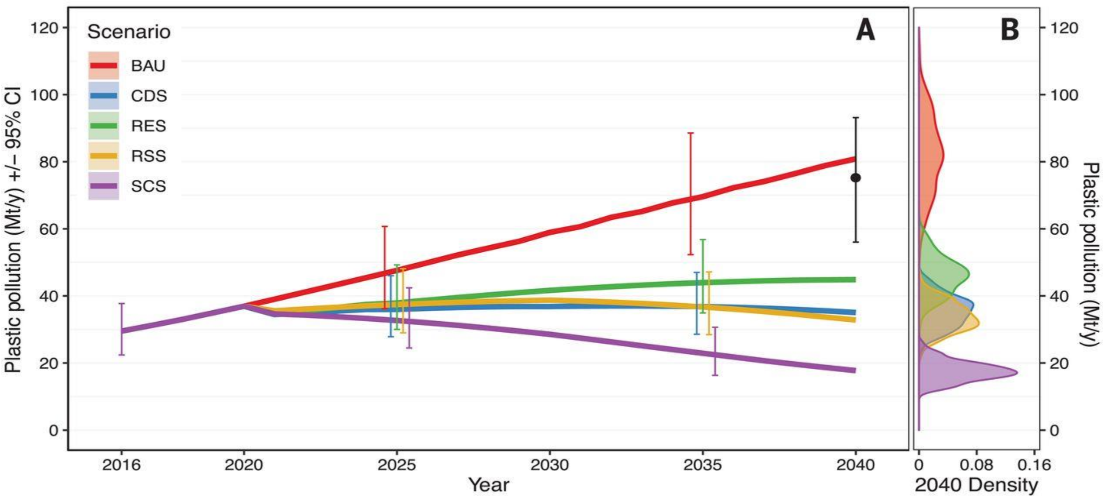


Figure 21- Business as usual scenario compared with other scenarios dealing with the treatment of plastic waste for the period from 2016 to 2040.

[45] [15] W. W. Y. Lau *et al.*, "Evaluating scenarios toward zero plastic pollution," *Science*, vol. 369, no. 6510, pp. 1455–1461, 2020, doi: 10.1126/science.aba9475.

3.1.9.2 Collect and Dispose (CDS)

Compared with BAU, the annual combined terrestrial and aquatic plastic pollution rates have reduced by 57 per cent in 2040 under the Collect and Dispose of scenario.

3.1.9.3 Recycling (RES)

Compared with BAU, the annual combined terrestrial and aquatic plastic pollution rates have reduced by 45 per cent in 2040 under the Recycling scenario (Fig. 1, A and B).

3.1.9.4 Reduce and Substitute (RSS), (considering Paper, coated paper, and compostable materials)

Annual combined terrestrial and aquatic plastic pollution in 2040 have decreased 59 per cent relative to in 2040 under the Reduce and Substitute scenario.

3.1.9.5 An integrated "System Change" scenario (SCS) that implemented the entire suite of interventions.

There are eight system- interventions:

- reducing plastic quantity in the system,
- substituting plastics with alternative materials and delivery systems,
- implementing design for recycling,
- increasing collection capacity,
- scaling up sorting and mechanical recycling capacity,
- scaling up chemical conversion capacity,
- reducing post-collection environmental leakage, and
- reducing trade in plastic waste

In this scenario, annual combined terrestrial and aquatic plastic pollution decreased by 78 per cent relative to BAU in 2040 but only by 40 per cent relative to 2016 pollution rates (Fig. 1, A and B). In 2040, the annual rate of land-based sources of plastic entering aquatic and terrestrial systems decreased by 82 per cent and 76 per cent relative to BAU, respectively (Fig. 11, C and D).

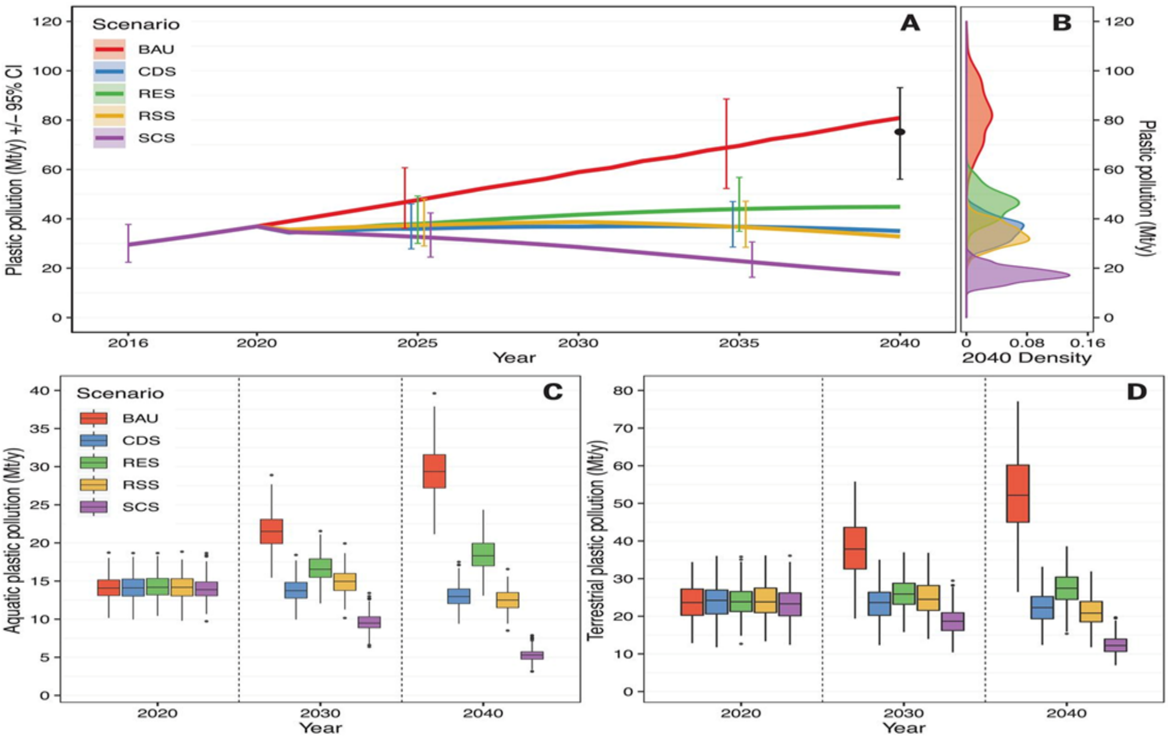


Figure 22- Business as usual scenario compared with System Change Scenario

Under the System Change scenario in 2040, a substantial reduction in mismanaged and disposed waste was achieved through increases in the proportion of plastic demand reduced, **substituted by alternative materials, and recycled**. These changes to the plastic system resulted in 11per cent less virgin plastic being produced in 2040 under the System Change scenario than was produced in 2016, and 55 per cent less than in 2040 under BAU. Moreover, this reduction was driven by **increases in recycled plastic feedstock**, which have lower life-cycle GHG emissions.

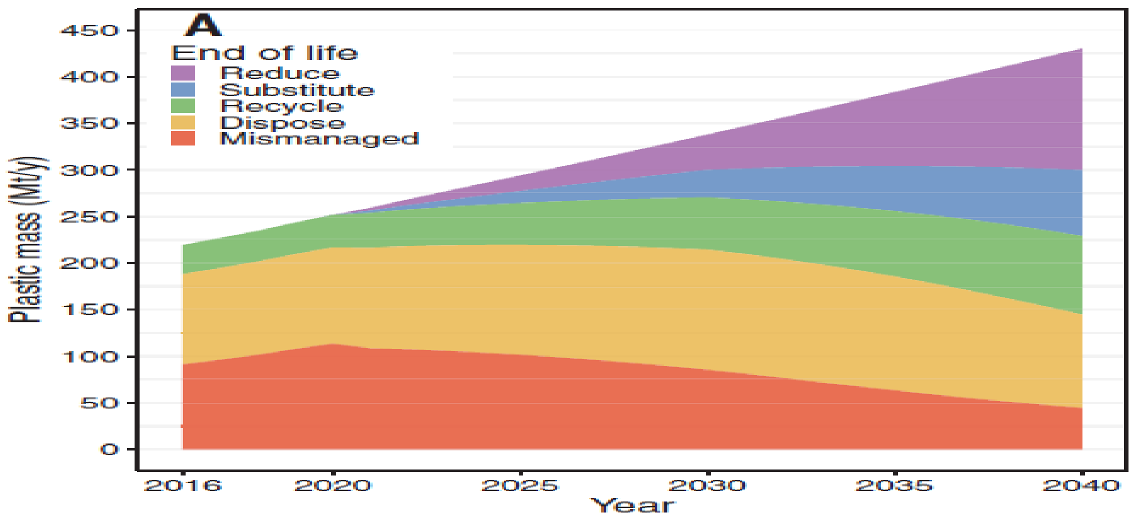


Figure 23- Annual mass of plastic for each of end of life fate of plastic

Nevertheless, it is evident from the study that the gap between the accumulated volume of plastic waste and the volume of plastic waste generated each year can be lessened more effectively by the System Change Scenario (SCS) which includes interventions such as substituting plastics with alternative materials and delivery systems, implementing design for recycling, increasing collection capacity etc. which are main components of the CE. Taken together, the System Change scenario moves toward achieving a CE in which resources are conserved, plastic waste generation is minimized, and GHG emissions are reduced. It also includes the use of plastic, reusing the accumulated plastic waste in various forms like tiles making, road construction or if possible can be recycled (either mechanically or chemically as per affordability & suitability) to extract the monomers.

3.1.10 Relevant points for the Audit point of view

- Plastic waste generation data at collection points/transfer stations may be important for the audit point of view.
- Collection and transportation need to be more efficient, as plastic waste is part of municipal solid waste and if Municipal Solid Waste (MSW) is collected, transported and segregated in an efficient manner, plastic waste management will also improve. Arrangements for transportation at transfer stations and Municipal Corporation documents may be examined during audit.
- Involvement of rag pickers for effective segregation and their welfare and arrangements are the important point for examination.
- Implementation of efforts regarding the segregation of plastic waste out of municipal waste as guided in Plastic Waste Management (PWM) guidelines needs may be examined and commented upon.
- Waste hierarchy in Jaipur follows just a reverse hierarchy. It was observed that tender entities follow the land-filling way of disposal, as the first priority for the top approach. While waste management hierarchy follows the waste land-filling bottom approach. It is clear that most of the MSW and Plastic Waste (PW) did not segregate by the responsible entities in the city before disposal.
- The Rajasthan State Pollution Control Board (RSPCB) is not providing data regarding the status of implementation of PWM in the State. Thus, there was no official detail which limits for verification of facts and figures that would be observed in the study and as such the scope of the document gets restricted to an overview of general effectiveness in the

implementation of PWM in Jaipur city. The finding illustrates the need for data collection mechanism.

- The study on the circular aspect of PWM emphasizes that effort of municipal bodies/initiatives by the Government for adopting circular measures may be examined and recommended.
- The study also attempted to provide approaches regarding the impact of various efforts in reducing PW. It will help auditors in understanding the business-as-usual model and the impact of circular measures.
- Case studies will help auditors in framing good recommendations on plastic waste management.

3.1.11 Recommendation

1) Municipal Corporation of Jaipur (Nagar Nigam Jaipur (NNJ)) may need to review its strategies in plastic waste management.
2) There is a requirement for effective monitoring of the working of the agencies awarded works for plastic waste management.
3) NNJ needs a proper database/information system regarding plastic waste generation.
4) Need to set up material recovery facilities (MRF) or secondary storage facilities with sufficient space for sorting of recyclable materials to enable informal or authorised waste pickers and waste collectors to separate recyclables from the waste.
5) Need to provide easy access to waste pickers and recyclers for collection of segregated recyclable waste such as paper, plastic, metal, glass and textile from the source of generation or material recovery facilities.
6) The establishment of intermediate transfer stations is determined by the distance between secondary waste collection points and the final treatment and disposal point. This distance should not be too much therefore, the establishment of more intermediate transfer stations is required.
7) Landfill site should be developed for the disposal of inert materials generated through the processing units at Sewapura compost plant and Langariyawas RDF plant.
8) To ensure safety and health, provide proper safety gear like dresses, gloves and face masks for staff, and a worker that works all day over a long period in a transfer station or door-to-door collection. There is a need to assign identity cards to waste pickers through NNJ.

3.1.12 Conclusion

CE Caters to three standpoints namely environment, society and economy hence best solution to PWM issue is to recycle PW. The plastic recycling industry already exists in almost all countries therefore, it's high time to carry out research and development work to make the industry technically advanced, make policies that are business and environment friendly and bring greater demand for recycled products. To bring the CE concept to plastic products recycling route should be accepted (keeping in mind 'Reduce' is followed as the first option before any type of recycling). Recycling being a major component of CE, the following route may be adopted:

a) Reuse (as recycled products still need to be re-manufactured and transported, meaning that reuse is advantageous over all other recycling routes).
b) The polymers should be mechanically recycled for as long as possible until they become low grade.
c) Once the polymers become low grade their monomers should be recovered via a chemical route, the monomers can then be repolymerised resulting in a truly CE.

However, more research and development work on the integration of mechanical, chemical and other evolving recycling techniques especially involving any biological activity is required to speed up true circularity in this sector.

CE practices in PWM can also help us achieve a few of the SDGs. There exists a direct relationship between CE practices and targets of SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 14 (life below water) and SDG 15 (Life on Land).

We need to take prudent steps to shift to non-plastic items made from bio-based raw materials which are biodegradable and compostable and leave future generations a planet full of wildlife and green space just like our ancestors used to have. Policy-makers should also help create favourable frameworks for this existing industry to thrive and flourish. There should be a collaboration of this industry with academics to accelerate R&D work which will cater for 3 standpoints.

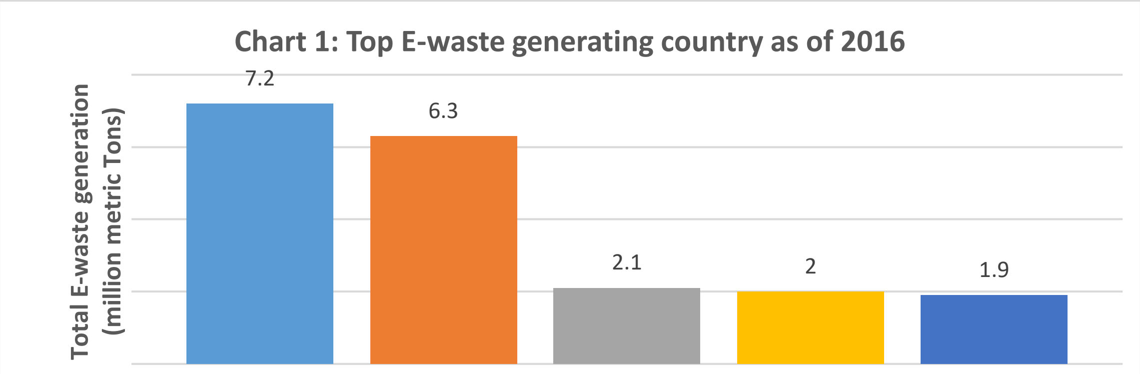
Lastly, consumer psychology and their awareness will accelerate this drive for recycling. On the global level, intergovernmental relations and all countries working on the same platform will boost sustainable development. The general public should be acknowledged of lethal effects from continuous low-level exposures such as from daily use of plastic containers, utensils and other products.

THEME 3.2: ELECTRONIC WASTE OR E-WASTE

3.2.1 Background on E-waste

The Electronics industry is one of the fastest growing industries in the world and expected to reach $ 400 billion in 2022 from $ 69.6 billion in 2012 in India *(Corporate Catalyst India, 2015)* [source1] [source2]. This tremendous growth in the manufacturing and consumption of electronic and electrical equipment combined with rapid product obsolescence and lower costs makes 'E-waste' the most rapidly growing waste problem in the world [source].

As per ASSOCHAM-NEC Joint Study on Electricals & Electronics Manufacturing in India, about 44.7 million Tons of E-waste were generated worldwide in 2016 and it is expected to grow at a rate of 3.15 per cent Compound Annual Growth Rate (CAGR). Following the current growth rate of rising E-waste, it is estimated that by 2021, E-waste will rise to 52.2 Million Tons. As of 2016, the India is 5th largest E-waste generating country with two million metric tons of annual E-waste generation (1.5 Kg per capita).



Source: ASSOCHAM – NEC Joint Study on Electricals & Electronics Manufacturing in India

Presence of many harmful materials and chemicals in electronic products is a major concern during the E-waste management phase, which can be hazardous and have the potential to severely impact human health and the environment if they are not handled properly [source][source]. Nevertheless, the presence of valuable resources such as copper, silver, gold and platinum makes it attractive to recycle E-waste [source]. Therefore, recycling E-waste is an important subject not only from the point of waste treatment but also from the recovery aspect of valuable materials. However, the process of take-back and disposal of E-waste is very complex, which involves various kinds of products, many people and enterprises, extensive areas and a long time span [source]. It is estimated that 75 per cent of electronic items are stored due to uncertainty about how to manage it. Thus, unused electronics lie unattended in homes, offices and warehouses until they are eventually mixed with regular waste and dumped in landfills *(Ramachandra and Varghese, 2004)* [source].

Given the volume of E-waste being generated and the content of both toxic and valuable materials in them; E-waste is an emerging problem as well as a business opportunity of increasing significance, [source]. But the system of determining the amount of E-waste generated in India is mostly estimated through independent Organization reports such as from Assocham-NEC, , Global E-waste monitor and articles such as in Business World wherein E-waste generated in India per annum is estimated to be around 3 Million Tons Per Annum (MTPA) in 2018 from 2 MTPA in 2016, which gives some ideas on the matter.

3.2.2 CAG Audit Reports finding

Till now, there are no stand-alone/ dedicated reports on the E-waste management; however few issues on E-waste management in India have been highlighted in audit reports on solid waste management as mentioned below:

Audit Report	Observations
All India Performance Audit report on 'Management of Waste in India', ANNEX 3 (Audit Reports on Waste) of CAG Environment Reports on Waste Management, [source]	• The Ministry of Environment Forest & Climate Change (MoEF&CC) Central Pollution Control Board (CPCB) State Pollution control Board (SPCB) did not have required data about different kinds of waste generated in India which includes E-waste. • There was an inadequate implementation of measures that provided for the safety and health of waste handlers. • The policy focuses more on the disposal but not on recycling despite being a signatory to Agenda 21.
CAG Report on the Performance Audit (PA) of Solid Waste Management in ULBs, Karnataka Report No. 4 of 2018 (8.3.3) [source].	• As per the information provided by Karnataka State Pollution Control Board (KSPCB), a total of 86,118 MT/ annum of E-waste was estimated (Environment Management Policy and Research Institute, Bengaluru) to be generated in 2014, however, details of E-waste generated, collected and channelized to recyclers, dismantles or otherwise disposed of in the State during the period 2012-13 to 2016-17 was not available with KSPCB/ Director of Municipal Administration. • E-waste was not handed over separately by the households but was mixed with Municipal solid waste (MSW) and the Urban Local Bodies (ULBs) did not

	collect and channelize E-waste to authorized dismantlers as of 2017. • The E-waste generated was kept undisposed exceeding the permissible limit of 180 days duration. • The ULBs did not maintain the required record of E-waste and did not file the annual returns.

Further, some of the issues highlighted in the CAG Report on the Performance Audit of Solid Waste Management in Urban Local Bodies, Government of Rajasthan, (Report no. 2 of 2018) are mentioned below:[source]

Key Features of the Report

- Need for inventorization of E-waste.
- Better regulation of import of E-waste with proper data and guidelines.
- Regulation of 'used' material, which is imported without restrictions.
- Stringent monitoring and enforcement of the provisions of the E-waste Management Rules 2016 so that EPR targets are met and that there is independent information about where this collected waste is 'recycled'
- Monitoring of the health and environmental conditions of informal E-waste hubs in the country so that people who are employed here get compensation for ill health.
- Improve and incentivize recycling through mandatory (not voluntary) deposit refund schemes by companies.

Key Issue	Observations
Data collection	• The Rajasthan State Pollution Control Board (RSPCB) did not have any information regarding assessment of E-waste. • The ULBs did not assess the quantum of E-waste generation under the area falling under their jurisdiction. • No future projection about composition & quantities of E-waste likely to generate. • No record of current & future capacity of manpower and vehicles.
Risk to the environment and human health	• The Local Self Government Department (LSGD), Panchayat Raj Department (PRD), Rural Development Department (RDD) and RSPCB did not conduct any assessment of risk to environment and human health posed by waste.
Treatment and disposal	• RSPCB and Department of Local Bodies (DLB) did not prepare any program for reduction of E-waste and to

Penalty		promote the use of recycled and environment friendly products in the State except in Jaipur.
	•	In spite of having sufficient powers under relevant rules/ bye-laws, action taken against the violation of rules was only 45 per cent.

3.2.3 Centre for Science and Environment

As per the report on 'E-waste management: generation; collection and recycling' by DG, Centre for Science and Environment submitted to the Hon'ble Delhi High Court in May 2018, E-waste management in India needs major improvements and updates [source]. The Hon'ble court had termed E-waste as a 'critical area' that has so far escaped attention of authorities.

3.2.4 Research Methodology

A study "Assessment of E-Waste in regard to management policy in Jaipur city, Rajasthan" was conducted by Mr. Sungrongti. The Data was collected from the available literature as well as field study which included surveys, site visits and interviews with the stakeholders to identify the missing links and problems associated with E-waste management in Jaipur city. Given the involvement of various stakeholders in the management of E-waste including unorganized sector, the research had followed the purposive method of sampling and specific stakeholders were selected for the data collection as per the objectives and needs of the research. The identified stakeholders for this research were:

A. Nagar Nigam Jaipur (NNJ)
B. ETCO E-waste recyclers.
C. Municipal Solid Waste (MSW) Plant.

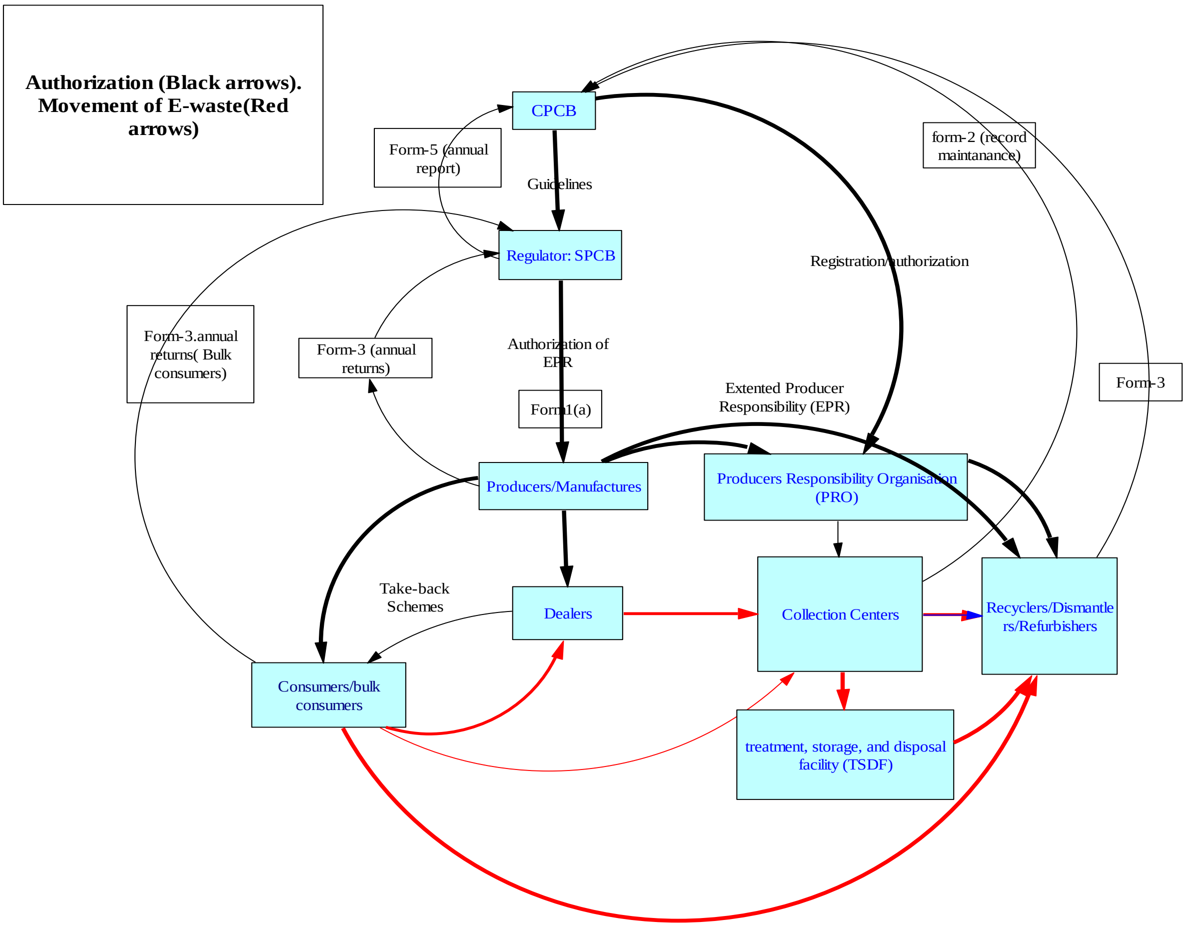
Some other observatory cases included from -

D. Mathuradaspura Dumping area.
E. Achrol open dump.

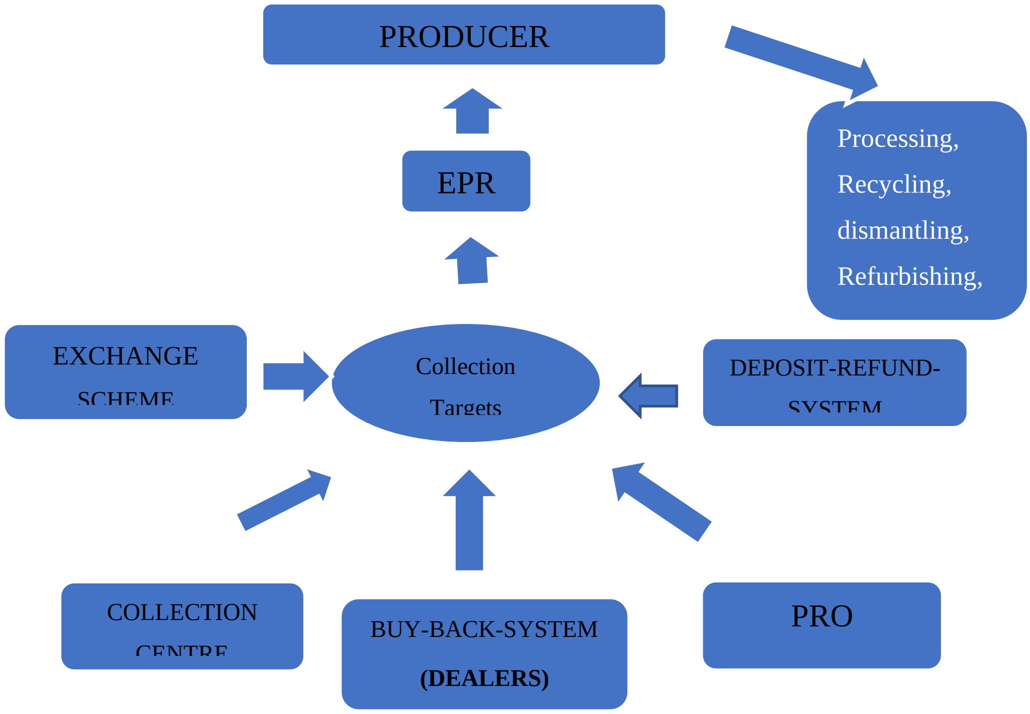
3.2.5 System thinking and Casual Loop Diagram (CLD)

System Thinking is a science that deals with the organization of logic and integration of disciplines for understanding patterns and relations of complex problems [source]. It is one of the most common concepts used for understanding how causal relationships and feedbacks work in a problem. The main purpose of causal analysis is to try to find the root cause of a problem and understanding the different factors responsible for the existence of the problem and its behavior. After analysing the different stakeholders along with the help of existing literature, few causal variables have been uncovered and as such these factors have been represented using a Causal

Loop Diagram model to depict the system of the current E-waste management in the Jaipur city as per the observation made during the study. The main design of the CLD model is to understand the cause and effect of different variables within the E-waste management system. Different colours for the stakeholders have been used to make it easier to follow and understand the relationships between the different processes. A CLD model is mainly signified by addressing the polarity which means a negative/ minus sign (-) or a positive/ plus sign (+) is indicated for each type of relationship. A negative sign simply means that the relation between the two or more variables has an indirect effect whereas a positive sign represents a direct relationship.

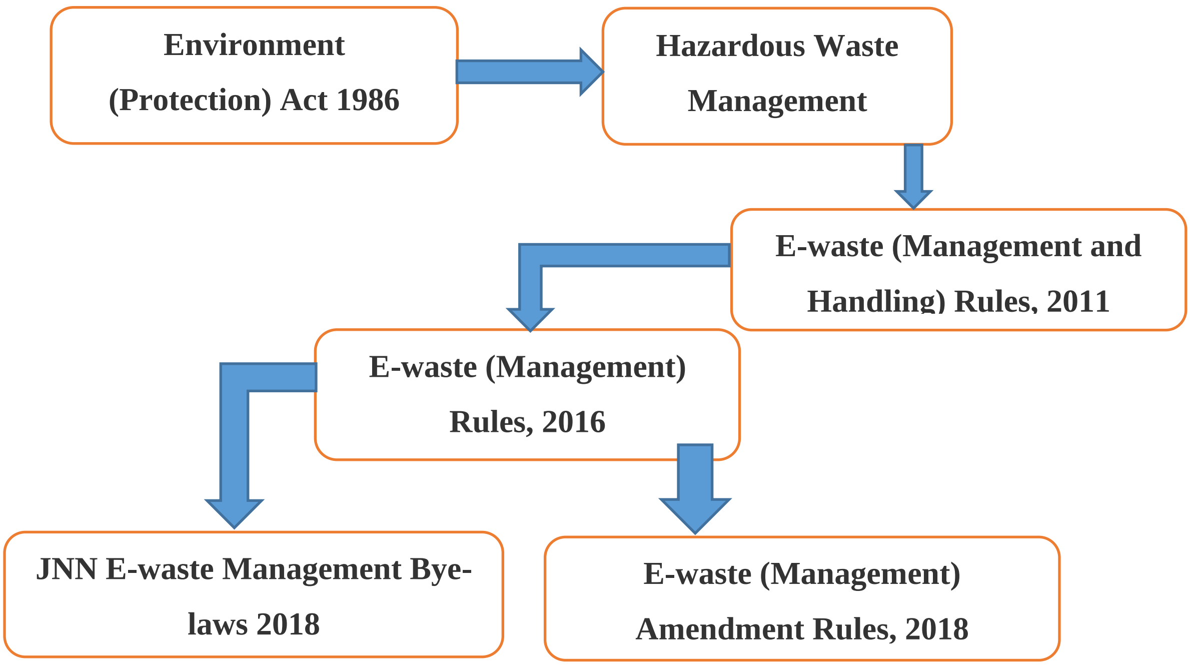


The most significant feature of the E-waste Management Rules is the Extended Producer Responsibility (EPR) where the producers of electronic and electrical equipment have the responsibility of managing such equipment after its end of life. The Basic framework of Extended Producer Responsibility (EPR) is shown below:



However, it's been less than a decade since the EPR was introduced in India but a revised and proper recycling and collection targets had been mandated only in 2018 under the new E-waste Management Amendments Rules.

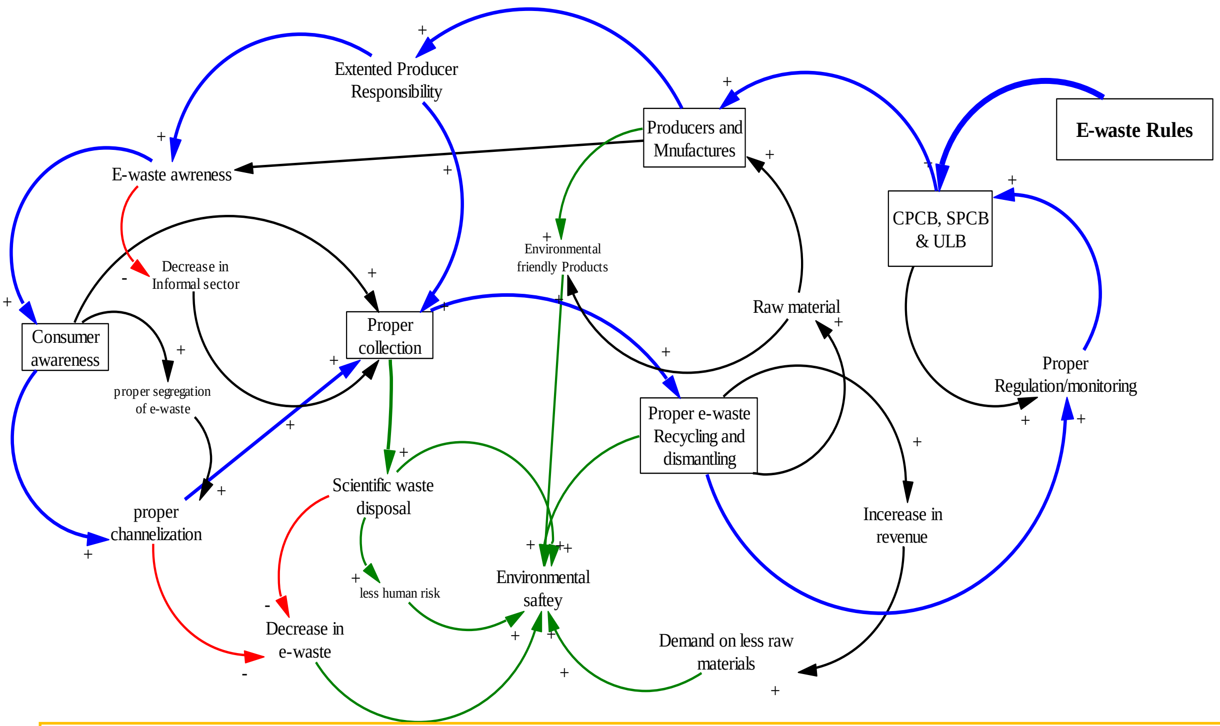
The genesis of the E-waste legislations can be briefly depicted as shown below:



3.2.6 Understanding the Ideal flow of E-waste

Before analysing and identifying the possible problems/ non-conformity of the stakeholders under the E-waste Management Rules, it is necessary to first understand the ideal scenario as to how E-waste should flow and be managed within the system as per the E-waste Management Rules. A loop diagram is developed to depict the ideal flow of E-waste considering without any violations and absolute conformance of the E-waste Rules by all stakeholders having their own responsibilities.

Fig 3: A Loop Diagram representing an ideal flow of E-waste



- *Blue arrows represent the direct relationship between each stakeholder variables*
- *Green arrows represent the relationship involving the environmental factors.*
- *Red arrows indicate the decrease factors and the Black arrows indicate the relationship within the sub-variables.*
- *A positive +ve sign indicates the direct relationship within the various variables such as, if there is an increase in one variable then there will be an increase in the other and vice versa.*
- *As for –ve sign, it indicates the indirect relationship such that, if one variable increase then the other variable will decrease and vice versa.*

It can be observed that the E-waste policies primarily target the producers and manufacturers because of the EPR, basically the present approach to tackle the E-waste pollution from its source. It can also be seen that the loop connects around the collection and proper recycling and dismantling of the E-waste producing a positive effect so that it can be properly utilized for its extractable raw materials and proper disposal as its final feedback.

In an ideal flow E-waste system, there will always be a minimal role for the informal sector handling the E-waste. It can also be seen that "Consumer awareness" also acts as an important variable within the E-waste management system interconnecting and influencing the outcome of many other variables generating a positive effect in the management of E-waste.

However, the final pivot of the loop narrows down to the safety of the environment which means that the overall E-waste policy centres on environmental safety and preventing any risk that might harm human health.

3.2.7 Status of E-waste management

The role of NNJ in the management of E-waste is of high importance. As per Bye-laws, 2018, ch-5.1, the NNJ is responsible for the management of E-waste within the city. It is supposed to collect the E-waste separately or segregate it from solid municipal waste and channelize it to dismantlers/recyclers who are authorized under the E-waste management guidelines. The field visit, observations of the CAG Audit Report and a TV Channel report, it was observed that:

- No work was being done in the concerned field as no specific engineer/personnel working on E-waste management projects in the Jaipur city.
- NNJ not provided any kind of data on E-waste generation and processing. Similarly, it was also observed that E-waste management in the current situation is of the less priority even though it was well aware of the current E-waste Rules.
- The NNJ was focusing only on the collection of municipal solid waste. Till a proper system for E-waste management is put up, its current goal is to run public awareness campaigns [source].
- A senior official from the RSPCB during an interview in June 2018 with a TV Channel stated that the current problem of E-waste in Rajasthan is that the E-waste is not reaching the designated recycler/dismantler and therefore, the recyclers/dismantlers are underutilized. According to him, the State is generating 20,000 tons of E-waste in a year while there are 10 recycling units, with a total capacity of 68, 670 tons.
- The common man has no knowledge/awareness of E-waste [source].
- According to the CAG of India on Urban Local Bodies, Audit Report (No. 2 of 2018) on waste management, the Government of Rajasthan released ₹ 292.8 crores to ULB's during 2015-2017 for solid waste management under the *Swachh Bharat Mission*, out of which only 20.69 per cent funds were utilized by all the ULBs in the State [source].

Further, the RSPCB did not have any information regarding assessment of E-waste [source].

- Inventory of E-waste was not being maintained even though the EWM Rules clearly enjoins the State to maintain inventorization of E-waste and submit annual returns to the CPCB as mentioned in Schedule IV (II) and Rule 18 (1) of the EWM Rules 2016.

3.2.8 Analysis of the current system of E-waste management

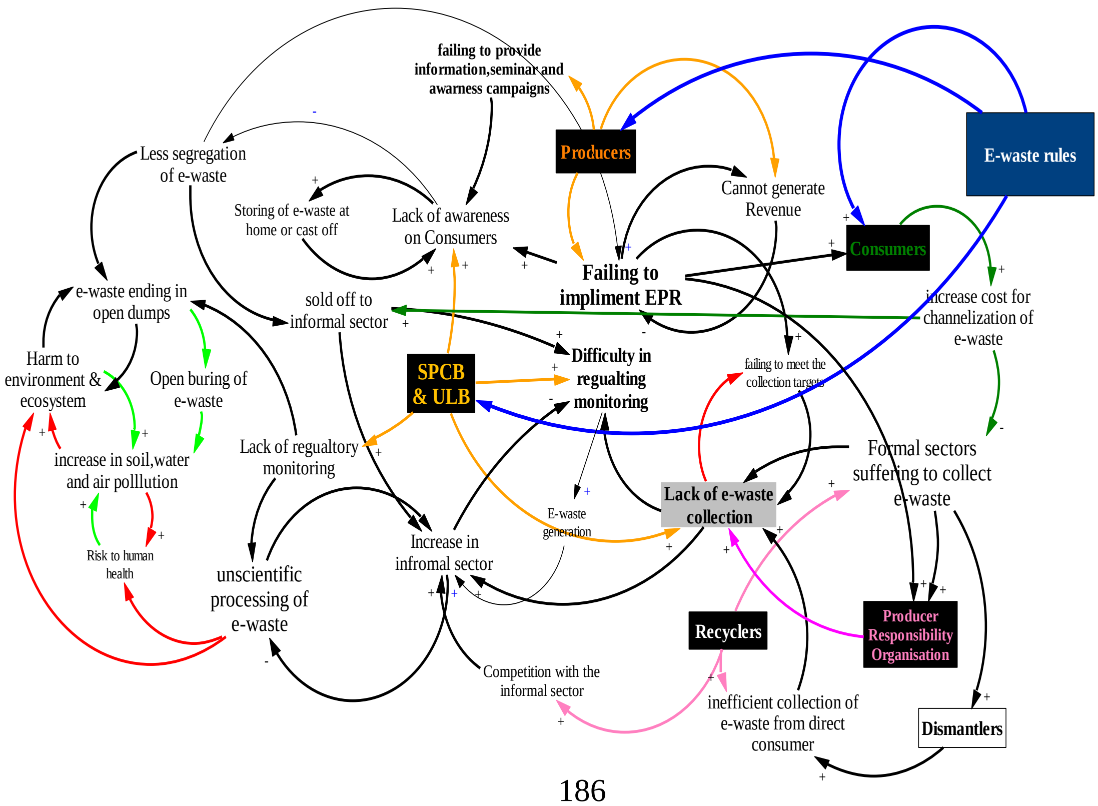
The CLD model developed below depicts the system of E-waste management in Jaipur city. As per the observation made during the study to understand the cause and effect of different variables.

Different colours have been used for the stakeholders to make it easier to follow and understand the relationships between the different processes. A CLD model is mainly signified by addressing the polarity which means a negative/ minus sign (-) or a positive/ plus sign (+) is indicated for each type of relationship.

A negative sign means that the relation between the two or more variables has an indirect effect whereas a positive sign represents a direct relationship.

The following Diagram shows the problems (cause & effect) in the current E-waste management:

Fig 10: A Causal Loop Diagram (CLD) representing the current management of E-waste



From the above CLD model, it is seen that the primary stakeholders within the E-waste management rules are the Producers, Consumers and the Regulatory Bodies (SPCB & ULBs). The study around these three stakeholders forms an interconnected web of effects that will help in understanding the current management of E-waste.

3.2.9 Factors affecting the implementation of the E-waste Management Rules and key interpretations from the CLD

3.2.9.1 Collection of E-waste (Extended Producer Responsibility (EPR)):

As per E-waste Management Bye-law (2018), it is mandatory for the producers and manufacturers to collect their targeted E-waste from the market through collection centre or by setting up collection points to ensure its proper channelization to authorized dismantler/ recycler under the EPR. Under the EPR, the producers may collect their E-waste from the consumers directly or through the Producer Responsibility Organization (PRO). However, according to one of the recyclers, such schemes cannot be fully implemented in practical terms because of "money recession" among the producers. Further, the producers are not generating revenue specifically for EPR as the cost of a product will increase with EPR affecting the cost competitiveness of their products.

There is less awareness among consumers about the EPR which leads to many problems such as failure in collecting the Waste Electric and Electronic Equipments [source] and it is channelized through informal sectors having environmental implications. While seeking EPR authorization, producers submit self-declaration to take corrective measures to bring their products into compliance but still the EPR Authorized Producers are not maintaining records related to the Reduction of Hazardous Substance (RoHS).

As per the survey conducted as a part of the study, it was observed that 23 per cent of the respondent were keeping the E-waste at home. This was mainly due to the absence of a proper E-waste collection mechanism. During the study, it was also found that:

- According to a notice S. No. F 29() X.E.N/(Project)/NNJ/2017 [source] there was no specific mode of collecting E-waste from different wards and no methods/ procedure for channelizing E-waste to authorized recyclers/ dismantlers has been notified.

- Lack of general schemes for collection of E-waste under the EPR such as through dealers, collection centres, PRO, Buy-back arrangement, Exchange Scheme, Deposit Refund System, etc.
- There was only one registered Producer Responsibility Organization (PRO) in Rajasthan (*M/s Pro Connect*) for collecting and channelling E-waste. The company was not reaching all the consumers for the collection of E-waste.
- There were no specific collection points assigned for the collection of E-waste by NNJ. Only three E-waste Bins, where consumers can drop their E-waste, are provided by ETCO with no specific location and capacity provided by them.
- There were no records of the collection Centre in Jaipur which is authorized under the RSPCB.

With problems in the implementation of EPR and associated issues in the collection of E-waste due to a lack of adequate Producers Responsibility Organization (PRO), a loophole is created within the system that fails to track and check the generation and processing of E-waste as per the prescribed mechanism. Further, a negative polarity has been established in the CLD for the lack of E-waste collection which means that with an increase in non-conformity by the stakeholders, there is a decrease in E-waste collection. Consequently, with a decrease in E-waste collection, there is a direct increase in the role of informal sector and its consequences for the health and environment.

3.2.9.2 Awareness programs:

During the meeting with the authority, respondent/s mentioned the preliminary steps needed for E-waste management was to start with E-waste awareness campaigns and other forms of information sharing. About 63 per cent of the respondents during the survey conducted to determine the level of public awareness were unaware of E-waste rules and their associated problems. NNJ is responsible for creating awareness among all the stakeholders about their responsibilities within the Jaipur City. There are many factors responsible for failure in generating consumer awareness such as:

- The Producers of Electric and Electronic items are not creating awareness to its users through media, publications, advertisements, posters or by any other means of communication and product user documentation accompanying the equipment as required under the E-waste bye-laws, 2018.

- Awareness on E-waste management is done on the scale of consultancy and organizing one-day awareness campaigns by NGOs such as CUTS International but till now there have been no awareness campaigns and co-ordination projects initiated with Government bodies to ensure compliance of the E-waste rules and E-waste collection drives which under the JMC bye-laws Section 5 are the responsibility of JNN.

It has been established in the CLD that segregation of E-waste is heavily dependent on the Producer and Consumer's relationship in terms of awareness establishing a positive polarity relationship between "Consumer awareness" and "segregation" which means that with decrease in consumer awareness there is also a decrease in the E-waste segregation, however there is a negative polarity relation between "segregation" of E-waste and "producer" which means that with increase in Producer's negligence there is a decrease in segregation of E-waste.

3.2.9.3 Monitoring:

One of the most important and fundamental initial relationship in the management of E-waste is to determine the amount of E-waste generated and to monitor its flow within the system involving role of different stakeholders. However, there is negligence on the part of NNJ in monitoring the generation and flow of E-waste even though it is their responsibility under the JMC E-waste Management Bye-Laws, 2018 Chapter 5. Hence, a negative polarity relationship has been established in the CLD which means that the amount of E-waste generation is increasing when there is a decrease in monitoring. However, it is not just the NNJ that's failing to monitor E-waste generation but the producers who are also neglecting their EPR and failing to monitor the flow of their EEE placed in the market. This relationship is trying to establish that the stakeholders are not conforming to the rules laid down by the CPCB such as:

- The NNJ does not have any assessment of the quantum of E-waste generated in Jaipur City.
- The NNJ did not make any future projections about the quantities of E-waste likely to be generated.
- In regard to the EPR authorized Companies, the data on E-waste generation will be invalid due to its failure in targeting all levels of consumers (as they have targeted only the Bulk consumers).

There is a sign of Negligence and absence of a proper monitoring mechanism on the part of the regulatory bodies such as NNJ and RPCB which lead to E-waste pollution unchecked and non-compliance with the E-waste rules.

3.2.9.4 Informal Sector and disposal of E-waste:

Competition from the informal sectors is one of the main problems faced by ETCO (and other recyclers/ dismantlers) to efficiently collect E-waste therefore, the flow of E-waste is hard to monitor. Due to the ineffective practical implementation of the EPR along with lack of monitoring and enforcement, there is an increase in informal sector managing more E-waste stocks than the formal sectors, with 98 per cent of the E-waste going to the informal sector [source]. As per the survey conducted as part of the study, 57 per cent of the respondent sold their E-waste to *Kabadiwalas*.

Scientific disposal of E-waste is the main concern under the management of E-waste due to its many negative effects on the environment and human health.

It is well established under the CLD that the scientific disposal of E-waste is poorly managed to establish a positive relationship with the informal sector which means that with the increase in the informal sector managing more E-waste, there is an increase in the unscientific disposal of E-waste.

Further, a clear result is established in the CLD between the informal sector and the other variables creating a negative relationship where there is an increase in informal sector and a decrease in the other stakeholder variables.

Unpredictable flow of E-waste: The collection and flow of E-waste are not consistent with other forms of waste. It was also revealed during interactions that most of the E-wastes are stored within the direct consumer's homes and it will be difficult for that E-waste to be channelized properly into the formal sector unless there are some consumer benefits/ revenue, awareness and enforcement measures.

3.2.10 Conclusion and Recommendations

Management of E-waste involves many stakeholders. Even after nine years since E-waste management rules had been implemented, the status of E-waste management is not satisfactory. Awareness of E-waste has been gradually rising among the consumers but due to the lack of practical efforts made by the formal sector, most of the E-waste generated ends up within the informal sector. Owing to the informal sector managing most of the E-waste along with producers failing to maintain their RoHS records poses many risks to our environment and human health.

There are many communication gaps between NNJ and the other stakeholders which result in the failure to properly collect and recycle E-waste generated from the city. The target set under the E-waste rules for the producers under the EPR is lacking in terms of practical use. There has been no direct mention of penal clause for the violation of the E-waste Management Rules, 2016.

There is a need for stringent penal provisions and robust monitoring mechanisms to deal and match up with E-waste generated in the present times. The NNJ must be strengthened in terms of monitoring and channelization of E-waste within the City.

Recommendations:

- The negligence or difficulty in executing the EPR must be addressed and the Producers must be monitored for compliance with the E-waste rules.
- For enforcing EPR, such regulations as "Take-back with Recycling targets"[46] practised by South Korea[source] can be incorporated for better management of E-waste.
- NNJ should maintain records on all the fractions of E-waste channelized through them to different recyclers/dismantlers as per its responsibility under the JMC E-waste Management Bye-laws, 2018.
- As there are total 30 dismantlers/re-furbishers/recyclers authorized by RSPCB out of them only four have been registered as a recycler and none of them is located in Jaipur. Therefore, it is recommended that NNJ may partner with eight dismantlers/ re-furbishers located in Jaipur for further recycling of E-waste in partnership with authorized recyclers located in other parts of Rajasthan.
- NNJ should inspect the landfills and other open dumps regularly so that there is no case of open burning of E-waste.
- Suitable penal provisions may be incorporated in these Rules in line with the Environment (Protection) Act, 1986 wherein **Section 15** prescribes imprisonment for a term which may extend to five years or with a fine which may extend to one lakh rupees, or with both in the event of contraventions of the provisions of the EPA. In case of failure, an additional fine can be imposed [source].

[46] If the association of producer or the importer does not satisfy the obligation rate/ target of recycling wastes, then the producer or the importer should pay the recycling charges with fine.

➢ Some recommendations specific to each stakeholder are listed below:

Stakeholders	Recommendations
Producers	• Provision of penalty in case of failure to E-waste collection. • Producers to provide information and schemes for the recovery of their end-of-life products. • Incentives for consumers for channelizing their E-waste to producers.
Recyclers and Dismantlers	• Collection of E-waste must be targeted to all types of consumers. • Beneficiary schemes to involve consumers in the channelization of E-waste. • Advertisement and information sharing platforms should be updated regularly.
Nagar Nigam Jaipur	• There should be a specific project for E-waste collection under NNJ. • Public E-waste awareness campaigns and workshops should be organized. • Regular checking/inspection for compliance with the E-waste Rules. • E-waste collection bins should be in every ward under the NNJ.
RSPCB & CPCB	• Registered stakeholders under the E-waste management should be regularly monitored and the license of the stakeholders failing to report their annual return to be cancelled. • The informal sector should be encouraged to come under the formal sector. • Construction of an E-waste processing plant should be a priority.
Consumers	• Consumers must seek help from the formal sector to channelize their E-waste. • Consumers must always read and question the terms and conditions of their electronic products. • Consumers must take active participation in E-waste awareness campaigns and workshops.

THEME 3.3: INDUSTRIAL HAZARDOUS WASTE MANAGEMENT IN RAJASTHAN AND GUJARAT

3.3.1 Introduction:

A major fraction of the waste generated around the world constitutes industrial or hazardous wastes (HWs). Hazardous wastes are the combinations of wastes that pose a substantial present or potential hazard to humans or other living organisms or natural resources because they are non-degradable or persistent, can be biologically magnified, toxic, or may otherwise cause cumulative detrimental effects. Hazardous wastes contain organic or inorganic elements that, due to their toxicological, physical, chemical, carcinogenic or persistent properties, may cause: Explosion or Fire, Infections including infection by parasites or their vectors, Chemical instability, reactions or corrosion, Acute or chronic toxic effects, Cancer, mutations or birth defects or Damage to ecosystems or natural resources.

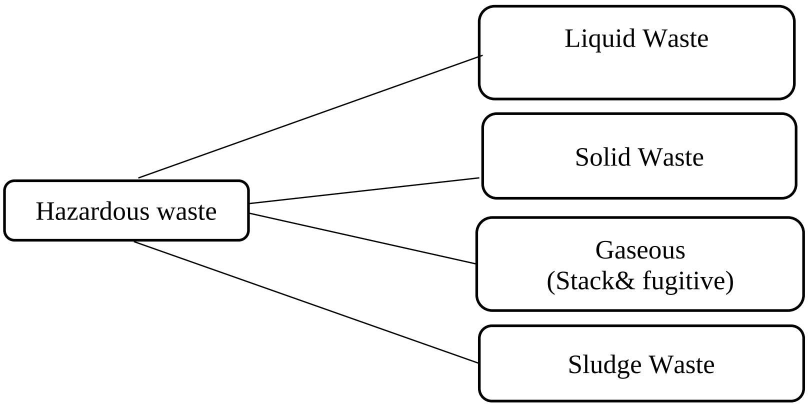


Figure- 1: Classification of Industrial Hazardous waste.

Hazardous waste is mainly generated from the following industrial sectors: chemical manufacturing, petroleum products and coal products, waste treatment and disposal, agricultural chemicals such as pesticides and fertilizers etc. Industries are the primary drivers of economic growth in a developed or developing country. Based on the size, industries can be classified as small, medium, and large-scale industries.

3.3.1.1 Important characteristics of hazardous waste:

A waste is considered hazardous when it exhibits the following characteristics[47]

[47] Berkeley lab bringing science solution to the world (Environment health and safety division) Environment/Health/Safety (EHS) (lbl.gov)

- **Corrosive**: Waste can degrade or corrode the metal container, drums, tanks and barrels. They can be Acid and Alkali.
- **Reactive**: Unstable Waste can explode under violent reaction and generate toxic fumes and gases when heated. For example, sodium metal, lithium metal, concentrated sulphuric acid etc.
- **Ignitability**: Waste can generate fires under certain conditions and are spontaneously combustible. For example, acetone, ethanol, benzene, methane etc.
- **Toxic**: Waste that is harmful or fatal when ingested or absorbed (for example mercury, lead etc.).

3.3.1.2 Status of Hazardous Waste:

Globally, around 400 million tons of hazardous waste are produced each year, almost 13 tons of hazardous waste every single second[48]. An estimated 60 kg of hazardous waste is generated a year by every person globally, and the amount is increasing. In just one generation, the production of man-made chemicals has increased by 40,000 per cent from one million to 400 million tons. Therefore, hazardous waste management and its disposal are major challenges all over the world.

India is currently among the top 10 industrial nations[49] and is considered one of the world's fastest-growing economies. In India, 69,308 hazardous waste generating units have an authorized annual capacity to generate about 39.46 million MT of hazardous waste[50]. However, during 2019-20, about 8.78 million MT of hazardous waste has been generated as per the annual returns submitted by such units. The top 10 hazardous waste generating states in India are Gujarat (28.30 per cent), Maharashtra (11.38 per cent), Tamil Nadu (10.99 per cent), Odisha (7.74 per cent), Andhra Pradesh (7.07 per cent), Rajasthan (6.69 per cent), Jharkhand (4.67 per cent), Uttar Pradesh (4.12 per cent), Telangana (3.61 per cent) and Kerala (3.54 per cent) which together contributes about 88.11 per cent of total hazardous wastes generated.

One of the useful options for the management of HWs was generated from industries are Treatment, Storage and Disposal Facility (TSDF). Guidelines issued by the Ministry of Environment and Forests under Hazardous Wastes (Management & Handling) Rules, 2016 promulgated under the Environment (Protection) Act, 1986 are available in India for selection of the best site for TSDF. However, there was no proper secured landfill facility available in

[48]The world counts (2021) waste. https://www.theworldcounts.com/challenges/planet-earth/waste/hazardous-waste-statistics/story.
[49] https://www.worldatlas.com/articles/10-countries-with-the-highest-industrial-outputs-in-the-world.html
[50]CPCB (2021). National Inventory on Generation and Management of Hazardous and Other Wastes (2019-20). https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf.

India to dispose of the HW till 1997. It is noted that very few industries in India, mostly on large scale and a few on a medium scale, own proper treatment and disposal facilities[51].

3.3.2 Industrial Profile and Status of Hazardous Waste Generated in Gujarat and Rajasthan

Gujarat and Rajasthan States have a significant proportion of hazardous waste generated in the country. While Gujarat is the major contributor, Rajasthan ranks sixth in terms of its proportion. With an area of 342,239 km², Rajasthan is a comparatively larger state than Gujarat having an area of 196,024 km². However, the number of industries in Gujarat is significantly higher than in Rajasthan.

Gujarat is the fifth largest state in India by area and ninth largest state by population. Gujarat has 106 product clusters and 60 notified special economic zones (SEZs)[52]. Thirteen major industry groups account for 82.05 per cent of total factories. The industrial sector of the state comprises around 6,03,000 micros, small & medium industries which employ about 38,51,000 people as per estimates. Rajasthan is the largest state (by area) and the seventh largest (by population). As per the environmental quality monitoring conducted by CPCB in the 100 identified industrial areas/clusters across India during 2018, Rajasthan had five (Jodhpur, Pali, Bhiwadi, Sanganer and Jaipur) industrial areas/clusters critically polluted based on Comprehensive Environment Pollution Index (CEPI) score. No industrial area/cluster was identified as severely polluted based on CEPI score[53].

[51] https://www.researchgate.net/publication/2883921_Hazardous_Waste_Management_In_India
[52]CPCB (2021). National Inventory on Generation and Management of Hazardous and Other Wastes (2019-20). https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf.
[53] CPCB Annual Report 2019-20

3.3.2.1 TSDFs (Treatment, Storage, and disposal facilities) sites for Hazardous Waste

A TSDF for the management of HWs generated from industries is one the useful options for the management of HWs generated from industries. Guidelines issued by the Ministry of Environment and Forests under Hazardous Wastes (Management & Handling) Rules, 2016 promulgated under Environment (Protection) Act, 1986 are available in India for selection of the best site for TSDF. The planning for Hazardous Waste Management comprises several aspects ranging from identification and quantification of HW to the development and monitoring of TSDF[54].

The TSDF follow the generator and transporter in the chain of waste management activities. The regulations about TSDFs are more stringent than those which apply to generators or transporters. These include general facility standards as well as unit-specific design and operating criteria. The general facility standards consist of good housekeeping provisions for any facility that handles hazardous waste. The unit-specific technical requirements are designed to prevent the release of hazardous waste into the environment.

Treatment facilities use various processes (such as incineration or oxidation) to alter the character or composition of hazardous wastes. Some treatment processes enable waste to be recovered and reused in manufacturing settings, while other treatment processes dramatically reduce the amount of hazardous waste.

Storage facilities temporarily hold hazardous wastes until they are treated or disposed of.

Disposal facilities permanently contain hazardous wastes. The most common type of disposal facility is a landfill, where hazardous wastes are disposed of in carefully constructed units designed to protect groundwater and surface-water resources.

TSDFs include facilities that have engaged in any of the following activities:

- Stored hazardous waste for greater than the allowed time frames for generators of hazardous waste; or
- Received hazardous waste from off-site; or Treated hazardous waste; or
- Disposed of hazardous waste (e.g., in a landfill, surface impoundment, or incinerator).

Essential components of TSDFs site

An HW landfill shall have the following seven essential components[55]

[54]Babu, B. V., & Ramakrishna, V. (2012). Hazardous waste management in India. Birla Institute of Technology and Science Pilani–333, 31.
[55] Criteria for Hazardous waste landfills; Technical guidelines, Hazardous Waste Management CPCB Pg 6-7

- A liner system at the base and sides of the landfill should be constructed, which prevents migration of leachate or gas to the surrounding soil.

- A leachate collection and treatment facility, which collects and extracts leachate from within and from the base of the landfill and then treats the leachate to meet standards, notified under the Environment Protection Act 1986.

- A gas collection and treatment facility which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery.

- A final cover system at the top of the landfill, which enhances surface drainage, prevents infiltration of water and supports surface vegetation.

- A surface drainage system, which collects and removes all surface runoff from the landfill site.

- A surface water drainage system, which collects and removes all surface runoff from the landfill site.

- An environmental monitoring system which periodically collects and analyses air, surface water, soil gas (optional) and groundwater samples around the landfill site.

A closure and post- closure plan lists the steps that must have taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.

3.3.2.2 Criteria[56]

Applicability: The criteria apply to owners and operators of facilities that dispose hazardous waste in landfills. The term ‘Hazardous waste landfill’ is used to designate a waste disposal unit designed and constructed with the objective of minimum impact on the environment and human health.

The Term encompasses other terms such as “secured landfill”, “engineered landfill”, “waste mounds” and “waste piles” etc.

Locational criteria: HW landfill shall not be located within a specified distance of the following: lakes, ponds, rivers, wetlands, flood plains, highways, habitations, critical habitat areas, water supply wells, Airports, or coastal zone. If it is essential to establish a landfill within

[56] Criteria for Hazardous waste landfills; Technical guidelines, Hazardous Waste Management CPCB Pg 1-5

the restricted zone, then appropriate design measures are to be taken and prior permission for the SPCB/PCC should be obtained:

A. **Lake or Pond:** No landfill shall normally be constructed within 200m of any lake or pond. Because of concerns regarding runoff of waste contaminated water, a surface water monitoring network with the approval of SPCB/PCC shall be established.

B. **River:** No landfill shall be constructed within 100m of a navigating river or stream.

C. **Flood Plain:** No landfill shall be constructed within a 100-years flood plain. A landfill may be built within the flood plains of secondary streams if an embankment is built along the streamside to avoid flooding of the area. However, landfills must not be built within the flood plains of major rivers unless properly designed protection embankments are constructed around the landfills.

D. **Highways:** No landfill shall be constructed within 500m of the right way of the state or national highways.

E. **Habitation:** A landfill site shall be at least 500m from a notified habitat area. A zone of 500m around a landfill boundary should be declared a no-development buffer zone after the landfill location is finalized.

F. **Public Parks:** No landfill shall be constructed within 500m of a public park.

G. **Critical Habitat Area:** No landfill shall be constructed within critical habitat areas including reserved forest areas. A critical habitat area is defined as the area in which one or more endangered species live. It is sometimes difficult to identify a critical habitat area. If there is any doubt, then the SPCB/PCC shall be consulted for clarification.

H. **Wetlands:** No landfill shall be constructed within wetlands. It is often difficult to identify a wetland area. Maps may be available for some wetlands, but in many cases, such maps are absent or are incorrect. If there is any doubt, then the SPCB/PCC shall be consulted for clarification.

I. **Airports:** No landfill shall be constructed within a zone around Airports as notified by the regulatory authority or the aviation authority.

J. **Water Supply Well:** No landfill shall be constructed within 500m of any water supply well.

K. **Coastal Regulation Zone:** No landfill shall be sited in a coastal regulation zone.

L. **Ground Water Table Level:** No landfill shall be located in areas where the groundwater table will be less than 2m below the base of the landfill.

M. Other criteria may be decided by the planners in consultation with SPCB/PCC commensurate with specific local requirements such as the presence of monuments, religious structures etc.

Hazardous waste(HW) landfills should preferably be located in areas of low population density, low alternative land use value, low groundwater contamination potential and at sites having a high clay content in the subsoil.

A HW landfill is to be selected following the guidelines published by the MoEF. The step-by-step procedure will be as follows:

i. Earmarking a 'Search area' taking into account the location of the waste generation units and a 'search radius' (typically 5 to 250 km). The search area will be so chosen that it minimizes the number of HW landfills in any region or state.

ii. Identification of a list of potential sites based on:
   (d) Availability of land.
   (e) Collection of preliminary data.
   (f) Restrictions listed in the locational criteria

iii. Collection of preliminary data as follows:

   a. **Topographic Maps:** A topographic map helps to find sites that are not on natural surface water drains or flood plains. Topographical maps may be procured from the Survey of India.

   b. **Soil Maps:** These maps, primarily meant for agricultural use, show the types of soil near the surface. They are of limited use as they do not show types of soil a few meters below the surface. They may be procured from the Indian Agricultural Research Institute.

   c. **Land Use Plan:** These plans are useful in delineating areas with definite zoning restrictions. There may be restrictions on the use of agricultural land or the use of forest land for landfill purposes. Such maps are available with the Town planning Authority or the municipality.

d. **Transportation Maps:** These maps, which indicate roads and railways and locations of airports, are used to determine the transportation needs in developing a site.

e. **Water Use Plans:** Such maps are usually not readily available. A Plan indicating the following items should be developed: private and public tube wells indicating the capacity of each well, major and minor drinking water supply line(s), water intake wells located on surface water bodies, and open wells.

f. **Flood plain Maps:** These maps are used to delineate areas that are within a 100-year flood plain. Landfill siting must be avoided within the flood plains of major rivers.

g. **Geologic Maps:** These maps indicate geologic features and bedrock levels. A general idea about soil type can be developed from a geological map. Such maps can be procured from the geological Survey of India.

h. **Aerial Photographs/ Satellite imagery:** Aerial photographs or satellite imageries may not exist for the entire search area. However, such information may prove to be extremely helpful. Surface features such as small lakes, intermittent stream beds and current land use, which may not have been identified in earlier map searches can be easily identified using aerial photographs.

i. **Ground Water Maps:** Groundwater contour maps are available in various regions which indicate the depth of groundwater below the land surface as well as regional groundwater flow patterns. Such maps should be collected from Groundwater Boards or Minor Irrigation Tubewell Corporations.

j. **Rainfall Data:** The monthly rainfall data for the region should be collected from the Indian Meteorological Department.

k. **Wind Map:** The predominant wind direction and velocities should be collected from the Indian Meteorological Department.

l. **Seismic Data:** The seismic activity of a region is an important input in the design of landfills. Seismic coefficients are earmarked for various seismic zones and these can be obtained from the relevant BIS Code or Indian Meteorological Department.

m. **Site Walk Over and Establishment of Ground Truth:** A site reconnaissance will be conducted by a site walk-over as a part of the preliminary data collection. All features observed in various maps will be confirmed. Additional information about the following will be ascertained from nearby inhabitants: (a) flooding during monsoons; (b) soil type; (c) depth to GW table (as observed in open wells or tube wells); (d) quality of groundwater and (e) depth of bedrock.

n. **Preliminary Borewells and Geophysical Investigation:** At each site, as a part of preliminary data collection, one to two boreholes will be drilled and samples collected at every 1.5m interval to a depth of 20m below the ground surface. The following information will be obtained: (i) soil type and stratification; (ii) permeability of each strata; (iii) strength and compressibility parameters (optional); (iv) groundwater level and quality and (v) depth of bedrock. In addition to preliminary boreholes, geophysical investigations (electrical resistivity/seismic refraction/others) may be undertaken to assess the quality of bedrock at different sites.

iv. Selection of two best ranked sites from amongst the list of potential sites on the based ranking system stipulated by the MoEF (1991).

v. Environmental Impact Assessment for the two sites for the following parameters:

(b) Ground water quality; (b) surface water quality; (c) air quality –gases, dust, litter, odor; (d) land use alteration; (e) drainage alteration; (f) soil erosion; (g) ecological impacts (h) noise; (i) aesthetics – visual, vermin, flies; (j) traffic alteration; and other (k) others.

vi. Assessment of public perception for the two sites.

vii. Selection of the final site.

The above site selection procedure shall not be applicable for the location of facility within the industrial areas of State Industrial Development Agencies. However, the EIA requirement will apply.

3.3.3 Common TSDF sites of Gujarat[57]

Gujarat is a major hazardous waste producing state. There are 19,662 hazardous waste generating units in Gujarat, of which only 49.29 per cent of units (i.e., 9,693 units) have submitted annual returns. Based on the annual inventory submitted by Gujarat PCB, about 24,85,317 MT of hazardous waste has been generated against the authorized capacity of 1,06,99,830 MT. of which, 39.55 per cent is land fillable, 6.25 per cent incinerable, 22.27 per cent recyclable and 31.93 per cent utilizable hazardous waste. Gujarat has managed more quantity of HW i.e., 33,14,327 MT against 29,34,447 MT of hazardous waste to be managed (i.e., including the previous year's stock and the waste received from other states for recycling/utilization/disposal[58]).

The quantity of hazardous waste managed (i.e. recycling/utilization/disposal/storage/sent to other states) in Gujarat in terms of percentage is shown in figure 2.

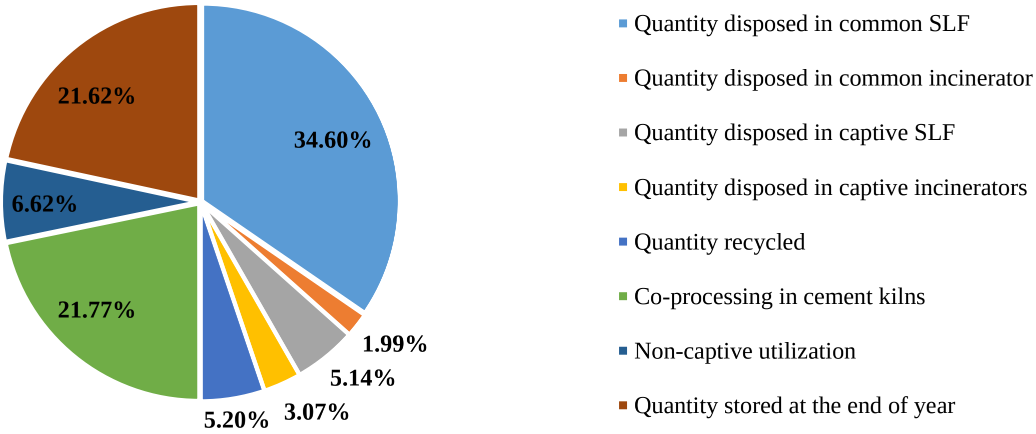


Figure-2: Percentage contribution of hazardous waste managed in Gujarat

[57] https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

[58] Hazardous waste management annual inventory report 2019-20 https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

Gujarat has 10 common TSDFs, out of which 3 are integrated (with both secured landfill and incinerator), 4 have only Secured Landfill Facilities (SLF)s and 3 have standalone incinerators facilities[59]. (figure 3)

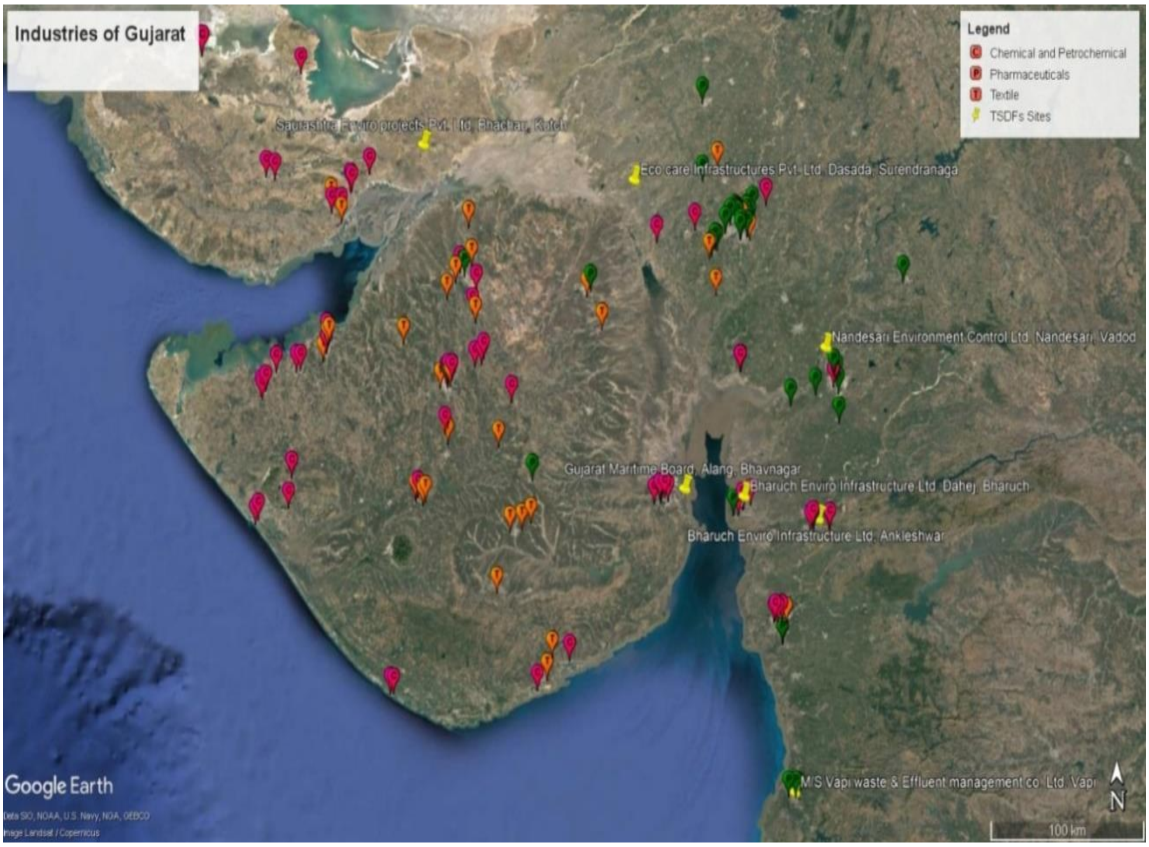


Figure-3 Representation of industrial locations and TSDFs sites of Gujrat

Table 1. Common Hazardous Waste TSDF [Treatment Stabilization Disposal Facilities] in Gujarat as of March -20

Sl. No.	Operator of TSDF	No. of Members	Capacity of TSDF in MT
1	A1 Firm	1453	34,81,132
2	A2 Firm		14,00,000
3	A3 Firm	520	14,00,000
4	A4 Firm	1650	6,44,000
5	A5 Firm	157	50,000
6	A6 Firm	1343	9,31,000

59 http://cpcbenvis.nic.in/tsdf.html#

7	A7 Firm	1755	7,20,000
8	A8 Firm	Capped and Closed	Capped and closed
9	A9 Firm	Capped and Closed	Capped and closed
10	A10 Firm	Capped and Closed	Capped and closed
11	A11 FIrm	Closed	Closure u/s 5 of EPA 1986 since November 2011

3.3.4 Common TSDFs sites of Rajasthan:

Rajasthan has 2,094 hazardous waste generating units, out of which 86.44 per cent (i.e. 1810 units) submitted annual returns. About 5,87,554 MT of hazardous waste has been generated against the authorized capacity of 80,92,583 MT[60]. Of this, 30.59 per cent is land fillable, 0.33 per cent incinerable, 13.86 per cent recyclable and 55.22 per cent utilizable hazardous Waste. Rajasthan has managed more quantity of HW i.e. 9,67,597 MT against the authorized capacity of 9,52,260 MT of hazardous waste to be managed (including previous year's stock and the quantity of hazardous waste received from other states for disposal in landfill, recycling & utilization).

[60] Based on the annual inventory submitted by Rajasthan PCB https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf

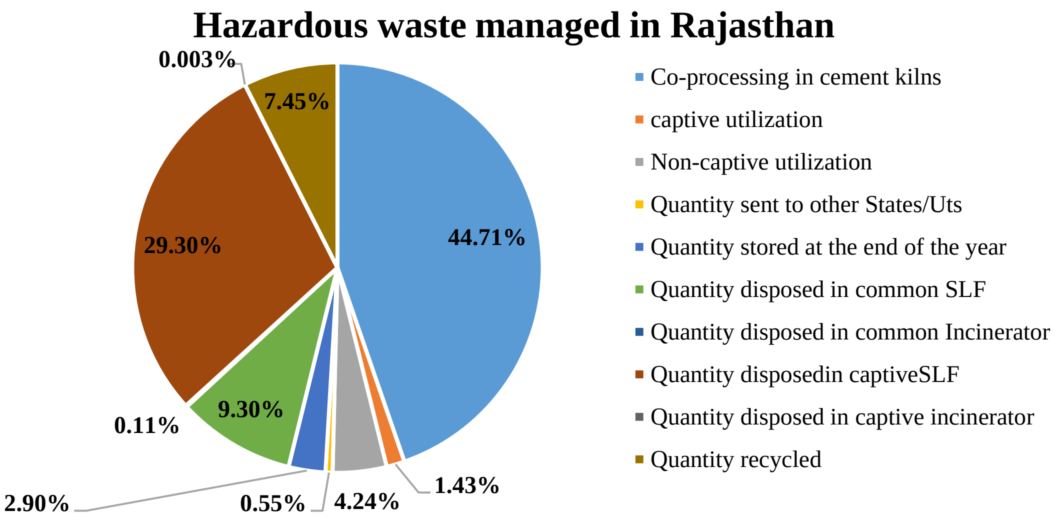


Figure-12: Percentage contribution of hazardous waste managed in Rajasthan

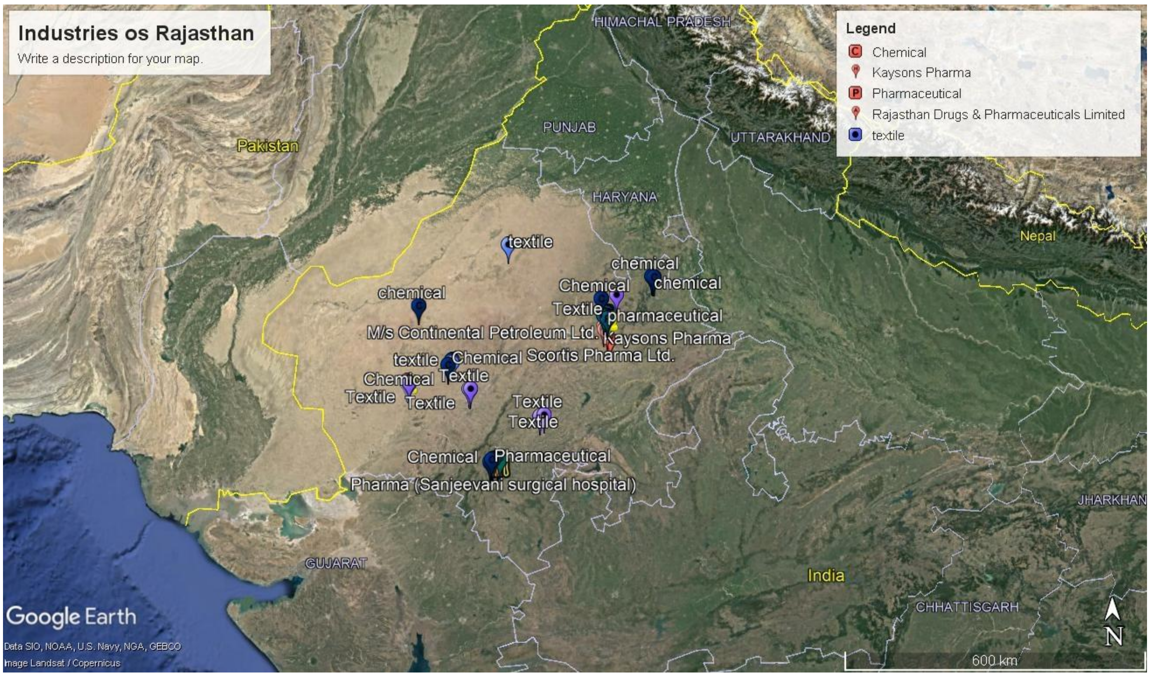


Figure-13: Representation of industrial locations and TSDFs sites of Rajasthan

Rajasthan has 03 common TSDFs (i.e. 02 exclusive SLFs and 01 standalone incinerators). During 2019-20, a total of 1,22,322 MT of hazardous waste has been disposed of.

Table-2 TSDF sites of Rajasthan

Sl. No.	Operator of TSDF	Status
1	B1 Firm	Sanitary Landfill facilities (SLFs)
2	B2 Firm	Sanitary Landfillfacilitiesy (SLFs)
3	B3 Firm	Standalone incinerators

3.3.5 Conclusion

In this study, the common TSDFs were focused and locational compliance was ascertained covering a total of 7 common TSDFs sites from Gujrat and 3 common TSDFs sites from Rajasthan. The distance from habitat area, vegetation, etc. was verified using the Google Earth Pro application (GIS tool) to assess their compliance with CPCB guidelines in terms of location. Two sites in Gujarat and one site in Rajasthan indicate non-compliance with stipulated guidelines based on Google Earth distance estimations. Such cases need to be examined further in detail to assess their implications and associated risks.

The result of the study is given as under:

Table-3 Summary of common TSDFs sites of Gujrat & Rajasthan

(Based on this study which is preliminary and based on distance criteria)

S.No	TSDF site	Compliance (Yes/No)
1	A1 Firm, Gujrat	Yes
2	A2 Firm, Gujrat	Yes
3	A3 Firm, Gujrat	No
4	A4 Firm Gujrat	No
5	A5 Firm, Gujrat	Yes
6	A6 Firm , Gujrat	Yes
7	A7 Firm, Gujrat	Yes
8	B1 Firm Rajasthan	Yes
9	B2 Firm Rajasthan	Yes

10	B3 Firm Rajasthan	No

3.3.5.1 Potential environmental risk

The US Army Corps of Engineers has identified two main hazards associated with hazardous waste. The first risk is the mismanagement of reactive, flammable or incompatible waste stored in landfill sites, which can result in fires, explosions or toxic fumes.

The second environmental risk is that of contamination of subsoil, groundwater or surface water from leachate, run-off or wind erosion resulting from the landfill, the second type of contamination is long-lived and amplified over time.

3.3.5.2 Potential areas of further analysis

Based on the above study including review of available literature, reports and other documents, the following points are identified for examination from an auditing point of view:

- The audit may examine whether the Pollution Control Boards/ Committees (PCBs/ PCCs) have ensured submission of annual returns by all the occupiers and submission of annual inventory to CPCB as per stipulated timelines.
- The audit may examine whether Boards/Committees have carried out the random verification of annual returns submitted by units as per criteria stipulated in CPCB guidelines on "Inventories on Hazardous and Other Waste Generation and their Management".
- The audit may examine whether PCBs/PCCs have ensured adequacy of the common TSDFs available in the State with respect to carrying capacity to cater to the disposal requirement based on the quantum of hazardous waste generation.
- Audit may examine the effectiveness of implementations of these guidelines. As discussed above,A3 Firm seems to be situated at location in compliance with stipulated guidelines, however, the highway is very close i.e. 410 m from this site and habitat area is also not so far indicating risk to the population. Such cases may be examined from view of the environmental consequences of waste management sites and adequacy/efficiency of relocation and alternative measures.
- Audit may consider recommending the inclusion of additional concerns in existing guidelines and after assessing the adequacy of measures for mitigation of environmental risk of TSDF sites. A3 Firm TSDFs site is around 0.32km from the river and according

to the guidelines, this is in compliance as the distance authorized is 100m from the water body. However, this river is adversely affected and shows degraded water quality. Similarly, as depicted in Figure14, the A7 Firm is 0.41 km from the water body, which connects with the main canal. Although, its location is in compliance with CPCB Guidelines the defined distance in the guidelines should be increased from 100m as the water body is becoming highly polluted due to the discharge of waste and treated effluent directly into water bodies from these sites.

- According to CPCB Guidelines, no construction is allowed within the critical habitat area. However, no specific distance is defined in the guidelines between TSDFs and critical habitat area and forest. The audit may recommend the inclusion of additional criteria in existing guidelines.
- Greater concerted and specific guidelines to address the issue of groundwater contamination are needed to address their risk and sustainability of the water in a long term scenario as groundwater is adversely affected due to leachate without proper measures for its mitigation measures.

3.3.5.3 Other useful information:

Undermentioned information regarding Hazardous Waste management may be useful for the audit purpose:

A - List of hazardous waste generating processes and hazardous waste generated[61] and their categorization into Red, Orange and Green as per the Ministry of Environment Forest and Climate Change (MoEFCC[62])

Process	Hazardous Waste	Category
Petrochemical processes and pyrolytic operations	1.1 Furnace/reactor residue and debris 1.2 Tarry residues 1.3 Oily sludge emulsion 1.4 Organic residues 1.5 Residues from alkali wash of fuels 1.6 Still bottoms from distillation process 1.7 Spent catalyst and molecular sieves 1.8 Slope oil from wastewater	RED
Drilling operation for oil and gas Production	2.1 Drill cuttings containing oil 2.2 Sludge containing oil 2.3 Drilling mud and other drilling wastes	RED
Cleaning ,emptying and maintenance of petroleum oil storage tanks including ships	3.1 Oil containing cargo residue, washing water and sludge 3.2 Chemical-containing cargo residue and sludge 3.3 Sludge and filters contaminated with oil 3.4 Ballast water containing oil from ships.	RED
Petroleum refining/re-processing of used oil/recycling of waste oil	4.1 Oily sludge/emulsion 4.2 Spent catalyst 4.3 Slop oil 4.4 Organic residues from process 4.5 Spent clay containing oil	RED

[61] Ahuja, A. S., &Abda, S. A. (2015). Industrial hazardous waste management by government of Gujarat. *Research Hub International Multidisciplinary Research Journal*, *2*, 1-11.
[62] CPCB (2016). Harmonization of Industrial sector into RED/ ORANGE/ GREEN/WHITE Category. https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTE4X0ZpbmFsX0RpcmVjdGlvbnMucGRm.

Industrialoperationsusingmineral /syntheticoilaslubricantinhydraulicsystemsorotherapplications	5.1 Used/spent oil 5.2 Wastes/residues containing oil		RED
Secondary production and/or industrial use of zinc	6.1 Sludge and filter press cake arising out of production of Zinc Sulphate and other Zinc Compounds. 6.2 Zinc fines/dust/ash/skimmings (dispersible form) 6.3 Other residues from processing of zinc ash/skimmings 6.4 Flue gas dust and other particulates		RED
Primary production of zinc/lead/copper and other non-ferrous metals except aluminium	7.1 Flue gas dust from roasting 7.2 Process residues 7.3 Arsenic-bearing sludge 7.4 Nonferrous metal bearing sludge and residue. 7.5 Sludge from scrubbers		RED
Secondary production of copper	8.1 Spent electrolytic solutions 8.2 Sludges and filter cakes 8.3 Flue gas dust and other particulates		RED
Secondary production of lead	9.1 Lead bearing residues 9.2 Lead ash/particulate from flue gas		RED
Production and/or industrial use of cadmium and arsenic and their compounds	10.1 Residues containing cadmium and Arsenic		RED
Production of primary and secondary aluminum	11.1. Sludges from off-gas treatment 11.2. Cathode residues including pot lining wastes 11.3. Tar containing wastes 11.4. Flue gas dust and other particulates 11.5. Wastes from treatment of salt slags and black drosses		RED

Metal surface treatment, such as etching, staining, polishing, galvanising, cleaning, degreasing, plating, etc.	12.1 Acid residues 12.2 Alkali residues 12.3 Spent bath/sludge containing sulphide, cyanide and toxic metals 12.4 Sludge from bath containing organic solvents 12.5 Phosphate sludge 12.6 Sludge From staining bath 12.7 Copper etching residues 12.8 Plating metal sludge	RED
Production of iron and steel including other ferrous alloys (electric furnaces; steel rolling and finishing mills; Coke oven and by product plant)	13.1 Sludge from acid recovery unit 13.2 Benzol acid sludge 13.3 Decanter tank tar sludge 13.4 Tar storage tank residue	RED
Hardening of steel	14.1 Cyanide-, nitrate-, or nitrite-containing sludge 14.2 Spent hardening salt	RED
Production of asbestos or asbestos-containing materials	15.1 Asbestos-containing residues 15.2 Discarded asbestos. 15.3 Dust particulates from exhaust gas treatment.	RED
Production of caustic soda and chlorine	16.1 Mercury bearing sludge 16.2 Residue/sludges and filter cakes 16.3 Brine sludge containing mercury	RED
Production of mineral acids	17.1 Residues, dusts or filter cakes 17.2 Spent catalyst	RED
Production of nitrogenous and complex fertilizers	18.1 Spent catalyst 18.2 Spent carbon 18.3 Sludge/residue containing arsenic 18.4 Chromium sludge from water cooling tower	ORANGE
Production of phenol	19.1 Residue/sludge containing phenol	RED

Production and/or industrial use of Solvents	20.1 Contaminated aromatic, aliphatic or napthenic solvents may or may not be fit for reuse. 20.2 Spent solvents 20.3 Distillation residues	RED
Production and/or industrial use of paints, pigments, lacquers, varnishes, plastics and inks	21.1 Process wastes, residues & sludges 21.2 Fillers residues	RED to ORANGE
Production of plastic raw materials	22.1 Residues of additives used in plastics manufacture like dyestuffs, Stabilizers, flame retardants, etc. 22.2 Residues and waste of plasticizers 22.3 Residues from vinyl chloride monomer production 22.4 Residues from acrylonitrile production 22.5 Non-polymerized residues	GREEN
Production and/or industrial use of glues, cements, adhesive and resins	23.1 Wastes/residues (not made with vegetable or animal materials)	RED
Production of canvas and textiles	24.1 Chemical residues	RED
Industrial production and formulation of wood preservatives	25.1 Chemical residues 25.2 Residues from wood alkali bath	RED
Production or industrial use of synthetic dyes, dye-intermediates and pigments	26.1 Process waste sludge/residues containing acid or other toxic metals or organic complexes 26.2 Dust from air filtration system	RED
Production of organo-silicone compounds	27.1 process residues	ORANGE
Production/formulation of drugs/ pharmaceuticals & health care Product	28.1 Process Residues and wastes 28.2 Spent catalyst / spent carbon 28.3 Off specification products 28.4 Date-expired, discarded and off specification drugs/ medicines	RED to ORANGE

	28.5 Spent organic solvents	
Production, and formulation of pesticides including stock-piles	29.1 Process wastes/residues 29.2 Chemical sludge containing residue pesticides 29.3 Date-expired and off-specification Pesticides	RED
Leather tanneries	30.1 Chromium bearing residues and Sludges	RED
Electronic Industry	31.1 Process residues and wastes 31.2 Spent etching chemicals and solvents	GREEN
Pulp & Paper Industry	32.1 Spent chemicals 32.2 Corrosive wastes arising from use of strong acid and bases 32.3 Process sludge containing adsorbableorganic halides [AOx]	RED
Disposal of barrels / containers used for handling of hazardous wastes / chemicals	33.1 Chemical-containing residue arising from decontamination. 33.2 Sludge from treatment of waste water arising out of cleaning / disposal of barrels / containers 33.3 Discarded containers / barrels / liners contaminated with hazardous wastes/chemicals	RED
Purification and treatment of exhaust air, water & wastewater from the processes in this schedule and common industrial effluent treatment plants (CETP's)	34.1 Flue gas cleaning residue 34.2 Spent ion exchange resin containing toxic metals 34.3 Chemical sludge from waste water treatment 34.4 Oil and grease skimming residues 34.5 Chromium sludge from cooling water	RED
Purification process for organic compounds/solvents	35.1 Filters and filter material which have organic liquids in them, e.g. mineral oil, synthetic oil and organic chlorine compounds	RED

	35.2 Spent catalyst 35.3 Spent carbon	
Hazardous waste treatment processes, e.g. incineration, distillation, separation and concentration techniques	36.1 Sludge from wet scrubbers 36.2 Ash from incineration of hazardous waste, flue gas cleaning residues 36.3 Spent acid from batteries 36.4 Distillation residues from contaminated organic solvents	RED

B - Categories of highly polluting industries, with the main hazardous wastes they produce

Category of Industry	Main Hazardous Wastes Produced
Aluminum Smelter	Sludges from off-gas treatment; cathode residues including pot-lining wastes; tar containing wastes; flue gas and other particulates; wastes from the treatment of salt Slags and black drosses
Caustic Soda	Mercury bearing sludge; residues/sludges and filter cakes/brinesludge containing Mercury
Cement	Wastes/residues; metal compound emissions from cement kilns and use of waste materials as fuel
Copper Smelter	Fluegas dust from roasting; process residues; arsenic-bearing sludge; non-ferrous metal bearing sludge and residue; sludge from scrubbers; spent electrolytic solutions; sludge sand filter cakes
Distilleries	Sludge from wet scrubbers; ash from incineration of hazardous waste; flue gas Cleaning residues; spent acid from batteries; distillation residues from contaminated organic solvents
Drugs & Pharmaceuticals	Process residues and wastes; spent catalyst/spent carbon; off specification products; date-expired, discarded and off-specification drugs/medicines; spent organic solvents
Integrated Iron and Steel	Sludge from acid recovery unit; benzol acid sludge; decantertanktar sludge; tar Storage tank residue
Leather Processing including Tanneries	Chromium bearing residues and sludges

Oil Refineries	Oily sludge/emulsion; spent catalyst; slop oil; organic residues from process; spent clay containing oil
Pesticides	Process wastes/residues; chemical sludge containing residue pesticides; date-expired and off specific action pesticides
Petrochemicals	Furnace/reactor residue and debris; tarry residues; oily sludge emulsion; organic residues; residues sieves; slop oil from wastewater; drill cuttings containing oil; sludge containing oil ; drilling mud and other drilling wastes; oil-containing cargo residue; washing water and sludge; chemical containing cargo residue and sludge; ballast water containing oil from ships; oily sludge/emulsion; spent catalyst; slop oil; spent clay Containing oil
Pulp & Paper	Spent chemicals, corrosive wastes arising from use of strong acid and bases; process sludge containing absorbable organic halides(AOx)
Sugar	Sugar processing waste water with a high content for genic material and high bio chemical oxygendem and(BOD)
Thermal Power Plants	(oil and grease copper, iron), cooling tower low down (chlorine, zinc, chromium,phosphate,corrosioninhibitingmaterials),ashpon deffluent(pH), suspended solids, oil and grease
Zinc Smelter	Sludge and filter press cake arising out of production of zinc sulphate and other zinc compounds; Zinc fines /dust/ash/skimming (dispersible form); other residues from processing of zinc ash/skimmings; fluegas and other particulates
Spent catalyst	Spent catalyst; spent carbon; sludge/residue containing arsenic; chromium sludge from water cooling tower
Dyes and Dye Intermediates	Process waste sludge/residues containing acid or other toxic metals or organic complexes; dust from air filtration system

C - Impacts of hazardous waste on human health and environment

There are many ways a person can be exposed to hazardous chemicals like inhalation, ingestion and dermal (skin). The contact as chemicals can transfer via air, water and soil.

Hazardous Waste and their effect on health[63]

Substance	Potential Health Impacts	Total Threshold Limit Concentration (TTLC) limits (mg/l)
Arsenic	Carcinogenic to humans (skin, lung, bladder, liver) stomach and intestinal irritation, nausea, vomiting–decreased production of red and white blood cells–damage to blood vessels–skin changes–abnormal heart rhythm	5.0
Benzene	Carcinogenic to humans(leukemia)–harmful to bone marrow, decreased red blood cells, anemia–vomiting, stomach irritation–drowsiness dizziness, rapid heart rate, headaches, tremors, convulsions, unconsciousness	0.5
Cadmium	Likely to be carcinogenic to humans–kidney, bone and lung damage–stomach irritation, vomiting	1.0
Chloroform	Likely to be carcinogenic to humans–liver and kidney	6.0
Lead	Likely to be carcinogenic to humans – damage to the brain and nervous system (adults, children, unborn children) – miscarriage, premature births, neonatal mortality due to decreased birth weight, decreased male fertility–diminished learning abilities in children–increased Blood pressure–kidney damage	5.0
Mercury	Brain, kidney, and lung damage – serious harm to neural development of fetuses and young children – chest pains, nausea, vomiting, diarrhea – skin rashes and eye irritation – increased blood pressureandheartrate–irritability,sleepdisturbances,tremors,coordination problems, Changes in vision and hearing, memory problems	0.2
Tetrachloroethylene	Likely to be carcinogenic to humans–dizziness, headaches, sleepiness, confusion, nausea, Difficulty speaking and walking, unconsciousness	0.7
Trichloroethylene	Carcinogenic to humans–liver, kidney and nervous system damage–impaired immune system and heart function–impaired fetal development–skin rashes,lungirritation,headaches,dizziness,nausea,unconsciousness	0.5

[63]IL&FS (2010). Technical guidance and manual for common hazardous waste treatment storage and disposal facility. http://environmentclearance.nic.in/writereaddata/Form-1A/HomeLinks/TGM_Comman%20Hazardous%20Waste%20Treatment_010910_NK.pdf.

Effect on fauna can be seen from one example; as DDT exposure at low levels was found to interfere with calcium deposition in the eggshells of birds of prey, causing them to be thin and fragile and often to be crushed by the parents in the nest. One well known species in this way was the Balt eagle. Toxic effluents from mining operations can have a very adverse effect on wildlife and human health. Marine ecosystems and wildlife have also suffered major damage as a result of oil spills resulting from accidents to large ocean- going tankers.

D - Hazardous Waste Management Regulatory framework

Constitution of India under part IV (Art 48A- Directive principles of State policies) stipulates that the state shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country. Part IVA (Article 51A fundamental duties) casts a duty on every citizen of India to protect and improve the natural environment.

Serious thrust for a well-developed framework for environmental protection came after the United Nations Conference on the Human Environment (Stockholm, 1972). National Council for Environmental Policy and Planning was set up in 1972 within the Department of Science and Technology to establish a regulatory body to look after the environment-related issues. This Council later evolved into a full-fledged Ministry of Environment in 1985. Since the 1970s, a number of environmental legislations have been put in place. The MoEF & CC, Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCB) and Pollution Control Committee **(**PCC**)** in case of UTs together form the regulatory and administrative core of the sector.

The following acts and rules have been promulgated by the government from time to time for protection and preservation of environment, in which every industry required to follow and comply with the acts and regulations-

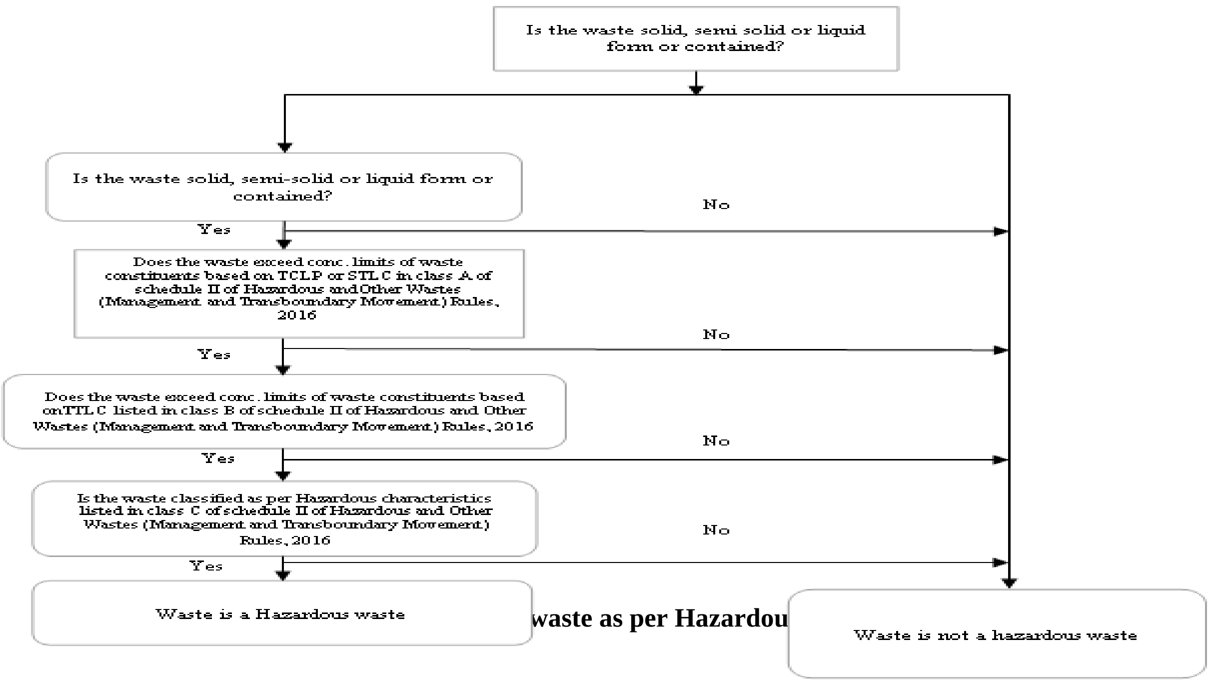
- The Water (Prevention & Control of Pollution) Act, 1974
- The Water (Prevention & Control of Pollution) Cess, Act, 1977
- The Air (Prevention & Control of Pollution) Act, 1981
- The Environment (Protection) Act, 1986 and Rules
- Forest (Conservation) Act, 1980
- Environmental Impact Assessment Notification dated-14th September 2006 and amendments thereafter.

- The Hazardous & other wastes (Management and Transboundary Movement) Rules, 2016.
- Chemical Accident (Emergency Planning, Preparedness and Response) Rules, 1996
- Noise Pollution (Regulation and Control) Rules, 2000 and its amendments
- The Public Liability Insurance Act, 1991
- Any other applicable acts

E - Identification, hierarchy and Strategies for HW

Identification of Hazardous waste- Identification of hazardous waste is the first and foremost aspect in hazardous waste management[64]. An occupier needs to first identify whether the waste generated by it is hazardous in nature or not. Identification of Hazardous waste is a very challenging process. It may not be immediately apparent that the waste being handled is potentially hazardous[65]. The process to determine if the waste is hazardous as per the Hazardous and

other wastes (Management and Transboundary Movement) Rules, 2016 is shown in the flow chart below. Industrial activities producing different types of hazardous waste (Details given in Annexure-A) which aims to give better clarity about the classification of hazardous waste by linking it with the industrial process and categories it on the basis of the pollution



64 MOEF (2016). Hazardous and waste management Rules. https://cpcb.nic.in/displaypdf.php?id=aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY=

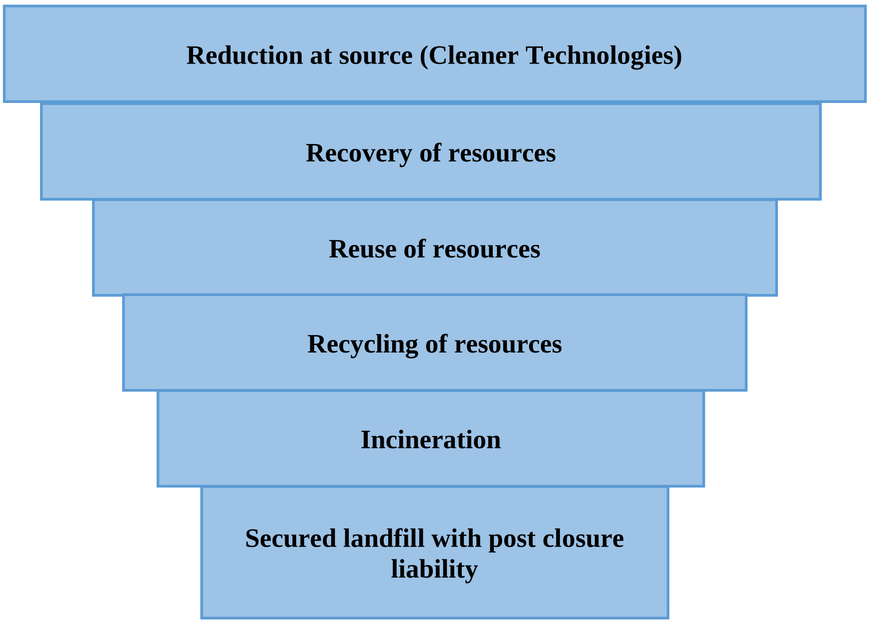
65 An occupier can also rely on professional expertise to determine whether the waste is hazardous waste or send it to a certified laboratory for testing and analysis. **Toxicity Characteristic Leaching Procedure (TCLP), Soluble Threshold Limit Concentration (STLC), Total Threshold Limit Concentration (TTLC)**

index score in red, orange, green and white category. MoEFCC with CPCB convened the meeting and result in the re-categorization of industrial sector with pollution index. Industrial Sectors having Pollution Index score of 60 and above – Red category ¬ Industrial Sectors having Pollution Index score of 41 to 59 –Orange category ¬ Industrial Sectors having Pollution Index score of 21 to 40 –Green category ¬ Industrial Sectors having Pollution Index score including& up to 20 –White category. The Ministry of Environment and Forests (MOEF), The Government of India has promulgated the Hazardous Waste (Management & Handling) Rules [HW (M&H)] in 1989 under the Environment (Protection) Act [E (P) Act], 1986. The entire methodology is presented in the form of a flowchart as shown in figure 18

Hazardous waste management hierarchy

In an effort to remedy existing problems and to prevent future harm from hazardous wastes, governments closely regulate the practice of hazardous-waste management.

The hierarchy for the hazardous waste management can be presented as shown below.



Hierarchy of management of hazardous waste

Certain hazardous waste is considered as recyclable, incinerable or suitable for landfill based upon their properties and scientific criteria. Recyclability is often decided based on economic feasibility (availability of end user, technological ease, price of recovery, transportation and legal requirement etc.). Incinerable waste is often classified based on calorific value of the waste and reference of this regard is the acceptable criteria for secured landfill. Further, the waste is not suitable for the other options given in Fig. 4 will be considered for disposal at secured landfill. However, the criteria set for acceptable characteristics of hazardous waste for disposal into secured landfill warrants prior treatment i.e. stabilization etc.

The purpose of hazardous waste management sequence, namely treatment and disposal steps, are perhaps the most complex and demanding. Currently, there are various strategies and technologies which are being replaced by newer and cleaner technology[66].

Underground injection (or 'deep well injection')

In a deep well injection system, several thousand feet below the surface hazardous wastes in liquid form are injected through a reinforced well shaft into porous injection zones that are confined by impermeable rock layers.

There are various limitations of underground injection practice like it can't be used in any area that is prone to seismic activity, since the presence of suspended solids at a concentration greater than 2ppm leads to clogging of the injection wells. Hazardous waste with high organic carbon content must be monitored carefully because the added carbon content can lead to a flourishing of bacterial population in the injection zone or well shaft resulting in fouling of the injection well[67].

Aqueous organic treatment

It refers to treatments in which the toxicity, ignitability, or reactivity is reduced in the liquid hazardous waste and this can be done before the underground injection if the waste is too toxic or can be done prior to landfilling. There are a number of treatment processes used to mitigate the hazardous waste[68].

Biological treatment, a technique used often on wastewater streams, refers to the use of bacteria or algae to metabolize hazardous compounds and concentrate these compounds in the biomass of the organisms for more efficient disposal as solid waste. This technology is used for the removal of the chemical like alcohols, aliphatic, amines, aromatics, halocarbons, metals, phenols, phthalates, polycyclic hydrocarbons, and various other compounds from aqueous hazardous waste. Reverse osmosis is also applicable for hazardous waste streams, but this is

---

[66]Rosenfeld, P. F., & Feng, L. (2011). *Risks of hazardous wastes*. William Andrew.
Current Practices in Hazardous Waste Treatment and Disposal - ScienceDirect
[67]Rosenfeld, P. F., & Feng, L. (2011). *Risks of hazardous wastes*. William Andrew.
Current Practices in Hazardous Waste Treatment and Disposal – Science Direct
[68] Rosenfeld, P.F., & Feng, L.(2011) Risks of hazardous wastes.

most effective in the case of removal of inorganic salts and less effective for the removal of the organic compound. Air stripping can also be used for the removal of volatile organic compounds from hazardous wastes.

The most widely used method of aqueous organic treatment is absorption with granular activated carbon (GAC). It aids in the removal of organic compounds from hazardous waste. Limitation of GAC is its efficacy decreases with the increase in the molecular weight of the compound.

There are numerous other method can be implied in the treatment of the hazardous waste like centrifugation, dialysis, distillation, evaporation, ion exchange, crystallization and solvent extraction etc.

Incineration

It is used for the hazardous wastes which can't be recycled or can't be disposed of safely in the landfill because of excessive toxicity or risk of infectious transmission. During incineration, the wastes are combusted and converted into gases containing trace amounts of organic contaminants and a highly toxic solid residue that is typically disposed of in a hazardous landfill site.

There are various risks associated with incinerators, the primary risk are the hazardous organic compounds and toxic heavy metals in stack emissions or leftover residues. The residues or the organic contaminants of incinerator emission are attributed to un-combusted or partially combusted wastes called as products of incomplete combustion (PICs). These products act as carcinogens, mutagens, and endocrine effectors.

The neurotoxic metals such as lead, mercury, and arsenic, and of carcinogenic metals such as beryllium, cadmium, and chromium released with hazardous waste incineration lead to various health impacts. These metallic compounds will not get destroyed in incinerators instead they simply oxidized and transformed[69].

Land Disposal

Land disposal refers to land–based disposal facilities and include landfill, surface impoundments, waste piles, land treatment units, injection wells, salt dome formations, underground mines and underground caves. The details of the above are given below:-

[69] Rosenfeld, P.F., & Feng, L.(2011) Risks of hazardous wastes.

Surface Impoundments

Consist of a natural topographic depression, man-made excavation, or diked area formed from earthen materials into which hazardous wastes are placed. They are required to have a double liner, a leachate collection and removal system and a leak detection system. An important distinction between surface impoundments and landfills is the temporary nature of impoundments. These units are used for the temporary storage and treatment of wastes and therefore a cap or cover is not required as is the case in landfills. However, if the operator chooses to permanently store wastes in an impoundment, landfill requirements will then be applicable, including post-closure care.

Waste piles

Water piles are temporary non-containerized piles of solid non-flowing hazardous wastes. They must be located under or in a structure and must be protected from water run-on. Similar to an impoundment, they are required to have liner and a leachate collection and removal system. Unlike an impoundment, they do not require a leak detection system but require a second leachate collection and removal system above the top liner.

Land Treatment Units

Waste is directly applied to the soil surface or upper layers of soil in order to degrade, transform, or immobilize the hazardous constituents of the wastes with soil microbes or sunlight acting to degrade the waste. Liners are not generally used in land treatment units. Prior to use, operators are required to perform a treatment demonstration to insure that the hazardous components of the wastes can be effectively degraded or immobilized using the treatment unit[70].

Hazardous waste landfills

These sites are also known as 'secure' landfills and intended to be the final disposal site for hazardous wastes. They are subjected to additional requirements for permanent monitoring in the closure and post-closure period. They consist of a natural or man-made depression with a soil foundation. They must have a double liner and a leak detection system. According to the guidelines they must have double liner and leak detection systems and these should have at least one leachate two leachate system and removal system and additionally must have stormwater run-on and run-off controls to withstand at least a 25- year storm and a cover to prevent wind

[70] Rosenfeld, P.F., & Feng, L.(2011) Risks of hazardous wastes.

dispersal. The final cover must minimize water migration through the landfill, promote drainage, and accommodate settlings.

Even after this final cover or post-closure, the owner of the landfill has to maintain it. The owner has to maintain the final cover, leak detection system, groundwater monitoring system and the water run-on/run-off protection systems. As we are clear from this case study the treatment has to be done before the disposal of the waste in the landfill. So this treatment will change the physical, chemical, or biological nature of a waste to make it less of an environmental threat.

This is to be noted that the bulk or non-containerized liquid wastes are not allowed in landfills because these liquids leaching in the ground. Liquids should be removed with absorbents or solidified prior to placement in a landfill[71].

F - Risk in Transportation of hazardous waste

Hazardous waste generated at a particular site like industries often requires transport to an approved treatment, storage, or disposal facility (TSDF). Because of potential threats to public safety and the environment, transport is given special attention by governmental agencies. In addition to the occasional accidental spill, hazardous waste has been in the past intentionally spilled or abandoned at random locations in a practice known as “midnight dumping”. This practice has been greatly curtailed by the enactment of laws that require proper labeling, transport, and tracking of all hazardous wastes[72].

Transport is one of the most important areas of concern associated with the handling of hazardous waste and it has to be done in such a way that this waste does not cause any danger to health and environment. Therefore, off-site requirement involves proper awareness about the following:

- Container should be designed in such a way that waste does not react and no inappropriate leakage occurs.
- Labelling of the container to identify the waste, describe the possible hazard and the remedial measures/first-aid required in case of any accidental spills.
- Collector/transporter selection to have technical competence and relevant skills and other requirements.

[71] Rosenfeld, P.F., & Feng, L.(2011) Risks of hazardous wastes.
[72]Nathanson, Jerry A.. "Hazardous-waste management". *Encyclopedia Britannica*, 30 Oct. 2020, https://www.britannica.com/technology/hazardous-waste-management. Accessed 1 October 2021.

THEME – 4.1: AIR POLLUTION IN DELHI (FOCUS ON VEHICULAR POLLUTION)

4.1.1 Introduction:

Air pollution is the presence of substances in the atmosphere that are harmful to the health of humans and other living beings or cause damage to the climate or materials. There are different types of air pollutants, such as gases (such as ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic), and biological molecules.

Air pollution may cause diseases, allergies and even death to humans. It may also cause harm to other living organisms such as animals and food crops and may damage the natural or built environment. Both human activity and natural processes can generate air pollution. Air pollution is a significant risk factor for several pollution-related diseases, including respiratory infections, heart disease, stroke and lung cancer etc.

The human health effects of poor air quality are far-reaching, but principally affect the body's respiratory system and cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics. Indoor air pollution and poor urban air quality are listed as two of the world's worst toxic pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report. Outdoor air pollution alone causes 2.1 to 4.21 million deaths annually.

Overall, air pollution causes the deaths of around 7 million people worldwide each year and is the world's largest single environmental health risk. Productivity losses and degraded quality of life caused by air pollution are estimated to cost the world economy $5 trillion per year.

Therefore, to control air pollution first, we need to understand the variation in concentration levels at various sections of a city. Air pollution concentration is under observation at Air Quality Monitoring Systems which provides real-time analysis.

4.1.2 Air Quality Monitoring System

Air Quality Monitoring System involves (AQMS) control of atmospheric emissions as well as an understanding of pollutant dispersion, monitoring emission levels, i.e. concentration in ambient air. The important criteria of the AQMS are as under:

Data Relevance: - One of the most important criteria while choosing any AQMS is its data relevance and accuracy. But no AQMS can ensure 100 percent accurate data until they are not located where they need to be to capture correct data. Many pollutants have high spatial variability. Their concentration varies over long and even shorter distances. Pollutant concentration is highest near the source and fades as the distance increases.

Data Completeness: Any air quality monitoring campaign is futile if it cannot produce complete data. Incomplete data can obstruct analysis and conclude out of it for its corresponding application. EPA's guidance for regulatory data mandates at least 75 percent data completeness over the defined period. If the AQMS units are deployed without a location study, it may be possible that the sensors are situated far from the emission source, so the data generated makes no sense for analysing the pollution level of that region. Monitoring can also be hindered by tall buildings and other such obstacles, local sources, etc. AQMS, thus, demands to be installed at a position facing minimum obstructions for data collection.

Data Averaging: Data averaging is the process of getting an average or aggregate of AQMS data. It helps in data comparison with other equipment, setting environmental standards, and health-related benchmarks.

Sensor Durability: The sensor location also depends on the equipment's durability or vice-versa. If the AQMS is not durable enough to withstand extreme weather conditions (like high winds, high dust concentration, heavy rains, extreme heat or cold), then it cannot be installed at such locations even if it has high data accuracy.

Sensor Calibration: Automatic AQMS needs periodic sensor calibration to reset the measurement parameters which have deviated from their actual performance. These deviations may be due to sensor drift or cross-sensitivity.

4.1.3 Monitoring Site Selection

Monitoring Scale: Evaluating the monitoring scale requires a few questions to be asked like – What is the area covered? How many sensors are required? What type of sensors will be needed? This will give a clear idea of the actual campaign logistics and cost.

Sensor Distribution: For city-wide environmental monitoring, it is important that the sensors are deployed strategically to cover all the geographic locations like green parks, industrial areas, major traffic routes, residential areas, etc.

Sensor Height – Sensor height plays a crucial role in collecting relevant data. If it is installed at ground level (breathing zone), then it may give data on the impact on human health. However, actual air quality information is at a higher level. So, sensors need to be installed at least at a height of 12-15 feet for capturing correct environment data.

Target Pollutants – Choosing a precise sensor location will heavily depend on the target pollutants, the primary sources, and the area with the highest concentration. Based on that, the sensor locations in that area can be decided.

Communication Protocols – Before sensor installation, it's important to look at the communication facilities available at the site for data transfer or that can be implemented given the site condition.

Geographic Obstructions – Nearby structures and terrains like tall buildings, towers, hills, etc. may obstruct the monitoring and give falsified data. So, the sensor has to be installed away from these obstructions, in an open area.

There is no perfect air monitoring site. Some compromises have to be made for any environmental study within any region. It's the question of prioritizing one factor over the other and balancing benefits with risks and costs. For environmental or pollution mapping of the entire city, a few carefully chosen locations with a defined number of sensors in the network can fit the purpose of the study. For understanding general air quality conditions in support of public health, monitoring stations should be located in highly populated areas. Monitors situated in residential areas may be more representative of average exposure across a geographic area, compared to monitors located next to industry or traffic. To manage air quality, additional monitoring sites in strategic locations can help to understand the local or regional nature of air pollution sources.

To ensure the quality of data, analytical quality control and following guidelines for monitoring and calibration, repair of instruments and evaluation of ambient air quality monitoring stations are must. Studies have found that average error ranges from 10 to 26 per cent for PM monitoring, primarily because of incorrect flow measurement and calibration in manual monitoring. In the case of gaseous pollutants, duration of sampling, sample dilution and temperature controls are essential to ensure that tests are done properly. Continuous Ambient Air Quality Monitoring System is sophisticated to deal with these issues, as it is a compact set up of different pollutant analysers and even calibration units.

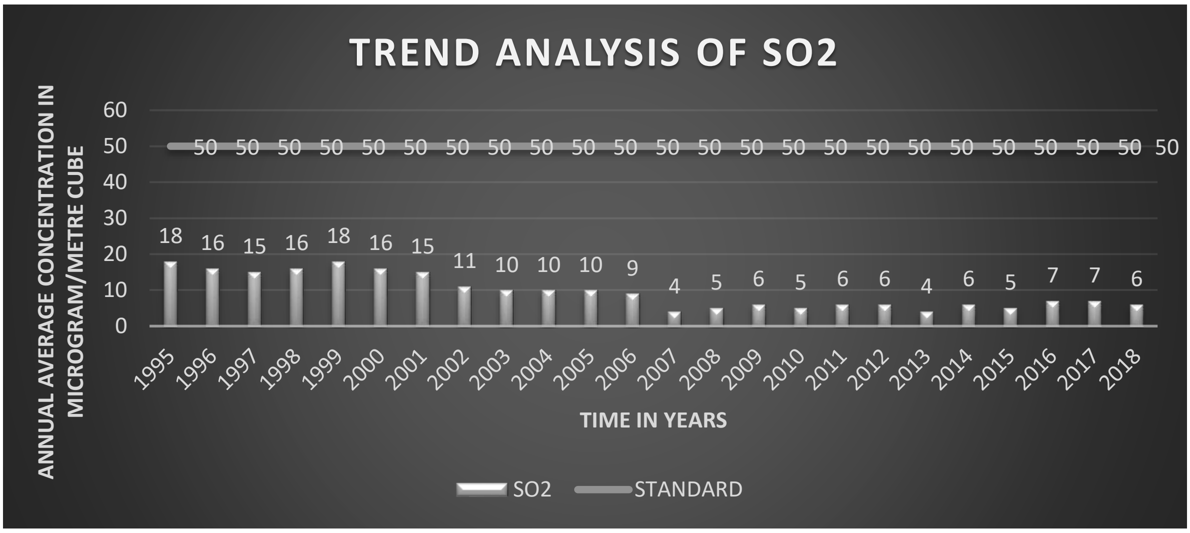
*Source (http://cpcbenvis.nic.in/air_pollution_main.html)

4.1.4 Trend Analysis of Critical Pollutants

Under the National Air Quality Monitoring Programme, four major air pollutants have been identified for regular monitoring Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2) Suspended Particulate Matter (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$). In the Delhi-NCR region yearly trend of the air pollutants SO2, NO2 and RSPM were as under:

SO2: Sulphur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest.

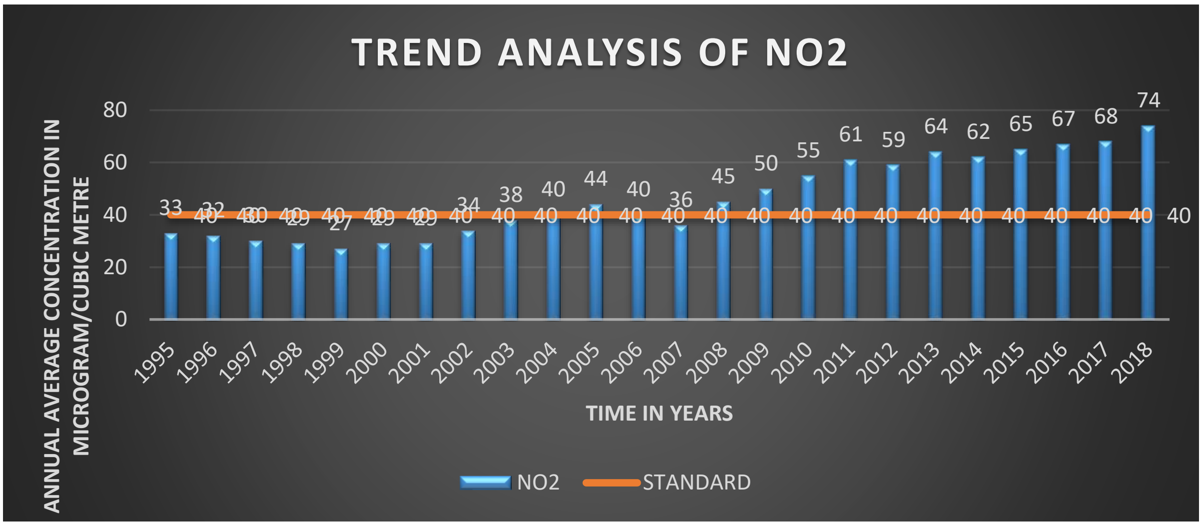
According to NAAQS standards, the annual average concentrations in1994 and 2009 are 80 and 50 respectively for industrial, residential and rural areas. Since the development of the Monitoring programme from 1984, there has been a likeable decrease in the concentration levels. SO2 level in past 24 years in Delhi-NCR reign is as under:



The main source of SO2 in ambient air is industrial activity that generates electricity from coal, oil or gas that contains sulphur along with certain mineral ores of sulphur which releases SO2. In 2005, direct use of coal having high sulphur contents has been restricted and made a standard to use pulverised coal which contains less. Other measures such as reduction of sulphur in diesel, use of LPG instead of coal as domestic fuel and conversion of diesel vehicles to CNG were also taken to reduce SO2 in the air. As a result, the SO2 level has come down from 18 (1995) to 6 (2018).

NO2: The adverse impact of nitrogen dioxide is on the respiratory system of the human body. Inhalation of nitrogen dioxide by children increases their risk of respiratory infection and leads to poorer lung function in later life. Nitrogen dioxide can decrease the lungs' defences against bacteria making them more susceptible to infections.

According to NAAQS standards 1994 and 2009, the annual average concentrations are 80 and 40 respectively for industrial, residential and rural areas. If we consider the 2009 standard, the concentration levels are increasing at a slow rate. NO2 level in the past 24 years in Delhi-NCR reign is as under:

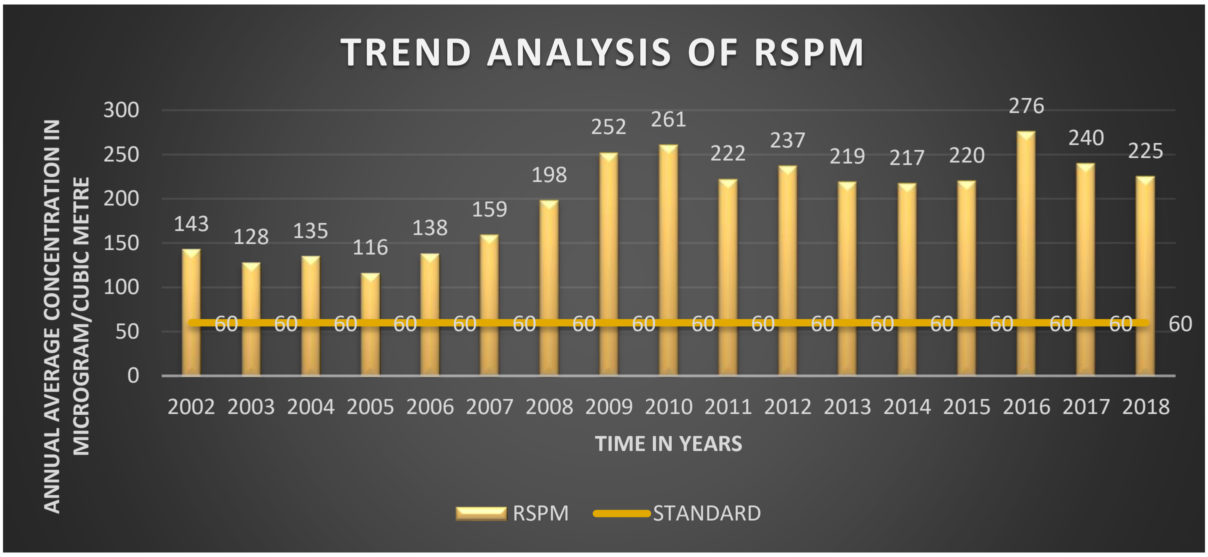


The main source of nitrogen dioxide resulting from human activities is the combustion of fossil fuels (coal, gas and oil) especially fuel used in cars. Since Delhi has such a high population density and improper management and maintenance of vehicles leads to the exhaust of nitrous oxides into the ambient. According to the above figure, it is increasing at an alarming rate which requires proper maintenance of vehicles' engines and fuel composition.

The reason behind the increase in NO2 levels whereas a decrease in SO2 is because SO2 is released mainly from power plants through stacks whereas NO2 is released from the exhaust of vehicles.

(https://www.epa.gov/no2-pollution/basic-information-about-no2#:~:text=Health%20effects&text=Such%20exposures%20over%20short%20periods,and%20visits%20to%20emergency%20rooms)

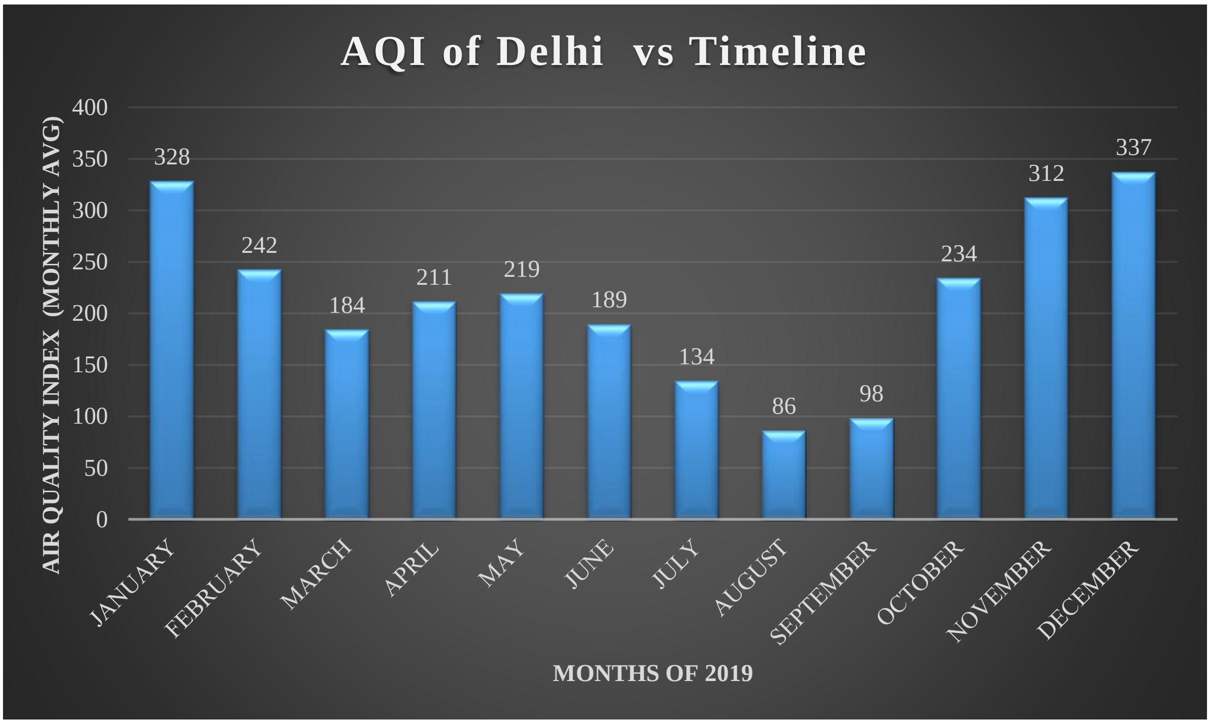
Respirable Suspended Particulate Matter (RSPM or PM10 & PM2.5): RSPM is one of the main causes of lung carcinoma, asthma, cardiovascular disease and premature deaths in human beings. Climates are affected by volcanic eruptions, drought, rainfall declines, greenhouse gases, ocean acidification etc. Vegetation is affected as due to the SPMs the stomata openings get clogged which doesn't allow the gases to pass through and the whole photosynthesis process fails. According to NAAQS standards 1994 and 2009, the annual average concentrations are 120 and 60 μg/m3 respectively for industrial areas. As per 2009 standards, the concentration levels are dangerously higher which is really harmful to any living being's health. RSPM level in the past 24 years in Delhi-NCR reign is as under:



Source of SPM is not only limited to humans but by natural means, they are also generated by volcanic eruptions, dust storms, forest and grassland fires, living vegetation etc. However, the major reason for such a huge concentration lies within human work like coal combustion, oil combustion, wood combustion, construction & demolition, industrial, agricultural and many more. In India, a high population corresponds to higher vehicle density and due to improper management more jam and poor signalling systems, the particulate matters remain in suspension, as a result, the concentration keeps on increasing.

4.1.5 Trend Analysis for Air Quality Index (AQI) in Delhi

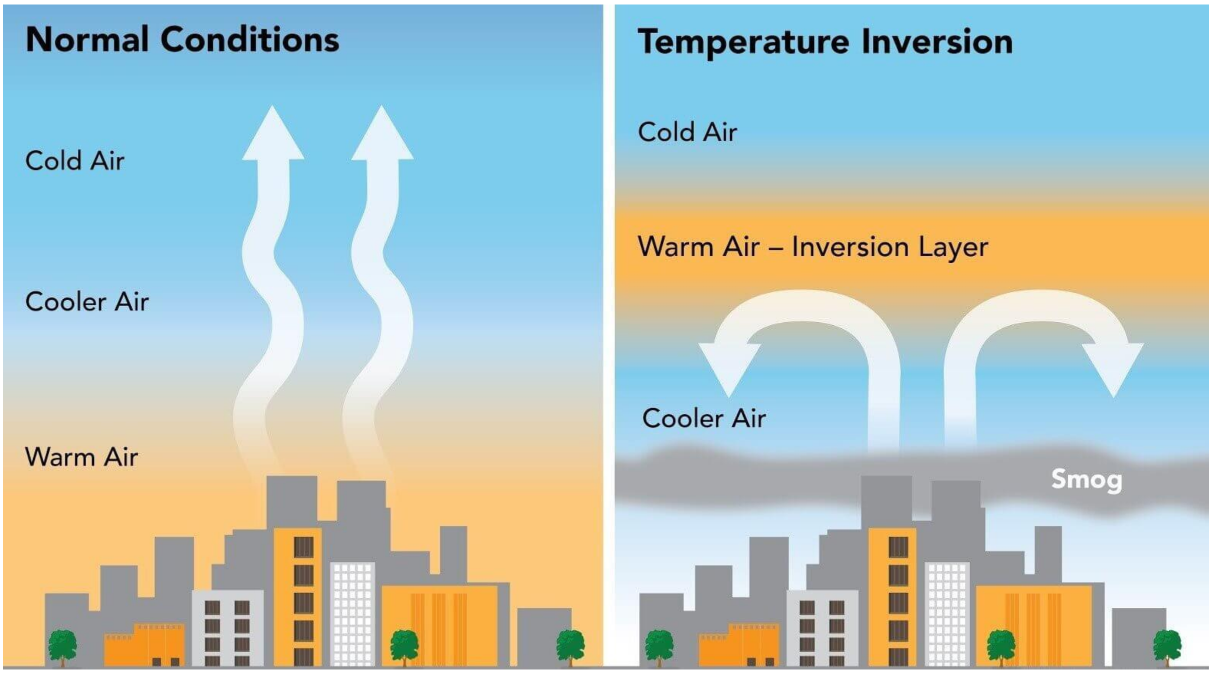
The Air Quality Index of Delhi with respect to the monthly average timeline for the year 2019 is shown in the below chart:



Source (https://cpcb.nic.in/AQI_Bulletin.php)

Trend Analysis:

- If AQI falling in the range of Poor to Severe Category is considered a bad day; then the total number of bad days for the region Delhi would be 124 days out of 365 days in the year 2019.
- The Maximum Air Quality Index was achieved in the winter season (between December and January) as during that time inversion takes place which in turn does not allow the pollutants to dissipate and dilute. They remain concentrated in a position proving to be harmful to human health.

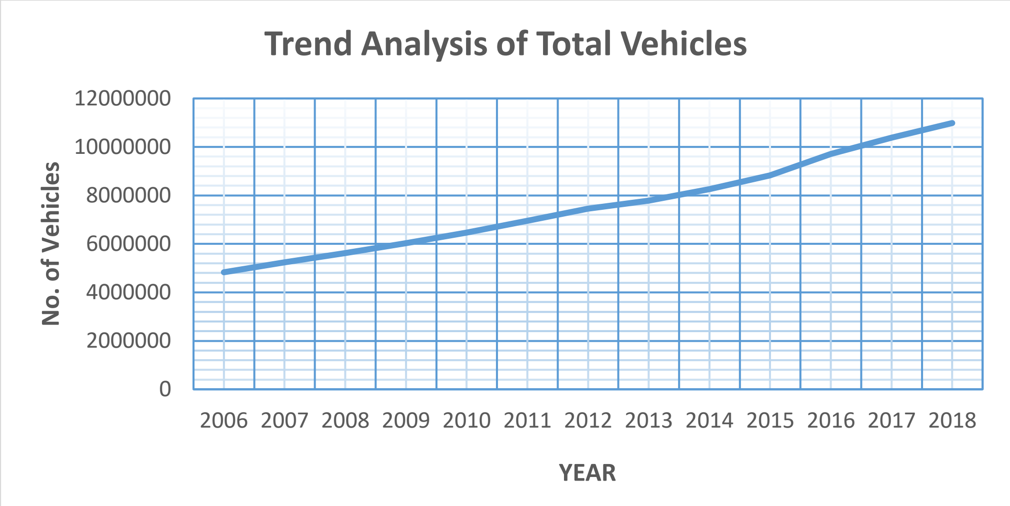


4.1.6 Reason behind the selection of Delhi as a subject of study:

Trend Analysis indicates that numbers of registered vehicles in Delhi & NCR Region are gradually increased:

Year	Number of vehicles	No. of vehicles per 1000 population
2005-06	4830136	317
2008-09	6026561	374
2011-12	7452985	436
2014-15	8827431	491
2017-18	10986015	598

(http://delhiplanning.nic.in/sites/default/files/Final%20Economy%20survey%20English.pdf)



From the above trend analysis, we can conclude that with time there has been a steady increase in the total number of vehicles due to which road congestion and loss of time in commutation have increased indicating an urgent need for the development of new road networks and transit modes.

4.1.7 Research framework and projects

4.1.7.1 Research objectives:

- Trend Analysis of Pollutant Concentration due to Vehicular Emissions in Delhi and NCR and understanding the variation in overall pollutant concentration with seasonal variation.
- Analysis of steps taken by the Government of India to reduce Air pollution and implementation of various advanced modes of transportation.

4.1.7.2 Transportation sector of Delhi-NCR region:

The Master Plan of Delhi (MPD) 2021 states that "The Vision for Delhi is to have a mobility transition which will deliver a sustainable urban transport system for the city that is equitable, safe, comfortable, affordable, energy-efficient and environment-friendly; a system that satisfies the mobility needs of all sections of the population and enhances their quality of life."

To achieve the Vision set by MPD 2021 and to decongest Delhi, the following goals need to be achieved within the next 5 years:

1. Mobility Target – Preferably 80-20 modal share in favour of public transport (considering motorized trips only);

2. Air Quality Target – reduction in vehicular emissions to meet the national ambient air quality standard;

3. Road Safety Target – achieving Zero fatality through an uncompromising approach to reduction of fatalities amongst all road and transport users;

4. Safety and Accessibility – through safe, convenient, comfortable and barrier-free movement for all users;

5. Equity – through equitable access to transport systems for all and equitable allocation of road space for all modes focusing on moving people rather than moving motor vehicles;

6. Affordability – by providing a range of mobility options for all users; and

7. Efficiency – in the movement of people and goods.

The "Prioritized Action Plan to Decongest Delhi', a 4-pronged strategy, is recommended by the High Powered Committee chaired by Secretary, Urban Development (UD), the Government of India.

Strategy One: Improving Public Transport and Dis-incentivizing the use of private vehicles.

Strategy Two: Road Safety & Traffic Management.

Strategy Three: Enhancing Institutional Capacity.

Strategy Four: Transit Oriented Development.

*(http://mohua.gov.in/upload/uploadfiles/files/Decongesting_TrafficDelhi06.pdf)

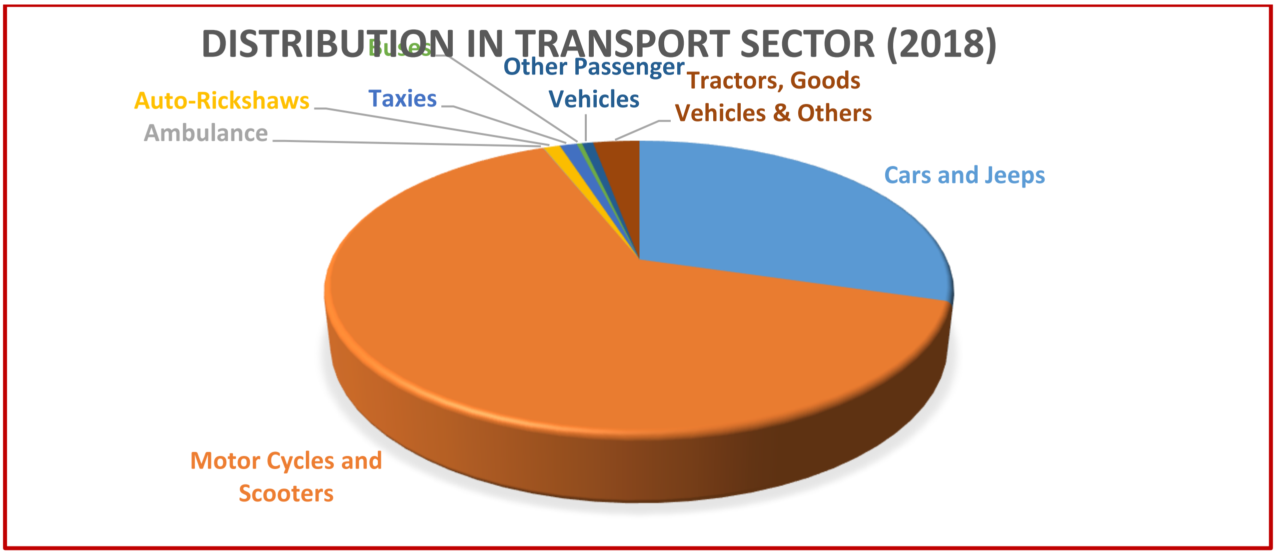
Delhi loses a large number of man-hours while commuting between home and workplaces through public transport by road due to traffic congestion. Public transport promotes the achievement of numerous social and economic objectives. It may save public man-hours. An effective public transport system not only replaces private vehicles, but it also improves road safety and reduces some of the adverse effects of traffic on the environment.

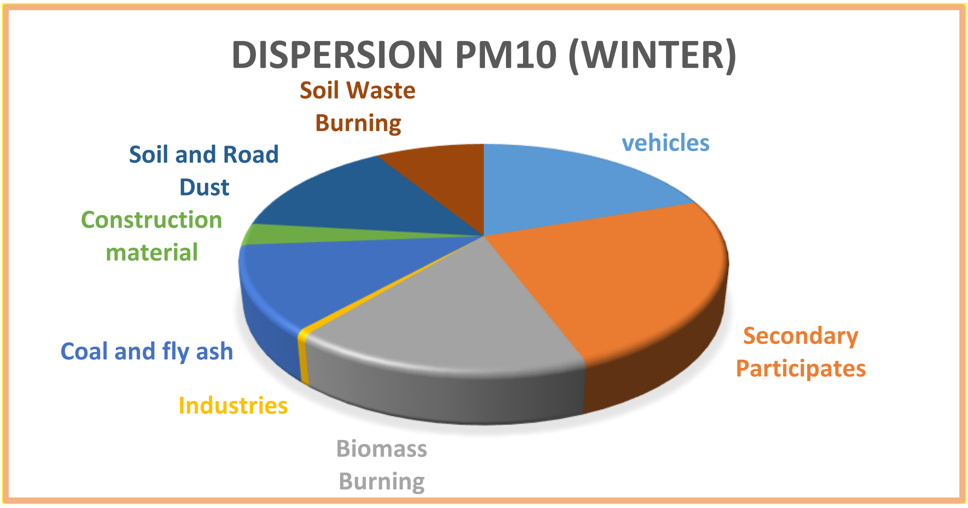
Public Transport in Delhi has two major components i.e. Bus Transport and Metro Rail. Both these systems are the lifeline of the people of Delhi. According to the survey, the daily ridership of Metro Rail in Delhi is 25 lakh and the daily passenger ridership on DTC buses happens to be around 29.86 lakh (2017-18).

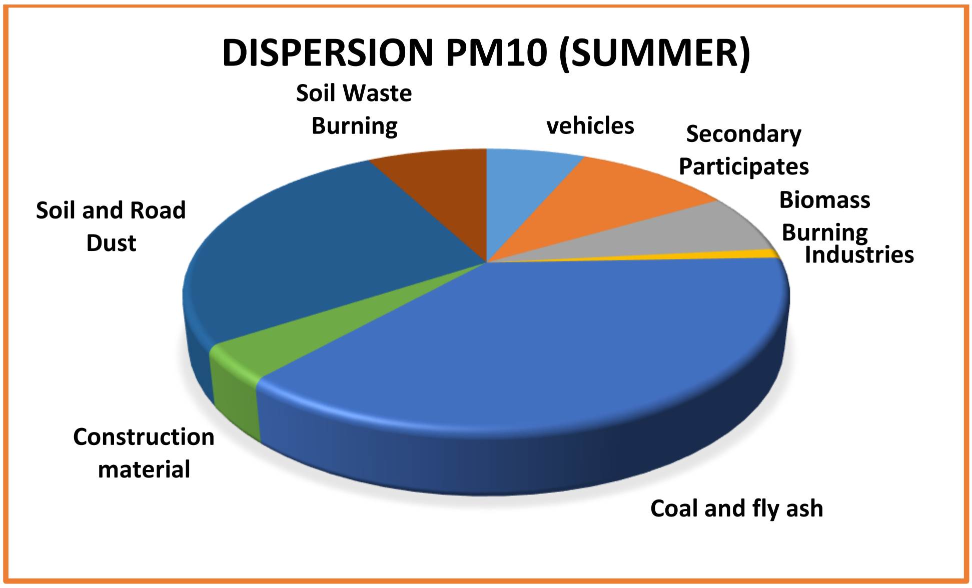
(http://delhiplanning.nic.in/sites/default/files/Final%20Economy%20survey%20English.pdf)

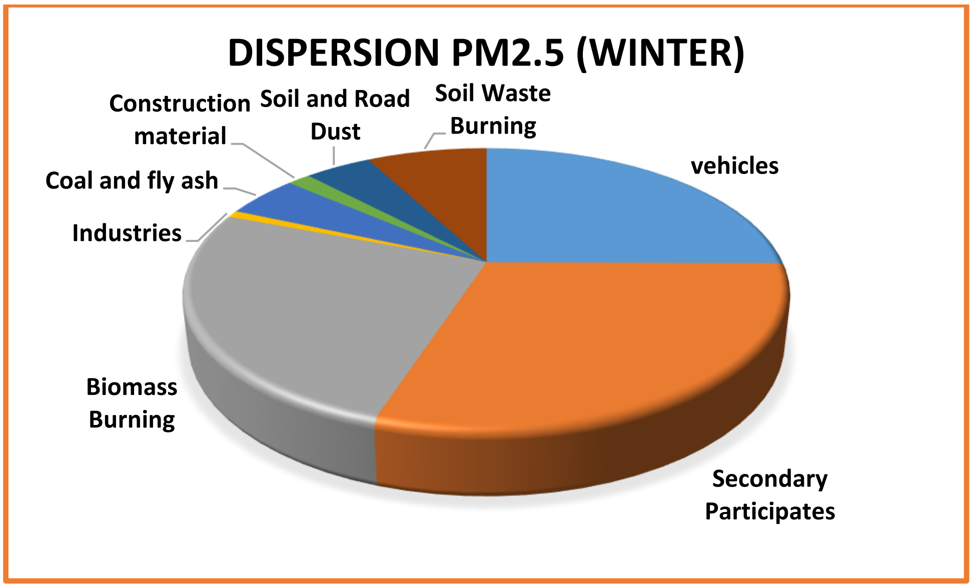
S No.	Details	Number of Vehicles		Growth Rate
		2016-17	2017-18	Percentage
1.	Cars and Jeeps	315270	3246637	2.98
2.	Motor Cycles and Scooters	6607879	7078428	7.12
3.	Ambulance	3059	3220	5.26
4.	Auto-Rickshaws	105399	113074	7.28
5.	Taxies	118308	118060	-0.21
6.	Buses	35206	35285	0.22
7.	Other Passenger Vehicles	59759	76231	27.56
8.	Tractors, Goods Vehicles & Others	300437	315080	4.87
	TOTAL	**10382757**	**10986015**	**5.81**

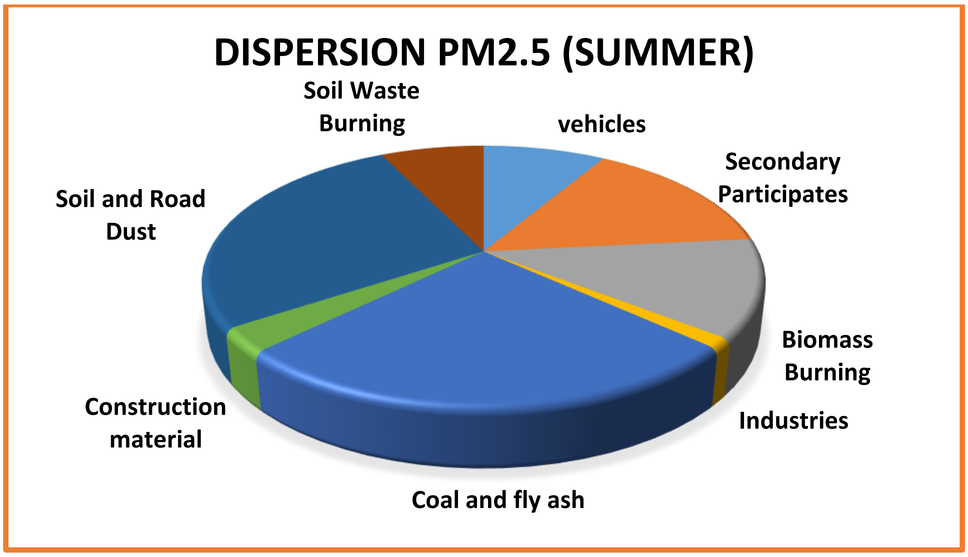
It may be observed from the above table that the two-wheeler industry performance has been strong during FY 2018. The growth rate of vehicles in Delhi during 2017-18 was recorded at 5.81 per cent. The highest growth of vehicles during the period was observed in other passenger vehicles at 27.56 percent during 2017-18. The annual growth rate during 2017-18 in comparison to the previous year was observed in goods vehicles & others at 4.87 percent. It is 5.26 percent for ambulances and 0.22 percent in the case of buses. However, a negative growth of 0.21 percent is observed in taxies.




DISPERSION PM10 (WINTER)
Soil Waste Burning
vehicles
Soil and Road Dust
Construction material
Coal and fly ash
Industries
Biomass Burning
Secondary Participates


DISPERSION PM10 (SUMMER)
Soil Waste Burning
vehicles
Secondary Participates
Biomass Burning
Industries
Soil and Road Dust
Construction material
Coal and fly ash


DISPERSION PM2.5 (WINTER)
Construction material
Soil and Road Dust
Soil Waste Burning
vehicles
Coal and fly ash
Industries
Biomass Burning
Secondary Participates



Performance of Delhi Transport Corporation:

Sl. No.	Years	No. of bus fleets (Numbers)	Vehicle utilization (Km/bus/day)	Passengers carried per bus daily (In Numbers)	Daily Average Passengers (In Lakh)
1	2005-06	3469	226	973	30.52
2	2006-07	3444	199	951	26.77
3	2007-08	3537	177	848	24.04
4	2008-09	3804	171	772	22.62
5	2009-10	4725	184	776	24.16
6	2010-11	6204	185	700	30.32
7	2011-12	5892	199	863	44.2
8	2012-13	5445	202	973	46.77
9	2013-14	5223	190	952	43.47
10	2014-15	4712	188	930	38.87
11	2015-16	4352	191	927	35.37
12	2016-17	4027	199	890	31.55
13	2017-18	3951	191	878	29.86

(http://delhiplanning.nic.in/sites/default/files/Final%20Economy%20survey%20English.pdf)

The above table denotes the variation in the number of buses which increased till 2010-11 and stagnancy in the vehicle utilization and yet the daily average passengers which were supposed to be increased rather decreased a bit. Reasons for such is due to:

- The use of more private vehicles.
- Development of Metro Rail which accommodated most of the population.

In order to counteract the increasing number of vehicles new road networks, ring systems and circular islands are needed to be established. The DMRC introduced metro rail connecting various hotspots and corridors throughout the Delhi and NCR region provokes the citizens to lean themselves on availing public transport systems in place of private transport which will be quite beneficial for the environmental aspect. After the completion of the Orange Line of Metro Extensions (Airport Express) on 23/02/2011, the number of bus fleets decreased from 6204 to 5892 and hence since then it has started decreasing which states that a majority of the citizens have shifted from bus to Metro Rail which caused the decrease in bus fleet and the number of passengers per bus.

According to the Economic Survey of India 2017-18, it was inferred that in the last decade the percentage of the population depending on motorcycle and scooters have increased by 64.43 per cent, along with the usage of cars and jeeps to 29.55 per cent.

4.1.7.3 Reasons for Delhi Being a polluted city specifically in the winter season:

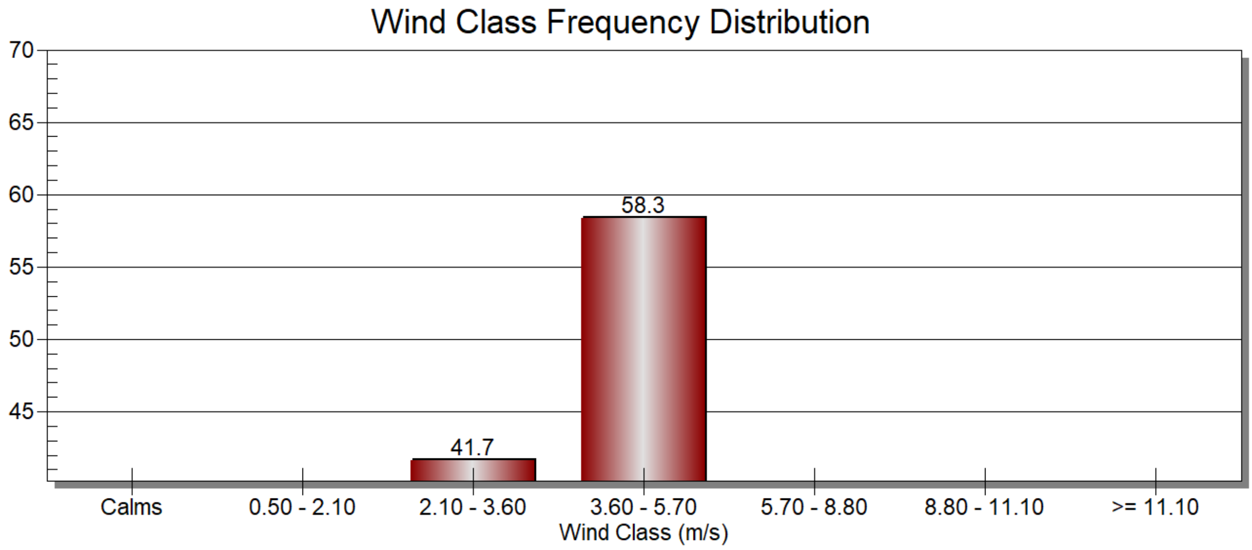
Air Pollution levels in Delhi and its surrounding regions is to be particular pollutant concentration is generally highest in the source and the reason behind such pollutant is the wind direction and velocity.

Now, considering the wind profiles of Delhi and NCR a chart is formed below to understand the direction of wind and average velocity on a yearly basis.

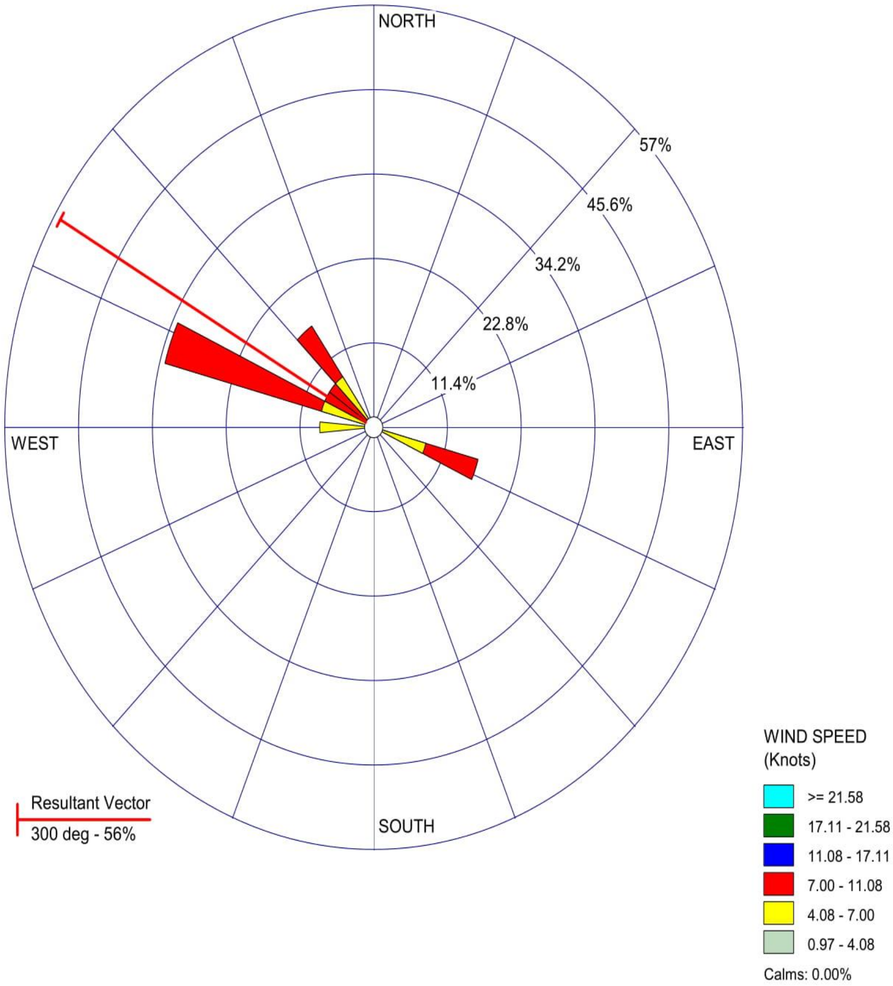
Sl. No.	**Month**	**Prevailing Wind Direction(Degrees)**	**Prevailing Wind Velocity Class (Kts)**
1	JANUARY	291	6
2	FEBRUARY	290	7
3	MARCH	295	7
4	APRIL	288	7
5	MAY	292	7
6	JUNE	315	8
7	JULY	113	7
8	AUGUST	110	6
9	SEPTEMBER	310	7
10	OCTOBER	316	5
11	NOVEMBER	294	5

12	DECEMBER	269	5

The Wind Class Frequency Distribution shows the overall percentage of winds whose wind speed lies within a certain class i.e. major percentage like 58.3 percent of winds lies within3.6 – 5.70 m/s class and the rest lies in 2.10-3.60 m/s range.



WIND ROSE PLOT:	DISPLAY: **Wind Speed** **Direction (blowing from)**



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 15-02-2019 - 02:00 **End Date: 15-12-2019 - 13:00**	MODELER:	
	CALM WINDS: **0.00%**	TOTAL COUNT: **11 hrs.**	
	AVG. WIND SPEED: **6.47 Knots**	DATE: **31-08-2020**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

The above Wind Rose Diagram is constructed as per the data available for Delhi and NCR Regions. It is evident that the prevailing wind direction for the majority of the year is approximately from the North West Region i.e. States of Punjab and Haryana.

The main reason behind the importance of these winds is not just the direction but the contents that are being swayed from certain regions of Punjab and Haryana which contains residues of stubble burning.

The states surrounding Delhi are known collectively as the "grain bowl" of India after the agricultural sector underwent a green revolution in the 1960s, leading to a dramatic increase in rice and wheat productivity. In Haryana alone, 80 percent of the almost 5 million hectares of land is now under cultivation, producing over 13 million tons of grain per year. But as production grew, the sector could not keep up with an increasing demand for labour, with farmers eventually abandoning hand harvesting in favour of less labour intensive methods such as the combine harvester. Unlike manual harvesting techniques however, combine harvesters leave behind rice stubble, which prevents machines from sowing wheat seeds. With as little as 10 days between rice harvesting season and the sowing of wheat, farmers often turn to stubble burning to quickly remove the remaining rice crop residue.

With one ton of residue containing 4-6 kg of nitrogen, 1-2 kg of phosphorus, and 15-20 kg of potassium, the **Centre of International Maize and Wheat Improvement's** research has shown that residue burning not only releases toxic gases into the air but also reduces soil nutrition and therefore crop yields. CIMMYT studies show that agricultural productivity can be improved with the use of happy seeders and super Straw Management System machines by reducing labour costs and time and allowing nutrients from the crop residue to be recycled back into the soil. Although the technology itself is not new, it was up until recently prohibitively expensive, with a happy seeder costing around 150,000 INR. With around 80 per cent of farmers in Haryana owning under 5 acres of land, the majority cannot afford to invest.

However, a central government scheme is investing over 11 billion INR in three states over a two-year period, to reduce crop residue burning by providing subsidies to farmers for buying the machines. Organizations like CIMMYT are working alongside State Governments to train farmers and promote the new technology, in an attempt to both increase grain productivity and reduce economic and labour inputs required by the farmers.

In 2019, stubble burning was reduced by 19 per cent as compared to that in 2018.

4.1.7.4 Increase in efficiency of Abating Pollution Concentration due to introduction of new Transportation Modes in Delhi and NCR Regions:

The Delhi Metro (DM) is a mass rapid transit system serving the National Capital Region of India. It is also the world's first rail project to earn carbon credits under the Clean Development Mechanism of the United Nations for reductions in CO2 emissions.

In the period of 2004-06, one of the extensions of the Delhi Metro led to a 34 per cent reduction in localized CO at major traffic intersections in the city. Data also reveals a decrease in NO_2 pollutant concentration whereas the concentration of PM2.5 remained inconclusive.

- **<u>Effect of Delhi Metro on Air Quality: Nine Week Symmetric Window</u>**

TIMELINE OF IMPLEMENTATION	**NO_2**	**CO**	**PM2.5**
	(PERCENTAGE CHANGE IN LEVEL OF POLLUTANT)		
Yellow Line 1st Extension(03/07/2005)	-6.6	-69.4	-
Std. Error	16.5	10.5	-
No. of Observations	1457	1497	-
Blue Line Introduction(03/12/2005)	-30.6	-	-
Std. Error	9.4	-	-
No. of Observations	1639	-	-
Blue Line 2nd Extension(11/11/2006)	-10.4	-13.1	-12.4
Std. Error	9.8	8.2	16.0
No. of Observations	1605	1605	1268
Siri Fort Blue Line 2nd Extension(11/11/2006)	-25.9	-3.0	-
Std. Error	24.0	9.9	-
No. of Observations	1601	1532	-

From the above table it can be concluded that the implementation of the Mass Rapid Transit System led to the decrease in pollutant concentration that was emitted through various privately owned vehicles.

However, with the MRTS running on electricity more amount of electricity needs to be generated as a result the load on coal combustion power plant increases which in turn increased the pollution concentration level due to more amount of coal combustion.

Since the generation of electricity is majorly based on coal combustion plants, it is high time to change the basic mode for generating electricity from coal combustion power plants to other eco-friendly methods like Solar Power Plants, Hydel Power Plants, Nuclear Power Plants and Wind Power Plants.

The latest addition to reforms in the transport sector is the introduction of electric and other alternative fuel vehicles. Faster Adoption & Manufacturing of Electric Vehicles (FAMEV-INDIA) Scheme was introduced to give a push to electric vehicles in public transport and seeks to encourage the adoption of EVs by way of market creation and demand aggregation.

The Indian Government is drafting a policy that supports investment in the manufacturing of such vehicles, development of efficient battery systems, and establishment of smart charging facilities. A proposal for shifting to 100 per cent electric vehicles by 2030 was announced. Some experts exclaimed that electric vehicles might not be able to abate the issue of air pollution, as these would still produce tiny pollution particles from brake and tyre dust. They recommended less use of motor vehicles, more cycling and walking and better public transit systems.

4.1.8 Legal framework and government policies

In 1972, the Stockholm conference was held by the United Nations on Human Environment, in which India participated and agreed to take appropriate steps for the preservation of natural resources of the earth which, among other things, include the preservation of the quality of air and control of air pollution.

The government of India enacted the Air (Prevention and Control of Pollution) Act 1981 under Article 253 of the Constitution to implement the decisions taken at the United Nations Conference on Human Environment held in Stockholm in June 1972 in general and to arrest the deterioration in the air quality in particular.

The Act provided for the preservation, control and abatement of air pollution, for the establishment, to carry out the aforesaid purposes throughout INDIA.

Central Pollution Control Board (CPCB) constituted under section 3 of the Water (Prevention and Control of Pollution) Act, 1974 was assigned power and functions to prevent and control air pollution as per Section 3 of the Air (Prevention and Control of Pollution) Act 1981.

CPCB launched National Ambient Air Quality Programme in 1984 which was renamed to National Air Quality Monitoring Programme (NAMP). The basic difference between ambient air and air is that ambient air comprises atmospheric air which is generally outdoors whereas air as a whole represents both indoor and outdoor air.

4.1.8.1 National Air Quality Monitoring Programme:

National Air Quality Monitoring Programme was launched by the CPCB which executes a nationwide programme of ambient air quality monitoring through 703 manual ambient air monitoring stations covering 307 cities/towns; 28 States and 7 Union Territories (UT) as per the NCAP strategy document 35 monitoring stations are functioning in NCR which is quite less with respect to the population density and pollution concentration levels throughout the UT. Besides, manual air monitoring stations a total of 234 Continuous Ambient Air Quality Monitoring Systems (CAAQMS) are located in 130 cities across India out of which 25 are located in the Delhi NCR region. *(https://app.cpcbccr.com/ccr/#/login)

The objectives of NAMP are:

- To ascertain whether the air quality standards are violated.
- To identify non-attainment cities.
- To determine the status and trends of ambient air quality.
- To gather knowledge and understanding to develop preventive and corrective measures.
- To understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind base movement, dry deposition, precipitation and chemical transformation of pollutants generated.

4.1.8.2 National Air Quality Index (AQI)

It was launched in 2014 by the Central Government with the concept of “One Number – One Colour – One Description” for the common citizens to judge the air quality within his/her vicinity. Air Quality Index is a tool for effective communication of air quality status to people in terms, which are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and colour.

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 (PM1O, PM2.5, NO_2, SO_2, CO, O_3, NH_3, and Pb) for which short-term (up to 24-hours) National Ambient Air Quality Standards are prescribed. Based on the measured ambient concentrations of a pollutant, sub-index is calculated, which is a linear function of concentration (e.g. the sub-index for PM2.5 will be 51 at concentration 31 µg/m3, 100 at concentration 60 µg/m3 and 75 at concentration of 45 µg/m3). The worst sub-index determines the overall AQI. AQI categories and health breakpoints for the eight pollutants are as follows:

AQI CATEGORY (RANGE)	PM10	PM2.5	NO_2	O_3	SO_2	CO	NH_3	Pb
(0-50) Good	0-50	0-30	0-40	0-50	0-40	0-1.0	0-200	0-0.5
(51-100) Satisfactory	51-100	31-60	41-80	51-100	41-80	1.1-2.0	201-400	0.5-1.0
(101-200) Moderate	101-250	61-90	81-180	101-168	81-380	2.1-10	401-800	1.1-2.0
(201-300) Poor	251-350	91-120	181-280	169-208	381-800	10-17	801-1200	2.1-3.0
(301-400) Very Poor	351-430	121-250	281-400	209-748	801-1600	17-34	1201-1800	3.1-3.5
(401-500) Severe	430 +	250 +	400 +	748 +	1600+	34 +	1800 +	3.5 +

4.1.8.3 Forty-two Action Plan:

- The CPCB was implemented within the specified period in major cities including Delhi and NCR under Section 18(1) (b) of the Air (Prevention and Control of Pollution) Act, 1986. The action plans constitute:

  a. **Control of Vehicular Emissions:**

Serial No.	Action Points	Time frame of implementation
1	Launch extensive awareness drive against polluting vehicles	Immediate

2	Ensure Strict action against visibly polluting vehicles	Immediate
3	Install weigh-in-motion bridges at Delhi borders to prevent overloading	Immediate
4	Take steps to prevent parking of vehicles in the non-designated areas	Immediate
5	Introduce an early alarm system for benefit of commuters related to traffic congestion on major routes for route diversion	Immediate
6	Consider introducing a plan for Flexi/staggered timings to minimize peak movement of vehicles on the road	Immediate
7	Take steps for retrofitting diesel vehicles with Particulate Filters	Immediate
8	De-congest pathways	Immediate
9	Synchronize traffic movements / Introduce intelligent traffic systems for lane driving	30 days
10	Install vapour recovery system in fuelling stations	30 days
11	Take steps for installation of sensor-based based PUC system	90 days
12	Formulate an action plan for controlling decongestion of fuel stations including increasing number of dispensing machines	90 days
13	Prepare an action plan to check fuel adulteration and random monitoring of fuel quality data	90 days
14	Prepare an action plan for public transport in CNG mode	90 days
15	Undertake road widening and improvement of infrastructure for decongestion of road	90 days
16	Promote battery-operated vehicles	90 days
17	Take steps to expedite early completion of Western and Eastern Peripheral expressway and submit completion schedule	60 days

b. **Control of Road Dust Re-suspension of Dust and Other Fugitive Emission:**

Serial No.	Action Points	Time frame for implementation
1	Formulate an action plan for creation of green buffers along the traffic corridors	immediate
2	Introduce wet/ mechanized vacuum sweeping of roads	30 days
3	Maintain pot-holes free roads for free-flow of traffic to reduce emissions and dust	60 days
4	Introduce water fountains at major traffic intersections, wherever feasible	90 days
5	Undertake greening of open areas, gardens, community places, schools and housing societies	90 days
6	Take steps for blacktopping/pavement of road shoulders to avoid road dust	180 days

- These 2 categories implemented affect directly the total air pollution computed by the vehicular emissions. The other factors such as:
  a. Control of Air Pollution from Bio-Mass Burning.
  b. Control of Industrial Air Pollution.
  c. Control of Air Pollution from Construction and Demolition activities.
  d. And other independent action points are also implemented across major cities.

4.1.8.4 Grand Response Action Plan (GRAP):

- The Central Government implemented the Graded Response Action Plan for Delhi and NCR region which comprises graded measures corresponding to each source as framed by the AQI categories.
- Certain origins of air pollution like vehicular pollution, industrial pollution, construction and demolition pollution, and biomass burning remains the same throughout all the seasons whereas certain other forms of air pollution like stubble burning, increase in biomass burning etc. vary with the change of seasons.
- During winters, the relative share of vehicles, biomass burning, MSW burning, fire-crackers, stubble burning increases and as a result the secondary pollutant concentration increases; the reasons are explained later.

- During summers, air pollution increases due to more concentration of road dust, fly ash, vehicles etc.
- The proposed graded measure was implemented after consideration of all the variable factors and their effect on health corresponding to the AQI index and categories. Certain actions need to be implemented throughout the year when the AQI health emergency level gets too poor.

4.1.8.5 Source Apportionment Studies:

- The data generated from National Air Quality Monitoring Programme reveals that the particulate matters i.e. PM2.5 AND PM10 possess the major challenging issues concerning the permissible limits set according to National Ambient Air Quality Standards throughout the country.
- Transport sector contributes to only 4 percent of total PM2.5 emissions on a national scale.
- According to the CPCB study from 2007 to 2010 source appointment studies were conducted in 6 major cities i.e. Delhi, Mumbai, Bengaluru, Chennai, Kanpur and Pune. The result shows road dust, re-suspensions, construction activities, and soil has a major contribution to PM10 concentration in these cities. The share of the transport sector remains smaller in PM10 but increases significantly in PM2.5 concentrations.

4.1.8.6 National Clean Air Programme:

The 5 most important parts of NCAP are as follows:

1) GOAL:

The goal of NCAP is to meet the prescribed annual average ambient air quality standards at all locations throughout the country within a fixed period.

2) OBJECTIVES:

(I) Stringent implementation of mitigation measures for prevention, control and abatement of air pollution.

(II) Augment and strengthen air quality monitoring networks across the country.

(III) Augment public awareness and capacity-building measures.

3) APPROACH:

(I) Multi-sectorial and Collaborative

(II) Mainstreaming and integration into the existing policies and programmes of the Government of India including NAPCC.

(III) Use smart cities framework to launch NCAP in the 43 smart cities falling in the list of 102 non-attainment cities.

4) TARGET:

(I) National level target of 20-30 per cent reduction of PM2.5 AND PM10 concentration by 2024.

5) TENURE:

(I) Mid-term five years action plan to begin with keeping 2019 as the base year. Further extendable to 20-25 years in the long term after a mid-term review of outcomes.

4.1.9 Implementation of policies and actions by government

4.1.9.1 Implementation of NCAP

1) The Central Pollution Control Board will execute nationwide programmes for the prevention, control and abatement of air pollution within the guidelines of the National Clean Air Programme.
2) The NCAP will be institutionalized by respective ministries and will be organized through inter-sectorial groups, which include, in addition to the related ministries, the Ministry of Finance, Ministry of Health, NITI Aayog and CPCB experts from the industry, academia, and civil society.
3) The Ministry of Road Transport and Highways acts as the guidance to various guidelines for the control and prevention of air pollution from vehicular emissions through Motor Vehicles Act, 1988 and Central Motor Vehicles Rules 1989.
4) Numerous other ministries i.e. MoEFCC, MoP, MoP&NG, MoN&RE etc. are responsible for determining the guidelines in their own fields contributing to the ultimate goal of control, prevention and abatement of air pollution.
5) Ministry of Environment, Forest and Climate Change implemented NAPCC with eight missions spreading across various sectors. Five of the missions are spread via National Mission for a Green India, National Mission for Enhanced Energy Efficiency, National Solar Mission, and National Mission on Sustainable Habitat & National Mission for Sustainable Agriculture; have a direct link with the mitigation of air pollution, which certainly can have advantageous benefits on these ongoing missions.

6) Comprehensive component-wise documents detailing objectives, strategies, plan of action, timelines and monitoring, and evaluation criteria are developed periodically and if any upgrades or any modification is required the concerning committee can take their prescribed steps.
7) The Apex Committee within the ministry will review the progress of these components. Appropriate indicators will be evolved for assessing the emission reduction benefits of actions.

4.1.9.2 Development of Road Network

- The road network in Delhi is being developed and maintained by the National Highway Authority of India (NHAI), Public Works Department (PWD), Municipal Corporations of Delhi, New Delhi Municipal Council (NDMC), Delhi Cantonment Board (DCB) and Delhi Development Authority (DDA).
- The road network is increasing day by day in the NCT of Delhi. A revised outlay of INR 1,098 crore was approved for Road and Bridges and an expenditure of INR 959 crores was incurred during 2017-18. Further, an outlay of INR 1302 crore has been kept in R.E. 2018-19 for the development of roads & bridges in the NCT of Delhi.
- The road networks as developed in Delhi (Agency-Wise):

Sl. No.	Agency	Road network (2017-18)
1	East DMC	512.46
2	South DMC	9592
3	North DMC	3272.65
4	New Delhi Municipal Corporation	1290
5	Public Works Department (Delhi Govt.)	
	a. National Highway	430
	b. Other Roads	6308
6	DSIIDC	1536.77
7	I&FC	294
8	DDA	435

*All distances are in lane KMs.

*Source (http://delhiplanning.nic.in/sites/default/files/12%29%20Transport.pdf)Pg-204

4.1.9.3 Development of Inter-State Bus Terminus

- According to the Economic Survey of 2017-18; Delhi Government suggested the working of five ISBTs by the year 2021. At present 3 ISBTs are operational i.e. Sarai Kale Khan, Anand Vihar and Kashmere Gate along with the addition of two more ISBTs to be constructed in Dwarka and Narela.

4.1.9.4 Mass Rapid Transit System (MRTS)

- The Mass Rapid Transit System (MRTS) is an ambitious project that aims at providing a non-polluting and efficient rail-based transport system, properly integrated with the road transport system.
- The Delhi Metro is being constructed in phases. Phase-I was completed with the construction of 59 stations covering a total distance of 65.1 km which consists of 13.17 km underground and elevated length of 51.93 km. The inauguration of the Barakhamba Road- Indraprastha corridor which was marked as the 'BLUE LINE' marked the end of Phase-I in 2006. Phase-II was completed with the construction of 86 stations covering a total distance of 124.93 km that was able to connect certain regions of NCR by the end of 2011. Phase-III included additional corridors and NCR extensions consisting of 109 stations covering a distance of 160 km was completed by 2018.
- The daily ridership of Delhi Metro was around 25 lakhs but it's expected to increase with the completion of Phase-III in 2018.

4.1.9.5 EPCA Report 2017-18:

Actions taken by the Government of India to combat air pollution in Delhi and NCR regions.

- According to the EPCA 2018 Report, the top five key sources of abnormal air pollution level in Delhi was Vehicular Pollution; i.e. vehicles are grossly polluting like trucks and diesel vehicles as well as the growing number which counteracts the impact of cleaner fuel and emission technology.
- Vehicles contributed up to 20 per cent of total PM2.5 concentration & 36 per cent of total NOx concentration.
- Vehicles generally emit toxic fumes, which are very hazardous to human health.
- According to their proven study Delhi and NCR regions have a higher level of pollution concentration during the winters due to the drop in temperature and formation of inversion layers due to which the pollutants become unable to dissipate

and as a result pollutant gets trapped close to the ground and concentrated over a certain area. As a result, it was advised to monitor the meteorological parameters like wind speed, wind direction etc. which played a crucial role. For example; Wind from WEST i.e. from beyond Afghanistan that travels via Punjab brings dust and crop residue burning and also the winds from EAST bring moisture; which in together forms smog incidents as seen in November, 2017.

- Also according to the data available from the monitoring stations located in Delhi itself, there has always been a spike increase in PM2.5 concentrations during early November every year due to coinciding crop dust, burning residue, Diwali, wind storms from western Asia.
- There is a direct relationship between the wind speed and pollutant concentration. They are inversely proportional i.e. with the increase in wind speed, pollutant concentration in a certain place decreases and vice versa.
- The overall pollution levels decreased and changed from very poor- severe category to poor- very poor category; however, they are still above the permissible limits as set by NAAQS which is even harmful for healthy people if comes in contact for a prolonged period of time.

4.1.9.6 Timeline for Implementation of Graded Action Response Plan (GRAP):

- On 2nd December, 2016 under EPCA's recommendation the honourable Supreme Court directed the MOEF&CC to notify Graded Action Response Plan as an emergency plan. Under GRAP there are 4 stages of pollution: Moderate- Poor, Very Poor, Severe and Severe+ or Emergency.

  Under the notification and directions of the Honourable Supreme Court the following system has been set up to implement GRAP:

  a. Expansion of the air pollution monitoring network so that NCR is covered and there is information about the level of pollution and the impact on human health.
  b. The Air Quality Index (AQI) has been established with links to the health advisory. The Index automatically takes the readings of the connected stations and puts out a daily index on the state of pollution.
  c. A task force, headed by CPCB has been set up to meet regularly (daily during the high pollution period) to assess the pollution levels and to deliberate with the officials of the Indian Metrological Department (IMD) on forecasts. This task force, in turn informs, EPCA on recommendations for action.

d. It was agreed that between March and October, when pollution levels are low, the measures listed under the Moderate to Poor category would be in effect.

- On 17th October, 2017 EPCA imposed GRAP under "Very Poor and Severe" category even though it was in "Poor and Very Poor" category as a precautionary measure for the impending winter and inversion.
- On 7th November, 2017 CPCB informed EPCA that the pollution levels increased alarmingly overnight in Delhi and NCR Regions and they were in the severe category. On that day the concentration of PM2.5 was approximately 10 times than the 24 hour-average standard. As a result, EPCA took certain steps:

  a. Immediately intensify public transport service, by ensuring there are more buses on road, which are run with reliable service.
  b. Immediately increase frequency of service, including deploying more coaches and introduction of lower fares during off peak hours during this severe period.
  c. All state pollution boards to immediately impose fines on all road -constructing agencies where there are inadequate dust control measures.
  d. Intensification of mechanized road sweeper and sprinkling of water.
  e. Immediate enhancement of parking fee by 4 times and deposit of additional funds in dedicated parking fund with municipalities.
  f. Immediate stop all use of unapproved fuels in Delhi and all use of coal and firewood in hotels and eateries.
  g. Intensify traffic management in all hot spots and increase deployment of traffic police across the city.
  h. Intensity the enforcement of non-destined goods traffic into Delhi by physically checking all vehicles and turning them back and putting out public announcement of the numbers turned back.

- On November 8, the level of pollution spiked further to 640 µ/m3, which is 11 times the standard. EPCA directed Delhi government to:

  a. Stop entry of truck traffic into Delhi (except essential commodities).
  b. Stop construction activities.

  It also directed Haryana, UP, Rajasthan to stop construction activities till further notice in the NCR districts.

On 29th March, 2017 the honourable Supreme Court banned the sales of BS-III vehicles in the country and ordered that from 1st April, 2017 onwards only BS-IV vehicles would be registered in the country.

As per the EPCA Report 2018; The Government of India decided to skip the BS-V set of vehicles and leapfrog directly to BS-VI for all vehicles in the country. The initial date for implementation of BS-VI vehicles were 2026 which was later preponed to April, 2020.

Accordingly, the Ministry of Petroleum and Natural Gas stated that on 1st April 2018, BS-VI (10ppm sulphur diesel and petrol fuels) would be sold in Delhi by 2018 i.e. 2 years ahead of schedule.

4.1.9.7 Actions Taken by the Government of India (GoI) to Reduce Air Pollution

- Delhi was ranked one among the world's most polluted cities, however it proved to be an exception since the honourable Supreme Court supervised closely developing of an array of policies that are responsible for the decrease in air pollution levels.
- As a direct order of Court, between 1996 and 2001 the sulphur content of diesel and petrol was reduced from 1 per cent to 0.2 per cent for petrol to 0.05 per cent for both fuels.
- Premixed lubricating oil and petrol replaced loosed supply of these fuels for 2-stroke engines by 1998.
- During the period of 1996 to 2000, three initiatives were taken by the State Government:
    a. Notification of the 1st set of emission standards for Indian vehicles; in 1993, new vehicles were required to achieve a stricter standard by 1996 and 2000, which were further tightened by the end of 2000.
    b. At the beginning of 1995, all new passenger vehicles were installed with catalytic converters which reduced vehicular emissions.
    c. In 2000 a Mass Rapid Transit System was introduced known as the Metro.
- After this period, as a result of these various interventions, especially the conversion to CNG improved particular pollutant concentrations in Delhi's air quality.
- In 2005, after conduction of various studies it was proved that due to conversion to CNG without controlling other parameters as a result PM10 levels did not decrease whereas there has been a decline in pollutants like CO and SO_2. However, the concentration of overall NO_2 increased during this period which was detrimental to the environment.

- The deficiencies in public transportation systems across NCR have led to phenomenal growth in the number of private vehicles. Delhi alone has seen a 4-fold increase in the volume of private motor vehicles in the last 20 years- from 2.5 million in 2000 to over 10 million in 2018.
- In 2016, the Delhi government implemented the odd-even number plate scheme for private vehicles, in two phases for 15 days each in January and April. The aim was to reduce the number of on-road private cars running on petrol and diesel, and thus reduce harmful vehicle emissions. This scheme was enforced seriously, resulting in fewer cars plying during the period. However, given the gaps in public transport, the scheme caused difficulties for a large population of NCR.
- In February 2018, the Ministry of Petroleum and Natural Gas suggested shifting from BS-IV to BS-VI grade fuels for motor vehicles to reduce emissions from petrol/diesel vehicles in NCR. All 397 petrol pumps in Delhi are reportedly selling BS-VI grade fuel from 1st April 2018 only and extended the fuel across NCR by 2019.

4.1.9.8 Investments done by the Delhi Government in Transport Sector and its outcome in mitigation of Air Pollution:

In response to a Supreme Court order of 2015, an Environmental Compensation Charge (ECC) was imposed on commercial vehicles entering Delhi to discourage them from using these roads as a shortcut to other locations outside the capital. This measure was taken to reduce the emissions from diesel vehicles.

The installation of Radio-frequency Identification (RFID) systems proposed to record the number of commercial vehicles entering Delhi; which was then delayed due to the underreporting of trucks entering the national capital, and the consequent huge loss in collection of ECC. The 1st such system was operational at Aya Nagar (South Delhi bordering Haryana) in October 2018. A private company (Tecsidel) was engaged by the Delhi Government's Transport Department and the South Delhi Municipal Corporation for carrying out the installation.

Another Supreme Court order of August 2016 led to the creation of an Environment Protection Fund (EPF) for raising revenues, a 1 per cent pollution charge on the sale of diesel SUVs was imposed and by 2018 over INR 750 billion has been collected under the fund. However, there has been a delay in the utilisation of collected funds, and it is proposed that the money be utilised for implementing pilot projects, such as installation of air filters at traffic intersections and on bus rooftops, and using chemicals to suppress dust at construction sites.

*http://delhiplanning.nic.in/sites/default/files/Final%20Economy%20survey%20English.pdf

According to the Economic Survey of Delhi-2018-19, The Delhi Transport Corporation is incurring working losses and accordingly, as a result, the Delhi Government is obliged to help the corporation by assisting them financially. Trend Analysis of total financial income and assistance is provided below according to the Delhi Transport Corporation. (The following values are in Crore of Rupees)

Sr.	**Item**	**Year**					
		2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
1	Income(Cr)	1229.02	1109.87	1005.00	918.70	889.33	955.31
2	Working Cost(Cr)	2171.91	2129.23	2255.14	2300.49	2619.35	2705.68
3	Working Loss(Cr)	-942.89	-1019.36	-1250.14	-1381.79	-1730.02	-1750.37
4	Assistance provided by GNCTD(Cr)	974.00	1083.00	1234.00	1615.90	2077.18	1925.00
i)	Grant(Cr)	900.00	1000.00	1150.00	1550.00	2007.00	1825.00
ii)	Subsidy for Concessional Passes(Cr)	74.00	83.00	84.00	65.90	70.18	100.00

The working losses, Revenue Receipt minus (-) Establishment Expenditure excluding Interest Payment and Depreciation of DTC was INR 1750.37 crore in 2018-19 in comparison to INR 1730.02 crore in 2017-18. Till the year 2010-11, the Delhi Government used to meet the working losses of DTC by providing them with a loan. However, from 2011 to 2012, the system was changed by providing them with Grant, instead of Loan, in order to meet working losses. The Delhi Government passed the “GREEN BUDGET” for the year 2018-19 consisting a total sum of Rs. 53,000 crore. With a major thrust on green initiatives to combat rising air pollution levels in the national capital. For the year 2019-2020 the “GREEN BUDGET” was increased by 5.57 per cent from last fiscal i.e. increase of Rs. 2954.72 crore.

Out of 116 national schemes, AMRUT and Smart City Mission have an estimated budget of Rs 13,750 crore for 2020-21 fiscal against Rs 9,842 crore during 2019-20 FY while modernization of police forces Rs 3,162 crore for the 2020-21 fiscal against Rs 4,155 crore in the previous year. According to budget documents, the Central government has proposed an estimated budget outlay for 116 projects, divided into three categories: 6 Core of the Core Schemes; 24 Core Schemes; and 86 major central sector schemes.

The Union Finance Minister in her Budget Speech allocated Rs 460 Cr for pollution control schemes including the National Clean Air Programme with a vision of pollution free India for the year 2019-20.

4.1.9.9 Investments in Metro Sector

Phase I: [10] The whole phase was completed with INR 10571 crore and with an average cost of INR 162 crore per km. Japan International Cooperation Agency (JICA), funded 60 per cent of the construction of Delhi Metro project in six tranches, at an interest rate of 1.2 per cent and the repayment period of 30 years, moratorium period of 10 years. Both the governments, State and Central, shared the same equity in the project and mutually invested almost 30 per cent of the cost of the project. The remaining 10 per cent was said to come from the loan, subordinated debt to acquire land and property development.

Phase II: [10] The whole phase was completed with INR 18,783 crore and with an average cost of INR 150 crore per km. JICA provided 54 per cent of funds at an interest rate of 2.3 per cent for the project and 32 per cent was financed by the Governments GOI and GNCTD. The remainder was through property development, subordinated debt and investment from the state government of Haryana (GOH). GOH invested 1 per cent or INR 1.87 crore in the Phase-II extension plan to cover parts of the city of Haryana i.e. Gurugram. Similarly, the State Government of Uttar Pradesh (GOUP) also invested funds to cover the metro's extension plan to the city in Uttar Pradesh, Noida.

Phase III: [10] The whole project is estimated to be completed with INR 41079 crore with an average of INR 250 crore per km. A considerable high cost of the project was due to the introduction of three new lines, Magenta, Pink and Grey, and extension of the older ones. Where Magenta Line has introduced the first-ever driverless technology in a metro in India and Pink Line will become the longest route by distance. JICA will invest 49 per cent for this phase, 20 per cent will be provided by the GOI/GNCTD and the remaining will be provided through grants by State Governments, GOH and GOUP, property development and Subordinate Tax.

The Airport Express: It was constructed during the Phase II construction in a Public-Private Partnership (PPP) model as opposed to the common DMRC model [4]. Where the public entity, the GOI and GNCTD, and the private companies Reliance Industries and CAF Beasain contributed 39 per cent and 46 per cent respectively, sighting reasons for low profits, the private companies abandoned the project after a year and DMRC took over its operations [5]. The groups invested INR 5700 crore where the Spanish company, CAF delivered the trains.

Table: Average daily ridership of passengers per year and the network length.

Year	Actual Average Daily Ridership	Length of Metro (km)	Actual Average Daily Ridership Per km
2002	40000	8.50	4706
2003	54000	22.00	2455
2004	124000	26.00	4769
2005	269000	55.80	4821
2006	484000	65.10	7435
2007	625000	65.10	9601
2008	722000	74.55	9685
2009	919000	95.79	9594
2010	1259000	184.14	6837
2011	1660000	190.03	8735
2012	1926000	190.03	10135
2013	2190000	190.03	11524
2014	2386000	193.06	12359
2015	2590000	212.40	12194
2016	2761000	212.40	12999
2017	2530000	231.00	10952
2018	2800000	351.00	7977

4.1.10 Conclusion and Recommendations:

4.1.10.1 Overview of the Project

- This project started by addressing the various schemes and action plans taken up by the Government of India in all these years following a proper timeline. The following mandates and objectives of the schemes were discussed along with the understanding of trend analysis of major pollutants. Various requirements for the selection of Monitoring Stations and maintenance parameters were discussed. The sources, causes and health problems were discussed along with the respective pollutants.
- Trend analysis of AQI for Delhi and NCR was conducted to understand the reasons behind high pollutant concentration majorly during the winter season. Differential

implementation of Graded Response Action Plan corresponding to the pollution case study of Delhi in 2019.

- National Clean Air Programme which proved to be one of the important scheme to be implemented by the GoI not only dealt with the pollutant concentration but also gave mitigation actions with respect to the level of pollution.
- Transport Sector played a vital role in the pollution level of Delhi and NCR. The total amount of vehicles on road in Delhi was discussed along with segregating them concerning various classes of vehicles and their percentage. Trend Analysis of the increment in total number of vehicles in Delhi region was constructed along with their growth rate. The performance of Delhi Transport Corporation was tabulated concerning a decade of data and it was concluded that there has been a harsh increase in the number of cars and jeeps as compared to public buses or scooters and bicycles which is very much responsible for today’s environmental problems.
- Development of Road Network was studied along with the work done by various agencies in and around Delhi was studied along with the study of the development of Inter-State Bus Terminus (ISBT) and Mass Rapid Transit System (MRTS).
- With Reference to the EPCA 2017-18 Report various important facts were stated that were responsible for the high pollution level during the Winter Season and the reason behind it was discussed and it was briefly explained by using the Case Study of Delhi Pollution 2017. Then we moved on to stating various methods to decrease vehicular pollution.
- We also discussed the investments done by the GoI for the transportation sector which indicated to prove that is presently going on a loss basis and the grant given by the government is what keeping it together but it fails to address the main issue which is by controlling the number of private vehicles Government can reinstate the transport sector to a gain sector.
- One of the main aspects of Delhi and NCR pollution was discussed later on i.e. Stubble Burning along with the important factor responsible for the transportation of crop residues. With the help of Frequency Class Distribution and Wind Rose Diagram, we were able to understand that wind Direction and velocity played the most vital role in addressing the crop residue transportation which is directly responsible for higher pollution levels. Also various methods on how to decrease such residue were also discussed and are being currently used by various other advanced countries.

- Delhi Metro Rail Corporation played quite role in decreasing the pollution concentration by attracting more passengers over the years due to which the overall efficiency of abating vehicular pollution increased. However, due to the higher requirement for electricity various negative points emerged which are positively answered with various alternative sources of generating electricity which is eco-friendly by nature.
- Various strict actions that need to be taken by the Government to rectify the present environmental crisis, energy crisis and many more. Even though some are quite harsh but in these critical times unpleasant action needs to be taken as it has been done earlier by the human generation.

4.1.10.2 Steps to decrease Vehicular Pollution

- Advance emission technology and fuel quality for vehicles (AUTO FUEL VISION AND POLICY 2025):
    - **Phasing out of Lead:**

      Health effects associated with the use of lead alkyl additive in gasoline have led to elimination of leaded gasoline in several countries. Lead content in gasoline in India was removed in 6 years in phases and only unleaded gasoline is being produced and sold from 01.02.2000. Initial lead limit of 0.56 g/litre for leaded gasoline was reduced to 0.15 g/litre for low lead gasoline and then to 0.013 g/litre for unleaded gasoline. In order to phase out the lead from gasoline, Catalytic Reforming Units (CRU)/Continuous Catalytic Regeneration Unit (CCRU) and Methyl Tertiary Butyl Ether (MTBE)/Tertiary Amyl Methyl Ether (TAME) units were put up at the refineries.
    - **Reduction of Benzene Content:**

      Benzene is a natural constituent of crude oil besides its production during catalytic reforming operation for making high octane gasoline components. It is known to be a human carcinogen. An effective way to reduce human exposure to benzene is to control benzene in gasoline. There was no benzene specification in gasoline in India till MoE&F notified a benzene limit of 3 per cent vol. max for 4 Metros and 5 per cent vol. max for the rest of the country from the year 2000. Benzene in gasoline supplied to NCR of Delhi and Mumbai was further reduced to 1.0 per cent vol. max since Oct/Nov 2000. This is at par with Euro III/IV norms and the best in the world.
- Improve implementation of pollution under control mechanism for vehicles on road.

- Build roads to divert truck traffic from entering the city and also put a congestion charge on trucks so that they look for alternatives.

Reduce the number of private vehicles on road by improving public transport and bring car restraint measures like parking.

4.1.10.3 Pollution Under Control (PUC) – Components and Issues:

- The Amended Motor Vehicles Act, which came into effect on 1 September 2019; levied hefty fines on vehicles without a valid PUC (pollution under control) certificate. Now, this fear of being penalized has ramped up the number of vehicles getting tested for pollution levels, though it is not likely to bring about a substantial drop in the levels of air pollution. This is because the PUC systems in our country fare poorly at their ability to detect harmful pollutants emitted by a vehicle.
- As per a TNN report, the PUC systems in our country are calibrated to check vehicles for hydrocarbons and monoxide only and no other components. This means that harmful pollutants like particulate matter and nitrogen oxides (NOX), which have a grave and lasting effect on health, are not checked. This leads to polluting vehicles legally plying on roads. So, there is an urgent need to upgrade the PUC systems to also check for particulate matters, nitrogen oxides, and other harmful components. One of the biggest problems with detecting nitrogen oxides is that they are emitted only beyond a certain speed limit and can't be measured through conventional systems. So, detecting NOX requires a vehicle to be simulated to a particular speed and have the exhaust emissions checked using a different and more advanced technology. This calls for a serious improvement of pollution check centres and upgrading them with advanced PUC systems.
- According to Anumita Roy Choudhury, Executive Director, Centre for Science and Environment, Delhi, there are some other methods which can be used to check vehicles for harmful pollutants. For example, using portable emission monitors or remote sensing technology to monitor vehicular emissions on road and screen the polluters.

4.1.10.4 Developing Ways to Decrease Traffic Congestion and Adopt ECO-FRIENDLY Modes of Transport:

The traffic congestion phenomenon can be decreased substantially by implementing of the following methods of transportation:

A. **BICYCLES:** This mode of transport has been always the most practical, eco-friendly method of transportation as well as the conventional method. They give off no emission whatsoever, require no car insurance or gas and very little maintenance. In present world many cities already have bike sharing programmes which one needs not to purchase or maintain.

B. **MOTORCYCLES:** This mode of transportation is not exactly a green choice but it is a lot more efficient than a massive SUV or Sedan cars. It is evident that if the majority of the people shifts to this mode of transportation then the traffic congestion along with the emission factors would decrease significantly. The lesser the traffic density, lesser will be the traffic congestion, lesser will be the emission of pollutants at a particular source as a result the overall pollution decreases.

C. **CARPOOLING:** This mode of transport is much better than a scenario in which one household purchases 2 or 3 cars for individual purposes. This mode will reduce the emission with a high factor. Also as stated above the lesser the traffic density the lesser will be the pollution.

D. **HYBRID AND ELECTRIC VEHICLES:** This mode of transport not only allows a household to purchase more than 1 car but also it being eco-friendly will reduce the conventional emission standards. Stating the fact that in the USA, already developed new electric cars named TESLA which runs on Lithium Ion Batteries which are incredibly efficient concerning Power Output. The rechargeable batteries, which are used in everything from mobile phones to electric cars came into highlight after three scientists behind its development were awarded the 2019 Nobel Prize for chemistry. The Nobel Committee said: "Lithium-ion batteries are used globally to power the portable electronics that we use to communicate, work, study, listen to music and search for knowledge."

4.1.10.5 Global Approach Towards Transport Sector:

- A study in early 2018 by the *Energy & Environmental Science* journal found that, to meet 80 percent of US electricity demand with wind and solar, it would require either a nationwide high-speed transmission system that can balance renewable generation over hundreds of miles or 12 hours of electricity storage for the whole system.
- A 2016 report on the value of energy storage in decarbonising the electricity sector by the Massachusetts Institute of Technology (MIT) and the University of

Chicago's Argonne National Lab found there are potential problems with using batteries for grid-scale storage.

- After receiving the Nobel Prize award, Akira Yoshino admitted that the key to the future of electric mobility is figuring out how to fully recycle batteries, saying the industry is not there yet. The Japanese chemist also revealed that recycling batteries are the key to securing enough raw materials to power the surge in electric vehicle demand.
- As part of the UK government's £246m ($312m) Faraday Challenge for battery research, the University of Birmingham is trying to find new ways of recycling lithium-ion.
- Research in Australia found that just 2 percent of the country's 3,300 tonnes of lithium-ion waste is recycled.
- This also leads to the potential scenario of fluids from the batteries leaking into landfills and releasing them into the environment.
- The most common procedure for recycling recovered lithium cells from devices and electric vehicles is to shred the cells, which creates a mixture of metal that can then be separated using burning techniques. But a lot of the lithium is wasted using this method.
- COCHIN INTERNATIONAL AIRPORT is the 1st Airport in the World which runs solely on SOLAR POWER. Huge power bills prompted the airport to build 12MW Solar Plant which consists of more than 46,000 solar panels.

THEME-5.1: A STUDY ON INVASIVE PLANT SPECIES (*PROSOPIS JULIFLORA* AND *ACACIA TORTILIS)* AND THEIR EFFECTS ON SOME SELECTIVE NATIVE ANIMAL SPECIES (SPINY TAILED LIZARD, BLUE BULLS, BENGAL TIGER and GREAT INDIAN BUSTARD) IN BIKANER REGION AND RANTHAMBORE NATIONAL PARK, RAJASTHAN

5.1.1 Abstract

Introduction of invasive plant species in Rajasthan has increased forest cover but they also have a number of negative consequences for local species. This study covers the effects of two invasive plants, *Prosopis juliflora* and *Acacia tortilis* on Spiny-tailed Lizard, Blue Bulls, Bengal Tiger and Great Indian Bustard in Bikaner region and Ranthambore National Park, Rajasthan.

In Bikaner region due to introduction of these species, soil has become harder, making it difficult for Spiny-tailed lizards to dig burrows. There was a decrease in the density of burrows (262.2±56.89 per Ha)[73] during 2014-17. Habitat degradation contributed as one of the factors responsible for extinction of the Great Indian Bustard in this area. The number of Blue Bulls has increased throughout Rajasthan due to abundance of food. According to Wildlife Census of Rajasthan Forest Department for the year 2013, the number of Blue Bulls has increased from 67924 in the year 2010 to 84476 in the year 2013[74]. The number of Blue Bulls decreased in 2014, but increased again in 2018 from 65823 in 2014 to 85502 in 2018[75]. The number of Bengal Tigers has also increased in Rajasthan, with the higher concentration in Ranthambore National Park.

Management of these invasive plant species is very difficult. When cut down, they give rise to denser branches. Hence, uprooting is only option for the reducing adverse impact of these invasive plant species. Government of Rajasthan is also playing an important role in controlling the spread of these invasive plant species by launching campaign for uprooting the plants and envisaging a policy for monitoring the afforestation in degraded lands. The draft policy[76]

[73]https://www.researchgate.net/publication/342693022_Population_status_habitat_suitability_and_threat_assessment_of_Indian_spiny-tailed_lizard_Saara_hardwickii_Gray_1827_in_the_Thar_desert_of_Rajasthan#pf3
[74] https://forest.rajasthan.gov.in/content/dam/raj/forest/rajasthan-wild-life/pdf/activities/Wild%20Animals%20Cansus%20Year-2013/Wild%20Animals%20Cansus%20Year-2013.pdf
[75] https://forest.rajasthan.gov.in/content/raj/forest/rajasthan-wild-life/en/public-information/wildlife-animal-census.html#
[76] https://india.mongabay.com/2021/01/rajasthans-latest-draft-forest-policy-proposes-strict-control-over-mining/

proposes measures to protect grasslands, increase forest cover, control invasive species and legislation to protect the unique landscape and skyline.

5.1.2 Introduction

Invasive species are those species which are being introduced in an ecosystem from another ecosystem by human beings for economic benefits and ecosystem restoration. They are sometimes known as alien species because they are not native to the area. International Union for Conservation of Nature (IUCN) defines an alien species as the one which has been introduced outside of its natural range. This species is classified as an invasive alien species if it poses a threat to native species (has negative impacts on native species and ecology). Invasive alien species[77] create competition with native species for resources and habitat. Sometimes they alter natural ecosystem by releasing certain toxic chemicals, nutrients, etc. which are not suitable for the native species. Due to this alteration, there is a rapid decrease in the number of native species. When invasive species invade huge areas, their negative influence on the economy, human health, and ecosystems are realized later.

Parties to the Convention on United Nations Convention on Biological Diversity (CBD) adopted a strategic biodiversity plan 2011-2020[78] in 2010 in Nagoya, Japan with the purpose of inspiring broad-based action in support of biodiversity over the next decade. India is a party to the Convention on Biological Diversity. Aichi Target 9 deals with invasive species. Under the National Biodiversity Strategies and Action Plans (NBSAP) of India, Target 4 in line with Aichi Target 9 seeks to identify invasive alien species and their pathways of introduction and to develop strategies to manage prioritized invasive alien species by 2020. UN Sustainable Development Goal 15 – Target 15.8[79] also envisaged the introduction of measures to prevent and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species by 2020.

5.1.2.1 Invasive species have following characteristics[80]

- **Widely adapted to a variety of environmental condition:** Invasive alien species can tolerate wide range of environmental conditions like extreme drought, cold, heat, salinity, and can also survive in different geographical regions like hills, deserts and on plains (Beisel, 2006)[81]. For example, *Lantana camara*, an invasive weed native to

[77] https://www.iucn.org/theme/species/our-work/invasive-species
[78] https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf
[79] https://www.cbd.int/development/doc/biodiversity-2030-agenda-technical-note-en.pdf
[80] https://ufi.ca.uky.edu/Treetalk/invasive-characteristics
[81] https://link.springer.com/article/10.1007/s10530-006-9001-0

American tropics has spread globally. In India, it has almost spread in every geographical region from tropical rain forest to arid zone (Rajendra Mohan Panda, 2017)[82].

- **Resistant to disease and pest:** The majority of invading species are disease and pest resistant. Therefore, they are a successful intruder and spread swiftly. Water hyacinth, for example, has few pests that feed on them (adult and larval weed weevils devour water hyacinth), therefore they have a low risk of being eaten and a higher likelihood of survival. As a result, water hyacinth has proven to be an effective invader.[83].
- **Rapid growth:** All invasive species have the ability to grow fast, reproduce and get mature in short period time. For example, *Prosopis julifora* matures in 2-4 years. Due to this character these species are able to reproduce and spread quickly to different areas.
- **More than one way of reproduction:** Most of the invasive plant species can reproduce sexually as well as through vegetative propagation methods such as root cutting, spores, and so on. For example, *Lantana camara* can reproduce by cutting, layering of roots and by seed germination too.
- **Produce large numbers of seeds:** Almost all invasive plant species are able to produce large number of seeds, which give rise to large number of plantlets. For example, *Prosopis julifora* and *Acacia tortillas* are able to produce hundreds of thousands of seeds at a time. [84]
- **Seed have high per cent of germination:** Most of the invasive species have high per cent of seed germination. Water hyacinth, for example, has 98 percent seed germination ability when stored in wet settings for 12 months, but only 35 per cent seed germination ability when stored in dry conditions (Wood)[85].

Due to above mentioned characteristics, invasive species have the ability to survive in a wide range of environmental conditions and successfully establish themselves in such environment.

5.1.2.2 Effects of invasive species on biodiversity (Invasive Alien Species, 2011-2020) [86]

- **Habitat destruction:** Introduction of invasive alien species leads to following physiochemical changes where they are introduced;

[82] https://www.researchgate.net/figure/Spatial-location-points-of-Cassia-tora-and-Lantana-camara-in-India-utilised-in-the_fig1_322118448
[83] https://www.cabi.org/isc/datasheet/20544
[84] https://en.wikipedia.org/wiki/Prosopis_juliflora
[85] https://www.cabi.org/isc/FullTextPDF/2012/20123367606.pdf
[86] https://www.cbd.int/undb/media/factsheets/undb-factsheet-ias-en.pdf

a) Soil composition change by introducing allelochemicals[87]. Allelopathy is a biological phenomenon by which an organism produces allelochemicals which influence the germination, growth, survival and reproduction of other organisms.
b) Invasive alien species that thrive in aquatic ecosystems block light, making it harder for aquatic organisms such as fish to live.
c) Invasive plants prohibit the growth of grassland by increasing forest cover.
d) Loss of habitat and threat to biodiversity[88]

- **Pollution:** Biological pollution presents a distinct threat to the environment. Invasive plants and animals can overwhelm an environment owing to their leguminous nature and allopathy potential. They may contaminate the air, water or soil. Non-native invaders can out-compete native species and reduce biodiversity, whether they come from remote environments or biotechnology labs.[89]

> *"In many areas, ecosystems are weakened by pollution, climate change and fragmentation. Alien species invasions are a growing pressure on the natural world, which are extremely difficult to*

- **Reduction in food resources/nutrients:** Invasive species deplete native species' nutrients and increase competition for food, resulting in decline in food availability for native species. Because of their ability to survive in adverse environmental conditions, invasive species are unaffected, but native species are affected to a higher extent and their number starts decreasing in case there is reduction in food resources.
- **Competition for resources:** Invasive species create competition for resources like habitat, water and food. Competition harms native species because it involves un-favourable interactions between native and invading species. Invasive species, on the other hand, tolerate the detrimental effects of negative interactions because they are more adaptable to a wide range of environmental stressors. Negative interaction greatly affects native species, due to which their population starts decreasing.

The impact from Invasive alien species can be compounded by climate change.[90] Climate change can carry invasive alien species to new places and reduce habitat resistance to invasions by causing extreme weather events such as hurricanes, floods, and droughts. Climate change

[87] https://en.wikipedia.org/wiki/Allelopathy
[88] https://www.sciencedaily.com/releases/2018/12/181210085919.htm
[89] https://www.icta.org/global-warming-and-the-environment/biopollution-invasive-species/
[90] https://www.researchgate.net/publication/235572201_Invasive_Alien_Plants_Increase_CH4_Emissions_from_a_Subtropical_Tidal_Estuarine_Wetland

is also opening up new pathways of their introduction[91]. For example, improvement in the Arctic shipping passages due to melting ice caps will greatly reduce the time taken for ships to travel from Asia to Europe. [92] As the climate changes, some ecosystems, such as temperate forests and freshwater systems that currently have thermal barriers preventing the spread of invasive alien species will become more suited for alien species. (Invasive alien species and climate change, 2021)[93].

5.1.3 Objectives

To assess the effects of invasive plant species viz; *Prosopis juliflora* and *Acacia tortillas* on selective native animal species (Spiny tailed Lizard, Blue Bulls, Bengal Tiger and Indian Bustard) in the Bikaner region and Ranthambore National Park area of Rajasthan

5.1.4 Background

The greening of desert leads to several changes in the ecosystem such as disturbance in the natural food chain and alteration in the ecosystem structure (network of interactions between biotic and abiotic components of the ecosystem) and affects biodiversity including the native species. In Rajasthan, invasive species like *Prosopis juliflora and Acacia tortilis*, the Indian Desert, which is a part of the Thar Desert, is turning green.

Prosopis juliflora is an exotic weed native to Central and South America that has become an invasive plant species all over the world. It was introduced in different parts of the world for restoration of degraded ecosystem. It swiftly became naturalized (got accustomed to local climatic conditions and vegetation) and began competing with native species and affecting biodiversity. In India *Prosopis juliflora* was introduced in second half of 19th century in the region of Sindh for stabilizing the sand dunes [94]. It got established and colonized itself in India, and spread in most parts of India (in the protected region too)[95]. In Rajasthan, *Prosopis juliflora* was introduced in the year 1913 for moderating the temperature. It quickly naturalized and spread throughout Rajasthan. It was named “Royal Plant” in the year 1940 as its introduction led to several benefits[96].

---

[91] Invasive alien species
[92] https://www.iucn.org/resources/issues-briefs/invasive-alien-species-and-climate-change
[93] https://www.iucn.org/resources/issues-briefs/invasive-alien-species-and-climate-change
[94] https://www.tropecol.com/pdf/open/PDF_58_3/1.%20Patnaik%20et%20al.%20455-483.pdf
[95] https://www.researchgate.net/figure/Regions-in-India-in-which-P-juliflora-has-spread-uncontrollably_fig2_322682224
[96]https://www.researchgate.net/publication/316471678_Prosopis_juliflora_A_Miracle_Species_of_Hot_Arid_and_Semi-Arid_Regions_of_India

Acacia tortilis is invasive plant species native to Savanna and Sahel of Africa, which was introduced in Rajasthan by the Central Arid Zone Research Institute (CAZRI), Jodhpur in the year 1958 for stabilizing sand dunes and improving soil quality for better crop production, in the Thar Desert and Indian Desert region[97&98]. The outcome was favorable because it expanded over a vast area, but it had negative consequences on local biodiversity over a time. In Bikaner, the active burrow density has reached 262.2±56.89. The introduction of this species attracted several insects like Locust Swarm in the region of Thar Desert in Rajasthan from Delhi NCR[99]. It is commonly known as "Umbrella Thorn Tree[100]", due to its umbrella like shape. It is commonly called "Israeli babul".

Prosopis juliflora and *Acacia tortilis* have several benefits like improved soil quality, but due to allopathy nature, it inhibits the growth of other nearby vegetation.

5.1.5 Reason behind selecting Bikaner and Ranthambore National Park for study

Bikaner region and Ranthambore National Park are two different geographical regions. Vegetation and the biodiversity of these areas are different. Bikaner is a desert region and Ranthambore National Park harbours dry deciduous forests and open grassy meadow.

Biodiversity is abundant in Ranthambore National Park, whereas Bikaner has comparatively less biodiversity. Ranthambore National Park is home to Bengal Tigers and Blue Bulls, whereas Bikaner is home to Spiny-tailed Lizards and Blue Bulls, as well as former home of the Great Indian Bustard. Invasive plant species have a variety of effects, both positive and negative, depending on the geographic region and native species.

5.1.6 Reason behind the spread of Prosopis Juliflora and Acacia Tortilis

Prosopis juliflora does not germinate through vegetative propagation. Seeds of *Prosopis juliflora* get spread mostly by cattle. Hundreds of thousands of seeds can be produced by a mature *Prosopis juliflora* plant, resulting in fast dissemination. In areas where water is scarce, the root of *Prosopis juliflora* grows up to 53 meters deep to meet the need for water. (Philips, 1963)[101]

Due to its hard-covering seed, *Acacia Tortilis* seed faces difficulty in germination. Cattle eat the plant's pods together with the seed; the seed coat is partially digested and demonstrates high

[97] http://www.frienvis.nic.in/WriteReadData/UserFiles/file/pdfs/Acacia_tortilis.pdf
[98] http://www.cazri.res.in/publications/KrishiKosh/20-(ACACIA%20TORTILIS%20FOSK%20A%20PROMISING%20FAST%20GROWING).pdf
[99] https://scroll.in/article/970919/indias-thar-desert-is-turning-green-that-isnt-a-good-thing
[100] https://en.wikipedia.org/wiki/Vachellia_tortilis
[101] https://esajournals.onlinelibrary.wiley.com/doi/abs/10.2307/1932198

germination, allowing the species to spread. *Prosopis. juliflora*[102] and *Acacia. tortilis*[103] can grow in a wide range of environmental conditions[104] as shown in Table 1 and Table 2 below:

Table 1: Different parameters tolerance of *P. juliflora*.

Parameters	**Tolerance level**	
Temperature	Germination	20-30^{0}C
	Survival	Up to 50^{0}C
	Soil	Up to 70^{0}C
Rainfall	Mean annual	100-1500mm
	Dry season	<40mm
Air temperature	Absolute minimum temp	-2^{0}C
	Mean annual temperature	25^{0}C (LL*) 35^{0}C (UL**)
	Mean maximum temp. of hottest month	20^{0}C (LL) 50^{0}C (UL)
	Mean minimum temperature of the coldest month	5^{0}C (LL) 25^{0}C (UL)
Soil type		Heavy clay o sandy to stony soil
pH		Up to 9

***Lower limit **Upper limit**

Table 2: Different parameters tolerance of *Acacia tortilis*[105]:

Parameters	**Tolerance level**
Temperature	Mean annual temp. 23.4- 31.3 ^{0}C, can tolerate up to 50^{0}C and 0^{0}C
Rainfall	100-1000mm/year(Mean annual rainfall)
Soil type	Sandy soil
pH	7.95-8.30

Human beings are the primary cause of the spread of these invasive plant species; and aid in its growth due to the numerous economic and environmental benefits. These plants have a low

[102] https://www.cabi.org/isc/datasheet/43942
[103] https://oxfamilibrary.openrepository.com/bitstream/handle/10546/121179/bk-trees-of-somalia-010194-en.pdf?sequence=5&isAllowed=y.
[104] https://www.cabi.org/isc/datasheet/43942
[105] http://apps.worldagroforestry.org/treedb/AFTPDFS/Acacia_tortilis.PDF

danger of illness and being eaten by insects later in life, they are allowed to be planted outside of the natural range.

5.1.7 Effects on eco-system due to invasive alien species

Ecosystem structure is defined as the interaction between biotic and abiotic components of the ecosystem (which means it includes all biogeochemical cycles). All living and non-living components of an ecosystem are interdependent on each other. Variation in any component, then it will affect the whole ecosystem.

Ecosystem functioning gets disrupted through three basic mechanisms as demonstrated in the figure below:

(a) Reduction in the diversity of native plants and animals,

(b) Remarkable changes in physio-chemical characteristics of soils (mostly through allopathy)

(c) Enhancement in ecosystems response towards altered fire regimes (PETR PYSˇ EK, 2012)[106].

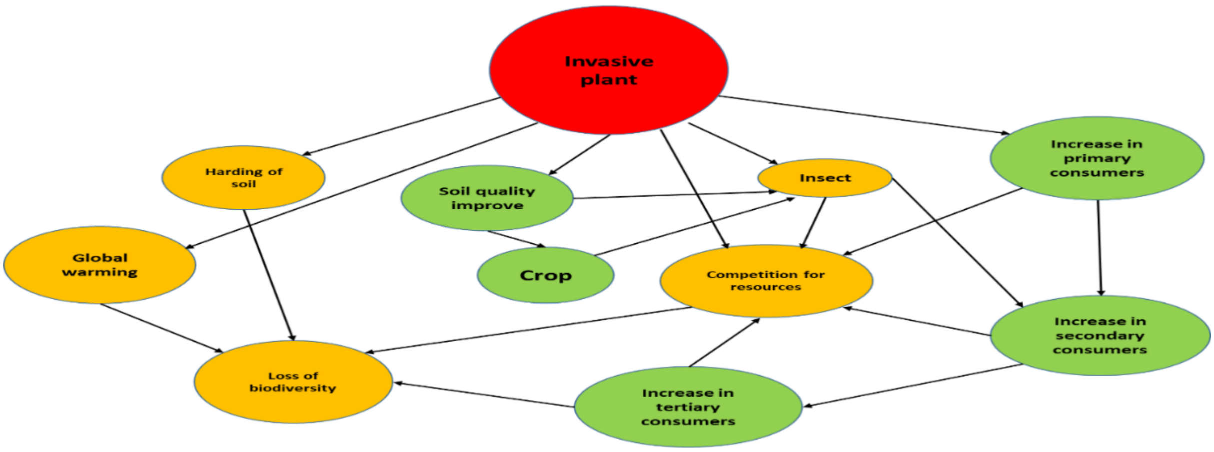


Figure 1[107]: Invasive species and their effects on a different component of ecosystem

In Figure 1, the web is starting from the invasive plant species. Interlinkage of abiotic and biotic components of an ecosystem is shown. If an effect on any component occurs, it will have an impact on the entire ecosystem, the effects may differ, but it affects biodiversity and other socio-economic consequences.

Invasive plant species lead to an increase in number of primary consumers, due to the abundance of food. A rise in primary consumers results in an increase in secondary and tertiary

[106] https://www.researchgate.net/figure/Distribution-of-Indian-spiny-tailed-lizard-in-Rajasthan_fig1_342693022
[107] Self

consumers. All groups of consumers compete for their resources. Due to invasive plant species, the insects like locusts swarm causes crop destruction and act as a food source for secondary consumers. Crop plant destruction results in economic loss, especially when they become a source of food for secondary consumers. Invasive plant species also lead to improve soil quality, good crop production, economic benefits and act as a good source of food for primary consumers. Invasive plant species causes the hardening of soil a result of which burrowing animal faces problem in digging. As consequence, their number starts decreasing, eventually leading to loss of biodiversity. According to IUCN, invasive alien species are one of the major threats to biodiversity loss. According to a 2015 report[108] invasive alien species have a direct impact on 354 vulnerable species (229 animals, 124 plants, and 1 fungus), accounting for 19 percent of all threatened species in Europe[109]. The effect of invasive plants can vary but it has various consequences.

5.1.7.1 Environmental effects of Prosopis Juliflora and Acacia Tortilis

Forest cover: Forestation in the desert is as bad as deforestation in the rainforest. Due to habitat loss and inadequate environmental circumstances, desert forestation may result in the extinction of native species. According to the forest survey of India, the forest cover of the Bikaner is increasing (Table 3 below). There has not been much variation in the forest cover of Ranthambore National Park as it has been a vast wildlife forest reserve area since long.

Table 3[110]: Forest cover of Bikaner and Ranthambore National Park[111]

Year	Forest cover (km sq.)	
	Bikaner	**Ranthambore National Park**
2011	208	1300
2013	210	-
2015	208	-
2017	247	466
2019	255.61	462.69

108 http://www.issg.org/pdf/publications/Genovesi_etal_2015.pdf

109 https://www.iucn.org/regions/europe/our-work/biodiversity-conservation/invasive-alien-species

110 Source: Forest Survey of India. *In the year 2013 and 2015 Sawai Madhopur geographical area was different it included nearby regions too.*

111 https://www.fsi.nic.in/forest-report-2019

Effects on Rainfall: Invasive plant species particularly *Acacia tortilis* and *Prosopis juliflora*, cause the greening of the Thar Desert. As a result, it may cause an alteration in the annual rainfall[112].

5.1.7.2 Effects on Indian Spiny Tailed Lizard

Spiny-tailed lizards live in arid and semiarid habitats from northern Africa to India. They are limbed lizards with large heads and sturdy bodies, with most adult males reaching 40 to 49 cm (16 to 19 inches) in length and adult females 34 to 40 cm (13 to 16 inches)[113]. Most predators are deterred by their stout tail, which is furnished with numerous defensive spines. Some spiny-tailed lizards protect themselves by partially entering their burrows and then furiously lashing their exposed tails at their adversaries from side to side[114]. As adults, all species lay eggs and are primarily herbivorous. The range of Indian Spiny Tailed Lizards extends from Uttar Pradesh in the east to Rajasthan in the west and the *Kachchh* region in Gujarat. It thrives in Rajasthan's hot Thar Desert, where it can be found in abundance in the districts of Jaisalmer, Bikaner, Barmer and Churu.

Spiny Tailed Lizard species prefer to burrow in loose sand. Introduction of *Prosopis juliflora and Acacia tortilis* causes hardening of soil. Due to the hardening of soil in their habitat, they are having difficulty burrowing for shelter. Indian spiny tailed lizard is listed in Convention on International Trade in Endangered Species[115] (CITES) (Appendix II) and in Indian Wildlife (Protection) Act 1972 (Schedule II)[116]. As the number and habitat of Indian Spiny-tailed Lizard is reducing, it is important to conserve them. Active burrow density per Ha of this species in Bikaner is 262.2±56.89[117].

---

112 Large-scale greening in Sahel [the region south of the Sahara in Africa] has feedback impacts on rainfall in the region. But there is no evidence yet that it has an impact on rainfall in the arid and semi-arid regions of north-west India,", Jagdish Krishnaswamy, a senior fellow at the Suri Sehgal Centre for Biodiversity and Conservation, ATREE. https://www.thethirdpole.net/en/nature/the-destructive-greening-of-the-thar-desert-in-india/

113 https://en.wikipedia.org/wiki/Saara_hardwickii

114 https://www.britannica.com/animal/spiny-tailed-lizard

115 CITES is a multilateral treaty to protect endangered plants and animals. It was drafted as a result of a resolution adopted in 1963 at a meeting of members of the International Union for Conservation of Nature. The convention was opened for signature in 1973 and CITES entered into force on 1 July 1975

116 https://www.researchgate.net/publication/330440442_INDIAN_SPINY-TAILED_LIZARD

117 https://www.researchgate.net/publication/342693022_Population_status_habitat_suitability_and_threat_assessment_of_Indian_spiny-tailed_lizard_Saara_hardwickii_Gray_1827_in_the_Thar_desert_of_Rajasthan#pf3

As per the journal of wildlife and biodiversity 2020[118], throughout the Thar Desert of Rajasthan, it has been observed that the Indian Spiny Tailed Lizard species is locally extinct in the surrounding area of Bikaner-Gajner state highway which was once considered one of the best habitats.

5.1.7.3 Effects on Blue Bulls (Nilgai)

The largest Asian antelope, the Blue Bull is found throughout the northern Indian subcontinent. According to IUCN Blue Bulls are categorized under the Least Concern category[119]. According to Rajasthan Wildlife Census (2010 to 2019)[120], the number of Blue Bulls is constantly increasing.

The introduction of *Prosopis Juliflora* and *Acacia Tortolis* have resulted in an increase in forest area. The abundance of food in a larger forest area has resulted in an increase in the number of Blue Bulls. As a result of the invasion of certain plant species, the open preying territory of the Bengal Tiger has shrunk. Because they can readily evade predation in the dense bushes of expanding forest areas, the number of Blue Bulls has increased.

The growth in the number of Blue Bulls in Rajasthan during a ten-year period can easily be seen in the graph above. The increase in the number of Blue Bulls could lead to more crop field destruction.

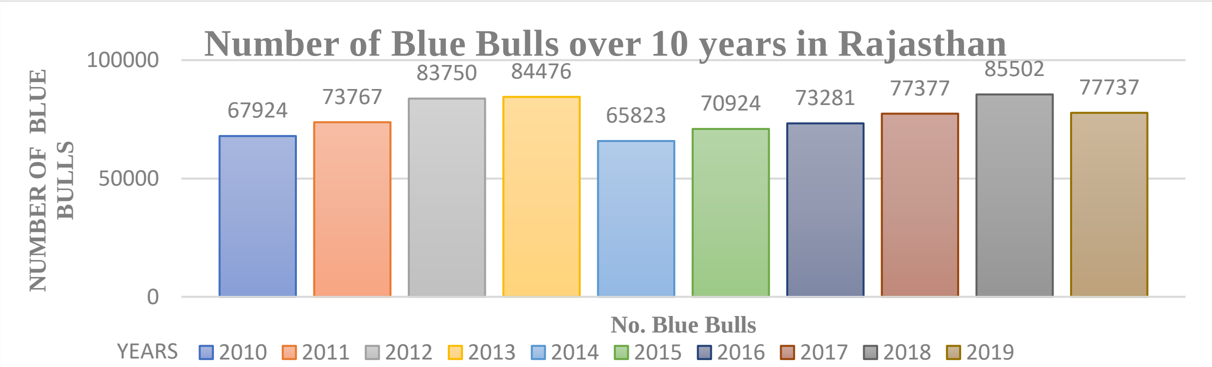


FIGURE 2: NUMBER OF RED BULLS IN RAJASTHAN[121]

---

[118] (PDF) Population status, habitat suitability and threat assessment of Indian spiny-tailed lizard Saara hardwickii (Gray, 1827) in the Thar desert of Rajasthan (researchgate.net)
[119] https://www.iucnredlist.org/species/2893/115064758
[120] https://forest.rajasthan.gov.in/content/raj/forest/en/aboutus/departmental-wings/wild-life1/public-information/wildlife-animal-census.html
[121] SOURCE: RAJASTHAN WILDLIFE ANIMAL CENSUS, GOVERNMENT OF RAJASTHAN

5.1.7.4 Effects on Bengal Tiger

Bengal tiger also known as Royal Bengal Tiger is native to the Indian subcontinent. Due to its reducing number all over the world, Bengal Tiger has been kept under critically endangered species by IUCN.[122]

Prosopis juliflora is affecting the Ranthambore National Park's ecosystem, ecology and economy. It has resulted in an increase in the number of livestock viz. goats, cattle etc. They graze in forest and compete with wild herbivores as well. As a result, wild herbivores' resources will be limited and their numbers will decline (fig 5 below with fig 1 in previous chapter). Such reduction in the number of wild herbivores will contribute to reduction in the number of tigers in Park[123].

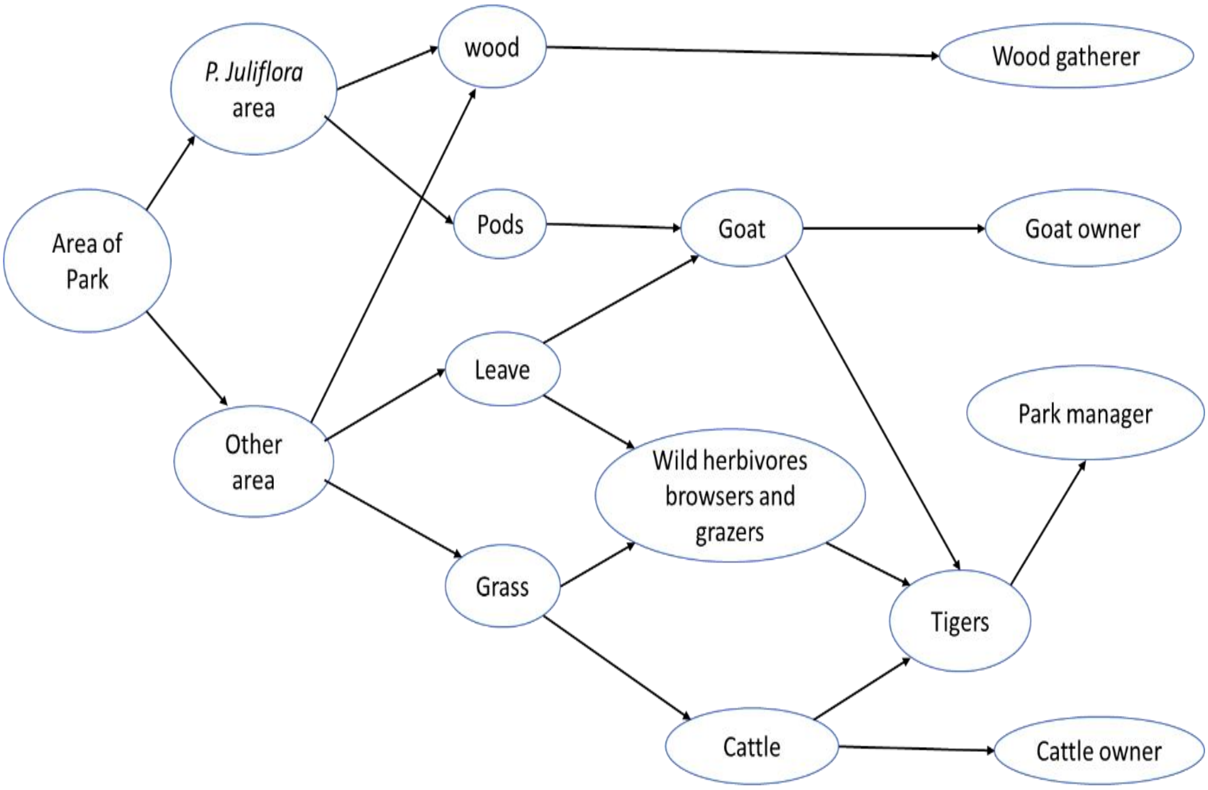


Figure 3[124] : Complex structure of Ranthambore National Park and their relationships

Area of the Ranthambore National Park is divided into two parts: area with *p. juliflora* and area without p. *juliflora*. There can be following situations:

---

[122] https://www.iucnredlist.org/species/136899/4348945

[123]https://www.researchgate.net/publication/4768312_Social_diversity_and_ecological_complexity_How_an_invasive_tree_could_affect_diverse_agents_in_the_land_of_the_tiger. The author compared situation **with *P. juliflora*** and **without *P. juliflora***. It was observed that if the *P. juliflora* will not be removed from the Park then the Tigers will get affected. It will result in restricted resources for wild herbivores due to conflict with native plants (green biomass: - leaves and grass) and by fostering competition between cattle and wild herbivores.

[124] Self created

a) **If *Prosopis juliflora* is not removed:** Goats and cattle will feed on leaves and pods of *juliflora* and their number will be increased. An increase in the numbers of cattle and goats will pose a threat to the wild Herbivores by exploring other areas of the Park. Due to limited food resources, there will be a reduction in number of wild herbivorous. This will affect the population of Bengal Tiger.

b) **If *Prosopis juliflora* got removed**: *Prosopis juliflora* enhances soil quality. Therefore, its removal would aid other vegetation to thrive. As a result, food resources for cattle, goats, and wild herbivores will grow, as will their numbers. The number of wild herbivores will increase, which will lead to an increase in the number of tigers.

c) The nodes of *Prosopis juliflora* have thorns in pairs. The tiger's soft pads may be harmed as a result of this. By competing with native plant species and modifying soil chemistry (due to leguminous and allelopathy potential), these invasive plant species are impacting the ecology of Ranthambore National Park. As a result, the Ranthambore National Park will deteriorate. The Bengal Tiger, whose natural habitat is Ranthambore National Park would suffer as a result of habitat loss.

5.1.7.5 Effects on Great Indian Bustard

The Great Indian Bustard (GIBs) inhabits large expanses of dry grassland and scrublands, feeds on grasses, insects, reptiles and crop plants etc. The Thar Desert in western Rajasthan is home to India's sole population of GIBs covering the district of Bikaner and Jaisalmer. The number of birds has decreased from an estimated 1,260 in 1969 to around 150[125]**.** The great Indian bustard (*Ardeotis nigriceps*) has been labelled as vulnerable (threatened species[126]). It is protected under Wildlife Protection Act 1972 (Schedule I) of India[127] and kept under Critically Endangered Species on the IUCN red list and National Wildlife Action Plan (2002-2016) [128]. It has also been identified as one of the species for the recovery programme under the Integrated Development of Wildlife Habitats of the Ministry of Environment and Forests, Government of India[129].

[125] https://india.mongabay.com/2020/06/the-great-indian-bustard-has-a-new-ally-its-human-neighbours/
[126] https://www.iucnredlist.org/resources/iucnhceflcd2016
[127] https://en.wikipedia.org/wiki/Great_Indian_bustard
[128] https://www.wwfindia.org/about_wwf/priority_species/threatened_species/great_indian_bustard/
[129] https://www.wwfindia.org/about_wwf/priority_species/threatened_species/great_indian_bustard/

With less than 150 individual birds remaining[130], Rural India Supporting Trust (RIST) and WCS-India[131] have launched a project to support the Rajasthan Forest Department towards the recovery of the Great Indian Bustards in the Thar Desert in January 2020.

By 2014[132], the estimated population declined to 200 with the potentially recoverable population in Thar Desert. It was **155±94 in 2014** and **166±74 in 2016** and now holds **140±53** (SD pers. obs.), with 50 percent of the population in army-controlled grasslands near Pokhran[133] (ENVIS Resources Patner On Avain Ecology, 2021). In Bikaner, the number of GIB were 30-50 in the early 1980s. But due to intensification of agriculture, poaching and overgrazing its number has been reduced to half and it is no longer present in the Bikaner anymore [134].

As inferred from the IUCN world congress resolution calling upon the Government of India to recognize semi-arid regions and grasslands that are important for bustards as important ecosystems[135]; it may be noted that the GIB's relocation or extinction from Bikaner is due to habitat damage caused by invasive plant species and anthropogenic activity besides other factors. The Great Indian Bustard bird species are migrating to the Jaisalmer and Pokharan regions of Rajasthan seeking protection since there is less human activity.

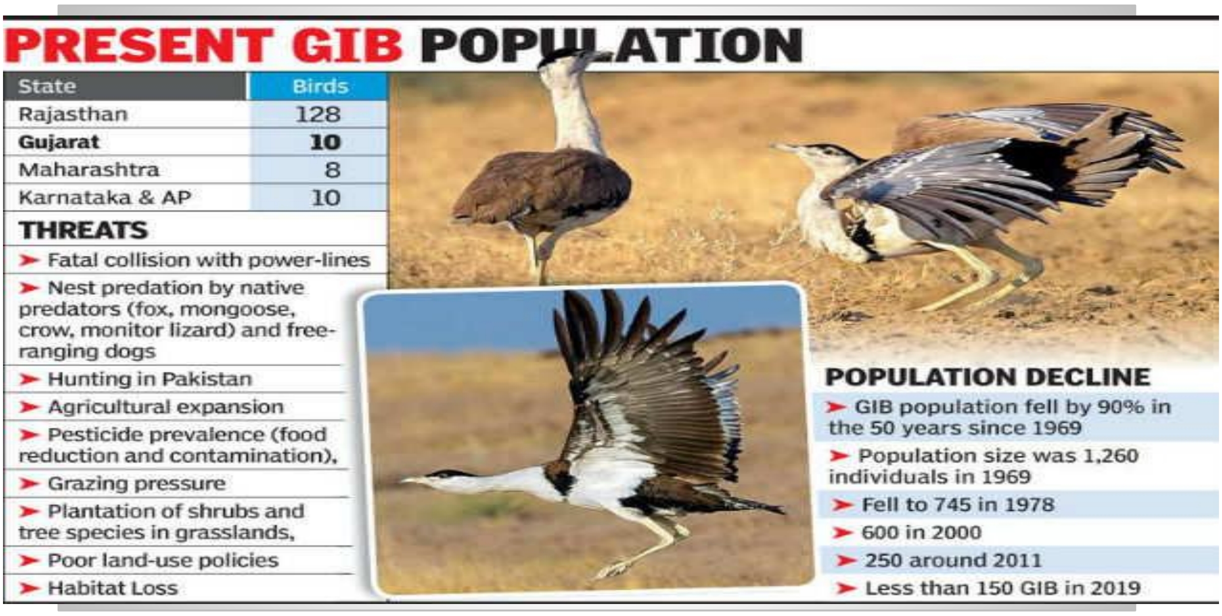


FIGURE 6: Decrease on the number of GIB in Rajasthan (Times of India, Dec 2nd 2019)[1]

[130] https://india.mongabay.com/2020/06/the-great-indian-bustard-has-a-new-ally-its-human-neighbours/
[131] https://plex.page/Great_Indian_bustard
[132] Averting-the-extinction-of-bustards-in-Asia.pdf (sustainablehoubaramanagement.org)
[133] http://arabic.sustainablehoubaramanagement.org/wp-content/uploads/2018/09/Averting-the-extinction-of-bustards-in-Asia.pdf
[134] http://datazone.birdlife.org/site/factsheet/diyatra-closed-area-iba-india
[135] https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2020_REC_089_EN.pdf

Source for image: https://timesofindia.indiatimes.com/city/ahmedabad/development-pushing-gibs-into-pakistan/articleshow/72323617.cms

5.1.8 Prevention and management of Prosopis Juliflora and Acacia Tortolis

Invasive alien species pose threats to agriculture, human health, and animal welfare in India. (Nirmalie Pallewatta, 2002)[136]. People go over the world carrying plants that appear to be valuable to them, without considering the negative implications. Due to globalization, invasive alien species have had a negative influence on societies for as long as people have moved organisms throughout the earth, both purposefully and accidentally. Mitigation and management methods are urgently required in order to solve the situation indefinitely (lasting forever).

Prosopis juliflora **and** ***Acacia tortilis*** **can be prevented through the following process:**

- **Physical or mechanical methods**: Mechanical mitigation and management involve uprooting of *Prosopis juliflora* and *Acacia tortilis*. This process involves root ploughing and chaining. Cutting is ineffective for *Prosopis juliflora and Acacia tortilis*, as when they are cut down, new shoots (more in number) regenerate. Hence, uprooting is the best option for their prevention[137].

- **Chemical methods**: Chemical treatments involve the use of herbicides to kill trees. The most effective method for chemical treatment is the stem or aerial applications of systemic herbicides. The effectiveness of this method is dependent upon chemical uptake. Chemical treatment has a limited effect on *Prosopis juliflora* due to its strong bark, woody stem, and small leaves with a protective waxy outer covering. In India, ammonium sulfamate was successful in killing *P. juliflora* trees and as a stump treatment[138].

- **Biological methods:** Several biological control programmes such as using species of seed-feeding bruchid beetles have been developed and implemented. Buchid beetles are also used in biological control of *A. tortilis*[139]. Other insect species known to have a deleterious effect on native and exotic *Prosopis* in the Americas are mainly twig girdlers and psyllids. They have also been suggested as possible biological control agents[140].

---

[136] https://www.doi.gov/sites/doi.gov/files/uploads/forging_cooperation_in_southeast_asia.pdf
[137] https://www.cabi.org/isc/datasheet/43942
[138] https://www.cabi.org/isc/datasheet/43942
[139] https://worldwidescience.org/topicpages/a/acacia+tortilis+insights.html
[140] https://www.cabi.org/isc/datasheet/43942

5.1.9 Steps undertaken by the Governments for controlling Prosopis Juliflora and Acacia Tortolis

The draft forest policy proposes protection of grasslands[141]: The National Forest Policy of 1988 has the ultimate objective of increasing tree cover to 33 per cent of the total geographical area. It has clearly mentioned that state government should have their own forest policy. According to Rajasthan Forest Policy for Grassland management, most of the western desert in Rajasthan is an annual grassland. The desert grassland/ scrub houses unique biodiversity and has its own role in climate stabilization, carbon sequestration and conservation of biodiversity. In the next decade, the focus of Rajasthan Forest department shall be on managing natural grasslands and creating new grasslands. These grasslands will also have an important role in drought proofing and supplying fodder for livestock to local communities in the pinch period. Nursery procedures for growing carefully selected native grasses and scrub vegetation should be standardized. Exotic tree species such as *Acacia tortillis* are no longer allowed to be planted in the desert, except for technical purposes such as sand dune stabilisation. Shelter belts along the canal, on the other hand, will be maintained, with the eventual goal of commercial exploitation.

Campaign to remove *P. juliflora:* Uprooting the plant is labour intensive exercise. Foresters advised that employees be hired under the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA). However, they discovered that MNREGA only covers planting, not uprooting! Therefore, measuring the work is difficult — for example, how many plants a worker has to uproot in a day to get the daily payment.

These invasive species have taken roots on the edges of the Ranthambore Tiger Reserve. *Prosopis juliflora* is a thorny plant and the thorns can do much harm to the soft pads of the tiger's paw. An authority served in Ranthambore National Park, said, "It would be good if we could get support for uprooting this plant under NREGA.[142]"

Villagers carrying *Prosopis juliflora* after uprooting

[141] https://ourgovdotin.files.wordpress.com/2021/01/draft-rajasthan-state-forest-policy.pdf
[142] https://timesofindia.indiatimes.com/city/jaipur/rajasthan-foresters-seek-nrega-help-to-clear-invasive-juliflora/articleshow/57670582.cms

5.1.10 Conclusion and Recommendations

Prosopis juliflora and *Acacia tortilis* were introduced for their economic and environmental benefits, such as sand dune stabilisation, soil quality improvement, and ecosystem restoration in ecosystems damaged by natural disasters, human activities, or overgrazing. Due to their dominating character, they have a negative impact on the ecology later on. They compete for resources and habitat with native species, affecting the native species and ecosystem.

It is observed that *Prosopis juliflora* and *Acacia tortilis* are beneficial for Blue Bulls as they feed on pods and leaves of these invasive plants. But they have adverse effect on Spiny-tailed Lizard. Great Indian Bustard is a grassland bird and impact of invasive species have *negative impact on grasslands* leading to degradation of habitat of GIBs and decrease in their number. Although the effects of *Prosopis juliflora* and *Acacia tortilis* on Bengal Tigers are indirect, they do have an impact on their habitat and conservation area. Invasive plant species such as *Prosopis juliflora* alter soil chemistry and herbivore animals, causing ecological changes. The natural food chain and tiger population are disrupted by negative impacts on floral diversity and competition among herbivore species.

The number of Blue Bulls has increased in the last 10 years (2010-2021)[143] in Rajasthan. However, since these plants contain animal toxicants, eating their pods and leaves might result in neurological disorders and hypoxia[144]. The number of Spiny-tailed Lizards decreased due to the hardening of soil brought by these invasive plant species affecting their ability to dig burrows. The IUCN has classified the Spiny-tailed Lizard as data deficient because there is no assessment due to a lack of data. In Rajasthan, there are only 150 GIBs, and they are no longer found in Bikaner, where they once thrived.

As invasive plant species have both positive and negative effects, their eradication is not only difficult but also imprudent. Various industries and power plants are dependent on these invasive plant species for raw materials (charcoal, flour, etc.). However, we cannot disrupt the entire ecology for our own economic gain. At the same time, it is important to remember that the arrival of invasive plant species has altered the ecosystem structure and varied impact on native species and the overall ecosystem.

[143] https://forest.rajasthan.gov.in/content/raj/forest/en/aboutus/departmental-wings/wild-life1/public-information/wildlife-animal-census.html

[144] https://www.researchgate.net/publication/271384711_Anticonvulsant_and_neuroprotective_effects_of_the_Acacia_tortilis_growing_in_KSA/link/54c681370cf256ed5a9e8c5d/download

Instead of planting these invasive plant species, preference should be given to native plants. By replacing invasive plant species with native vegetation in shelter belts, the detrimental impact and spread of invasive plant species can be mitigated.

Before planting on a bigger scale, plant species that are not native to the ecosystem should be monitored. With effective monitoring, the plant's impact and risk may be calculated and invasion risk can be reduced in the future.

THEME-5.2: UNDERSTANDING THE VALUE ADDITION OF NON-TIMBER FOREST PRODUCE (NTFP) PRODUCTS USING SYSTEM DYNAMICS IN TELANGANA, INDIA

5.2.1 Abstract

This research paper is an exploratory study done on the system of Non-Timber Forest Product (NTFP) extraction and sales in the state of Telangana led by the Girijan Cooperative Corporation[145] (GCC). The purpose of the study is to understand the scenario of NTFP collection and sales in the state of Telangana and how it affects the tribal population and the forest resources.

In this paper, we try to examine the disadvantages of the current system and provide a better option that will help in achieving overall development. The study is purely based on secondary data acquired from Girijan Cooperative Corporation and the Telangana Forest Department. The data shows the current state of NTFP collection and sales in the state and help us in understanding the system of NTFP sales and marketing from the perspective of value addition through empowering tribe run cooperative enterprises using system dynamics.

The results show that the state is able to earn significant revenue but the main stakeholders (tribal people) end up making a meagre income when compared to the profits made by Girijan Co-operative Corporation (GCC) and the state government. The forest resources are also in most instances being over extracted and diminished. The methodology of system dynamics through models portray the current system and helps us in understanding, predicting and putting forth better alternatives for the future through simulations. However, a deeper research on this subject can help us find a much better alternative to bring forth an overall development of the tribal population and the forest resources in the state if implemented.

Girijan Co-operative Corporation is a Public Sector Undertaking of the Government of Andhra Pradesh established in the year 1956 for socio-economic upliftment of tribal people

Its main goal is overall development of tribal people.

[145] The Girijan Co-operative Corporation is a Public Sector Undertaking of Government of Andhra Pradesh established in the year 1956 with a Single Mission which is the Socio-economic upliftment of Tribals in the State of Andhra Pradesh

State-wise availability of NTFPs. Map from Ministry of Tribal Affairs, Government of India

5.2.2 Background and Approach

Background

The term "Forest product" almost immediately brings to mind wood and wood-based products, but there are equally important non-wood products that are procured from the forest. These include all botanical and other natural products extracted from the forest other than timber. Non-timber forest products (NTFPs) are components of the forest system that exist in nature and are generally not cultivated. As per official data, the population of the tribal community in India is 104.3 million (10.43 crore), which is about 8.6 per cent of the total population of the country [146]. Of that, about 90 per cent live in rural areas where apart from farm work, they are primarily dependent on non-timber forest products (NTFPs) for their livelihood.

Products such as Mahua seeds, Tendu leaves, Sal seeds, Kaunch seeds, Chironjee, wild honey, Bael, Jamun, Karanj seeds etc. are included in the NTFPs. Though authorities emphasize that the tribal people are the real owners of the NTFPs and a minimum support price (MSP) is announced for several NTFPs, the ownership of the tribal communities largely remains notional[2].

Those working with tribal communities argue that the Minimum Support Price (MSP) scheme needs to evolve beyond a mere safety net for tribals and there needs to be a better system for them to realise the true value of the NTFPs. Under the MSP scheme, the government looks at fixing and declaring MSP for the selected minor forest produce and then procurement and marketing of those products are undertaken by state agencies. Under this scheme, the government has spent about Rs. 530 million (Rs. 53 crore) between 2014-15 and 2018-19[147].

The central and state governments have been running several programmes to support the tribal communities in increasing their earnings from the NTFPs, with the latest being the Van Dhan Yojana in 2018 which aims to ensure the fair return of the NTFPs. Tribal leaders, environmentalists and experts working with the tribal communities believe a continuous focused effort is required to ensure that the tribal people get a proper value of the NTFPs collected. They also believe that it also requires a special focus on women of the tribal communities.

Every year millions of Indians, who belong to scheduled tribes, collect Rs. two trillion (Rs. 200,000 crore)[148] worth of non-timber forest products NTFP from the country's forests. However, in the absence of an organized approach, they are not able to realise[149] the actual worth of their products. Their struggle intensifies in cases when the forests are diverted for infrastructural or developmental products.

---

[146] https://tribal.nic.in/ST/StatisticalProfileofSTs2013.pdf

[147] https://india.mongabay.com/2020/02/india-urgently-needs-to-streamline-multi-billion-rupees-worth-ntfp-market/

[148] http://trifed.in/trifed/(S(5kujw4yfkwsqjtrdrjcdlvoc))/pdf/Concept_Note_NTF-P_Led_Tribal_Dev2-2019.pdf

[149] http://trifed.in/trifed/(S(5kujw4yfkwsqjtrdrjcdlvoc))/pdf/Concept_Note_NTF-P_Led_Tribal_Dev2-2019.pdf

NTFP COLLECTION AND MARKETING IN INDIA

Non- Timber Forest Product (NTFP) refers to all biological materials other than timber extracted from natural forests for human and animal use. Forests yield NTFP like bamboo, fodder, resin, lemon grass etc. They are also referred to as minor forest products[150]. A survey carried out by the National Sample Survey Organisation (NSSO)[151] indicated large scale dependence of the population on common property resources, of which forests are a major part including fodder, fuel wood, thatching materials, fruits, bamboos, canes, reeds, honey and other products. *NTFP valuation is done by employing Natural Resource Accounting (NRA) methods which multiply forest resource accounts with the discounted value per hectare of the products computed from the statistics provided by the Central Statistical Organisation (CSO).* As the only input required in collection of NTFP is the labor and mostly consists of people who have no opportunity to work elsewhere, thus the cost of the inputs is considered zero and the entire output value is considered resource rent. Like timber and fuel wood, the value of unrecorded NTFP production as 10 times the value recorded by the State Forest Departments, which are based on a nominal royalty charged to forest users for collecting NTFPs, but are largely unenforceable.

Value addition stages of NTFP:

Non-Timber Forest Products (NTFPs) assume an important role in providing seasonal employment and income to villagers. Though most NTFPs are free, they are sold by collectors in raw form and yield poor returns. Frequently, collectors are cheated on the pretext of impurities, moisture, inferior quality, etc. Incomes could be significantly raised by simple value addition options carried out at household or community level.

---

[150] Minor Forest Produce (MFP) is a subset of forest produce and got a definition only in 2007 when the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, was enacted. Section 2(i) of the said Act defines a Minor Forest Produce (MFP) as all non-timber forest produce of plant origin and includes bamboo, brushwood, stumps, canes, Tusser, cocoon, honey, waxes, Lac, tendu/kendu leaves, medicinal plants and herbs, roots, tuber and the like. (http://www.arthapedia.in/index.php?title=Minor_Forest_Produce_(MFP)#:~:text=Section%202(i)%20of%20the,roots%2C%20tuber%20and%20the%20like.)

[151] Common Property Resources and Village Facilities, January - June 1998, NSS 54th Round

The term “bioprospecting” (Bioprospecting is the process of discovery and commercialization of new products based on biological resources) has been widely used to assess the economic potential of different plant species and their value-addition (Gairola Y, 2008).

Value addition at the local level in potential wild edibles has begun to attract attention as being one of the income generating components of the non-farm part of the rural economy. Interest in wild edibles has grown significantly with the increasing awareness of linking participatory biodiversity conservation with rural development. More recently edible wild bioresources are being viewed as untapped or underutilized resources that could play a significant role in rural development, poverty alleviation, livelihood and nutritional security of local communities through bioprospecting with the applications of suitable science and technological interventions (Dhayani D, 2007).

Unlike timber-based products, NTFPs come from a large variety of plant parts and are formed into a diverse set of products: leaves & twigs that may be components of decorative arrangements, food items such as fruits, fungi and juices, wood carved or woven into pieces of art or utilitarian objects and roots, leaves and bark processed into herbal remedies or medicines.

Like timber, NTFPs may further be processed into consumer oriented products. Description of these products may pose a problem due to lack of information concerning the distribution systems used to get the products to final consumers. NTFPs are found in a wide variety of outlets e.g. health food store, pharmacy, etc., unlike timber-based products. People have benefited from those plants for many generations. In some cases, NTFPs contribute significantly to local and regional economics; and with the current trend in the trade and use of NTFPs, it is bound to grow substantially over the next decades. Some illustrative case studies of NTFP extraction, marketing and value addition in different regions of India are provided toward the end of paper to understand the real potential of the value addition factor of Non Timber Forest Products.

Even though huge incentives and economic gains can be acquired from NTFPs, the distribution of income is unequal in a majority of the cases and depletion and degradation are a result of high rates of extraction, which can lead to serious environmental consequences.

5.2.3 Importance of non-timber forest products (NTFP)

Local people often depend on the products, services or land to meet their livelihood needs. Their uses include demand on the biological resources of these areas and at the same time their conservation objectives coupled with those of the state and outside groups. Tropical forests provide a large number of products such as fruit, seed, resin, medicine, wildlife meat and by-products defined as NTFPs. It has been proposed that NTFP extraction can contribute positively to sustainable forestry management because it provides tangible economic benefits to poor rural communities whilst simultaneously conserving biodiversity[152]. In India for example, sustainable harvesting and management of NTFP extraction, together with improved market structures, have been promoted as a strategy to aid poverty alleviation and wildlife conservation simultaneously[153].

The past decade has witnessed rapid growth and upsurge in global interest in NTFPs among conservation and development organizations with increasing recognition of their role in contributing toward livelihoods of forest dependent communities, household food security and nutrition, generating additional employment and income and offering opportunities for NTFP based enterprises[154]. Around one billion people rely on wild harvested products for nutrition and income and the invisible trade in wild resources is estimated to generate $ 90 billion/annum. In India alone, the livelihoods of around 6 million people are maintained by the harvest of forest products[155].

The conflicts, compatibility or complementarity resulting from the interaction between demands created by livelihood activities and conservation objectives have been the focal point of much discussion and efforts over the last two decades. However, there is evidence that such positive benefits from NTFP extraction may be more elusive than first thought. Examples from India have demonstrated that excessive commercial harvesting of NTFPs can denude forest ecosystems by destructive collection practices for valued target species such as *Garcinia gummi-gutta, Phyllanthus indofischeri, Emblica officinalis, Boswellia serrata and Sterculia urens* (Tiwari, 1995); (Bhattacharya, 2002); (Ganesan, 2003); (Rai, 2004); (Shaanker, 2004). There is also a link between NTFP collection and illegal activities, including bush meat hunting and poaching, although the nature of this relationship is poorly understood and documented

[152] (C.M, 1989), (Shahabuddin, 2004); (Kaushal, 2005); (Mahapatra A. A., 2005)

[153] (Mahapatra A. &., 1997); (Shaanker, Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India., 2004); (Hiremath).

[154] (Belcher et al., 2005; FAO., 2006; Poffenberger, 2006)

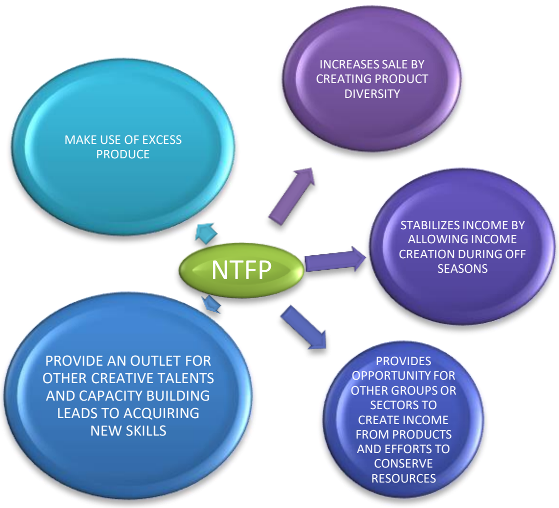
[155] A.K. Pandey, Y.C. Tripathi and Ashwani Kumar, 2016. Non Timber Forest Products (NTFPs) for Sustained Livelihood: Challenges and Strategies. Research Journal of Forestry, 10: 1-7. https://scialert.net/abstract/?doi=rjf.2016.1.7,

(Kaul, 2004). Legislation in India (The Scheduled Tribes and Other Traditional Forest Dwellers Recognition of Forest Rights Act 2006) gives the right from 31 December 2007, of NTFP collection to communities living within forests, even in protected areas (Kothari, 2005); (Prabhu, 2005), there is an urgent need to investigate the role of NTFPs in rural development.

5.2.3.1 Value addition of NTFP

The majority of NTFPs sold by collectors/harvesters do not undergo any value addition as they are only involved in collecting and selling the NTFP as raw materials itself. The activity of value addition is largely performed by market intermediaries and manufacturers after collecting from the collectors. There is little value addition at the primary collector’s level. Interventions like preparing a time schedule for the collection of material, identification of correct plant and their parts, maintaining hygienic conditions while collection, following non-destructive harvesting techniques, removal of foreign material from the collected product, sorting, drying and storing appropriately and packaging of collected material can considerably increase the value of the final product. We can also make models based on the other commodities presented in the study by modifying the provided model.

Advantages of NTFP value addition



The study is based on system of NTFP extraction and sales in the state of Telangana led by the Girijan Cooperative Corporation[156] (GCC).

OBJECTIVES OF THE STUDY

- ✓ How can we make current extraction rates more sustainable?

[156] The Girijan Co-operative Corporation is a Public Sector Undertaking of Government of Andhra Pradesh established in the year 1956 with a Single Mission which is the Socio-economic upliftment of Tribals in the State of Andhra Pradesh

- ✓ Does value addition of NTFP products help in poverty alleviation and conservation of forest resources?
- ✓ What are the insights we can derive from the study for audit purposes?

Hypothesis

NTFPs sold as finished products i.e. after value additions has any positive effect in the form of increased income and conservation of forest resources.

NULL HYPOTHESIS

If NTFP are sold as finished product instead of raw material, there will be greater economic and conservational sustainability.

ALTERNATE HYPOTHESIS

NTFP sold as finished products instead of raw materials will have no impact on economic or conservational stability.

5.2.4 Methodology

Based on the hypothesis set for this study, data collected has been compiled into two models; *a control model* and *an experiment model*, using System Dynamics Modelling.

5.2.4.1 What is the System Dynamics

A System can be defined as a set of interdependent, interrelated, interconnected parts which form a unified whole with a long-term emergent purpose. The purpose of a system is defined by the interaction of its parts. Systems are dynamic, and hence, change with time. As the variables continue to interact, the purpose evolves. It must be noted, that systems are more than just a mere collection of variables, and is defined by the interaction of the variables.

System dynamics (SD) modelling offers a dynamic concept of process-based orientation. It is a method developed particularly for the study of dynamic trends and behaviours of complex systems **Invalid source specified.**. SD has been used extensively to examine the dynamics of population, ecological, social and economic systems.

Influence diagrams are commonly used to conceptually indicate the relationships among system elements. Relationships are sometimes referred to as feedback or causal loops, which can be either positive or negative **Invalid source specified.**. The relationships then are converted to stocks and flows, which represent material and information transfers. The overall dynamics of the system depend on which feedback loops are dominant. The behaviour of the system shifts from acceleration to deceleration, and the system gradually approaches equilibrium. In this fashion, the modelling process can continue

The SD method comprises:

(a) Conceptual model development;

(b) Specification and execution of the model;

(c) Evaluation of the model; and

(d) Use of the model **Invalid source specified.**.

5.2.4.2 Relevance of System Dynamics to the study

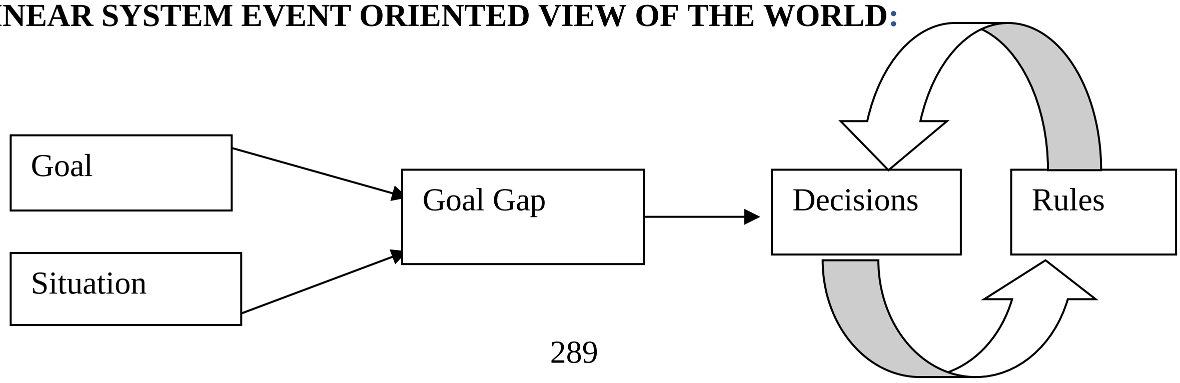
The model is developed to understand the trend of the current NTFP supply and demand and to develop scenarios to deal with the future sustainability of these non-timber forest products. The model's realism takes the form of explicit reality, in which the model represents real situations and resources. **Invalid source specified.**, proposed an ecosystem–human interaction characteristics framework for understanding natural resource management. The model was implemented with STELLA, System Dynamics software.

The methodology mentioned above has been used for this study and is the best methodology that can be applied to study subjects relating to Natural Resource Accounting.

The objective of the model is to examine policy options that can reduce forest degradation and how well the value addition of NTFPs helps at the forest management unit level through the simulations and other analyses of available data. To accomplish this, it is necessary to understand the dynamic interactions between the communities and the forest resources and how they affect forest cover, human well-being and forest resources under different policy scenarios. Hence, the focus of the 'system' under study lies at the intersection of forest, people and economic and policy environments.

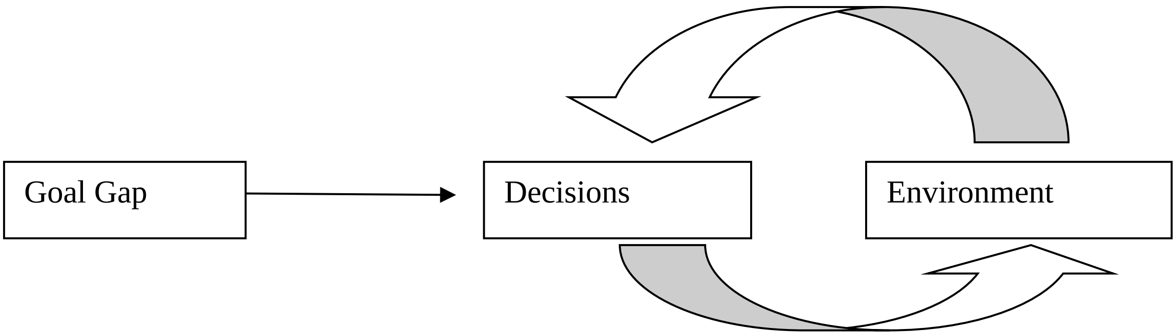
Following is a description of systems theory, which will be able to help justify the use of the same in this study. There are three ways in which variables of a system interact with each other.

LINEAR SYSTEM EVENT ORIENTED VIEW OF THE WORLD:



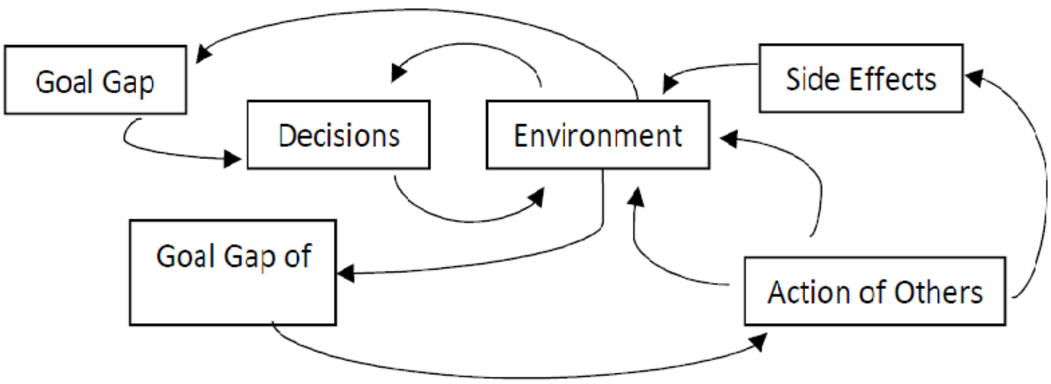
Goals and situations lead to goal-gaps, which then leads to decisions and rules. The first two steps occur once, while the last step keeps reinventing itself indefinitely. In due time, the context is lost. Systems like this tend to form rigid structures with linear views.

ITERATIVE SYSTEM FEEDBACK VIEW OF THE WORLD:



Slightly different from the above type, this kind of system talks about the relationship between decisions and the environment. The consequence of the decision impacts the environment, and the environment in turn impacts the decisions made. Our decisions alter our environment, leading to new decisions.

COMPLEX REAL WORLD

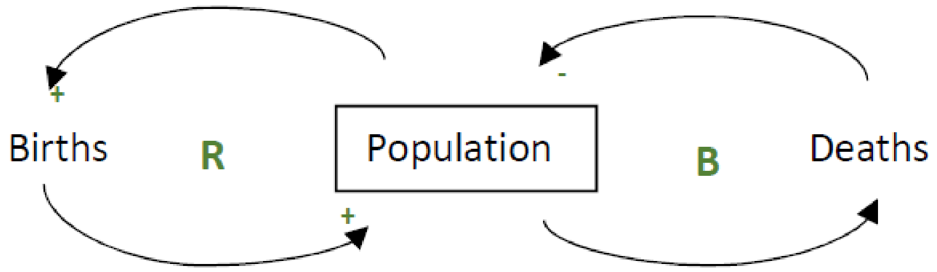


Like in the previous kind of system, the decisions and the environment have an iterative relationship. But the environment also impacts the goals. Changing decisions have side effects, which, in turn, have the ability to alter the environment you live in, and so forth. But also, triggers side effects, delayed reactions, changes in goals and interventions by others. These feedbacks lead to unanticipated results and ineffective policies.

The above three diagrams are indicative of extent of complexity and how hard it is to predict systems in the real world. But the creation of System Models allows one to understand the relationship that variables within a system, the relationship between two separate systems, and how they influence the behavior of each other over time.

Feedback Loop:

A feedback loop[157] is system structure that causes output from one node to eventually influence input to that same node.



A feedback loop occurs when a change in something ultimately comes back to cause a further change in the same thing. If the further change is in the same direction, it's a positive or *reinforcing loop*. If it's in the opposite direction it's a negative or *balancing loop,* also called a goal-seeking loop

Tools of System Dynamics:

Much of the art of system dynamics modelling lies in discovering and representing the feedback processes and other elements of complexity that determine the dynamics of a system.

One might imagine that there is an immense range of different feedback processes to be mastered before one can use system dynamics effectively. In fact, all dynamics arise from the interaction of just two types of feedback loops, positive (or self-reinforcing) and negative (or self-correcting) loops. Positive loops tend to reinforce or amplify whatever is happening in the system: The more nuclear weapons NATO deployed during the Cold War, the more the Soviet Union built, leading NATO to build still more. If a fili lowers its price to gain market share, its competitors may respond in kind, forcing the firm to lower its price still more. The larger the installed base of Microsoft software and Intel machines, the more attractive the Wintel architecture became as developers sought the largest market for their software and customers

157 https://www.thwink.org/sustain/glossary/FeedbackLoop.htm#:~:text=Glossary%20%3E%20Feedback%20Loop-,Feedback%20Loop,input%20to%20that%20same%20node.&text=Using%20system%20dynamics%20notation%2C%20this,the%20Population%20Growth%20loop%20shown.

sought systems compatible with the most software; the more Wintel computers sold, the larger the installed base. These positive feedback loops are what chemists call autocatalytic—self-stimulating processes that generate their own growth, leading to arms races, price wars, and the phenomenal growth of Microsoft and Intel, respectively.

Negative loops counteract and oppose change. The less nicotine in a cigarette, the more smokers must consume to get the dose they need. The more attractive a neighborhood or city, the greater the migration from surrounding areas will be—increasing unemployment, housing prices, crowding in the schools, and traffic congestion until the city is no more attractive than other places people might live. The larger the market share of dominant firms, the more likely is government antitrust action to limit their monopoly power.

These loops describe all processes that tend to be self-limiting, processes that create balance and equilibrium. Tools for learning about complexity must also facilitate the process of systems thinking and policy design. While the virtual world enables controlled experimentation, it does not require us to apply the principles of the scientific method.

5.2.4.3 Limitations

This study has been executed with the help of secondary data from several sources. Due to probable inconsistencies in the collection of the data, the models will not accurately represent a real-world scenario, even though Systems Dynamics Modelling has the ability to do so.

Additionally, when attempting to execute a model to represent a real-world scenario, several externalities need to be measured and included, which is not possible in a study based on secondary data.

The results of the study will instead depict an estimation that is based solely on the available data.

5.2.5 Study and its findings:

Through this chapter we try to understand the economic benefits and sustainable extraction of NTFP by introducing cooperatives in the system of NTFP extraction, manufacturing and marketing. The economic returns of the NTFP extraction, manufacturing and marketing of the main Minor forest products in Telangana, is presented in this chapter.

For understanding this concept, two models have been presented: Control model and Experimental model.

The **Control model** shows an NTFP collection and marketing system where there is no agency or co-operative helping in the manufacturing and marketing of products.

The **Experimental model** portrays a system of NTFP extraction and marketing scenario where a *cooperative has been introduced* and how it helps in better income through methods of value addition and reduction of extraction rates as well as making the system more sustainable in nature.

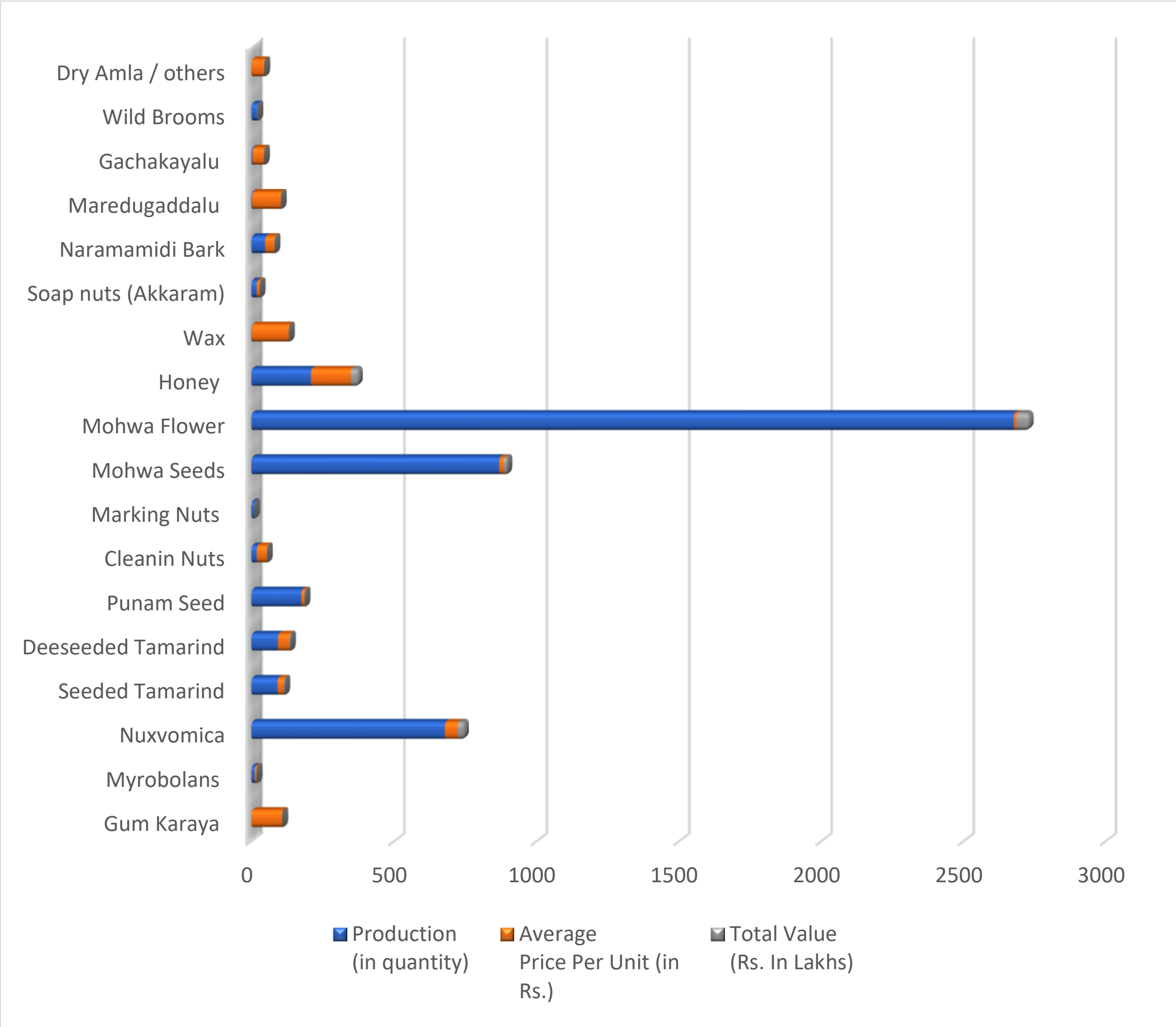
Telangana has a tribal population of more than three million with more than 30 different tribes. The Girijan Cooperative Corporation (GCC) procures 18 different types of NTFP from the Integrated Tribal Development Agency (ITDA)[158] districts. The GCC then send the procured stocks of NTFPs to the state owned processing plants. Here, they are manufactured into various finished products, packed, certified and sent to the market for sale. The state government, with the help GCC acts as the one and only middleman who promise a fair amount of money to the tribal people for NTFPs. At the same time, there are schemes put in place that encourages the tribal communities to cultivate specific species of indigenous NTFP species with the help of ITDA so that resource depletion does not take place. ITDA collaborates with the GCC and the State Government which helps in deploying schemes that benefit tribal community development and increase awareness about the importance of sustainable NTFP marketing, mainly focusing on the regeneration and decreased extraction of specific species of NTFP.

The data shows that the quantity of some of the commodities has shown an exponential increase and decrease. Below is a look at what the data from the GCC:

State Domestic Report of Telangana regarding the procurement procedure (2016-2017) (Data source : Girijan Cooperative Corporation, Telangana)

The bar graph shows procured units of raw materials from the forest districts (ITDA) of Telangana along with the average price paid per unit by the agency and estimation of their value for the year 2016 to 2017.

[158] Integrated Tribal Development Agencies (ITDAs) are established to cater the needs of the tribal population of the state. In other words, they are the sources of the NTFP resources of the entire state.

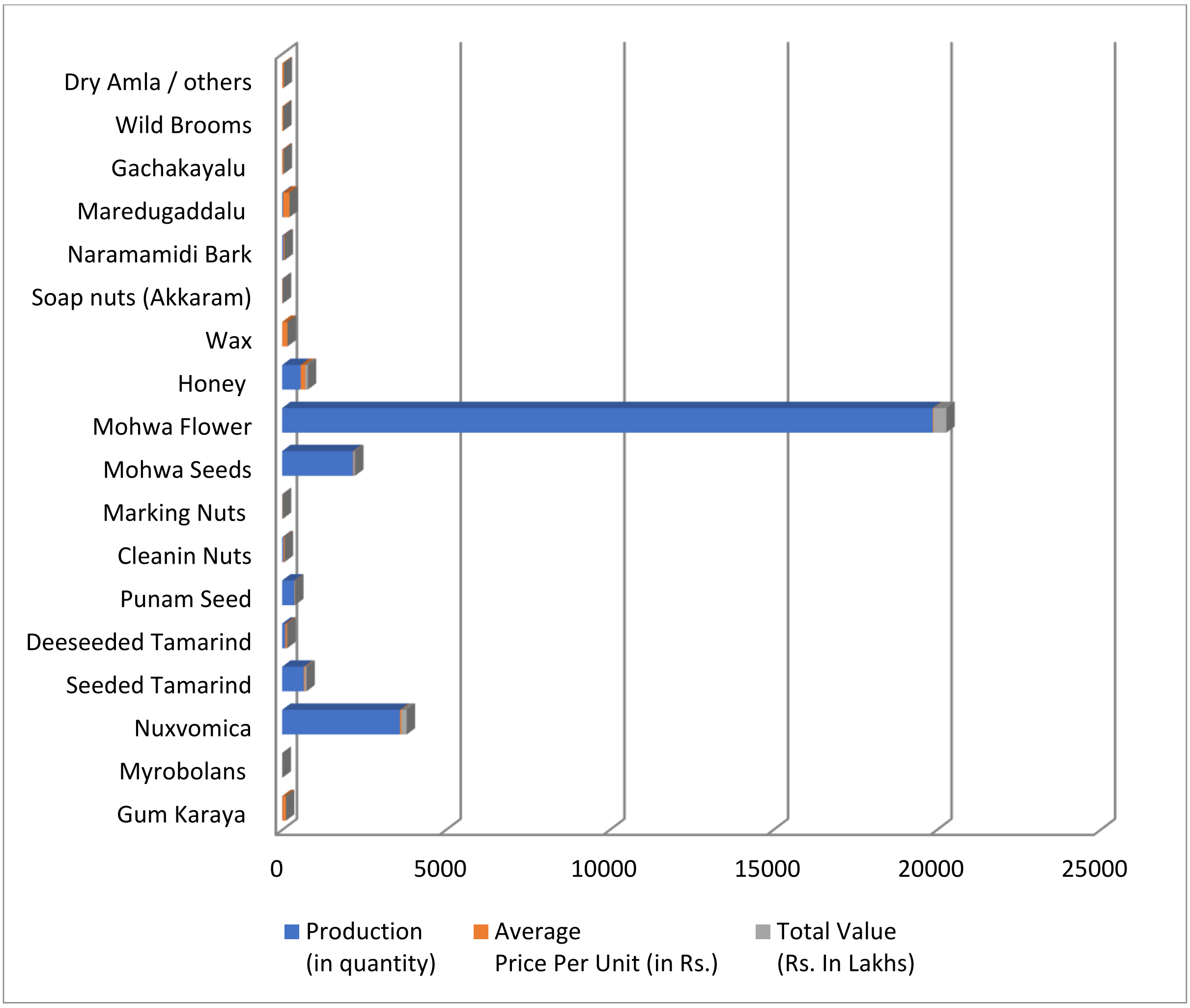


The GCC procured 18 different types of NTFPs. Mohwa flowers are the commodity with the highest extraction followed by Mohwa seeds, Nuxvomica and honey respectively.

Even though the extraction rates of Mohwa flowers, Mohwa seeds and Nuxvomica are high, the collectors get more income from honey due to better prices per unit. The remaining commodities were procured in small quantities and some were not procured at all.

Telangana

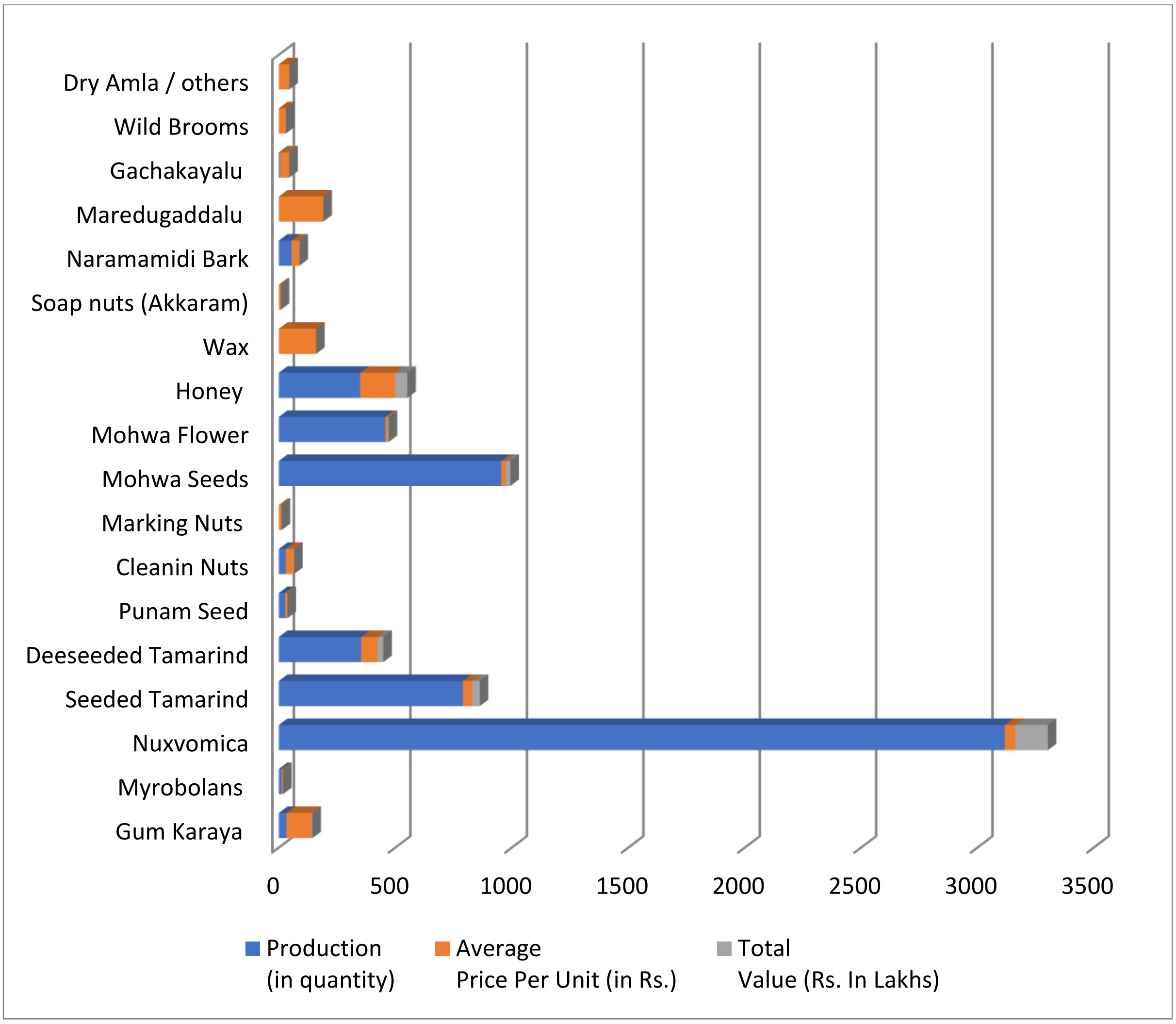
The bar graph shows procured units of raw materials from the forest districts (ITDA) of Telangana along with the average price paid per unit by the agency and an estimation of their value for the year 2017 to 2018.



The above graph shows us a similar trend in the procurement process when compared to the year 2016-17. Mohwa flower is still the commodity with the highest quantity procured but the quantity of Mohwa seeds, Nuxvomica and honey has declined.

State Domestic Report of Telanagana regarding the procurement procedure (2018-2019) (Data source: Girijan Cooperative Corporation, Telangana

The bar graph shows the procured units of raw materials from the forest districts (ITDA) of Telangana along with the average price paid per unit by the agency and an estimation of their value for the year 2018 to 2019.

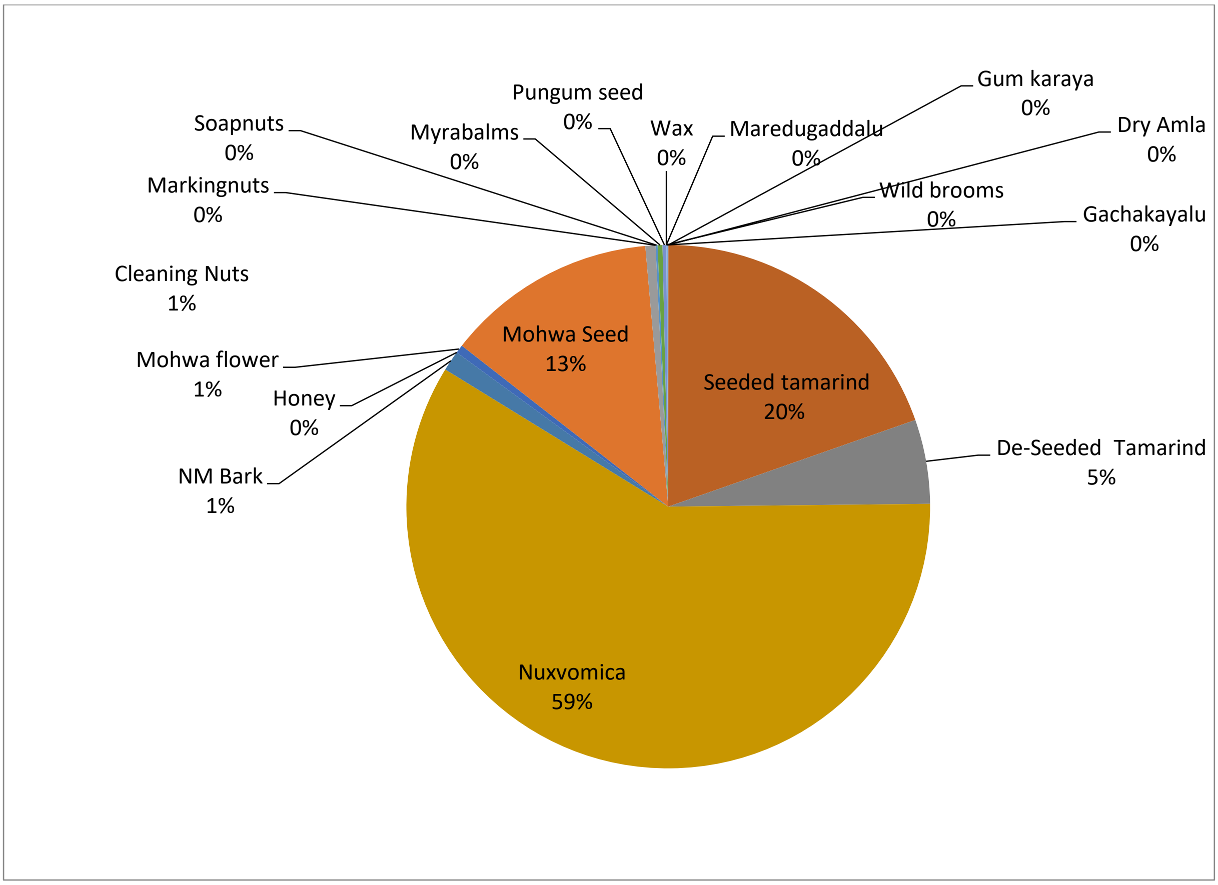


We can see that there is a steep increase in the quantity of procured and the procured quantity of the Mohwa flower has declined.

Even if it has been able to help the collectors increase their income, the corporation and appropriate agencies must make sure the right schemes are put in place according to the dynamics of the market.

Bhadrachalam ITDA (Particulars of MFP procurement 2018-19) Source: Girijan Cooperative Corporation

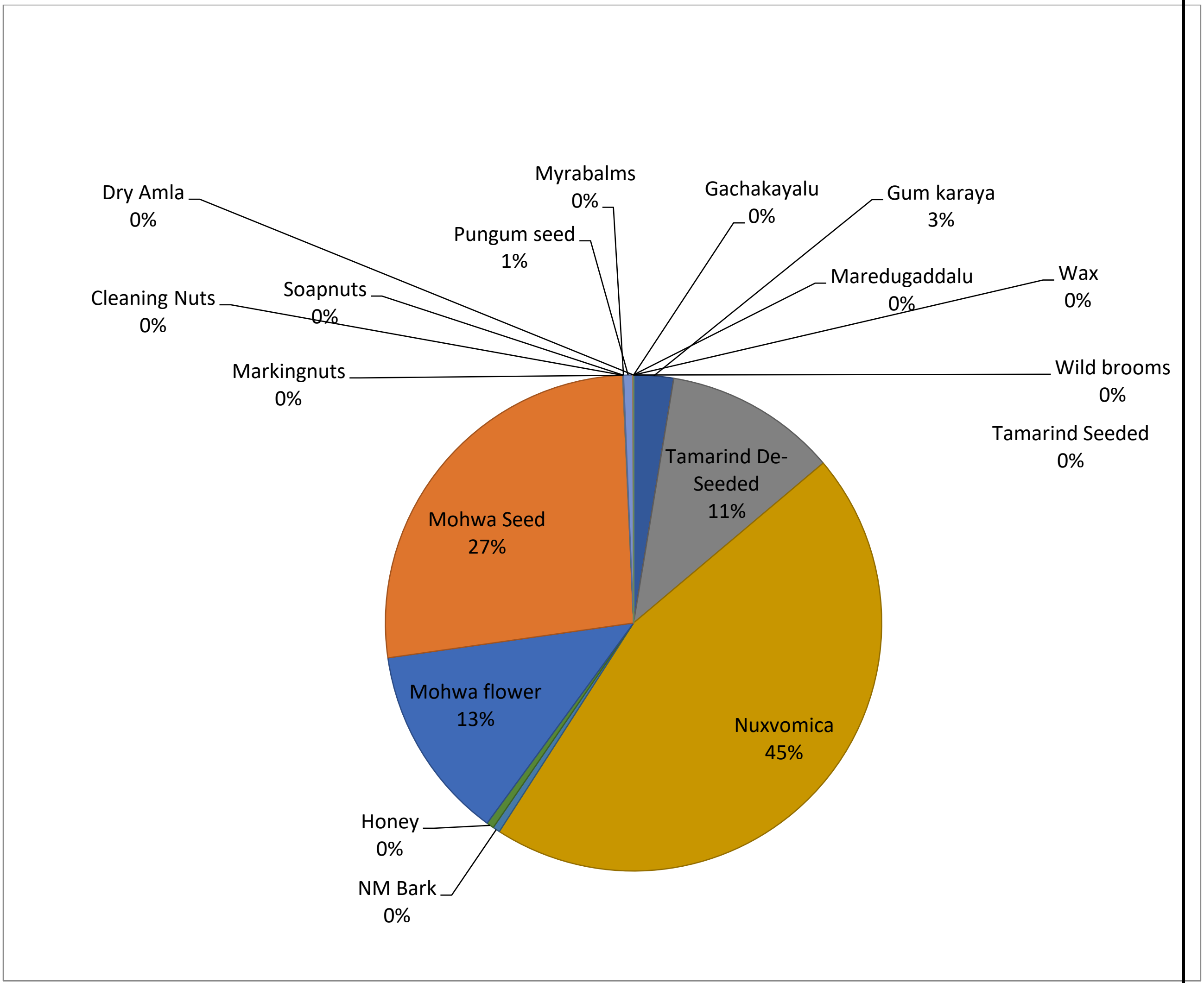
The pie chart shows the particulars of Minor Forest Produce (MFP) or NTFP from the Bhadrachalam ITDA for the time period of 2018-19



ITDAs are established to cater the needs of the tribal population of the state. In other words, they are the sources of the NTFP resources of the entire state. From the pie chart for the bhadrachalam ITDA we can summarie that Nuxvomica is the commodity with the maximum extraction followed by seeded tamarind, Mohwa seed and deseeded tamarind respectively. Mohwa flower, cleaning nuts and N.M bark were procured in small quantities and the remaining were having 0 percent procurement including the highly extracted commodity, Mohwa flower.

Eturanagaram ITDA (Particulars of MFP procurement 2018-19) Source: Girijan Cooperative Corporation

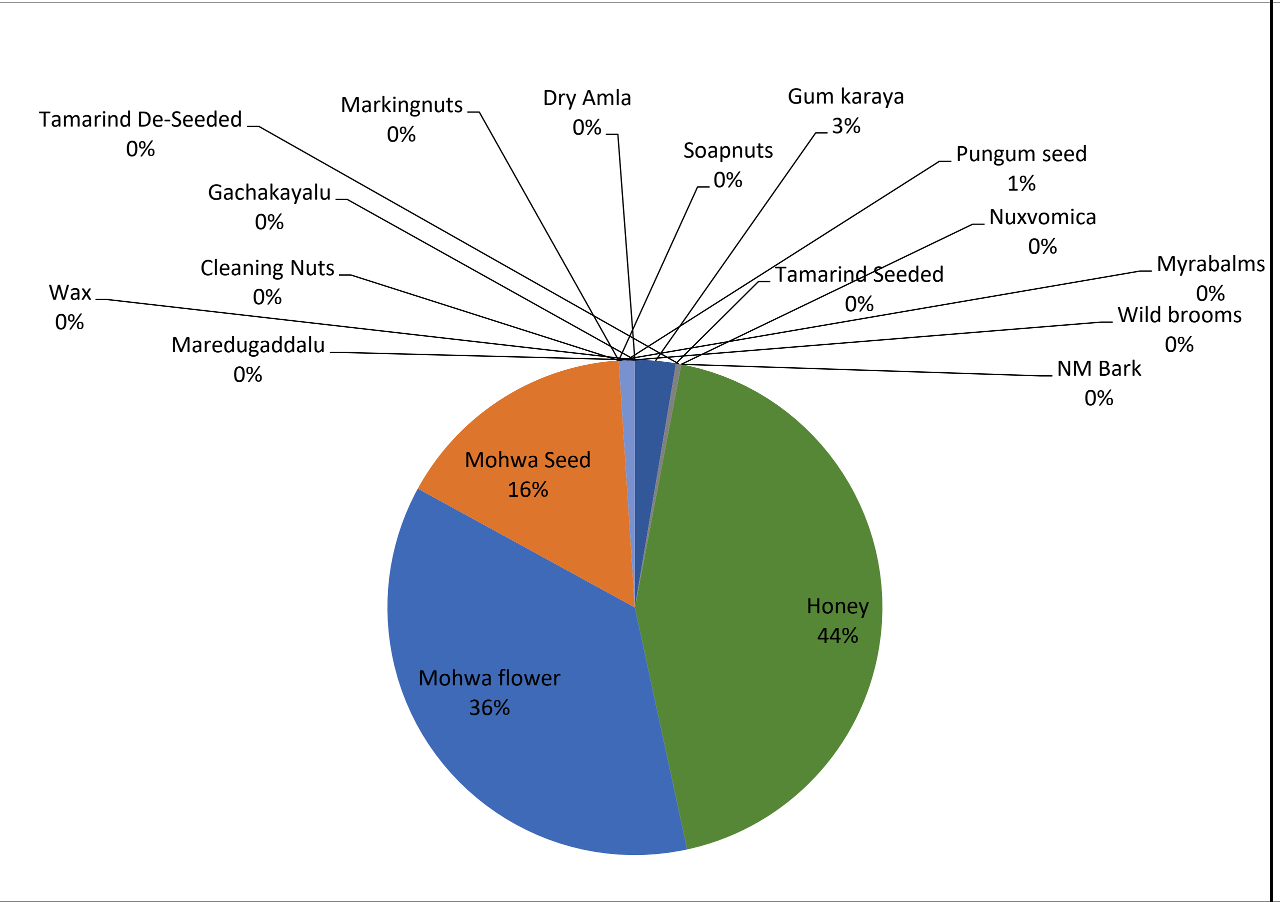
The pie chart shows the particulars of Minor Forest Produce (MFP) or (NTFP) from the Ettooranagram ITDA for the time period of 2018-19.



The procurement rates in this ITDA in the chart show us similar trends in the procurement of NTFPs when compared to the bhadrachalam ITDA. Here, nuxvomica is the commodity which has the highest rate of procured quantity followed by mohwa seed, mohwa flower and tamarind. However, honey procured from both the bhadrachalam and ettooranagaram ITDA is 0 per cent.

Utnoor ITDA (Particulars of MFP procurement 2018-19) Source: Girijan Cooperative Corporation

The pie chart shows the particulars of Minor Forest Produce (MFP) or NTFP from the Utnoor ITDA for the time period of 2018-19.



The pie chart shows that honey is the commodity with the highest rate of extraction. This means that the majority of the honey sold in the markets of the state comes from Utnoor ITDA and it also has a higher rate of procurement of mohwa flower compared to the other ITDAs. At the same time, the rate of the quantity of nuxvomica procured from the Utnoor ITDA is 0 per cent.

<u>The current scenario of the system of NTFP collection and marketing is portrayed through the control model</u>.

Introducing a cooperative can result in a more profitable and sustainable form of NTFP marketing. This scenario and the possibilities it holds are explained through the experimental model. The model introduces the concept of a cooperative of the villagers which handles the activities from collection to marketing with the help of the authorities, which improves the overall development of the tribal population of the state and sustainable extraction of forest resources.

For this study, the current model of NTFP extraction and marketing conducted by GCC is represented in the first model, which will serve as the control, while the experiment model will depict a scenario where a co-operative run by the local community manages the extraction and marketing.

CONTROL MODEL

The following image represents the control model, created on the STELLA software, by ISEE Systems.

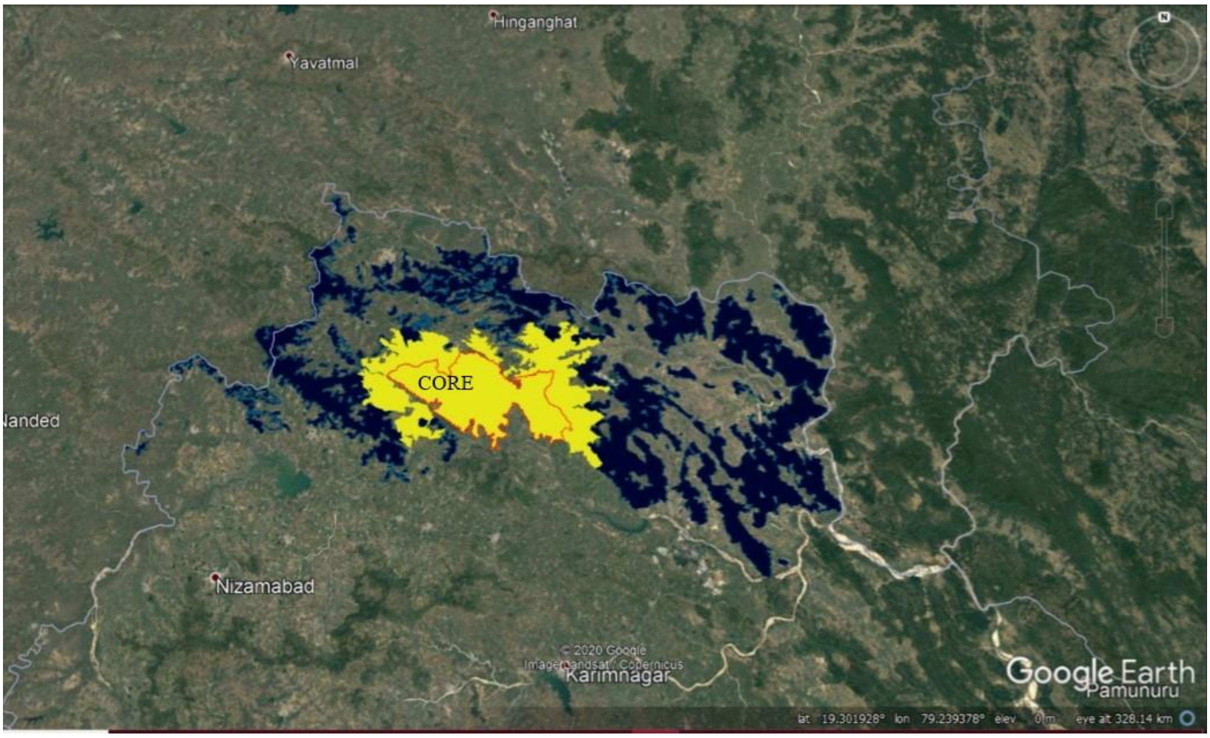
The model was created based on the data received from the GCC and the Telangana State Forest Department. The process exists in three distinct steps;

- the regeneration and growth of the bamboo forest,
- the extraction of the bamboo,
- and the sale of the bamboo.

These steps have been marked out in the following diagram for convenience. We can also make models based on the other commodities presented in the study by modifying the provided model.

<u>Step 1: Bamboo Regeneration and growth</u>

Map of the study area:



Map: Forest cover in Adilabad district. (Includes Kawal Tiger Reserve)

The forested land available and the bamboo density determine the ideal scale of the bamboo forests in Adilabad district. As and when bamboo is extracted, it regenerates and replenishes the stock of bamboo in the forest. Ideally, one clump of bamboo takes up to three years to fully mature, which is represented in the growth component of the model. Once the bamboo clumps are fully grown, they are ready to be extracted.

Step 2: Bamboo Extraction

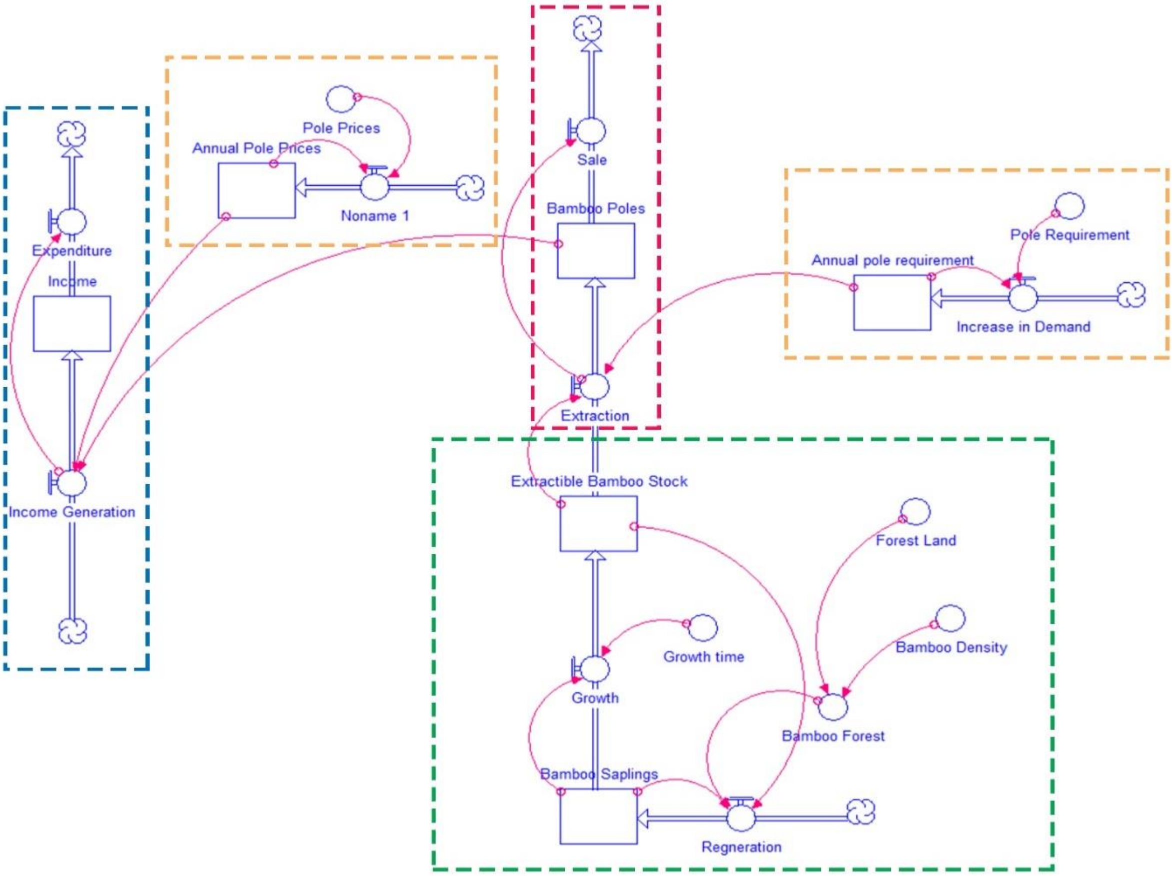
The rate of extraction of bamboo poles from the forest is determined by the demand for bamboo poles. This demand grows exponentially over a period of time. Once extracted, the stock of bamboo poles is ready to be sold, and determine the annual income of the communities.

Step 3: Sale of Bamboo

Once extracted from the forests, the bamboo is sold to the GCC at a fair price. Their annual income is determined by the number of poles that have been extracted, and the fair price set by the GCC. This fair price, too, rises annually to account for inflation.

CONTROL MODEL ANALYSIS

Impact on Bamboo Stock



Yellow Boxes stand for the externalities which impact the functioning of this system.

The following graph represented below details the change in fully grown bamboo clumps over a period of hundred years. The Blue line represents the change in the bamboo stock, while the red line represents the ideal bamboo stock value (based on the area available and bamboo density).

As we can see, the stock briefly remains stable. In some years, we see the stock touching zero value. This could prove disastrous for the local ecology of the forest. We also see the maximum stock achievable reducing towards the end.

<u>Impact on Income</u>

As we can see in the graph below, the income appears to have an upward trend and the general rate of income increases as well. However, there are period showing drop in income as well.

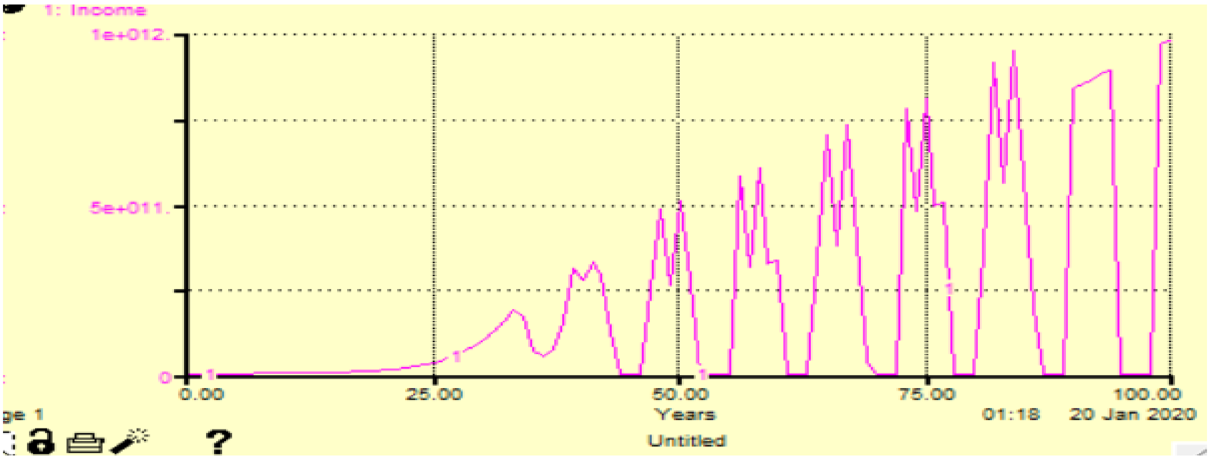


Image 2. The change in Income of the local communities over a period of one hundred years.

Just as observed with the forest stock, the income also tends to reach zero periodically. This could be disastrous for the stability of bamboo extraction as a profession.

<u>Overall Impact</u>

As clearly depicted in the two simulations depicted above, although the income of the local communities does increase over time, it is not a stable increase. Additionally, the dipping of the forest stock to dangerously low numbers can wreak havoc for Bamboo based NTFP professions. This trend tends to go against the objective of the GCC.

EXPERIMENT MODEL

The model was created based on the data received from the GCC and the Telangana State Forest Department. The process exists in three distinct steps;

- the regeneration and growth of the bamboo forest,
- the extraction of the bamboo,
- and the sale of the bamboo.

These steps have been marked out in the following diagram for convenience.

Step 1: Bamboo Regeneration and growth

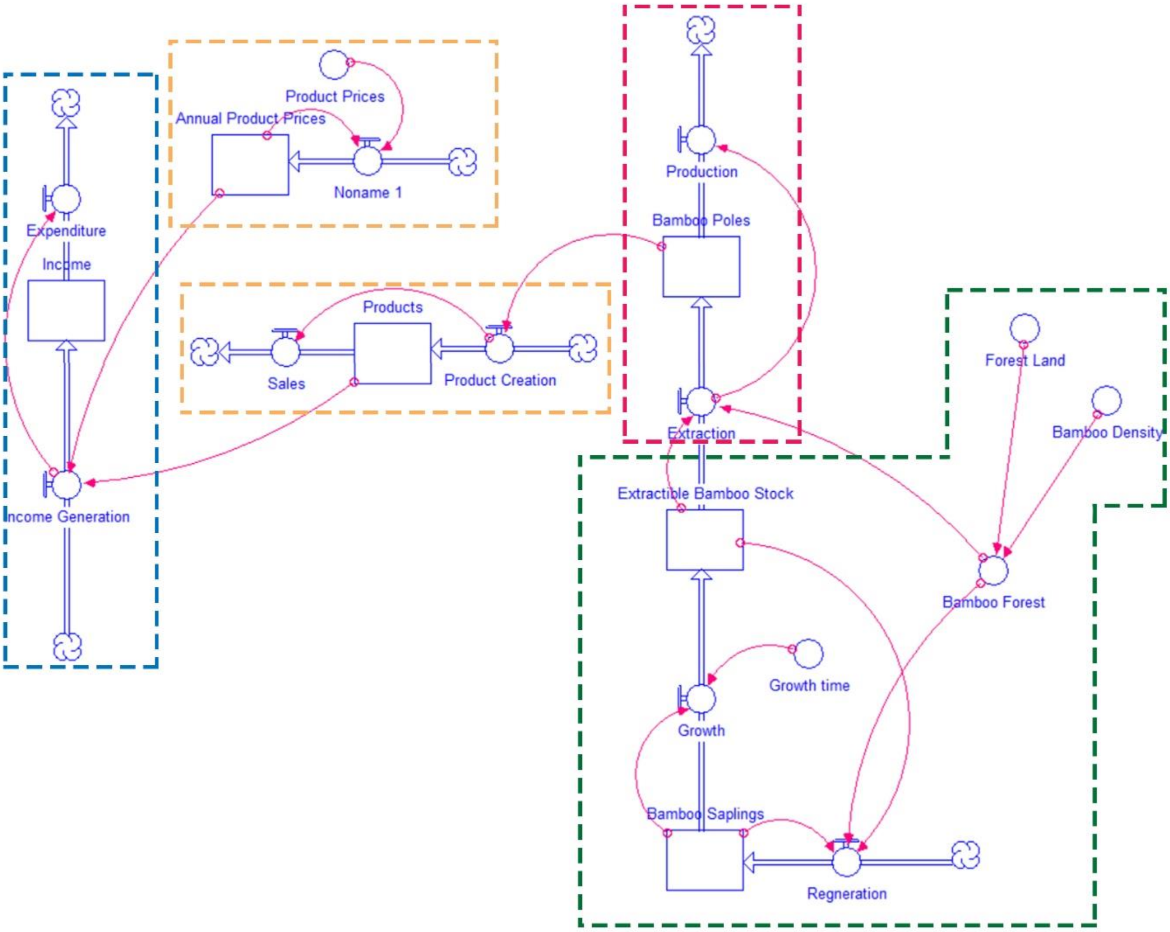
The forested land available and the bamboo density determine the ideal scale of the bamboo forests in Adilabad District. As and when bamboo is extracted, it regenerates and replenishes the stock of bamboo in the forest. Ideally, one clump of bamboo takes up to three years to fully mature, which is represented in the growth component of the model. Once the bamboo clumps are fully grown, they are ready to be extracted.

Step 2: Bamboo Extraction

Unlike the previous model, the rate of extraction of bamboo poles from the forest is not determined by the demand for bamboo poles, but by the regeneration rate of the bamboo forest. This means that the communities will set the rate of extraction according to the capacity of the forest instead of the pole requirement. Once extracted the stock of bamboo poles is ready to be sold, and determine the annual income of the communities.

Step 3: Sale of Bamboo

Once extracted from the forests, the bamboo is converted into products by the local communities, and sold directly to the market. Their annual income is determined by the number of products they've produced, and the selling price of the products. This selling price, too, rises annually to account for inflation.



<u>EXPERIMENT MODEL</u>

GREEN BOX DESCRIBES STEP 1

RED BOX DESCRIBES STEP 2

BLUE BOX DESCRIBES STEP 3

YELLOW BOXES STAND FOR THE EXTERNALITIES WHICH IMPACT THE FUNCTIONING OF THIS SYSTEM

EXPERIMENT MODEL ANALYSIS

<u>Impact on Bamboo Stock</u>

The following graph show the change in fully grown bamboo clumps over a period of hundred years. The Blue line represents the change in the bamboo stock, while the red line represents the ideal bamboo stock value (based on the area available and bamboo density).

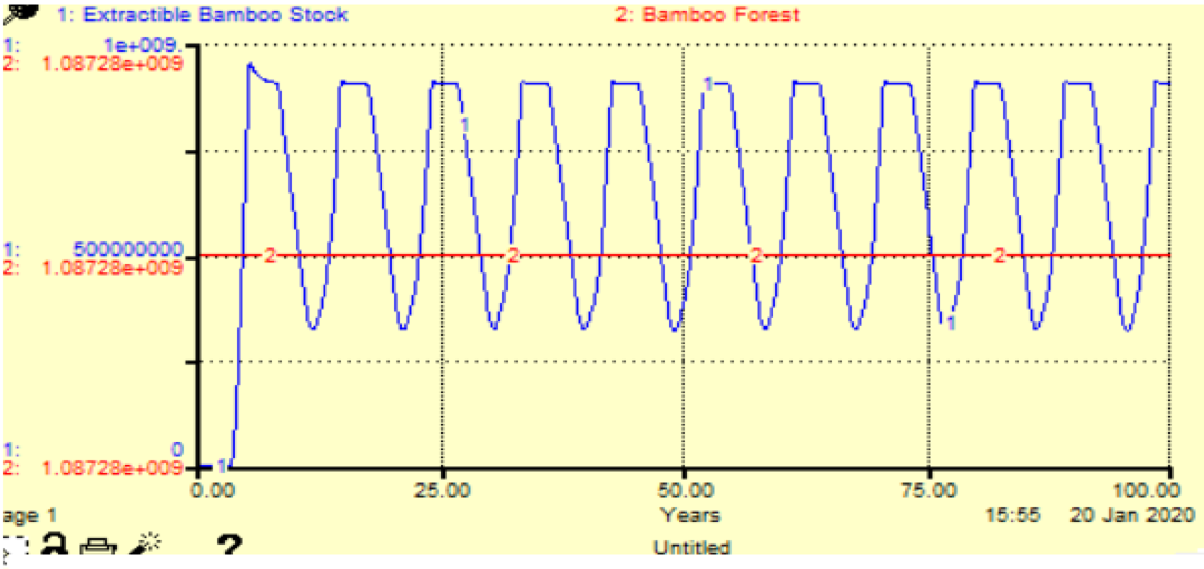


Figure 24. The change in fully grown bamboo clumps over a period of one hundred years.

As shows, even though the values of the stock fluctuate, the values never really drop to zero like in the previous model. Instead, we see a healthy input and output from the forest stock of bamboo. This doesn't affect the ecology of the forest vastly as in the previous case, and maintains a minimum and maximum value constantly.

Impact on Income

The following graph represents the change in income patterns of the local communities over a period of hundred years. As we can see, the income appears to have an upward trend, i.e. as the time increases, the general rate of income increases as well.

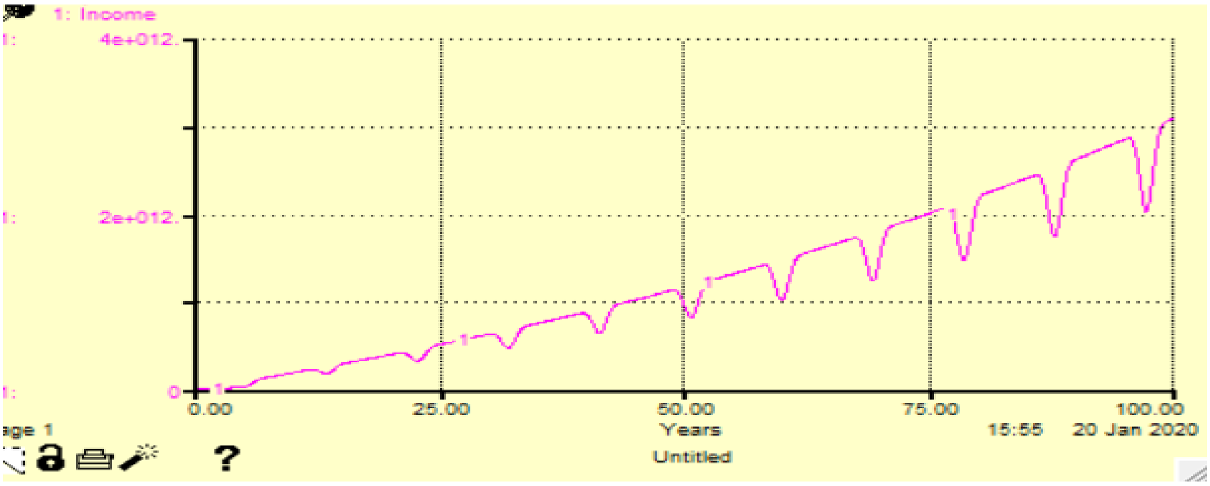


FIGURE 25. THE CHANGE IN INCOME OF THE LOCAL COMMUNITIES OVER A PERIOD OF ONE HUNDRED YEARS.

We see that, unlike in the previous example, the income is largely stable, with very minor drops periodically. An adequate business model may be able to cut the losses on these particular years. This model ensures that NTFP extraction of Bamboo can indeed be a stable means of income.

Overall Impact

The experiment model shows, that both the shortfalls of the control model have been addressed. Sustainability of forest resources, and income, are both adequately improved as well. The co-operative will help in identifying markets and training the people to run the business on their own. The co-operative provides a trademark and a place in the market where they can sell their finished products at profitable rates and at the same time ensures that the extraction rates do not grow exponentially.

5.2.6 Discussion and Conclusion

The government admits that the NTFPs have a major role in the economy of tribal societies. Every year, tribals collect the NTFPs worth around Rs. two trillion (Rs. 200,000 crores) which are then traded in the local markets. The government knows that the potential of this huge capital is grossly under-managed[159].

NTFP collection and marketing in the case of state of Telangana indicate that the efforts made by the State Government and a private entity like GCC backed by the government has been effective in terms of revenue for the State and GCC but not in terms of overall development on the millions of tribal people in the State.

The income accruing to tribal gatherers in the above business is far below what would be fair and equitable. This is possible if fair-trade practices are enforced and the long chain of middlemen is curtailed[14]. Another major gap[160] is that the trade mechanism of the NTFPs at the "primary *haat bazar* level remains highly inequitable to the tribals" as a result of which, when the market prices appear impressive, the cash that comes to the tribals' hands remains low and gains are reaped by a long chain of middlemen.

[159] http://trifed.in/trifed/(S(5kujw4yfkwsqjtrdrjcdlvoc))/pdf/Concept_Note_NTF-P_Led_Tribal_Dev2-2019.pdf
[160] http://trifed.in/trifed/(S(eeqzxfq5a3wkls1xqe5n44a3))/pdf/Annexure_5_Guidelines_Revised-2019.pdf

SOME OTHER HIGHLIGHTS

NTFPs: a viable option for biodiversity conservation and livelihood enhancement in central Himalaya: This specific study conducted in Uttarakhand, studied the cost - benefit analysis of a variety of value added edible products prepared from different wild edibles. It showed that total monetary output as well as the net return of value added product of selected wild edibles is very high for all value added products. These wild fruits/flowers and their edible have numerous medicinal properties and are used to treat various diseases in traditional health care system.

Marketing side of the value added products: In Uttarakhand, a total of 75 households in 11 valleys of the Garhwal region have adopted bio prospecting of wild edibles as an off-farm activity and average income earned was estimated about Rs. 5212/household/yearly. Demand of these products is more as compared to synthetic products owing to increasing people's interest towards nutritional food products of wild edibles and interest shown by some NGOs in popularizing and value addition

Case of Amla (Phyllanthus spp.) fruit harvest by Solingas in South India: As per study conducted at the Biligiri. Rangaswamy Temple Wildlife Sanctuary (BRT), Chamarajanagara, Karnataka, India enhancing incomes from sustainable harvest of NTFPs can help in maintaining local livelihoods and provide local communities with economic incentive to conserve biodiversity. It also shows that, setting up cooperatives or enterprises run by the community can help in value addition as well as implementation of monitoring activities. Certain low volume high value NTFPs can be of major economic potential when converted into finished products (example: lemon grass).

Sanjog : A small NGO of Orissa, along with small NTFP based enterprises and District Industries Centre helped in established trade relations with the Tirupati temple which procure siali leaf plates produced by more than 200 tribal women in the Mohangiri Hills of Kalahandi-Balangir border area. The women gain 20 percent extra income from the Tirupati deal. Sanjog is also working on promoting lac cultivation, since the product procured from just 3 trees of the Kusum (lac – host) gives a net income higher than that from 1 acre paddy cultivation.

Presently, GCC has managed to expand their sales of diversified, finished NTFP through mega online platforms like Amazon. Even though huge revenue is generated from the sales, tribal people who are the collectors appears ending up receiving meagre amounts of income compared. It tends to promote high extraction rates.

Tribal have been made owners of NTFP in their areas. MSP has been announced for several NTFPs. But the ownership is still largely notional. It needs to be actualized.

Though there is an immense ability for NTFP markets to bring continued income and provide opportunities to conserve forests sustainably due to their unique renewability feature it needs to be continuous and through proper monitoring.

The value addition of NTFP produce and proper marketing can result in increased economic incentives and improved conservation of non – timber forest products as noticed w.r.t collection and marketing data of key NTFP products like honey and bamboo in this study.

For Telangana to achieve the goal of overall development of the tribal people of the state, the system has to go through a complete transfer of power and rights from the authorities to the main stakeholders (Tribal people of the state) through cooperatives owned and run by the tribal people. MSP scheme needs to become a driver, rather than a mere safety net[14]. This will actually help in the overall development of the tribal population of the state, increase the standards of living in the country and its GDP, and there will still be helpful to the state for making revenue.

Procedure Recommendations:

Some of the procedure recommendations gathered from the study in helping the tribal people achieve maximum revenue and at the same time making the system more sustainable are as follows:

- Implementation of a sound monitoring and evaluation system which involves all the main stakeholders, thus leading to adaptive management.
- Detailed and thorough study of the forest resources in the study area (extraction rates, regeneration rates etc.).
- Establishment to evolution of the Participatory Resource Monitoring Activities through initiation of cooperatives and capacity building exercises.
- However, the initial step being the establishment of tribe run Enterprises for the processing and value-addition of all NTFPs available.

- Other steps in the Participatory Resource Monitoring System included participatory mapping, assessments of fruit production, fruit harvest and regeneration, pre and post-harvest meetings and adaptive management. Over the years, the harvesters rejected, changed and accepted various Participatory Resource Monitoring System methods to select the one appropriate for them.

Further, maintaining long term participation and interest in the latter requires ensuring resource tenure and for sustainable involvement, there must be sound ecological information, provision of economic incentives relating to participatory monitoring, capacity building that improves empowerment, local policy and institutional reforms. And the most important thing is, being adaptive in nature because of the highly dynamic nature of such systems.

ANNEXURES

STATE DOMESTIC REPORT OF TELANAGANA REGARDING THE PROCUREMENT PROCEDURE (2016-2017) (DATA SOURCE: GIRIJAN COOPERATIVE CORPORATION, TELANAGANA

Commodity	**Production (in quantity)**	**Average Price Per Unit (in Rs.)**	**Total Value (Rs. In Lakhs)**
Gum Karaya	4.86	108	0.52
Myrobolans	7.15	6	0.05
Nuxvomica	3593.7	45	162.33
Seeded Tamarind	661.49	30	47.32
Deeseeded Tamarind	96.05	50	5.82
Punam Seed	368.79	10	14.05
Cleanin Nuts	38.89	35	1.35
Marking Nuts	5.4	12	0.1
Mohwa Seeds	2164.75	15.5	44.38
Mohwa Flower	19874.02	20	397.29
Honey	563.39	140	79.19
Wax	1.34	160	0.16
Soapnuts(Akkaram)	7.2	13	0.06
Naramamidi Bark	38.03	32	1.22
Maredugaddalu	27.93	190	5.3
Gachakayalu	2.16	40	0.09
Wild Brooms	0	30	0
Dry Amla / others	0	45	0
Total			**759.23**

STATE DOMESTIC REPORT OF TELANAGANA REGARDING THE PROCUREMENT PROCEDURE (2017-2018) (DATA SOURCE: GIRIJAN COOPERATIVE CORPORATION, TELANAGANA

Commodity	**Production (in quantity)**	**Average Price Per Unit (in Rs.)**	**Total Value (Rs. In Lakhs)**
Gum Karaya	32.42	108	3.53
Myrobolans	11.94	6	0.07
Nuxvomica	3117.41	45	140.28
Seeded Tamarind	789.97	40	31.89
DeeseededTamarind	353.45	70	24.65
Punam Seed	26.73	10	0.35
Cleanin Nuts	29.27	35	1.02
Marking Nuts	0	12	0
Mohwa Seeds	954.27	20	19.14
Mohwa Flower	456.77	10	4.57
Honey	348.63	150	52.3
Wax	0	160	0
Soapnuts(Akkaram)	0	8	0
Naramamidi Bark	54.53	32	1.76
Maredugaddalu	0.6	190	0.1
Gachakayalu	4.45	40	0.11
Wild Brooms	0	30	0
Dry Amla /others	0	45	0
Total			**279.77**

STATE DOMESTIC REPORT OF TELANAGANA REGARDING THE PROCUREMENT PROCEDURE (2018-2019) (DATA SOURCE: GIRIJAN COOPERATIVE CORPORATION, TELANAGANA

Commodity	**Quantity**	**Value**
Gum karaya	0.4	0.04
Tamarind Seeded	787.27	31.69

Tamarind De-Seeded	208.82	14.58
Nuxvomica	2365.2	106.53
NM Bark	50.03	1.51
Honey	0	0
Mohwa flower	20.8	0.21
Mohwa Seed	523.92	10.52
Cleaning Nuts	25.18	0.88
Markingnuts	0	0
Soapnuts	5	0.04
Myrabalms	11.94	0.07
Pungum seed	9.44	0.1
Maredugaddalu	0	0
Wax	0	0
Wild brooms	0	0
Gachakayalu	4.57	0.11
Dry Amla	0	0

BHADRACHALAM ITDA (PARTICULARS OF MFP PROCUREMENT 2018-19) SOURCE: GIRIJAN COOPERATIVE CORPORATION

Commodity	**Qty**	**Val**
Gum karaya	31.51	3.41
TamarindSeeded	0	0
TamarindDeSeeded	136.54	9.54
Nuxvomica	549.35	24.72
NM Bark	5.7	0.19
Honey	5.85	0.88
Mohwa flower	154.19	1.55
Mohwa Seed	322.16	6.45
Cleaning Nuts	0.75	0.03
Markingnuts	0	0
Soapnuts	0	0

Myrabalms	0	0
Pungumseed	7.26	0.15
Maredugaddalu	0.6	0.11
Wax	0	0
Wild brooms	0	0
Gachakayalu	0	0
Dry Amla	0	0

ETURANAGARAM ITDA (PARTICULARS OF MFP PROCUREMENT 2018-19) SOURCE: GIRIJAN COOPERATIVE CORPORATION

Commodity	**Qty**	**Val**
Gum karaya	20.61	2.22
Tamarind Seeded	0	0
Tamarind De-Seeded	2.7	0.19
Nuxvomica	0	0
NM Bark	0	0
Honey	337.93	50.68
Mohwa flower	281.78	2.82
Mohwa Seed	123.94	2.48
Cleaning Nuts	0	0
Markingnuts	0	0
Soapnuts	0	0
Myrabalms	0	0
Pungum seed	8.06	0.08
Maredugaddalu	0	0
Wax	0	0
Wild brooms	0	0
Gachakayalu	0	0
Dry Amla	0	0

The data used in making the models can be accessed here

REFERENCES

THEME-1.1: IMPACT OF TOURISM IN GOA and STUDY - 2: COASTAL REGULATION ZONE (CRZ) AND SHACK POLICY:

- https://webunwto.s3-eu-west-1.amazonaws.com/2019-08/glossary_EN.pdf
- https://cag.gov.in/webroot/uploads/download_audit_report/2012/Goa_Transation_2012.pdf
- Hemalatha, K. (2018). Ogling tourists disturb dolphin behaviour in Goa. Mongabay. Retrieved from https://india.mongabay.com/2018/01/22/ogling-tourists-disturb-dolphin-behaviour-in-goa/
- Ganesan, R. (2016). DTE Impact: Goa to regulate boat tours affecting corals, dolphins. Down to Earth. Retrieved from http://www.downtoearth.org.in/news/dte-impact-goa-government-to-issueregulations-for-dolphin-tourism-and-coral-protection-54774
- WWF-India. (2016). Promoting sustainable marine tourism in Goa. Retrieved from https://www.mangrovesforthefuture.org/assets/Repository/Documents/Report-FINAL-IUCNFormat-.pdf
- Government of India. (2011). Coastal Regulation Zone Notification, 2011. Retrieved from http://www.moef.nic.in/downloads/public-information/CRZ-Notification-2011.pdf
- https://www.goa.gov.in/wp-content/uploads/2016/12/Beach-Shack-policy-2016-2019.pdf

THEME – 1.2: TSUNAMI DISASTER PREPAREDNESS

- Taylor, Alan (26 December 2014). "Ten Years Since the 2004 Indian Ocean Tsunami". Retrieved 1 February 2016
- https://economictimes.indiatimes.com/how-tsunami-shook-indian-economy/articleshow/974793.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
- 2 January 2005 at the Wayback Machine
- https://india.mongabay.com/2018/08/indian-ocean-tsunami-nicobar-islands-lost-97-percent-of-mangrove-cover-uncovered-new-species/
- http://www.tsunamisociety.org/281Usha.pdf
- https://scroll.in/article/953334/plan-to-develop-andaman-and-nicobar-islands-into-tourist-hub-has-put-its-forests-under-pressure#:~:text=%E2%80%9CAll%20of%20the%20Andaman%20and,the%20most%20severe%20seismic%20zone.&text=A%202020%20study%2C%20which%20assessed,loss%20of%206%2C500%20hectares%20mangroves.
- Understanding Recovery in Andaman and Nicobar Islands - Southasiadisasters.net Issue No. 175, October 2018
- https://www.thehindubusinessline.com/news/national/andaman-tsunami-warning-system-can-alert-in-3-min-scientist/article20623189.ece1#

THEME 2.1: APPLICATIONS OF GEOGRAPHICAL INFORMATION SCIENCE & REMOTE SENSING IN ENVIRONMENTAL AUDITING & PLANNING

- Study of Water Quality Parameter Assessment using GIS and Remote Sensing in DR. B.A.M University, Aurangabad, MS Mahesh Ramkrishna Huchhe1, Dr. N. N Bandela
- Application Of Remote Sensing And GIS In Water Quality Assessment - Review Paper Alina Nero*1 and Saju Simon S.G.
- Remote Sensing and GIS Approach for the Water Pollution and Management In Tiruchirappalli Taluk, Tamil Nadu, India Alaguraja .P, Yuvaraj .D, Sekar.M Muthuveerran.P Manivel .M.
- Application of Geographic Information System (GIS) in ForestManagement Sonti SH* Department of Environmental and Occupational Studies, Symphony Way, Bellville South Industrial, Cape Town-7535, South Africa.
- The Application of Remote Sensing Technologies for Disaster Management Ronald T.Eguchi1, Charles K. Huyck2, Shubharoop Ghosh3 and Beverley J. Adams.
- Monitoring the Coastal Environment Using Remote Sensing and GIS Techniques Dong Jiang, Mengmeng Hao and Jingying Fu.
- Application of Remotely Sensed Data and GIS in Assessing the Impact of Mining Activities on the Environment T.Woldai International Institute for Aerospace Survey & Earth Sciences (ITC). Enschede, The Netherlands
- A Remote Sensing Approach to Environmental Monitoring in a Reclaimed Mine Area Rajchandar Padmanaban 1,*, Avit K. Bhowmik 2 and Pedro Cabral Climate change and landbased activities: a review of economic models Working Paper No. 34 CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) Gaspard Dumollard, Petr Havlík, Mario Herrero.
- Urbanization in India: Patterns, Visualization of Cities, and Greenhouse Gas Inventory for Developing an Urban Observatory Bharath Haridas Aithal, Mysore Chandrashekar Chandan, Shivamurthy Vinay, and T.V. Ramachandra.
- WATER QUALITY MANAGEMENT USING GIS AND RS TOOLS Arjumand Z. Zaidi Assistant Professor, RS and GIS department, Institute of Space Technology (IST), Karachi, Pakistan; PH
- INTEGRATION OF REMOTE SENSING AND GIS IN GROUND WATER QUALITY ASSESSMENT AND MANAGEMENT Nadia Babiker Ibrahim.Shakak.

- Application of Remote Sensing in Water Quality and Water Resources Management – An Overview Author: D. Bagchi & R. Bussa.
- Mapping of Degraded Lands Using Remote Sensing and GIS Techniques G.S. TAGORE, G.D. BAIRAGI*, N.K. SHARMA, R. SHARMA, S. BHELAWE AND P.K. VERMA.
- THE USE OF REMOTE SENSING AND GIS TECHNOLOGIES FOR EVALUATION OF TURKISH RIVER BASINS: A CASE STUDY OF MARMARA RIVER BASIN AND ISTANBUL Necla Ulugtekina*, Filiz Bektasb, Ahmet Ozgur Dogrua, Cigdem Gokselb, Idil Aslan Alatonc, Derin Orhonc.
- Remote Sensing and GIS: Applications for Groundwater Potential Assessment in Eritrea Semere Solomon.
- THE APPLICATION OF REMOTE SENSING AND GIS IN THE STABILITY EVALUATION OF GOAVES Wan Yuqing, Kuang Jingshui, Sun Shunxing, Zhou Riping.
- Identification of ground water potential zones using GIS and Remote Sensing Techniques: A case study of Mysore taluk -Karnataka Ramu, Mahalingam B, Vinay M

THEME 2.2: A COMPARATIVE STUDY OF CHANGE IN URBAN LANDSCAPES COVERING FIVE INDIAN CITIES (DELHI, BENGALURU, KOLKATA, PUNE AND INDORE) BY USING SATELLITE IMAGES AND QGIS TOOL

- Pai et al. (2014). Pai D.S., Latha Sridhar, Rajeevan M., Sreejith O.P., Satbhai N.S. and Mukhopadhyay B., 2014, MAUSAM, 65, 1(January 2014), pp1-18
- https://landsat.gsfc.nasa.gov/about/landsat-timeline
- https://davidsuzuki.org/what-you-can-do/discourage-urban-sprawl/
- https://eos.com/blog/ndvi-faq-all-you-need-to-know-about-ndvi/
- Hari Ilam Vazhuthi and Ashwani Kumar, 2020, Causes and Impacts of Urban Floods in Indian Cities: A Review
- https://www.agricolus.com/en/vegetation-indices-ndvi-ndmi/
- https://eos.com/blog/ndvi-faq-all-you-need-to-know-about-ndvi/
- Mr Gawali Santosh Bapurao, 2021, TREND AND LEVEL OF URBANIZATION IN PUNE DISTRICT USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS) APPROACHES
- http://s3-ap-southeast-1.amazonaws.com/ijmer/pdf/volume10/volume10-issue6(10)/25.pdf
- https://indianexpress.com/article/cities/pune/pune-civic-body-funds-worth-rs-26-crore-protect-urban-forest-7416550/
- https://mohua.gov.in/cms/acts.php
- http://iguonline.in/journal/Archives/17-2/4usde.pdf
- https://www.niti.gov.in/sites/default/files/2021-09/UrbanPlanningCapacity-in-India-16092021.pdf
- https://ndma.gov.in/Natural-Hazards/Urban-Floods
- https://www.youtube.com/watch?v=aASofRmeqic&list=PLVOgwA_DiGzrOZ062PskBVE83abtupy3z
- https://www.civilsdaily.com/sansad-tv-urban-deluge-floods/
- Indore Municipality, http://imcindore.mp.gov.in/#
- UN-HABITAT, RBAP-PR-2014-Urbanization-Climate-Change-Issue-Brief-02.pdf
- http://www.gsdrc.org/docs/open/hdq1082.pdf
- https://quod.lib.umich.edu/m/mjs/12333712.0005.101?view=text;rgn=main

- Shaden Abusafieh & Miss Razem, Human Behavior and Environmental Sustainability, 2017

THEME 2.3 AND THEME 3.3 : INDUSTRIAL HAZARDOUS WASTE MANAGEMENT IN RAJASTHAN AND GUJARAT

- The world counts (2021) waste.13 tons of hazardous waste produced every second. Retrieved from: https://www.theworldcounts.com/challenges/planet-earth/waste/hazardous-waste-statistics/story.
- Berkeley lab bringing science solution to the world (Environment health and safety division)
- Available at: Environment/Health/Safety (EHS) (lbl.gov).
- Babu, B. V., & Ramakrishna, V. (2012). Hazardous waste management in India. *Birla Institute of Technology and Science Pilani–333, 31*.
- EPA (2021). Hazardous waste.Available at:https://www.epa.gov/hw/criteria-definition-solid-waste-and-solid-and-hazardous-waste-exclusions.
- CPCB (2021). National Inventory on Generation and Management of Hazardous and Other Wastes (2019-20). Available at:https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf.
- India Brand equity foundation (2020). Gujarat the growth engine of India.Available at:
- https://www.ibef.org/download/Gujarat-June-20202.pdf.
- Vibrant Gujarat (2017). Chemical and petrochemical sectors in Gujarat. Retrieved from: http://vibrantgujarat.com/writereaddata/images/pdf/chemical-and-petrochemical-sector.pdf.
- Vibrantgujarat (2017). Gems and Jewellery sector profile. Retrieved from: http://vibrantgujarat.com/writereaddata/images/pdf/gems-jewellery-sector.pdf.
- PopulationU (2021). Rajasthan population. Available at:https://www.populationu.com/in/rajasthan-population.
- IBEF (2020). Rajasthan Royal heritage. Retrieved from:https://www.ibef.org/download/Rajasthan-March-2020.pdf.

- MOEF (2016). Hazardous and waste management Rules.Available at: https://cpcb.nic.in/displaypdf.php?id=aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY=

- Ahuja, A. S., &Abda, S. A. (2015). Industrial hazardous waste management by government of Gujarat. *Research Hub International Multidisciplinary Research Journal*, *2*, 1-11.

- CPCB (2016). Harmonization of Industrial sector into RED/ ORANGE/ GREEN/ WHITE Category. Available at:https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTE4X0ZpbmFsX0RpcmVjdGlvbnMucGRm.

- Nathanson, Jerry A.. "Hazardous-waste management". *Encyclopedia Britannica*, 30 Oct. 2020, https://www.britannica.com/technology/hazardous-waste-management. Accessed 1 October 2021.

- CPCB (2021). Guidance Document for Conducting Environmental Audit of Common/Captive Treatment, Storage and Disposal Facilities (TSDFs). Available at: https://cpcb.nic.in/uploads/hwmd/Guidelines_HW_3.pdf.

- Earth 5R (2020). Daman ganga: restoration of the river is choked by toxin. Available at:https://earth5r.org/damanganga-restoration-river-choked-toxins/.

- UT Administration (2019). Action plan on Daman Ganga river. Available at: https://www.daman.nic.in/websites/Pollution-Control-Committee/2019/Action-Plan-on-Damanganga-River-03-04-2019.pdf.

- GPCB (2020). Monthly Progress Report of PRS Damanganga (Gujarat State) for July – 2020. Available at: https://gpcb.gujarat.gov.in/uploads/Monthly_Progress_Report_July_Damanganga_2020.pdf.

- Kapil Dave (2021). Gujarat govt approves five sites for disposal of hazardous waste. The Times of India. Retrieved from: https://timesofindia.indiatimes.com/city/ahmedabad/govt-approves-five-sites-for-disposal-of-hazardous-waste/articleshow/83968985.cms.

- IL&FS (2010). Technical guidance and manual for common hazardous waste treatment storage and disposal facility. Available at:

http://environmentclearance.nic.in/writereaddata/Form1A/HomeLinks/TGM_Comman per cent20Hazardous per cent20Waste per cent20Treatment_010910_NK.pdf.

- Grasso, D., Kahn, D., Kaseva, M. E., &Mbuligwe, S. E. (2009). Hazardous waste. *Natural and Human Induced Hazards and Environmental Waste Management*, *1*, 1-54. Available at: http://www.eolss.net/sample-chapters/c09/e1-08-00-00.pdf.
- Rosenfeld, P. F., & Feng, L. (2011). *Risks of hazardous wastes*. William Andrew.Available at: Current Practices in Hazardous Waste Treatment and Disposal – ScienceDirect

THEME - 3.1: PLASTIC WASTE AND THEME - 3.2: ELECTRONIC WASTE OR E-WASTE

- The world counts (2021) waste.13 tons of hazardous waste produced every second. Retrieved from: https://www.theworldcounts.com/challenges/planet-earth/waste/hazardous-waste-statistics/story.
- Berkeley lab bringing science solution to the world (Environment health and safety division)
- Available at: Environment/Health/Safety (EHS) (lbl.gov).
- Babu, B. V., & Ramakrishna, V. (2012). Hazardous waste management in India. *Birla Institute of Technology and Science Pilani–333, 31*.
- EPA (2021). Hazardous waste.Available at:https://www.epa.gov/hw/criteria-definition-solid-waste-and-solid-and-hazardous-waste-exclusions.
- CPCB (2021). National Inventory on Generation and Management of Hazardous and Other Wastes (2019-20). Available at:https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2019-20.pdf.
- India Brand equity foundation (2020). Gujarat the growth engine of India.Available at:
- https://www.ibef.org/download/Gujarat-June-20202.pdf.
- Vibrant Gujarat (2017). Chemical and petrochemical sectors in Gujarat. Retrieved from: http://vibrantgujarat.com/writereaddata/images/pdf/chemical-and-petrochemical-sector.pdf.
- Vibrantgujarat (2017). Gems and Jewellery sector profile. Retrieved from: http://vibrantgujarat.com/writereaddata/images/pdf/gems-jewellery-sector.pdf.
- PopulationU (2021). Rajasthan population. Available at:https://www.populationu.com/in/rajasthan-population.
- IBEF (2020). Rajasthan Royal heritage. Retrieved from:https://www.ibef.org/download/Rajasthan-March-2020.pdf.

- MOEF (2016). Hazardous and waste management Rules.Available at: https://cpcb.nic.in/displaypdf.php?id=aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY=

- Ahuja, A. S., &Abda, S. A. (2015). Industrial hazardous waste management by government of Gujarat. *Research Hub International Multidisciplinary Research Journal*, *2*, 1-11.

- CPCB (2016). Harmonization of Industrial sector into RED/ ORANGE/ GREEN/ WHITE Category. Available at:https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTE4X0ZpbmFsX0RpcmVjdGlvbnMucGRm.

- Nathanson, Jerry A.. "Hazardous-waste management". *Encyclopedia Britannica*, 30 Oct. 2020, https://www.britannica.com/technology/hazardous-waste-management. Accessed 1 October 2021.

- CPCB (2021). Guidance Document for Conducting Environmental Audit of Common/Captive Treatment, Storage and Disposal Facilities (TSDFs). Available at: https://cpcb.nic.in/uploads/hwmd/Guidelines_HW_3.pdf.

- Earth 5R (2020). Daman ganga: restoration of the river is choked by toxin. Available at:https://earth5r.org/damanganga-restoration-river-choked-toxins/.

- UT Administration (2019). Action plan on Daman Ganga river. Available at: https://www.daman.nic.in/websites/Pollution-Control-Committee/2019/Action-Plan-on-Damanganga-River-03-04-2019.pdf.

- GPCB (2020). Monthly Progress Report of PRS Damanganga (Gujarat State) for July – 2020. Available at: https://gpcb.gujarat.gov.in/uploads/Monthly_Progress_Report_July_Damanganga_2020.pdf.

- Kapil Dave (2021). Gujarat govt approves five sites for disposal of hazardous waste. The Times of India. Retrieved from: https://timesofindia.indiatimes.com/city/ahmedabad/govt-approves-five-sites-for-disposal-of-hazardous-waste/articleshow/83968985.cms.

- IL&FS (2010). Technical guidance and manual for common hazardous waste treatment storage and disposal facility. Available at:

http://environmentclearance.nic.in/writereaddata/Form1A/HomeLinks/TGM_Comman%20Hazardous%20Waste%20Treatment_010910_NK.pdf.

- Grasso, D., Kahn, D., Kaseva, M. E., &Mbuligwe, S. E. (2009). Hazardous waste. *Natural and Human Induced Hazards and Environmental Waste Management*, *1*, 1-54. Available at: http://www.eolss.net/sample-chapters/c09/e1-08-00-00.pdf.

- Rosenfeld, P. F., & Feng, L. (2011). *Risks of hazardous wastes*. William Andrew.Available at: Current Practices in Hazardous Waste Treatment and

THEME – 4.1: AIR POLLUTION IN DELHI (FOCUS ON VEHICULAR POLLUTION)

- http://cpcbenvis.nic.in/air_pollution_main.html - National Ambient Air Quality Monitoring Programme
- https://oizom.com/location-selection-for-air-quality-monitoring-system - Selection of Air Quality Monitoring System location and its maintenance
- http://www.indiaenvironmentportal.org.in/files/file/Air%20Quality%20Index.pdf – National Air Quality Index
- https://cpcb.nic.in/AQI_Bulletin.php - AQI of Delhi every month
- http://moef.gov.in/wp-content/uploads/2019/05/NCAP_Report.pdf - 42 Action Points, Graded Response Action Plan, National Clean Air Programme detailing.
- http://delhiplanning.nic.in/sites/default/files/12%29%20Transport.pdf – Transport Sector and trend analysis of vehicles with growth rate.
- http://delhiplanning.nic.in/sites/default/files/Final%20Economy%20survey%20English.pdf – Investments done by the Central Government for the transport sector
- https://www.windfinder.com/windstatistics/delhi_indira_gandhi_airport - Wind Direction and velocity to plot Wind Rose Diagram
- https://www.dw.com/en/india-pollution-how-a-farming-revolution-could-solve-stubble-burning/a-51166417 - In depth study on Stubble Burning and ways to overcome it
- https://www.researchgate.net/publication/281579058_Delhi_Metro_and_Air_Pollution - Effect of Delhi Metro on Air Pollution
- https://government.economictimes.indiatimes.com/news/economy/budget-2020-national-schemes-get-balance-budgets/73866977 - Financial Green Budget.
- https://www.drishtiias.com/loksabha-rajyasabha-discussions/in-depth-bs-vi-emission-norms#:~:text=With%20BS%2DVI%20fuel%2C%20for,compared%20to%20BS%2DIV%20fuel. – Advantages of BS-VI fuels.
- https://www.timesnownews.com/auto/features/article/are-puc-systems-in-india-really-effective/525978 - PUC improvements and problems.
- https://www.nsenergybusiness.com/features/lithium-ion-battery-environmental-impact - To understand the research work going around the world on an alternative mode of transportation.

THEME-5.1: A STUDY ON INVASIVE PLANT SPECIES (*PROSOPIS JULIFLORA* AND *ACACIA TORTILIS)* AND THEIR EFFECTS ON SOME SELECTIVE NATIVE ANIMAL SPECIES (SPINY TAILED LIZARD, BLUE BULLS, BENGAL TIGER and GREAT INDIAN BUSTARD) IN BIKANER REGION AND RANTHAMBORE NATIONAL PARK, RAJASTHAN

Anon. (1990). *Plant for reclamation of wasteland.* New Delhi: Publication and Information Directorate. CSIR.

Arora, K. .. (1979). *Acacia tortilis (forsk), A promising fast growing tree for Indian arid zones.* Jodhpur: Central Arid Zone Research Institute.

Azmat, W. D. (2015). Anticonvulsant and neuroprotective effects of the Acacia tortilis growing in KSA. *Pakistan Journal of Pharmaceutical Science*, 531-533.

Beisel, S. D.-N. (2006). Biological and ecological characteristics of invasive species: a gammarid study. *Springer*.

Bhattacharya, P. J. (2002). Sustainable harvesting of kullu (Sterculia urens) gum. In P. J. Bhattacharya, *Indian Institute of Forest Management Newsletter, 1 & 2* (pp. 3 - 5).

C.M, P. (1989). Valuation of an Amazonian rainforest. In P. C.M, *Nature* (p. 339).

CHAIEB, Z. N. (2011). ALLELOPATHIC EFFECTS OF ACACIA TORTILIS (FORSSK.) HAYNE SUBSP. RADDIANA (SAVI) BRENAN IN NORTH AFRICA. *Pakistan Journal of Botany*.

Dhayani D, M. R. (2007). Basic nutritional attributes of Hippophae salicifolia (Seabuckthorn) populations from Uttarakhand Himalaya, India. *Current Science 92(8)*, 1148–1152 .

ENVIS Resources Patner On Avain Ecology. (2021, 08 20). *In 1 year, Great indian Bustard population falls from 44 to just 13 in Rajasthan*.

Fountain, W. M. (n.d.). Invasive species: Understanding the characteristic. *URBAN FOREST INITIATIVE*.

Gairola Y, B. S. (2008). Bioprospecting in Garhwal Himalayas, Uttarakhand. *Current Science 90(9)*, 1139–1143 .

Ganesan, R. (2003). Identification, distribution and conservation of Phyllanthus indofischeri, another source of Indian gooseberry. In R. Ganesan, *Current Science, 84* (pp. 1515 - 1518).

Hiremath, A. (n.d.). The ecological consequences of managing forests for non-timber productrs. In A. Hiremath, *Conservation and Society, 2* (pp. 211 - 216).

India, W. o. (1979). *A dictionary of Indian raw material and industrial products. Raw material, vol 8.* Council of Scientific and Industrial Research (CSIR).

(2011-2020). *Invasive Alien Species.* United Nations Decade on Biodiversity.

Invasive alien species and climate change. (2021, 02). *IUCN*.

(2020). *IUCN Red List.* IUCN.

J. C. Tewari, B. K. (2013). Prosopis juliflora: A Miracle Species of Hot Arid and Semi-Arid Regions of India. *Popular kheti*.

J.P., G., G.G.S.N., R., Y.S., R., & B.V.R., R. (1984). Role of Shelterbelts in arid zone. *Indian-Farming* , 29-30.

Jhalani, N. (2021). Desert areas of Rajasthan bloom under afforestation efforts. *MONGABAY*.

Kaul, R. H. (2004). Hunting of large mammals and pheasants in the Indian western Himalaya. In R. H. Kaul, *Oryx, 38* (pp. 426 - 431).

Kaushal, K. &. (2005). International Forestry Review, 7. In K. &. Kaushal, *India: achieving the Millennium Development Goals through non-timber forest products.* (pp. 128 - 134).

Kothari, A. (2005). Bungle in the jungle. In A. Kothari, *Seminar 552* (pp. 63 - 69).

Mahapatra, A. &. (1997). Sustainable development of non-timber forest products: implication for forest management in India. In A. &. Mahapatra, *Forest Ecology and Management, 94* (pp. 15 - 27).

Mahapatra, A. A. (2005). Environmental Management, 35. In A. A. Mahapatra, *The impact of NTFP sales on rural households' cash income in India's dry deciduous forest.* (pp. 258 - 265).

Maikhuri RK, R. K. (2004). Bioprospecting of wild edibles for rural development in the central Himalayan mountain of India. . *Mt Res Dev 24*, 110–113.

Maikhuri RK, S. R. (1994). Wild fruit as a contribution to sustainable rural development: A case study from the Garhwal Himalaya. *International Journal of Sustainable Development and World Ecology* , 1:56–68 .

Mandeep Kaur, M. J. (2020). Population status, habitat suitability and threat assessment ofIndian spiny-tailed lizard Saara hardwickii (Gray, 1827) in theThar desert of Rajasthan. *Journal of Wildlife and Biodiversity*.

McGlade, J. (2013). Invasive alien species: a growing problem for environment and health. *European Environment Agency*.

Mohany, D. (1990). TREES OF SOMALIA, A Feild Guide For Workers. *Oxfam Research Paper*, 29.

Nirmalie Pallewatta, J. K. (2002). Prevention and Management of Invasive Alien Species:. *The Global Invasive Species Programme*.

Pardhikar, R. (2020). Distructive Greening of the Thar Desert. *Science the Wire*.

PETR PYSˇ EK, V. C. (2012). A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of. *Global Change Biology*.

Philips, W. S. (1963). Depth of Root in Soil. *ECOLOGY: ECOOGICAL SOCIETY OF AMERICA*, 424-967.

Prabhu, P. (2005). The right to live with dignity. In P. Prabhu, *Seminar, 552* (pp. 14 - 19).

Prastiksha Patnaik, T. A. (2017). Prosopis (Prosopis juliflora): Blessing and bane. *researchgate*.

Queensland, U. o. (2018). Invasive species and habitat loss our biggest biodiversity threats. *ScienceDaily*.

Rai, N. &. (2004). Forest product use, conservation and livelihoods: the case of Uppage fruit harvest in the Western Ghats, India. In N. &. Rai, *Conservation & Society, 2* (pp. 289 - 313).

Rajendra Mohan Panda, M. D. (2017). Assessing distributions of two invasive species of contrasting habits in future climate. *ELSEVIER*.

Rongsen. (1992). Sea buckthorn: a multipurpose plant species for fragile mountains. *ICIMOD Occasional paper No. 20*.

Shaanker, R. G. (2004). Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. In R. G. Shaanker, *Environmental Conservation, 31* (pp. 242 - 253).

Shaanker, R. G. (2004). Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. In *Environmental Conservation, 31* (pp. 242 - 253).

Shahabuddin, G. a. (2004). Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. In G. a. Shahabuddin, *Conservation & Society, 2* (pp. 235 - 250).

(2019). *STATUS OF TIGER IN INDIA 2018.* Wildlife Institute of India.

Sundriyal M, S. R. (2003). Underutilized edible plants of the Sikkim Himalaya: need for domestication. *Current Science 85(6)*, 731–736 .

Tiwari, K. (1995). Collection of aonla (Emblica officinalis) fruits from forest: an impact assessment. In K. Tiwari, *Vainiki Sandesh, 14* (pp. 1 - 5).

Wood, P. R. (n.d.). Water hyacinth (Eichhornia crassipes (Mart.) Solms) seed longevity and the implications for management. *Eighteenth Australasian Weeds Conference*.

THEME-5.2: UNDERSTANDING THE VALUE ADDITION OF NON-TIMBER FOREST PRODUCE (NTFP) PRODUCTS USING SYSTEM DYNAMICS IN TELANGANA, INDIA

Anon. (1990). *Plant for reclamation of wasteland.* New Delhi: Publication and Information Directorate. CSIR.

Arora, K. .. (1979). *Acacia tortilis (forsk), A promising fast growing tree for Indian arid zones.* Jodhpur: Central Arid Zone Research Institute.

Azmat, W. D. (2015). Anticonvulsant and neuroprotective effects of the Acacia tortilis growing in KSA. *Pakistan Journal of Pharmaceutical Science*, 531-533.

Beisel, S. D.-N. (2006). Biological and ecological characteristics of invasive species: a gammarid study. *Springer*.

Bhattacharya, P. J. (2002). Sustainable harvesting of kullu (Sterculia urens) gum. In P. J. Bhattacharya, *Indian Institute of Forest Management Newsletter, 1 & 2* (pp. 3 - 5).

C.M, P. (1989). Valuation of an Amazonian rainforest. In P. C.M, *Nature* (p. 339).

CHAIEB, Z. N. (2011). ALLELOPATHIC EFFECTS OF ACACIA TORTILIS (FORSSK.) HAYNE SUBSP. RADDIANA (SAVI) BRENAN IN NORTH AFRICA. *Pakistan Journal of Botany*.

Dhayani D, M. R. (2007). Basic nutritional attributes of Hippophae salicifolia (Seabuckthorn) populations from Uttarakhand Himalaya, India. *Current Science 92(8)*, 1148–1152 .

ENVIS Resources Patner On Avain Ecology. (2021, 08 20). *In 1 year, Great indian Bustard population falls from 44 to just 13 in Rajasthan*.

Fountain, W. M. (n.d.). Invasive species: Understanding the characteristic. *URBAN FOREST INITIATIVE*.

Gairola Y, B. S. (2008). Bioprospecting in Garhwal Himalayas, Uttarakhand. *Current Science 90(9)*, 1139–1143 .

Ganesan, R. (2003). Identification, distribution and conservation of Phyllanthus indofischeri, another source of Indian gooseberry. In R. Ganesan, *Current Science, 84* (pp. 1515 - 1518).

Hiremath, A. (n.d.). The ecological consequences of managing forests for non-timber productrs. In A. Hiremath, *Conservation and Society, 2* (pp. 211 - 216).

India, W. o. (1979). *A dictionary of Indian raw material and industrial products. Raw material, vol 8.* Council of Scientific and Industrial Research (CSIR).

(2011-2020). *Invasive Alien Species.* United Nations Decade on Biodiversity.

Invasive alien species and climate change. (2021, 02). *IUCN*.

(2020). *IUCN Red List.* IUCN.

J. C. Tewari, B. K. (2013). Prosopis juliflora: A Miracle Species of Hot Arid and Semi-Arid Regions of India. *Popular kheti*.

J.P., G., G.G.S.N., R., Y.S., R., & B.V.R., R. (1984). Role of Shelterbelts in arid zone. *Indian-Farming* , 29-30.

Jhalani, N. (2021). Desert areas of Rajasthan bloom under afforestation efforts. *MONGABAY*.

Kaul, R. H. (2004). Hunting of large mammals and pheasants in the Indian western Himalaya. In R. H. Kaul, *Oryx, 38* (pp. 426 - 431).

Kaushal, K. &. (2005). International Forestry Review, 7. In K. &. Kaushal, *India: achieving the Millennium Development Goals through non-timber forest products.* (pp. 128 - 134).

Kothari, A. (2005). Bungle in the jungle. In A. Kothari, *Seminar 552* (pp. 63 - 69).

Mahapatra, A. &. (1997). Sustainable development of non-timber forest products: implication for forest management in India. In A. &. Mahapatra, *Forest Ecology and Management, 94* (pp. 15 - 27).

Mahapatra, A. A. (2005). Environmental Management, 35. In A. A. Mahapatra, *The impact of NTFP sales on rural households' cash income in India's dry deciduous forest.* (pp. 258 - 265).

Maikhuri RK, R. K. (2004). Bioprospecting of wild edibles for rural development in the central Himalayan mountain of India. . *Mt Res Dev 24*, 110–113.

Maikhuri RK, S. R. (1994). Wild fruit as a contribution to sustainable rural development: A case study from the Garhwal Himalaya. *International Journal of Sustainable Development and World Ecology* , 1:56–68 .

Mandeep Kaur, M. J. (2020). Population status, habitat suitability and threat assessment ofIndian spiny-tailed lizard Saara hardwickii (Gray, 1827) in theThar desert of Rajasthan. *Journal of Wildlife and Biodiversity*.

McGlade, J. (2013). Invasive alien species: a growing problem for environment and health. *European Environment Agency*.

Mohany, D. (1990). TREES OF SOMALIA, A Feild Guide For Workers. *Oxfam Research Paper*, 29.

Nirmalie Pallewatta, J. K. (2002). Prevention and Management of Invasive Alien Species:. *The Global Invasive Species Programme*.

Pardhikar, R. (2020). Distructive Greening of the Thar Desert. *Science the Wire*.

PETR PYSˇ EK, V. C. (2012). A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of. *Global Change Biology*.

Philips, W. S. (1963). Depth of Root in Soil. *ECOLOGY: ECOOGICAL SOCIETY OF AMERICA*, 424-967.

Prabhu, P. (2005). The right to live with dignity. In P. Prabhu, *Seminar, 552* (pp. 14 - 19).

Prastiksha Patnaik, T. A. (2017). Prosopis (Prosopis juliflora): Blessing and bane. *researchgate*.

Queensland, U. o. (2018). Invasive species and habitat loss our biggest biodiversity threats. *ScienceDaily*.

Rai, N. &. (2004). Forest product use, conservation and livelihoods: the case of Uppage fruit harvest in the Western Ghats, India. In N. &. Rai, *Conservation & Society, 2* (pp. 289 - 313).

Rajendra Mohan Panda, M. D. (2017). Assessing distributions of two invasive species of contrasting habits in future climate. *ELSEVIER*.

Rongsen. (1992). Sea buckthorn: a multipurpose plant species for fragile mountains. *ICIMOD Occasional paper No. 20*.

Shaanker, R. G. (2004). Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. In R. G. Shaanker, *Environmental Conservation, 31* (pp. 242 - 253).

Shaanker, R. G. (2004). Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. In *Environmental Conservation, 31* (pp. 242 - 253).

Shahabuddin, G. a. (2004). Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. In G. a. Shahabuddin, *Conservation & Society, 2* (pp. 235 - 250).

(2019). *STATUS OF TIGER IN INDIA 2018.* Wildlife Institute of India.

Sundriyal M, S. R. (2003). Underutilized edible plants of the Sikkim Himalaya: need for domestication. *Current Science 85(6)*, 731–736 .

Tiwari, K. (1995). Collection of aonla (Emblica officinalis) fruits from forest: an impact assessment. In K. Tiwari, *Vainiki Sandesh, 14* (pp. 1 - 5).

Wood, P. R. (n.d.). Water hyacinth (Eichhornia crassipes (Mart.) Solms) seed longevity and the implications for management. *Eighteenth Australasian Weeds Conference*.

-