State of Environment Report
India 2015

सत्यमेव जयते

प्रकृतिः रक्षति रक्षिता

Nature Protects if She is Protected

Government of India

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"The world has enough for everyone's need, but not enough for everyone's greed."

- Mahatma Gandhi

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सत्यमेव जयते

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GOVERNMENT OF INDIA
MINISTER OF ENVIRONMENT, FOREST & CLIMATE CHANGE

MESSAGE

It gives me great pleasure to present the 'State of Environment Report – India, 2015', an effort towards taking stock of the state of the country's environment. I hope that the publication of this comprehensive report provides us the opportunity to pause and reflect upon the environmental challenges facing the country as also to celebrate the positive changes that we have collectively managed to bring about and thus reinforce or realign our strategies towards ensuring a healthy environment for our future generations.

Faster, more inclusive and sustainable growth has been identified as the cornerstone of India's growth policy for the Twelfth Plan Period – 2012-17. In this context, this report presents a perspective on our performance with respect to mainstreaming concerns of environmental protection and natural resource management in our development policies and programmes even as we pursue our goals for socio-economic growth. Continuing our commitment to sustainable development, we have over the past few years, invested in several flagship initiatives in sectors of critical importance such as water, renewable energy, urban waste, sanitation, agriculture and sustainable production and consumption, to name a few, that aim at sustainable and inclusive growth.

This national report is an outcome of extensive multi-stakeholder consultative processes coupled with participatory expert assessments. These processes and the publication of this report have been facilitated by Development Alternatives under the guidance and oversight of the Apex Committee formed for the purpose by the MoEF&CC. The significance of this report lies in the fact that besides providing a holistic perspective on the state of the environment in the country, it also provides a glimpse into the state of readiness, starting 2016, for implementing the Post-2015 Development Agenda embodied in the 17 Sustainable Development Goals and its 169 associated targets and for meeting the country's ambitious commitments towards mitigating its greenhouse gases emissions, as a signatory to the Paris Agreement.

I would like to express my heartiest congratulations to all who have been involved in bringing out this report and have contributed to it in some way. Their hard work and dedication is evident in the layout and comprehensiveness of the report. I am confident that this report will serve as a useful resource for policy makers, planners, academicians, researchers, non-governmental organisations and civil societies to access information on the state of the country's environment and to inform their respective spheres of work.

(Dr. Harsh Vardhan)

सत्यमेव जयते

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ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA

MESSAGE

India today, as a fast growing economy, stands at a crossroads in its development trajectory where it will have to deal with the multi-dimensional challenges that modern development brings in its wake. We will have to chart a course of sustainable growth that brings development to each of its citizens without impinging on the health of its environmental and ecological systems. This report hints towards the need to invest in rebuilding our ecological infrastructure and the synergies that are possible and required between multiple sectors, stakeholders and actions towards meeting this difficult yet achievable challenge. Therefore, there is an urgent need for proper monitoring and management of the environment to achieve the goal of sustainable development.

The growing concern on environment has prompted the Ministry of Environment, Forest & Climate Change, Govt. of India to ascertain the actual status of environment in the country. To achieve this goal of sustainable development and to provide an overview of the prevailing bio-physical and socio-economic conditions of the states in the country, MoEF&CC, Govt. of India also launched a scheme during the Tenth Plan Period for assisting the State Governments in bringing out State of Environment Reports (SoER) for all the states.

The 'State of Environment Report, India – 2015' presents an overview and assessment of several issues that affects the environment. Clearly, every citizen happens to be a part of the anthropogenic factors that change the environment for the better or worse. The report, though technical in content, carries numerous illustrations and messages that could provide the general reader a good exposure to current issues of importance.

This report is expected to serve as a baseline and provide information on the state of the environment and at the same time assist in suggesting action plans and in formulating recommendations for efficient environmental management.

(Dr. Mahesh Sharma)

सी के मिश्रा
C K Mishra

सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय

SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE

FOREWORD

The 'State of Environment Report, India – 2015' in being brought out by the Ministry of Environment, Forest and Climate Change, New Delhi, wherein serious efforts have been made to assess and document the ecological changes in various disciplines. The report presents an overview of the state of the environment of the country and also attempts to trace the trajectory it has been taking over the past few years. It gains additional significance in the current scenario as it will serve as a baseline document in the context of the Post-2015 Development Agenda defined by the Sustainable Development Goals.

The report covers the gamut of key environmental issues in the country that are currently being witnessed and also those that are foreseen to become critical in the coming years. The report covers key ecological components such as water, land, forests, biodiversity and marine and coastal areas and also sectors and processes that are impacting the environment, such as industry, mining, agriculture, energy and urbanisation besides providing a view on the overall impacts being witnessed in terms of environmental pollution and climate change.

The report is an outcome of collaborative efforts of the MoEF&CC and Development Alternatives through an extensive consultative process with various ministries, research agencies, non-government organisations, academicians and experts. The Apex Committee, comprising of eminent experts in the field of environment, provided quality assurance and oversight to the state of environment reporting process.

I take this opportunity to express my utmost gratitude to the members of the Apex Committee and specially its chairman, Mr. R H Khwaja for their able guidance and unstinting support through the process of preparation of the report. I also congratulate and thank my colleagues in the Ministry for their dedicated efforts in helping us to come out with this important report. Finally, I express my appreciation to the hard work put in by the team of Development Alternatives, New Delhi.

I am sure that the report would serve as a reliable source of information on environmental status and issues in the country not only to the policy makers and planners but also to the stakeholders who are interested in learning about and contributing towards improving the state of the environment in our country.

(C K Mishra)

आर एच ख्वाजा
R H Khwaja

अध्यक्ष
सर्वोच्च समिति
स्टेट ऑफ एनवायरनमेंट रिपोर्ट – इंडिया 2015

CHAIRMAN
APEX COMMITTEE
STATE OF ENVIRONMENT REPORT – INDIA 2015

PREFACE

As Chairman of the Apex Committee, I congratulate the Ministry of Environment, Forest and Climate Change (MoEF&CC) and Development Alternatives for the successful publication of the State of Environment Report – India, 2015. It has been a challenging task to analytically synthesize complex, varied and extensive data in attempting to weave a sustainable and coherent narrative.

We have followed a participatory approach involving multiple stakeholder consultations and guidance from technical experts in the preparation of the report. The consultative process followed focused on building a consensus on prioritization of eco-systems based on factual data for evolving an integrated approach. Chapters have been authored by members of a core team under the mentorship of leading domain area experts.

The report has been divided into ten chapters covering major sectors that represent core components of the environment, the pressures they create, and their overall impact. A common thread in the report is the Sustainable Development Goals (SDGs) which holds the report in a conceptual framework highlighting synergies across sectors. The objective of the report is to give factual data in a scientific manner. The time-tested 'Pressure-State-Impact-Response' (PSIR) analysis framework has been applied, duly verifying the authenticity of the data.

Our attempt will be rewarded if the report serves its core objective of helping in framing of policies which promote sustainable development of our country. I extend my sincere gratitude to Prof. S P Gautam for his constant guidance in framing of the report and for ensuring its technical rigour. I extend my thanks to all colleagues of the Apex Committee for their active help and collaboration in this report. I must specially mention Dr. Anandi Subramanian, Mr. M P Johnson, Dr. M Salahuddin from MoEF&CC, the representatives from Central Pollution Control Board (CPCB), The Energy and Resources Institute (TERI), Centre for Science and Environment (CSE), Dr. K Vijaya Lakshmi and team members of Development Alternatives, who were extremely cooperative and helpful in the preparation of this report.

I sincerely thank MoEF&CC for giving me and the members of our Committee the privilege of being a part of this extremely important process. We hope that the Post-2015 Sustainable Development Agenda implementation phase will be benefitted by this report and it will help in the environmentally sustainable development of our country.

(R H Khwaja)

ACKNOWLEDGEMENTS

The preparation of the 'State of Environment Report – India, 2015' has been a collaborative journey that has witnessed the participation of a large and diverse array of stakeholders who have contributed immense value to the report. We would like to take this opportunity to thank them all for their generosity in providing their time and effort.

We would first of all like to extend our heartfelt gratitude to the members of the Apex Committee that was instituted for providing guidance and supervision for the development of this report. The report has benefited greatly from the leadership of Mr. R H Khwaja as Chairman and the supportive guidance of Prof. S P Gautam, who relentlessly impressed upon the team to deliver a report of the highest standard. We would also like to acknowledge our utmost indebtedness to Dr. Anandi Subramanian, Senior Advisor, MoEF&CC for providing critical inputs and expectation setting at the time of inception of the report.

We thank Mr. M P Johnson for facilitating access to various line ministries, government departments and agencies for consultations and data collection. We thank the member representatives on the Apex Committee – Dr. A B Akolkar from Central Pollution Control Board (CPCB), Mr. Chandra Bhushan from Centre for Science and Environment (CSE), Mr. M P Johnson from MoEF&CC and Dr. Suneel Pandey from The Energy Research Institute (TERI) – for being generous with their time and constructive suggestions on the report.

We express our utmost appreciation and gratitude to the subject area experts who contributed to the drafting of the chapters and thus brought their wealth of knowledge and experience into the report. We thus thank Mr. Abhijit Chatterjee, Mr. Jay Kumar, Ms. Kriti Nagrath, Dr. M L Kannan, Dr. N K Verma, Dr. R K Chaturvedi and Dr. S M Ilyas for their dedication and tireless efforts.

We also thank all the eminent experts who reviewed the report and provided their valuable inputs for its betterment. Thanks are thus due to Dr. B Sengupta, Dr. Bharat Sharma (IWMI), Ms. Charu Jain, Mr. Dipankar Saha (CGWB), Dr. G V Subramanyam, Dr. K K Saxena, Dr. M V Ramana Murthy (MoES), Mr. Nikhilesh Jha, Dr. Shrawan Acharya (JNU), Dr. Vijaya Ravindran (NIOT), Dr. Vijay Kumar Soni (MoES) and Ms. Aastha Dwivedi (MoEF&CC). We also thank each one of the participants of the meetings of the Apex Committee for their feedback and suggestions and their participation has been acknowledged in the report appendices. We would also like to thank Dr. Chhavi Pant Joshi (Ministry of Health and Family Welfare), Mr. Gopal Iyengar (MoES) and Mr. Peeyush Kumar (Ministry of Coal) for their efforts in providing constructive suggestions and data for the report.

We also extend our gratitude to all the Ministries and Government departments and agencies that provided us with the data and inputs without which this report would not have been possible. Some of the Ministries and Agencies that contributed actively include Central Pollution Control Board, Coal India Limited, Gujarat Pollution Control Board, Ministry of Mines, Punjab Pollution Control Board, Tamil Nadu Pollution Control Board and Uttar Pradesh Pollution Control Board.

Finally we thank the Development Alternatives team led by Mr. George C Varughese. Acknowledgement is thus due to the report drafting team comprising of Dr. Alka Srivastava, Anand Kumar, Anindita Singh, Avanindra Kumar, Garima Maheshwari, Kavya Arora, Krishna Chandran, Mayukh Hajra, Pradeep Mishra, Dr. Pranay Kumar, Pravara Krunal Amreliya, Prerna Sodhi, Rishabh Misra, Sumit Saxena, Syed Abdul Aziz Ishaqi Farhan, Vaibhav Rathi and Zeenat Niazi, the layout and design team of Binu K George, Jay Vikash Singh and Pritam Poddar and the support team of Devender Giri Goswami, Jayati Rautela, Ramita Rawat, Amar Bhadur, Jawahar Singh and Neeraj Sharma.

While it will be a herculean task to list and thank by name, everyone that contributed to this report, we have made a modest effort to acknowledge atleast some of them. This is however by no means an exhaustive list, and it does not seek to undermine the value of the multifarious support provided by those whom we have inadvertently missed to mention. We once again express our immense gratitude to them all.

Development Alternatives
New Delhi



CONTENTS

EXECUTIVE SUMMARY

As India, along with the rest of the world, steps into the implementation period of the Post-2015 Development Agenda it becomes more pertinent than ever before to take stock of the state of the country's environment and how far we are from achieving the ambitious Sustainable Development Goals (SDGs) and therefore which path we must take and with what pace and strategy towards reaching there. Moreover, the interlinked nature of the SDGs means that the environmental dimension needs to be understood and addressed within every aspect of development. This report is the most up to date publication under the ambit of State of Environment (SoE) Reporting processes being coordinated by the Ministry of Environment, Forest and Climate Change (MoEF&CC) and it documents the state of the environment in 2015 and the trends and emerging challenges that have been recorded since 2009 when the previous report was published.

The SoE Reporting process was formally introduced in India in the year 2002 in accordance with the intent laid down in the Tenth Five Year Plan that came into effect in the same year. The overall objective of the scheme was to present an overview on the state of the environment at both the country level and disaggregated at the level of the states and the union territories. The intent was to provide a foundation for mainstreaming the addressal of environmental concerns in development planning and decision making and institute a robust mechanism for tracking progress made towards sustainable development. The systems and processes for state of environment reporting were initiated under the stewardship of the Ministry of Environment & Forests, Government of India. Systematised processes for collection and collation of environmental data have been instituted and streamlined using a range of tools including in digital enabled and interactive modes. Institutional mechanisms for anchoring the reporting process and for linking the learning outputs with decision making platforms have also been established.

The milieu of SoE reporting in India has witnessed a wide diversity of methodologies and presentation formats ranging from the formalized state led reports to people's reports generated through grassroots participatory and consultative methods, from wall paintings in villages to open access digital and interactive formats and from straight-forward data reportage to in-depth analytical enquiry. While state of the environment reporting in India straddles both government and civil society led efforts, this present report, being brought out by the MoEF&CC is to be considered as the definitive report on the state of the country's environment.

Development Alternatives, in its capacity as the host institute, has facilitated the process of preparation of this report under the aegis of the MoEF&CC and the guidance of an Apex Committee set up for providing steering support and oversight to the process. The report has been developed through an elaborate process of collation of data from various ministries, line departments at state and central level and various academic and research organisations followed by participatory analysis through consultative workshops and interaction with technical experts.

The main chapters in the report have been arranged in three sections, each with a distinctive colour scheme. The first section of chapters deals with sectors that are themselves a component of the ecological base and includes four chapters addressing Land and Forests, Biodiversity, Marine and Coastal Ecology and Water. The second set of chapters addresses sectors that have a significant impact on the environment and includes four chapters on Agriculture, Energy, Industry and Mining and Urbanisation. The final set of chapters deals with overall impact areas of environmental change taking place and include two chapters addressing the issues of Environmental Pollution and Climate Change. While the chapters essentially present a country level overview of the subject under discussion, in many instances where there exists pronounced variability across states, the same has been substantiated with information disaggregated at the state level.

The chapters in the report have been structured adopting the PSIR (Pressure-State-Impact-Response) frame of analysis that enables the presentation of a holistic perspective on the environmental issue under consideration. It depicts the current scenario along with any observable positive or negative trends, the factors that have contributed to it and the various resultant effects before highlighting the key measures that have been taken to address the issue. Each chapter begins with an introduction section that lays out the importance, both in environmental and socio-economic terms, of the sector or issue being addressed therein. The conclusion section examines some of the critical interlinkages with other sectors and thereby highlights integrated approaches towards addressing these issues through complementary policy and ground level interventions. This last section also attempts to provide a perspective on how the country is geared towards achieving the Sustainable Development Goals (SDGs) pertaining to this sector.

The following sections are essentially chapter briefs and highlight the key findings presented in each chapter along with an outlook on how the sector can be sustainably managed in an integrated and inclusive manner with the collaborative energies of all stakeholders.

OVERVIEW

This chapter portrays the overview profile of the country and serves to lay down the ecological and socio-economic context in which the information and discussions set forth in the following chapters are to be understood.

India exhibits immense diversity, not only in terms of its climate, physio-geography and ecological regime but also its people and culture. With the Tropic of Cancer passing through the center of India, the climate is predominantly tropical but owing to a vast range in altitudes and topographies, and the national borders traversing through mountainous and coastal territory, a variety of climate contexts are experienced across the country. This also translates into a multitude of agro-ecological systems and the intertwined evolution of unique cultural contexts. The country has an abundance of natural resources and biodiversity wealth that is also closely interlinked with the lives and livelihoods of the people, especially in the rural and remote areas.

The country has witnessed some socio-economic trends that have direct or indirect bearing on the environment in the country. The total population as per Census 2011 was 1.21 billion and the human development index is in the medium range with a value of 0.609. Despite the sluggish economic growth following the great recession experienced across the globe, India managed to demonstrate economic resilience by maintaining a growth rate of 7-8 per cent over the past few years. The urban population grew by as much as 31 per cent between 2001 and 2011 depicting an accelerating trend of urbanisation and bringing in its wake an increasing spread and intensity of environmental problems.

The institutional structure for environmental governance in the country has multiple tiers extending from the village level to the national level with legislative powers on environmental matters distributed between the central and state governments. The National Environment Policy 2006 is the overarching legal framework that governs decision making in environment arena and the MoEF&CC is the nodal ministry for the same.

LAND & FORESTS

India covers a land area of 3.28 million hectares that is only 2.4 per cent of the total land in the world; yet it is home to about 17 per cent of the world population, signifying a poor per capita availability of land. This situation assumes even greater significance when considered in the backdrop of about three quarters of the population being dependent on land based agriculture for their livelihood. Against the stated intent of having atleast a third of the land under forests, the forest cover of India stands at 21.34 per cent that is an increase from 20.60 per cent reported in the previous report. While this represents a significant increase in carbon stock, the share of soil organic carbon has fallen and this may be indicative of the loss of old growth forests important from the ecosystem services perspective.

Land degradation is a major pressure with as much as 96.40 million hectares of land being under degradation. Of this, 82.64 million hectares or about a quarter of the total land in the country is undergoing desertification. Soil erosion, which has major impacts in terms of loss of soil fertility and thereby agri-productivity, has also registered an upsurge from 3,000 million tonnes in the 1980s to 5,300 million tonnes in 2010. Fragmentation of natural habitats, majorly including forested areas, is a major impact of the land use changes that have taken place as also an increasing trend of forest fire incidents. This loss of natural habitat has also manifested in the form of an increase in man-animal conflict across geographies.

The engagement of local communities in the governance and management of forest and forest resources has yielded significant positive outcome in terms of improved sustainability in management and about 24.6 million hectares of forests are being managed by 100,000 Joint Forest Management Committees. The meaningful alignment of afforestation based programmes like Green India Mission, CAMPA and REDD+ as also the number of programmes for watershed and wasteland development are geared towards contributing significantly to the SDGs on reducing land degradation and desertification. This will also simultaneously contribute to the mitigation targets committed to in the INDCs besides helping secure the livelihoods of millions.

BIODIVERSITY

India has immense biodiversity wealth in terms of not just the number of faunal, floral and other species but also a diverse range of ecological landscapes represented in as many as ten unique biogeographic zones. Four of the 34 global biodiversity hotspots are in India, replete with a diversity of endemic species. It has been estimated that nearly 350-400 million people depend on the biodiversity resources of forests, with simply the value of biodiversity related exports notching up a figure of INR 9,000 crores. The protected area network in India covers 5.07 per cent of its area and includes 690 protected areas representing a range of conservation regimes i.e. national parks, wildlife sanctuaries, conservation reserves and community reserves. There are 18 biosphere reserves, of which nine are recognized by UNESCO. The number of protected areas has increased by over 50 per cent since 1988.

A rise in biodiversity loss has been registered as indicated by an increase in the number of threatened species. Some of the major threats to the biodiversity of the country include the land use changes such as the unabated and even accelerated conversion of forest land into agricultural land and the expansion of urban areas encroaching upon the surrounding green spaces. Expansion in developmental and industrial activities such as the establishment and operation of dams and mines are also posing significant threats in terms of habitat loss, fragmentation and degradation. Other important threats include the continuing illegal trade in protected species and animal parts and the increasing chemical load in land and water resulting from excessive use of chemical formulations in agriculture and pest control. The invasive spread of alien species also poses a rising risk to the native species and disrupts the ecological balance. The loss of biodiversity is resulting in the loss of livelihoods in the short term and a decline in ecological resilience that will severely impact human health and the economy in the long term. Forest dwelling communities are already at the receiving end of such impacts.

A National Biodiversity Action Plan with twelve well defined targets has been adopted with the objective of mainstreaming biodiversity conservation in policy and planning and building conservation capacities across various directly and indirectly linked stakeholder groups. The engagement of forest dwelling communities in the conservation management of protected areas has been positively impactful, including in the more effective implementation of existing laws on wildlife protection. This approach can be further supported through the building of technical and financial capacities of these community based management groups.

MARINE AND COASTAL ECOLOGY

The coastline of India extends over an extensive 5,423 kilometers and along with the two major island groups of Andaman & Nicobar and Lakshadweep provides habitat to a rich tapestry of marine and coastal life that provide an extensive range of ecosystem services. With 73 or about a tenth of the total number of districts in India being classified as coastal districts, these areas also support the livelihoods of a large population. The diversity in the range of marine and coastal habitats is represented by coral reef, lagoon, mangrove and seagrass ecosystems amongst others providing an array of unique ecological niches for supporting both endemic and globally dispersed flora and fauna.

Pressing anthropogenic threats to marine and coastal ecology in the country can be segregated into land based and sea based pollution sources, with the former including the discharge of untreated industrial effluents and municipal wastes and the latter including oil spills from maritime accidents and offshore oil industry operations. An even greater threat is however being experienced from climate change with its impacts ranging from those of sudden mortality events to slow onset decline of species population that disrupt marine food chains and affect the abundance and distribution of species. Most of these impacts are manifest through habitat degradation, often associated with disasters and coastal erosion but also through gradual processes such as ocean acidification. Illegal trade in marine species and the consequent extraction of resources to unsustainable extents also continue to pose significant threat.

The country has invested significantly in the protection of its marine and coastal ecology with the building of strong institutional and research capacities besides the establishment of 129 marine protected areas (MPAs), many of which have effectively adopted the principles of ecosystem based adaptation in their conservation management. Efforts have been made towards adoption of an Integrated Coastal Zone Management Plan with the objective of sustainably securing the livelihoods of coastal fishing and other communities. Several initiatives representing community based ecological restoration and climate change adaptation, for example the plantation of tree walls as shelter belts to protect from cyclonic impacts, the engagement of communities in management of sensitive ecosystems such as the fishery supporting saltwater lagoons and community based monitoring of turtle nesting sites and coral reefs, have yielded positive results in terms of more effective conservation coupled with the simultaneous generation of sustainable livelihoods.

WATER

The fresh water resources in India are represented by a large number of rivers crisscrossing the country, the Himalayas and its multitude of glaciers that are frequently referred to as the water towers of Asia and of course rainfall, mainly received during the monsoon season. There are as many as 12 major rivers and 21 river basins that comprise the complex drainage pattern in the country. Despite such a rich portfolio of water resources, as much as a quarter of the population of India is experiencing water scarcity. Both the spatio-temporal variation in the distribution of water resources and its mismanagement contribute to the general status of scarcity represented by poor per capita availability of water.

The foremost pressure, causing the unabated depletion of water resources, is poor efficiency in the irrigation sector that consumes about 80 per cent of the resources, owing largely to the widespread adoption of flood irrigation as also the adoption of other water intensive agricultural practices. Rising industrial demand is also contributing to source depletion. The parallel issue is in terms of quality with arsenic, fluoride and bacterial contamination being widespread phenomena with a consequent plethora of health impacts. Low levels of environmental flow in rivers, coupled with rampant pollution are imperiling the health of riverine and wetland ecosystems. Nearly 80 per cent of sewage gets discharged without treatment in surface water bodies. Water resource depletion and contamination has been projected to result in a loss of 6 per cent to the Indian economy by 2050 if business as usual with respect to the management of water resources continues. The greatest challenge is that ground water sources are considered as personal assets rather than as community resource and thereby continue to be indiscriminately exploited.

An integrated approach based on river-basin and flood plain management principles, especially in the case of major riverine lifelines in the country such as the Ganga is required. Improving water use efficiency including through waste water recycling and adopting systems for integrated analysis of multi-disciplinary data streams pertaining to geologic, hydrologic, hydrogeologic, geophysical and water quality information will enable improved planning and management of water resources. Revival and conservation of traditional water harvesting structures through scientific management and community engagement is increasingly being taken up as an important avenue for averting water resources crises.

AGRICULTURE

The agriculture sector assumes critical significance in India, not only from the perspective of addressing the food security of its rising population but also maintaining the farm based livelihoods on which nearly 60 per cent of its population depends. Nearly 85 per cent of the land under agriculture is in the form of small farms that make it challenging and economically unviable to introduce improved, resource efficient and productivity enhancing agri-technologies. Besides, these small farmers generally lack both the skills and the investment capacities that would be required for the same. About 60 per cent of India's agriculture is rainfed in nature and lacking in surface water based irrigation infrastructure, resulting in tremendous pressure on the ground water resources as reflected in the statistic that 91 per cent of the ground water draft is on account of irrigation.

Agriculture being sensitive to shift in seasons and climate variability, not to mention disaster events such as drought, flood and hailstorms is already widely witnessing the emergence of climate change as the greatest threat, and one that is projected only to intensify further in the near future. This is getting manifested as decline in productivity, total crop losses and the shifting of suitable growing zones and thereby resulting in immense economic and livelihood loss. Besides being sensitive to the changes in the environment, the sector itself has been contributing significantly to land use changes converting natural ecosystems to managed ones, depletion of natural resources and GHG emissions and thereby climate change. The objective of increasing production and productivity in order to meet food security goals has been the major driver of this assault on the natural resource base.

To minimize the impact of climatic and environmental stressors on the sector, India has made large investments in research for genetic enhancement of major crop varieties to introduce traits of tolerance to drought, flood, salinity and heat related stresses. Extension services for the large scale adoption of such technologies and enhanced engagement of scientists in understanding and responding to farmers' needs have been promoted with positive results including in the form of scientific validation and inclusion of traditional practices within mainstream systems. Organic modes of cultivation and climate adaptive technologies and approaches are being encouraged through capacity building and financial, extension and market linkage support with an eye on minimizing the ecological footprint while enhancing farm returns. Increasing the productivity of rainfed areas, securing the natural resource base, modernisation of agriculture and the introduction of financial instruments to enable farmers access to credit and insurance are crucial elements of the strategic orientation being adopted in policies towards meeting the food security requirements of the country. Capacity building and interlinking of community based institutions, rural banks and local governance institutions can play an important role towards meeting these objectives.

ENERGY

Much of India's development ambitions will be contingent upon the availability, including at the last mile, of adequate quantum of reliable energy. Yet, about 600 million people in India or half of its population today do not have access to electricity and about 840 million people are still dependent on biomass as their primary source of cooking fuel. On the positive side, the share of renewable energy in the energy mix of the country has seen an exponential rise from 3.7 per cent to 14.2 per cent over the last seven years.

The energy sector contributes about 71 per cent to the overall GHG emissions profile of the country. Fossil fuels are meeting about three quarters of the energy demand in the country and of the 600 billion KWh of electricity generated, about 70 per cent is generated from coal, one of the most polluting and emission intensive of all energy sources. Obsolete technologies with poor efficiencies, along with transmission and distribution losses that stand at about 21 per cent, constitute the major factors behind the emission intensity of the sector.

With India's power generation expected to peak at 400 GW in response to the rise in demand, there is a urgent need to reduce the environmental impact of the sector, and multifaceted effort is required including stepped up promotion of energy efficiency, investment in technologies for improving production efficiencies and minimizing of transmission and distribution losses. Several central schemes have already been introduced towards these ends. India's renewable energy capacity in 2014-15 was 42,849 MW but by 2020, just solar energy generation is expected to exceed the 100 GW milestone, contributing handsomely to the intended nationally determined contributions to climate change mitigation. However, such projections also calls for preemptive planning for the management of the associated hazardous waste generation that may be expected and facilitative renewable energy policy and infrastructure that address in a differentiated manner the various consumer segments such as residential, commercial and industrial.

INDUSTRY & MINING

Following the global financial crisis, the recovery of the industrial sector in India since 2011-12 has been led by the manufacturing and mining sectors. The government too has been promoting growth in the manufacturing sector initiatives such as 'Make in India' programme, labour sector reforms and streamlining of the process for obtaining environmental and forest clearances for industrial and infrastructural projects.

About 70 per cent of the industrial pollution in the country stems from the industries categorized as micro, small and medium enterprises (MSME) and which comprise the bulk of the manufacturing industries. The rising trend in industrial production is expected to overload natural sinks with wastes and pollutants leading to severe detrimental effect on environmental health and deterioration in ambient conditions. Industry associated resource extraction pressures, primarily including the mining of natural resources, are in several cases crossing the limits of sustainable extraction and leading to damage to land, water and air thereby causing habitat disturbance. A major factor behind the rise in industrial pollution has been non-compliance with regulations for pollution control and remediation, especially in power, cement, iron, steel, distilleries and sugar industries.

Managing the environmental footprint of the rapidly expanding industrial and mining sectors will necessitate the improvement of efficiencies to maximise output while minimizing wastes. This calls for cleaner technologies with lower GHG emissions footprint and higher resource efficiency and the recycling of wastes as secondary raw materials. The orientation is towards the creation of a facilitative environment for the wider adoption of such technologies through policy instruments that will pave the way for decoupling growth from environmental degradation.

URBANISATION

The trend of urbanisation in India has taken a path of near exponential growth, fueled by an expanding population and rapid industrial growth. Most of our urban agglomerations are experiencing severe resource stress and some have already crossed their carrying capacity. High rate of migration to the urban centers have led to rapid population increase that has in turn led to the creation of slums, characterized by some of the highest figures for population per unit area and a severe lack or shortage in basic infrastructure.

Urbanisation has brought in its wake a slew of environmental challenges that is a direct outcome of the low per capita resource and infrastructure availability in these urban agglomerations. Some of the major issues include depleting water tables, deteriorating water quality, increasing air pollution, inadequate waste management and inordinate congestion in the built environment. Slums majorly add to this scenario through pollution of waterways, creation of open waste dumps, creation of heat islands and the hindering of resource recovery and recycling. The impacts of these multifarious environmental effects are manifest in the drastic reduction in green belts in and around these areas and high incidence of pulmonary, water borne and vector borne diseases amongst others.

The management of urban areas is being coordinated by the urban development authorities that were set up in the 1990s and JNNURM has been the flagship programme for urban renewal in selected cities across the country. Efforts towards reducing or mitigating the impacts of urbanisation in India have included some positive examples of service delivery and environment restoration. The National Urban Sanitation Policy launched in 2008 has helped address the critical issues of water and sanitation in urban areas through efficient service delivery and infrastructure establishment. The recent past has witnessed a launch of number of programmes for urban renewal, including amongst others, Swachh Bharat Mission with a focus on sanitation, Smart Cities Programme with a focus on planning and technology based solutions and improved governance, the National Transportation Policy launched in 2014 and programmes for establishment of urban housing infrastructure. Promoting citizen awareness and engagement on environmental issues feature as integral elements in many of these programmes and is geared towards the protection and restoration of urban environmental health, especially in the space of sanitation, waste management and the reduction of vehicular pollution.

ENVIRONMENTAL POLLUTION

The spate of environmental pollution in India is largely driven by the trend of rapid and unregulated industrialisation and unplanned urbanisation and it is emerging as a major hazard to human and ecological health. The capacities of natural sinks to absorb and regulate, and available infrastructure to treat wastes discharges and emissions from urban and industrial centers is being challenged and overwhelmed. CPCB has identified 17 highly polluting industries that have been placed in the red category. At last count, there are 3,260 highly polluting industrial units of which only 929 have installed pollution abatement devices and only 920 have installed real time monitoring systems.

Levels of particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and ozone in the air have continued to routinely exceed national standards, especially in urban areas. Dependence on coal fired thermal plants for power generation, industrialisation, vehicular growth, burning of agricultural wastes and the continued dependence of 87 per cent of rural and 26 per cent of urban households on biomass for meeting their energy needs are the primary causes for the situation. Noise pollution is also a rising environmental nuisance in urban and industrial spaces.

Generation of municipal solid waste (MSW) has witnessed an increase of more than 200 per cent from 39,031 TPD in 2001 to 81,073 TPD in 2011. More than 81 per cent of MSW is generated by Class I cities. Electronic waste or e-waste is another emerging area of concern in India with volumes being generated rising almost exponentially. The issue is further compounded by the inclusion of new e-waste streams such as spent CFLs that are additionally associated with hazardous substances like mercury. Increasing population and thereby generation of wastes, inadequate and unscientific management regimes, poor public awareness and a dynamically evolving profile in terms of composition are key drivers of waste management emerging as one of the most critical environmental challenges.

Water quality and pollution of water sources is a critical concern for India with over 70 per cent of the surface water and an increasing percentage of ground water sources being contaminated. Microbial contamination is the major form of surface water pollution in India and the primary cause is the discharge of domestic sewage into water streams. Arsenic and fluoride are the most significant inorganic contaminants with 96 districts in 22 states affected by high level of arsenic in ground water and 14 states reporting levels of fluoride beyond permissible limits. Other emerging threats are posed by iron contamination and nitrate pollution that is largely due to leaching of fertilisers into agricultural runoff. Overdraw of water due to increasing demand from industry and agriculture is also having negative impact on water quality because of lower rates of dilution.

Besides the immense public health impacts of environmental pollution, there is considerable evidence that environmental pollution is impacting human productivity and economic growth. A World Bank study suggests that the annual cost of air pollution alone is equivalent to 3 per cent of India's GDP and this represents about 52 per cent of the relative share of damage cost by environment category. Mitigating the grim scenario with respect to environmental pollution will require not only improved enforcement of environmental regulation along with appropriate punitive action on the principle of 'polluter pays' but also the promotion of enabling environment through improvement in access of technological solutions, awareness, education and capacity building.

CLIMATE CHANGE

India has been less of a driver of global climate change by way of GHG emissions, and on the contrary, its forests contribute significantly to the global carbon sink. The energy sector is the largest contributor to the GHG emissions of the country at 71 per cent followed by agriculture at 18 per cent. In terms of variation in climate, mild variation in the form of increasing temperatures and erratic rainfall patterns have been registered. The projections for the country indicate that it is at risk from both rapid and slow onset and extreme climate events and may expect a further increase in temperatures and higher frequency of cyclonic disturbances.

The impacts of climate change continue to be manifested across many sectors, with vulnerable sectors such as agriculture, water and natural ecosystems being the most affected with consequent socio-economic repercussions. India, as a developing nation, is one of the countries with highest vulnerability to climate change and the situation is exacerbated by its increasing population. Increasing frequency of floods, droughts, cyclones and storm surges, accelerated coastal erosion, increasingly rapid glacial retreat in the Himalayas and the slow march of desertification across the country's drylands are some of the physical impacts being attributed to climate change. While the research on these linkages is not yet conclusive, a pattern of correlation is becoming increasingly evident. All of these impacts along with climate variability is having further downstream negative impacts on human health, livelihoods and the economy.

Managing the impacts of climate change has become critical to the realization of the country's goals for socio-economic development. Response measures are being taken on the parallel fronts of both adaptation to and mitigation of climate change. India's Intended Nationally Determined Contribution in the Paris Agreement commits an ambitious reduction by 20-25 per cent in the GHG emissions intensity of its GDP by 2020 as compared to 2005. Between 2005 and 2010, India already reduced its emissions intensity by 12 per cent. As of 2015, both the NAPCC and the SAPCCs have been revisited and four new missions on wind energy, human health, waste to energy and coastal resources have been introduced. The encompassing nature of climate change and its impacts means that not only will appropriate response have to be framed within sectors to manage the specific impacts but synergies in the response strategy will have to be worked out for an overall reduction in climate risk. The critical challenge for India in addressing climate change lies in the raising of resources in terms of both finances and technology access while in parallel, investing in climate change research, education, communication and systems for monitoring and evaluation.

CONCLUSION

While this Executive Summary has attempted to provide a brief overview of the state of environment in the country and touched upon some of the major issues and responses in each of the sectors under assessment, the following chapters will be able to supply more detailed information and in-depth analysis of these issues along with illustrative data sets. The message however that is already emerging is that of the importance of managing the country's environment, especially in the SDGs context, in not only protecting the ecological base but also in enabling sustainable socio-economic progress of the country. This message brings into relief the critical importance of adopting cross-sectoral integrated approaches in development, potentially using the SDGs as one of the guiding frames and investing in creating a conducive environment for such collaborative effort. It also calls for enhanced participatory engagement of a wider range of stakeholders from the grassroots to the apex levels in the management of the environment through community based approaches, complemented with investment in building their awareness and capacities. Complementary effort in promoting and incentivizing the adoption of technologies with lower environmental footprint will also support to achieve a safe environment for current and future generations.

OVERVIEW

INTRODUCTION

India is one of the oldest civilizations in the world with a rich, varied and unique culture. It is a vast country with great diversity in physical features that include amongst others, dry deserts, evergreen forests, snow-clad mountains, a long coast and fertile plains. India's economy has been growing at an average GDP growth rate of 8.025 per cent for the last eight years (Ministry of Finance, 2014-2015). The urban population has increased from 286.1 million in 2001 to 377.1 million in 2011, with the annual growth rate of urban population being 2.76 per cent in 2011. Rapid urbanisation has resulted in environmental degradation through increased pressures on the limited land resources that are available. This has led to reduction in open spaces, increase in air and water pollution and problems of management and disposal of waste.

LOCATION

India extends over a stretch of 3,214 km from north to south, and 2,933 km from east to west, occupying a total land area of 3,287,263 km^2. Located in the northern hemisphere, India stretches from 37°06' N to 08°04' N latitude with the mainland extending from Kashmir in the North to Kanyakumari in the South. Indira Point in Car Nicobar is the southern-most point of the country. India extends from 68°07' E to 97°25' E longitude, i.e. from Gujarat in the West to Arunachal Pradesh in the East. India is surrounded by water on three sides, i.e. by the Bay of Bengal in the East, the Arabian Sea in the West, and the Indian Ocean in the South. In the North, India is land-locked by the Himalayas. India shares its boundaries with China, Nepal and Bhutan in the North, Myanmar and Bangladesh in the East, Pakistan in the West, and Afghanistan in the North-West. Amongst neighboring island countries, Sri Lanka is situated in the South and Maldives lies to the South-East. India has trade relations as well as cultural links with all its neighbouring countries.

CLIMATE

The climate of India may be broadly described as tropical monsoonal type and four seasons are identifiable:

- Winter (January-February)
- Summer (March-May)
- Monsoon (June-September)
- Post-Monsoon (October-December)

The climate of India is affected by two seasonal winds - the South-West Monsoon and the North-East Monsoon. The South-West Monsoon, also known as the summer monsoon, blows from the sea to the land after crossing the Indian Ocean, Arabian Sea, and the Bay of Bengal whereas the North-East Monsoon, commonly known as the winter monsoon, blows from the land to the sea. The summer monsoon brings most of the rainfall during a year in the country.

PHYSIOGRAPHY

India is a country of diverse and varied landforms that include torrid plains, tropical islands, long stretches of coastline, parched desert and the highest mountain ranges in the world. On the basis of physical features, India can be divided into following six physiographic regions:

- The Northern Mountains
- The Northern Plains
- The Peninsular Plateau
- The Indian Desert
- The Coastal Plains
- The Islands

DRAINAGE SYSTEMS

The drainage system refers to the system of flow of surface water, mainly through rivers. On the basis of origin, the drainage system in India can be divided into two parts:

- The Himalayan Drainage System
- The Peninsular Drainage System

The Himalayan Drainage System

Most of the rivers originating in the Himalayas are perennial, i.e. they have water throughout the year. This is because most of these rivers originate from glaciers and snow peaks and also receive water from rainfall. These rivers are a major source of water for irrigation. The main river systems in this category are:

- The Indus River System – Jhelum, Ravi, Beas and Satluj
- The Ganga River System – Yamuna, Ramganga, Ghaghara, Gomti, Gandak, Kosi
- The Brahmaputra River System – Dibang, Lohit, Tista, Meghna

The Peninsular Drainage System

Most of the peninsular rivers flow eastwards and drain into the Bay of Bengal. Narmada and Tapi are the exceptions that flow westwards and through the Western Ghats to drain into the Arabian Sea. These rivers have significant hydropower generation potential as they have many rapids and waterfalls. The other major peninsular rivers are Mahanadi, Godavari, Krishna and Kaveri.

The Deccan Plateau rivers are rainfed. The coastal rivers, especially those on the western coast, are short and do not retain water throughout the year. The rivers in the inland drainage basin of western Rajasthan are also rainfed and normally drain into silt lakes.

NATURAL RESOURCES AND AREAS OF ECOLOGICAL IMPORTANCE

India is richly endowed with biotic and abiotic resources such as minerals, energy sources, forests and biological resources. The plains are a fertile source for agriculture, the peninsular plateau has abundant reserves of minerals, the mountains give rise to perennial rivers and the oceans and forests sustain a huge variety of flora and fauna. India is one of the leading producers for many minerals and ranks amongst the top ten countries in the world for production of bauxite, iron ore and steel. The country also houses many indigenous species of plants and animals that enriches its natural heritage. It has a host of biodiversity hotspots that have immense ecological value and harbour many endemic species. India also has several natural world heritage sites such as the Sunderbans.

BIODIVERSITY

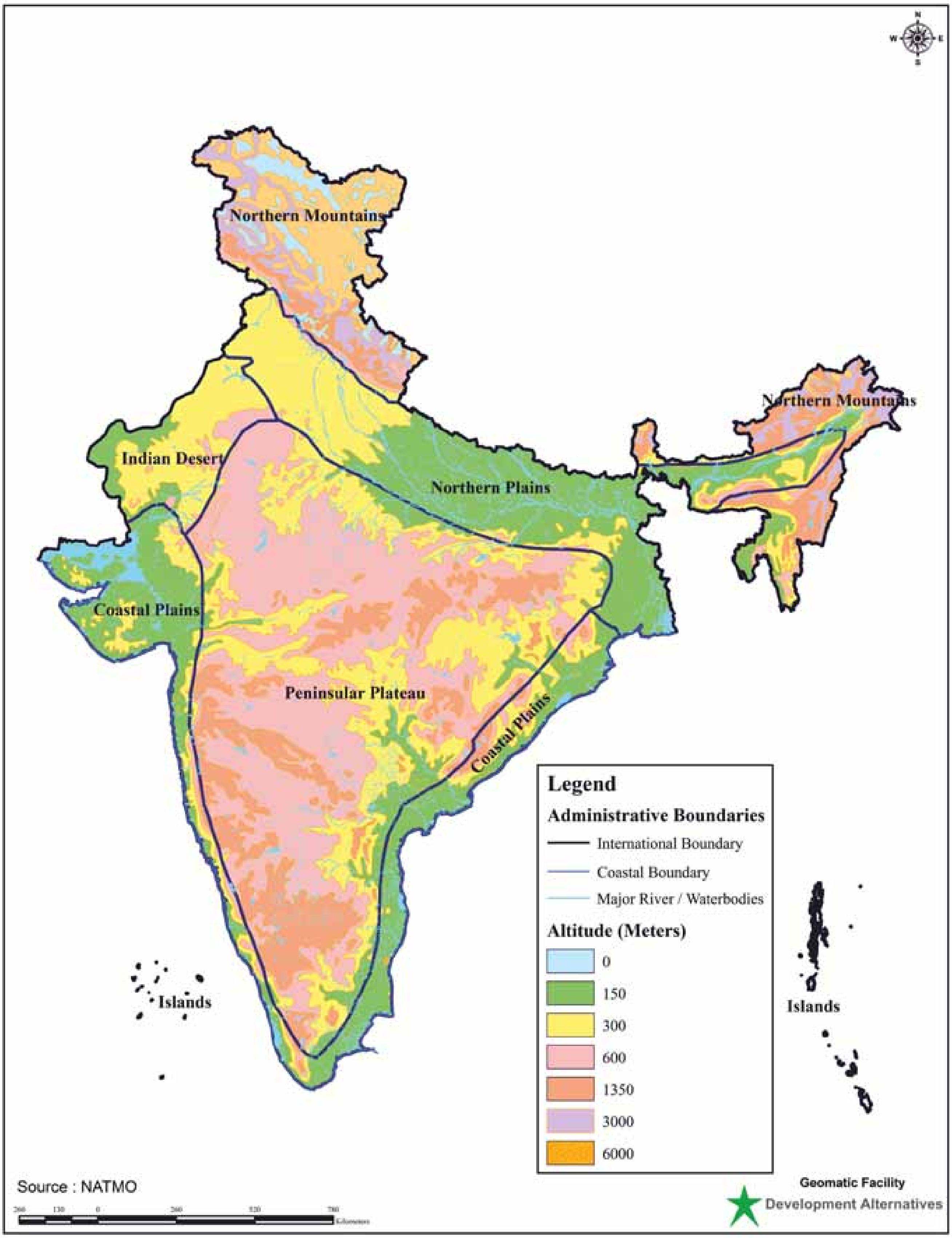
India is one of the mega-diverse countries of the world, harboring nearly 7-8 per cent of the recorded species of the world, and representing four of the 34 globally identified biodiversity hotspots. The country is also a vast repository of traditional knowledge associated with biological resources. So far, over 91,200 species of animals and 45,500 species of plants have been documented across the ten biogeographic regions of the country. Inventories of floral and faunal diversity are being progressively updated with several new discoveries through the conduct of continuous surveys and exploration. Besides species richness, India also demonstrates high rates of endemism. India is also recognized as one of the eight Vavilovian Centers of Origin and Diversity of crop plants, having more than 300 wild ancestors and close relatives of cultivated plants.

The varied edaphic, climatic and topographic conditions and years of geological stability have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, deserts and seas and coasts. Arid and semi-arid regions represent 38.8 per cent of India’s total geographical area.

POPULATION

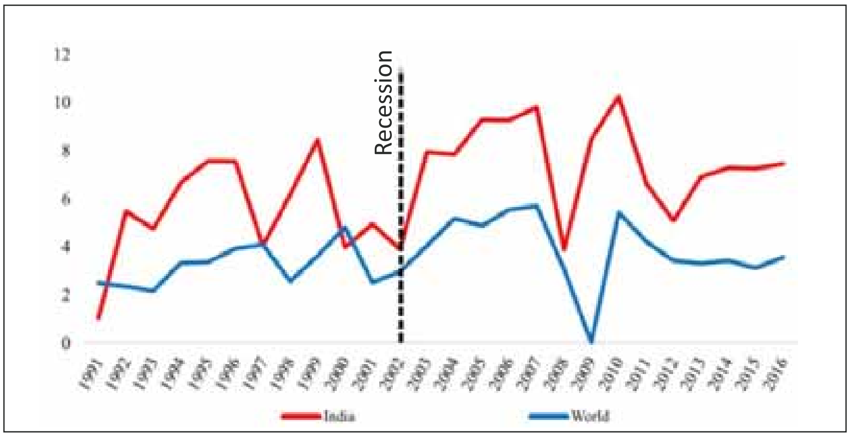
India supports 17 per cent of the world’s population on just 2.4 per cent of the total land area on the planet. The population of India is 1.210 billion with 51.54 per cent males and 48.46 per cent females. Sex ratio per 1000 males is 940. The population density is 382 persons per square kilometer and the decadal population growth rate is 17.64 per cent. As per the Human Development Index (HDI) Report 2015, India has a medium level of human development with an index of 0.609 and its global rank is 130. About 74.4 per cent of India’s population is literate with a significant gap of approximately 15 per cent between urban and rural populations.

Map I: Physical Map of India



Source: National Atlas and Thematic Mapping Organization, 2011

Figure I : Economic Growth in India and the World between 1991-2016



Source: National Atlas and Thematic Mapping Organization, 2011

Table I: Health of Indian Economy

Key Indicators	2012-13	2013-14	2014-15
Growth Rate (%)	5.1	6.9	7.4
Per Capita Net National Income (INR; at current market prices)	71,593	80,388	88,533

Source: Economic Survey of India, 2014-15

ECONOMY

Despite the poor economic growth witnessed across the world since 2006, India demonstrated a remarkable economic growth rate of 8.7 per cent per annum between 2004-05 and 2009-10. Gross Domestic Product (GDP) grew by 7.0 per cent in the first quarter of the financial year 2015-16, making India the fastest growing large economy in the world. The World Bank has predicted a growth rate of 8 per cent for India by 2017 (Press Trust of India, 2015).

One significant indicator of this economic development is the considerable decline in the population living below the poverty line between 2004-05 to 2011-12, evident in Figure II.

India is an agrarian economy and agriculture, forestry and fishing together contributes 17.4 per cent to Gross Domestic Product.

KEY ENVIRONMENTAL CONCERNS

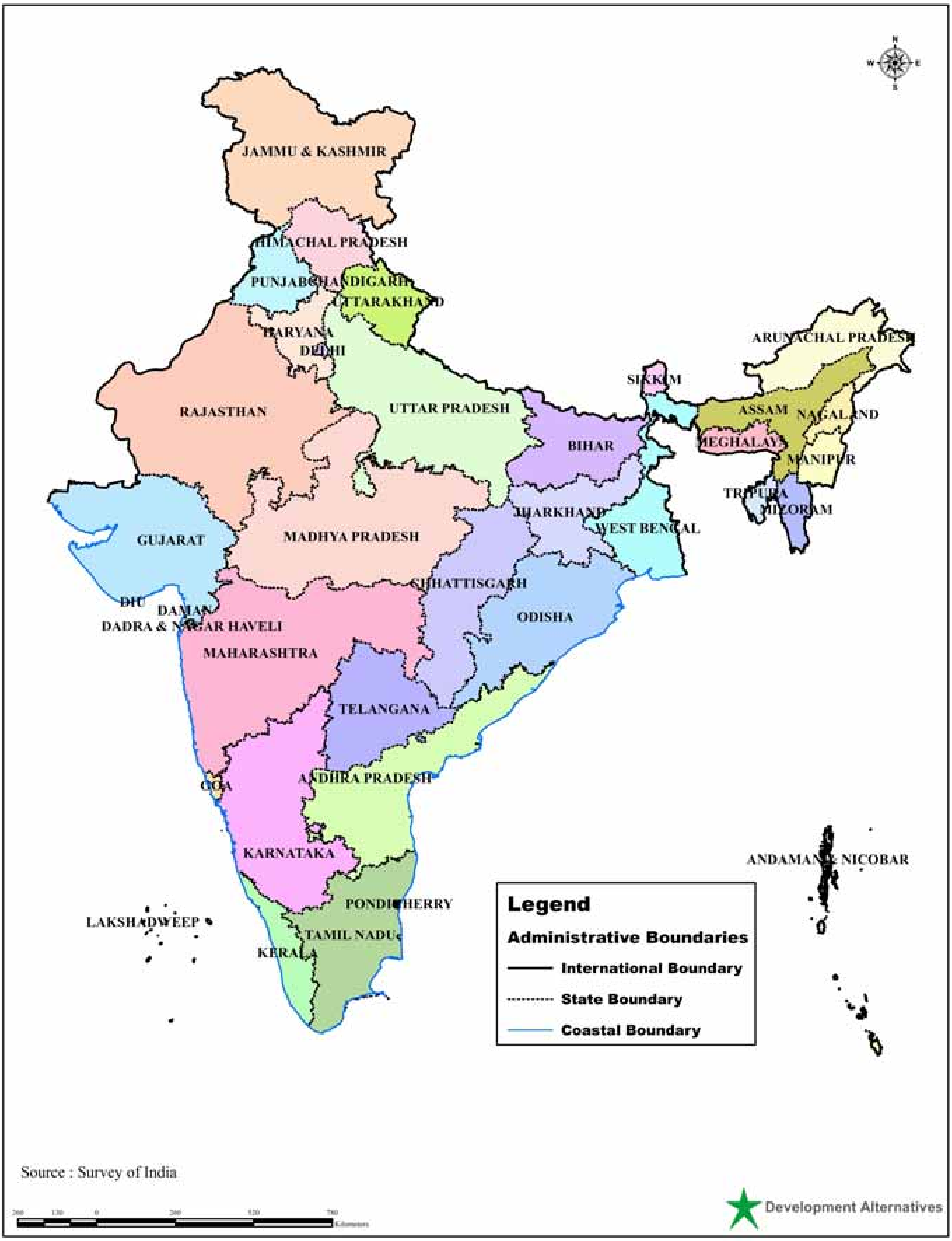
India faces the challenge of providing for its ever-growing population and maintaining economic growth while also protecting its natural environment and mainstreaming sustainability in its management of natural resources. As has often been said, poverty is the greatest polluter, and for a country where 28.3 per cent of the population lives below the poverty line, protecting the environment emerges as a critical challenge (Ministry of Social Justice and Empowerment, 2016).

Issues of climate change, rapid urbanisation, improper solid waste management, deforestation, loss of biodiversity, contamination of air and water and environmentally damaging mining and industrial activities constitute major challenges for India as also in the global context. Though these issues are prevalent across the country, the scale of its manifestation and impacts vary between regions and states and are also influenced by the level of economic development and the response of the government.

ENVIRONMENTAL GOVERNANCE

As economic growth and development continue to exert pressures on the natural resources of the country, there is a need for environmental governance to balance the often competing priorities of environment and development. India has a multilateral environmental governance system with distribution of legislative powers between the central and the state governments. The Ministry of Environment, Forests and Climate Change is the nodal ministry for national legislation and action on environmental issues and it is also responsible for meeting and reporting on the nation's commitments made under various international agreements on environmental protection and sustainable development.

Map II: Political Map of India



Source: National Atlas and Thematic Mapping Organization, 2011

Figure II: Population Below Poverty Line (in millions)

Source: Planning Commission, 2011-12

CULTURE

India has a rich and diverse cultural heritage that has preserved the age-old traditions while absorbing new influences from immigrating and invading cultures over millennia in a syncretic manner. Many of the customs, traditions and cultural expressions have evolved in response to the environmental and seasonal transitions observed in nature. Principles of a sustainable way of life that is attuned to the rhythms of the natural environment have thus become intrinsic to the various manifestations of the traditional ways of living. India is also a treasure house of traditional knowledge pertaining to the use of biological and other natural resources.

SUSTAINABLE DEVELOPMENT GOALS – THE INDIA CONTEXT

India has committed itself to the Post-2015 Development Agenda, agreeing in principle to achieve the seventeen Sustainable Development Goals by 2030. These goals address various socio-economic and environmental outcomes ranging from food security, access of basic needs such as water, energy, education and environment health including the state of both terrestrial and aquatic ecosystems. It also includes goals on economic growth, urbanisation and industrialisation to ensure these processes are in alignment to the natural and human endowments available for the well being of people and the planet.

According to the Global Footprint Network, in 2012, India's ecological footprint exceeded its bio-capacity by 160 per cent. With 70 per cent of surface water being polluted and 60 per cent of ground water sources expected to be in critical state by the next decade, there is an impending water crisis at India's doorstep (Asia Development Bank Institute, 2012).

Many of the seventeen goals, such as those that address concerns of agriculture and food security, water and energy for all, sustainable habitats, healthy terrestrial and marine ecosystems concern sectors that are vulnerable to the common concern of climate change. The achievement of targets against these goals will be influenced by climate change as manifested in changing weather patterns and water availability. Conversely, the country's performance against many of the targets will also impact its ability to realize its climate mitigation targets.

The 2030 Agenda for Sustainable Development presents an opportunity for India to align its national plans and development trajectory with the principles of sustainable development, and thereby ensure the well being of its people and the planet. At the same time, India's commitments at COP 21 position it on a low carbon pathway and an inclusive economy.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 1

LAND AND FORESTS

Key Messages

- *India has low per capita availability of land that manifests in pronounced anthropogenic pressures on the natural resources represented in land.*
- *The extent of land degradation in the country is 96.40 Mha and the states of Goa, Gujarat, Rajasthan and Jharkhand have highest percentage of land under degradation.*
- *The area undergoing desertification is 82.64 Mha which constitutes 25.14 per cent of the country's geographical area.*
- *Loss from soil erosion increased from 3,000 million tonnes in 1980's to 5,300 million tonnes in 2010.*
- *The forest cover in India is 21.34 per cent of its total geographic area.*
- *From 2011-14, the contribution of forests and logging to India's GDP has shown slight decline from 1.53 per cent to 1.38 per cent.*
- *Odisha, Madhya Pradesh, Maharashtra, Telangana and Assam are some of the states that have displayed highest vulnerability to forest fires.*
- *24.6 Mha of forest is under the management of more than 100,000 Joint Forests Management Committees.*

1.1 INTRODUCTION

Land and forests comprise one of the basic elements of life's support systems on our planet. Forests are major repositories of biodiversity and provide essential goods and services to mankind. India measures 3,214 km from North to South and 2,933 km from East to West, and it possesses a land frontier of 15,200 km, and a coastline of 7,517 km. The total forest cover of India is 701,673 sq. km, which is 21.34 per cent of the total geographical area that stands at 3,287,263 sq. km. Though India is the seventh largest country in the world, yet in terms of population, it ranks second with a population of 1.21 billion people (Census, 2011). High rate of population growth has had repercussions both on the nature of land use and per capita land availability.

Forests are fundamental for the food security and livelihoods of millions of people. They support sustainable agriculture and human well being by stabilizing soils and climate and regulating water flows. Forests are invaluable renewable natural resources. The direct benefits of forests include the provisioning of fuelwood, timber, bamboo, food etc. The indirect benefits from forests include conservation of soil, soil improvement, reduction of atmospheric pollution, control of climate, control of water flow etc. Population explosion poses a grave threat to land and forests. Large scale deforestation leads to destruction of habitat for wild animals and increased soil erosion, as a consequence of reduced vegetation cover. Forests minimize soil erosion, thereby reducing sediment load in runoff and consequently, siltation.

India's intended nationally determined contribution for forestry sector envisages creation of additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 (Ministry of Environment Forests and Climate Change, 4th December, 2015).

1.2 STATUS

Land

1.2.1 Land Use Pattern

Land use refers to the various uses and management regimes for land resources, as adopted by humans. Land cover refers to what is on the land surface, whether it be natural such as forests, water bodies, rock and soil or human induced such as agriculture, construction etc. Land use is generally based on the land cover and the terms are often interchangeably used. Land use and land cover (LULC) information is

Photo 1.1: Pristine Forests

essential for the identification, planning and implementation of land management strategies that are required to meet the increasing demands for basic human needs and welfare of the ever growing population.

In 2013, agricultural land occupied a major part of the land i.e. 53.7 per cent with gross cropped area accounting for 43.96 per cent. Area under kharif or monsoon crop was 120.7 Mha, while rabi cropped area or winter cropped area was 93.2 Mha. Forests, water bodies and snow covered areas occupied 20.41 per cent, 2.34 per cent and 2.26 per cent respectively of total land in 2013 (NRSC, 2013).

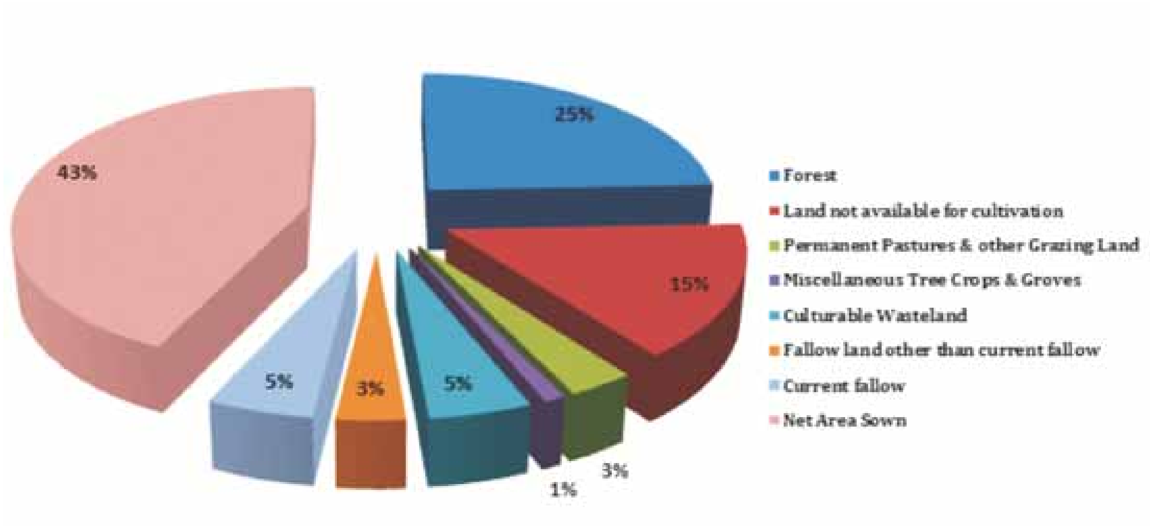
Changes in land use patterns are closely associated with corresponding changes in the environment; and are also influenced by physical, social and economic changes. In India, the factors that have contributed predominantly to changes in land use include changes in forest cover; and the diversion of land for agriculture as well as for non-agrarian purposes such as urbanization, industry and mining.

In 2011, India's population reached 1.21 billion, while net sown area was about 140 Mha in 2012-13 indicating a per capita availability of about 0.12 ha which is about half of the global average of 0.23 ha (GoI, 2015). According to the land use statistics of the Ministry of Agriculture, GoI, agricultural land of nearly 3.16 Mha was lost to other sectors in the years between Triennium Ending (TE) 1991-92 and TE 2012-13 (GoI, 2015). Land classified as non-agricultural use, includes land under settlements (rural and urban), infrastructure (roads, canals etc.), industries, shops etc. On the other hand, area under non-agricultural uses increased by over 5 Mha from 21.3 Mha to 26.4 Mha, during the same period. Taking into account the additional area of about 2.4 Mha added by reclamation and rehabilitation of culturable wastelands, it is estimated that a total net sown area of about 4 Mha or 0.18 Mha per year has been lost during the last two decades. The culturable wastelands include land for cultivation. The total cultivated land consists of net sown and current fallows. Current fallow represents cropping area which is kept fallow during current year. Net sown area represents total area sown with crops and orchards. Area sown more than once in the year is counted only once. Cultivable lands (175 Mha) make

Economic Valuation of Indian Forests

In order to compensate the forest and ecosystem services loss due to conversion of forest land to non forest use, the Indian Supreme Court commissioned and economic valuation study of Indian forest. After detail deliberation a system of evaluation of ecosystem service, which are expected to be lost, due to diversion, had been evolved. Rates of ecosystem services area calculated based on density, and type of forests. This value is charged from the user agency for diversion of forest land for non forestry purpose, in form of Net Present Value. Besides compensatory afforestation charges and land are ensured so that the loss of tree cover is compensation appropriately. The compensation are deposited in the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) fund and subsequently released by Adhoc CAMPA to the State as per approved Annual Plan of Operation.

Figure 1.1: Land Use Distribution (2012-13)



Source: Ministry of Agriculture (2012-2013) up almost 60 per cent of the total Indian territory, 80 per cent of which is under crops (141 Mha), and six per cent (10 Mha) of which is under rangelands. The remaining cultivable lands are not cultivated. Forests (70 Mha) are the second most important land cover category, making up about a quarter of the total area.

Figure 1.1 shows that the largest category, at 42.6 per cent, is net sown area, which does not include the land under tree crops and groves. The second largest category is forests at 21.3 per cent. Eight per cent is under non-agricultural usage while 5.3 per cent is barren and unculturable land.

1.2.2 Land Degradation Status

Land is considered to be degraded when it suffers a deterioration of its intrinsic qualities or a decline in its productive capacity. Land degradation may be caused by either natural or human factors or a combination of both. Desertification refers to land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors; including climatic variations and human activities leading to loss of productive ecosystems and biodiversity. The extent of land degradation in the country is 96.40 Mha, including 36.10 Mha under water erosion and 18.23 Mha under wind erosion, which are amongst the major causes of degradation.

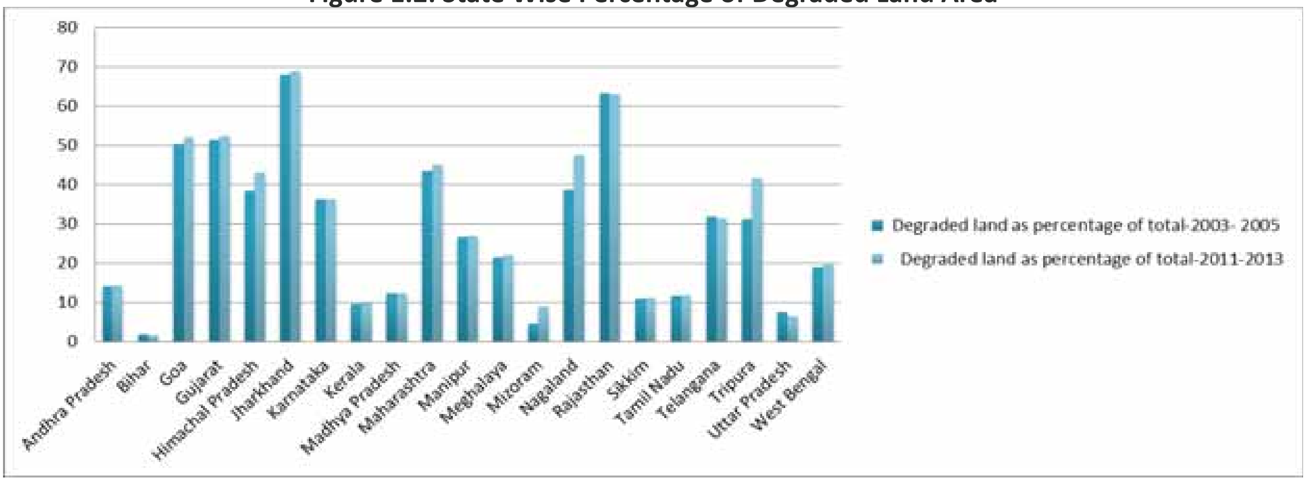
The data indicates that states like Goa, Gujarat, Rajasthan and Jharkhand have the highest percentage of land under degradation. There has been a cumulative increase of 1.87 Mha under land degradation in the country between 2003-05 and 2011-13. The change analysis carried out for the period indicates that around 1.95 Mha has been reclaimed, and 0.44 Mha has been converted from high severity to low severity degradation class. On the other hand, around 3.63 Mha productive lands have degraded, and 0.74 Mha land has converted from low severity to high severity degradation class.

Table 1.1: Ownership and Extent of Degradation for Key Land Use Categories

Category	Area in Mha	Ownership and Status of Degradation
Area Under Forests	67 Mha (22.0 %)	Almost entirely owned by government, about 40 per cent with canopy cover below 40 per cent, 5 Mha considered encroached or under shifting cultivation
Cultivated Area	142 Mha (46.7 %)	Private ownership, about 100 Mha is rainfed, subject to water and wind erosion
Culturable Wasteland + Pastures + Groves	38 Mha (12.5 %)	Groves privately owned; others vested with government (Revenue Department) or village councils, are in the nature of open access and highly degraded, sometimes encroached.
Fallow Land	17 Mha (05.6 %)	Private ownership but degraded

Source: Planning Commission 2013

Figure 1.2: State Wise Percentage of Degraded Land Area



Source: Desertification & Land Degradation Atlas of India (based on IRS Advanced Wide Field Sensor data of 2011-13 & 2003-05)

High levels of increase in land degradation by 4.34-11.03 per cent was observed in the states of Delhi, Tripura, Nagaland, Himachal Pradesh and Mizoram; whereas Odisha, Rajasthan, Telangana and Uttar Pradesh noted reduction in percentage of land under degradation by 0.11-1.27 per cent (Desertification & Land Degradation Atlas of India based on IRS AWiFS data of 2011-13 & 2003-05).

The area undergoing desertification is 82.64 Mha which constitutes 25.14 per cent of the country's geographical area. As indicated in Table 1.2, water erosion is the most significant contributor to desertification, followed by vegetation degradation and wind erosion. Between 2003-05 and 2011-13, there has been an increase of 1.16 Mha under land degradation.

The estimates of land degradation in India by different agencies vary widely from about 53 Mha to 188 Mha, mainly owing to different approaches, or differentiating criteria adopted in defining degraded lands.

Table 1.2: Area under Desertification

Process of Degradation	Area under Desertification (Mha)							
	2003-05				2011-13			
	Arid	Semi-Arid	Sub-Humid	Total	Arid	Semi-Arid	Sub-Humid	Total
Vegetation Degradation	2.81	13.39	6.34	22.55	2.86	13.48	6.65	22.99
Water Erosion	3.12	17.07	8.91	29.11	3.03	17.51	8.97	29.51
Wind Erosion	17.72	0.57	0	18.3	17.63	0.56	0	18.19
Salinity / Alkalinity	2.52	1.07	0.21	3.8	2.52	0.86	0.09	3.48
Waterlogging	0.02	0.08	0.25	0.36	0.02	0.08	0.31	0.42
Mass Movement	0.76	0.11		0.87	0.84	0.11	------	0.96
Frost Shattering	2.74	0.43	0.01	3.18	2.94	0.46	0.01	3.41
Man Made	0.04	0.14	0.14	0.32	0.94	0.14	0.16	0.35
Barren	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58
Rocky	0.29	0.97	0.02	1.28	0.3	0.97	0.02	1.29
Settlement	0.07	0.75	0.33	1.15	0.11	0.93	0.44	1.47
Grand Total	**30.35**	**34.85**	**16.28**	**81.48**	**30.54**	**35.4**	**16.7**	**82.64**

Source: Desertification & Land Degradation Atlas of India, 2016

Table 1.3: Forest Cover as Percentage of Geographical Area

Forest Class	Area (sq. km)	Percentage of Geographical Area
Very Dense Forest (VDF)	85,904	2.61
Moderately Dense Forest (MDF)	315,374	9.59
Open Forest (OF)	300,395	9.14
Total Forest Cover*	701,673	21.34
Scrub	41,362	1.26
Non-forest	2,544,228	77.40
Total Geographic Area	**3,287,263**	**100.00**
*Includes 4,740 sq. km under mangroves		

Source: India State of Forest Report, 2015

Forests

1.2.3 Forest Types and Diversity

Forests in India range from the moist evergreen forests in the southern tip of the Western Ghats to the evergreen forests in the North-East; and the temperate and high mountain forests of the Himalayas in the North, to the desert and scrub forests in the West. Dry deciduous and semi-moist deciduous forests are found in Central India, which transition to coastal forests, and mangroves along the coasts and islands.

Climate, soil type, topography, and elevation are the main factors that determine the type of forest. Forests are classified according to their nature and composition; the type of climate in which they thrive; and its relationship with the surrounding environment. Indian forests contain 15 major forest types. These include Tropical Wet Evergreen, Tropical Semi-Evergreen, Tropical Moist Deciduous, Littoral and Swamp, Tropical Dry Deciduous, Tropical Thorn, Tropical Dry Evergreen, Sub-Tropical Broad-Leaved Hill, Sub-Tropical Pine, Montane Wet Temperate, Himalayan Moist Temperate, Himalayan Dry Temperate, Sub-Alpine, Moist Alpine Scrubs (India State of Forest Report, 2015).

1.2.4 Forest Cover

As per the latest estimate by Forest Survey of India (FSI), in 2015, the forest cover stood at 21.34 per cent of India's total geographical area, with a marginal rise from 20.05 per cent in 2009. Forests and tree cover together constitute about 24.16 per cent of the geographical area. Forest cover has increased from 692,027 sq. km in 2010 to 701,673 sq. km in 2015 (MOSPI, 2015) FSI defines forests as 'all lands, more than one hectare in area, with a tree canopy density of more than 10 per cent'. This is fairly in alignment with the internationally accepted definition by Food and Agriculture Organisation which defines forest as land spanning more than 0.5 hectares with trees higher than five meters, and a canopy cover of more than 10 per cent.

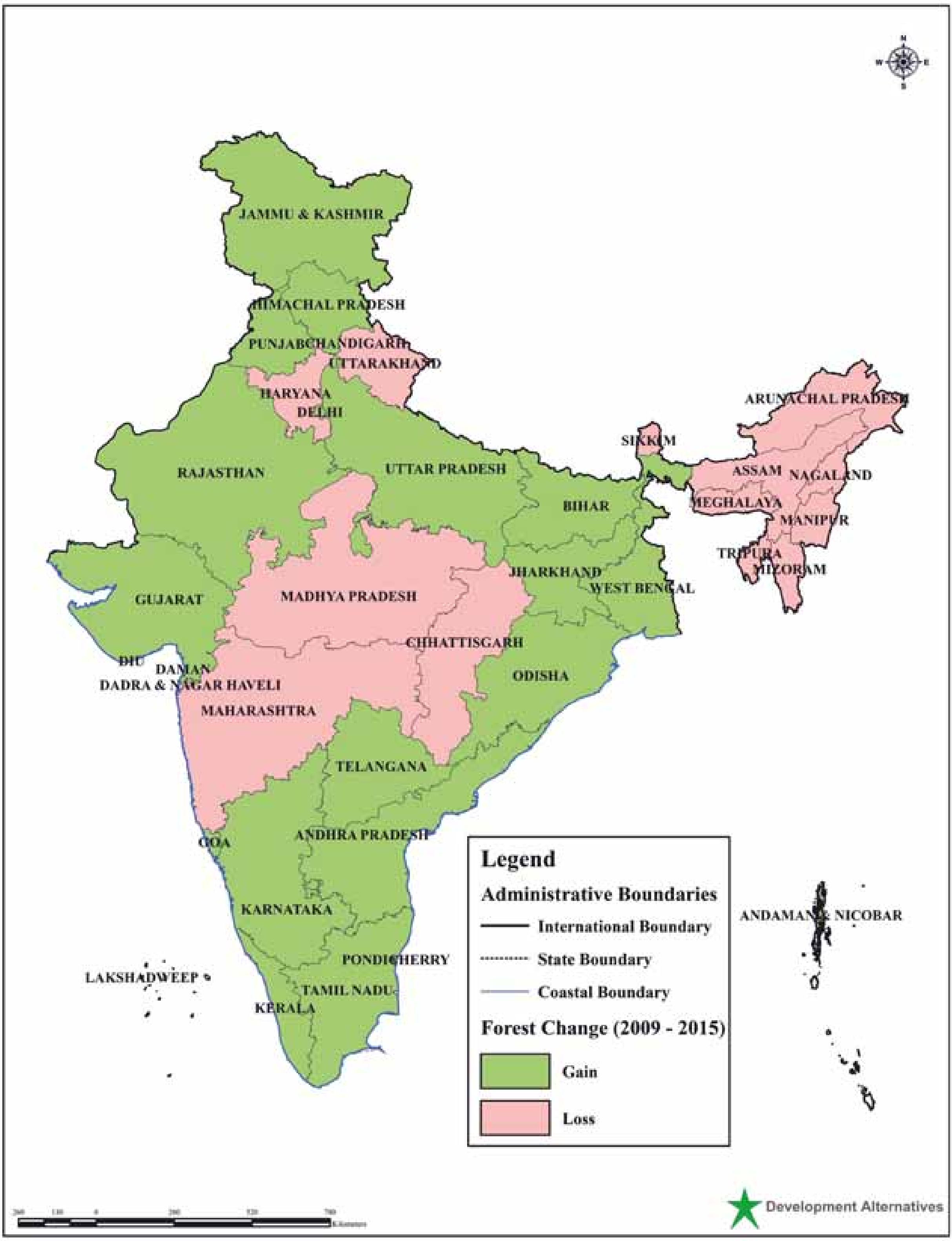
Out of the total forest cover, moderately dense forest covers 9.59 per cent of total geographical area and very dense forest covers only 2.61 per cent as indicated in Table 1.3. The total growing stock of India's forest and trees outside forests is 5,763 million m^3 which

Table 1.4: States/UTs with Forest Cover more than 33 per cent (area in sq. km).

2015 Assessment							
States/UTs	**Geographical Area**	**VDF**	**MDF**	**OF**	**Total**	**Scrub**	**Forest Cover percent**
Mizoram	21,081	138	5,858	12,752	**18,748**	0	89
Lakshadweep	32	0	17.22	9.84	**27.06**	0	84.56
A&N Islands	8,249	5,686	685	380	**6,751**	1	82
Arunachal Pradesh	83,743	20,804	31,301	15,143	**67,248**	264	80
Nagaland	16,579	1,296	4,695	6,975	**12,966**	622	78
Meghalaya	22,429	449	9,584	7,184	**17,217**	348	77
Manipur	22,327	727	5,925	10,342	**16,994**	1,182	76
Tripura	10,486	113	4,609	3,089	**7,811**	55	74
Goa	3,702	542	580	1,102	**2,224**	0	60
Kerala	38,863	1,523	9,301	8,415	**19,239**	36	50
Sikkim	7,096	500	2,160	697	**3,357**	311	47
Uttarakhand	53,483	4,754	13,602	5,884	**24,240**	307	45
Dadra & Nagar Haveli	491	0	80	126	**206**	5	42
Chhattisgarh	135,191	4,152	34,846	16,588	**55,586**	117	41
Assam	78,438	1,441	11,268	14,914	**27,623**	384	35

Source: India State of Forest Report, 2015

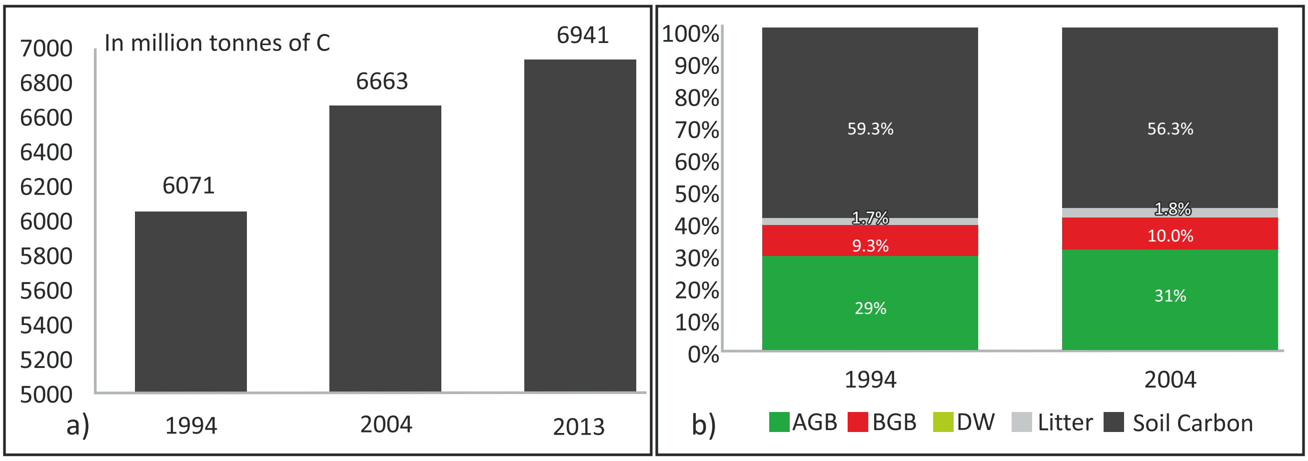
Map 1.1: Change in Forest Cover 2009-2015



Source: India State of Forest Report, 2009-2015

comprise of 4,195 million m^3 inside forests, and 1,573 million m^3 outside the forest. There has been net increase of forest cover in hill states. Mizoram, Andaman and Nicobar and Lakshadweep, are few of the states having forest cover more than 33 per cent (Table 1.4).

Figure 1.3 Carbon Stock in Indian Forests



a) Increasing carbon stock in Indian forests; b) Proportion of Above Ground Biomass (AGB) carbon, Below Ground Biomass (BGB) carbon, Dead Wood (DW) carbon, Litter carbon and soil carbon in Indian forests in the year 1994 and 2004

Source: India State of Forest Report, 2015

Degraded forest land with canopy density less than 10 per cent are classified as scrub. The area under scrub is reported to be 41,362 sq. km, which is 1.26 per cent of total geographical area of the country (India State of Forest Report, 2015). Scrubs do not fall within the classification of forests.

The North-Eastern States of India account for one-fourth of the country's forest cover. In the year 2015, there has been a net decline of 628 sq. km in forest cover and an increase of 112 sq. km in mangroves. As per Forest Survey of India 2015, the maximum forest cover is in Madhya Pradesh (72,462 sq. km).

1.2.5 Deforestation and Forest Degradation

The FAO defines deforestation as 'the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 per cent threshold'. Forest degradation and quality of forests have major implications for forest conservation. Forest degradation is quite evident from the low level of growing stock in forests.

Total growing stock in the country is estimated to be 5,768 million CUM including 4,195 million CUM forests outside recorded forests. Western Himalayas (985.518 million CUM) has highest growing stock amongst forest areas. Forest fires contribute significantly to forest degradation and has been covered in the Pressures section of this chapter.

1.2.6 Forest Carbon Stock and GHG Emissions Trend

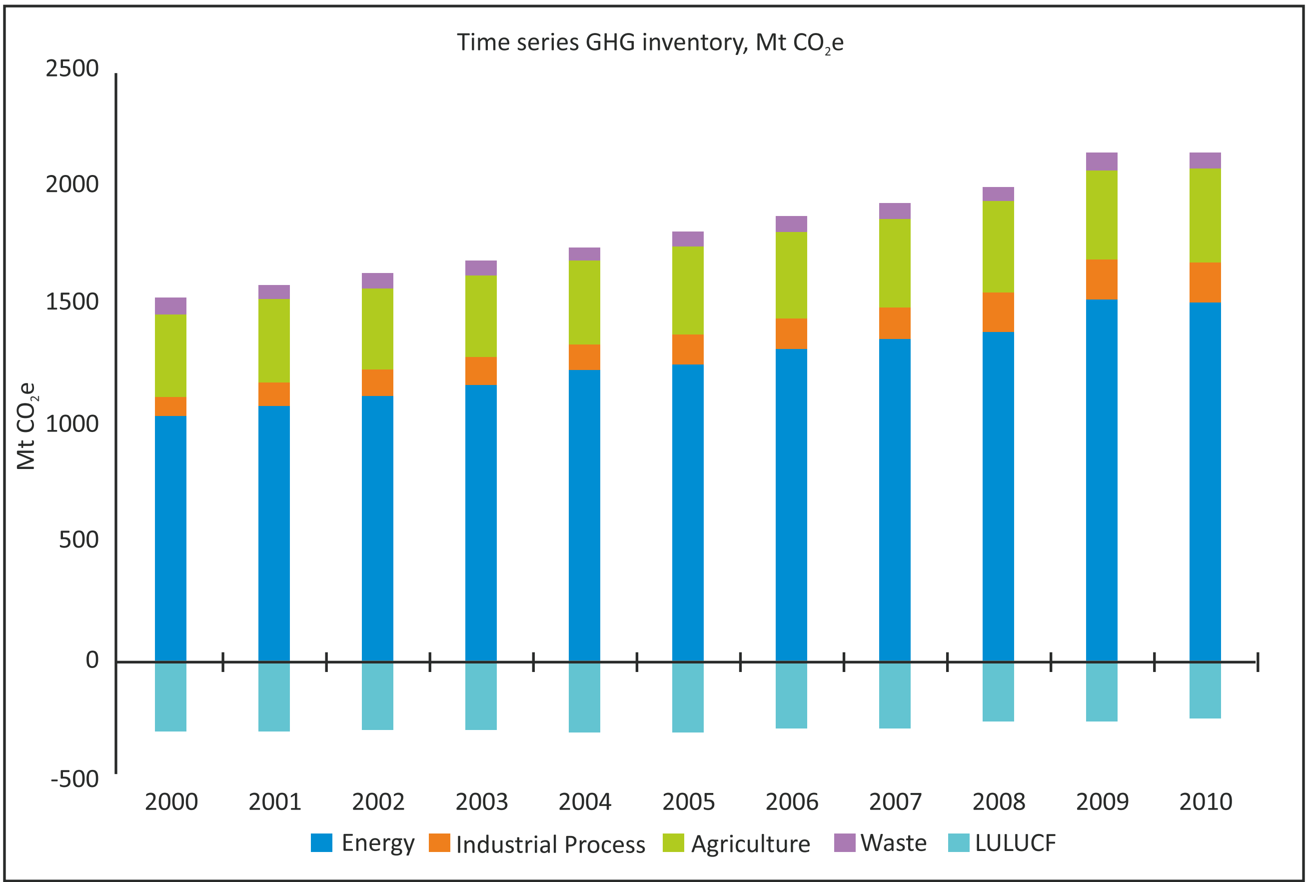
According to the Indian State of Forests Report 2015, the total carbon stock in Indian forests is estimated to be 7,044 MT. This represents an increase of 278 MT during the decade of 2004-13 as indicated in Figure 1.3.

Shorea robusta has the maximum contribution in total volume (12.06 %) of Indian forests, followed by *Tectona grandis, Pinus roxberghi, Terminilius crenutala* and *Anogeissus latifola* having a contribution of 5.30, 4.02, 4.01 and 3.13 per cent respectively (India State of Forest Report, 2015).

Uttarkhand has maximum growing stock of 440 million cum in forests followed by Arunachal Pradesh (413 million CUM) and Chhattisgarh (362 million CUM). In trees outside forests, Maharashtra has maximum growing stock of 155 million CUM followed by Jammu and Kashmir (147 million CUM), Gujarat (112 million CUM) and Madhya Pradesh (91 million CUM) (India State of Forest Report, 2015).

The national GHG inventory estimates that forests neutralize approximately 11 per cent of India's GHG emissions (MoEF&CC, 2012). Contribution of the forest sink in mitigating the national GHG emissions over the last decade is shown in Figure 1.4 represented as the LULUCF bar. There is a decline in carbon sequestration from year 2000 to 2010 as depicted.

Figure 1.4: Contribution of Forest Sink (LULUCF Sector) in Mitigating GHG Emissions in India



Source: Ministry of Environment, Forest and Climate Change, 2012

1.2.7 Ecosystem Services and Dependence of Population on Forest Resources

Forests are not only a source of subsistence for millions of poor households but also provide employment. It has been estimated that more than 40 per cent of the poor in the country live in forest fringe villages and that there are around 1.73 lakh villages located in and around forests (MoEF, 2006). The estimated forest dependent population is 350-400 million (MoEF, 2009). Forest fringe villages depend upon forests for a variety of goods and services. These includes edible fruits, flowers, tubers, roots and leaves for food and medicines; firewood for cooking (and also for selling), materials for agricultural implements, house construction and fencing, fodder (grass and leaves) for livestock and grazing of livestock in forest and collection of a range of marketable non-timber forest products (NTFPs). The collection of and trade in medicinal plants constitutes a major share of livelihoods for forest dwellers in India (MoEF, 2009). Such extensive dependence both in terms of pattern and population means that forests are under duress, and at risk of degradation from over-exploitation and unsustainable harvest practices.

A study (Saha & Sundriyal, 2012) conducted in North-East India suggests that tribal communities use 343 NTFPs for diverse purposes; including 163 species used as medicines, 75 species of fruits and 65 species of vegetables. Additionally, these communities are completely dependent on forests for firewood and house construction material; while contribution to household income from NTFPs stands at 19-32 per cent. The total forest cover in the tribal districts is 451,223 sq. km, which is 40.59 per cent of the geographical area of the country (India State of Forest Report, 2015).

Local communities have been continuing with diverse models of ownerships, rights and concessions over the use of natural resources such as forests, inland waters, coastal areas, and alpine meadows etc. Thus, the ecosystem services, as characterized by the framework of Millennium Ecosystem Assessment, form an integral part of the association of local communities with the ecosystems in India (Gokhale, n.d.).

The FAO estimates that forest based industries contribute more than US$ 450 billion to national incomes, contributing nearly 1 per cent of the global GDP in 2008, and providing formal employment to 0.4 per cent of the global labour force (FAO, 2012). In India, forests are an important contributor to the rural economy in the forested landscapes of the country. In the decades since the 1980s, official measures for contributions from forests as a proportion of overall economic activity have registered a steady downward trend, falling by more than 50 per cent on a number of key economic dimensions. The contribution of forests to India's GDP declined from 1.53 per cent to 1.38 per cent over the seven year period from 2011-12 to 2013-14.

1.3 PRESSURES

Land is the most important natural resource for the country and encompasses soil, water, associated flora and fauna involving the total ecosystem; all the activities of human beings are based on it. Immense human demand on land resources has accelerated the pressures driving land degradation in the country. Its main drivers of change include the unsustainable utilization or over-exploitation of natural resources.

Photo 1.2: Landscape under Degradation from Soil Erosion

Land

1.3.1 Drought

Drought is a slow-onset phenomenon that affects people more than any other natural hazards. It causes serious economic, social and environmental losses. The period of unusual dryness or drought, is a normal feature of the climate and weather system in semi-arid and arid regions of the tropics, which covers more than one-third of the land surface, and is vulnerable to drought and desertification. Drought is not a purely physical phenomenon, but represents an interplay between natural water availability and human demands. Drought contributes to desertification and

Table 1.5: Forest Type Groups in Different Soil Erosion Classes

Sr. No.	Forest Type Group	Soil Erosion Class (%)			
		Heavy	Moderate	Mild	No erosion
1	Tropical wet evergreen	9.16	21.06	58.61	11.17
2	Tropical semi-evergreen	2.47	17.81	73.88	5.84
3	Tropical moist deciduous	1.34	10.26	76.2	12.2
4	Littoral and swamp	2.53	8.86	55.7	32.91
5	Tropical dry deciduous	3.48	20.05	61.62	14.85
6	Tropical thorn	10.27	32.63	49.24	7.86
7	Tropical dry evergreen	5.56	44.44	33.33	16.67
8	Subtropical broadleaved hill	0.72	6.47	61.87	30.94
9	Subtropical pine	0.61	10.55	75.66	13.18
10	Montane wet temperate	0	9.55	90.45	0
11	Himalayan moist temperate	0.5	11.04	75.25	13.21
12	Himalayan dry temperate	3.12	9.37	71.88	15.63
13	Sub-Alpine	0	10.75	79.57	9.68
14	Moist Alpine scrubs	0	9.67	72.59	17.74
	National level	**2.82**	**16.54**	**67.66**	**12.98**

Source: India State of Forest Report, 2015

land degradation, particularly under dryland situations. Drought acts as a catalysing factor and restricts gainful utilisation of land.

1.3.2 Soil Erosion

Soil erosion is the physical removal of the top-soil layer or soil particles by mobile agents and by human activities. Running water, rainfall and wind are the primary mobile agents, which cause soil erosion in the absence of vegetative cover and moisture and it is further helped by gravity and ruggedness of topography (ENVIS). In India, soil lost due to erosion increased from 3,000 million tonnes in the 1980s to 5,300 million tonnes in 2010 (Khadka, 2016).

As Table 1.5 shows, the classification of soil erosion is of three main types viz. 'heavy', referring to the extent of soil erosion, 'moderate' when mild gullies and rills are formed on the top surface of soil and 'mild', when only surface erosion has occurred.

1.3.3 Intensive Agricultural Practices

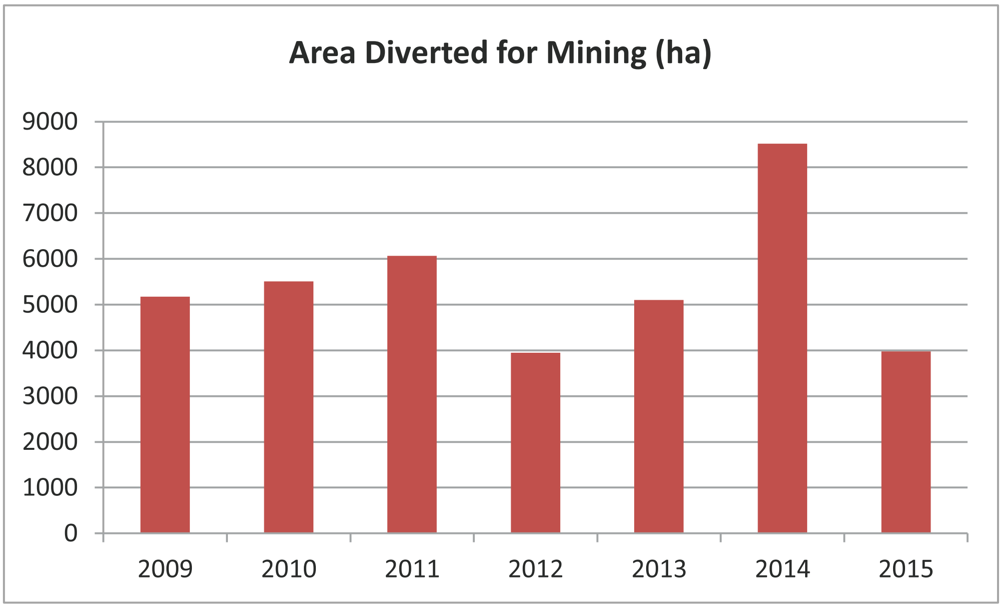
Intensive farming practices, particularly for wheat and rice in India, have virtually mined nutrients from the soil. Heavy use of fertilizers has caused contamination of land along with leaching of excess nitrates into groundwater. The cultivable lands have lost their fertility due to over-application of chemicals (Mythili, Madras School of Economics). Intensive agricultural practices have led to soil erosion, land salinization and loss of nutrients. In particular, the agricultural practice of shifting or Jhum cultivation, especially in the hilly areas of the eastern and north-eastern states of India, has been responsible for land degradation.

Photo 1.3: Land under Intensive Agriculture

1.3.4 Submergence, Flooding and Landslides

In India, natural disasters, many of them related to the climate, cause massive losses to life and property. Droughts, flash floods, cyclones, avalanches, landslides triggered by torrential rains, and snowstorms pose the greatest threats. In terms of vulnerability, out of 35 States and Union Territories in the country, 27 are disaster prone. Almost 58.6 per cent of the landmass is prone to earthquakes of moderate to very high intensity and over 40 million hectares (12 per cent of land) are prone to floods and river erosion. Of the 7,516

Figure 1.5: Diversion of Forest Land for Mining under Forest Conservation (FC) Act, 1980 in India



Source: Forest Conservation Division, MoEF&CC 2016

Table 1.6: States with Highest Incidences of Forest Fires in India

States	2011	2012	2013	2014	2015
Odisha	780	3,022	2,221	1,904	1,467
Madhya Pradesh	1,451	3,076	753	534	294
Maharashtra	882	3,329	1,433	702	721
Telangana	-	-	898	548	1,052
Assam	1,321	2,172	1,608	2,536	1,656

Source : MoEF&CC, 2014 and 2016

km long coastline, close to 5,700 km, is prone to cyclones and tsunamis and 68 per cent of the cultivable area is vulnerable to drought (NIDM, 2012).

1.3.5 Land Degradation caused by Mining

Mining leads to considerable land degradation, especially due to lack of restoration of land after closure of mining operations. Open-cast mines in particular contribute majorly to land degradation and directly affects large swathes of land.

The minerals which have a serious negative impact on the environment include coal, iron ore, zinc, lead, copper, gold, pyrite, manganese, bauxite, chromite, dolomite, limestone, apatite and rock phosphate, fireclay, silica sand, kaolin, barytes (Sahu, 2011). Figure 1.5 indicates the area of forest land diverted during the years from 2009 to 2015.

Forests

1.3.6 Forest Fires

Forest fires are a major cause of forest degradation. The National Forest Commission Report 2006 indicated that about 55 per cent of the forests in India are prone to forest fires. Figure 1.6 presents the forest fire spots as reported by Forest Survey of India (India State of Forest Report, 2015). It suggests very high prevalence of forest fires in India.

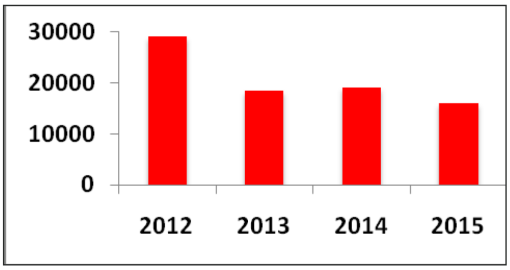
Table 1.6 shows the trends in the occurrence of forest fires for those states where it is most prevalent.

Photo 1.4: Forest Fires

1.3.7 Over-exploitation of Forest Resources

The industries which have maximum demand of raw wood are paper and paper board, construction wood and plywood. Urbanization and industrialisation are major drivers of this increasing demand of forest resources as raw wood.

Figure 1.6: Number of Forest Fire Spots Detected From Satellite Based Observations



Source: Forest Survey of India, 2015

Fuel-wood trade in India is estimated to have an annual turnover of about $17 billion, and is a source of livelihood for more than 11 million people, making it the largest employer (formal and informal) in the

Table 1.7: Total Demand and Projected Demand of Raw wood by different Industries in India (in million cubic metres)

Industries	2000	2005	2010	2015	2020
Paper & Paper Board	4.48	8.96	15.4	26.24	35.84
Construction Industry	15.9	19.4	22.1	26.3	28.5
Plywood	11	14	17.96	22.9	29.2

Source: Ministry of Environment, Forest and Climate Change, Government of India 2015

Indian energy sector. However, the extraction of fuel-wood and NTFPs continue to pose serious environmental challenges. Several field based studies have documented the adverse impact of the collection of fuel-wood and NTFPs.

Open grazing in the forest is conventionally practiced by forest fringe communities, and this has adverse impact on growing stock as well as regeneration capacity of the forest.

1.3.8 Climate Change

Climate is one of the most important influencers on the distribution of forests. Though ecological systems including forests are often capable of adapting to changes in the environment, yet when the changes are rapid and significant, it leads to significant impacts on its health and characteristics. According to Indira Gandhi National Forest Academy (IGNFA, n.d.), the following are the projected impacts of climate change on Indian forests:

By 2085,

- 77 per cent (A2) and 68 per cent (B2) of the forested grids in India are likely to experience shift in forest types
- Shift towards wetter forest types in the north-eastern region and drier forest types in the north-western region in the absence of human influence
- Increasing atmospheric CO_2 concentration and climate warming - doubling of net primary productivity under the A2 scenario and nearly 70 per cent increase under the B2 scenario
- 77 per cent of the grids under A2 and 68 per cent under B2 scenario, are likely to undergo vegetation change. This indicates that well over half of the area under forests in India is vulnerable to the projected climate change.

1.4 IMPACTS

The pressures described in the previous section have a range of impacts on land and forests and much of this has already been referred to in previous sections. Some of the other key impacts have been discussed in the following sections.

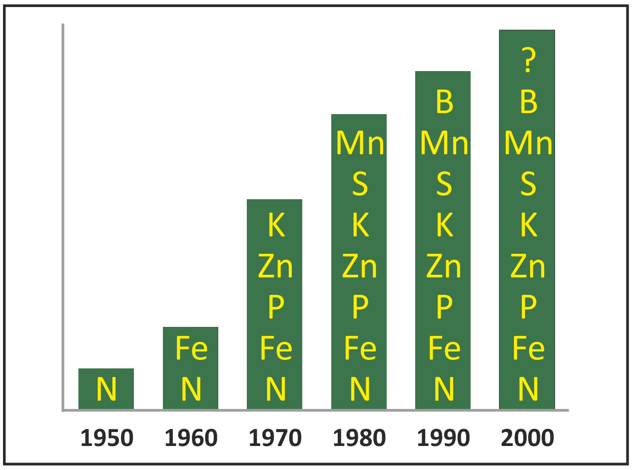
Land

1.4.1 Impact on Soil Health and Agriculture

A third of India's soil is degraded, which, in turn, is a threat to the sustainability of agriculture in future. Excess use of chemical fertilizers is one of the main reasons for soil degradation. Additionally, soil erosion, which increased from 3,000 million tonnes in the 1980s to 5,300 million tonnes in 2010 has been another key driver for depleting soil health.

Nutrient deficiencies have multiplied with every passing decade, being the outcome of a near-exclusive focus on NPK (Nitrogen, Phosphorous, Potassium) based fertilisers, nutrient mining and inadequate uptake by farmers of soil testing for targeted fertiliser application.

Figure 1.7: Progressive Growth in Occurrence of Nutrient Deficiencies in Soil



Source: Managing Soil and Land Resources, 2016

Another issue that affects soil health is that of the 600 MT of crop residues generated annually, about 125 MT is burnt on the farm leading to the gradual loss of soil organic matter (Managing Soil and Land Resources, 2016).

Forests

1.4.2 Forest Fragmentation

Forest fragmentation is the breaking of large, contiguous, forested areas into smaller pieces of forest; typically, these pieces are separated by roads, agriculture, utility corridors, sub-divisions, or other human development. Fragmented forests are especially vulnerable to a number of stressors including forest fires, invasive species, anthropogenic pressures, biodiversity loss and climate change. An assessment has reported that 49.63 per cent of forests are under low fragmentation, 21.89 per cent under medium fragmentation, while 5.16 per cent is under high fragmentation. In this study, fragmentation was calculated as the number of patches of forest and non-forest types per unit area (India State of Forest Report, 2015).

1.4.3 Man-Animal Conflict

The growing human population and the resultant overlap of the same with established wildlife territories has been the major cause of man-animal conflict. As human activities continue to encroach upon more and more forest land for settlements, agriculture and other developmental activities, the habitat available for wildlife shrinks and the wildlife population is constrained within its limits. The exploitation of forests for timber and NTFPs may, apart from restricting the area, further degrade the habitat and lower the resource base for the wildlife considerably (Sukumar, 1994). As the carrying capacity of our habitations is surpassed and wildlife spaces encroached upon, animals are forced to enter the human domain, which results in conflicts. There are various kinds of man animal conflicts experienced across India. Loss of agricultural crops and property represents one of the most common consequences of man-animal conflict.

1.5 RESPONSES

Management of land resources, in general, and potentially cultivable lands in particular, are essential in securing the country's food needs, sustaining environment, reducing the impacts of climate change, preserving and enhancing natural resources, and supporting livelihood of farmers and rural population in the country (ICAR, 2010). India, as a member of the United Nations Convention to Combat Desertification (UNCCD), has committed to becoming land degradation neutral by 2030. This is in alignment with Goal 3 of SDG 15 that mandates to, 'by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation neutral world'.

Photo 1.5: Terrace Based Cultivation on Hillside

Many of the response measures taken by the Government, that will contribute towards the realisation of these commitments, are illustrated in the following section.

1.5.1 Policies & Programmes for Land Management

Integrated Wasteland Development Programme (IWDP)

The Integrated Wasteland Development Programme was launched during 1989 - 90. The basic objective of this scheme is integrated wastelands development, based on village or micro-watershed plans. These plans are prepared after taking into consideration the land capability, site condition and needs of local people.

This programme has been integrated with other programmes, such as the Integrated Watershed Management Programme (IWMP), the Desert Development Programme (DDP) and the Drought Prone Areas Programme (DPAP) (Table 1.8) with effect from 2009. The main objectives of the IWMP is to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water. The outcomes are prevention of soil run-off, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table.

Soil conservation, water conservation, afforestation and pasture development form an important part of the IWMP. Under the IWMP, a total of 1,227 projects, covering an area of 7.22 Mha, were completed up to March 2014 (MoRD, 2014).

The basic objective of the DPAP, which is now integrated with the IWDP, is to minimise the adverse effects of drought on production of crops, and livestock and productivity of land, water and human resources ultimately leading to drought proofing of the affected areas. The programme also aims to promote overall economic development and improving the socio-economic conditions of the resource poor and disadvantaged sections inhabiting the programme areas.

More recently, a World Bank assisted watershed management project called Neeranchal is being initiated for the duration 2014-15 to 2019-20.

Table 1.8: States under Drought Prone Areas Programme

Name of the State	No. of Districts	No. of Blocks	Area (Sq. Kms.)
Andhra Pradesh	11	94	99,218
Bihar	6	30	9,533
Chhattisgarh	8	29	21,801
Gujarat	14	67	43,938
Himachal Pradesh	3	10	3,319
Jammu & Kashmir	2	22	14,705
Jharkhand	14	100	34,843
Karnataka	15	81	84,332
Madhya Pradesh	23	105	89,101
Maharashtra	25	149	1,94,473
Odisha	8	47	26,178
Rajasthan	11	32	31,969
Tamil Nadu	17	80	29,416
Uttar Pradesh	15	60	35,698
Uttarakhand	7	30	15,796
West Bengal	4	36	11,594
Total	**183**	**972**	**7,45,914**

Source: Department of Land Resources, Government of India

1.5.2 Policies & Programmes for Forest Management

Forest Conservation Act

Forest Conservation Act 1980 is one of the most effective legislations contributing to reduction in deforestation. It is a living example of the political will of the nation to preserve its precious forest and wildlife wealth. The implication of the Act has been in the successful reduction in the average annual rate of diversion of forest land for non-forestry purpose. The average rate at which the forest land got diverted from 1951-52 to 1975-76 was 1.65 lakh hectares. per annum. This rate of diversion was permanent because there was no mechanism to compensate this loss. However, after the enactment of Forest Conservation Act, 1980 the annual average rate of forest land diversion has gone down to 35000 hectares per annum. It is ensured that all these diversion are to be compensated through compensatory afforestations. Prior to the enactment of the Act, 4.135 million ha. was diverted without any mitigative measures but after enactment only 1.2 million ha. forest land has been diverted. This Act has contributed in taking a balanced approach in the development of the country at one hand and conserving the natural resources of our country on the other hand.

National Afforestation Programme

The government is adopting the latest scientific techniques to increase productivity of the forest land. The National Afforestation Programme (NAP) is being implemented since 2010-11, under the revised guidelines which inter alia addresses the concern of forest cover by the use of quality planting material (QPM). The programme is monitored using remote sensing and GIS based tools; along with independent evaluations conducted periodically (National Afforestation & Eco-Development Board, MoEFF&CC). Its purpose is the rehabilitation of degraded forests and other areas by institutionalizing decentralized and participatory forest management, and supplementing livelihood improvement processes.

Joint Forest Management (JFM)

Joint Forest Management was initiated in 1990, under which local communities and the forest department jointly plan and implement forest regeneration programmes, and the communities are rewarded for their efforts in protection and management.

The total number of Joint Forest Management Committees in the country as on 2010 are 112,896 and the forest area brought under under these 24.6 million hectare, till March 2010. Though there is overall increase in the number of JFMCs, the area covered under forests has decreased compared to 2006 status There has been downward correction in number of JFMCs and forest area covered in the states of Andhra Pradesh, Himachal Pradesh, Mizoram and Punjab, as many registered JFMCs were found non-functional on monitoring (ENVIS Centre on Forestry, n.d.).

Green India Mission

The Green India Mission (GIM) is one of the eight Missions outlined under the National Action Plan on Climate Change (NAPCC). It aims to increase forest or tree cover by over 5 Mha, and improve quality of forest or tree cover over another 5 Mha of both forest and non-forest lands. Through this, it aims to enhance ecosystem services like carbon sequestration and storage in forests and other ecosystems, hydrological services, biodiversity along with provisioning services like fuel, fodder, and timber and non-timber forest produces (NTFPs). The mission aims to increase forest based livelihood income for about three million households.

REDD+

India's national REDD+ strategy aims at enhancing and improving the forest and tree cover thereby enhancing the quantum of forest ecosystem services that flow to the local communities (MoEF&CC, 2015). Government of India is in the process of developing its National REDD+ strategy. MoEF&CC has prepared a draft national REDD+ policy and strategy.

CAMPA

Compensatory Afforestation Fund Management and Planning Authority (CAMPA) is meant to promote afforestation and regeneration activities, as a way of compensating for forest land diverted to non-forest uses.

The Compensatory Afforestation Act, 2016 has been notified on 3rd August, 2016 and the CAF Rules is being framed for effective utilization of the Compensatory Afforestation Fund collected and managed by CAMPA. Under the CAF Act 2016, 90 per cent of the Fund will be transferred to the States for compensatory afforestation and allied activities for conservation of forests and wildlife in the states. 10% of the Fund will be retained with the National Authority for implementation of various Schemes related to Forests and Wildlife Development and Research Works. The fund will be managed by National and State authorities instead of Adhoc CAMPA.

1.6 CONCLUSION

In the context of the increasing population and the limited land resources available, it is important to streamline land use in India and also in parallel to limit land degradation by addressing its causes.

Land degradation needs to be contextualised through the trans-disciplinary approach of accounting for the rising human costs and its spill-overs into other areas. This means addressing Desertification, Land Degradation and Drought (DLDD) as an integral component of achieving the Sustainable Development Goals (SDGs). Though none of the 17 SDGs specifically mention land, the way the land resources are managed will be critical to the achievement of many of the goals. For example, achieving food security through sustainable agriculture will have major implications on the land resources. DLDD contributes significantly to climate change and biodiversity loss and diminishes livelihoods and contributes to poverty. Threats to forest resources are over-exploitation, forest fires etc. There is a need to step ahead and promote awareness for sustainable management of resources and avoid the over-exploitation of forest resources.

Therefore, policy suggestions for a land degradation neutral nation by 2030 hinges around the need to implement sustainable land management and forest management practices, such as agro-forestry, sustainable agriculture and livestock practices, water management, and soil conservation, and regeneration or reclamation of degraded land.

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***Note:** Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 2

BIODIVERSITY

Key Messages

- *India is a mega-biodiversity country and accounts for 7-8 per cent of species recorded globally.*
- *India's biodiversity resources are intricately interlinked with not only the country's environment but also the lives and livelihoods of its population.*
- *Similar to the global scenario, there has been accelerated biodiversity loss in the country. One of the most significant measures to redress this has been to increase the coverage of Protected Areas in the country.*
- *Anthropogenic pressures like developmental activities and trade are the most severe pressures acting on biodiversity.*
- *India is investing resources in preserving its natural wealth by inculcating involvement of local communities in conservation and introducing legal measures for its protection.*

2.1 INTRODUCTION

India is recognized as a mega-biodiversity country, accounting for 7-8 per cent of the globally recorded species in just 2.4 per cent of global land area. The country has 10 biogeographic zones, and four out of the 34 biodiversity hotspots recognised all over the world. India harbours rich biological diversity: from large mammals to tiny invertebrates, the towering trees, variety of agricultural crops and microscopic organisms. India also has vast genetic diversity, mainly in agricultural crops like rice, maize and millets. This huge diversity contributes to many economic sectors like pharmacy, tourism, agriculture and livelihoods of forest dwellers in addition to making intangible contributions to the quality of human life and development. There has been major investment of resources towards conservation of biodiversity, clearly evident in the increase of protected areas in the country. Despite its dependence on biodiversity, the country struggles for its preservation owing to the increasing pressures from population rise, industrialisation, poor protection laws and the growing disconnect between its citizens and nature.

India is divided into 10 biogeographic zones possessing significantly diverse flora and fauna (Rodger et al, WII, 2000). Such a classification is an essential tool for integrated ecosystem management. It assists in understanding the distribution of different taxa and the factors responsible for it, ultimately facilitating conservation planning and implementation. The classification of the Indian mainland is as mentioned:

- Trans Himalayan Region
- Himalayas
- Desert Zone
- Semi-Arid Zone
- Western Ghats
- Deccan Plateau
- Gangetic Plains
- North-East Region
- Coasts
- Andaman & Nicobar Islands

The Trans Himalayan region, spanning the cold and arid mountains of Ladakh, Jammu and Kashmir, North Sikkim, and the Lahaul and Spiti regions of Himachal Pradesh has cold dry deserts, representing a unique ecosystem. The Himalayas are covered with alpine and sub-alpine forests which are the ecological habitat for rare animals like Hangul (*Cervus eldi eldi*) and Musk Deer (*Moschus moschiferus*).

The desert zone includes, the Kutch and Thar deserts, which support many endangered animals and some birds of immense conservation importance like the Great Indian Bustard (*Ardeotis nigriceps*). The semi-arid zone is the transition belt between the desert areas and the densely forested Western Ghats, covering a huge 16.6 per cent of the country's total geographical area. The Western Ghats constitute a significant part of India's tropical evergreen forests, which are commonly cited as one of the richest biodiversity areas across the world. They are also recognised as a biodiversity hotspot with many endemic plant and animal species.

The greatest percentage of India's area (42%) is classified under the Deccan Plateau biogeographic zone. It mostly houses deciduous forests across the states of Madhya Pradesh, Maharashtra and Odisha. Next to the Deccan Plateau, lie the fertile Gangetic Plains which are majorly under agricultural and industrial pressure because of high fertility of the land that also hosts a high population. The North-East region, the coasts, and the Andaman & Nicobar Islands stretch over a comparatively smaller part of the country but harbour significant biodiversity owing to their physio-geographic characteristics. The mangroves, considered as one of the most productive ecosystems, are a part of the coastal biogeographic zone. Wetlands are present in all the ten zones.

Table 2.1: Percent of India's Geographical Area Under Different Biogeographic Zones

Biogeographic Zone	Percentage area
Trans Himalaya	5.6
Himalayas	6.4
Desert	6.6
Semi-arid	16.6
Western Ghats	4.0
Deccan Peninsula	42.0
Gangetic Plains	10.8
Coasts	2.5
North-east	5.2
Islands	0.3

Source: Rodger et al, WII, 2000

2.2 STATUS

2.2.1 Human-Biodiversity Interaction

The interaction between humans and biodiversity is valuable, many intangible aspects of which cannot be quantified. Though basic resources essential for survival are obtained from nature, biodiversity also significantly contributes to the economy. It supplies primary resources for sectors such as agriculture, which contributes 17.4 per cent of the country's GDP (World Bank, 2014), and nature tourism in national parks, zoos etc. The annual domestic trade of the AYUSH (Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy) industry is of the order of Rs. 80 to 90 billion (National Medicinal Plants Board). Table 2.2 indicates the huge economic potential of biodiversity.

The increase in export values between 2009 and 2011 reiterates that the commercial application of biodiversity has gone up over the last few decades, owing to the availability of better technological resources.

Additionally, 350-400 million people are dependent on forests in India for subsistence and income. (MoEF, 2009) People's survival and livelihood is inextricably linked to the forest ecosystem (Livelihood of Local Communities and Forest Degradation in India: REDD+, TERI).

In addition to these biodiversity resources, the country also has about 960 species of medicinal plants which are currently in trade and nearly 6,500 are known to be used by several ethnic communities. These are effectively used in many traditional systems of medicine like Ayurveda, Unani and Naturopathy; and are sole sources of drugs in some allopathic medicines. Important uses of some CITES (the Convention on International Trade in Endangered Species) listed species have been mentioned in Table 2.3.

Treasure houses of biological diversity, the sacred groves are defined patches of natural forest or vegetation that hold enough religious significance to be preserved, and is revered by the local community. Sacred groves exist all over the country though they have the most significance in the north-east region where they are closely woven into traditional belief systems. These dense vegetation patches are

Table 2.2: Economic potential of biodiversity in India

Segment	Exports in 2009-2010 (Rs. in crores)	Exports in 2010-2011 (Rs. in crores)
Bio-pharma	4,767.7	5,535.4
Bio-agri	58.1	74.4
Bio-services	2,507	2,986.3
Bio-industrial	124.1	150.2
Bio-informatics	73.9	106.02

Source: National Biodiversity Authority, 2010-11

Table 2.3: Uses of some CITES (the Convention on International Trade in Endangered Species)-listed Indian Medicinal Plants

Plant	Uses
Elephant's Foot	Derive precursor for the synthesis of steroid hormones such as progesterone, corticosteroids and anabolic steroids
Jatamansi	Antispasmodic and stimulant benefits, useful in the treatment of fits and heart palpitations, and to regulate urination, menstruation and digestion
Kutki	Is a major component of Arogyavardhini, an Ayurvedic formulation used to treat liver ailments
Red Sanders	Useful for treating diabetes, boils, scorpion-stings and some skin diseases
Snakeroot	Prescribed for treating various central nervous disorders, including anxiety states, maniacal behaviour associated with psychosis, schizophrenia, insanity, insomnia, and epilepsy
Himalayan Yew	Used in Unani system as a source of the drug zarnab, used as a sedative and aphrodisiac, and for the treatment of bronchitis, asthma, epilepsy, snake bites and scorpion stings

Source: Review of the Status, Harvest, Trade and Management of Seven Asian CITES-listed Medicinal and Aromatic Plant Species, TRAFFIC and Bfn, 2008

Table 2.4: Sacred Groves in India

State/UT	Number of Sacred Groves	Local Term for Sacred Groves
Andhra Pradesh	580	Pavithravana
Arunachal Pradesh	101	Gumpa Forests (Sacred Groves attached to Buddhist monasteries)
Goa	55	Deorai, Pann
Jharkhand	29	Sarana
Kerala	299	Kavu, Sara Kavu
Maharashtra	1,559	Devrai, Devrahati, Devgudi
Manipur	166	Gamkhap, Mauhak (sacred bamboo reserves)
Meghalaya	101	Ki Law Lyngdoh, Ki Law Kyntang, Ki Law Niam
Puducherry	108	Kovil Kadu
Rajasthan	255	Orans, Kenkris, Jogmaya
Tamil Nadu	527	Swami shola, Koilkadu
Uttarakhand	18	Deo Bhumi, Bugyal (sacred alpine meadows)
West Bengal	39	Garamthan, Harithan, Jahera, Sabitrithan, Santalburithan

Source: CPR Environmental Education Center, Conservation of Ecological Heritage and Sacred Sites of India

storehouses of genetic diversity since they contain many wild varieties crop plants and medicinal plants. The groves are characteristically linked with a small water body, thus also contributing to water and soil conservation in the area. Table 2.4 shows a quantitative list of sacred groves in India.

2.2.2 Biodiversity Hotspots

India is home to over 45,000 species of plants and 91,000 species of animals (MoEF&CC, 2014). A national level assessment of biodiversity richness was carried out by the Indian Institute of Remote Sensing using spatial data on a 1:50,000 scale, to identify and to map potential biodiversity rich areas in the country (Roy et. al., 2012). The findings of this study indicate that the North-East, the Western Ghats, the Himalayas and in the Andaman & Nicobar Islands, have the greatest biodiversity richness and are recognized as global biodiversity hotspots.

Of the 34 global biodiversity hotspots, four are represented in India. A hotspot is defined as an area of exceptional plant, animal and microbe wealth that is under threat. The key criteria for determining a hotspot are endemism, that is, it should contain at least 1,500 species of vascular plants found nowhere else on Earth, and the degree of threat (Conservation International, 2013). The four biodiversity hotspots represented in India are as follows:

- Himalayas
- Western Ghats
- North-Eastern India
- Nicobar Islands

The Indian part of the Himalayas fall in the global Himalayan hotspot which also includes the mountain range in Tibet, Pakistan, Afghanistan and Nepal. The Western Ghats and Sri Lanka combined are one global hotspot; and the region in the north-eastern part of India falls under the Indo-Burma global biodiversity hotspot, which spans across parts of Thailand, Laos, Cambodia, Myanmar, Bangladesh and Vietnam. The Nicobar Islands are a part of the Sundaland hotspot which includes the western part of the Indo-Malayan archipelago.

Himalayas

The variation in the altitude of the Himalayan mountains ranging from 500 meters to more than 8,000 meters, results in a diversity of ecosystems- from alluvial grasslands and subtropical broadleaf forests, along the foothills, to temperate broadleaf forests in the middle elevations, mixed conifer and conifer forests in the higher hills, and alpine meadows above the tree line. Keystone species such as tiger and elephant are found in the foothills and Terai region. The Snow Leopard, Musk Deer, Himalayan Tahr, Blue Sheep, Black Bear, Chir Pheasant, Himalayan Monal and Western Tragopan, are some of the characteristic fauna of Himalayas. Of the estimated 10,000 species of plants in the Himalayas hotspot, 71 genera and approximately 3,160 species are endemic. The Himalayan region in the north-eastern part of the country is exceptionally rich in diversity and endemism, and hence, is of great significance. It houses an estimated 9,000 plant species, out of which approximately 39 per cent are endemic. The portion falling in India itself houses 5,800 plant species, approximately 36 per cent of which are endemic. The area is also a rich centre of avian diversity, reporting more than 60 per cent of the bird species found in India. The region also harbours 35 endemic reptilian species including two genera of lizards, and two turtle species. Out of 341 Indian amphibian species recorded so far, at least 68 species are known to occur in this hotspot, 20 of which are endemic (Conservation International 2012).

Western Ghats

The Western Ghats run roughly in a North-South direction for about 1,500 km parallel to the coast bordering the Arabian Sea. Western Ghats are home to 7,388 species of flowering plants, of these 5,584 are indigenous; 377 are exotic naturalised, and 1,427 are cultivated or planted. Of the indigenous 5,584 species, 2,242 species are endemic to India and 1,261 are endemic to the Western Ghats. Among the invertebrate groups, about 350 ant species (20 per cent endemic), 330 butterfly species (11 per cent endemic), 174 species of dragonflies and damselflies (40 per cent endemic), and 269 mollusc species (76 per cent endemic) have been described from this region. The known fish fauna of the Ghats comprises 288 species (41 per cent endemic).

North-Eastern India

The North-Eastern region of India is a part of the Indo-Burma biodiversity hotspot. The plant diversity of the entire hotspot is estimated to comprise about 13,500 vascular plant species, of which about 52 per cent are

Photo 2.1: Birds in Flight in Protected Area

endemic. Of the 1,277 bird species found in the Indo-Burma hotspot, 74 are endemic. Similarly, 71 of the 430 mammal species in the hotspot are endemic. Other vertebrate groups show much higher levels of endemism, with 189 of the 519 non-marine reptile species and 139 of the 323 amphibian species being endemic to the hotspot. Indo-Burma region probably supports the highest diversity of freshwater turtles in the world. The hotspot also has a remarkable diversity in freshwater fish, with 1,262 documented species, accounting for about 10 per cent of the world total, including 566 endemics (Tordoff et al, 2012).

Nicobar Islands

The Nicobar Islands are part of the Sundaland hotspot, which extends further into South-East Asia, and covers several countries. They belong to the Andaman and Nicobar group of islands, consisting of some of the most pristine island ecosystems in the world. These island groups form a distinct eco-region, and are fringed by one of the most spectacular reefs in the Indian Ocean.

2.2.3 Threatened Species

Flora

India, being one of the tropical countries harbours 46,824 species including species of virus, bacteria and fungi. The floral diversity is concentrated in four geographically unique regions, viz., Himalayas, Western Ghats, Northeast India and Andaman and Nicobar Islands. The Indian flora accounts for 11.4 per cent of the total recorded plant species of the world, and about 28 per cent of these are endemic to India.

With an estimated 29,015 species of algae, bryophytes, pteridophytes, gymnosperms and angiosperms, India holds 9.13 per cent of the world's known floral diversity in these groups. Angiosperms are the largest plant group in India constituting 38.15 per cent of floral diversity of the entire country, followed by fungi representing 31.38 per cent (ENVIS Centre on Floral Diversity, 2016). About 4,045 species of flowering plants (angiosperms) endemic to India are distributed amongst 141 genera belonging to 47 families. The richness of Indian plant species in context of the global biodiversity is shown in Table 2.5 (MoEF, 2014). A comparison of India's threatened plant species with the global figures is given in Table 2.7.

Fauna

With only about 2.4 per cent of world's total land surface, India is known to have over 7.50 per cent of the species of animals that the world holds; this percentage accounts nearly for about 92,000 species described so far in the country (ENVIS Centre on Faunal Diversity, 2016).

The numbers of threatened faunal species in different taxonomic categories as listed by the International Union for Conservation of Nature (IUCN 2013) are given in Figures 2.1 and 2.2. From 646 threatened species in 2013, the numbers have gone up to 665 in 2016 (IUCN Red List 2016-Version 3). The list includes species that are endangered, critically endangered or vulnerable, which clearly highlights a trend towards more species being at risk. The threatened endemic species in India with respect to the total endemic species are also graphically depicted, highlighting the urgent need of initiatives for their conservation.

Table 2.5: Endemism of Different Plant Groups in India

Plant Group	Total Number of Species in India	Number of Endemic Species	Percentage
Angiosperms	17,926	4,045	22.57
Gynmnosperms	74	8	10.81
Pteridophytes	1,267	196	15.47
Bryophytes	2,504	642	25.64
Algae	7,244	1,949	26.91

Source: Ministry of Environment, Forest and Climate Change, 2014

2.2.4 Protected Areas and Conservation Programmes

India has a diverse set of unique ecosystems with rich and endemic biodiversity. For protection of this huge treasure, a widespread network of national parks, wildlife sanctuaries, biosphere reserves, and reserved and protected forests has been set up. National parks differ from wildlife sanctuaries in the respect that no human activity is allowed inside the former, while the latter permits a limited number of activities. Biosphere reserves on the other hand refer to larger areas focused on protecting the natural habitat which may be a combination of a terrestrial and/or coastal ecosystems. These are representatives of an entire biogeographic zone, and not targeted at conserving any species in particular.

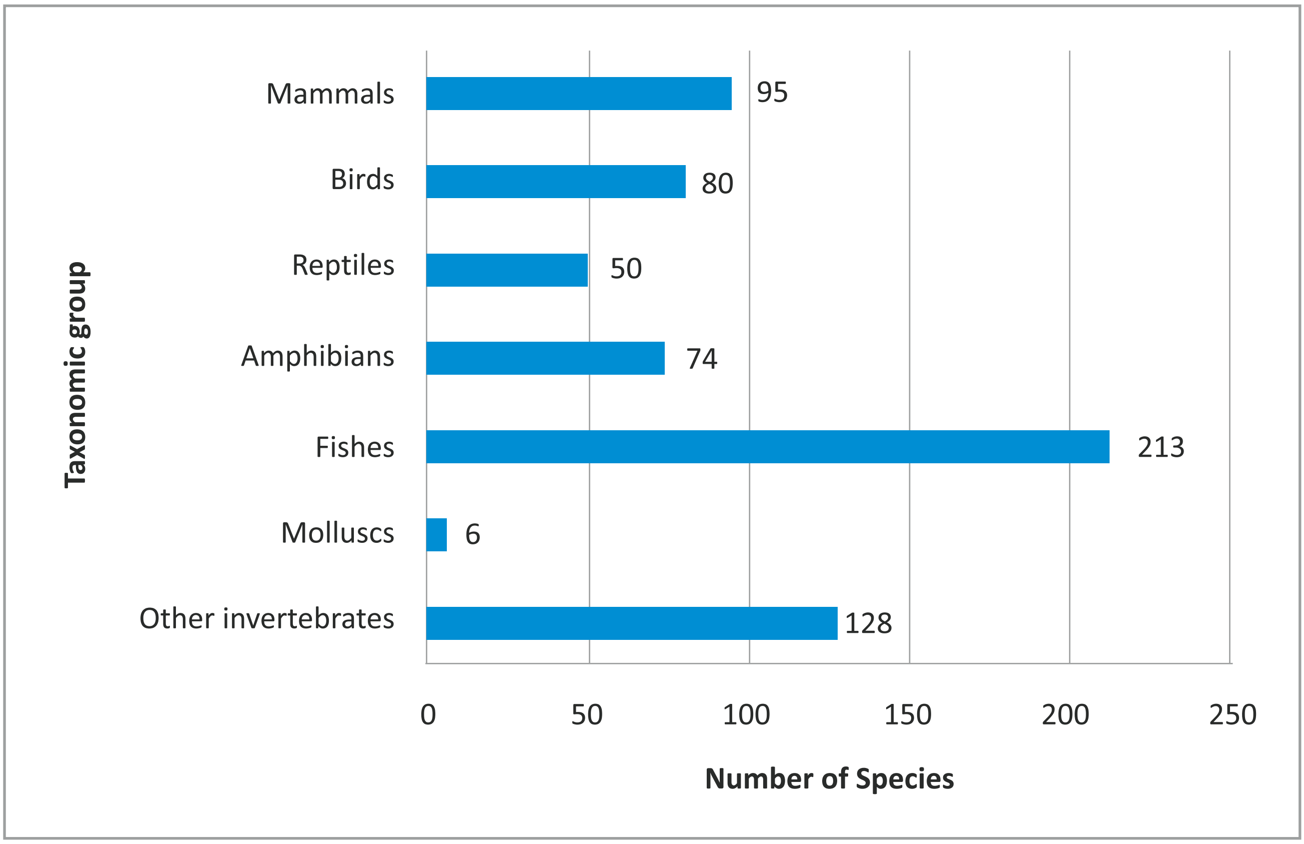
As of 2014, the country has designated 690 Protected Areas, which includes 102 National Parks, 527 Wildlife Sanctuaries, 57 Conservation Reserves and four Community Reserves covering 1,66,851 sq. km or 5.07 per cent of the country's geographical area. The country also has 23 Marine Protected Areas (MPAs) in peninsular India and 106 in the islands. The network has steadily grown since 1988 when India had just 54 National Parks and 373 Sanctuaries covering an area of 1,09,652 sq. km or 3.34 per cent of the country's geographical area. Also, there are 18 notified biosphere reserves in India, nine out of which have been included in the World Network of Biosphere Reserves by UNESCO (WII ENVIS, 2015). The augmentation has been depicted in Table 2.6 (India's 5th National Report to CBD, 2014).

Protection of keystone species helps in maintaining the integrity of the ecosystem and structuring conditions essential for survival of the whole biological community. The government has, thus, supported recovery plans for species with critically low numbers like Indian Rhino, Snow Leopard, Asiatic Lion, Swamp Deer etc. These species recovery plans details current status of the species, its population size, threats and identified conservation measures.

Project Tiger was launched by the Central Government in 1973 to stabilise the dwindling

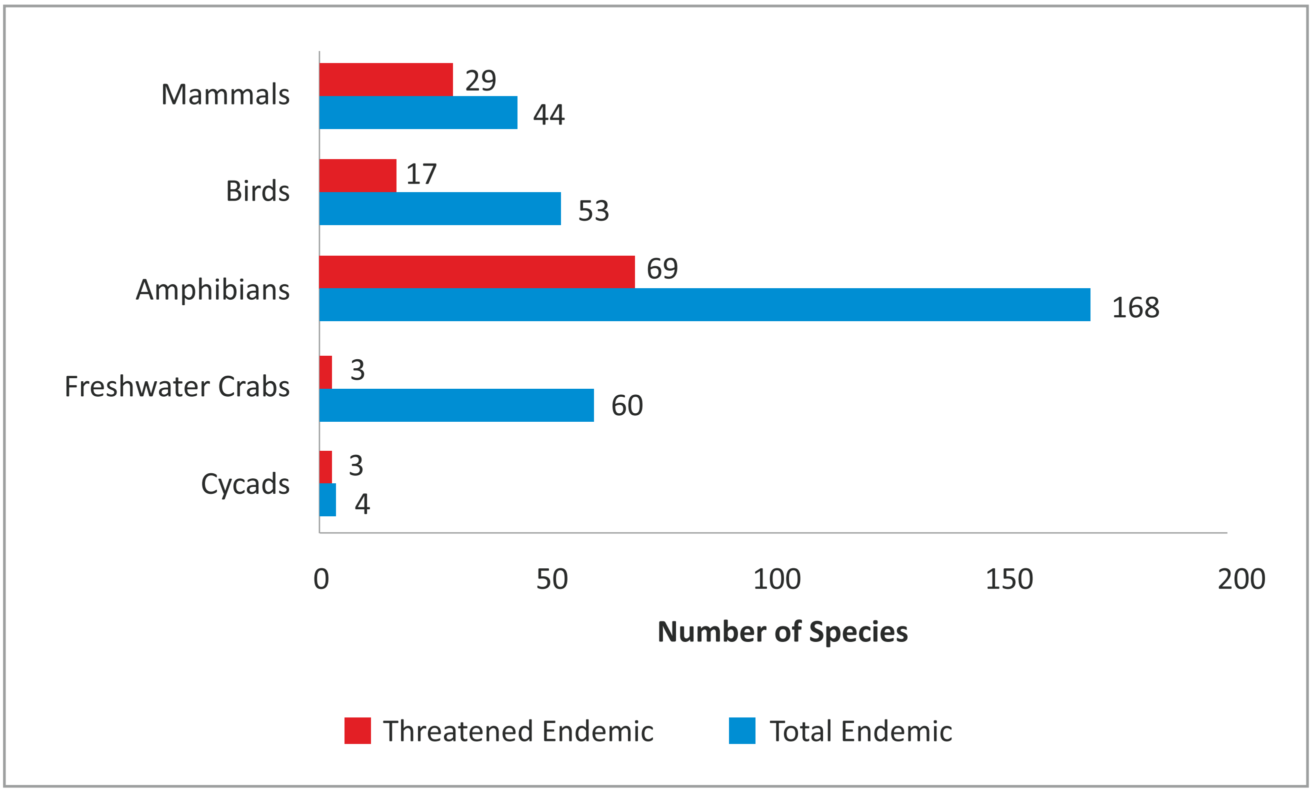
Photo 2.2: India's rich floral diversity

Figure 2.1: Threatened Fauna in India as per IUCN (2013) Red List



Source: 5th National Report to Convention on Biological Diversity, 2014

Figure 2.2: Total Numbers of Endemic and Threatened Endemic Species in India



Source: 5th National Report to Convention on Biological Diversity, 2014

Table 2.6: Status of Protected Areas from 1988 to 2014

Category	1988			2014			Increase in		
	Number	Area (sq. km)	Percentage of TGA	Number	Area (sq. km)	Percentage of TGA	Number (%)	Area (%)	Net area (sq. km)
National Park	54	21,003	0.64	102	40,074	1.22	89	91	19,072
Wildlife Sanctuary	373	88,649	2.7	527	124,738	3.78	41	40	36,089
Conservation Reserve	-	-	-	57	2,018	0.06	-	-	21
Community Reserve	-	-	-	4	21	0	-	-	2,018
Protected Areas	**427**	**109,652**	**3.34**	**690**	**166,851**	**5.07**	**62**	**52**	**57,199**

Source: Wildlife Institute of India, 2014 as reported in 5th National Report to Convention on Biological Diversity, 2014

population of the national animal. From nine tiger reserves in 1973, the Project Tiger coverage has increased to 50 reserves at present, covering an area of 71,027 square kilometres spread out in the 18 tiger range states across the country. This amounts to around 2.08 per cent of the geographical area of our country. The tiger reserves are constituted on a core-buffer strategy wherein the core areas have the legal status of a national park or a sanctuary, and the buffer or peripheral areas are a mix of forest and non-forest land, managed as a multiple use area. The population of tigers in India has steadily gone up from 1706 in 2010 (National Tiger Conservation Authority) to 2,226 in 2015 (MoEF&CC: as quoted in 3rd Asia Ministerial Conference on Tiger Conservation).

Similar initiatives were also taken up for the elephant, which lost habitat with disappearing forests, and vanishing elephant corridors, as roads and highways were constructed through green areas. Despite numerous anthropogenic pressures like illegal poaching and loss of natural habitat, India has been able to maintain the population of its elephants. This is evident in the statistics given in Table 2.7.

Wetlands

Freshwater wetlands are an important ecosystem that support rich biodiversity. There are 115 identified wetlands under the National Wetlands Conservation Programme, in which 26 are of global importance and are recognised as Ramsar Convention sites. (ENVIS center, 2015)

Freshwater wetlands are intended to be managed according to the Ramsar Convention guidelines. Management of marine and coastal wetlands has been discussed in detail in the Marine & Coastal Ecology chapter.

Table 2.7: Elephant Population In India

State	Elephant Population	
	2007	**2012**
Arunachal Pradesh	1,690	1,690
Assam	5,281	5,281
Meghalaya	1,811	1,811
Nagaland	152	212
Tripura	59	59
West Bengal	325-350	325-350
Jharkhand	624	688
Odisha	1,862	1,930
Chattisgarh	122	215
Uttarakhand	1,346	1,346
Uttar Pradesh	380	380
Tamil Nadu	3,867	3,726
Karnataka	4,035	3,900-7,458
Kerala	6,068	6,177
Andhra Pradesh	28	41
Maharashtra	7	4
	27,657-27,682	27,785 - 31,368

Source: 5th National Report to Convention on Biological Diversity, 2014

2.3 PRESSURES

2.3.1 Habitat Loss and Degradation

Population and Economic Growth

India supports about 17.5 per cent of the global human population and it is predicted to become the most populous country in the world by 2030. The increasing population consequently leads to greater resource consumption, which would involve clearing of green areas for human habitation and greater pressure on land for cultivation of food crops, making it one of the key drivers of biodiversity loss. Agricultural practices like mono-cropping and use of hybrids are a potent threat to wild varieties, negatively affecting our vast indigenous gene pool.

Rapid economic growth, industrialisation and higher consumption pattern, require greater resource extraction from the wild areas, by way of activities such as mining and harvesting products from forests and natural water bodies. Construction of dams also submerges a lot of forest land, threatening the biodiversity of that area. About 13,386 ha of forest land has been known to be submerged by the Sardar Sarovar Dam on Narmada River.

Mining is also an established cause threatening forests and biodiversity. The issue has been elaborated in the Land & Forests chapter. Habitat loss and degradation are the major threats to coastal and marine biodiversity in India. The status and threats to the marine ecosystem have been mentioned in complete detail in the Marine & Coastal Ecology chapter (MoEF&CC, 2014).

Land Use Change

Deforestation, habitat destruction and fragmentation, along with conventional intensive land management practices, often reduce the diversity of plants and animals in their natural habitats. Encroachment of forest land for agricultural activities is another major concern. Monitoring of such illegal and unchecked activities becomes difficult due to the Forest Rights Act, as people living on the forest land for three generations, are permitted to use the resources for sustenance and income generation. The destruction of natural flora destroys the habitat of the indigenous fauna and micro-organisms. The land conversion process is dynamic, as the agricultural land could be diverted for human settlements. The box item in the next page demonstrates a case where urbanization has been a prominent threat to biodiversity.

Photo 2.3: Elephants in their natural habitat

Okhla Bird Sanctuary

The Ministry of Environment, Forest and Climate Change has recently announced its intention to reduce the radius of the eco-sensitive zone around Okhla Bird Sanctuary, which is a haven for various migratory and resident birds. The new draft notification was approved under which the Eco-sensitive Zone (ESZ) around the bird sanctuary will range from 1.27 km on the northern boundary to 100 m on the others, down from the 10 km prescribed earlier (Notification declaring ESZ around Okhla Bird Sanctuary in the State of Uttar Pradesh and National Capital Territory of Delhi, MoEF&CC, 2015). This may eventually lead to diminishing migrating grounds for foreign and native birds, in addition to extreme anthropogenic disturbances from the housing societies being established in the vicinity.

2.3.2 Use of Pesticides and Insecticides

Developments in agriculture and the green revolution have accelerated crop production in our country; it also led to excessive use of hazardous chemicals like insecticides, pesticides, herbicides etc. The risk to flora and fauna is from the toxicity of pesticides (as compounds vary in toxicity to different species) and the level of exposure. The risk also varies geographically, with the chemical compounds used and the type and scale of land management, and potentially with the refuges provided by untreated semi-natural or natural habitats in the landscape. Insecticides are toxic to insect pollinators and the direct risk is increased, for example, if label information is insufficient or not respected, where application equipment is faulty or not fit for purpose, or the regulatory policy and risk assessment are deficient. A reduction of pesticide use or use within an established Integrated Pest Management approach would lower the risk of pollinator populations becoming unstable.

Pesticides, particularly insecticides, have been demonstrated to have a broad range of lethal and sub-lethal effects on pollinators under controlled experimental conditions. It is currently unresolved how sub-lethal effects of pesticide exposure recorded for individual insects affect colonies and populations of managed bees and wild pollinators, especially over the longer term.

2.3.3 Invasive Alien Species

In many instances, the indigenous flora and fauna of an area suffer from invasion by alien species, diseases and pests. An alien species, also referred to as exotic, introduced, foreign, non-indigenous or non-native, is one that has been introduced by humans intentionally, or otherwise through human agency or accidentally from one region to another. Invasive species usually flourish due to lack of predators or controlling factors in the foreign environment, thus posing tough resource competition for the native species. Some of the alien plant species in India include *Alternanthera philoxeroides, Cassia uniflora, Chromolaena odorata, Eichhornia crassipes, Lantana camara, Parthenium hysterophorus* and *Prosopis juliflora* (ENVIS Centre on Floral Diversity, 2016). Foreign invasives like *Prosopis juliflora* and *Lantana camara* are threats to traditional Indian sacred groves, since they have a proliferative growth pattern owing to the high number of seeds produced and efficient dispersal mechanisms; thus, not sparing enough resources for growth of the native plants.

The Rhinoceros, *(beetle, Oryctes rhinoceros*) is a known pest of coconut palms trees in India. The pest has recently spread to the oil palm trees in plantations in the vicinity of natural forests. The adult beetles cause extensive damage to the trees by chewing away the leaves and burrowing into the crown, thus stunting plant growth. It can also ravage arecanut plantations (FAO).

Another major concern is the release of ballast water from ships, which may be a carrier of spores/ proliferative forms of alien species from other countries. This issue has been elaborated in the Marine & Coastal Ecology chapter.

Commercial management, mass breeding, transport and trade in species outside their original ranges have resulted in new invasions, transmission of pathogens and parasites and regional extinctions of many of the native species.

Impact of DDT on Biodiversity

Dichloro Diphenyl Trichloroethane or DDT is a Persistent Organic Pollutant (POP) that has been historically used to control malarial vectors and agricultural pests. A global ban on DDT was proposed on account of its severely carcinogenic and toxic effects on human and environmental health. India is party to the Basel and Stockholm Conventions and has banned the use of DDT in agriculture. Use of DDT is permitted for restricted use in the public health sector for control of vectors causing no-vaccine diseases like Malaria and Dengue. The Ministries are continuously trying to reduce dependence on such toxic chemicals.

DDT is also catastrophic for avian reproductive systems because it causes thinning of the egg shells resulting in embryo deaths. Birds like eagles, pelicans, hawks and falcons are known to be sensitive to DDT. The toxin persists in the ecosystem and can be transported across continents by way of food or water, constituting a toxic trail.

Source: Toxics Link, May 2011; and Implementation of Basel, Rotterdam and Stockholm Conventions in India (presentation by MoEF&CC)

2.3.4 Over-exploitation of Natural Resources and Illegal Trade

The medicinal plants industry in India suffers from over-exploitation of rare and wild varieties of beneficial plants that are used in Ayurveda, Siddha and Unani medicine systems. IUCN reports quote that compounds such as Reserpine from Snakeroot and paclitaxel from Himalayan Yew are in great demand in western society too. There is a delicate link between harvest of these precious resources, and the local communities that rely on them for their livelihood. Unregulated trade may endanger the income of such communities which may lead to the loss of this traditional knowledge forever. In order to address illegal trade of medicinal plants, some states like Sikkim have imposed bans on the commercial collection of medicinal plants.

Similarly, the population of Olive Ridley Turtles which nest on the beaches of Odisha has undergone a major decline due to the demand for their meat and eggs (WWF India). They are now under the vulnerable category according to the IUCN Red List. Illegal trafficking of many other animals is also a widespread

Photo 2.4: Pressure on biodiversity - excessive exploitation of fisheries

practice. Tiger skins and skulls are used for making decorative items; bones, teeth and claws are for use in traditional Asian medicine systems. Animals like deer and reptiles are hunted for their skins to make leather products. Trading in ivory or elephant tusks is also a widespread trade practice in the country. As per reports by the Wildlife Protection Society of India, 26 tigers have been known to be poached in 2015. Such activities are counter active to the biodiversity conservation efforts by environmentalists and the government.

2.3.5 Climate Change

Climate change is one of the most pressing environmental challenges of our time. Natural ranges of many species like butterflies have shifted due to change in climate over the last few decades. In many instances, their abundance and seasonal activities have also been affected. For many other species, climate change induced shifts within habitats have had severe impacts on populations and overall distribution.

Forests, by acting as a sink for greenhouse gases, help mitigate the effects of climate change. However forest biological diversity is also directly and indirectly impacted by changing climatic conditions. These changes question the degree to which forests will be able to continue sequestering greenhouse gases in the future (Convention on Biological Diversity).

Photo 2.5: Collection of fuelwood is a pressure on forests and biodiversity

Anthropogenically accelerated climate change remains an overarching threat, particularly for vulnerable ecosystems such as mountains and coastal areas. Manifestations of climate change like increase in the frequency of floods, changing temperature and altered rainfall patterns have dire impacts on biodiversity.

Photo 2.6: Mining activities endanger indigenous flora and fauna

Kaziranga Floods

The Kaziranga National Park, globally known for the one-horned Indian Rhinoceros, was acutely affected by floods in July-August 2016. Incessant heavy rain and overflowing rivers drowned approximately 80 per cent of the park's area killing nearly 200 animals. This included about 17 rhinos and 170 hog deer. Other animals like sambar deer, wild boar and swamp deer have also been reported to have succumbed to drowning.

Flooding of the Brahmaputra valley is an annual event that gets aggravated by higher than normal rainfall causing damage to wildlife in the national park and human life in villages on the fringes. Such climate change related events may have serious implications on biodiversity preservation if not mitigated effectively.

Climate change impacts like flooding or low rainfall may also interplay with factors such as animals congregating at a safe spot or wandering in search of food and water, respectively to aggravate the risk of being poached.

Other climate related threats include erosion (especially in islands), flooding, submergence and deterioration of coastal ecosystems such as mangroves and salinisation. A rise in the sea level may also result in devastation of coastal infrastructure, shoreline erosion, flooding of low-lying agricultural fields and soil salinisation. The impacts have been comprehensively dealt with in the Marine & Coastal Ecology chapter.

2.4 IMPACTS

2.4.1 Biodiversity Loss

Threat to biodiversity stems from pressures such as habitat fragmentation, declining forest resource base and commercial use and over exploitation of resources. Other factors like impact of development projects and pollution, introduction of invasive alien species and climate change also serve as significant threats to biodiversity. Even in situations where populations are stable, the species may suffer from inbreeding depression. This indicates that biodiversity loss may be at the genetic or species level. As per the IUCN Red List 2016, 341 Indian faunal species are 'near threatened' in addition to 665 threatened species. 387 plant species are also listed in the threatened category which includes species that are critically endangered, endangered and vulnerable.

Table 2.8: Status of threatened vascular plant species in India and the world

Status	Global	India
Extinct	380	19
Extinct/Endangered	371	41
Endangered	6,522	152
Vulnerable	7,951	102
Rare	14,505	251
Indeterminate	4,070	690
Total under Threat	**33,779**	**1,255**
Total number of species	**242,013**	**16,000**
Percentage under threat	**13.8**	**7.7**

Source: Botanical Survey of India, Kolkata, as reported in Compendium of Environment Statistics 2015, Ministry of Statistics and Programme Implementation

Table 2.8 gives an estimate of India's threatened plant species with respect to the global statistics and indicates that a significant percentage of India's species diversity is under threat from the numerous factors mentioned in the pressures section of this chapter.

2.4.2 Impact on Ecosystem Services

Loss of biodiversity has large implications for global economy as it may translate in loss of vital ecosystem services. For example, many important cash crops are pollinator dependent. These constitute leading export products in developing countries (e.g., coffee and cocoa), providing employment and income for millions of people. Many other aspects of ecosystem services, for example human (e.g., employment of bee-keepers), social (e.g., bee-keepers associations), physical (e.g., honey bee colonies), financial (e.g., honey sales) and natural assets (e.g., wider biodiversity resulting from pollinator friendly practices), are usually not accounted for in economic evaluation studies. Food security of the country may directly suffer due to absence of pollinators since some plants can be pollinated by specific pollination partners only.

In Kolkata, wetlands facilitate the biological and chemical processes that help in treating the waste water from the city. The natural system also benefits from the process by obtaining important nutrients from the water which stimulate growth in vegetable and fish farms. Loss of these wetlands would devoid the area of the natural system of regeneration and pollution mitigation (TEEB).

2.4.3 Impact on Economy and Livelihoods

As per estimates, nearly 350-400 million people in India are dependent on forest resources for livelihood. These include timber and non-timber forest produce like flowers, resins, fruits, medicinal plants etc. Communities also rely on forests for collection of fodder and fuel-wood. Some favour bee-keepers and honey hunting, as minimal investment is required; diverse products can be sold; and family nutrition and medicinal benefits can be derived from it. Lifestyles such as nomadism and pastoral shifting are also entirely dependent on forest resources. Loss of forest and biodiversity resources thus, would significantly impacts livelihoods of these communities.

Nature tourism or ecotourism is also a growing economic sector that tremendously benefits from the presence of pristine and rich natural habitats. Many wildlife or environment enthusiasts travel to protected areas for documentation, recreational or academic purposes, generating revenue for the government and local people. Loss of in-situ biodiversity will adversely affect the Indian tourism industry, which is expected to grow by 7.5 per cent annually from 2015 onwards.

Loss of native biodiversity can also remarkably reduce India's potential economic benefits from patenting indigenous crops, medicinal plants etc. There are also opportunities for patenting crops like turmeric and basmati rice, which may reap huge economic benefits for Indian farmers and exporters.

2.5 RESPONSES

2.5.1 In-situ Conservation

In-situ conservation refers to protecting the wild form of species in their natural habitat. In addition to designating and managing a number of protected areas across the country (discussed in detail in the Status and Trends section of this chapter), the government has also initiated species specific programmes that target conservation of keystone or flagship species. The idea is to conserve species at the

Photo 2.7: Biodiversity and agriculture are intricately related

highest trophic levels which is essential to conserve the entire natural habitat. Species at the lower trophic levels benefit from the conserved habitat, and are thus, able to thrive better. Such initiatives promote biodiversity conservation at all levels. Some such projects are:

Project Elephant: The government launched this project in 1991-92 to save the Asiatic elephants in India. Main objectives of this programme are to protect elephants and their habitat and corridors as also to address issues of man-animal conflict and to ensure welfare of captive elephants.

The project covers major elephant populations spread over 12 states and inhabiting an area of over 60,000 sq. km. The project is being implemented by the central government in collaboration with the state governments, to provide connecting corridors of protected areas for free movement of elephant herds in their natural range, which may involve inter-state movement. This measure would help in the preservation of the gene pool and also minimise man-elephant conflict (Press Information Bureau).

Project Tiger: Project Tiger is a centrally sponsored scheme to protect our national animal in its natural habitat. Nearly 50 tiger reserves have been demarcated in the 18 tiger states of the country. Under the 12th Five Year Plan, Rs. 1245 crore were allocated for Project Tiger.

From 2010 to 2015, the number of tigers in India has gone up by nearly 30 per cent, such that India now hosts 70 per cent of the global tiger population (2,226 out of 3,890 total), which makes the conservation efforts noteworthy (National Tiger Conservation Authority).

Current progress of Project Tiger and Project Elephant has been discussed in detail in the status and trends section.

Project Snow Leopard: The Snow Leopard, state animal of Himachal Pradesh, is threatened by poaching, low availability of prey and anthropogenic interference. The Snow Leopard Project worth Rs. 5.15 crore was supported by the State Government and MoEF&CC commencing from 2010-11 onwards for a period of four years. Under this project, setting up of a field-based snow leopard research and conservation facility in the Spiti Valley has been proposed, to undertake India's first comprehensive and long term radio-collaring project on snow leopards and their prey.

The 'State Animal' concept has also been promoted by declaring unique animals as state symbols. The native Red Panda is the state animal of Sikkim; and the charismatic Asiatic Lion represents the state of Gujarat. Such a title generates awareness amongst the community and helps focus conservation efforts on the endemic species found in various states.

2.5.2 Ex-situ Conservation

Besides the in-situ conservation measures stated above, India has some comprehensive ex-situ

Photo 2.8: The State Animal Concept - Red Panda-State animal of Sikkim

conservation programmes too. In addition to 33 Botanical Gardens, and 275 zoos, numerous deer parks, safari parks, aquaria etc. have been set up. India also has 110 Medicinal Plant Conservation Areas, each of an average size of 200 hectares, across 13 States.

A Central Zoo Authority was set up to secure better management of zoos. The zoos help in creating awareness among the people and also serve as captive breeding centres to replenish the wild stock. Germplasm banks have been set up, which help in the preservation of the genetic diversity of the flora and fauna of India. These repositories conserve about 260 strains of marine cyanobacteria, 650 blue green algae, 10,000 industrial micro-organisms and 800 in-vitro conserved crop accessions. The National Cryobank accessed 3624 germplasms in 2014 (National Bureau of Plant Genetic Resources, Annual Report - 2014-15).

2.5.3 Institutions for Research, Inventorisation and Management

A strong institutional infrastructure to cater to the needs of India's conservation programmes has been set up. Some of the premier governance, research and education institutions set up are:

1. **National Biodiversity Authority of India:** The NBAI was set up in 2003 to act as an implementing body for the National Biological Diversity Act, 2002, and also as an advisory body for the government on issues like conservation and fair sharing of natural resources.

2. **Zoological Survey of India:** ZSI was established in 1916 as an institution for carrying out research, exploration, surveys and taxonomic studies for the fauna in India. The institute also takes up Environmental Impact Assessment with special reference to ecology and wildlife.

3. **Botanical Survey of India:** BSI was set up in 1890 to study the plant resources in the country to identify plants with economic value. It also undertakes the task of inventorying the Indian flora, and providing information like their distribution, taxonomic classification, economic utility etc. The BSI also stores plant samples in herbariums.

4. **Wildlife Institute of India:** WII located in Dehradun, is an acclaimed wildlife research and management institute. It was established in 1982 and conducts extensive research on wildlife across the country.

5. **Indian Council for Forestry Research and Education:** ICFRE supervises the holistic development of forestry research in India with the objective of promoting forestry in education, research and application fields; and by being the knowledge center for all related resources. The Forest Research Institute in Dehradun is governed by this institution.

6. **Indira Gandhi National Forest Academy:** IGNFA serves as a training institute for the IFS professionals in India, imparting them quality training and helping them develop competence for sustainably managing the country's wildlife and forests.

7. **Salim Ali Centre for Ornithology and Natural History:** SACON is a center of excellence under the MoEF&CC for research on ornithology encompassing all aspects of history and ecology. It also maintains a data bank on Indian ornithology, and its history.

8. **Centre for Biodiversity Policy and Law:** CEBPOL was set up by the Indian government in collaboration with the Norwegian Government in the National Biodiversity Authority, Chennai, for strengthening the biodiversity policy and laws in India. It aims to provide professional support and expertise, to both the Government of India and Norway; to develop professional expertise in biodiversity related policies and laws; to develop and implement capacity building programmes; and to help develop India as a regional and international resource centre for biodiversity policy and law through provision of training and human resource development.

9. **National Mission on Himalayan Studies (NMHS)**: On initiating the Mission in the end of year 2015-16, the Scheme NMHS has taken a great expansion across all 12 Indian Himalayan States involving 42 projects and 12 fellowship grants to reputed IHR Universities, Academic Institutions, government agencies, NGOs etc. at the state as well as regional levels.

   A total of 241 project intervention sites are being studied and 7 innovative models or methods are being developed at present in different Himalayan States, which include "Ecological Niche Modeling" in Uttarakhand and a low-cost "Bio-waste Conversion Model" in J&K.

10. **G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD):** The Institute, established in August 1988, is an autonomous institute of the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, with a mandate of achieving sustainable development and environmental conservation in the Indian Himalayan Region (IHR). The Institute executes its mandate through its Headquarters at Kosi-Katarmal, Almora (Uttarakhand), and five regional Units located at Mohal Kullu (Himachal Pradesh), Srinagar-Garhwal (Uttarakhand), Pangthang (Sikkim), Itanagar (Arunachal Pradesh) and Mountain division (located at MoEF&CC, New Delhi). Over the years, the Institute has achieved Scientific Excellence, which is aptly reflected in SCOPUS database that indicates the Institute stands first in the world w.r.t. publications in Himalayan biodiversity conservation and sustainable development.

2.5.4 Conservation through Participatory Approaches:

Biodiversity Conservation and Rural Livelihood Improvement Project (BCRLIP)

Biodiversity Conservation & Rural Livelihood Improvement Project (BCRLIP) aims at conserving biodiversity in selected landscapes, including wildlife protected areas and critical conservation areas, along with improving rural livelihoods through participatory approaches. Development of Joint Forest Management (JFM) committees and eco-development are models of new approaches in some states to provide benefits to both conservation and local communities. The project intends to build on these models and expand lessons to other globally significant sites in the country to strengthen linkages between conservation and improving livelihoods of local communities as well as enhance the local and national economy (MoEF&CC, 2016).

This programme is aimed at strengthening biodiversity conservation and improving rural livelihoods at landscape sites.

The activities to be supported under the project are-

- Component 1 - Demonstration of Landscape Conservation Approaches in two Pilot Sites.
- Component 2 - Strengthening Knowledge Management and National Capacity for Replication of Landscape Conservation Approaches.
- Component 3 - Scaling up and Replication of Successful Models of Conservation in Additional Landscapes Sites.
- Component 4 - Coordination for Landscape Conservation.

The project is to be implemented over a course of six years (July 2011-July 2017).

People's Biodiversity Register

Another participatory approach involves preparation of People's Biodiversity Registers (PBRs), which would be a compendium of comprehensive information on the local biological resources; medicinal or economic applications, and traditional knowledge for conservation and management. This is an enriching scientific activity that may greatly contribute to research and development of conservation plans for the resources. 5465 PBRs have been documented in 17 states in the country (Ministry of Environment, Forest and Climate Change, 2015).

2.5.5 Biological Diversity Act 2002 and National Biodiversity Action Plan

Pursuant to the Convention on Biodiversity, India enacted the Biological Diversity Act in 2002, and notified Biological Diversity Rules in 2004, to give effect to the provisions of this Convention. The Act is implemented through a three-tiered institutional structure at the national, state and local levels. The National Biodiversity Authority (NBA) was set up in October, 2003 in Chennai (MoEF&CC, 2016).

The vision of NBA is the conservation and sustainable use of India's rich biodiversity and associated knowledge with people's participation; ensuring the process of benefit sharing for wellbeing of present and future generations. The mission of NBA is to ensure effective implementation of Biological Diversity Act, 2002 and the Biological Diversity Rules 2004 for conservation of biodiversity, sustainable use of its components and fair and equitable sharing of benefits arising out of utilization of genetic resources (MoEF&CC, 2016).

Under the National Biodiversity Action Plan, India has set 12 National Biodiversity Targets that are in sync with the 20 Aichi Biodiversity Targets. The National Biodiversity Action Plan, details the framework and the targets to be met by 2020. The targets can be summarised as follows:

- Raising awareness about biodiversity values amongst the youth and making it a part of the education system.
- Integrating biodiversity conservation values into national and state level planning processes, and all developmental programmes.
- Finalising strategies and methods to reduce degradation, and loss of natural habitats.
- Identifying and managing alien invasive species.
- Implementing sustainable management of agriculture, fisheries and forests.
- Protecting areas that are ecologically valuable such as habitats of certain keystone or rare species; and, designating and scientifically managing a protected area network.
- Maintaining and safe guarding the genetic diversity in the country.
- Identifying and enumerating ecosystem services in the country, and developing measures to protect the resources.
- Ensuring access to genetic resources for fair and equitable sharing of benefits, as per the Nagoya Protocol.
- Ensuring an operational participatory and effective National Biodiversity Action Plan by 2020.
- Preservation of traditional knowledge from communities and strengthening of national initiatives using them.
- Ensuring increase in availability of human, financial and technical resources to aid implementation of Strategic Plan for Biodiversity 2011-2020.

2.6 CONCLUSION

The biosphere functions on the intricate linkages between its components: flora, fauna and humans, thus, having multidimensional impacts on human life. It aids pivotal ecosystem functions, provides livelihoods and resources like fuelwood and food to forest dwelling communities, whilst also contributing to the economy by way of tourism and recreation and trade of crops and plants. Many tribal communities are dependent on seasonal forest produce to earn a substantial part of their annual income, for example, the Baiga tribes that harvest Mahua flowers. 58 per cent of India's households report farming as their main occupation, which includes agriculture, livestock rearing, and other forms of cultivation. India has many indigenous plant varieties like basmati and turmeric that are in demand the world over, making it all the more urgent for India to preserve and invest in its biodiversity resources.

Biodiversity loss is not an immediate and evident phenomenon; and most of its effects can only be analysed over a longer period of time, a decade probably being the minimal unit of measurement. In the long term, biodiversity loss may impact entire food chains and webs; may hamper economic growth and adversely affect human health through effects such as increased man-animal conflicts and consumption of genetically modified crops. It is evident that disruption of food chains due to biodiversity loss will have the most profound impact on humans, severely jeopardising food security. This provokes us to give greater consideration to the issue and manage it well.

The Aichi Biodiversity Targets were defined considering the impending threats from biodiversity loss. These include 20 goals ranging from raising awareness regarding biodiversity, to legally protecting and scientifically studying it. The SDGs also have aptly defined goals for preserving life on both land (goal 15) and in water (goal 14). India has taken many initiatives like introducing the Forest Rights Act to enable the participation of the local communities to better manage their forests. India is also determined to fulfil its commitment to the Convention on Biological Diversity, by complying with the National Biodiversity Targets. The twelve national targets have been set to be met by 2020. Nearly 51 composite indicators have been formulated under the National Biodiversity Action Plan (that defines 12 National Biodiversity Goals), which would include setting up institutions for quality research activities and to inevitably include biodiversity as a component in state and national level planning. Studying trends in areas of concern such as medicinal plants, trade and equitable access to resources has also been indicated as primarily important. The focus on preserving traditional knowledge and indigenous gene banks is stronger than ever. The MoEF&CC has involved all stakeholders, and is currently in the process of defining its indicators to fulfil the Sustainable Development Goals for environmental and biodiversity protection.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 3

MARINE AND COASTAL ECOLOGY

Key Messages

- *India harbours rich coastal and marine biodiversity.*
- *Coastal habitat degradation is the most critical threat, largely emanating from land and sea based activities and climate change.*
- *India has taken significant measures for the protection and conservation of its coastal and marine resources.*
- *Some interventions for ecological restoration of coastal habitats through community participation, with a focus on adaptation and generation of sustainable livelihoods, have been made. Such approaches need to be mainstreamed with greater involvement of communities in aspects of conservation and management.*
- *India has built many robust research and institutional capacities for the sustainable management of its coastal and marine resources.*

3.1 INTRODUCTION

The Indian peninsula is bounded by the Bay of Bengal on the East, the Indian Ocean on the South and the Arabian Sea on the West. The country has an extensive coastline of 7,516.6 km that includes 5,422.6 km of mainland coast and 2,094 km, represented in the two major island clusters of the Andaman & Nicobar islands off the eastern coast and the Lakshadweep islands off the western coast. The Exclusive Economic Zone (EEZ) of the country that is the area extending beyond the shores up to 200 nautical miles and including both marine waters and seabed stands at 2.02 million km^2. Coastal marine realm of India has different habitats and ecosystems that include sandy beaches (Fig.3.1) rocky shores, mud-flats, mangroves, coral reefs and seagrass meadows.

These, with their ecological services play a vital role in sustaining the economic stability of the country as nearly 4 million people in the country are majorly dependent on the rich coastal and marine resources for their livelihoods and basic needs (Draft National Policy on Marine Fisheries, 2016).

3.2 STATUS

India has very striking coastal and marine features which are depicted in Table 3.1. These include geographical spread, geomorphology, fisheries, maritime states and ports and harbours.

3.2.1 Coastal Environment

In India, Integrated Coastal Marine Area Management Centre of the Earth System Science Organisation (ICMAM-ESSO) has been implementing the COMAPS (Coastal Ocean Monitoring and Prediction System) programme with the objectives of monitoring the physico-chemical and biological water quality parameters periodically in selected locations of the coastal waters of India and developing possible prediction of sea water quality to assess the state of marine environment. Under the COMAPS programme, data for 25 parameters such as dissolved oxygen (DO), nutrients, pH, biological oxygen demand (BOD), plankton, benthos and pathogenic bacteria are being monitored at 20 coastal locations. Water quality data collected from 2011-12 to 2014-15 indicate the coastal ecological status of India (Table 3.2).

3.2.2 Coastal and Marine Biodiversity

Coastal and marine floral diversity (Table 3.3) includes

Photo 3.1: Sandy beach and intertidal area in the Andamans

14 species of seagrasses, 39 species of mangroves and hundreds of species of diatoms, macroalgae and dinoflagellates. Marine faunal diversity includes 3,498 species of crustaceans, 3,370 species of molluscs, 765 species of echinoderms, 2,546 species of fishes, 35 species of reptiles and 25 species of marine mammals. In addition, a large number of sea bird species have also been recorded (Fig. 3.2-3.7).

Various fish species recorded from the Indian waters contribute to the fisheries potential of the country. In 2011, the potential yield from the Indian Exclusive Economic Zones (EEZ) was estimated at 4.412 million metric tonnes (mmt). This estimate is 12.2 per cent higher than the previous estimate made in the year 2000 (3.934 mmt). Pelagic resources such as Indian Oil Sardine, Indian Mackerel and ribbonfish form 2.128 mmt (48.2 per cent); demersal resources such as penaeid and non-penaeid prawns, cephalopods, perches and croakers comprise 2.067 mmt (46.8 per cent) and oceanic resources mainly comprising Yellowfin Tuna, Skipjack Tuna, Bigeye Tuna, billfishes, pelagic sharks, Barracuda, Dolphinfish and Wahoo constitute 0.217 mmt (4.9 per cent). Depth-wise distribution of the estimated potential yield from the Indian EEZs has been estimated as 3.821 mmt up to 100 m depth (86.6 per cent), 0.259 mmt from depths between 100-200 m (5.8 per cent) and 0.115 mmt from depths between 200-500 m (2.6 per cent). The remaining 0.217 mmt (4.9 per cent) is from the oceanic waters. The average marine fish catch during the last four years (2012-13 to 2015-16) is 3.499 mmt. While the fisheries resources from the near-shore waters are fully utilized, the deep sea and oceanic waters offer opportunities of increasing the harvest (GoI, 2016) through sustainable approaches.

3.2.3 Important Coastal Ecosystems

In India, estuaries, lagoons, seagrass meadows, mangroves and coral reefs are some of the important coastal and marine ecosystems.

Table 3.1 Coastal and Marine Features of India

Coastal data	
Length of coastline	7516.6 km Mainland: 5422.6 km Island Territories : 2094 km
Total land area	3,287,263 km^2
Area of continental shelf	372, 424 km^2
Territorial sea (up to 12 nautical miles)	193,834 km^2
Exclusive Economics Zone	2.02 million km^2
Maritime States and UTs	
Number of coastal States and Union Territories	Nine states 1. Gujarat 2. Maharashtra 3. Goa 4. Karnataka 5. Kerala 6. Tamil nadu 7. Andhra Pradesh 8. Odisha 9. West Bengal Two Union Territories 1. Daman & Diu 2. Puducherry
Island Territories	1. Andaman & Nicobar Islands (Bay of Bengal) 2. Lakshadeweep Islands (Arabian sea)
Total number of coastal districts	69 coastal districts in mainland India, 3 in Andaman & Nicobar and 1 in Lakshadweep
Coastal Geomorphology (Mainland)	
Sandy Beach	43%
Rocky Coast	11%
Muddy Flats	36%
Marshy Coast	10%
Coastline affected by erosion	1624.435 km mainland 132 (islands) (CPDAC)
Coastal ecosystems	
Coastal wetlands	43230 km^2
Major estuaries	97
Major lagoons	34
Mangrove areas	31
Area under mangroves	6740 km^2 (75% east coast, 23% west coast, 20% Andaman & Nicobar islands)
Coral reef areas	5
Marine Protected Areas (MPA)	31
Area covered by MPA	8214 km^2
Marine Fisheries	
Number of marine fishing villages	3288 (CMFRI Census 2010)
Fishermen population	about 4 million in 864,550 families
Number of Fishing Harbours	Major fishing harbours: 6 Minor fishing harbours: 40
Number of fish landing centres	1511 (CMFRI Census, 2010)
Estimated marine fish landing	3.59 million tonnes (ENVIS report WII 2014)
Fishing craft	194,490 crafts Mechanized :37% Motorized : 37% Non-motorized: 26%
Ports and Harbous (sources: Indian Ports Association)	
Major ports	13

Source : Institute for Ocean Management, Anna University (2016)

Table 3.2: Water Quality Parameters Recorded from the East and West Coasts of India

State/UT	Period	Ecological Status
Gujarat (Vedinar and Hazira/Tapi)	2014-2015	Vadinar: Good with high values of DO (6-7 mg/l) with low levels of nutrients and pathogenic bacteria Tapi estuary: Moderate level of DO, nutrients and pathogenic bacteria
Maharashtra (Thane Creek / Worli, Ratnagiri and Malvan)	2013-2014	Thane, Worli: Moderate with high levels of nutrients, (NO_3: 9-124 µmol/l) and normal DO (2-6 mg/l). Ratnagiri and Malvan: Good with normal values of DO (5-7mg/l) and nitrate (1- 6 µmol/l)
Goa (Mandovi)	2012-2013	Good with normal level of DO (4-6mg/l), nutrients and SFLO (ND-12 CFU/ml)
Karnataka (Mangalore)	2013-2014	Good with normal levels of DO (3-8 mg/l) and nutrients (nitrate: 5 - 12 µmol/l); high occurrence of pathogenic bacteria (SFLO: NG–8400 CFU/ml), indicating contamination due to domestic sewage discharge
Kerala (Kochi)	2014-2015	Normal DO (5-7 mg/l) and nutrient values (nitrate: 1-10 mol/l); high levels of pathogenic bacteria (SFLO: 0-7600 CFU/ml), indicating contamination due to domestic wastes
Lakshadweep (Kavaratti)	2013-2014	Normal range of DO (3-7 mg/l) and nutrients; high levels of pathogenic bacteria (SFLO: NG-13600 CFU/ml), indicating contamination due to domestic wastes
West Bengal (Sandheads, Hoogly estuary)	2012-2013	Good with high levels of DO (6-8 mg/l) and moderate levels of nutrients; high levels of pathogenic bacteria at Sandheads (SFLO: 15-13500 CFU/ml), indicating contamination due to domestic sewage
Odisha (Paradip)	2013-2014	Normal range of DO (6-8 mg/l) and nutrients; moderate levels of pathogenic bacteria (SFLO: 25-4000 CFU/ml), indicating contamination due to domestic sewage
Andhra Pradesh (Kakinada)	2014-2015	Good with normal levels of DO (5-7mg/l) and moderate levels of nutrients
Tamil Nadu (Ennore, Tuticorin) and Puducherry	2014-2015	Moderate with normal ranges of DO and nutrients; significantly high levels of pathogenic bacteria (SFLO: 230-2500 CFU/ml) at many shore locations, indicating contamination due to domestic sewage
Andaman & Nicobar islands	2014-2015	Port Blair: Good with normal levels of DO (5-8mg/l) and nutrients; low levels of pathogenic bacteria (SFLO: 6-177 CFU/ml).

Source: Coastal Ocean Monitoring and Prediction System

Estuaries

Estuaries mark the transitional zone between the lower tidal region of a river and the marine environment. They are sheltered coastal water bodies which act as nutrient traps, shelter and nursery for a variety of marine life forms. They are very important from commercial, industrial and recreational point of view. There are fourteen major estuaries on the eastern coast and sixteen on the western coast. Major eastern coast estuaries are Adyar, Agniyar, Corum, Edaiyur, Ennire, Godavari, Hoogly, Kallar, Kavery, Kollidam, Krishna, Rushikulya, Uppanar and Vellar. Major western coast estuaries are Asthamudi, Amba, Beypore, Gangolli Kali, Kaninamkulam, Korapuzha, Madovi, Mahi, Mahim, Netravathi and Gurupur, Pavenje, Periyaar, Vembanad and Zurai.

Lagoons

Lagoons are shallow water bodies along the low lying coast separated from the ocean by a barrier but also connected to the ocean by one or a few restricted inlets. There are eight major lagoons on the eastern coast and nine on the western coast. Lagoons on the eastern coast include Bende, Chilka, Gulf of Mannar, Muthupet, Muthukadu, Nizampatnam, Pennarand Pulicat. Lagoons on the western coast include Asthamudi, Ettikulum, Paravur, Murukumpuzha, Talapady, Veli, Vembanad.

Seagrasses

Seagrasses are monocots found submerged in shallow and sheltered localities of the sea, gulf, bays, backwaters and lagoons. They play an important role

Table 3.3: Diversity of Coastal and Marine Species in India

Group	Number of Species
Plantae	
Diatoms	200+
Dinoflagellates	90+
Macroalgae	844
Seagrasses	14
Mangroves	39
Protista	
Protozoa	532+
Foraminifera	500+
Tintinnids	32+
Animalia	
Porifera	486+
Cnidaria	842+
Ctenophora	12+
Platyhelmintha	350
Annelida	338
Chaetognatha	30+
Sipuncula	35
Echiura	33
Gastrotrocha	75
Kinorhyncha	10
Tardigrada	10+
Crustacea	3,498
Mollusca	3,370
Bryozoa	200+
Echinodermata	765
Hemichordata	12
Protochordata	119+
Pisces	2,546
Reptilia	35
Mammalia	25
Total number of Species	**15,042 +**

Source: Wafar et al., 2011

in the conservation of many endangered species like sea cows, marine turtles etc. Based on remote sensing studies, seagrass cover has been estimated as about 225 sq. km in the four major seagrass areas i.e. the Gulf of Mannar, Palk Bay, Lakshadweep and Andaman & Nicobar islands (Thangaradjou, 2016).

Major seagrass meadows are found along the southeast coast (Gulf of Mannar – 5,710.66 ha and Palk Bay – 2,658.31 ha), lagoons of Lakshadweep (1066.59 ha) and the Andamans (1,223.9 ha) and Nicobar (1,719.4 ha). In India, there are 14 species of seagrass in 7 genera Shallow waters of the Gulf of Mannar and Palk Bay have rich seagrass meadows of 11 species with three exclusive species. These meadows are of greater significance as they represent the largest feeding grounds for the globally endangered *Dugong dugon*. In the Gulf of Mannar

Photo 3.2: Padina (Seaweed, brown alga)

Photo 3.3: Syringodium isoetifolium (Seagrass)

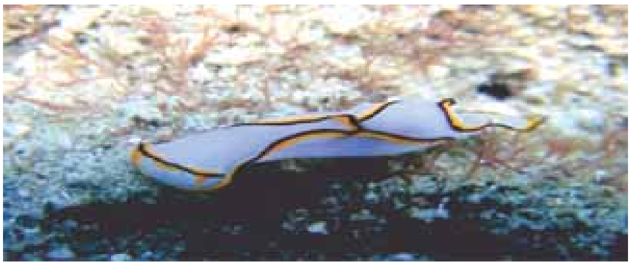

Photo 3.4: Chelidonura pallida (sea slug)

Photo 3.5: Arothron nigropunctatus (Blackspotted Puffer Fish)

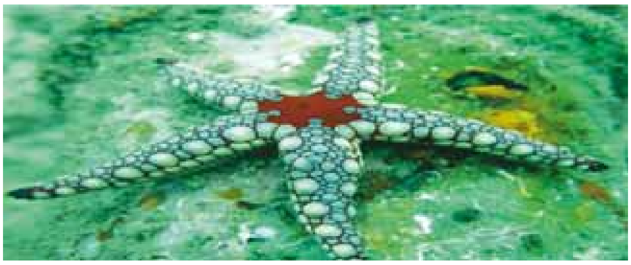

Photo 3.6: Fromia monilis (Tiled Starfish)

Photo 3.7: Heteractis magnifica (Magnificent Sea Anemone)

Photo 3.8: Mangroves

and Palk Bay, main seagrass species are *Tahalassia hemprichii, Cymodocea rotundata, C. serrulata, Halodule uninervis* and *Halophila ovata. Syringodium isoetifolium* and *Halophila spp.* occur in patches as mixed species. Seagrass flora of Lakshadweep is dominated by *T. hemprichii and C. Rotundata,* and include *S. isoetifolium and H. ovalis.*

Seagrass meadows provide a host of ecosystem services. Provisioning services include the use of some seagrass species as food; supporting services include maintenance of marine biodiversity, primary production and nutrient enrichment and regulating services include carbon sequestration and prevention of pollution and sedimentation. Seagrasses also act as 'biological sentinels' and 'coastal canaries' in that, their presence is indicative of the health of the ecosystem.

Recent remote sensing studies have revealed the loss of seagrass meadows in India, with cover reductions in the Palk Bay (261.31 ha), Gulf of Mannar (2,860.34 ha), Lakshadweep (73.03 ha) and Andaman (146.50 ha) & Nicobar (1,472.90 ha), due to various natural and anthropogenic stressors (Jagtap et al., 2016).

Mangroves

Mangroves are salt tolerant forest ecosystems found mainly in tropical and sub-tropical inter-tidal regions. They are shrubs or trees, growing in shallow and muddy brackish waters, especially along quiet shorelines and estuaries. Mangroves protect the shorelines from the action of waves, storms and

Table 3.4: Mangrove Cover in Indian Coastal States and Union Territories

State /UT	Assessment year (Area in km^2)												
	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005	2009	2011	2013
A & N Islands	686	973	971	966	966	966	966	789	658	635	615	617	604
Andhra Pradesh	495	405	399	378	383	383	397	333	329	354	353	352	352
Daman & Diu	0	0	0	0	0	0	0	0	1	1	1	2	2
Goa	0	3	3	3	3	5	5	5	16	16	17	22	22
Gujarat	427	412	397	419	689	901	1,031	911	916	991	1,046	1,058	1,103
Karnataka	0	0	0	0	2	3	3	2	3	3	3	3	3
Kerala	0	0	0	0	0	0	0	0	8	5	5	6	6
Maharashtra	140	144	113	155	155	124	108	118	158	186	186	186	186
Odisha	199	192	195	195	195	211	215	219	203	217	221	222	213
Puducherry	0	0	0	0	0	0	0	1	1	1	1	1	1
Tamil Nadu	23	47	47	21	21	21	21	23	35	36	39	39	39
West Bengal	2,076	2,109	2,119	2,119	2,119	2,123	2,125	2,081	2,120	2,136	2,152	2,155	2,097
Total	**4,046**	**4,255**	**4,244**	**4,256**	**4,533**	**4,737**	**4,871**	**4,482**	**4,448**	**4,581**	**4,639**	**4,663**	**4,628**

Source: Forest Survey of India, 2015

Photo 3.9: Establishment of mangrove seedlings in Andaman

cyclones and prevent coastal erosion. They provide shelter and breeding grounds to a variety of marine life forms and act as nursery grounds for juveniles and larvae of many marine animals. Mangroves provide a range of critical ecosystem services. Provisioning services include the provision of food in the form of fin fish, shell fish and vegetables, timber, fuel wood, medicines and other non-timber forest products. Regulating services include the protection of the shoreline, flood attenuation, promotion of land accretion, carbon sequestration and trapping of pollutants while supporting services include primary production and maintenance of biodiversity.

Mangroves in India fall within the Indo-Pacific tropical zone that have the dominant mangroves and are important in respect of species diversity, richness, abundance and succession. The most dominant and single largest mangrove region of the world is situated in the Ganga-Brahmaputra-Meghna deltaic regions and estuarine mouths in India and Bangladesh. 39 species of mangroves are found in India and some of the common genera represented include Avicennia, Rhizophora (Figure 3.8), *Sonneratia, Bruguiera, Heritiera, Ceriops, Xylocarpus* and *Nypa.* India accounts for 2.6 per cent of the global mangrove cover of 14 Mha. The Forest Survey of India (2015) has reported an increase in mangrove cover in India from 4,046 km^2 in 1987 to 4,628 km^2 in 2013 (Table 3.4). There is a net increase of 582 sq. km with a maximum area increment in Gujarat (676 km^2) followed by Maharashtra (46 km^2), Goa (22 km^2), West Bengal (21 km^2) and Odisha (14 km^2). There is a decline of 143 km^2 in Andhra Pradesh followed by Andaman & Nicobar (82 km^2).

The mean annual change in the mangrove area during the period of 1987-2013 was 24.25±82.57 km^2. Most states showed mean annual increment in area except Andhra Pradesh (-5.95±15.70 km^2) and Andaman and Nicobar (3.41±52.32 km^2). This decline can be attributed to the devastating tsunami that swept the Andaman & Nicobar coast during 2004, and the spread of agriculture and other developmental activities in Andhra Pradesh. Mean annual increase in area was maximum in Gujarat (28.16±50.58 km^2), followed by Maharashtra (1.91±11.14 km^2) and Goa (0.91±1.57 km^2). Mangroves in India are well protected owing to the efforts of the State Forest Departments and MoEF&CC in initiating plantations and other restoration and conservation measures (Sahu et al., 2015).

Coral Reefs

Corals are tiny organisms, capable of secreting a massive calcareous skeleton and collectively deposit calcium carbonate to build ornate and sometimes large colonies. Concerted growth of a variety of corals in a localized habitat gives rise to a coral reef, a complex and biodiversity rich ecosystem, which consists of a variety of organisms.

Coral reefs are among the most dynamic and productive ecosystems of the world. They prevent coastal erosion, act as important breeding and nursery grounds for shell and fin fish and offer sustenance and employment to coastal communities. Ecosystem services provided by the coral reefs include provisioning of fish and other species for food and aquaria, curios, ornamental and medicinal products and cultural services in the form of recreation and tourism opportunities. Supporting services include the maintenance of biodiversity, primary production, prevention of coastal erosion and beach accretion while regulating services include protection of coastline from climate related natural hazards.

There are mainly three types of coral reef formations – fringing reefs, barrier reefs and atolls. In India, fringing reefs are found in the Gulf of Mannar, Palk Bay, Gulf of Kachchh and the Andaman & Nicobar islands. Barrier reefs are found on the western side of the Andaman islands and atolls are common in the Lakshadweep islands. Biodiversity (microbial, floral and faunal) of the coral reefs is very rich (Amita Saxena, 2015). A total of 199 species of corals belonging to 71 genera were recorded from the Indian Ocean in 1996. Later, a team of UNDP and Indian experts in 2000-01 reported the occurrence of more than 200 species of corals in the Andaman islands alone. It is likely that more extensive surveys would lead to a rise in the number of coral species recorded in India. Dominant genera are *Acropora* (34 species) (Fig. 3.10), *Montipora* (14 species) (Fig.3.11)

Photo 3.10: Acropora formosa (New growth)

Photo 3.11: Montipora aequituberculata (Foliose Coral) in Andamans

and *Porites* (12 species). Massive forms are represented by *Porites, Favia, Favites, Goniastrea, Platygyra, Symphyllia* and *Leptoria. Cyphastrea* and *Leptastrea* are common in reefs. There are also species of *Pocillopora, Seriatopora, Stylophora* and *Cycloseris*.

A review of the health of the Indian reefs from 1998 to 2011 has revealed that coral bleaching was the major factor, determining the extent of live coral cover in the Lakshadweep, Gulf of Mannar and Andamans (Rajan et al, 2015). Reduction in the live cover was observed in the Lakshadweep and Gulf of Mannar reefs. Recovery from the bleaching event was found in the Andaman region, though the combined long term impacts of bleaching, reef area loss due to seismic uplift and the tsunami of 2004 were indicated by the declining trend in reef health. Local scale stressors were intense in the Gulf of Kachchh and Gulf of Mannar reefs, more chronic in the former. In the latter, recovery from the bleaching event was impeded by the local stressors. Good species diversity and richness were observed in majority of the reefs of the Lakshadweep and Andamans where the local stressors were minimal, revealing the fact that there is resilience in these reefs in terms of maintaining diversity.

3.2.4 Important Coastal and Marine Fauna

Some of the important fauna recorded from the Indian coastal and marine regions and their present status have been described by Joshi et al. (2015).

Marine Mammals

Major marine mammals found in India include dolphins, whales and sea cows. Species diversity of dolphins in India is amongst the richest in the world, with five species that include Spinner Dolphin (*Stenella longirostris*), Humpback Dolphin (*Sousa chinensis*), Common dolphin (*Delphinus delphis*), Bottlenose Dolphin (*Tursiops truncatus*) and Risso's Dolphin (*Grampus griseus*). Whales constitute the dominant group of marine mammals in India with as many as ten species including Longman's Beaked Whale (*Indopacetus pacificus*), Sei Whale (*Balaenoptera borealis*), Blue Whale (*B. musculus*), Minke Whale (*B. acutorostrata*), False Killer Whale (*Pseudorca crassidens*), Sperm Whale (*Physeter macrocephalus*) and Cuvier's Beaked Whale (*Ziphius cavirostris*).

The most endangered marine mammal in India is the Dugong (*Dugong dugon*) or sea cow. Listed as vulnerable (IUCN, 2013) and protected under Schedule I of the Wildlife Protection Act, it mostly inhabits the Gulf of Mannar and Palk Bay. In 2010, its population was estimated between 131 to 254 individuals, of which about 60 per cent was found in the Gulf of Mannar and 30 per cent, in the Palk Bay.

Turtles

Five species of sea turtles reported from India include Olive Ridley (*Lepidochelys olivacea*), Green (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*) and Loggerhead (*Caretta caretta*). All the five species are protected under Schedule I of the Wildlife Protection Act, 1972.

Except for the Loggerhead, the remaining four species are known to nest along the Indian coastline. Olive Ridleys nest along both the eastern and western coasts of India, with globally significant nesting sites at Gahirmatha and Rushikulya in Odisha. There are three mass nesting grounds of Olive Rridley turtles in Gahirmatha, Rushikulya and Devi in Odisha, where more than hundred thousand turtles nest every year. However, mass nesting has not been recorded from Devi for the last fifteen years. Leatherbacks are restricted to Great and Little Nicobar islands, and Little Andaman island. Green turtles nest in Gujarat, Lakshadweep and the Andaman and Nicobar Islands. There are also important foraging grounds for Green turtles in the Gulf of Mannar, Lakshadweep and Andaman and Nicobar islands.

Photo 3.12: Holothuria atra (Black Sea Cucumber)

Leatherbacks are one of the most charismatic creatures, inhabiting the tropical and temperate waters from Pacific to North Atlantic and throughout the Indian Ocean. It is the largest extant marine turtle in the world and follows the longest migratory route known for turtles. This species is currently listed as vulnerable under the IUCN red list and given the highest level of protection under Schedule I (Part II) of the Indian Wildlife protection Act, 1972.

Marine Molluscs

A total of 3,271 species of molluscs have been recorded. They are distributed in 220 families and 591 genera, of which 1,900 are gastropods, 1,100 bivalves, 210 cephalopods, 41 polyplacophores and 20 scaphopods. Among these, eight species of oysters, two species of mussels, seventeen species of clams, three species of pearl oysters, three species of giant clams, one species of windowpane oyster and gastropods such as Sacred Chank, *Trochus*, *Turbo* and fifteen species of cephalopods are exploited from the marine sector of India. Species like *Cassis cornuta, Charonia tritonis, Conus milneedwardsi, Cypraecassis rufa, Nautilus pompilius, Hippopus hippopus, Tridacna maxima, T. squamosa* etc. are some of the molluscs protected under the Wildlife (Protection) Act 1972, Schedule I.

Corals and Gorgonians

Reef building corals (all Scleractinians), Black Coral (all Antipatharias), Organ Pipe Coral (*Tubipora musica*), Fire coral (all *Millipora* species) and Sea Fan (all Gorgonians) are protected under Wildlife (Protection) Act 1972, Schedule I.

Other Marine Organisms

Sea horses, pipe fishes (Sygnathidae) and sea cucumbers (Holothurians) (Fig.3.12) are included in the list of protected animals as per the Wildlife (Protection) Act 1972, Schedule I.

3.3 PRESSURES

Despite the tremendous ecological and economic importance and the existence of a policy and regulatory framework, India's coastal and marine ecosystems are under threat (Sivakumar et al., 2012). Numerous direct and indirect pressures arising from different types of economic developments and associated activities are causing adverse impacts on coastal and marine biodiversity. These pressures are major drivers of ecosystem- degradation by habitat conversion for other forms of land use, overexploitation of species and associated destructive harvesting practices, spread of invasive alien species and discharge of agricultural, domestic and industrial sewage and wastes. Development of ports and harbours all along the coasts is also threatening the coastal biodiversity. Further, natural phenomena such as tsunamis, cyclones, hurricanes and storms alter the habitats. Indirect drivers of ecosystem change include demographic, socio-political, cultural, economic and technological factors.

3.3.1 Land Based Pollution

Discharge of Industrial and Domestic Wastes

Approximately, eighty per cent of the pollution that enters the marine environment originates from land based sources, and pollution in the marine and coastal areas is from both point and non-point land based sources, such as rivers, drainage ditches and coastal cities (Vikas and Dwarakish, 2015). In India, coastal pollution arises mainly from land based sources such as domestic wastes, industrial effluents and agricultural runoff. Other sources include shipping activity, offshore exploration, infrastructure development and coastal industries. Some earlier observations have demonstrated high concentration of nutrients, low dissolved oxygen, and biochemical and chemical oxygen demand in coastal surface waters near cities. Trace/toxic metal concentrations have been found to be significantly higher than the permissible limit of international standards. Some major environmental hotspots include Mumbai, Kolkata, Chennai, Ankleshwar (Gujarat), Kochi and Goa, where human health and the coastal environment are significantly impacted by pollution. Hence, strong institutional mechanism and good governance principles are needed for the protection, conservation and sustainable development of the coastal habitats and their resources (Marle and Mishra, 2011).

3.3.2 Sea Based Pollution

Introduction of Invasive Species through Ballast Water

Introduction of invasive marine species into new environments through discharge of ballast water from ships, attachment to the hulls of ships and by means of various other vectors, has been identified as one of the four greatest sea based threats to the world's oceans. Ballast water dumped from a single ship may contain hundreds of species of microbes, phytoplankton, zooplankton, larval fish and invertebrates, introducing non-native organisms into the point of discharge. These introduced species are referred to as exotic, nuisance, alien, or non-indigenous species (UNU-INWEH, 2012). Of these, those that survive and establish a population have the potential to become invasive aliens and cause ecological and economic harm. In India, CSIR-NIO is helping the Ministry of Shipping, Government of India, as a lead R&D agency, in addressing the ballast water issues and preparing comprehensive and port specific management plans.

Oil Spills

Among the different sources of pollution, oil pollution in various dimensions, impacting the flora and fauna, is the most devastating. Oil spills occur through accidents of ships and tankers, grounding of ships, rupture of seabed and onshore oil pipelines, and offshore oil production and exploration platforms. Such oil spills severely affect habitats including beaches and their adjoining land as well as seagrass, mangrove and coral reef ecosystems, causing irreversible damage to the biodiversity including birds. When the oil eventually sinks, it affects the benthic organisms such as clams and mussels, as tar particles are deposited in the mantles of these organisms. Besides being toxic to marine life, polycyclic aromatic hydrocarbons (PAHs), found in crude oil, are very difficult to clean up and they persist for many years in the sediments and marine environment.

Oil spill that occurred due to the collision between MSC Chitra and MV Khalijiaoil off the coast of Mumbai in 2010, resulted in the death of about 150 sting rays and a dolphin along the beaches at Uran and Mandva, respectively. Although oil itself is not highly toxic, the spill with other chemicals and pesticides is likely to produce synergistically far more hazardous, long-lasting impacts on the marine ecosystems. Therefore, effective oil spill management policy and efforts are needed to reduce the menace of oil spill incidents in the country (Sukhdhane et al., 2013).

3.3.3 Threats to Specific Ecosystems

Pressures and threats exerted on the seagrass, mangrove and coral reef ecosystems are presented below (UNISDR/UNDP, 2012a).

Seagrass Ecosystem

Sedimentation affecting water clarity, pollution due to eutrophication, habitat destruction or degradation, laying artificial structures for prevention of erosion, irresponsible fishing and tourism, introduction of invasive alien species and climate change are posing threats to the seagrass ecosystem.

Mangrove Ecosystem

Over exploitation of resources, habitat destruction, shrimp farming and aquaculture, coastal development and land reclamation, diversion of inland freshwater, invasive alien species, pollution and climate change are the pressures exerted on the mangrove ecosystem. Impacts are destruction of species and habitats and deterioration of the ecosystems, affecting their vital functions.

Coral Reef Ecosystem

Over exploitation for food, aquarium trade and medicinal products, destructive fishing practices, coral mining, pollution (sediment, nutrient and chemical), unregulated tourism and climate change are the major threats.

3.3.4 Livelihood Linked Extraction Pressures

Indian coastal and marine areas are critical for sustaining the livelihoods of large populations residing in these regions. Their tendency to shift to unsustainable and destructive fishing practices has led to an increase in pressures acting on the marine bio-resources. Some such destructive practices are the use of inappropriate nets and explosives for fishing. Incidental capture, in trawl nets, is a well-known cause of mortality of sea turtles. More than 10,000 dead turtles are washed ashore in Odisha alone, every year. Both gill and trawl nets cause considerable mortality along the mainland coast.

3.3.5 Trade in Marine Species

Trade in marine species, harvested illegally or through unsustainable means, has emerged as a severe pressure on the marine and coastal biodiversity. Illegal and unsustainable harvesting is fuelled by the trade in animal parts for medicinal or aesthetic uses. Species under severe threat due to such pressures include corals, molluscs and horse-shoe crabs, among others. Increasing demand of marine ornamental fishes for aquaria has resulted in the over-exploitation of the natural stock and consequent destruction of the reef habitats. More than 98 per cent of the ornamental fishes are directly collected from the coral environment for the aquarium trade, causing depletion of natural resources. Recent advances in fish husbandry and aquarium equipment technology have further facilitated the hobby. International trade in all wild fauna and flora in general, and the species covered under CITES is controlled jointly through the Wildlife (Protection) Act 1972, Amendment Act, 2002, Foreign Trade (Development Regulation) Act 1992 and Foreign Trade Policy of Government of India and Customs Act, 1962.

3.3.6 Climate Change

Climate change has overarching, seriously damaging and long term impacts on the Earth's ecosystems, including the coastal and marine systems. These impacts include a likely increase in the frequency of extreme weather events, rise in the sea level, increased sea surface temperature and ocean acidification (IPCC, 2014). A rise in the sea level is likely to have significant implications for the coastal populations and productivity. For example, some of the islands in the Sundarbans, Gulf of Mannar and Nicobar have already witnessed these changes. Climate change poses a threat to the species present in three distinct ecological zones that make up the Sundarbans. If the saline water front moves further inland, many species (including mammals, birds, amphibians, reptiles and crustaceans) would be threatened.

These changes are likely to have major economic impacts, given that an estimated 500,000 to 600,000 people are in direct employment through the Sundarbans (for at least half of the year), with many of them employed in industries that use raw materials from this ecosystem (Smith et al., 1998). The largest mass nesting ground of the Olive Ridley turtle, in Odisha is undergoing dynamic changes probably due to climate change. Apart from this, climate change is also rapidly affecting the socio-economic conditions of the coastal communities, which in turn is intensifying the pressures on the marine bio-resources. It should be remembered that cities and townships along the Indian coastline support a large section of poverty ridden people, the section most vulnerable to climate change (UNISDR/UNDP, 2012b).

According to the IPCC, the most threatened flood plains will be those in South Asia. In addition, around 30 per cent of Asia's coral reefs are likely to be lost in the next 30 years due to the effects of multiple stresses and climate change. Composition of species and their dominance could also be altered, and large-scale forest depletion and loss of biodiversity are likely to mark the beginning of the bleak scenario (IPCC, 2007). Hence, predicted impacts of climate change need to be understood clearly in the context of the diverse and rich portfolio of ecological services that the coastal and marine ecosystems offer to the human populations for remedial actions.

3.3.7 Disasters and Coastal Erosion

Coastal communities are vulnerable to catastrophic events such as tropical cyclones, tidal surges, tsunamis and floods that result from heavy monsoonal winds. Much of the coastline of South Asia lies in the cyclone prone area of the Bay of Bengal. Coastal ecosystems such as the seagrasses, mangroves and salt marshes and coral reefs of India are at the forefront of such recurrent natural disasters and often bear the brunt. Although, they play a vital role in mitigating the impacts of such disasters, they, in turn, are often damaged beyond their natural resilience when the disasters are intense or frequent. Investing in enhanced conservation and restoration of such ecosystems and integrating disaster reduction strategies into coastal conservation, therefore, become important (UNISDR/UNDP, 2012a), considering the socio-economic (food, medicine, tourism, education, research etc.) importance to the dependent coastal communities.

3.4 IMPACTS

3.4.1 Impact of Land Based Pollution

Harmful Algal Blooms (HABs)

Worldwide, along many urbanized coastal regions, massive input of industrial, agricultural and sewage effluents has had tremendous impact by altering the nutrient characteristics, causing eutrophication and triggering toxic algal blooms, affecting the biodiversity, fisheries, tourism, recreation and other activities. Ballest water discharge also causes toxic algal blooms. In India, 80 algal blooms were recorded during 1998–2010. Of these, 31 blooms were formed by dinoflagellates, 27 by cyanobacteria and 18 by diatoms. Three raphidophyte and one haptophyte blooms were also observed. Potentially toxic microalgae recorded from the Indian waters were the species of *Alexandrium, Gymnodinium, Dinophysis, Coolia, Prorocentrum* and *Pseudo nitzschia.* In particular, species responsible for several of the major shellfish poisoning syndromes were observed. These include *Alexandrium catenella* and *Gymnodinium sp.* (implicated in Paralytic Shellfish Poisoning - PSP), *Dinophysis acuminata, D. caudata, D. fortii, D. miles* and *D. tripos* (all implicated in Diarrhetic Shellfish Poisoning (- DSP episodes) and *Coolia monotis* and *Prorocentrum lima* (causing Ciguatera poisoning).

In addition, other harmful algal bloom species linked to fish and animal mortalities have been observed. *Chattonella marina, Cochlodinium polykrikoides, Gonyaulax sp., Ceratium sp.* and several *Prorocentrum* species have been found abundantly in the phytoplankton population. Examination of available data from the literature during the last hundred years and in-situ observations during 1998-2010 indicate a clear increase in the occurrence of HABs in the Indian EEZ. Hence, effects of these HABs on the seafood quality, economic liabilities on fishing communities, correct assessment of factors triggering blooms and subsequent effects in the trophodynamics need elaborate studies (Padmakumar et al., 2012).

3.4.2 Impact of Climate Change

Observed and projected impacts of climate change on the costal and marine ecosystems and their ecological services have been studied extensively. Serious impacts are expected on the coastal and marine ecosystems, especially mangroves, estuaries and coral reefs, which are already under stress because of the coastal zone development and population growth.

Some of the main climate related concerns in the context of Indian coastal zones are erosion, flooding, submergence and deterioration of coastal ecosystems and salinisation. Key climate related risks in the coastal zone include tropical cyclones, rising sea levels and changes in temperature and precipitation. A rise in the sea level is likely to have significant implications for the coastal population and agricultural performance. A one meter rise in the sea level is projected to displace approximately 7.1 million people, with about 5,764 km of land being lost, along with 4,200 km of roads. Diverse impacts expected as a result of rise in the sea level include land loss and population displacement, increased flooding of low-lying coastal areas and a loss of yield and employment resulting from inundation and salinisation. Damage to coastal infrastructure, aquaculture and coastal tourism due to the erosion of sandy beaches is also likely. The extent of vulnerability, however, depends not just on the physical exposure to rise in the sea level and the population affected, but also on the extent of economic activity in the areas and its capacity to cope up with the impacts, since socio-economic impacts of climate change include the loss of income of fishermen, cost of rehabilitation, increase in fuel costs and impaired health due to increase in diseases.

Impact on Ecosystem Services

Impacts on provisioning services: Climate change will affect food security and cause water stress, which in turn, would have considerable impacts on the lives and livelihoods of people; Impacts on regulating services: Climate change will exacerbate the vulnerability of coastal communities to natural disasters, which may increase in frequency and intensity. In addition, climate change can act as a catalyst to vector-borne diseases and epidemics, while climate change attributable diseases and heat related deaths are also expected to rise. Climate change is having and will continue to have long term impacts on human wellbeing as benefits and services will be affected when the important coastal and marine ecosystems are degraded and lost.

3.5 RESPONSES

3.5.1 Marine Protected Areas for In-situ Conservation

Managing natural ecosystems as carbon sinks and resources for adaptation is increasingly being recognised as a necessary, efficient and relatively cost effective strategy. The world's protected area network already helps mitigate climate change and designation of protected areas has advantages over other approaches to natural ecosystem management, in terms of legal and governance clarity, capacity and effectiveness. In India, protected areas have been established including Marine Protected Areas (MPAs), considering their importance in biodiversity conservation and management through Ecosystem based Adaptation (EbA) approach (Sivakumar et al., 2014). Specific programmes for management and conservation of wetlands, mangroves and coral reefs are being implemented. National and sub-national level committees oversee and guide these programmes to ensure strong policy and strategic support.

In India, PAs that fall entirely or partially within the swathe of 500 metres from the high tide line and the marine environment are considered to be in the MPA network. As depicted in Table 3.5, there are 25 MPAs in peninsular India and more than 100 MPAs in the country's islands; The Gulf of Mannar Marine National Park, Sundarbans National Park, Gulf of Kachchh National Park, Gahirmatha Marine Sanctuary, Coringa Wildlife Sanctuary and Chilika Wildlife Sanctuary, protected areas on the mainland, have unique marine biodiversity and provide a range of ecological services to the local communities. Total area of the Andaman & Nicobar islands is 4,947 km^2, of which 1,510 km^2 is protected under the provisions of India's Wildlife (Protection) Act, 1972. There are 105 PAs in the Andaman & Nicobar islands, and all are part of the MPA network of India. The MPAs cover more than 30 per cent of the terrestrial area of the islands and protect more than 40 per cent of the coastal habitats. The Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park are important MPAs here.

In the Lakshadweep group of islands, Pitti island (0.01 km^2) is the only island having the status of an MPA. Two of the MPAs (Sundarbans National Park and Gulf of Mannar Biosphere Reserve) have been identified

Table 3.5: Marine Protected Areas in Peninsular India

MPA	State / UT	Category	IUCN Category	Area (km^2)	Year of Establishment
Coringa	Andhra Pradesh	Sanctuary	IV	236	1978
Krishna	Andhra Pradesh	Sanctuary	IV	195	1989
Pulicat Lake	Andhra Pradesh	Sanctuary	IV	500	1980
Dadra & Nagar Haveli	Dadra & Nagar Haveli	Sanctuary	IV	92	2000
Fudam	Daman & Diu	Sanctuary	IV	2	1991
Chorao Island	Goa	Sanctuary	IV	2	1988
Gulf of Kachchh	Gujarat	National Park	II	163	1995
Gulf of Kachchh	Gujarat	Sanctuary	IV	295	1980
Khijadia	Gujarat	Sanctuary	IV	6	1981
Kadalundi Vallikkunnu	Kerala	Community Reserve	NA	2	2007
Malavan	Maharashtra	Sanctuary	IV	29	1987
Thane Creek Flamingo	Maharashtra	Sanctuary		17	2015
Bhitarkanika	Odisha	National Park	II	145	1998
Bhitarkanika	Odisha	Sanctuary	IV	672	1975
Chilika (Nalaban)	Odisha	Sanctuary	IV	16	1987
Balukhand Konark	Odisha	Sanctuary	IV	72	1984
Gahirmatha	Odisha	Sanctuary	IV	1,435	1997
Gulf of Mannar	Tamil Nadu	National Park	II	6	1980
Point Calimere	Tamil Nadu	Sanctuary	IV	173	1967
Pulicat Lake	Tamil Nadu	Sanctuary	IV	154	1980
Sundarbans	West Bengal	National Park	II	1,330	1984
Haliday Island	West Bengal	Sanctuary	IV	6	1976
Sajnakhali	West Bengal	Sanctuary	IV	2,091	1976
Lothian Island	West Bengal	Sanctuary	IV	38	1976
West Sundarban	West Bengal	Sanctuary	IV	556	2013

Source: K. Sivakumar et al., 2014 (Wildlife Institute of India) as transboundary protected areas under the framework of the IUCN Transboundary Protected Area Programme. Sundarbans National Park is also designated as a UNESCO World Natural Heritage Site.

Major Marine and Costal Protected Areas (MCPAs)

MCPAs along the coastline of India (excluding the islands) that are important from a fishing community and marine resource conservation perspective have been detailed by Ramya Rajagopalan, 2008 and the author has given suggestion and recommendations for their conservation and management. The MCPAs are the Gulf of Mannar Marine National Park (GOMNP), Sundarbans National Park, Gulf of Kachchh National Park, Gulf of Kachchh Wildlife Sanctuary, Malvan (Marine) Wildlife Sanctuary and Gahirmatha (Marine) Wildlife Sanctuary.

GOMNP comprises a group of 21 islands, located on the Tamil Nadu coast. Originally proposed in 1976, the National Park was created in 1986, to conserve the coral reef, mangrove and seaweed habitats of the area. This National Park forms the core area of the Gulf of Mannar Biosphere Reserve (GoMBR), which was set up in 1989 under the UNESCO-MAB programme. Buffer zone of this biosphere reserve includes the waters between the main coastline and the islands, according to the original notification. The Biosphere Reserve covers a very large area, making it the largest MCPA (including the land and territorial sea components) in India.

Regions of the Sundarbans in West Bengal form a unique ecosystem with a network of tidal rivers, channels, mud-flats, creeks, dunes, mangrove forests and numerous islands. The Sundarbans National Park includes the sanctuaries of Lothian, Sanjnekhali and Haliday. The Sundarbans Biosphere Reserve includes the national park and the sanctuaries, as well as a large buffer area. Besides these categories, the core area, which is the habitat of tigers, is designated as a Tiger Reserve.

Gulf of Kachchh, located on the western coast in the State of Gujarat, is designated as both a Wildlife Sanctuary and a National Park, to protect the coral reefs and mangroves. It was first designated as a Sanctuary in 1980 and later in the same year, it was declared as a National Park to provide complete protection to the islands and the intertidal area. The MCPA comprises 42 islands, 20 of which have mangroves, while 33 support coral reefs. Malvan (Marine) Wildlife Sanctuary in Maharashtra, also located on the western coast, was designated in 1987, to protect the scattered patches of coral reefs that occur in the intertidal zones. Gahirmatha Wildlife Sanctuary, located on the eastern coast of India in the State of Odisha, was designated in 1997, to protect the turtle breeding and nesting grounds. While the turtle nesting grounds on the beach were earlier part of the Bhitarkanika National Park, the Sanctuary was designated especially to include the territorial sea component in 1997.

Conserving Marine Ecosystems In The Gulf of Mannar

Establishing and effectively managing protected area systems ensures continued delivery of ecosystem services that increase resilience to climate change and disaster.

Activities such as mining, over-fishing, pollution and unsustainable coastal development activities have degraded the coral reefs in the Gulf of Mannar region. Invasion by exotic species, algal blooms, trap fishing, sewage disposal and seaweed collection are the other major threats to its biodiversity. A GEF-UNDP intervention in the region coordinated different stakeholders and departments (such as fisheries, agriculture, rural development, and environment and forests, pollution control board; local communities and women's groups) to take up joint conservation initiatives and enforcement mechanisms for better management of the coastal region. Awareness campaigns, conducted by the Gulf of Mannar Biosphere Reserve Trust (GoMBRT), have increased awareness on the significance of the coastal and marine ecosystems. The project's interventions have resulted in an increase of the live coral cover from 37 per cent to 43 per cent so far, prevented saltwater intrusion and ameliorated the impacts of flooding and cyclones.

3.5.2 Restoration and Maintenance of Coastal Habitats

Climate change is causing increased coastal erosion and saline water intrusion in the Sundarbans, the largest mangrove in the world straddling India and Bangladesh. Increased salinity has reduced crop productivity and affected fish farming. Repeated occurrences of violent cyclones in the region has reduced livelihood options. After the devastating cyclone Aila of 2009, the local community recognized the role of EbA in responding to disasters and has started planting mangroves and tree walls as an adaptation strategy to withstand cyclones and violent storms. This has proved to be very effective. Other adaptation measures introduced after Aila include planting saline resistant cereal and vegetable crops, maintaining non-shrimp brackish water fisheries, raising mangrove nurseries and plantations as an alternative livelihood option, food processing, and other non-farm activities.

Ecological Restoration of Chilika Lagoon

Chilika brackish water lagoon, situated in the State of Odisha, forms the base of livelihood security for more than 200,000 fishers and 400,000 farmers, living in and around the wetland and its adjoining catchments. Siltation from degraded catchments choked the connection of the lagoon with the Bay of Bengal leading to a rapid decline in fisheries (from 8,000 MT to less than 1,000 MT) along with the proliferation of invasive weeds, and there was shrinkage of the area and volume. This had a tremendous impact on the livelihoods of communities, especially fishing communities who depended on the lagoon for sustenance. Introduction of shrimp culture also led to pressures on the ecology of the lagoon. Therefore, objectives of the intervention were to restore Chilika lagoon with an ecosystem approach by rejuvenating its biodiversity and securing the livelihoods of the dependent communities. Chilika Development Authority (CDA) was constituted in 1991 to implement an ecological restoration programme. Hydrological intervention in the form of development of a new mouth was done in September 2000.

Programmes for watershed management, fisheries development, ecotourism development, education and outreach were initiated. Several positive changes have taken place in the lagoon system which include the reappearance of six species of fish, in addition to recording of forty three fish, four prawn, seven crab and two Indian spiny lobster species; decrease in area under water hyacinth (*Eichhornia crassipes*), the freshwater weed; expansion in area and species diversity of seagrass meadows and increase in the population and habitat of Irrawaddy Dolphin from 70 in 2003 to 152 in 2013. Recovery of the ecosystem has revived the lagoon fisheries significantly and the annual catch grew from 1,747 MT in 2000 to 14,228 MT in 2012 (MoEF&CC, 2014).

Maintaining Shelter Belt as Adaptation Strategy

East Midnapur District in West Bengal has been facing the impacts of severe cyclones since 2004. After the Cyclone Aila of 2009, local communities supported planting a tree wall as an adaptation measure to withstand cyclones and violent storms. The community takes care of the plants and monitoring activities.

3.5.3 Adaptation to Climate Change

Third Assessment Report of the IPCC (2001) states that coastal and marine areas are most vulnerable to climate variability and the long term impacts of climate change. Further, Global Assessment Report on Disaster Risk Reduction has identified ecosystem decline as one of the four major drivers of risks and called for greater protection and enhancement of ecosystem services. UNFCCC negotiations have also recognized that ecosystems are vital in adapting to climate change. Sustainable ecosystem management is, therefore, increasingly viewed as an effective approach for achieving both Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) (Krishnan and Soni, 2011).

Ecosystem Based Adaptation

There are several ecosystem based adaptation (EbA) activities that can be cited as illustrations for effective Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA). These not only include conservation but also restoration activities which embrace limiting activities such as resources extraction to allow ecosystems to recover, and restoring ecological components to provide connectivity of hydrological regimes. Many EbA activities have been undertaken in India in its different coastal areas.

3.5.4 Community Based Management of Protected Areas

There has been a rapid change in the economy of the Lakshadweep islands during the past decade, from a subsistence economy to a commercial one. Communities were engaged in 2001 and 2002 to monitor the coral reef resources of the islands, given the shift in economy. This has automatically raised awareness about the pressures on the coral reef resources.

3.5.5 Livelihood Diversification for Dependent Communities

Seaweed cultivation and Ornamental Fish Culture

In India, significant contributions have been made in the development of adaptation strategies through seaweed cultivation and marine ornamental fish culture, involving local communities for improving their livelihood as well as conserving the precious coastal ecosystems and their biodiversity.

Seaweed Cultivation

CSIR's Central Salt and Marine Chemicals Research Institute (CSMCRI) pioneered *Kappaphycus alvarezii* cultivation, heralding an era of commercial seaweed farming in India. Production of *K. alvarezii* has been substantially increased from 21 tonnes (dry) in 2001 to 1,490 tonnes in 2013. Its cultivation has been well established in the state of Tamil Nadu and is progressing rapidly in Gujarat, Andhra Pradesh and Maharashtra. Currently, in six coastal districts of Tamil Nadu, cultivation is mostly undertaken by SHGs comprising primarily women. Commercial farming of *K. alvarezii* is a good example of community based coastal resource management, offering diversified livelihood options to coastal inhabitants.

Food and Agriculture Organisation of the United Nations (FAO) under the Bay of Bengal Programme (BOBP), with the funding support of Swedish International Development Agency, Overseas Development and Administration of United Kingdom and Department of Fisheries, Government of Tamil Nadu, has initiated large scale trials of *Gracilaria*

Photo 3.13: Ornamental fish associated with Massive Coral (Porites solida)

Photo 3.14: Amphiprion ocellaris (Hatchery produced young ones)

edulis farming along the south-eastern coast of Tamil Nadu, as a measure towards commercial cultivation.

Marine Ornamental Fish Culture

To preserve the delicate reef ecosystem and its biodiversity, many studies have been carried out to develop breeding and rearing technology for the marine ornamentals (Figure 3.13), essential for the development of sustainable ornamental fish aquaculture.

In this regard, significant achievements have been made by the Annamalai University (CASMB), on breeding and larval rearing of various marine ornamentals including clownfish *(Amphiprion percula, A. Ocellaris (Figure 3.14), A. sebae, A. Clarkii, A. frenatus, A. ephippium, A. akallopisos, A. nigripes, A. perideraion, A. sandaracinos* and *Premnas biaculeatus),* damselfish *(Dascyllus aruanus, Chromis viridis and Neopomacentrus cyanomos), cardinal fish* (jewel cardinal perch, *Pterapogon kauderni),* dotty back *(Pseudochromis delictus) and shrimps (Ancylomenes magnificus, Stegopontonia commensalis, Lysmata wurdemanni, L.debelius and Gnathophyllum americanum)*, in captivity. Culture and breeding of these reef associated organisms using brackish water, are the first of its kind in the aquaculture industry.

CASMB has established two demonstration hatcheries with all the infrastructural facilities with the financial support of the Department of Biotechnology and Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, at Parangipettai and Agatti island of the Lakshadweep. Training programmes on the marine ornamental fish culture have been conducted for the fish farmers, aquarists and entrepreneurs, in the Gulf of Mannar Marine Biosphere Reserve, Parangipettai and Agatti island, which helped in setting up backyard hatcheries as an alternate livelihood development, thereby conserving the coral reef ecosystem and its biodiversity.

3.5.6 Compliance to International Frameworks

MoEF&CC has established the National Biodiversity Authority of India for fulfilling the objectives of the Convention on Biological Diversity (CBD) viz. conservation and sustainable development of national biodiversity and equitable sharing of benefits arising out of the use of biodiversity resources. Its contributions are immense in the context of coastal and marine biodiversity.

India has taken several steps towards achieving the Aichi Biodiversity Targets, especially Target No. 11 (at least 10 per cent of coastal and marine areas are conserved in networks of protected areas) and Target No.14 (ecosystems that provide water, health, livelihoods and wellbeing are restored and safeguarded). Towards achieving these two targets, 106 coastal and marine sites have been identified and prioritized as Important Coastal and Marine Biodiversity Areas (ICMBAs), by the Wildlife Institute of India; 62 ICMBAs have been identified along the western coast of India, and four have been identified along the eastern coast. These sites have also been proposed as conservation or community reserves to increase the participation of the local communities in their governance and management.

These response measures will help the country to consistently move towards achieving not just the Aichi targets but also SDG 14 pertaining to the conservation and sustainable use of the oceans, seas and marine resources for sustainable development.

International trade in all wild fauna and flora in general, and the species covered under CITES is regulated jointly through the Wildlife (Protection) Act 1972, Amendment Act, 2002, Foreign Trade (Development Regulation) Act 1992, Foreign Trade Policy of Government of India and Customs Act, 1962. Director of Wildlife Preservation, Government of India is the Management Authority for CITES in India. Import of animals and their parts and products for zoological parks and circuses or for research may be permitted subject to the provisions of CITES and on the recommendations of the Chief Wildlife Warden of the States and Union Territories under the license from the Director General of Foreign Trade (DGFT). All marine species that have been included in the Schedules of the Wildlife (Protection) Act, 1972 are not permitted for export.

3.5.7 Legal and Institutional Mechanisms

Indian policies and legislation relevant to coastal and marine biodiversity, ecosystems and protected areas are as follows:

- Wildlife (Protction) Act, 1972
- The Water (Prevention and Control of Pollution) Act, 1974
- Environment Protection Act, 1986
- The Indian Fisheries Act, 1987

- Biological Diversity Act , 2002
- Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006
- Wetlands (Conservation and Management) Rules, 2010
- Coastal Regulation Zone Notification, 2011
- Territorial Waters and the Exclusive Economic Zone
- Biosphere Reserves
- The National Action Plan on Climate Change
- Eco-sensitive Zones

Costal Regulation Zone (CRZ)

MoEF&CC issued the Coastal Regulation Zone Notification in 1991 and restrictions were imposed on the setting up and expansion of industries, operations and processes in the said zones. After amendments, MoEF&CC introduced in 2011 a new notification under the Environment (Protection) Act, 1986, declaring all the coastal stretches as CRZ and imposing restrictions on certain human activities. Vulnerable ecosystems such as mangroves, coral reefs, sand dunes and seagrass beds have been accorded the highest protection in CRZ Category I under this notification. It also includes Critically Vulnerable Coastal Areas such as the Sundarbans, which are to be managed with the involvement of coastal communities. Similarly, Andaman & Nicobar islands were brought under the Island Protection Zone to regulate the developmental activities in CRZ areas and for the preparation of the Coastal Zone Management Plan.

In implementing the CRZ programme, there are several constrains, ranging from inadequate scientific basis and guidelines, lack of baseline information and weak social basis, ambiguity in project activities, ineffective implementation and enforcement. Poor governance, rapid economic reforms, lack of scientific forecast and undue favours to coastal infrastructure are some of the foreseen threats to the system. Opportunities are realized as increasing public awareness, initiative of environmental groups and forward thinking to sustainably manage the coastal resources by integrating ICZM to plans and polices (J.K. Panigrahi and P.K. Mohanty 2012).

3.5.8 National Institutions for Conservation & Management

Considering the significance and importance of the costal and marine resources, Government of India has taken many effective measures for their conservation and management and established many institutions, in different areas of coastal and marine biodiversity realm, for the purpose.

Institutions for Survey, Inventorisation and Monitoring and Information Systems

Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) are the premier institutes of MoEF&CC, which work for the survey and inventorization of floral and faunal diversity in India. Botanical and zoological collections with voucher specimens of identified species help address issues relating to bio-prospecting and establishing India's sovereign rights over her flora and fauna. Marine Biological Regional Centre of ZSI was established in 1973 to promote surveying and inventorying the marine fauna in Indian waters. It is actively involved in studying the distribution and status of marine and coastal fauna, their assessment in less explored areas and inventorying the coastal and marine habitats for management and conservation. A new unit of ZSI was also established in Jamnagar, Gujarat to assess the faunal diversity of the marine protected areas. BSI is involved in floristic survey of fragile ecosystems such as mangroves and seagrasses. Indian National Centre for Ocean Information Sciences (INCOIS), an autonomous body under the MoES, studies coral reefs in the coastal zone. With the commissioning of OCEANSAT, real-time, satellite pictures of ocean colour (chlorophyll a) are being provided, allowing identification of fish aggregations, which is one of the main requirements of economical fishing activity. Coral Bleaching Alert System developed by the INCOIS helps monitor and predict the coral bleaching events in the Andaman & Nicobar and Lakshadweep islands, Gulf of Kachchh, Gulf of Mannar and Malvan.

Institutions Conducting Research on Coastal and Marine Ecology

National Institute of Oceanography (NIO), one of the constituent laboratories of the Council of Scientific and Industrial Research (CSIR) established in 1966, works in the areas of physical, chemical, biological and geological oceanography and also in marine instrumentation and archaeology. It also addresses ballast water management issues and prepares comprehensive port specific management plans for the country. Central Salt and Marine Chemicals Research Institute (CSMCRI), set up in 1954, is actively pursuing research to understand the utilization potential of coastal and marine bio-resources. Its activities include the isolation and characterization of salt-tolerant genes from halophytes. National Institute of Ocean Technology (NIOT) has been established under MoES with the main aim of developing reliable indigenous technology to solve various engineering problems associated with harvesting of nonliving and living resources in the Indian EEZ. Centre for Marine Living Resources and Ecology (CMLRE) of the MoES established at Kochi, facilitates the implementation of the Marine Living Resources Programme. This centre is developing management strategies for the marine living resources through ecosystem monitoring and modelling.

Institutions for Sustainable Management

National Centre for Sustainable Coastal Management (NCSCM), an autonomous body under the MoEF&CC, supports integrated management of the coastal and marine environment for livelihood security, sustainable development and hazard risk management by enhancing knowledge and research, giving advisory support, developing partnerships, fostering networks and providing with a coastal community interface. Integrated Coastal and Marine Area Management (ICMAM) promotes and facilitates sustainable management of the coastal zone and rational utilization of resources by incorporating environmental and social concerns in all sectoral developmental activities. It is currently involved in predicting the primary production of coastal waters under changing environmental conditions and to suggest appropriate environmental conditions to achieve the same. ICMAM is also involved in detecting the water quality changes in the coastal, estuarine and marine systems and mapping the shoreline along the Indian coast to estimate the sediment transport. Integrated Coastal Zone Management Project (ICZMP) was initiated by the MoEF&CC in 2010 in the States of Gujarat, Odisha and West Bengal for mapping, delineation and demarcation of ecologically sensitive areas along the mainland coast of India, conservation of coastal and marine resources, pollution management and improving the livelihood opportunities of the coastal communities. Its significant achievements are completion of aerial photography of 70,000 sq. km of the coastal zone, plantation of over 9,000 ha of mangroves, protection of about 100,000 sea turtles, first successful regeneration of corals on the mainland coast and conversion of 20 villages into solar villages. National Centre for Sustainable Coastal Management has been established under the ICZMP to assess, using satellite imagery, the changes that have taken place in the shoreline of the Indian coast. Central Inland Fisheries Research Institute (CIFRI), has been established by MoA at Kolkata to increase the sustainable productivity of inland fisheries and the ecosystem health.

Institutions for Research and Application of Technologies for Sustainable Utilisation of Bio-Resources

Central Institute of Brackish Water Aquaculture (CIBA), established under MoA, promotes research and provides technology support for the country's growing brackish water aquaculture sector. Currently, it is involved in developing economically viable and environmentally sustainable culture technologies for finfish and shellfish, evaluating the commercially important brackish water resources and their utilization, providing policy and plans to support socio-economic development and undertaking human resource development measures through training and extension. The Central Institute of Fisheries Technology (CIFT) undertakes research, training, education and extension in various aspects of fishing and fish processing for the promotion of responsible fishing and sustainable management.

Central Institute of Fisheries Education (CIFE), under MoA is a premier Fisheries University in India and contributes for the development of fisheries sector through teaching, research and extension. It conducts basic and frontier research for helping different stakeholders, provides with technical support for policy development and offers consultancy. Department of Animal Husbandry, Dairying and Fisheries, one of the departments of MoA, is involved in the management and expansion of aquaculture of fresh and brackish water, for the welfare of communities dependent on fishing. Central Marine Fisheries Research Institute (CMFRI), under the MoA is working towards the development and refinement of the unique national marine fishery database. It is currently involved in the development of the Strategic Multistage Random Sampling method, implementation of a trawl ban as a long term management measure, assessment of stocks of major marine fishery resources in the EEZ and development of artificial reefs to enhance the sustainability of artisanal fisheries and increase the natural productivity. Efforts are being made to develop a model to estimate and forecast potential fish yields at regular intervals and thus to increase the accuracy of forecasts, leading to the better management of efforts and fishery resources. National Fisheries Development Board (NFDB) focuses attention on the sustainable management and conservation of natural aquatic resources, including fish stocks. It is also involved in research and development for improving the production of capture and culture based fisheries, value added products and marketing. Fishery Survey of India (FSI) is a nodal agency under the MoA with the responsibility of surveying and assessing the fishery resources in the Indian EEZ and promoting sustainable exploitation and management of the resources.

3.6 CONCLUSION

Coastal environment of India plays a vital role in India's economy by virtue of its resources, productive habitats and rich biodiversity. Different coastal habitats such as seagrass, coral reef and mangrove ecosystems contribute a lot through their ecological, economic, cultural and other services. Coastal vegetation habitats, such as mangrove forests, serve as buffers to protect the shoreline from wind generated storms and support coastal ecology. It is an important part of the coastal ecosystem as it strongly modulates land-ocean interactions and the mixture of fresh water and salt water in estuaries, providing with many nutrients for marine life. Salt marshes and beaches also support a good diversity of plants and animals, along with the beaches, which prevent salt water intrusion into the ground water which is used for drinking and agriculture and therefore fundamental for our water and food security. Coastal fisheries are also important, both economically and in terms of environmental health. In India, they provide essential livelihoods and shape the local cultures of a large part of the population.

Coastline of India is both a precious natural resource and an important economic asset. Once the coastline is disturbed, due to natural or demographic pressures, it may be impossible to fully restore either the coastal ecology or the lost livelihoods. So, timely measures are needed to protect and restore this irreplaceable national treasure for a sustainable future.

From the studies conducted so far in the costal and marine areas of India, it is understood that there is a need for a systematic assessment of the conservation status of coastal and marine species of India using the IUCN Regional Red Listing guidelines. This is largely due to a lack of required data on the status and distribution of most of the marine species in India. Therefore, they have been protected under the Wildlife (Protection) Act, 1972 by being listed in Schedule I. The highly threatened marine species of India need to be conserved on priority basis using special 'Species Recovery Plans'.

Research on the culture of organisms of export value such as ornamental fishes has been carried out by the state and central fisheries departments and academic institutions. Research on corals, mangroves, seagrasses and certain threatened fauna has also been carried out, but in a sporadic manner and only in selected areas. Moreover, recent threats such as climate change, invasive species and faster economic development are posing major challenges to the conservation of coastal and marine biodiversity. These need to be addressed adequately through long term scientific research programmes and generation of information on the ecology of habitats and the resources for successful management for posterity and sustainability (Sivakumar, et al., 2014).

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 4

WATER

Key Messages

- *One-fourth of India's population is struggling with water resource scarcity and it is emerging as a major crisis in certain parts of the country.*

- *Significant spatial and temporal variations exist in quality and per capita availability of water and, part of it can be attributed due to poor management of the resources.*

- *Ground water continues to be considered as an individual rather than a community resource and its exploitation remains inequitable, without a well defined action plan for its long term sustainability.*

- *Nearly 80 per cent of the sewage generated in India flows untreated into its dwindling surface water resources, rendering them too polluted for use, and creating a ticking health bomb.*

- *Poor irrigation efficiency resulting from practices such as flood irrigation is one of the major causes of depleting water resources.*

- *India may lose 6 per cent of its GDP by 2050, if it continues to mismanage its water resources on account of costs incurred in agriculture, livelihoods and health. On the other hand, India can enhance its GDP by 1 per cent, if it follows efficient water resource management practices.*

4.1 INTRODUCTION

Water is one of the most critical components for the life support system. It is a multi-faceted sector which is interlinked with almost all other sectors. Securing water resources both in terms of quality and quantity for various sectoral uses continues to be the key challenge for India's sustainable economic growth and development.

Home to about 18 per cent of the world's population, India has only 2.4 per cent of the world's land area and 4 per cent of its water resources (Ministry of Water Resources, 2015). What is effectively available for consumption and other uses is a small proportion of the quantity available in rivers, lakes and as ground water. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management.

India's water management has been unsustainable since the last several decades owing to demand-supply mismanagement. The focus has always been on increasing supply rather than to manage demand and increase conservation practices. The water crisis has a direct impact on the growing economy of the country where 60 per cent of the population depends on agriculture which accounts for 15 per cent of GDP. Rising suicide rates among the farmers due to drought is an illustration of this crisis. One example is the recent and well known incident at Marathawada, the worst drought hit area where, in the eight districts comprising Marathawada, the number of farmers' suicide was over 1,100 according to government data.

Frequent fluctuations in temperature, humidity and precipitation due to climate change can have a significant long term consequences on water resources both qualitatively and quantitatively. Further to this, as per India's Communication to UNFCCC (2012), climate change can have a likely impact on agriculture under irrigation, installed capacity of power generation and aggravation of floods and droughts in various parts of the country due to fluctuating environmental flows in dry and wet seasons (Ministry of Water Resources, 2015).

4.2 STATUS

As water on the Earth is in constant motion through the hydrological cycle, this very dynamic nature is a determinant of how much is available for the key users i.e. human, animals or plants. This dynamic and renewable nature of water resources necessitates that the water resources are measured in terms of its flows and stocks on a recurrent basis for optimising it's use. Thus, the two facets of the water resources: the dynamic nature of the resource measured as flow is relevant for most of the developmental needs, while the static nature of the resource involving the quantity of water is measured as the length of the water bodies.

Water Resources - Variability and Vulnerability

Water resources in India are characterized by their uneven temporal and spatial distribution. Most of the water in the rivers, lakes and other reservoirs either evaporates, percolates to the ground, or flows to the seas. What is available for agriculture, industry, domestic consumption and other activities is just a part of what falls to the ground through precipitation and glacial melt. A portion of this water is absorbed by the soil and is stored in underground aquifers. A much smaller percentage is stored in inland water bodies both natural (lakes and ponds) and man-made (tanks and reservoirs).

The latest estimate of total water resources available in India is 1,869 Billion Cubic Meters (BCM), and owing to topographic, hydrological and other constraints, the utilisable water available is only about 1,121 BCM (690 BCM from surface water and 431 BCM from replenishable groundwater resources) (Table 4.1).

The demand for water has been increasing at a high pace in the past few decades. The per capita annual water availability in the country was approximately 1,720 m^3 in the year 2015, which was 1,816 m^3 in year 2001 (Central Water Commission, 2013) (Table 4.2).

4.2.1 Precipitation

India receives an average annual rainfall of about 1,170 mm which corresponds to precipitation of 4,000 BCM including snowfall. Nearly 75 per cent of this, i.e. 3,000 BCM occurs during the monsoon season confined to three to four months (June to

September) in a year (Central Water Commission, 2013). There is considerable variation in rainfall both temporally and spatially. The average annual rainfall of the country is about 1,170 mm, whereas in the case of the north eastern region, it is as high as 10,000 mm and in some parts of western Rajasthan, it is about 100 mm.

With increasing population, rapid urbanization, unplanned industrial growth, expansion of agriculture, there has already been a many fold increase in the demand for water over the years. Currenty, the hydrological cycles in many climatic regions and river basins are being modified due to changes in cropping pattern, land use pattern, over extraction of water resources, besides marked changes in irrigation and drainage systems. While rainfall contributes 68 per cent of annual replenishable ground water, the remaining 32 per cent is contributed by other sources such as canal seepage, return flow from irrigation, recharge from tanks and water harvesting structures (Central Ground Water Board, 2013-14). Erratic rainfall due to climate change affects the water resource availability and ultimately it impacts agriculture, land degradation, livestock and food security.

Studies based on the observed precipitation records of the India Meteorological Department (IMD) have shown that the occurrence of extreme precipitation events and their variability has already gone up in many parts of India.

Average annual rainfall trends vary for different states. Annual rainfall trends have increased over

Table 4.1: Table Depicting Status of Water Resources

Details	Quantity
Average Annual Rainfall (2010)	3989.25 BCM
Mean Annual Natural Run-Off	1869 BCM
Estimated Utilisable Surface Water Potential	690 BCM
Total Replenishable Ground Water Resources	431 BCM
Ground Water Resources Available for Irrigation	369.6 BCM
Ground Water Potential Available for Domestic, Industrial And Other Purposes	71 BCM (approx.)
Ultimate Irrigation Potential	140 Mha
Irrigation Potential from Surface Water	76 Mha
Irrigation Potential from Ground Water	64 Mha
Storage Available Due to Completed Major and Medium Projects (Including Live Capacity less than 10 M CUM)	253 BCM
Estimated Additional Likely Live Storage Available due to Projects Under Construction / Consideration	155 BCM

Source: Annual Report 2013-14, Central Water Commission

Table 4.2: Per Capita Annual Availability of Water

Year	Population (In Million)	Per capita Average Annual Availability (m^3 /year)	Remarks
2001	1029 (2001 census)	1816	
2011	1210 (2011 census)	1545	water stressed condition*
2025	1394 (Projected)	1340	water stressed condition*
2050	1640 (Projected)	1140	water stressed condition*

*Source: INDC - Vulnerability Report, 2015*According to the Falkenmark Water Stress Indicator, a per capita availability of less than 1700 cubic meters (m^3) is termed as a water-stressed condition, while if per capita availability falls below 1000 m^3, it is termed as a water scarcity condition.*

Andhra Pradesh, Bihar, Gujarat, Haryana, Jammu & Kashmir, Jharkhand, Lakshadweep, Manipur, Meghalaya, Mizoram, Odisha, Rajasthan, Tamil Nadu, Tripura, West Bengal during 1951-2010. The highest increase and decrease in annual rainfall was observed over Meghalaya (+14.68 mm/yr.) and Andaman and Nicobar Islands (-7.77 mm/yr.) respectively (India Meteorological Department, 2013)(Table 4.3).

4.2.2 Surface Water

Inland water resources of the country are classified as rivers and canals; reservoirs; tanks and ponds; beels, oxbow lakes, derelict water; and brackish water. The total renewable fresh water resource of the country is the total volume of river run off and ground water recharge generated annually by precipitation within the country plus the total volume of actual flow of rivers coming from neighboring territories.

In absolute terms, out of 4,000 BCM/year total precipitation, 440 BCM of water flows in to the river, 250 BCM gets stored in dams and reservoirs, 432 BCM gets stored in aquifers and the rest flows in to the seas and oceans (Central Water Commission, 2013).

The distribution of water bodies in India is presented in Table 4.4. Other water bodies (except rivers and canals) covered an area of about 7.4 million hectares (Mha) in 2010 which reduced to 7.31 Mha in 2014. Among these water bodies, 'reservoirs' have maximum area (2.91 Mha), followed by 'tanks and ponds' (2.41 Mha). The total area of inland water resources (other than rivers and canals) is unevenly distributed across the States. Most of these water bodies are dependent on rains and ground water aquifers for recharge (Central Water Commission, 2015).

Rivers

India is blessed with many rivers and 12 of them are classified as major rivers with total catchment area of 252.8 Mha. Of the major rivers, the Ganga-Brahmaputra-Meghna system is the biggest, with a catchment area of about 110 Mha which is more than 43 per cent of the catchment area of all the major rivers in the country. Other rivers with catchment areas of more than 10 Mha are Indus (32.1 Mha), Godavari (31.3 Mha), Krishna, (25.9 Mha) and Mahanadi (14.2 Mha) (Central Water Commission, 2013).

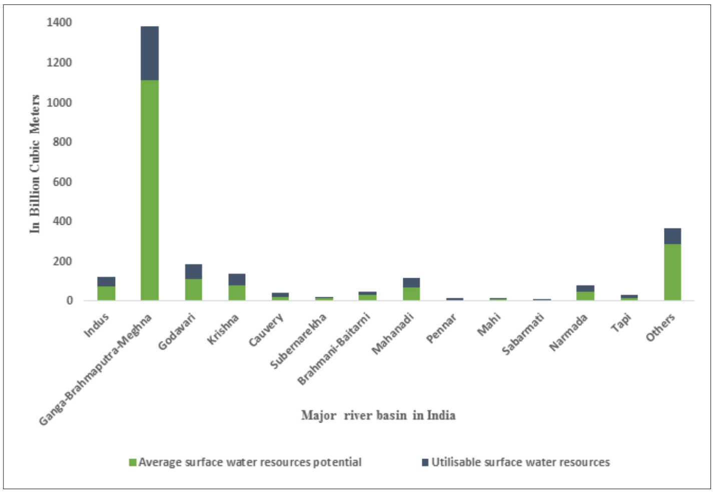
A river basin is considered as the basic hydrologic unit for the planning and development of water resources. The entire country has been divided into 22 basins as per Central Water Commission. The basin-wise availability of water is quite varied and it is about an average of 1,869.4 BCM/year with major contributions coming from the Ganga-Brahmaputra Basin (1,110 BCM/year), followed by west flowing rivers from Tadri to Kanyakumari and Godavari (Fig.4.1). Only 60 per cent of water can be utilised out of the 1,869.4 BCM which indicates the importance of integrated river basin management for planning of water resource development (Central Water Commission, 2013).

Table 4.3: Rainfall Trends in Indian States between 1951-2010

State	Rainfall trend
	Decrease
	Increase
Andhra Pradesh	0.14
Arunachal Pradesh	2.3
Assam	2.19
Bihar	1.11
Chhattisgarh	2.38
Delhi	0.22
Goa	2.61
Gujarat	1.27
Haryana	0.01
Himachal Pradesh	2.85
Jammu & Kashmir	0.16
Jharkhand	0.44
Karnataka	0.61
Kerala	2.42
Madhya Pradesh	1.74
Maharashtra	0.29
Manipur	0.89
Meghalaya	9.27
Mizoram	7.71
Nagaland	1.69
Odisha	0.23
Punjab	1.49
Rajasthan	0.09
Sikkim	1.36
Tamil Nadu	1.35
Telangana	0.14
Tripura	1.11
Uttar Pradesh	3.52
Uttarakhand	1.45
West Bengal	1.45

Source: India Meteorological Department, 2013

Fig. 4.1: Basin Wise Water Availability



Source: Water and Related Statistics, Central Water Commission, 2013

The total storage capacity of about 253.4 BCM has been created in various basins due to major and medium irrigation projects. The projects under construction will contribute to an additional 51 BCM. Thus, likely storage available will be 304.3 BCM once the projects under construction are completed against the total water availability of 690 BCM in the river basins of the country. Maximum storage lies in the Ganga Basin followed by Krishna, Godavari and Narmada. Pennar is the leading basin in terms of storage capacities as percentage of average annual flow. The storage capacities as percentage of average annual flow exceeds 50 per cent for Krishna, Tapi and Narmada basins while for Ganga and Brahmaputra sub-basins, the corresponding figures are 11 per cent and 0.5 per cent respectively (Central Water Commission, 2013).

Table 4.4: Distribution of Water Bodies

Types of water bodies	2010	2014
Rivers & Canals (length in km)	1,95,210	1,95,095
Other Water Bodies (area in Million Hectares)		
Reservoirs	2.91	2.93
Tanks & Ponds	2.41	2.43
Flood Plain Lakes & Derelict Water bodies	0.80	0.80
Brackish Water	1.24	1.15
Total	**7.40**	**7.31**

Source: Handbook on Fisheries Statistics- 2010 and 2014, Department of Animal Husbandry, Dairying & Fisheries, M/o Agriculture, India statistics

Table 4.5: Sub-basins of Major River Basins

Basin	Sub-basin
Ganga	Gomati, Ghaghra, Gandak, Bagmati, Kosi-Kamla, Mahananda, Damodar, Chambal, Yamuna, Ram Ganga, Son, Betwa-Ken, Punpun-Falgu
Godavari	Wainganga-Pranhita, Indravati, Waradh-Penganga, Godavari-Manlara-Maner
Krishna	Bhima, Musi-Muner, Tungabhadra, Malprabha

Source: Central Water Commission

Lakes, Ponds and Other Water Reservoirs

The available estimates of water bodies in India vary widely from one per cent to five per cent of the geographical area (MoEF&CC and Space Application Centre, Ahmedabad, 2011). These are distributed in different geographical regions ranging from Himalayas to Deccan plateau.

While some southern states such as Andhra Pradesh, Karnataka and Tamil Nadu are home to most of the ponds and tanks, on the whole, these states account for 62 per cent of the total area under tanks and ponds in the country along with West Bengal, Rajasthan and Uttar Pradesh. In terms of reservoirs, a large section of area is under reservoir in the major states like Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan and Uttar Pradesh. Of the total area under beels, oxbow, lakes and derelict water, Odisha, Uttar Pradesh and Assam account for more than 77 per cent. In terms of total area of brackish water, Odisha ranks first, followed by Gujarat, Kerala and West Bengal.

The number of artificial water reservoirs has increased in the last decades due to prioritization given to water conservation by the government and non-government organizations. The interventions have resulted in the construction of farm ponds, check dams, field bounds, gabions etc to support irrigation and prevent floods.

Glaciers

As per the study conducted by NIH-Roorkie, there are about 9,575 glaciers in the Indian Himalayas. Majority of the rivers originating from the Himalayas have their upper catchment in the snow covered and glaciated areas. An inventory of the snow cover and glacier by using satellite based mapping across glaciated regions was conducted in Indus, Ganga and Brahmaputra river basins. Under this study, 2,767 glaciers were monitored of which 2,184 are retreating, 435 are advancing, and 148 glaciers do not show any changes (Ministry of Water Resources, 2015).

Among the 18 advancing glaciers of Karakoram, an average movement of 300 m of snout was observed. A study focused on the mean retreat of snout for 248 retreating glaciers was found to be 170 m (17 m annually approx.), and the maximum retreat was observed in Sikkim followed by Karakoram and Himachal Pradesh.

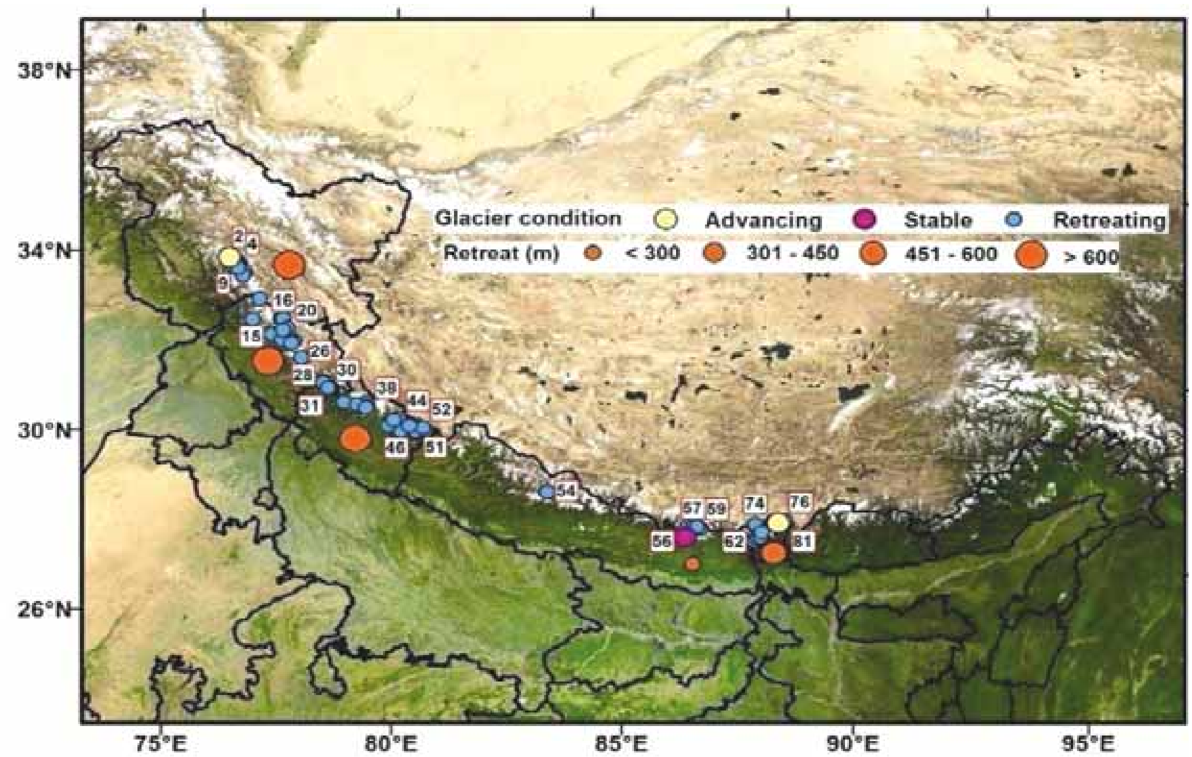
Further studies covering other areas of Himalayan glaciers are underway. The rate of melting of Himalayan glaciers (15 metres per year) is the highest in the world. The causative factors are stated to be subnormal snowfall, higher temperature during summer, less severe winter or a combination of all of them (Ministry of Water Resources, 2015).

Glacier retreat feeds thousands of miles of rivers for its natural flow (Photo 4.1). Also if there is increasing seasonal melt coupled with rain water, it leads to intense floods in the surrounding areas.

Monitoring of Glaciers

MoEF&CC and Dept. of Space in Sikkim conducted monitoring of 2018 glaciers with the satellite data of 2000/01/02 and 2010/11. The data indicated that 1752 (86.8 per cent) glaciers could be regarded stable (no change in the snout position), 248 (12.3 per cent) exhibited retreat and 18 of them (0.9 per cent) have experienced advancement.

Location of Glaciers and Amount of Retreat Between 1960 and 2000



Source: Kulkarni et al, 2014, Current science journal (published by Indian Academy of Science)

Photo 4.1: Glacial Retreat in Himalaya

4.2.3 Ground Water

Ground water is an important source of water in India. Monsoon rainfall is the major source of ground water and it sustains almost 60 per cent of the country's irrigated area. Of the total annual replenishable ground water resources estimated as 431 BCM, about 68 per cent of this resource i.e., 293 BCM is contributed by monsoon rainfall recharge (Table 4.4). Keeping 35 BCM for natural discharge, the net annual ground water availability in the Country is 396 BCM (92 per cent).

The annual ground water draft is 243 BCM out of which 221 BCM (91 per cent) is for irrigation use and 22 BCM is for domestic & industrial use (As on 31st Mar 2011, MoWR RD & GR, 2014).

Ground water level monitoring is carried out four times in a year to assess the fluctuation and impacts of various sectoral demands on a regional basis through a network of observation wells in the country. The monitoring data for pre-monsoon 2014 compared with decadal mean of pre-monsoon (2004-2013) indicates that out of the total observation wells, approximately 39 per cent were showing decline in water levels as observed in parts of Andhra Pradesh, Assam, Chhattisgarh, Daman & Diu, Delhi, Gujarat, Haryana, Karnataka, Kerala, Punjab, Rajasthan, Tamil Nadu and West Bengal. However, the situation can't be termed as drought-like situation (Standing Committee on Water Resources, MoWR, 2015).

As a result of indiscriminate withdrawal of ground water for irrigation, industries and domestic purposes, out of 6,607 numbers of assessment units (blocks/taluks/ mandals/watershed), 1,071 units are over-exploited which is about 16.21 per cent of total units. Similarly 217 units are 'critical', 697 units are 'semi-critical', 92 units are 'Saline' and 4,530 units are 'Safe' (Table 4.7).

Table 4.6: Ground Water Statistics

Ground Water Statistics (In BCM)	
Annual Replenishable Ground Water Resources	431
Net Annual Ground Water Availability	396
Annual Ground Water Draft for Irrigation, Domestic and Industrial uses	243
Stage of Ground Water Development	62%

Source: Water and related statistics, Central Water Commission, 2013

Nearly 1,071 units (categorized as 'over-exploited') are in 16 States and two UTs, where the annual ground water extraction exceeds the net annual availability. The Standing Committee on Water has observed significant decline in long term ground water level trend either in pre monsoon or post monsoon or both in these assessment units (Standing committee on Water Resources, MoWR, 2015).

Sectoral Water Demand

The demand for water has already increased manifold over the years due to increase in irrigated area, urbanisation, increasing population, rapid industrialisation, and economic development. The water demand in the year 2000 was 634 BCM and it is likely to be 1,093 BCM by the year 2025 (India-WRIS, 2014).

4.2.4 Irrigation Demand

In agriculture, water is the most critical resource, even more than soil. For crop cultivation, large parcels

Table 4.7: Categorization of Blocks/ Taluks/Mandals/Watershed

Status	No. of units
Safe	4,530
Semi-critical	697
Critical	217
Over-exploited	1,071
Saline	92
Total Assessed Units	**6,607**

Source: Central Ground Water Board, 2015-16

Table 4.8: Annual Replenishable Ground Water resources in India

Range	States
0-4.99	Punjab, Haryana, Delhi, Rajasthan, Gujarat, Karnataka, Tamil Nadu, Kerala, Odisha, Jharkhand, Chhattisgarh
5.00-24.99	Madhya Pradesh, Maharashtra, Telangana, Andhra Pradesh, West Bengal, Bihar, Assam
25.00-49.99	Jammu And Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunanchal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya
50.00-77.19	Uttar Pradesh

Source: Central Ground Water Board

of land in India are highly dependent on seasonal rainfall. Shortage in rainfall has ramifications in terms of adoption of high yielding varieties and other inputs resulting in low productivity. If the data from the current trends which suggest continuing low yields in rain-fed areas is to be considered, it only underscores the importance of irrigation in the country. NCIWRD estimates that the share of irrigation demand would decline to 72 per cent by 2025 and to 68 per cent by 2050. The role of irrigation differs between states due to agrarian practices, electricity availability and climatic conditions.

Table 4.9 (NCIWRD data) indicates projected demand gap of nearly 200 BCM between 2025 and 2050 for irrigation sector per year. It is assumed that from 12th five year plan onwards, the demand gap could be of the order of 250 BCM. To fill this gap, even if one assumes a fair share of 100 BCM by the ground water sources, that still leaves an extra burden on surface irrigation to the tune of 150 BCM to achieve self-sufficiency by 2050.

To meet the demand of water for agriculture, minor irrigation potential of about 100 BCM was created in 2012-13 consisting of check dams, small ponds, etc., and nearly 243 BCM potential of groundwater was available. It cumulatively made possible to irrigate about 66.1 Mha out of the 139.9 Mha of net sown area (Ministry of Agriculture, 2015). The urgency for creating more storage through major and medium irrigation schemes and fast tracking the implementation is of paramount importance.

The decadal trend of various sources of irrigation shows that the number of tube wells, which was otherwise also high as compared to other sources of irrigation has increased followed by canal irrigation (Fig. 4.3).

Table 4.9: Water Demand in India

Sector	Water Demand (Billion Cubic Metre)			
	Standing Sub-Committee of MoWR		NCIWRD	
Year	**2025**	**2050**	**2025**	**2050**
Irrigation	910	1,072	611	807
Drinking Water	73	102	62	111
Industry	23	63	67	81
Energy	15	130	33	70
Others	72	80	70	111
Total	**1,093**	**1,447**	**843**	**1,180**

Source: Standing Sub-Committee of Ministry of Water Resources, National Commission for Integrated Water Resource Development (NCIWRD)

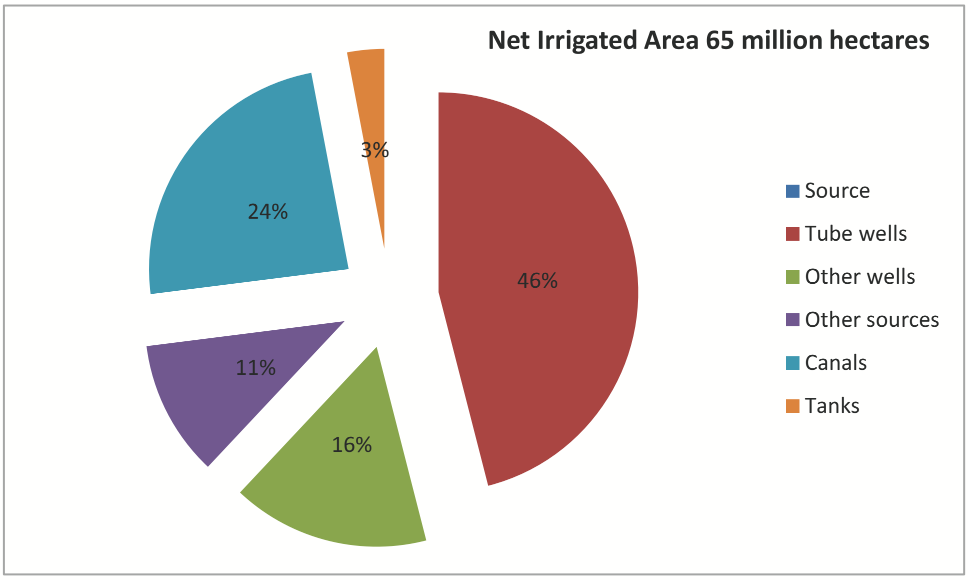
4.2.5 Domestic Demand

The NSSO data (2011) on water availability reveals that, 71 per cent of the urban households in India have adequate supply. The city wise figures are 73 per cent in Delhi, 77 per cent in Mumbai and Kolkata, 49 per cent in Hyderabad, 75 per cent in Kanpur, 63 per cent in Ahmedabad and 82 per cent in Madurai. The Census-2011 provides details of sources of domestic water supply accessed by households in India. Hand pump/ tube well (51.9 per cent) is the main source of water followed by tap (30.8 per cent) in rural India. In urban India, tap water (70.6 per cent) is the major source followed by hand pump / tube well (20.8 per cent).

The quantity of water consumed (per capita water consumption) in most of the Indian cities is not determined by the demand, but the supply. There is also a wide variation in the proportion of households in different cities consuming water more than the standards. Figure 4.4 depicts the decadal growth rate of population and per capita water availability for consumption.

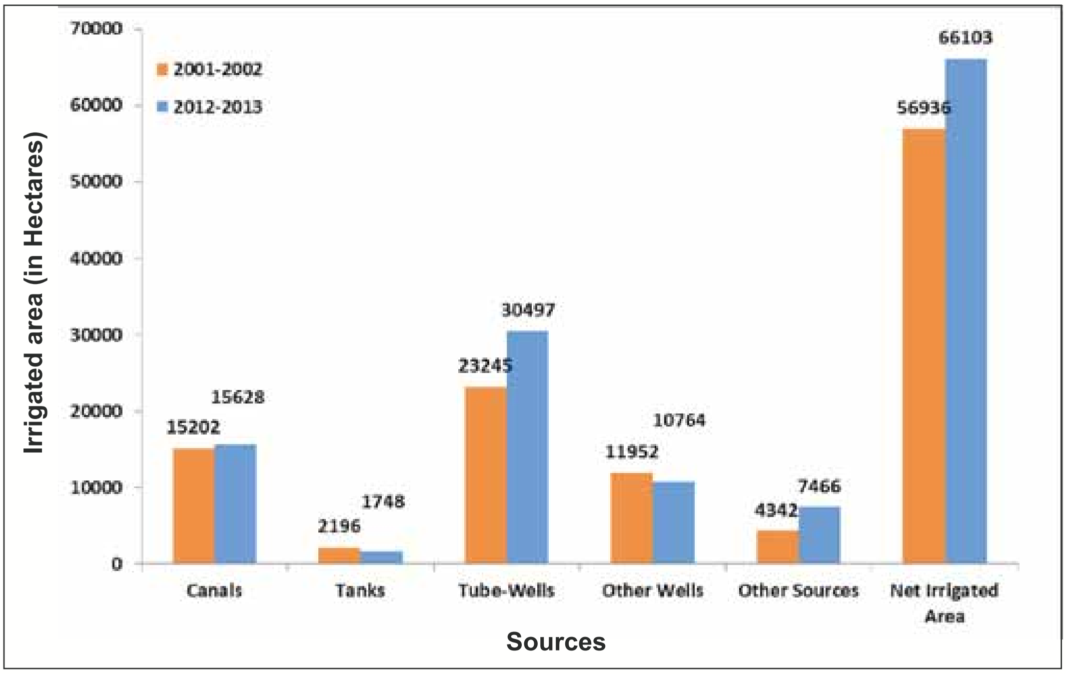
It highlights that per capita availability has tremendously decreased with increasing population. In 1951, it was 5,177 cubic meter per capita water availability which was 1,820 cubic meter in 2015, and future projections indicates that in year 2025 and 2050 the per capita water availability will gets decreased to 1,340 cubic meter and 1,140 cubic meter, respectively.

Fig.4.2: Various Sources of Irrigation in 2012-13



Source: Land Use Statistics (2012-13), Ministry of Agriculture & Farmers Welfare

Fig.4.3: Decadal Trend for Various Sources of Irrigation and Net Irrigated Areas



Source: Land Use Statistics (2012-13), Ministry of Agriculture & Farmers Welfare

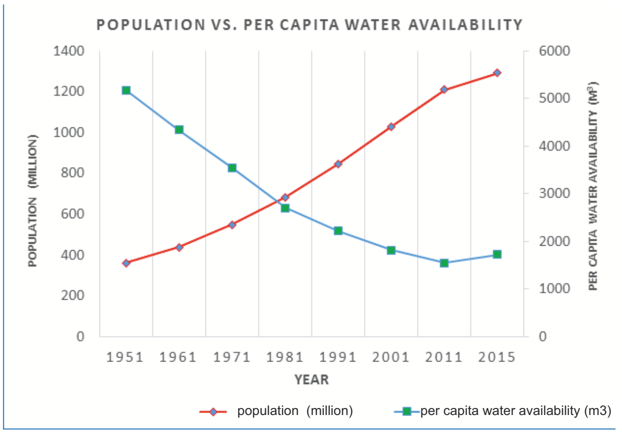
4.2.6 Industrial Demand

Water comprise an integral part of the industrial infrastructure. India is the 10th most industrialised country in the world with approximately 88 industrial clusters distributed in various states across the country (Central Pollution Control Board, 2009). Thus sustaining the water resources for industrial use is of paramount importance (Central Pollution Control Board, 2009). In recent years, businesses have started looking at their per day water consumption more comprehensively than done previously (when they directly looked at the water usage for production), and have started investigating the water consumption throughout the supply chain. Water use efficiency in Indian industries continues to be much lower when compared to some other developing countries in the world.

In India, industry is the second highest consumer of water resource and demand has been increasing with the pace of industrial development. The annual water consumption in Indian industry is 40 BCM and the annual wastewater discharge is about 30.7 BCM. According to the World Bank, the current industrial water use in India is about 13 per cent of the total freshwater withdrawal in the country. It also predicts that the water demand for industrial uses and energy production will grow at a rate of 4.2 per cent per year, rising from 67 BCM in 1999 to 228 BCM by 2025. (Industrial Infrastructure report, 2011).

Resource Management: Scarcity and Security

Fig.4.4: Population Stress and Water Insecurity



Source: Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, and Census of India

Considering the high variability in the yield of the rivers both temporally and spatially, water resource management becomes very important. As per latest data, the per capita storage of about 190 cubic meters in India is miniscule as compared to per capita storages in the developed countries like USA, Australia, Brazil and China which are about 5, 961, 4, 717, 3,388 and 2,486 cubic meters respectively (Ministry of Water Resources, 2013).

Efficient water management is key to higher, cost-effective yield and sustainable water use, and its prerequisite is the merging of resources of various concerned line ministries and departments. For instance, to enable effective water conservation and effective project delivery, the watershed development project authorities have to realign with ministries of rural development, agriculture, water resources, urban development and power etc. Ministry of Agriculture, Water Resources and Power would have to put a combined effort to enhance productivity of water using micro irrigation, supplemental and deficit irrigation.

Resource management aspects include conservation of water, recycling of water into utilisable water, introducing efficient methods and better management practices. This is more so to meet the increasing demand of water for various purposes in view of growing population, industrialisation and urbanisation.

4.2.7 Flood Plain Management

To a large extent, river water quality has been ruined by discharge of untreated domestic sewage and industrial effluents; and the impact has been aggravated by reduced flows and channelization of the rivers. In many stretches, rivers have been virtually turned into sewers. Catchments have been extensively degraded and led to increased sediment

Photo 4.2: Women collecting water from pits during summer days

loads of the rivers, as a direct consequence of, human settlements, deforestation, mining, quarrying, grazing and other activities.

Conservation and management of rivers started receiving attention during the 1970s. A flood plain is a land area subject to overflow from a river or lake and to a variety of human management schemes. The management strategy encompass a spectrum from leaving the area in its natural state to comprehensive changes in both the water flow and the societal uses of the land.

4.2.8 Ground Water Development

The ground water system, is unique in terms of source and amount of water flowing through its pores or cracks below the earth surface. While each system is unique, it gets affected by external factors such as rate of precipitation, location of streams and other surface bodies and rate of evapo-transpiration. The system is largely affected by activities changing the natural course of flow due to withdrawals for irrigation and various other competing needs without consideration for provision for recharge, removal of land encroachments due to unplanned urbanization etc.

The stage of ground water development is a ratio of annual ground water draft and annual ground water availability in percentage. As per Central Ground Water Board data, the overall increase in ground water development is one per cent (from 61 per cent (2009) to 62 per cent (2011)) in India. In the states of Delhi, Haryana, Punjab (172 per cent; highest among the states) and Rajasthan, the stage of ground water development is more than 100 per cent where as in the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh and UT such as Daman & Diu and Puducherry, it is 70 per cent and above. In the rest of the states / UTs, it is below 70 per cent (CGWB, MoWR, RD & GR, 2014). Analysis says that annual ground water drafting is more than the recharge which impacts on the health of aquifer (Table 4.10).

4.2.9 Water Quality

The Central Pollution Control Board (CPCB) has been monitoring the water quality of rivers under the National Water Quality Monitoring Programme in collaboration with State Pollution Control Boards. Around 302 polluted river stretches have been identified based on the levels of BOD (Biological Oxygen Demand) for the years 2009-12 (2015 report), a critical and important parameter for the surface water quality (2015 report).

Under the National River Conservation Plan (NRCP) of Ministry of Environment, Forest and Climate Change, financial assistance is provided to the State Governments for taking up pollution abatements works in various towns along identified river stretches in the country which will lead to improvement in their water quality.

India has progressed in access to safe drinking water for household from 38 per cent in 1981 to 85.5 per

Table 4.10: Stage of ground water development in Indian states

Stage of Ground Water Development (%)	States
0.00 - 14.00	Rajasthan, Chhattisgarh, Telangana, Assam, Meghalaya, Tripura, Nagaland, Arunachal Pradesh, Mizoram, Manipur, Arunachal Pradesh, Goa, Lakshadweep, Andaman & Nicobar, Pondicherry.
14.00 - 47.00	Kerala, Andhra Pradesh, Odisha, West Bengal, Jharkhand, Bihar, Sikkim, Jammu & Kashmir.
47.00 - 77.00	Himachal Pradesh, Uttara Khand, Chandigarh, Uttar Pradesh, Madhya Pradesh, Gujarat, Daman & Diu, Dadra & Nagar Haveli, Maharashtra, Karnataka, Tamilnadu.
77.00 - 172.00	Haryana, Delhi, Punjab.

Source: Central Ground Water Board

cent in 2011 (Fig 4.5). Though rural-urban differential has declined over time, regional differences (state wise) in access to safe drinking water still exist (Central Pollution Control Board, 2012).

The problem of water pollution is most serious in urban agglomerations especially in developing countries, where control on industrial emissions are not enforced and sewers, drains and treatment plants are usually lacking. WHO estimates that, at least 600 million urban dwellers in the developing countries live in what it termed "life and health threatening homes and neighborhoods" (FAO, UN, 1994). This aspect is presented in detail in the Environmental Pollution chapter.

4.3 PRESSURES

Availability of water for the increasing demands is the main concern which calls for a deeper understanding of pressures on this vital resource. India's water crisis is in two contexts: quantitative and qualitative. Water insufficiency gets reflected as per capita availability. The total amount of usable water has been estimated to be between 700 to 1,200 BCM (Central Water Commission, 2014). With a population of more than 1.2 billion, India has only 1,820 cubic meters of water per person, by using the higher estimate. A related problem is dwindling groundwater supplies due to over-extraction, poor irrigation efficiency and lack of water conservation practices.

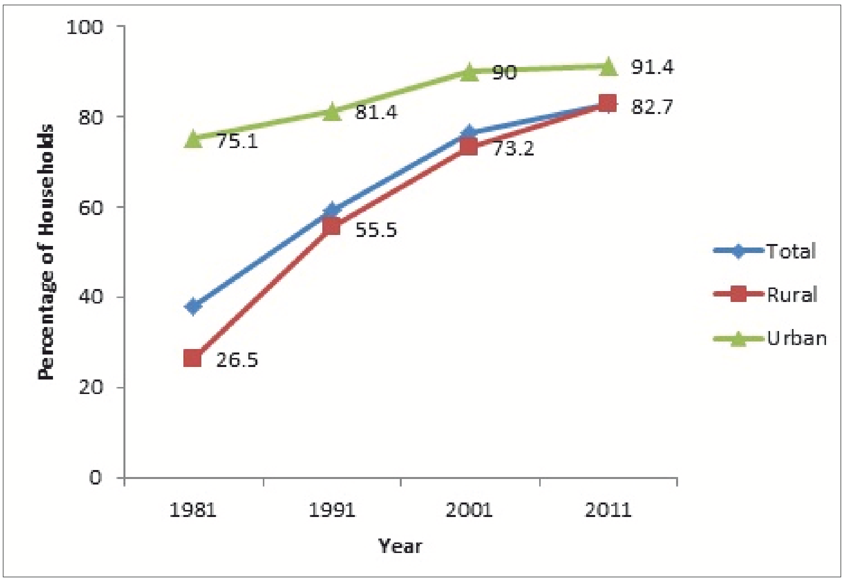
4.3.1 Poor Irrigation Efficiency

In India, the average annual rainfall is 1170 mm or 1.17 m (assuming that 70 per cent of the rainfall effective for crop consumptive use) out of which, the water use for gross irrigation is about 1.45 m per ha. This is very high compared to water use in irrigation systems in developed countries such as the USA, where water allocation for irrigation is about 0.9m per ha. This overuse reflects low irrigation efficiency of about only 25 per cent to 35 per cent in most irrigation systems and a few exceptional cases, where efficiency is about 40 per cent to 45 per cent (Planning Commission, 2011).

From cleaning of the channels by de-silting and weeding, raising earthwork in embankments or dressing, bed and sideslopes, to the design standard and removing undercuts in hard strata, strengthening of banks in filling sections, restoring bed gradients, replacing and painting metal parts in gates and hoists, and making control and measuring devices fully functional, a number of irrigation projects have been operating much below their potential. The widening gap between iriigation potential created and utilized each year is also a measurable factor for depleting water resources.

Flood irrigation practices are often stated to be the main reason behind the poor irrigation efficiencies in Indian agriculture sector, as it needs more water when compared to micro irrigation (sprinkler or drip). In the absence of proper drainage arrangements this

Fig. 4.5: Trend in Access to Safe Drinking Water in Households in India (in %)



Source: Census 2011

often leads to water accumulation. By adopting micro irrigation methods like sprinkler and drip over flood irrigation, about 15-90 per cent of water can be saved, besides increase in farm yields according to the Sub-Group-II report on Efficient Utilization of Existing Irrigation Facilities 2008 (Ministry of Agriculture, 2015).

4.3.2 Rapid Urbanisation, Population Growth and Increasing Pollution Levels

Water being one of the most essential elements of nature to sustain life, societal development always revolved around availability of water. Human settlement sites have always been chosen nearby to rivers keeping in view, the water availability to the inhabitants. Shortfall of supply both in terms of qualitative and quantitative aspects was experienced as the cities grew in size and number. Migration from rural areas as well as from small towns into cities further compounded the pressure on water supply. With increasing population, load is increasing on available water resources and majority of towns and cities are not getting recommended quantities. It was found that the demand and supply gap in major metropolitan cities, viz., Mumbai, Kolkata, Delhi and Chennai varies from 10-20 per cent (11 Major Problems of Urbanisation in India, 2016).

The urban population (377.1 million) accounts for about 31.16 per cent of the country's total population (Census of India, 2011) in India. In 2001-11,the decadal urban population growth rate was 31.8 per cent, which is 1.8 times of the overall and 2.6 times than the rural population growth.

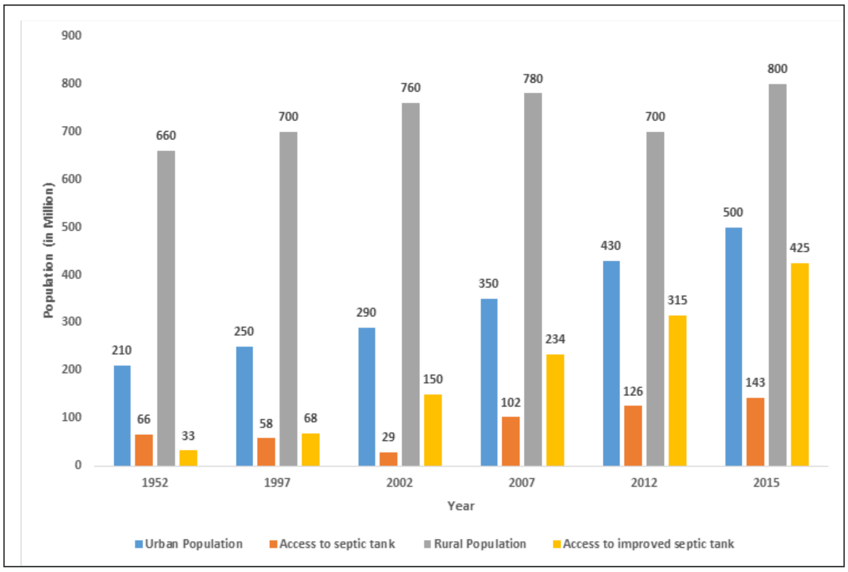
Water supply is not uniform across all states or cities in India. The average per capita water supply for Class I cities of Tamil Nadu is 79.9 liter and for Maharashtra it is 310.09, whereas for Class II cities of Tamil Nadu, it is 106.74 liter and for Maharashtra, it is 34.5 liter. One of the reason for wide variation in per capita water supply is the mismanagement of the water supply system.

Increasing population requires water as an input for productive activities such as domestic, agriculture,

Municipal Solid Waste

The latest figure obtained from the Ministry of Urban Development (MoUD) says that, over 400 municipalities/municipal corporations in the Class I and Class II cities across India at price level of 2009-2010, predictably require close to Rs.7 Lakh crores of money to recycle their municipal waste water and convert it for suitable mass consumption. But most of such municipalities are highly stressed and impaired to generate such an amount. Because of this, the water supplies for domestic purpose stay substantial with no proper plans on paper to improve on the menace. As a result, water prone diseases are multiplying in India without any proper check on them.

Fig.4.6: Growth in Population and Access to Sanitation in India



Source US-AID India, 2010

industrial (including energy generation), other service sectors and finally in evacuation of effluents (sanitation, removing industrial waste etc.). Demands from all those sectors are mounting and competing with each other.

In most parts of the country, waste water from domestic sources with high organic pollutant load hardly undergoes proper treatment and finds its way into surface water bodies and groundwater. According to the Census 2011, out of the 247 million households, about 123 million do not have toilets within the premises. Of the 47 per cent Indian households who report having a toilet, 55 million have installed semi-sealed septic tanks and 19 million have leach pit latrines. Almost 18.6 per cent households in urban India do not have toilet facilities within the premises, six per cent urban households use public latrines and 32.7 per cent with pour flush which is connected to sewer line. At the same time, pour flush latrine connected to a septic tank is recorded in 38.2 per cent of households. Urbanization if not combined with proper sanitation infrastructure, can lead to pollution load on water resources.

It is estimated that about 38,000 Million Litres per Day (MLD) of wastewater gets generated in the urban centres having population more than 50,000 (housing more than 70 per cent of urban population). So far, the sewage treatment capacity developed in India is about 11,000 mld accounting for 29 per cent of wastewater generation. It is estimated that the projected wastewater from urban centres may cross 1,00,000 MLD by 2050 and the rural India will also generate not less than 50,000 MLD in view of water supply designs for community supplies in rural areas. However, waste water management is not getting addressed to that pace as required (Central Pollution Control Board, 2015).

The sanitation issue is closely related to rapidly increasing urbanisation. Major part of rural India has no sewer systems, whereas urban India has not been connected to municipal sewer systems, which makes people dependent on the conventional individual septic tanks, or the faecal material in untreated form getting into water bodies. Access to improved sanitation in urban and rural India has risen (Figure 4.5) but the management of on-site sanitation systems such as septic tanks remains a challenging component, which directly leads to water contamination. This aspect is covered in more details in the Urbanisation and Environmental Pollution chapters.

4.3.3 Climate Change

There are no precise quantitative estimates of the climate change impacts on water resources as yet. However, as per various reports it is certain that climate change could result in further intensification of variations in water availability, both temporally and spatially leading to extreme events of floods and droughts. Hydrological cycles are driven by temperature and pressure fluctuations in atmosphere and therefore have direct or indirect influence on hydrological processes. A warmer climate may result in higher rates of evaporation and increased rates of precipitation. These phased changes can prove to be detrimental as it affects spatial and temporal distribution of runoff, soil moisture and ground water reserves. Intensified rainfall events can increase the risk of flooding. More prominent effects can be noticed on estuarine ecology, with sea level rise, besides effecting behavior of the rivers in innumerable ways. Cumulatively, the river basins as a whole can come under strong influence, both hydrologically and ecologically.

The impact of climate change on water resources need to be assessed quantitatively and precisely, which may cause extreme events of flood and drought. Intense rainfall increases the risk of flooding in low line areas and also rise in sea levels which have a distinct effect on marine ecology and river ecosystems. Overall, it can have a significance impact on hydrology as well as ecology on river basins.

From the above discussion, the likely impact of climate change on water resources could be in the form of:

1. Decline in the **glaciers** and the snowfields in the Himalayas;
2. Increased **drought** like situations due to overall decrease in the number of rainy days in many parts of the country;
3. Increased **flood** events due to erratic rainfall in non-monsoon period, overall increase in rainy days in monsoon.
4. Effect on **ground water quality** in alluvial aquifers due to increased flood and drought events;
5. Influence on **ground water recharge** due to changes in precipitation and evapo-transpiration:
6. Increased **saline intrusion** of coastal and island aquifers due to rising sea levels.

The vulnerable areas will be affected due to potential impact of climate change on water resources includes drought prone, flood prone, coastal regions, the region with deficient rainfall, areas with over-exploited, critical and semi-critical stage of ground water development, water quality affected areas, and snow-fed river basins.

Droughts

Drought is the most widespread hydro-meteorological syndrome of 'prolonged periods of water scarcity affecting natural resources, environment and the people'. Environmental changes, viz. climate change, land-use changes and natural resource degradation have aggravated drought occurrences and vulnerability thus, disrupting the normal socio-economic settings.

Drought affects all parts of our environment as well as our communities. Different types of droughts have varying economic, environmental and social impacts. Approximately, 16 per cent of India's geographic area, mostly arid, semi-arid and sub-humid is drought-prone (Reserve Bank of India, 2013). Due to high temporal and spatial variability in rainfall and wide variations in physiographic and climatic conditions in the country, droughts are experienced in varying intensities (moderate or severe) almost every year, irrespective of a good monsoon.

Table 4.11: Floods in India (2009-2015)

Year	Flood Region
2009	Andhra Pradesh
2009	Karnataka
September 2011	Odisha
June 2012	Assam
September 2012	Uttarkashi
September 2012	Rudraprayag
September 2012	Bageshwar
June 2013	Uttarakhand
October 2013	Andhra Pradesh
October 2013	Odisha
October 2013	West Bengal
July 2014	Odisha
August 2014	Uttar Pradesh
August 2014	Assam
August 2014	Bihar
September 2014	Meghalaya
October 2014	Jammu & Kashmir
July 2015	Gujarat
August 2015	Odisha
August 2015	Manipur
August 2015	West Bengal
August 2015	Assam

Source: http://nrsc.gov.in/floods (National Remote Sensing Center).http://www.ndma.gov.in/en/disaster-data-statistics.html

Floods

Floods have been a recurrent phenomenon in many parts of India, causing loss of lives and public property and bringing untold misery to the people, especially those in the rural areas (Table 4.11).

Flash floods occurs due to a high rate of water flow as also due to poor permeability of the soil. Areas with hardpan just below the surface of the soil are more prone to floods as water fails to seep down to deeper layers (Ministry of Home Affairs, 2015).

As per the Planning Commission of India, the three kinds of flood management strategies suggested in the 12th Plan have been passed. These are 1) engineering/structural measures, including construction of reservoirs for impounding monsoon flow and its release after peak flows have passed (attenuation) and providing river embankments/ flood walls; 2) non-structural measures, including flood plain zoning, flood forecasting, flood warning and flood proofing; and 3) catchment area treatment, including watershed management and restoring the health of natural drainages.

4.3.4 Salinity, Hydraulic Fracturing and Subsidies on Electricity

Salinity, a feature of both inland and coastal states, is a major source of ground water pollution. Ground water salinity is a combined effect of a) inherent formation of water salinity, b) sea water ingress, c) tidal water, d) saline water percolation in low lying marshy lands inundated by sea water, e) irrigation with saline water and f) salt laden winds (Status of Ground Water Quality in coastal aquifers of India – Central Ground Water board (CGWB, 2014). Unequal water distribution already exists within our country and fresh water salination due to sea water ingress will get concentrated more on coastal water scarce areas such as Gujarat, Tamil Nadu and Rajasthan (Ministry of Water Resources, 2015). The increasing levels of salinity have wide ranging impacts on agriculture and health. It is difficult to assess the extent of saline ground water quantitatively because it can occur in particular horizons or be pervasive across entire aquifer systems. The extent of the problem is controlled by understanding the characteristics of the aquifer and the local geology (Green Indian States Trust, 2007).

Hydraulic fracturing is a well-stimulation technique in which rock is fractured by a pressurized liquid to extract oil and gas. The main limitation is that the process requires about three to four million gallons of fresh water which create huge pressure on aquifer. The problem associated with the controversial extraction has been flagged by the Ministry of Environment of India recently and cannot be ignored since poisonous mixture of chemicals and carcinogens seep into the ground water and lead to its contamination.

Heavy subsidies in electricity for farmers in many parts of the country has had unintended consequences such as excessive use of energy for pumping leading to wasteful extraction of ground watereven from deep aquifers. Over extraction of water damages the health of aquifer causing water resource depletion besidesdeterioration of water quality as well. Punjab for example has subsidized power to an extent that there is no control on its farmers to extract ground water not only from within its geographical boundaries but also from neighboring states such as Haryana, Himachal and even Rajasthan.

4.4 IMPACTS

In addition to threatening food supply, water shortages severely reduce biodiversity in both aquatic and terrestrial ecosystems, while water pollution leads to diseases and other biotic stresses. Increasing pollution of surface and ground water not only pose a threat to public and environmental health but also contribute to the high costs of water treatment, further limiting the availability of water.

4.4.1 Impact on Human Health

The drinking water needs of 80 per cent of the rural and 50 per cent of the urban population in India are met by ground water sources. Unfortunately, due to a combination of anthropogenic activities and geogenic reasons, both ground and surface water sources are reported to be plagued with quality issues. Most prominent of these include Bacterial contamination besides Arsenic, Nitrate, Iron, Fluoride and Salinity, which have both socio, economic and health consequences. It is reported that 1.5 million children under five die each year, two hundred million person days of work are lost and economic losses are about Rs 366 billion each year due to water related diseases. Water borne diseases are a great concern in India where one third of all deaths of children under five years of age are due to diarrhea and pneumonia (UNICEF, 2010).

Arsenic contamination is by far the biggest mass poisoning case in the world putting 20 million people from West Bengal and Bangladesh at risk, though some other estimates put the figure at 36 million people (International Water Management Institute). Arsenic, fluoride and heavy metal contamination in ground water sources has health impacts such as damaged joints and bone deformities, yellowing of teeth and toxicological effects on genetic material in living organisms. Chromium is also a carcinogens.

High arsenic concentration was reported in the mining areas of Rajasthan in western India especially around areas of Khetri Copper Complex and Zawar mines in Jhunjhunu and Udaipur district, respectively. This problem is also frequent in Bihar mining belts where it has contaminated ground water resources. Due to absence of alternate source of drinking water the standards have been relaxed from permissible limits of 0.01mg/l to 0.05 mg/l maximum. This section has been further elaborated in the Environmental Pollution chapter.

4.4.2 Impact on Economy and Livelihoods

Economic impact of water borne diseases cost India USD 53.8 billion, which was then equivalent to the state income of Tamil Nadu (Water and Sanitation Program, 2010, assessed in Water in India, UNICEF, 2013), making water pollution one of the biggest challenges India faces economically, environmentally and socially. Domestic, industrial and agricultural pollution makes a significant contribution in reducing the GDP growth.

Economic growth of the country also get affected because of lag in achieving best water saving irrigation practices in agriculture, on which about 60 per cent of population depends for their livelihood.

The cost of industrial water pollution abatement was estimated and it was found that these costs account for about 2.5 per cent of the GDP in India. The cost of avoidance is much lower than damage costs.

India lost about Rs 366 billion, which account for about 3.95 per cent of the GDP, due to ill effects of water pollution and poor sanitation facilities in 1995

(Pathak, 2004; Source: CPCB). The study carried out by ADB in 2006 estimates that the total economic impacts of inadequate sanitation in India amounts to Rs. 2.44 trillion (US$53.8 billion) in a year, which was equivalent of 6.4 per cent of India's GDP in 2006. This means a per person annual impact of Rs. 2,180 (US$ 48). If India had made efforts for mitigating these affects in terms of providing better sanitation facilities and doing abatement of water pollution the required resources would range between 1.73 to 2.2 per cent of GDP (An Economic Appraisal, India Infrastructure Report 2011).

It is quite apparent that water is an essential pre-requisite for sound socio-economic development. Since majority of the poor and the marginalized communities continue to depend on natural resource base for sustenance, water security assumes utmost importance and becomes an essential pre-requisite for creating livelihood security. Water is also inextricably linked to agriculture and other production functions and it can be a focal point around which other interventions get designed. However, the dynamic nature of water makes it an indispensable input in almost all livelihood generating activities namely livestock rearing, home gardening and other small and micro-enterprises (UNESCO, 2009).

4.4.3 Impact on Ecology

If a river has a permanent hydraulic connection with ground water, and water is extracted primarily from surface water or only from ground water, ideally there should be a limit to which this aquifer is exploited. This limit is determined by the ecological flow requirements of the river. Flow in the water bodies below minimum ecological needs damages ecosystems. "Aviral Dhara" (continuous flow) is a consequence of long term stability of the rivers and other flowing water bodies. Anthropogenic activities have violated this aspect in several ways by erecting obstacles to flow, by significant water withdrawals, by increased disposal of debris and by altering the natural water recharge or extraction. Minimum ecological flow in the river is the lifeline of the ecology surviving in the river system. The flow deficit occurs mostly in non-monsoon periods. Due to high fluctuation in the flow rate, perennial river's ecosystems are affected along with the seasonal. Thus, in estimating ecological flow demands, these could be perceived to be more than adequate, since the estimates are based on annual river flows. However, the actual surpluses depend on the deficits of flow in non-monsoon periods, which are critical for maintaining the desired ecosystem functions.

Construction of big dams and structures for hydroelectric project affects the environmental flow in the river water systems and damages ecology and aquatic life. While there are short term local benefits in an inequitable way, the long-term, basin wide impacts in-terms of soil and water fertility, ecological balance, structural stability and flooding etc. leading to submergence, livelihood losses are difficult to predict (UNEP & World Water Council).

Similar adverse effects are also caused by anthropogenic activities that significantly alter river flows or sediment loads. CPCB in a study in 2009 indicated that microbial contamination was a major form of surface water pollution in India, to which domestic sewage contributes heavily. The aquatic life of the ecosystem gets affected severely due to pollution load. The food chain of the ecosystem gets disturbed and spoils the life support system of the rivers and other water bodies.

4.5 RESPONSES

Several adaptation measures and certain policy initiatives have been in place as response strategies to address the concerns related to water resources.

Adaptation and Preparatory Measures

These are mainly under agriculture related use of water resources.

4.5.1 On-Farm Water Management, In-situ Moisture Conservation and Rainwater Harvesting

Under this initiative, water harvesting structures like percolation ponds, khadins, tanks, check dams, gabions construction have been initiated to replenish the ground water. These interventions help create micro-storage for irrigation and for replenishment of groundwater through seepage. Aquifer recharge is considered the most ecologically sound conservation technique. Also techniques for in-situ moisture conservation such as zero tillage and sub-soiling, inter-row cultivation and contour farming were found useful for soil health, water holding capacity and enhance the annual agriculture productivity. On-farm water management reduces water wastage and utilization of excess water for other crops simultaneously. The watershed approach has been found to be the best for these interventions and is being vigorously promoted. The All India Coordinated Research Programmes (AICRP) through water management network have successfully demonstrated at various places under the programme in terms of economizing water use, increasing agriculture productivity and improving water use efficiency.

4.5.2 Improved Irrigation Techniques

The problem of water-logging is very often observed in surface irrigation systems and also in areas of poor drainage, leading to soil salinity. Apart from lining the canals, drainage development through either surface, sub-surface, bio-drainage, or a combined approach is being given priority, followed by appropriate agronomic measures (Ministry of Agriculture, 2015).

Water saving in various crops from sprinkler irrigation ranges from 16 per cent to 69 per cent over traditional methods and increase in crop yield from three per cent to 57 per cent. Whereas in drip water saving range is 5 per cent to 68 per cent and, yield increase in crop is 10 per cent to 50 per cent (MOWR, RD & GR, 2008). Although, it involves more operations and maintenance cost as well as for energy as compared to surface irrigation, micro-irrigation is a more efficient system to increase water use efficiency.

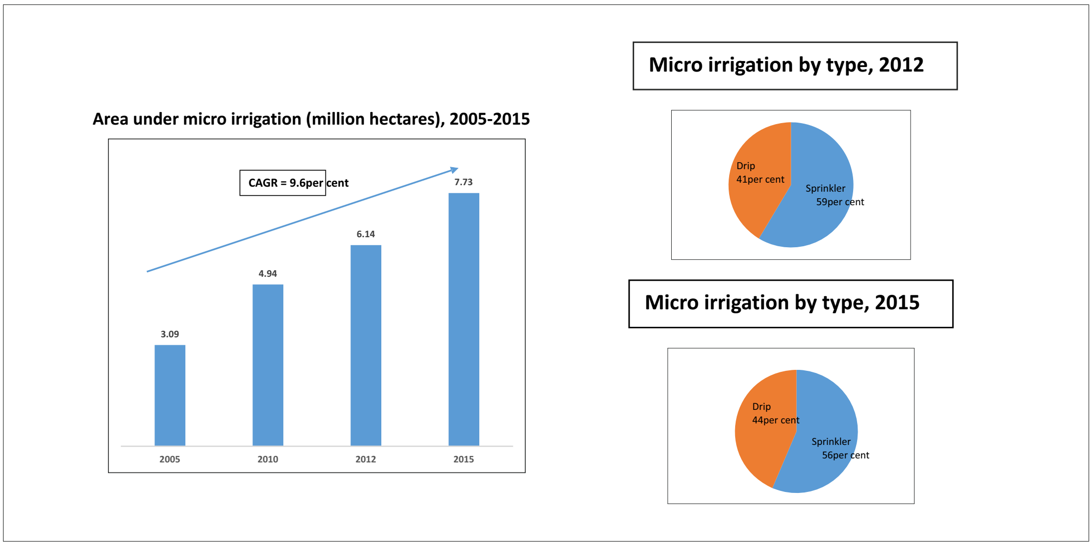
Micro-irrigation has seen a steady growth over the years in India. Since 2005, area covered under micro-irrigation systems has grown at a Compound Annual Growth Rate (CAGR) of 9.6 per cent geographically, states with the largest area under micro-irrigation include: Rajasthan (1.68 Mha), Maharashtra (1.27 Mha), Andhra Pradesh (1.16 Mha), Karnataka (0.85 Mha), Gujarat (0.83 Mha) and Haryana (0.57 Mha).

Majority of the area covered under micro irrigation systems come under sprinkler irrigation with 56.4 per cent, while 43.6 per cent comes under drip irrigation (Fig 4.6). Area under drip irrigation has shown growth in recent years, growing at a CAGR of 9.85 per cent in the 2012-2015 period, while sprinkler irrigation has grown at a pace of 6.60 per cent in the same time period. Overall, the area under micro-irrigation has grown at a CAGR of 7.97 per cent in this time frame (Fig. 4.7) (FICCI, 2016)

4.5.3 Monitoring of Reservoir Storage

Live storages of important reservoirs are being monitored by Central Water Commission. The Crop Weather Watch Group constituted by Ministry of Agriculture for reviewing the crop uses this information for planning the strategy based on the water availability in reservoirs. During the year 2013-14, Central Water Commission monitored live storage of 85 important reservoirs of the country having storage capacity at FRL of 155.008 BCM which is about 61 per cent of the live storage capacity created in the country as per the assessment carried out in 2010. Central Water Commission is issues a bulletin every week based on the monitoring of the status of reservoir storages. The weekly bulletin contains current storage position vis-à-vis storage status on the corresponding day of the previous year, and an

Fig 4.7: Status of Micro-irrigation in India by 2015



Source: Task force for Irrigation report, FICCI 2016 average of last 10 years on the corresponding day (Central Water Commission, 2014).

4.5.4 Benchmarking of Irrigation Projects

A Core Group under the Chairmanship of Member (Water Planning and Projects Wing), Central Water Commission was set up for benchmarking the Irrigation Systems in India. Guidelines for benchmarking have brought out in 2002 and monitored under various performance indicators such as system performance, agricultural productivity, financial and environmental aspects. The concept helps to improve the performance of irrigation system and water utilization, timely maintenance, rehabilitation and restoration of damaged canal, de-siltation, adopting low cost advanced water saving methods and techniques, promotion of rotational cropping pattern etc. and optimal use of water in agriculture (Central Water Commission).

4.5.5 Study of Water Use Efficiency in Irrigation Systems

About 83 per cent of water resources are consumed by irrigation sector in India which is highest among the developing countries. As a part of the water saving in agriculture initiative, Central Water Commission is undertaking water use efficiency studies of completed or ongoing major/medium irrigation projects. The action plan will be prepared based on the study results and will be recommended for necessary action.

4.5.6 Water Audit and Water Conservation

Water audit, an effective tool for sustainable water management plan can be used to minimize losses and optimize the use not only for irrigation sector alone but for other sectors as well. In 2005, Central Water Commission and Central Ground Water Board have formulated "General Guidelines for Water Audit and Water Conservation" taking into consideration the views of central/state government ministries and other stakeholders dealing with water resources management plan development and execution. These guidelines have been circulated to all the State Governments, concerned central ministries and other utilities (Central Water Commission, 2014). It will help to improve the knowledge and practices of regulating authorities and decision makers with a better understanding of channel and distribution system.

4.5.7 Policies & Programmes for Water Resource Management

National Water Policy

The National Water Policy (NWP), 2012 was published by MoWR, RD & GR which seeks to address issues such as scarcity, inequities in distribution and lack of unified perspective in planning, management and use of water. The NWP was approved and adopted by the National Water Resources Council at its meeting held on 28th December 2012.

Some of the basic principles of the NWP are as follows:

- The principle of equity and social justice must inform the use and allocation of water.
- A common integrated perspective should govern the planning and management of water resources. Such a perspective would consider local, regional and national contexts and have an environmentally sound basis.
- Water needs to be managed as a common pool community resource that is held by the state under the public trust doctrine to ensure equitable and sustainable development for all.
- Water may be treated as an economic good to promote its conservation and efficient use after basic needs, such as those of drinking water and sanitation are met.
- The river basin should be considered as the basic hydrological unit for the purpose of this policy.

The NWP also recommends other issues such as adapting the availability of water to climate change, water pricing and conservation and infrastructure development (MoWR, compiled by PRS Legislative Research, 2012).

National Water Mission

India's National Action Plan for Climate Change (NAPCC) contains eight national missions, representing multi-pronged, long term and integrated strategies for achieving key goals in the context of climate change. The National Water Mission under the Ministry of Water Resources, River Development and Ganga Rejuvenation is India’s 8th Mission.

The main objectives of the National Water Mission are conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management. The five identified goals of the Mission are: (a) comprehensive water data base in public domain and assessment of impact of climate change on water resource; (b) promotion of citizen and state action for water conservation, augmentation and preservation; (c) focused attention to vulnerable areas including over-exploited areas; (d) increasing water use efficiency by 20 per cent, and (e) promotion of basin level integrated water resources management.

National Aquifer Mapping and Management Program (NAQUIM)

Aquifer mapping is one of the components of the scheme of Ground Water Management & Regulation by Central Ground Water Board. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geologic, geophysical, hydrogeologic, hydrologic, and water quality data are integrated to characterize the quantity, quality, and distribution of ground water in aquifers in 3-dimension with their characterization on 1:50,000 scale. This is followed up by formulation of Aquifer Management Plan for different aquifers for facilitating sustainable management of ground water resources at regional and local level through participatory approach. The target for the 12th Plan is to map 8.89 lakh sq.km in areas that are over-exploited, critical, semi-critical and stressed.

Namami Gange

'**Namami Gange Programme**', is an integrated mission, approved as 'Flagship Programme' by the Union Government in June 2014 with a budget of Rs.20,000 Crore to achieve the twin objectives of effective abatement of pollution, conservation and rejuvenation of the national River Ganga.

Under the programme, National Mission for Clean Ganga (NMCG) was formed to undertake the mandate of National Ganga River Basin Authority

Photo 4.3: Check dam for water conservation in Bundelkhand

(NGRBA) which has been dissolved since October 2016 vide notification no. S.O. 3187 (E) dt.7th October 2016 under Environmental Protection Act 1986 with the following objectives;

1. To ensure effective abatement of pollution and rejuvenation of the river Ganga by adopting a river basin approach to promote inter-sectoral coordination for comprehensive planning and management.

2. To maintain minimum ecological flows in the river Ganga with the aim of ensuring water quality and environmentally sustainable development.

The programme envisages the structure from national level to district level to measure the prevention, control and abatement of environmental pollution and to ensure environmental flow (continuous adequate flow of water) to rejuvenate the river Ganga.

National River Conservation Plan (NRCP)

The Ministry of Environment, Forest & Climate Change has been supplementing the efforts of the State Governments in the abatement of pollution in identified stretches of various rivers under the National River Conservation Plan (NRCP). NRCP (excluding Ganga and its tributaries which is handed by Ministry of Water Resources, River Development and Ganga Rejuvenation) has covered polluted stretches of 30 rivers in 74 towns spread over 14 States. So far, sewage treatment capacity of 2295.88 million litres per day (mld) has been created under the NRCP programme (excluding Ganga and its tributaries). Various pollution abatement plans taken under NRCP, inter-alia, includes interception and diversion of raw sewage, construction of sewage systems, setting up of treatment plants, low cost sanitation facilities, electric/improved wood crematoria and river front development etc. (NRCD, MoEF&CC, 2015)

National Plan for Conservation of Aquatic Ecosystems

The Ministry Environment, Forest & Climate Change had been earlier implementing two separate programmes, namely National Wetland Conservation Programme (NWCP) and National lake Conservation Plan (NLCP) for conservation and management of identified lakes and wetlands in the country. To have better synergy and avoid overlap, both the programmes have been merged in February, 2013 into an integrated scheme of National Plan for Conservation of Aquatic Eco systems (NPCA). NPCA aims at holistic conservation and restoration of wetlands and lakes for achieving the desired water quality enhancement, besides improvement in biodiversity and ecosystems through an integrated and multidisciplinary approach and a common regulatory framework. The various activities covered under the scheme include interception, diversion and treatment of waste water, shore line protection, lake front development, de-silting, bioremediation, catchment area treatment, lake beautification, survey and demarcation, bio-fencing, fisheries development, weed control, biodiversity conservation education and awareness creation and community participation, etc. so far, financial assistance has been provided under the scheme to 82 identified wetlands and 64 urban/peri-urban lakes in the country for their conservation.

The central Government has notified the Wetlands (Conservation and Management) Rules 2010 to regulate certain activities within the notified wetlands in the country.

Inter-linking of Rivers

Under the Ministry of Water Resources, River Development & Ganga Rejuvenation, Interlinking of River (ILR) programme was initiated to ensure equity in the distribution by enhancing the availability of water in drought prone and rainfed areas. Under the National Perspective Plan (NPP), 14 links under Himalayan rivers and 16 links under Peninsular rivers have already been identified for inter basin transfer of water based on the field surveys and secondary investigation. Out of which, feasibility reports of 2 links under Himalayan river and 14 links under Peninsular Component and have been prepared. Under phase I, Ken-Betwa link project has been declared as national project and Terms of Reference for Environmental Impact Assessment study and Environmental Clearance (EC) of the project has been approved. Under phase II, DPR for other ILRs such as Damanganga-pinjal, Par-Tapi-Narmada, Mahanadi-Godavari and Mansa-Sankosh-Teesta-Ganga has been initiated.

National Rural Drinking Water Programme (NRDWP)

The financial allocations and expenditure under NRDWP have been increased substantially since the launch of Bharat Nirman in 2005-06. Under NRDWP program, selected state-wise funds released for tackling Fluoride and Arsenic problem is 7439.73 crore (Ministry of Drinking Water and Sanitation, 2015).

Integrated Watershed Management Programme (IWMP)

The Parthasarthy Committee observations in addition to the provisions in the Common Guidelines have imposed modifications in the watershed schemes of the Department of Land Resources. Accordingly, Drought Prone Areas Programme (DPAP), Desert Development Programme (DDP) and Integrated Wastelands Development Programme (IWDP) of the Department of Land Resources have been integrated and consolidated into a single modified so called Integrated Watershed Management Programme (IWMP). This consolidation is for optimum use of resources, sustainable outcomes and integrated planning. The scheme is subsumed under Pradhan Mantri Krishi Sinchai Yojana (PMKSY).

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was launched on 1st July 2015, the government allocated Rs. 50,000 crores over a period of five years (2015-16 to 2019-20) to enhance irrigation facilities. The slogan of the PMKSY is "***Har Khet Ko Pani***" and "***More crop per drop***". The scheme focuses on developing an overall coordination between the ministries, departments, agencies and research and financial institutions involved in the potential of recycling of water under a common platform to evolve a comprehensive and holistic view of the entire "water cycle". This process will enable proper water budgeting for all sectors, namely, household, agriculture and industries.

The PMKSY merges ongoing schemes, viz., Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, Integrated Watershed Management Programme (IWMP) of the Department of Land Resources; and On-Farm Water Management (OFWM) component of the National Mission on Sustainable Agriculture (NMSA) of the Department of Agriculture Cooperation and Farmers Welfare (DAC & FW).

National Water Quality Monitoring Program (NWQMP)

Nearly 1,019 water quality monitoring stations were established by CPCB in collaboration with State pollution control boards in 27 States and six Union Territories. The process of water quality monitoring is undertaken on a monthly or quarterly basis for surface water and on a half yearly basis for groundwater. The network consists of 200 rivers, 60 lakes, five tanks, three ponds, three creeks, 13 canals, 17 drains and 321 wells.

4.6 CONCLUSION

In the view of newly emerging water-related issues in many parts of the world, policy-makers are keenly interested in emphasizing non-structural approaches to water management. It includes demand management, scientific research, education and persuasion to coordinate human civilization utilisation of water resources. Policies are often influenced by demand leading to human causes of water problems: degradation of water quality, over exploitation of aquifers; and the continuous decrease decreasing access to water flows to meet non-consumptive water uses such as hydroelectric power, pollution assimilation and fish and wildlife habitats.

Water resources are affected by natural and anthropogenic activities. Poor management of water resources has led to crisis and spatial temporal variation in per capita availability. Extremely poor management, unclear laws, corruption, and industrial and human waste have caused this water supply crunch and rendered available water practically useless. Currently, reuse and recycling of waste water is not practiced on a large scale in India. There is considerable scope and incentive to use this recycled water in irrigation.

As climate change impacts the availability of water, to capture the true correlation between water and climate change, it would require not only an understanding of a wide range of inter-related coexisting subjects but also technical abilities to extract relevant information for water sector. At present, few climate impact models explicitly consider how climate variability and change would affect ground water recharge. The quantitative estimates and impact patterns of climate change in India still have large uncertainties associated with them. Further research is needed to strengthen assessments and reduce uncertainty in predictive models.

The belief that water is available in abundance often becomes a barrier in its efficient use; irrigation water is poorly managed, leading to serious economic and ecological implications. Volumetric metered supply of water is required to minimize wastage of water. Water is the most important natural resource; to protect wastage of water, there is an urgent need to develop a comprehensive regulatory system of water-usage, integrating effective distribution and competitive pricing, to ensure that it is treated as a national property and used prudently. In addition to water pricing, there is also requirement to introduce regulation of the price of energy that is required in accessing water.

Since water is a state subject in India, each state has its own strategy to deal with its water sector, which becomes a challenge because rivers and ground water aquifers are trans-boundary. The state governments have been requested to create detailed state action plans for climate change specific to water resource sector. The elements identified are exhaustive and would provide a much detailed outlook of state level scenarios. The integrated database model will also provide a unique basis for states to understand trans-boundary issues and water needs, while creating their own action plans for climate change.

The Sustainable Development Goal (SDG6) sets out to "ensure availability and sustainable management of water and sanitation for all. SDG 6 builds on the Millennium Development Goals focus on drinking water and basic sanitation is expanded to cover the entire water cycle, including the management of water, wastewater and ecosystem services. Water is at the core of sustainable development; and it underpins SDG 6 strong linkages to all the other SDGs; realizing that it would in fact goes a long way towards achieving much of the 2030 Agenda. The agenda contains six targets on outcomes across the entire water cycle and two targets on the means of implementing the outcome targets. Targets 6.1 and 6.2 of SDG 6 improvises the MDG targets of drinking water and basic sanitation, providing continuity, while increasing their scope and streamlining definitions. Targets 6.3 to 6.6 address the broader water context that was not explicitly included in the MDG framework, but whose importance was acknowledged at the Rio+20 Conference such as water quality, wastewater management, water scarcity and use efficiency, integrated water resources management and the protection and restoration of water ecosystems.

Targets 6.a and 6.b acknowledge the importance of an enabling environment, addressing the means of implementation and aiming for international cooperation, capacity-building and the participation of local communities in water and sanitation management.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 5

AGRICULTURE

Key Messages

- *Around 85 per cent of operational land holdings in the country are categorized as small and marginal. Average size of operational land holdings dropped from 1.33 ha in 2000-01 to 1.15 ha in 2010-11.*
- *37 per cent of the total geographical area of the country is affected by some kind of land degradation.*
- *About 60 per cent of India's agriculture is rainfed, making the sector highly dependent on ground water.*
- *Due to climate change, zones suitable for certain crops are getting shifted to new areas and this results in economic and social impacts.*
- *The agricultural sector is a major driving force of GHG emissions and land use changes. 18 per cent of annual GHG emissions of India during 2007 were from Agriculture sector.*
- *Genetic enhancement of tolerance to drought, heat, flooding and salinity stresses in major crops has been an important response measure to mitigate climate change impacts.*
- *Some of the important measures taken for instilling sustainability in the agriculture sector include the promotion of organic farming and the incorporation of adaptation strategies.*
- *Area covered under organic manure in India in 2008-09 was 24.58 Mha and it increased to 52.61 Mha in 2010-11.*
- *Increasing productivity of rainfed cropping systems is of critical importance to meet the increasing food demand of the country.*

5.1 INTRODUCTION

In the overall economic and social well being of India, agriculture has a key role to play. Agriculture is the principal means of livelihood for more about 58 per cent of the rural households.

In the quest for increased production and productivity, there has been over-exploitation of natural resources like soil, water and forests at an alarming rate; which has resulted in critical situations such as the transformation of productive land into saline land, depleted water tables, and imbalance in soil nutrients caused by overuse of nitrogenous fertilizers. The excessive use of fertilizers has led to reduced availability of phosphorus, potassium and other micro-nutrients.

On one hand, agriculture is directly impacted by climate change and alterations in the environment (for example, global warming is projected to have significant impacts on environmental variables such as rising temperatures, erratic precipitation and extreme weather events) and these factors together affect agriculture. They determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. On the other side, the process of agriculture contributes to climate change through anthropogenic emissions of greenhouse gases (GHGs), and by the conversion of non-agricultural land (e.g., forests) into agricultural land (HLPE, June 2012).

The productivity in agriculture is sensitive in two broad classes of climate-induced effects (a) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations and (b) indirect effects which happen through changes in soil moisture and the distribution and frequency of infestation by pests and diseases.

5.2 STATUS

According to the data in the land use statistics 2011-12, the total geographical area of the country is 328.7 Mha of which 140.8 Mha is the reported net sown area and 195.2 Mha is the gross cropped area with a cropping intensity of 138.7 per cent. The net irrigated area is 65.3 Mha (Annual Report of Agriculture, 2014-15).

5.2.1 Contribution to Economy

Growth in agricultural GDP has shown high volatility since the beginning of economic reforms in 1991. As per the Annual Report on Agriculture by Government of India, 2014-15, the agriculture and allied sectors contributed approximately 13.9 per cent of India's GDP (at constant 2004-05 prices) during 2013-14 (Table 5.1).

Steady decline in the share of Agriculture and Allied Sector in the GDP has been observed from 14.6 per cent in 2010-11 to 13.9 per cent in 2013-14 (at 2004-05 prices).

With changing dietary patterns, agricultural production has got diversified over the years. This is supported by the data as between 2004-05 and 2014-15, horticultural output achieved an annual growth of 7 per cent as compared to 3 per cent growth in food grain production.

As represented in the data, the increase in acreage (Table 5.2) and more significantly increase in productivity (State of Indian Agriculture , 2015-16) has resulted in to the increase in production.

Since time immemorial, livestock have been an integral component of India's agricultural and rural economy. As per the report of the working group on Animal Husbandry and Dairying 12th Five Year Plan (2012-17), livestock are now more valued as source of food and contribute over one-fourth to the agricultural gross domestic product and engage about 9 per cent of the agricultural labour force.

Evidence from the National Sample Survey Office's (NSSO) 70th round of survey showed that more than one-fifth (23 per cent) of agricultural households with very small parcels of land (less than 0.01 hectare)

Table 5.1: Share of Agriculture & Allied Sector in Total GDP (2010-2014)

Items	Year			
	2010-2011	2011-2012	2012-2013	2013-2014
GDP of Agriculture and Allied Sector (Rs. in Crore)	717,814	753,832	764,510	800,548
Per cent of Total GDP	14.6	14.4	13.9	13.9

Source: Central Statistics Office, Ministry of Statistics &Programme Implementation, Govt. of India

Table.5.2: Area, Production and Productivity of Horticulture Crops (2009-2014)

Year	Area (Ha)	Production (MT)	Productivity (MT/ha)
2009-10	20.8	223.2	10.7
2010-11	21.8	240.4	11.0
2011-12	23.2	257.3	11.1
2012-13	23.7	268.8	11.3
2013-14	24.2	277.4	11.5

Source: Department of Agriculture and co-operation, Central Statistics Office, Ministry of Statistics & Programme Implementation, Govt. of India; (From Annual Report of Agriculture 2014-2015)

reported livestock as their principal source of income. There is evidence to show that farming households with some cattle head are better able to withstand distress arising due to extreme weather conditions as compared to their counterparts (State of Indian Agriculture, 2015-16).

The growth of the dairy sector has been a major success story. With an estimated production of 146.3 million tonnes in 2014-15, India continues to be the largest producer of milk in the world. In the case of meat, egg, wool and fish production, significant progress has been realized. As per the Basic Animal Husbandry and Fisheries Statistics (2014), the total meat production in the country was reported as 4.3 million tonnes in the year 2008-09 and the production of meat showed an escalating trend during the period 2008-09 to 2012-13 with an average annual growth rate of 8.2 per cent.

The agriculture sector is, however, currently facing a dilemma. The annual average growth rate of the agriculture sector was at five per cent between 2004-05 and 2007-08, but fell to three per cent between 2008-09 and 2013-14. It is facing crisis which is characterized by lower rates of institutionalized credit to small farmers; predatory lending, lowering farm productivity and deepening indebtedness amongst small farmers.

5.2.2 Common Agricultural Practices

The status and trends regarding some of the prevalent agricultural practices in India are mentioned here as follows:

Rainfed Agriculture

Rainfed agriculture plays a crucial role in Indian economy. It has about 54 per cent of country's net sown area; and accounts for 40 per cent of the total food production (Rainfed farming system). Also, the rainfed areas support two-thirds of the livestock population, and are critical to food security, equity and sustainability. Added to this, stagnant yield growth from irrigated production systems makes productive and sustainable rainfed farming an issue of national importance.

Increasing productivity of rainfed cropping systems is of critical importance to meet the food demands of increasing population in India.

But rainfed agriculture is diverse and subject to variable intensity and frequency of rainfall, meaning there is little possibility for the adoption of standardized technologies. Far more significant for rainfed farming are location specific knowledge, agronomic principles and options of practices, time-dependent decisions, and the flow of skills and knowledge into the farming system to ensure efficient production (IIED, 2015).

Farming on Small Land Holdings

About 85 per cent of the operational holdings in the country are small and marginal, i.e., that is holdings of less than 2 hectares each. During 2000-01 and 2010-11, the number of marginal holdings increased from 75.41 million to 92.83 million (rise of 23 per cent) and number of small holdings increased from 22.70 million to 24.78 million (rise of 9 per cent). In comparison, the medium holdings dropped by 3 per cent and large holdings by approximately 11 per cent (State of Indian Agriculture 2015-16).

The data shows that the average size of operational land holdings dropped from 1.33 ha in 2000-01 to 1.15 ha in 2010-11 (Table 5.3). It is estimated that the average size of land holding, which is presently 1.15 hectare, is likely to reduce further by 2020-21 (Figure 5.1).

The results of the Situation Assessment Survey of Farmers/Agricultural Households (SAS, 2013) show that positive net monthly income accrues only to the farmers with land holdings of more than one hectare. It is, therefore, established that marginal holdings are too small to provide the farm household with sufficient returns and incomes.

The productivity of smallholder agriculture and its contribution to the economy, food security and poverty reduction is dependent on the services provided by well-functioning ecosystems. This includes majorly aspects of soil fertility, freshwater delivery, pollination and pest control. In turn, smallholder farming practices affect the state of ecosystems. These impacts are not always negative, but poverty and pressing needs can drive smallholders to put stress on ecosystems, for example through habitat modification, over extraction of water and nutrients, and use of pesticides, there can be stress on ecosystems.

Obsolete and Inappropriate Farming Practices

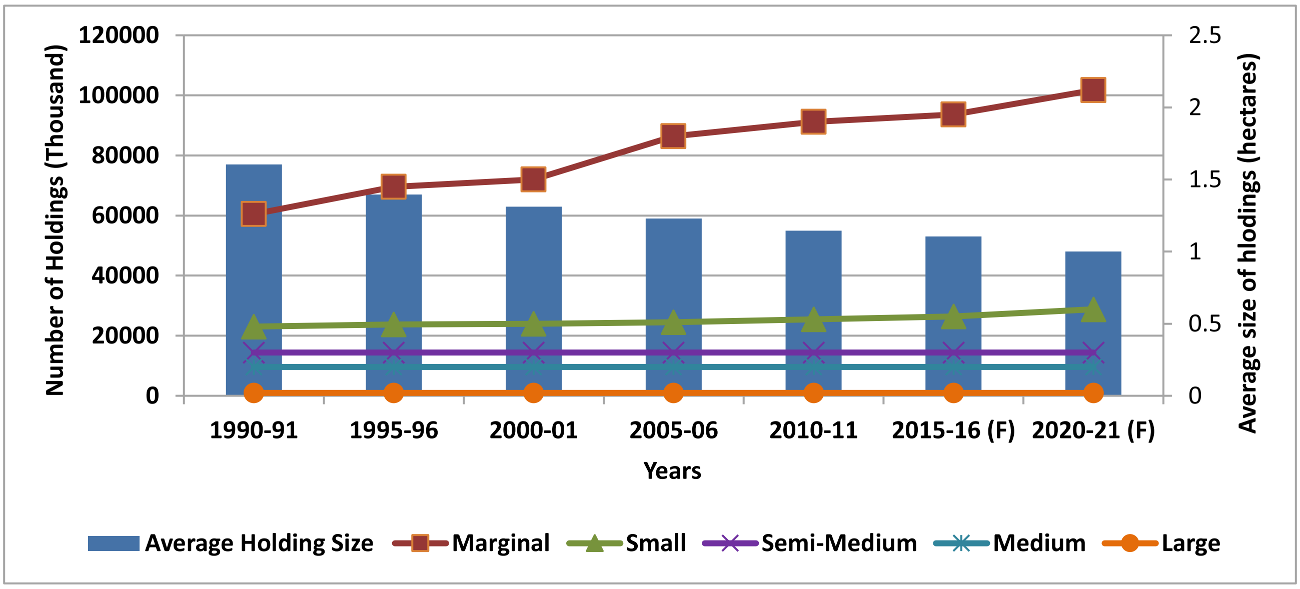
Indian agricultural productivity is very low compared to world standards due to use of obsolete farming technologies. Illiteracy and general socio-economic backwardness among majority of farmers.

Excessive Tillage and Use of Heavy Machinery

Almost all farmers use tillage to loosen the soil for planting and to help with managing weeds.

Physical properties of soil such as infiltration rate, water holding capacity, aggregate stability, soil structure, soil aeration etc. can be improved by the carbon stored in the soil. The loss of carbon as CO_2 gets accelerated by the oxidation and breakdown of plant residue/organic matters. Soil moisture, soil pH, the oxidation-reduction process, soil temperature, chemical and physical soil properties, nutrient status, and plant residue quantity and quality are the factors which accelerate organic carbon breakdown and production of greenhouse gases and this gets impacted by excessive tillage practices.

Fig. 5.1: Number of Operational Holdings and Average Holding Size in India



Source: Fourth Semi-Annual Medium Term Agricultural Outlook Report, September, 2015, NCAER; Department of Agriculture, Cooperation & Farmers Welfare.

Table 5.3: Average Size (in hectares) of Operational Holdings as per Agriculture Censuses

Size Groups	1970 - 1971	1976-1977	1980-1981	1985-1986	1990-1991	1995-1996	2000-2001*	2005-2006*	2010-2011
Marginal	0.40	0.39	0.39	0.39	0.39	0.40	0.40	0.38	0.39
Small	1.44	1.42	1.44	1.43	1.43	1.42	1.42	1.38	1.42
Semi medium	2.81	2.78	2.78	2.77	2.76	2.73	2.72	2.68	2.71
Medium	6.08	6.04	6.02	5.96	5.90	5.84	5.81	5.74	5.76
Large	18.10	17.57	17.41	17.21	17.33	17.20	17.12	17.08	17.38
All Sizes	2.28	2.00	1.84	1.69	1.55	1.41	1.33	1.23	1.15

*Source: Agriculture Census, Directorate of Economics & Statistics (* excluding Jharkhand).*

Model Law by NITI Ayog on Liberalizing Farmland Leasing

The model law drafted by NITI Aayog on liberalizing farmland leasing, if and where enacted, can have positive impacts in accelerating the productive use of unused lands, optimising cultivation, and improving agricultural mechanisation, since currently using tractors and machines for just 2-3 acres is unviable. It would also allow tenants to get access to credit, insurance and compensation for crop damage, while ensuring that land owners do not loose their land. This does away with restrictions on leasing of farmlands, and makes the process transparent from the tenants' perspective. This law has already been passed by Madhya Pradesh and partially by Uttar Pradesh.

The adoption of No-tillage practices by farmers in India has been primarily seen for the wheat crop and has occurred mainly in the rice-wheat double cropping production system. The Rice-Wheat Consortium for Indo-Gangetic-Plains, an initiative of Consultative Group for International Agricultural Research (CGIAR) that involves a number of National Agricultural Research Centres, has been promoting No-tillage and it is mainly their efforts that have resulted in the substantial uptake of No-tillage wheat in the region.

Poor Crop Rotation and Burning of Crop Residues

In lands under cultivation, inappropriate crop rotation coupled with lack of proper soil and water conservation measures are seen as significant reasons contributing to soil erosion. The rotation of crops is not only required to offer a varied "diet" to the soil micro organisms, but also for exploring different soil layers for nutrients that have been leached to deeper layers. These can be "recycled" only if particular crops are grown in rotation.

India is the world's largest consumer of fuel-wood, agricultural waste and biomass for energy purposes. Burning of crop residues for cooking, heating or simply disposal contributes to Soil Organic Matter (SOM) loss. Decline in SOM leads to limited soil life and poor soil structure. Such soils become excessively prone to erosion. Moreover, this also leads to air pollution which is a health hazard. The details are discussed in the Environmental Pollution chapter. According to the Ministry of New and Renewable Energy (MNRE), ~500 Mt of crop residues is generated every year and ~125 Mt are burned (Annual Report of the Ministry of New and Renewable Energy, 2009).

Inefficient Irrigation Practices

For increase in agricultural productivity and production, more cropped area should be under assured irrigation. The irrigation potential of the

Table 5.4: Distribution of Net Irrigated Area and Net Area Sown by Size Groups of Holdings as per Agriculture Census 2010-11

Major size classes of holdings	Net Irrigated Area		Net Sown Area		Percentage of Net Irrigated Area to Net Area Sown
	Area (Ha)	Per cent to Total	Area (Ha)	Per cent to Total	
Marginal	16,835	26.07	32,219	22.81	52.25
Small	14,263	22.09	31,976	22.63	44.61
Semi medium	14,995	23.22	33,778	23.91	44.39
Medium	13,266	20.55	29,442	20.84	45.06
Large	5,209	8.07	13,864	9.81	37.57
Total	**64,567**	**100.00**	**141,279**	**100.00**	**45.70**

Note: Total may not tally due to rounding off.

Source: Agriculture Census, 2010-11

country is estimated at about 140 Mha, with about 76 Mha from surface water sources, and about 64 million hectares from ground water sources. The data on distribution of net irrigated area and net area sown by size group of holdings show that percentage of net irrigated area to net area sown is little more than 50 per cent for marginal size of holdings; and it is 45 per cent for medium and 37.57 per cent for large size of land holding (Table 5.4).

Due to inefficient irrigation practices, there is often an overuse of surface water leading to drainage problems. This in turn leads to waterlogging and excessive evapotranspiration resulting in accumulation of salts leading to low fertility of the soil.

Farming with Intensive Use of Agro-chemicals

A wide range of agricultural chemicals are being used to enhance agricultural yields; and some of them become pollutants through use, misuse, or ignorance. These include fertilizers, and crop protection chemicals like the insecticides, pesticides, fungicides and the herbicides.

Information related to trend of chemical fertilizer usage since 2009 onwards is given in Table 5.5. Excess fertilizer usage not only makes the plants dependent on artificial fertilizers; but also erodes the land quality, pollutes ground water; and in case of a surface runoff, pollutes the nearby water bodies.

The use of fertilizers in India in terms of NPK has increased substantially. The data shows the increase from a mere 1.1 million tonnes in 1966-67 in the pre-green revolution period to more than 25 million tonnes in 2014-15. According to the International Fertilizer Association, India ranked second in total world fertilizer consumption in 2012. In terms of the all India average consumption of fertilizers, the increase is from 69.84 kg per hectare in 1991-92 to 128.08 kg per hectare in 2014-15.

Agricultural pollutants have a huge effect on soil and water quality. Information regarding pollution is covered in the Environmental Pollution chapter in more details. Agricultural non-point source (NPS) pollution impacts lakes, rivers, wetlands, estuaries and groundwater. Agricultural NPS can be caused by poorly managed animal feeding operations, overgrazing, plowing, fertilizer and improper, excessive or badly timed use of pesticides. Pollutants from farming include sediments, nutrients, pathogens, pesticides, metals, and salts (EPA, 2015).

These agro-chemicals release ammonia, nitrate, phosphorus, and other chemicals that affect air, water, and soil quality, as well as biodiversity.

On the basis of soil testing, bio-fertilisers and locally available organic manures, like Farm Yard Manure (FYM), vermi-compost and green manure to maintain soil health and its productivity, Department of Agriculture and Cooperation is promoting balanced and judicious use of chemical fertilizers. In order to encourage balanced fertilizer use, Government is providing grant for setting up / strengthening of soil testing laboratories, trainings and demonstrations on the topics of balanced use of fertilizers and promotion of micro-nutrients. Figure 5.2 depicts the increasing number of soil testing laboratories since 2010.

At present, there are 1,206 Soil Testing Laboratories with analyzing capacity of 1.28 crore samples per annum (Annual Report of Agriculture, 2014-15).

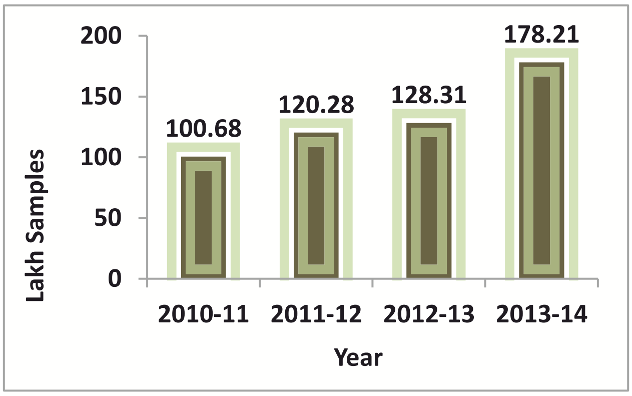
The practice of organic cultivation is seen to be increasing but in context of consumption of organic products, it is more observed in metro and other big cities and among affluent classes. One of the recent accomplishments, however, is Sikkim becoming a

Table 5.5: Consumption of Chemical Fertilizers in Lakh tonnes (2009-2014)

Year	Urea	DAP	MOP	Complex	Nitrogen (N)	Phosph ate (P)	Potash (K)	Total (N+P+K)
2009 -10	266.74	104.92	46.34	80.25	155.80	72.74	36.32	264.86
2010 -11	281.12	108.70	39.31	97.64	165.58	80.50	35.14	281.22
2011 -12	295.65	101.90	30.29	103.95	173.00	79.14	25.75	277.90
2012 -13	300.02	91.54	22.11	75.27	168.21	66.53	20.62	255.36
2013 -14	306.00	73.57	22.80	72.63	167.50	56.33	20.99	244.82

Source: Department of Agriculture and co-operation, Central Statistics Office, Ministry of Statistics &Programme Implementation, Govt. of India; (From Annual Report of Agriculture 2014-2015)

Fig 5.2: Soil Testing Capacity (2010-2014)



Source: Department of Agriculture and co-operation, Central Statistics Office, Ministry of Statistics & Programme Implementation, Govt. of India; (from Annual Report of Agriculture 2014-2015)

complete organic state. The Government of Sikkim adopted the Organic Mission since 2013, the same year it stopped imports of chemical fertilizers in the state. The process for bringing the total cultivatable land of 58,168 hectares under organic farming commenced at ground level since 2010 (Sikkim Organic Mission).

5.3 PRESSURES

The main factors which act as pressures for the agriculture sector are as follows.

5.3.1 Soil Degradation

Top soil is the upper, outermost layer of soil, usually the top two inches (5.1 cm) to 8 inches (20 cm). It has the highest concentration of organic matter and micro-organisms. A major environmental concern known as top soil erosion occurs when the top soil layer is blown or washed away. Without top soil, little plant life is possible; half of the top soil on the planet has been lost in the last 150 years (Soil erosion and degradation, World Wildlife Fund).

As per available estimates of Indian Council of Agricultural Research (ICAR, 2010), Department of Agriculture & Cooperation Annual Report 2014-15, out of total geographical area of 328.7 Mha, about 120.4Mha (37per cent) is affected by various kind of land degradations. This includes water and wind erosion (94.9 Mha), water logging (0.9 Mha), soil alkalinity/sodicity (3.7 Mha), soil acidity (17.9 Mha), soil salinity (2.7 Mha) and mining and industrial waste (0.3 Mha).

Frequent droughts, floods and climatic variations also impact soil fertility and cause land degradation, thereby, affecting food grain production across the country. Causes of soil degradation are both natural and human-induced. Natural causes include earthquakes, tsunamis, droughts, avalanches, landslides, volcanic eruptions, floods, tornadoes, and wildfires. Human-induced soil degradation results from inappropriate agricultural practices, improper management of industrial effluents and wastes, over-grazing, poor management of forests and deforestation, surface mining, urban sprawl, and commercial/industrial development.

Soil degradation has become a serious environmental problem; and it is exacerbated by climate change. It encompasses physical, chemical and biological deterioration. Of late, in a comprehensive study made on the impact of water erosion on crop productivity, it was revealed that soil erosion due to water resulted in an annual crop production loss of 13.4 Mt in cereal, oil seeds and pulse crops equivalent to ~US$162 billion (ICAR-NAAS Report, 2010).

Crops grown in most soils in India suffer from deficiencies of one or more micronutrients, even though the soils often contain apparently adequate total amounts of the respective elements. The nature and the extent of deficiencies seems to vary with the soil type, crop genotype, management and agro-ecological situations.

Analysis of soil and plant samples has indicated that 49 per cent of soils in India are potentially deficient in Zinc, 12 per cent in Iron, 5 per cent in Manganese, 3 per cent in copper, 33 per cent in boron and 11 per in molybdenum (Maha V Singh, 2008).

5.3.2 Erratic Precipitation and Declining Ground Water Level

Water is the most critical resource for agriculture, gaining primacy even over soil. Its availability impacts agriculture in several ways.

Erratic Rainfall

India has only about four per cent of the world's fresh water resources. Thus, large tracts of land are dependent on seasonal rainfall for crop cultivation, which hampers productivity and the adoption of high yielding varieties and other inputs. Figure 5.3 depicts the rainfall pattern between year 2000 and 2012.

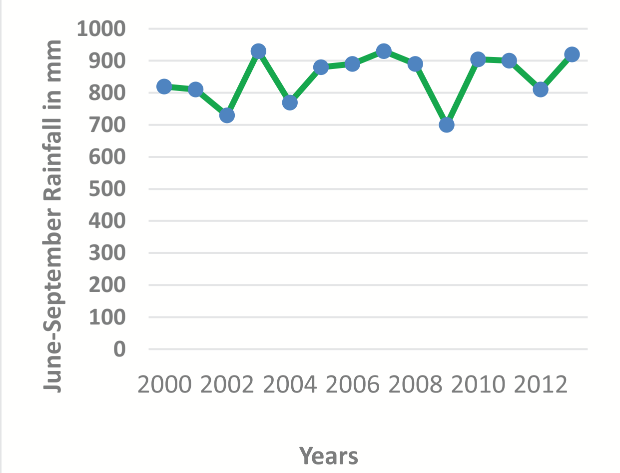
Since 45 per cent (2009-10) of the total cropped area is under irrigation, any shortfall in rainfall adversely impacts crop production (GOI, 2013).

Declining Ground Water

The dependence of irrigation on ground water has increased post Green Revolution, which depended on intensive use of inputs such as water and fertilizers to boost farm production. Instead of, extending surface water irrigation to un-irrigated regions; providing incentives for ground water extraction has led to uncontrolled extraction and misuse of water. About 60 per cent of India's agriculture is rainfed, making the country highly dependent on ground water. Although, it is difficult to predict future ground water levels, falling water tables can be expected to further deplete, on account of increasing demand for water from a growing population; more affluent life styles; and from the services sector and industry (India Climate Change Impacts, 2013).

Photo 5.1: Ground water: Plenty today and not sure for tomorrow

Fig 5.3: Figure depicting rainfall pattern (2000-2012)



Source: India Metrological Department, Analysis by Tata Strategic Management Group

Table 5.6 gives information on groundwater stressed blocks of India and the state-wise depleting water resources.

Table 5.6: Depleting Water Resources (In Billion Cubic Meter)

State	Extraction	Irrigation	Domestic + Industrial
Punjab	34.88	34.17	0.71
Haryana	13.05	12.35	0.71
Karnataka	9.41	8.59	0.82
West Bengal	10.69	9.72	0.97
Maharashtra	17.18	16.15	1.03
Madhya Pradesh	18.83	17.48	1.35
Bihar	11.95	10.25	1.70
Rajasthan	14.84	13.13	1.71
Tamil Nadu	14.93	13.17	1.76
Uttar Pradesh	52.78	48.74	4.04

(Source: Central Ground Water Board Report, 2014)

National Sample Survey Organisation (NSSO, 2005) indicated that 69 per cent of kharif and 76 per cent of rabi irrigated areas depended on ground water.

5.3.3 Population Pressure and Related Issues

Studies and debates about the interactions between population growth and the environment are widely available. Growing population exerts stress on agricultural land, causing environmental degradation, and forcing the cultivation of land of poorer and poorer quality. This environmental degradation eventually reduces agricultural yields and food accessibility.

The non-availability of land for cultivation is enhancing year by year. The availability of arable land per capita has shown a reducing trend, as it is evident in Figure 5.4. The projections for 2025 and 2030 indicate the scenario in the years to come.

Due to decreasing size of the farms, the input prices are increasing along with wages; without much increase in produce price, making these farm units unviable.

With increasing urbanisation, the requirement of land has also increased. With declining grazing lands, the pressure on animal rearing is observed to be increasing. The situation has become quite alarming.

Capacity and Investment Constraint

Agriculture is largely taken up by un/semi-skilled people. Recent trends indicate that more and more women, who mostly lack the knowledge and access to latest technologies and equipment, are beginning to take up agriculture as a primary source of income. The availability of timely inputs like seeds, water, fertilizer, chemicals, energy and soft credits etc. is majorly inadequate, especially for poor and for women.

Due to paucity of resources, it is not possible for these farmers to apply expensive farm inputs like seeds, fertilizers and pesticides on time, resulting in very low productivity and perpetuation of poverty most prevalent in agriculture dominated rural areas.

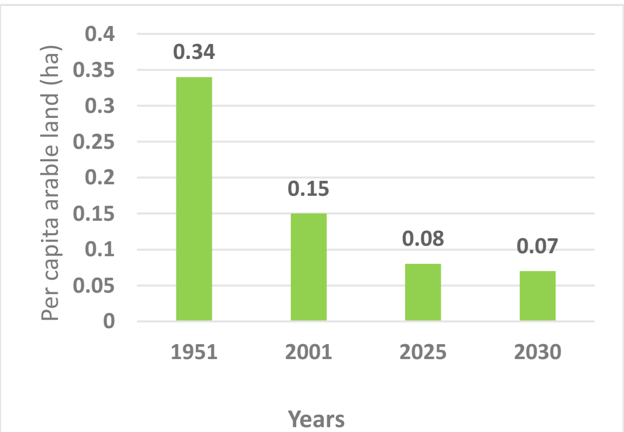
5.3.4 Climate Change and Other Environmental Factors

Climate Change

Intergovernmental Panel on Climate Change (IPCC) indicates that adverse impact of climate change due to rising temperatures and extreme weather events on food production system could impact agricultural growth.

Climate change is a major risk to areas like coastal areas, Indo-Gangetic plains and the drought and flood prone regions of the country. Besides production from crops and livestock, fresh water and marine ecosystem are also likely to be affected due to warming of sea surface temperatures. Such climatic fluctuations could adversely affect agricultural sustainability which can impact other economic sectors.

Fig 5.4: Figure Showing the Data on Per Capita Arable Land



Source: Directorate of Economics and Statistics, Ministry of Agriculture

Cyclones and Droughts

The most serious climate change risk to the Indian economy and its people is the increased intensity, frequency and geographical coverage of drought. Higher temperatures, increased evapo-transpiration and decreased winter precipitation, may bring about more droughts. The possibility of winter drought will increase in certain areas impacting the yield of Rabi crops. Another most important risk is that of cyclonic storms and storm surges. A storm surge is an abnormal rise of sea level caused by a cyclone moving over a continental shelf. A sea surface temperature rise of 2-4°C, as anticipated in the Indian Ocean over the century, is expected to induce a 10-20 per cent increase in cyclone intensity.

As per the World Bank report, droughts are expected to be more frequent in some areas, especially in north-western India, Jharkhand, Odisha and Chhattisgarh. Crop yields are expected to fall significantly because of extreme heat by the 2040s (India Climate Change Impacts, 2013).

Air Pollution

A great deal of the attention around air pollution in developing countries tends to focus on its impact on human health. However, air pollution in and around these cities, and in the surrounding countryside, could also have significant impacts on agricultural production. The economic, environmental and social impacts of these effects could be very significant, but the importance of this issue, and its inferences for both pollution control and agricultural policy, has not been recognized or documented by many national and international agencies. The research study done by the Imperial College Centre for Environmental Technology (ICCET) and IIED, outlines the way in which air pollution represents a threat to agriculture in the developing world. It presents field based evidence of significant crop yield reductions as a result of air pollution, and discusses approaches to the assessment of the extent and nature of this risk in other regions (IIED Gatekeeper Series No.73).

As per a paper published on 'Recent climate and air pollution impacts on Indian agriculture' in the proceedings of National Academy of Sciences, analysis of the results of the combined effects of climate change and the direct effects of short-lived climate pollutants (SLCPs) on wheat and rice yields in India from 1980 to 2010 suggests that, averaged over India, yields in 2010 were up to 36 per cent lower for wheat than they otherwise would have been, absent climate and pollutant emissions trends, with some densely populated states experiencing 50 per cent relative yield losses.

Biodiversity Loss

Loss in biodiversity is emerging as a pressure for productivity from agriculture and allied sectors. Ecosystems provide regulating as well as supporting services that are necessary for agriculture and allied sectors. These consist of provisioning of food, fibre and water; regulating services such as air, water and climate regulation, pollination and pest control; and providing resilience against natural disasters and hazards.

Pollinators are essential for the production of a large number of crops (e.g., cereal, orchard, horticultural and forage production), and add to improvements in quality of both fruit and fiber crops. This service is ensured by a large quantity and diversity of pollinators, mainly provided by wild biodiversity. Pest control is another key ecosystem service provided by biodiversity.

5.4 IMPACTS

This section comprises of two major sub sections. First part deals with the impact of climate change on agriculture and allied sectors, while the second section is the impact of this sector on climate change.

Impact of Climate Change on Agriculture and Allied Sectors

5.4.1 Impact on Agriculture

Agriculture is directly dependent on climate; as temperature, sunlight and water are the main drivers of crop growth.

Climate change impacts on agriculture are being witnessed all over the world, but in view of the higher demographic pressure on natural resources and poor coping mechanisms, countries like India are more vulnerable. Models generally envisage that rising temperatures, increased climate variability and extreme weather events could significantly affect food production in the coming decades (ICAR Annual Report, 2010-11).

For getting better understanding on the risks of climate change to development, the World Bank Group commissioned the Potsdam Institute for Climate Impact Research and Climate Analytics to look at the likely impacts of temperature increases from 2^{0}C to 4^{0}C in three regions (South Asia, South East Asia and Sub-Saharan Africa). Best available evidence was used by the scientists and this was supplemented with advanced computer simulations to arrive at likely impacts on agriculture, water resources, cities and coastal ecosystems in the three above mentioned areas. Some of their findings for India include: Unusual and unprecedented spells of hot weather are expected to occur far more frequently and cover much larger areas. Under 4°C warming, the west coast and southern India are projected to shift to new, high-temperature climatic regimes with major impacts on agriculture (India climate change impacts, 2013).

Climate change impact assessment depicts that India's overall crop yields could fall by 30 per cent by 2050 (IPCC, Working Group II). Other major impact will be coastal flooding, greater drought incidence, and reduced water availability. The Intergovernmental Panel on Climate Change (IPCC) indicates that rice and wheat production of India will drop significantly because of climate change.

A 1.5°C rise and two mm increase in precipitation could result in a decline in rice yields by 3-15 per cent. More detailed analysis of rice yields by the International Rice Research Institute (IRRI) predicts 20 per cent reduction in yields per degree Celsius of temperature rise. Rice crop becomes sterile if exposed to temperatures above 35°C for more than one hour during flowering and as a result produces no grain. Although the net impact of climate change on agricultural production is uncertain it is likely that it will shift the suitable growing zones for individual crops. As anticipated, adjustment to this geographical shift will involve considerable economic costs and social impacts.

While a number of global vulnerability studies are available, very few vulnerability assessments are available at the country level in India. Research on pulse crop shows that with rising temperature, a host of biotic and abiotic stresses is predicted to become more severe and adversely impacting productivity and stability of production of pulse crops (Bahl, June 2015).

5.4.2 Impact on Horticulture

Regarding the impact of climate change on the horticulture crops, the knowledge is limited. It has been observed that at higher temperature (31-32°C), in general, the rate of plant maturity in annual species increases, thus shortening the growth stages, during which developing fruits and suckers absorb photosynthetic products to get healthier or juicier.

The changes in climate are observed in many forms like erratic precipitation, increase in temperature, lesser days serving as the chilling period etc. These have started affecting the mountain agricultural production systems and ultimately the food security and the livelihoods of the people. Wind and windiness are significant factors governing the success of horticultural plants and the scale of their impacts may change as climate alters. Damaging winds could limit crop growing in areas where earlier it flourished.

5.4.3 Impact on Animal Husbandry

The four main areas of impacts of climate change on animal production are as follows: a) availability of feed grain, b) pasture and forage crop production and quality, c) health, growth and reproduction and, d) disease and their spread. Studies show that animal health gets affected by climate change in four ways: heat-related diseases and stress, extreme weather events, adaptation of animal production systems to new environments, and emergence or re-emergence of infectious diseases, especially vector borne diseases (which are critically dependent on environmental and climatic conditions).

Studies done by scientists at regional research centers across the country have concluded that direct effects from air temperature, humidity, wind speed and other climate factors influence animal performance: growth, milk production, wool production and reproduction. Therefore earnings of the farmers dependent primarily on animal husbandry become vulnerable when these stress conditions prevail. Delayed and deficit rainfall during the pre-monsoon season (especially during May) adversely affected fish seed production in Asom (DARE/ICAR Annual Report 2015-16).

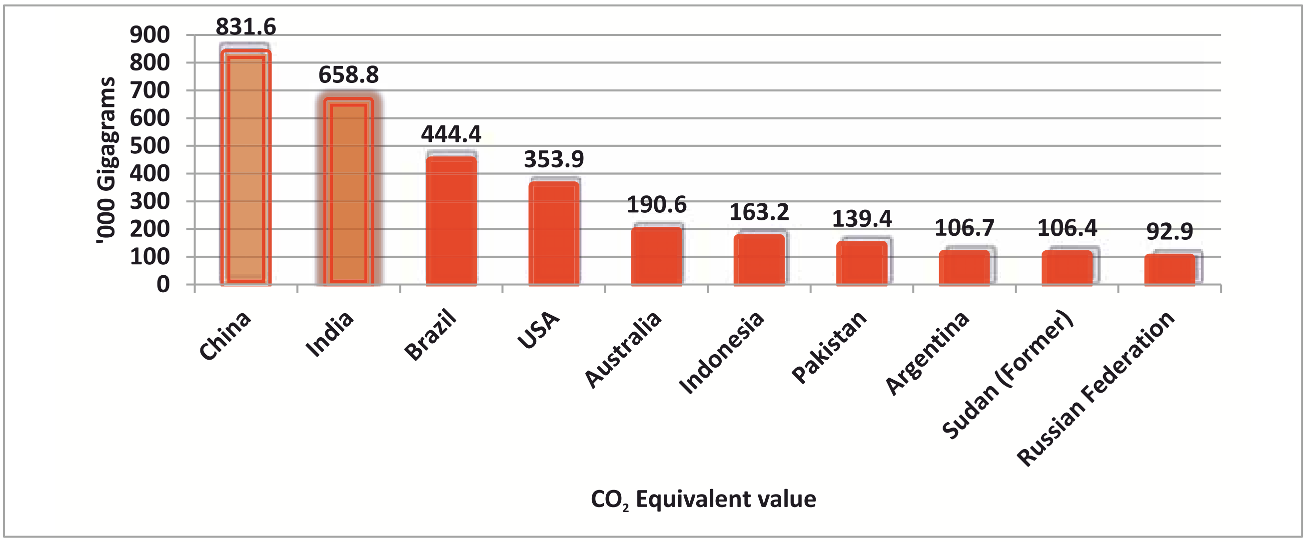
Impact of Agriculture and Allied Sectors on the State of Environment

This is mainly seen in context of green house gas emissions and as air and water pollution, as well as biodiversity loss.

5.4.4 GHG Emissions

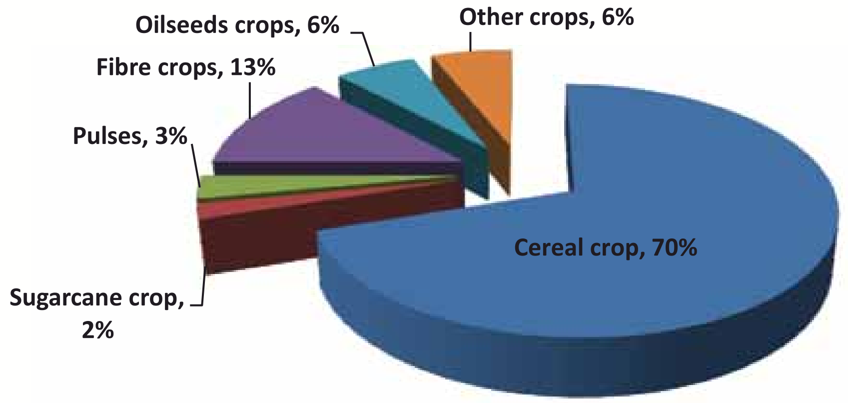
The agricultural sector is a driving force in the GHG emissions and land use effects. As per the data available, fossil fuels, land use and agriculture are the three major causes of the increase in GHGs observed over the past 250 years. The GHG emissions from the agriculture sector are mainly in the form of methane (CH_4). These are due to enteric fermentation and from rice paddy cultivation. Agriculture sector also

Fig. 5.5: Total GHG Emission from Agriculture Sector in Major Countries (2012)



Source: Food and Agriculture Organisation Statistics (2012)

Fig. 5.6: Residue Generation by Different Crops in India (calculated from MNRE, 2009)



Source: Crop Residues Management with Conservation Agriculture: Potential, Constraints and Policy Needs (From Annual Report Indian Agricultural Research Institute-2009)

contributes to N_2O emissions and this is mainly from the agricultural fields due to application of fertilizers. Fig. 5.5 shows data on the total GHG emissions from Agriculture sector in major countries in 2012, where India is at second after China.

Estimations have shown that about 18 per cent of the annual GHG emissions in India during 2007 were from the agricultural sector. In the agricultural sector, major sources of these emissions were enteric fermentation (63.4 per cent), rice cultivation (20.9 per cent), agricultural soils (13.0 per cent), manure management (2.4 per cent) and on-field burning of crop residues (2.0 per cent). Thus, quantification and reduction of GHGs from agriculture is basic for identifying adaptation solutions that are consistent with the goals of achieving greater resilience in production systems and food security and in sustaining farmers in adopting less carbon intensive farming practices.

5.4.5 Air and Water Pollution

With the aim to get best harvests, farmers as a regular practice apply nutrients like fertilizer and manures to their fields. This helps crops grow stronger, and give better yields but these nutrients also release a gas called nitrous oxide, which is a potent greenhouse gas and leads to air pollution.

Agriculture emerges as both cause and victim of water pollution. It is a cause because pollution happens through discharge of pollutants and sediments to surface and/or groundwater, through net loss of soil by poor agricultural practices, and through salinization and water logging of irrigated land. It is a victim through use of wastewater and polluted surface and groundwater which contaminate crops and transmits diseases to consumers and farm workers.

Major seasonal source of air pollution is the annual crop residual burning practice in North-West India, North India and Eastern Pakistan, which normally happens to clear the field fast after monsoons (October to December). Data shows that approximately 500 million tonnes of crop residues is burnt in open, releasing smoke, soot, NO_x, SO_x, PAHs and particulate matter into the air. Even in other States of India, rice straw and other crop residue burning in open is a major source of air pollution. The crop residue generated by the cereals crops is the highest in quantum followed by that of the fibre crops (Figure 5.6).

Modern day pesticides and fertilizers have to deal with the local pests that have existed for hundreds of years along with the new invasive species. And so, they comprise of chemicals that are not found in nature. Once they have been sprayed, it does not disappear completely. Some of it mixes with the water and seeps into the ground polluting the underground water. Some of it goes in to the nearby surface water sources and the rest of is absorbed by the plant itself. As a result, the local streams that are supplied water from the ground become contaminated, as do the animals that feed these crops and plants.

5.4.6 Loss of Biodiversity

Diverse types of agricultural practices and systems affect the soil biota in different ways depending on which part of the soil, and which type of the biota, e.g. fungal or bacterial is affected by the agricultural processes. For example, organisms which are sensitive to pH will be affected by the addition of lime and their activities will get affected. The bacterial: fungal ratio gets affected by the addition of fertilizers and manures which alters the C:N ratio. Similarly with excessive tillage the microbe population in the soil gets affected. In nutshell, the processes which are followed to improve agricultural yield at times are damaging for the flora and fauna leading to loss of biodiversity.

Growing exotic crops and reducing the natural species in a certain area has become the norm for agriculture in recent times. However, it is simply adding to the process of agricultural pollution. With the advent of new crops, the native population has to deal with new diseases, pests and weeds that it is not capable of fighting.

Fertilizers, manure, waste and ammonia turns into nitrate that reduces the amount of oxygen present in water which results in the death of many aquatic animals including fishes.

5.5 RESPONSES

Though the sector has made contribution in achieving the agricultural development goals of food security, availability and accessibility, it is still being challenged by an alarming agrarian crisis. This situation has recently led to fresh thinking on the developmental approach in the agriculture sector.

As per FAO's definition, 'sustainable agricultural development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations'. Such Sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

Policy Initiatives

In this fresh approach, priority is to be accorded to making agriculture and allied sectors not only ecologically sustainable in its use of natural resources of soil, water and forests, but also socio-economically sustainable for farmers in terms of prosperity, welfare and social security. Some such policy initiatives are mentioned here.

5.5.1 Restructuring of Schemes in 12th Five Year Plan

In order to keep up the thrust gained during the 11th Plan period and achieve the targeted growth rate of 4 per cent during the 12th Five Year Plan as also to make sure focused approach and to keep away from overlap, all the schemes of the Department of Agriculture & Cooperation have been reorganized into five Missions viz. National Food Security Mission (NFSM), Mission for Integrated Development of Horticulture (MIDH), National Mission on Oil Seeds and Oil Palm (NMOOP), National Mission for Sustainable Agriculture (NMSA) and National Mission on Agricultural Extension & Technology (NMAET).

Four Central Sector Schemes viz. National Crop Insurance Programme (NCIP), Integrated Scheme on Agri-Census & Statistics (ISAC&S), Integrated Scheme of Agriculture Marketing (ISAM) and Integrated Scheme of Agriculture Cooperation (ISAC); and one State Plan Scheme viz. Rashtriya Krishi Vikas Yojana (RKVY), are important in this context.

The Crop Diversification Programme is being implemented as a sub scheme of Rashtriya Krishi Vikas Yojana in Punjab, Haryana and Western Uttar Pradesh. The erstwhile Scheme 'Support to State Extension Programmes for Extension Reforms - Agricultural Technology Management Agency (ATMA)' which is implemented since 2005 has now been included as a part of the Sub-Mission on Agriculture Extension (SMAE) under NMAET. It is getting implemented in 640 districts of 29 states and 3 UTs of the country.

Mission for Integrated Development of Horticulture (MIDH) was launched by Department of Agriculture & Cooperation by subsuming different Missions/ Schemes on horticulture. National Mission for Sustainable Agriculture (NMSA) as a programmatic intervention made operational from the year 2014-15 works towards making agriculture more productive, sustainable, and remunerative and climate resilient by promoting location specific integrated/composite farming systems; soil and moisture conservation measures; comprehensive soil health management;

In-situ Management through Incorporation of Leftover Paddy Straw in Soil

In-situ management is one of the best options for utilization of major part of the left over paddy straw in fields by incorporating through use of equipments like Happy Seeders, zero-till-drills, movers and mulchers, etc. It is estimated that 1.1 million tonnes of paddy straw will be reincorporated in the soil by 2016-17. This will not only help in reducing air pollution but would improve soil health characteristics and fertility. It would also reduce dependence on chemical fertilizers on one hand and prevent soil pollution from agro chemicals on the other. Soil micro-flora, moisture level, etc. would also considerably improve. All this would result into economic benefits in terms of reduced input costs in the form of reduced application of fertilizers, low irrigation requirements, improvement in soil organic matter, etc.

Source: Draft, 17.11.2014, White Paper on 'Management and Utilisation of Paddy Straw in Punjab'.

efficient water management practices and mainstreaming rainfed technologies. Parts of NMSA include Rainfed Area Development (RAD), On-Farm Water Management (OFWM), Soil Health Management (SHM), and Climate Change and Sustainable Agriculture Monitoring, Modeling & Networking (CCSAMMN).

The National Livestock Mission was launched in 2014-15 during the 12th Plan. This aimed to bring about sustainable and continual development in the livestock sector by emulating the success achieved in the dairy and poultry sectors across species and regions. It consists of four Sub-Missions: Sub-Mission on Livestock Development; Sub-Mission on Pig Development in the North-Eastern Region; Sub-Mission on Fodder and Feed Development and Sub-Mission on Skill Development, Technology Transfer and Extension.

5.5.2 National Agro-forestry Policy, 2014

Realizing the importance of Agro-forestry, National Agro-forestry Policy, 2014 was formulated with the intention to bring coordination, convergence and synergy between various initiatives on agro-forestry scattered across various existing Missions, programmes and schemes of the Government. An Inter-Ministerial Committee having representation for all the relevant Department/Ministries has been formed to oversee the implementation of the Policy.

Besides the restructuring of the missions and schemes during the 12th Five Year Plans, four new schemes have been introduced in the year 2014-15:

- **Soil Health Card Scheme -** The Scheme has been approved for issue of Soil Health Cards to every farmer of the country by the end of the 12th Five Year Plan (before 2017). Total outlay of Rs.568.54 crore has got approved for the scheme. State-wise provision has also been made for establishing 100 mobile soil testing laboratories in 2014-15.
- **Pradhan Mantri Krishi Sinchai Yojana -** The Scheme got formulated with an objective to take irrigation water to each and every agricultural field in the country.
- **Price Stabilization fund for Cereals and Vegetables -** Price Stabilization Fund of Rs.500 crore has been established by Government in order to reduce price volatility in perishable agricultural commodities.
- **National Agri-tech Infrastructure** - As a first step towards creation of a national market, an Agri-Tech infrastructure fund has been proposed. The aim was to create a common e-marketing platform for agri-commodities in the Agriculture Produce Marketing Committees (APMCs) in the State.

Sustainable Practices

Following agricultural practices are being promoted and practiced as responses towards sustainability.

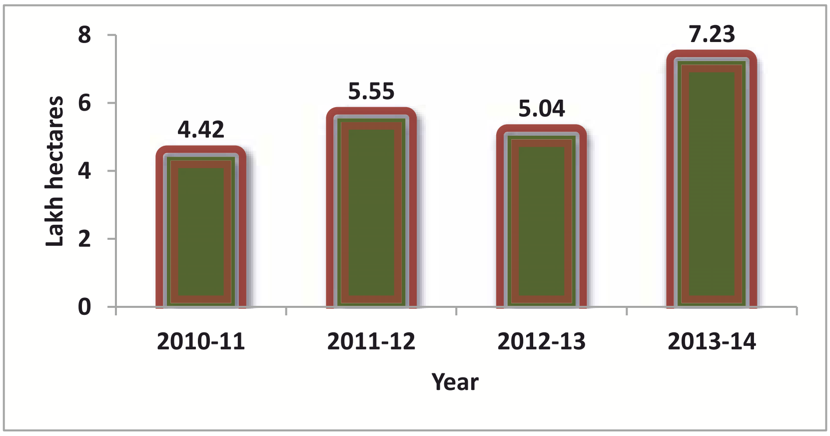
5.5.3 Organic Farming and Use of bio-fertilizers

Organic farming is a set of sustainable agriculture practices that can have a lower impact on the environment. There is no doubt that the organic movement has begun in India. Area under organic farming has been increasing as compared to previous years (Fig. 5.7)

According to the International Federation of Organic Agriculture Movement (IFOAM), "the role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings."

Natural techniques consist of crop rotation, composting and the use of "green" manure. Organic farming also extends to livestock, which are often fed

Fig. 5.7: Area under Organic Farming (2010 -2014)



Source: Department of Agriculture and co-operation, Central Statistics Office, Ministry of Statistics &Programme Implementation, Govt. of India; (from Annual Report of Agriculture 2014-2015)

antibiotics and growth hormones in the conventional animal husbandry methods. Organic farmers use organic feed and follow the principles of minimal confinement.

Department of Agriculture and Cooperation is implementing Integrated Nutrient Management (INM) and organic farming component under National Mission for Sustainable agriculture.

The government has been trying to promote an improved approach involving use of bio-fertilizers along with fertilizers. These inputs have multiple beneficial impacts on the soil, and can be relatively cheap and convenient to use.

The development and application of microbial-based fertilizers has been increasing worldwide due to the recognition of the harmful effects on the environment generated by the excessive and/or improper usage of chemical fertilizers. This has also enhanced due to the improved knowledge about the relationships between the plant and soil microorganisms occurring in the rhizosphere (rhizosphere is the narrow region of soil that is directly influenced by root secretions and associated soil micro-organisms).

Mycorrhizal fungi (one kind of organism used as bio-fertilizer) increases the surface absorbing area of roots hundred to thousand times, thereby greatly improving the ability of plants to access soil resources. These also release powerful enzymes that dissolve nutrients, such as organic nitrogen, phosphorus, iron, and other tightly bound soil nutrients. Trend of production of bio-fertilizers in India is given in figure 5.8 which depicts an increasing trend.

Paramparagat Krishi Vikas Yojana (PKVY) project has been designed to encourage organic farming. Area covered under organic manures in India in 2008-09 was 245.83 lakh hectares; in 2010-11 was 526.08 lakh hectares and in 2013-14 was 458.83 lakh hectares (Indian Agristat, Indiastat.com).

5.5.4 Promotion of Adaptation Strategies

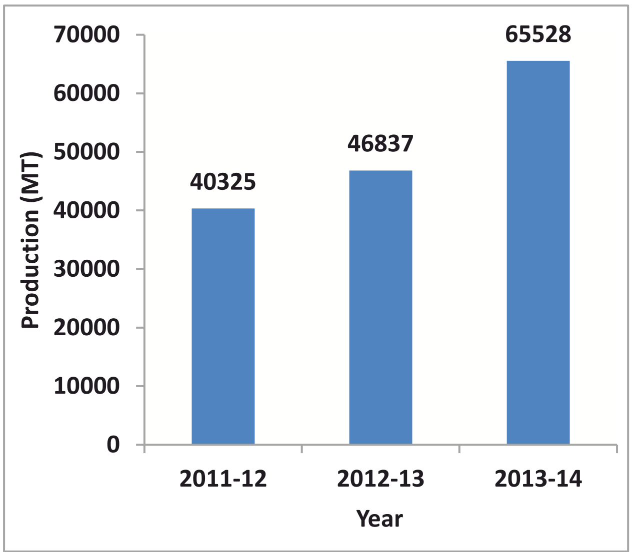
Some pertinent technologies and practices that hold promises of reducing adverse impacts of climate change include mixed/inter-cropping, agro-forestry; afforestation, growing drought tolerant crops, changes in planting dates and crop varieties. Other important adaptations include water harvesting and the conservation and efficient use of water through micro-irrigation techniques such as sprinkler and drip irrigation. More specifically for the horticultural crops, the focus of growth strategy at present is on raising productivity by supporting high density plantations, protected cultivation, micro-irrigation, quality planting material, rejuvenation of senile orchards and a thrust on post-harvest management.

Study on green house gas (GHG) emissions in diversified agriculture on reclaimed sodic land have shown that on hectare basis, diversified agriculture system emitted 1,547 kg CO_2eq per ha as compared to 2,862 kg CO_2eq per ha in rice-wheat system. The global warming potential under diversified agriculture system was 46 per cent (1,316 kg CO_2eq per ha) less than that of rice-wheat. (Section 3, Climate Change, DARE/ICAR Annual Report 2015-16)

5.5.5 Development of Improved Cultivars and Breeds

This is regarding the development of new cultivars of

Fig.5.8: Production of Bio-Fertilizers (2011-2014)



Source: Department of Agriculture and Co-operation, Central Statistics Office, Ministry of Statistics & Programme Implementation, Govt. of India (from Annual Report of Agriculture 2014-2015)

Fertilizer Companies Going Natural

Fertilizer companies like GSFC has more than 200 farm information centers-cum-depots situated in remote areas. In order to provide biofertilisers up to village level, GSFC has established its own distributor's network. MLF and SPIC have also organized themselves in this respect. It is found that bio-fertilizers like Rhizobium can supply 20-25 kg N per ha. Considering the prospects of bio-fertilizers in the country, the bio-fertilizer development centers are being established both in government and private sector.

Source: Potential of Biofertilizers in Crop Production in Indian Agriculture, 2014

agricultural and horticultural crops tolerant to high temperature, resistant to pests and diseases; short duration and producing good yield under stress conditions. To address this, genetic enhancement of tolerance to drought, heat, flooding and salinity stresses in major food crops and in horticultural crops is being attempted under NICRA. In wheat, 45 terminal heat tolerant advanced lines were evaluated in multi-locational trials.

Regarding animal husbandry, currently the policies are focusing more on promoting indigenous breeds which are robust and less affected by extreme temperature and high humidity conditions, with potential to produce equivalent amounts of milk as crossbreeds. Similar experiments are being done for other livestock's also.

Breeding for stress-tolerance has been an important thrust area of agricultural research, and the returns to investment on drought-tolerant breeding have been estimated to be quite attractive.

5.5.6 Promotion of Traditional Practices

Traditional farming methods have proved beneficial to the conservation of biodiversity, and to sustainable rural development. Local and traditional knowledge has been successfully built into several areas of agriculture, for example in the domestication of wild trees, in plant breeding, and in soil and water management.

Traditional knowledge is also often held collectively by communities, rather than by individual owners, and women have a major role in this regard. The need to protect the traditional knowledge captured the attention of the international community only recently.

Efforts are in progress to archive and evaluate the knowledge of local people, and to protect it under fairer international intellectual property legislation. The Indian legislation for the Protection of Plant Varieties and Farmers' Rights Act 2001 (PPV&FRA) acknowledges that the conservation, exploration, collection, characterization, evaluation of plant genetic resources for food and agriculture are necessary to meet the goals of national food and nutritional security as also for sustainable development of agriculture for the present and future generations.

Realizing different types and different levels of women's role in agriculture, National Gender Resource Centre in Agriculture (NGRCA) has been set up as a unit of Directorate of Extension (DoE) of the DAC under the Scheme of Extension Support to Central Institutes/DOE.

5.5.7 Reclamation of Degraded Land

Since last few years, the Government has implemented several programmes to work with and reclaim degraded soils. These programmes include National Watershed Development Projects, and Rain-fed Areas, Soil Conservation in the Catchments of River Valley Projects and Flood Prone River, Integrated Watershed Management Programme, etc.

Photo 5.2: Line sowing

Nearly 82 million hectares of degraded soils were covered during the Eleventh Five Year Plan.

5.5.8 Focus on Extension and Related Services

Towards developing an integrated approach for communication process in the agricultural sector, all mobile based initiatives in the field of agriculture and allied sectors have been subsumed under the m Kisan Portal. Since its launch on 16 July 2013, 1.6 crore farmers and more than 8,000 subject experts have registered on the m Kisan portal. The data shows that as on 30.11.2015, more than 1,040 crore SMSs have been sent to farmers by all agencies/ organizations/ departments in agriculture and allied sectors down to block level throughout the country (State of Indian Agriculture , 2015-16).

5.5.9 Promotion of Storage Infrastructure

Current scenario of the preservation infrastructure in India depicts that against the total production of more than 500 MMT of horticultural and non horticultural produces, the total cold storage capacity is estimated approximately 31 MMT, which is not even 10 per cent of the total production. A study conducted by the National Spot Exchange limited (NSEL) in December 2010 estimated a cold storage requirements of 61.13 million tonnes in the country.

Photo 5.3: Construction of small dams under watershed management

e-NAM Facility as Electronic Trading Platform

Accelerating farm incomes is a central component of ensuring sustainable livelihoods, which is critical given the labour-intensive dependency of agriculture as a whole. To this effect, the April 2016 launch of the government e-NAM facility should be given due recognition. It is an electronic trading platform to improve farm incomes, and is mainly set to benefit small and marginal farmers, since farmers will no longer have to sell their output at distress prices.

Union Minister of Agriculture & Farmers Welfare, Shri Radha Mohan Singh on 6 October 2016 announced that most of the implementation issues faced in pilot phase have been addressed and e-NAM platform is connected to 250 markets across 10 States as of now (Andhra Pradesh (12), Chhattisgarh (05), Gujarat (40), Haryana (36), Himachal Pradesh (07), Jharkhand (08), Madhya Pradesh (20), Rajasthan (11), Telangana (44), Uttar Pradesh (67). Union Minister informed that so far, Detailed Project Reports (DPRs) for integrating 399 mandis with e-NAM has been received from 14 states and all of them have been approved.

Source: Press Information Bureau, Government of India, Ministry of Agriculture, 2016

Government policies for cold chain infrastructure are for providing enabling policy frame work, providing financial support to encourage private investment and promotion, awareness campaigns, study surveys, knowledge sharing etc. National Centre for Cold Chain Development (NCCD), an autonomous centre for excellence, has been established as a registered society to work in close collaboration with industry and other stake holders to promote and develop integrated cold chain in India (Ministry of Food Processing Industries, 2014).

5.6 CONCLUSION

India has emerged as one of the most vulnerable countries in the world as major part of its population depends largely on climate sensitive sectors like agriculture, water resources, and forestry. The pressures emanating from natural resource constraints, increasing fragmentation of holdings, rising input costs, frequent climatic variations, and

Bio-engineering Interventions for Degraded Ravine Lands

Bamboo plantation based bio-engineering interventions, viz. (i) Bamboo plantation with staggered contour trenches, (ii) Bamboo plantation as live check dams, and (iii) Bamboo plantation supported by bori bunds were found promising for reclamation and productive utilization of three major ravine systems of India namely, Mahi ravines at Vasad (Gujarat), Chambal ravines at Kota (Rajasthan), and Yamuna ravines at Agra (Uttar Pradesh). These interventions could absorb more than 80 per cent of rainfall and reduce the soil and nutrient losses by 90 per cent and 70 per cent, respectively. The system increased the soil organic carbon content by five times on degraded ravine bed over the years. The gully head and bank extension was checked completely. These interventions gave an average annual net return varying from 63,910 to 88,780 per ha with a benefit cost ratio from 1.96 to 2.09. (DARE/ICAR Annual Report, 2015-16).

post harvest losses put a huge challenge to sustaining agricultural growth. The agrarian distress in recent years is the result of a complex interaction of these factors.

Sustainable agriculture is one of the greatest challenges. Sustainability implies that agriculture not only secures a sustained food supply, but that its environmental, socio-economic and human health impacts are understood and duly accounted for. Right kind of technologies and policies are required to strengthen the ability of communities to manage effectively with both climatic variability and changes.

Agriculture sector is India's largest user of water. Increasing competition for water between industry, domestic use and agriculture has highlighted the need to plan and manage water on a river basin and multi-sectoral basis. As urban and other demands increases, less water is likely to be available for irrigation. Ways to radically enhance the productivity of irrigation ("more crop per drop") has emerged as a focus area.

In view of the growing demand for food grains in the country, there is a necessity to develop and improve the productivity of rainfed areas. If managed properly, these areas have remarkable potential to contribute a larger share in food production and faster agricultural growth.

Scientists and policy makers both at their ends have been trying their best to lessen the impact of adverse weather conditions on the agriculture and the allied sectors. Information on socio-economic aspects of climate change is relatively weak, and future scenarios are to be generated for various agro-ecological regions, for subsequent linking of other relational layers to the impact.

More than any other sector, agriculture is the common thread which holds many of the 17 Sustainable Development Goals (SDGs) together. Agriculture has played a significant role in reducing hunger (SDG 2) through increased production of food. Recently, the Government has undertaken focused efforts to enhance income of farmers through increase in productivity and efficient marketing, especially engaging the women whose role in agriculture is well known. For enhancing women's role (step towards gender equality which is SDG 5), efforts are in progress to have the facility of soft credit and other empowering support.

A farmer friendly market system is being created by weeding out archaic and dysfunctional systems and by digitization of the market; providing reliable and timely market intelligence which was one of the important constraints in movement of grains. This will also ensure more remunerative prices to farmers. SDG 8 of decent work and economic growth can be fulfilled substantially by this sector as it engages substantial proportion of population by providing livelihood opportunities; fulfilling SDG 10 (reducing inequality). SDG 9 of Industry innovation and infrastructure is getting addressed through this sector substantially as the produce of agriculture forms the raw materials for many industries, and many industries cater to the sector in different ways.

Indian Council for Agricultural research (ICAR) had initiated a Project on Climate Resilient Agriculture (NICRA). Not only for crops, but research is required to reduce the impact of climate change in the productivity of animals and fishes (SDG 13 Climate Change).

Efficient water conservation, judicious utilisation through water sharing and similar efforts are being made along with fulfilling controlled use of agro-chemicals which also helps in SDG 14, 15 (life below water, life on land). The above and many more reforms are in pipelines which directly or indirectly are working towards achieving the SDGs.

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***Note:** Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 6

ENERGY

Key Messages

- *Indian economic growth is majorly driven by energy derived from fossil fuels. 71.01 per cent of India's electricity is produced from coal, which is thus the primary source of energy in our country.*
- *Fossil fuels are known to have serious environmental impacts, climate change being the gravest of all.*
- *840 million people in rural India are still dependent on biomass, mostly fuel wood, as a primary source of cooking fuel.*
- *The share of renewable energy in India has increased to 14.2 per cent of the total, from 3.7 per cent in 2010. The augmentation spurted with the formulation of the NAPCC and the initiation of the Jawaharlal Nehru National Solar Mission (JNNSM).*

6.1 INTRODUCTION

Energy is a critical enabler for every advanced economy. Secured access to modern sources of energy is required to underpin economic growth. India, with over a billion people, produces only 660 billion KWh of electricity; and over 600 million, split across rural and urban centers, have no access to electricity, and inadequate access to clean fuels (IEA, 2015). The Indian economy is witnessing a GDP growth in excess of 7 per cent. Energy is at the core of India's development ambitions, leading to rapid and sustained growth in demand, which would be majorly met by consumption of fossil fuels. A large section of the population, nearly 840 million, in the rural sector use solid biomass, mostly fuel wood, as a primary source of cooking fuel (Planning Commission, 2012). India's urbanization would also be a key driver of energy trends: an additional 315 million people – almost United States' population today – are expected to be urban dwellers by 2040 (IEA, 2015). In addition to the rise in demand of energy in the rural and urban sector, India needs a huge demand of energy for the new infrastructure born out of its economic development.

India has significant reserves of coal, nearly 306.60 billion tonnes, which is a major source of energy in the country (MOSPI, 2016). The power sector is a major consumer of coal as a fuel. Although, the per-capita electricity consumption of the country has now crossed 957 kWh (CEA, 2015), but still, it is far below the energy consumption scale of many developed countries. India ranks sixth in the world in terms of energy demand. The energy sector is grappling with obsolete energy production technologies leading to massive environmental pollution. In the future energy scenarios, India would contribute more than any other country in global energy demand. Data predicts it will be nearly one quarter of the total energy demand.

Soon, India will be the world's most populous country. It will impact the global energy scenario, as the rapidly rising demand for energy, currently fulfilled with fossil fuels, would lead to several serious impacts on the environment. India is inexplicably affected by climate change as compared to most of the industrialised countries. In the view of future emissions emerging from combustion of fossil fuels, the impact could be more severe on the poor, and on climate dependent sectors such as agriculture. Then there would be impacts on water, air and land by way of over-exploitation of fuels as well as destruction of natural resources. The energy policy-makers for the country need to chart a way forward for the energy sector that is unique: sustainable and innovative.

This chapter, firstly, discusses the status of energy generation and its various sources in India, these are the avenues through which the demand created is met. Secondly, the chapter elaborates on the drivers that shape demand for energy in India this demand creates the direct impact on environment. The chapter would then describe the impacts that the generation and consumption of energy have. The impacts in terms of pollution and GHG emissions are covered in the other chapters also. Finally, this chapter takes a look at how the government is responding to the growing energy needs, while throwing light on key energy policy measures as well as initiatives that address energy security as well as reduce the impact on environment.

6.2 STATUS

Growth in industrial activities, population, economy, prosperity, and urbanization, along with rising per-capita energy consumption, has led to the emergence of a widening of gap in access to energy in the country (CII, 2015). According to Ministry of Statistics and Programme Implementation (MOSPI)(2015), the status in the in agriculture, industrial, commercial and household sectors, has witnessed an increasing trend in demand, which has mounted huge pressure on its resources. The increase in energy demand leads to depletion of resources, and increases concentration of pollutants in the environment due to combustion of fossil fuels. The current state of economic development in the country is mounting an incredible pressure leading to an enormous demand on its energy resources. According to the Integrated Energy Policy Report (Planning Commission, 2007), India requires a sustainable and futuristic energy policy outlook, to establish robust policy guidance on the energy sector growth.

The crude oil and natural gas production in the country has been experiencing a stagnating trend in the recent years. As a consequence, India is heavily dependent on imported fossil fuels. Currently, India imports nearly 80 per cent of the crude oil. To reduce dependency on imports, and to protect the environment from the hazards of fossil fuel combustion, India is strategizing an integrated framework for the development of renewable

Table 6.1: Energy Scenario in India: Comparison between 2009 and 2015

Parameter	2009	2015
India's electricity production	147,965 MW	302,100 MW
Share of Thermal Energy (Coal / Oil and Gas)	93,725 MW (79 per cent)	210,675 MW (70.01 per cent)
Share of Renewable Energy	13,242 MW (3.7 per cent)	42,849 MW (14.2 per cent)
Transmission & Distribution losses	27.2 % (2008 Estimate)	21.46 % (2013-14)

Sources: Ministry of Power (2016)

sources of energy, by aligning the incentives between the Federal and State governments. The resulting energy alignment would include use of nuclear energy, promoting wind farms and solar energy.

Since independence, the power sector has grown significantly in the installed electricity generating capacity and the resulting transmission & distribution (T&D) in the energy supply system. The total power generating capacity (utilities and non-utilities) has increased from meager 1,362 MW in 1947 to 267 GW at the end of March 2015 (MOSPI, 2016).

According to Central Energy Authority (CEA, 2016) the installed capacity has crossed 30,0 00 GWh, and the per capita electricity consumption, which was quite low at around 16.3 kWh in 1947, has increased over six times to 1,010 KWh in 2014-15. Combined RES share 14.14 per cent, hydro shares 14.12 per cent and nuclear power based generation capacity shares 1.91 per cent of the total installed power generation capacity (MOSPI, 2016).

The Table 6.1 indicates, installed capacity of power in the country doubled from around 148 GW in 2009 to over 302 GW as of March, 2015. The share of thermal energy has reduced from 79 per cent to 70.01 per cent, a 10 per cent dip, though it is not a very high decline in the energy generated from fossil fuels, on the other hand, it is an indication that the energy sector is moving towards mainstreaming of renewable energy in the country's energy mix. The increase in share of renewables is also vital to energy security. Energy security is achieved by ensuring uninterrupted supply of energy to power the economic and commercial activities, deemed important for sustained economic growth.

Primary and Conventional Sources of Energy

6.2.1 Thermal Energy

The share of thermal energy sector in India has grown steadily since independence. From a modest generation of less than 1,000 MW at the time of independence, total thermal energy generation stood at over 210,000 MW by 2015. The share of thermal energy in the country has remained in the band between 60 per cent and 75 per cent in terms of installed capacity (MOSPI, 2016). However, between 1960 and 1979 the share of thermal energy remained between 50 per cent and 60 per cent, reflecting higher stress on hydro-power generation by contemporary governments.

However, the fact that thermal alone accounted for over 50 per cent of India's installed capacity shows dependence on coal, oil and of late gas-based generation. In fact, coal based power generation has been the prime driver for industrial growth and development in India since independence, with several industries located at or near coal-mining belts.

India produces a cumulative total of 301.56 Billion tonnes of geological resources of Coal, making it the world's third largest producer. The production data is based on the exploration carried out up to the maximum depth of 1200 m by the Geological Survey of India (GSI), Central Mine Planning & Design Institute Ltd. (CMPDI), The Singareni Collieries Company Limited (SCCL) and Mineral Exploration Corporation Ltd. (MECL) etc. Table 6.2 provides details of state-wise geological resources of coal, as per the coal ministry. The principal deposits of hard

Table 6.2: State Wise Geological Resources of Coal
(Million tonnes)

State	Proved	Indicated	Inferred	Total
Jharkhand	41,377	32,780	6,559	80,716
Odisha	27,791	37,873	9,408	75,073
Chhattisgarh	16,052	33,253	3,228	52,533
West Bengal	13,403	13,022	4,893	31,318
Madhya Pradesh	10,411	12,382	2,879	25,673
Andhra Pradesh	9,729	9,670	3,068	22,468
Maharashtra	5,667	3,186	2,110	10,964
Uttar Pradesh	884	178	0	1,062
Meghalaya	89	17	471	576
Assam	465	47	3	515
Nagaland	9	0	307	315
Bihar	0	0	160	160
Sikkim	0	58	43	101
Arunachal Pradesh	31	40	19	90
Total	125,909	142,506	33,149	301,564

Source: Geological Survey of India, 2014

coal are in the eastern half of the country, ranging from Andhra Pradesh, bordering the Indian Ocean, to Arunachal Pradesh in the extreme North-East. In the eastern states, the reserves are located in: Chhattisgarh, Jharkhand, Odisha and West Bengal.

According to the Ministry of Coal, the resources are available in older Gondwana Formations of peninsular India and younger Tertiary formations of North-Eastern region. The formation-wise and category-wise coal resources of India as of 2014 are given in Table 6.3.

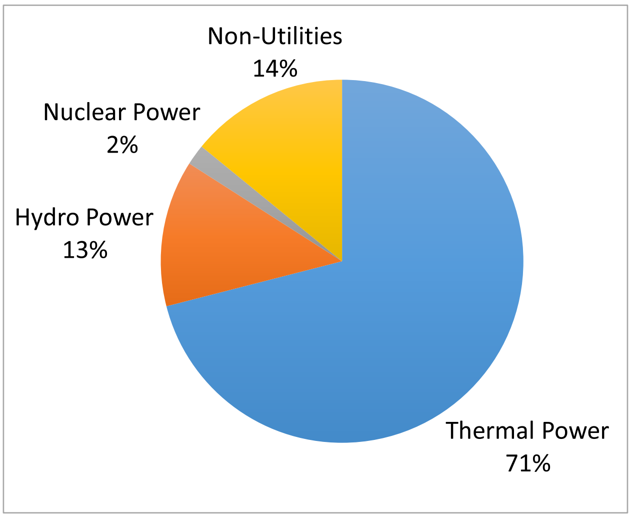
Indian coal reserves cover all ranks - from lignite to bituminous; these reserves are prone to high ash content along with a low calorific value. Inferior quality of coal, prevents India from being a competitor in the global coal market, rather it is recognized as a large importer (around 20 million tonnes per annum of coking coal and 17 million

Table 6.3: Type and Category-Wise Coal Resources of India
(Million tonnes)

Formation	Proved	Indicated	Inferred	Total
Total	125,909	142,506	33,149	301,564
Gondwana Coals	125,315	142,407	32,350	300,072
Tertiary Coals	594	99	799	1,493

Source: Geological Survey of India, 2014

Figure 6.1: Sources of Electricity by Installed Capacity In India



Source: Energy Statistics, Ministry of Statistics and Programme Implementation, 2016

tonnes per annum of steam coal) from Australia, China, Indonesia and South Africa. At the end of March 2015, 71.01 per cent (figure 6.1) of electricity was produced from coal (MOSPI, 2016). Coal remains the primary source of power in India, amounting to installed capacity of 186.24 GW, which, along with gas and diesel combines to occupy 69.84 per cent of the total installed capacity (MOSPI, 2016).

Concerns about coal-based generation emanate from the lower calorific value of Indian coal, which led private sector and National Thermal Power Corporation to import coal for power generation. Reduced value of Indian coal prompted questions over the justification of operating power plants exclusively on imported coal, as opposed to other sources such as natural gas.

Second, concerns over environment and especially climate change led to solid and liquid fossil fuels being increasingly substituted by gaseous fuels and renewable energy. Finally, a number of coal mining belts have been identified by the CPCB as critically polluted areas, such as the Singrauli – Sonebhadra, Angul-Talcher and so on.

More recently, the Green Rating Project (GRP) that was undertaken over a period of two years, selecting about half of all the plants operating in 2011-12; 47 power plants spread over 16 states. The findings revealed that the Indian coal sector's overall rating was a low 23 per cent (a plant adopting all the best practices would have scored 80 per cent). The average efficiency of the plants in the study was 32.8 per cent, one of the lowest among major coal-based power producing countries, and the plants were operating at 60 to 70 per cent below capacity (Center for Science and Environment). The study highlighted rampant issues, such as, excessive water withdrawal, violation of air pollution norms, and, fly ash disposal (Center for Science and Environment).

India is grappling with the adoption of clean coal technologies, considered to be efficient, for generation of power leading to reduced environmental impacts due to combustion of coal. Clean coal is been widely discussed at the global level, it includes contemporary scientific technologies for mining leading to land repossession and reducing coal ash at source.

Investment in cleaner energy generation practices via coal liquefaction and coal gasification, and developing sustainable energy pathway for the country requires clean coal technologies including Coal Bed Methane (CBM) as a clean energy option. Coal formation process produces methane as a by-product. It is trapped in coal beds and released during and after mining. It is also responsible for causing disasters in underground coal mines. Essentially three main factors obstruct the efficient utilization of CBM: lack of latest technology in the country, lack of expertise and experience, and inadequate data on commercial viability and utilization of Methane.

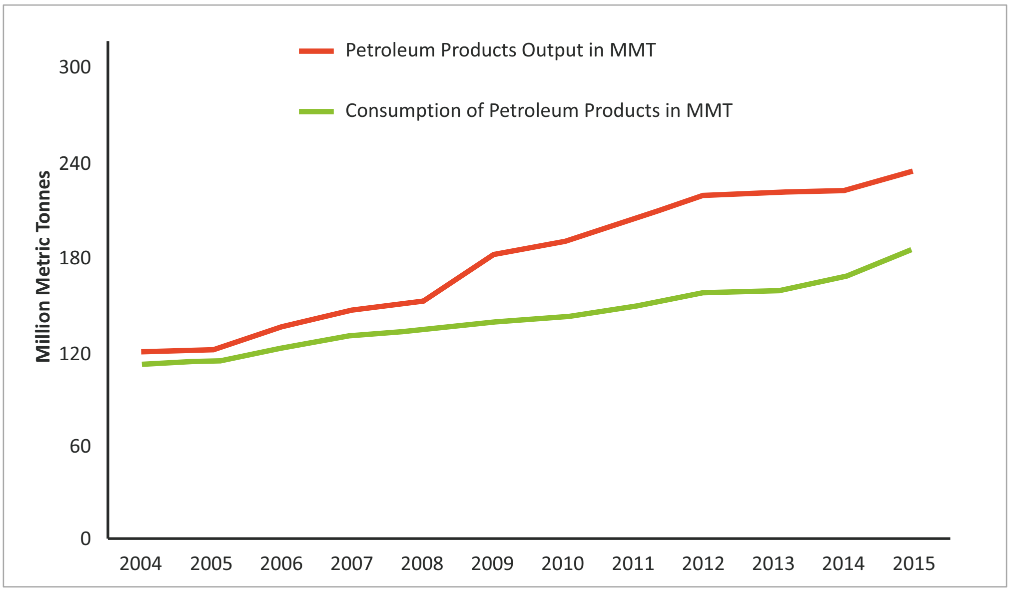
The Directorate General of Hydrocarbons has carved out CBM blocks along with Ministry of Coal (MoC) &Central Mine Planning and Design Institute (CMPDI), Ranchi. The Gondwana sediments of eastern India host the bulk of India's coal reserves and all the current CBM producing blocks. The government is planning to operationalize seven more CBM blocks for commercial production in future. But CBM has environmental implications as well: (i) Groundwater table are disrupted, (ii) extraction process leads to disposal of large volumes of water, (iii) shallow groundwater is vulnerable to methane contamination, and (iv) resulting air pollution from compressor exhaust gases, methane leakage and dust. These reasons contribute to impede the efficient utilization of CBM.

6.2.2 Oil and Natural Gas

Oil-based energy is driving India's transportation and process-based industries along with a large number of rural enterprises. While crude oil production has remained between 35 and 40 million metric tonnes (MMT), India's total consumption of petroleum products stood at 184.6 MMT, thereby requiring imports of crude and the second highest refining capacity in Asia. According to Ministry of Petroleum and Natural Gas, India's total production of oil and petroleum products, adding domestic generation along with refined oil, is 232 MMT as projected for 2015. In the figure 6.2, the production (red) widens away from that of consumption (green). The difference is actually due to petroleum exports: India is one of the ten largest oil- refining countries of the world, with a refining capacity of over 240 million metric tonnes (MMT). The graph also shows that the growth in production has somewhat slowed post 2010, which is partly due to lower international prices that act as a dampener to higher production due to possibility of refining costs being lower than actual margins received.

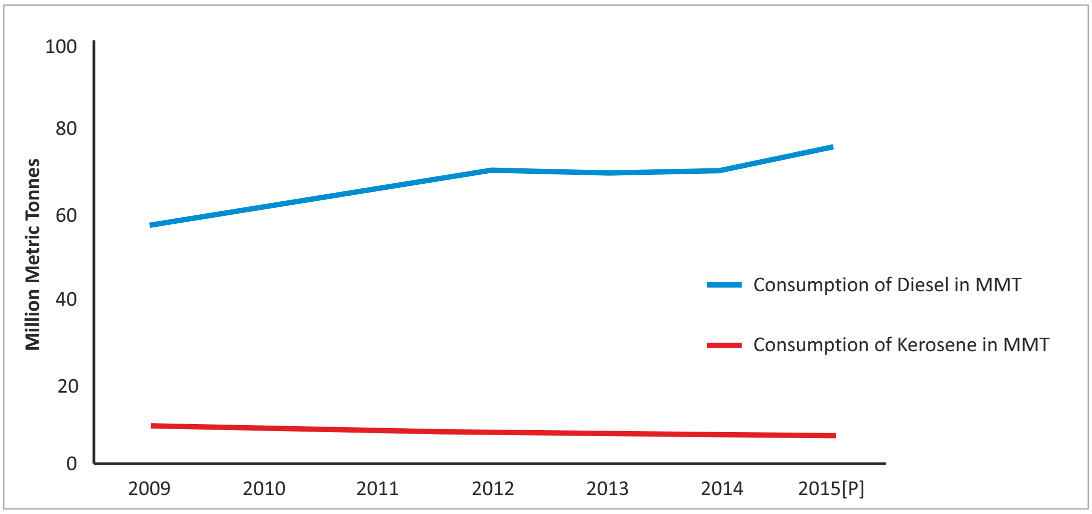
In natural gas, India's gross production for 2015-16 has been predicted at 32.25 Billion Cubic Meters (BCM), while that for 2014-15 was 33.66 BCM. As against this, consumption has been 46.95 BCM (in 2014-15) and 47.85 BCM (predicted for 2015) (Indian Petroleum and Natural Gas Statistics, 2015). As a result, India has to import gas, which is commonly imported through Liquefied Natural Gas (LNG) terminals. It is the primary raw material for fuels such as LPG and CNG, and constitutes relatively small share

Figure 6.2: Production and Consumption of Diesel and Kerosene in India, 2004-2015



Source: Ministry of Petroleum and Natural Gas Statistics 2015

Figure 6.3: Consumption of Diesel and Kerosene in India, 2009-2015



Source: Ministry of Petroleum and Natural Gas Statistics 2015

of the energy mix (6 per cent in 2013 compared with 21 per cent globally). It is used mainly for power generation and as a feedstock and fuel for production of fertilizers, and its demand is growing in the residential sector and as well in the transportation sector.

6.2.3 Diesel and Kerosene

Within the petroleum world, diesel and kerosene are flagship fuels for the transport and rural sectors in India. The Figure 6.3 indicates the trend for diesel and kerosene consumption in India since 2009-10, financial-year-wise.

The consumption of diesel is on the rise in comparison with the consumption of kerosene, as indicated by the red line in the graph. The consumption of kerosene is on a downward trend, as more rural households opt for improved means of cooking (such as LPG and induction cookers) and lighting (grid electricity and solar powered devices).

From an environmental perspective, the trend is valuable. The trend indicates kerosene is being increasingly replaced by alternatives. Decrease in consumption of kerosene will reduce global greenhouse gas (GHG) emissions, along with indoor air pollution, as burning of kerosene is linked to emissions of carbon monoxide as well as other, more toxic pollutants. This is also a result of adulteration of kerosene that is prevalent, which involves mixing it with other substances.

As far as diesel is concerned, the demand for diesel increases as more urban commuters opt for diesel powered passenger vehicles for their higher mileage and lower price per unit (liter) compared to petrol (or gasoline or motor spirit, as it is known). The emissions performance of diesel vehicles is also under improvement with lower emissions of particulates.

Over the long run, new options such as electric and hybrid vehicles are expected to cut into present user base of diesel cars by offering cost-effective yet high-performance options. In two-wheelers, petrol is the common fuel being used, although there are a slew of electric powered two-wheelers in the market today.

Clean and Renewable Sources of Energy

India receives abundant sunlight, is rich in water resources and biomass. Despite being a late participant in mainstreaming renewable energy in the existing energy framework, it is beginning to take leaps with an annual growth rate of 33 per cent in 2010 against the global growth rate of 26 per cent during the same period. The share of renewable energy has increased rapidly from 3.7 per cent to 14.2 per cent, a growth of over 400 per cent in seven years (MNRE, n.d.).

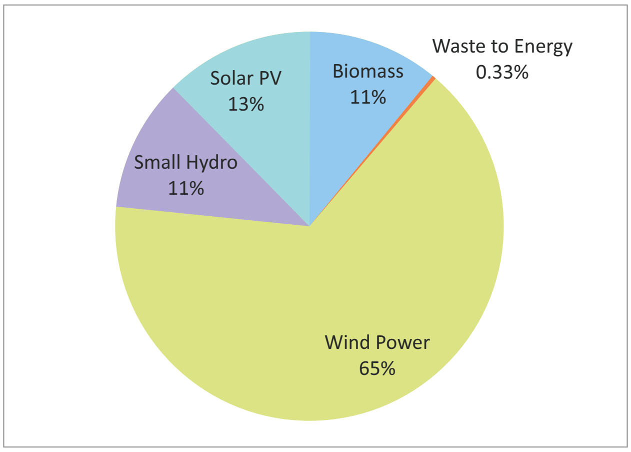
Table 6.4: Break-up of Installed Capacity of Grid-Interactive RETs in India (as of March 2015)

Sub-sector	Installed Capacity (MW)
Biomass	4,450.55
Waste to Energy	127.08
Wind Power	25,088.19
Small Hydro	4,176.83
Solar PV	4,878.88
Total	**38,821.53 MW**
As on 31st March 2015, grid interactive systems only	

Source: Ministry of New and Renewable Energy

Photo 6.1: Solar panel installed in a village

Figure 6.4: Tentative Break-up of Renewable Power Target to be Achieved by the Year 2022



Source: Energy Statistics 2016, Ministry of New and Renewable Energy

In terms of market shares within the broad ambit of renewable energy, the table 6.4 shows various renewable energy technologies together with their market shares.

The increasing share of renewables in the country's energy mix is a key achievement, that is, installed capacity has increased 14 per cent (MOSPI, 2016). This is especially noteworthy, since prior to 1990s the share of renewables in India's power mix was negligible.

Wind projects dominate the renewable energy spectrum in the country. This is more due to the fact that several solar PV units are off-grid, not connected to the mainstream electricity supply system. Moreover, several government programmes have introduced solar PV based home and lighting systems that are not considered within the grid interactive systems.

The data is reproduced in the form of a pie chart (Figure 6.4) derived from state-wise target for 2022, as per cent of the total installed capacity of Grid Interactive Renewable energy Targets to demonstrate the shares of individual renewable energy technologies.

6.2.4 Nuclear Energy

Nuclear power is one of the oldest and widely-used, forms of energy. The Nuclear Power Corporation of India Limited (NPCIL) is operating 21 nuclear power reactors with an installed capacity of 5780 MW (MOSPI, 2016). The reactor fleet comprises two Boiling Water Reactors (BWRs) and 18 Pressurised Heavy Water Reactors (PHWRs) including one 100 MW PHWR. Recently, the Government of India, made an addition to its nuclear fleet, the unit-1 of Kudankulam Nuclear Power Project, a 1000 MW VVER (Pressurised Water Reactor type), has started its commercial operation in 2014.

The NPCIL has projected electricity generation at about 3800 MW, from its five reactors, which are under various stages of construction/commissioning. According to NPCIL, India's nuclear programme is largely indigenous and expects to have 14.6 GW nuclear capacities online by 2024 and 63 GW by 2032. The nuclear energy programme aims to supply 25 per cent of electricity from nuclear power by 2050 (DAE, 2015).

Nuclear power is considered to be emissions free, and if commercials are worked out, then it could emerge as an alternative energy investment, which could reduce the adverse environmental and ecological impact of coal-fired power plants. Being emissions free, the production of energy from nuclear power plants would not add to the stress on the environment. However, the nuclear waste that is left over from nuclear reactors is usually an issue. In India, Bhaba Atomic Research Centre (BARC) manages the radioactive waste. These waste immobilisation plants are in operation at Tarapur and Trombay and a new one at Kalpakkam.

6.2.5 Hydro Energy

Hydro energy or hydropower energy is the energy generated by fast running water, and it is one of the most conventional renewable sources of energy around the world. In India, hydropower is generally categorized into two segments i.e. small and large hydro. The Ministry of Power, Government of India, is responsible for large hydro projects, and the Ministry of New and Renewable Energy is responsible for Small Hydro Projects (SHPs) (up to 25 MW).

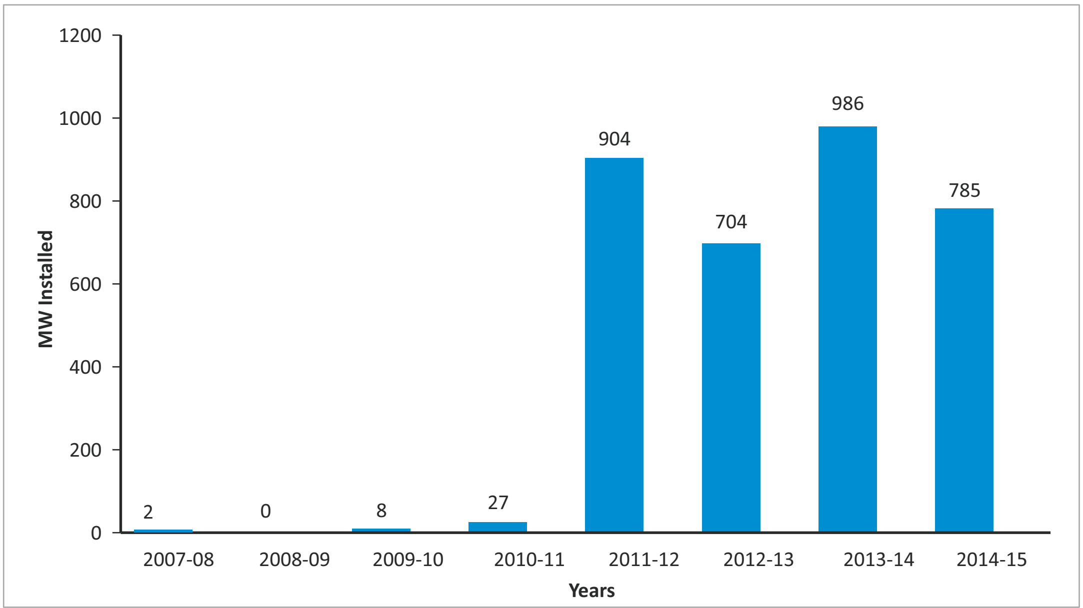
The hydropower potential of India is around 145,000 MW at 60 per cent load factor, and there is a potential to meet the demand of around 85,000 MW. According to the Power Ministry, around 26 per cent of potential has been exploited in India. Since large hydropower projects have socio-economic implications, the

Photo 6.2: Small Hydro Project in Himachal Pradesh

Photo 6.3: Roof top solar panels

government is investing huge in developing SHP projects up to 25 MW station capacities. The potential of power generation from SHPs is at about 20,000 MW (World Energy Council, 2013). For the future generation of electricity, the government has identified maximum potential in Himalayan States; SHPs could be developed as river-based projects, and in other states on irrigation canals. The current SHP programme is now principally private investment driven with the government being the facilitator. The Ministry's aim is that at least 50 per cent of the potential in the country is harnessed in the next 10 years.

Figure 6.5: Growth of Solar Power in India, 2007-2014



Source: Ministry of New and Renewable Energy Annual Report 2014 - 2015 (: Updated till 31st December 2014)*

6.2.6 Solar Energy

The government has set an ambitious target of installing 100 GW (100,000MW) of solar power capacity by 2022. Currently, India's solar capacity stands at 4878.88 MW as on March end, 2015 (MOSPI, 2016).

India's solar potential is in excess of 750 GW, and India Security Scenarios 2047 shows a possibility of achieving a high of 479 GW of solar PV by 2047 (NITI Aayog, 2015). Solar energy has the potential to anchor the development of India's electricity sector, as it would reduce revenue outflows for highly expensive imported fuels. India is staring at rapidly rising imported coal bills in the future energy scenario. According to Ministry of Coal, the country's coal import in 2014-15 was over Rs 1 Lakh crore. In April 2015, the Ministry of New and Renewable Energy (MNRE) had submitted proposals to the Expenditure Finance Committee (EFC), Government of India, for funds to support achievement of 100 GW solar by 2022. The cost of generating energy from solar photovoltaic generation is cheaper than conventional energy system. From an economic perspective, expanding the potential of solar energy would eventually reduce the burden of coal import bills.

The past ten years have witnessed tremendous support for renewable energy, from the government as well as the private sector. The first steps in this direction were provided by the Jawaharlal Nehru National Solar Mission (JNNSM), which was set up as a flagship programme to promote solar energy, and as a follow up to the National Action Plan on Climate Change (NAPCC).

The JNNSM is a broad-spectrum regulation that supports power generation from solar PV and other solar technologies across the size band, from micro (household scale) to MW scale solar projects. Under the JNNSM scheme, in 2010, solar energy was mainstreamed in the country's energy mix, as potential source of energy in the future. Figure 6.5 shows the status of solar power in India in the last decade.

Solar power has three distinctive advantages: a) sunshine is abundantly available and it is a non-polluting source b) It can electrify villages in remote setting where grid lines are absent, therefore, making access to electricity possible for millions and, c) solar power costs have fallen sharply in recent times, making it financially viable for industrial and commercial consumers.

6.2.7 Wind Energy

In March 2015, wind energy accounted for 102,772 MW of installed capacity of power stations in the country (MOSPI, 2016). It forms 11.46 per cent of the overall renewable energy capacity of 896,603 MW.

Photo 6.4: Wind power plant in India

Along with solar power, wind power has been one of the top performing sectors in the Indian renewable energy market. The growth of wind energy was facilitated after witnessing the depreciation in the late 1990s. In the subsequent years, with the availability of detailed wind data, and the provision of fiscal, and financial incentives and positive global outlook, uptrend was observed.

6.2.8 Biomass Energy

A large proportion of India's rural population still depends almost exclusively on biomass fuels. As per Census 2011, 85.7 per cent of rural population depends upon traditional means for cooking, which include firewood (62.5 per cent), crop-residues (12.3 per cent) and cow dung cakes (10.9 per cent). Across urban households, the corresponding fractions are 20 per cent (firewood), 1.4 per cent (crop-residues) and 1.7 per cent (cow-dung cakes), thereby showing significant variance. A further 1.4 per cent (overall) of India's population use coal, lignite and charcoal that are serious contributors to climate change and indoor air pollution. The result ranges from climate change, deforestation and chronic illnesses from indoor air pollution that are discussed later under impacts.

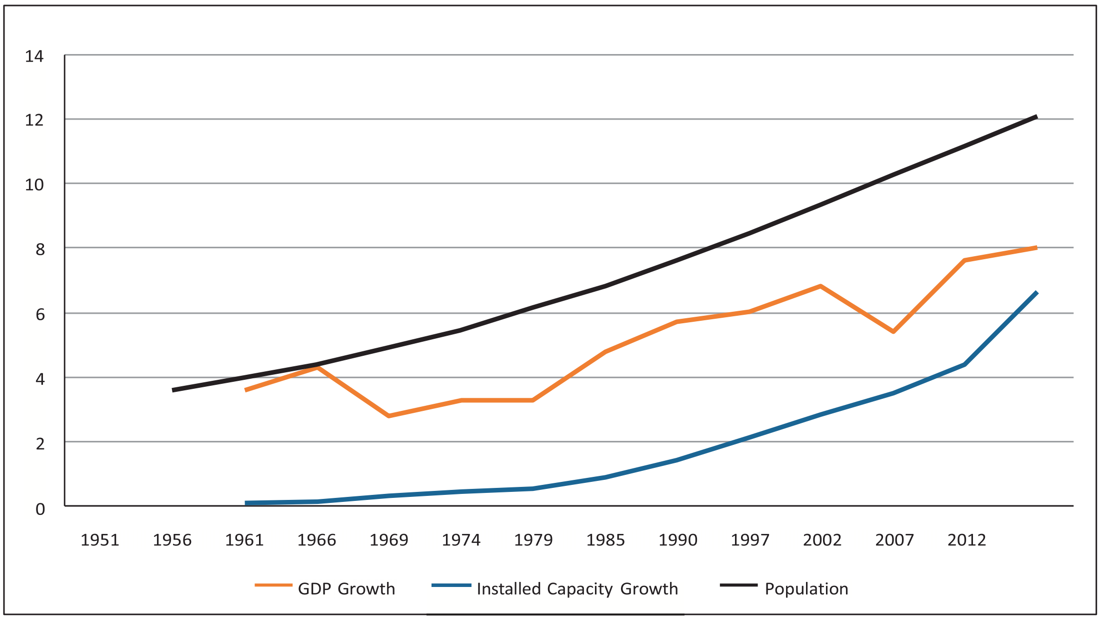
6.2.9 Geothermal Energy

Geothermal energy is generated due to the natural decay of radioactive elements inside the earth. As of May 2012, approximately 11,224 MW of installed geothermal power capacity was online globally. It deploys four types of power plants at present: flashed steamed plant, dry steam plant, binary power plant, hybrid power plant, and, enhanced geothermal system. India has 10,600 MW of potential in the geothermal provinces. Whatever be the potential, it has not been exploited till now. The thermal springs of India span: Himalayan Province; Areas of Faulted blocks – Aravalli belt, Naga-Lushi, West coast regions and Son-Narmada lineament; Andaman & Nicobar; Deep sedimentary basin of Tertiary age such as Cambay basin in Gujarat; Radioactive Province – Surajkund, Hazaribagh, Jharkhand; Cratonic province – Peninsular India (Green Clean Guide, 2013).

6.2.10 Tidal Energy

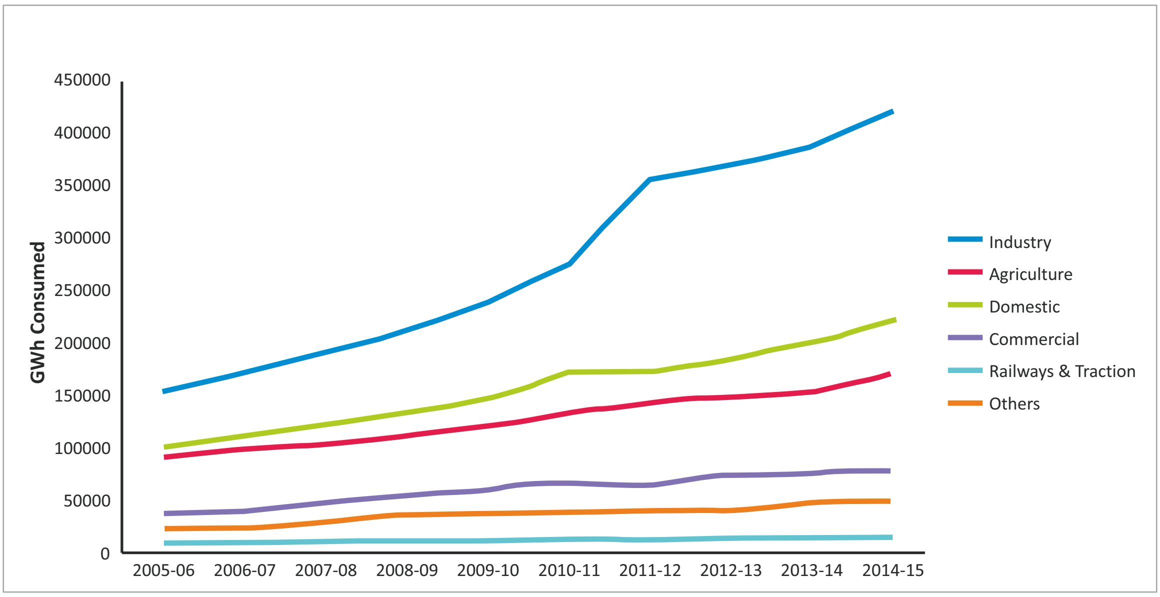
Tidal energy from oceans forms a key part of meeting India's renewable energy obligations. Over 100 different ocean energy technologies are currently under development in more than 30 countries. Most types of technologies are currently at demonstration stage or the initial stage of commercialization. Similar to traditional hydropower, tidal water can be captured in a barrage during high tide and forced through a hydro-turbine during low tide. There are only approximately 20 locations on earth with tides this high and India is one of them. The Gulf of Cambay and the Gulf of Kutch in Gujarat on the west coast have the maximum tidal range of 11m and 8m with average tidal range of 6.77m and 5.23m respectively (MNRE, n.d.).

Figure 6.6: Population, Power Generation and GDP Growth (1951-2012)



Source: Census of India 2011

Figure 6.7: Sectoral Growth in Electricity Consumption in India over the past 10 years (2005-2015) in Gigawatt-hours Consumed



Source: Energy Statistics produced by the Ministry of Statistics and Programme Implementation, Govt. of India

6.3 PRESSURES

The state of the power sector is influenced by a number of pressures. These pressures push for the demand of energy that causing impact on environment. Major factors are here as follows:

6.3.1 Energy Demand and Consumption Trends

In India, fossil fuels meet almost three-quarters of energy demand, due to rapid rise in coal consumption since 2000. Coal now accounts for 44 per cent of the primary energy mix (compared with under a third globally). Coal dominates the energy mix due to its availability and affordability in comparison with other fossil fuels; the power sector consumes most of the coal reserves.

Population in India has been growing steadily since independence. Along with the growth in the population, there has been an increase in the demand

Photo 6.5: Koteshwar Dam & Spillway

for power. Rise in per capita income has a similar trajectory to the rise in power supplied.

The Figure 6.6 plots the growth in installed power capacity, superimposed on the rate of population growth considered as a decennial trend. As one can see, the growth rate of capacity of power generation approximately mirrors the rates of growth of population, which proves that the growth in population induces associated growth in demand for electricity.

With an 18 per cent share of the world population, India accounts for less than 10 per cent of the world's demand for energy (IEA, 2015). In addition, this demand does not reflect demand for electricity and thermal energy from the rural sectors, which are still partially met from using traditional sources of fuel.

By 2030, India's population is expected to reach 1.46 billion from1.09 billion in 2005, consequentially, the power generation will peak from 144 GW to 400 GW, and this power would be utilized in driving the Indian economy (WEO, 2007).

The economic growth would expand the middle class of the country, leading to an increase in demand of power- intensive goods and services, such as home electrical appliances and cars. Increase in India's GDP, would make it a large consumer for foreign industries, and with the boost in the manufacturing sector it would more for the rest of the world to consume. It is considered that electricity generated from coal would be a major driver for the country's economic progress. The three largest consumers of electricity in India are: Industry (44 per cent), domestic (23 per cent) and agriculture (18 per cent) (MOSPI, 2016).

Along with this information, Figure 6.7 indicates the movement of sectoral growth in electricity consumption categories over the past 10 years. The industrial sector demand rose from roughly 36 per cent in 2005-06 to 44 per cent in 2014-15, demonstrating a growth of nearly 300 per cent in electricity in past 10 years. The domestic and agricultural sectors also grew 2.17 times and 1.87 times respectively, thereby reflecting the spurt in demand for energy from the domestic (buildings) sector. Commercial demand also grew 2.18 times. The slowest movement is observed in the railways sector whose demand grew by 1.63 times over the past 10 years.

In addition to electricity, the other sources of energy consumed are liquid petroleum fuels, coal and gaseous fuels. The major consumers of these fossil fuels are various industries. For instance, over 75 per cent of coal consumption in 2005-06 was in the production of electricity, which is around 64.2 per cent as of 2014-15 (MOSPI, 2016).

High Speed Diesel Oil (HSDO), petrol and LPG are used for transportation, industrial and commercial activities, and the domestic sector consumes kerosene almost exclusively. Figure 6.8 elaborates consumption pattern of selected petroleum fuels in past 10 years.

It indicates a high consumption pattern of diesel, which includes demand from transportation, industries, in addition with demand from agricultural sector, wherein it is widely used in pumping and power tilling activities. Interestingly, the demand for kerosene (shown by the black line) has been falling, as households move away from kerosene and towards LPG cylinders.

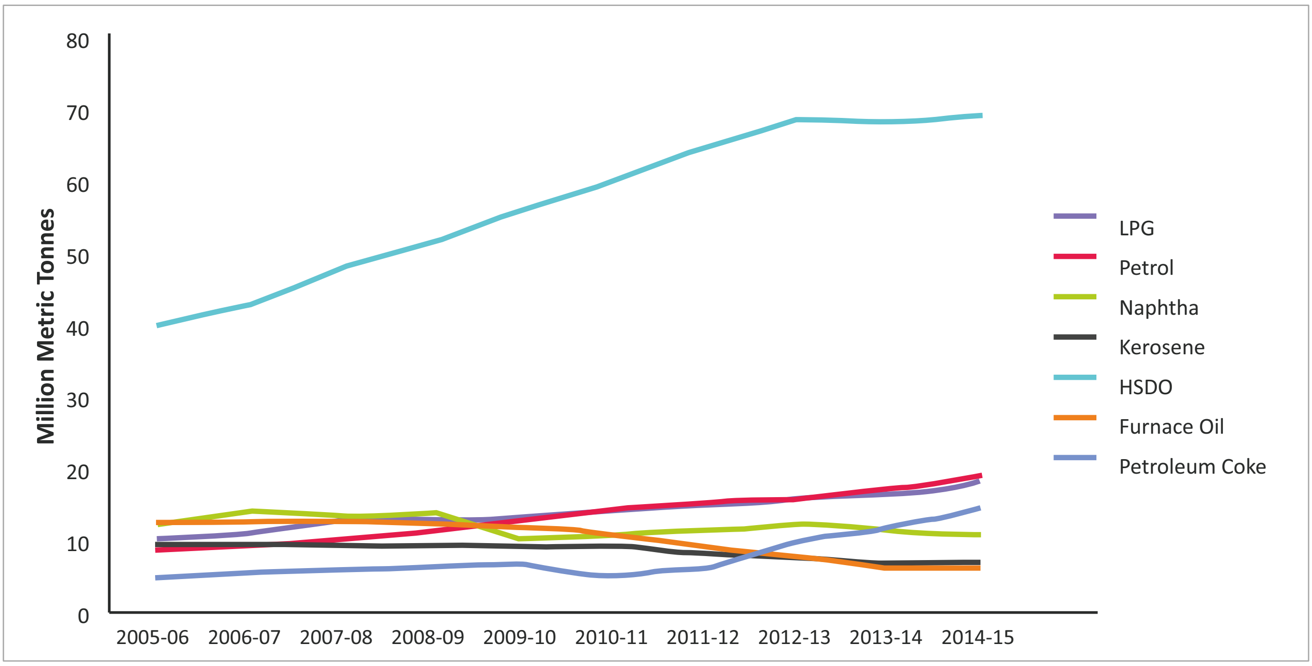
6.3.2 Transmission and Distribution losses

Energy efficiency is central to the production process, transmission & distribution and consumption. Historically, there has been significant priority accorded to augmenting generation capacity. In the current scenario, the Indian electricity sector is beset with major losses occurring during the transmission and distribution of the electricity.

In the process of supply of electricity, energy losses or transmission and distribution losses occur at the consumers end, due to technical and commercial losses. In the process of transmission, energy is dissipated in the conductors, and energy is also lost from the equipment used for transmission, sub-transmission and distribution of power.

Despite being inherent in a system, they could be reduced to an optimum level. The electricity supply system is reeling under immense commercial losses caused by electricity theft, absence of modern infrastructure of wiring, errors in meter reading and in estimating unmetered supply of energy. According to a report published by CEA (2015), India's T&D losses are around 21.46 per cent as of 2013-2014.

Figure 6.8: Sectoral Trend in Consumption of Liquid and Gaseous Fuels in India, 2005-2015



Source: Energy Statistics produced by the Ministry of Statistics and Programme Implementation, Govt. of India.

India is far ahead of China (6 per cent), Brazil (16 per cent) and almost all the European nations in the transmission and distribution losses (The World Bank, 2014).

The trend in T&D losses since 1950s depicts that losses in electricity transmission and distribution were prohibitively high at around 50 per cent, which have been brought down to 21.46 per cent (Central Electricity Authority).

6.3.3 Energy Demand for Agriculture

The agriculture sector is the third largest consumer of electricity and diesel in India. Though, the Gross Domestic Product share of agriculture in the country's is falling, the sector still employs more than half of the country's workforce, in addition to providing low cost farm products used as feedstock for several key industries like sugar, fertilizers, food processing, fast moving consumer goods (since they depend on agro products), industry etc.

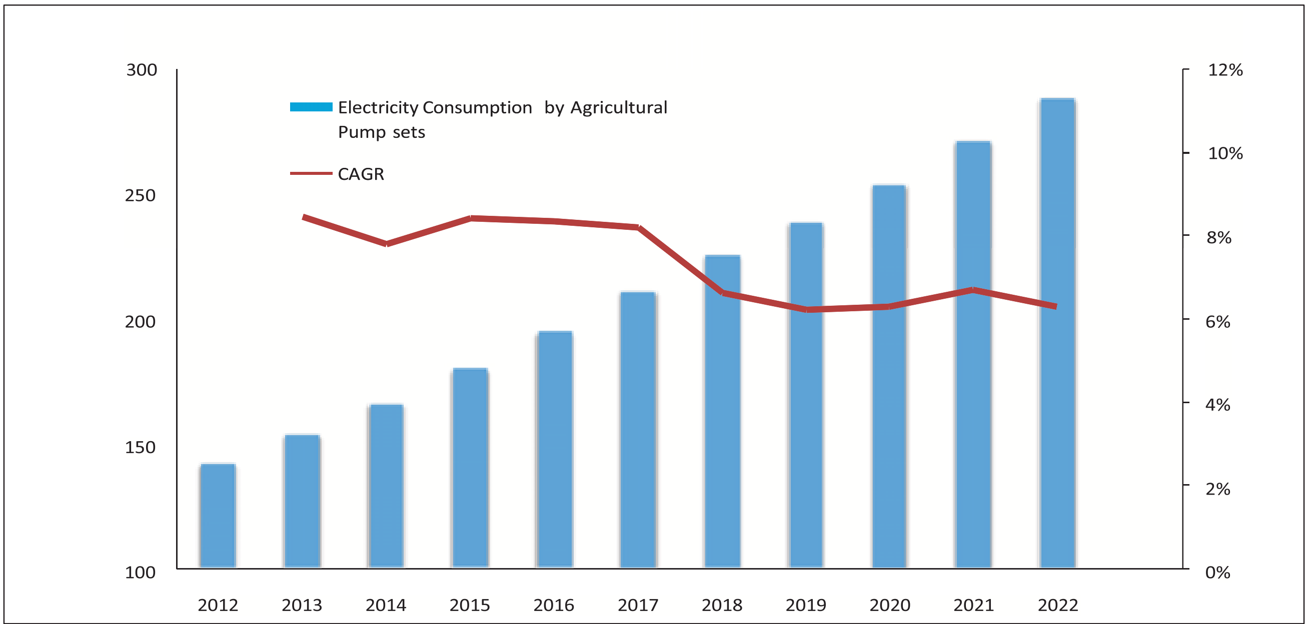
The sector consumes about 18 per cent of the country's electricity. Preliminary estimates indicate that about 12 per cent of diesel is also consumed by the agriculture sector (2047 Energy Calculator for Agriculture Sector). Demand for electricity for the agriculture sector grew at a Compounded Annual Growth Rate (CAGR) of 6.47per cent between 2005-6 and 2013-14, as reported by the Central Electricity Authority. The Indian Energy Security Scenarios 2047, a report developed in 2014, estimates 19per cent of total pump sets in India are energized by diesel-based pumps. Further, the eighteenth Electric Power Survey (EPS) carried out by the CEA, electricity requirement for pumping is estimated to grow at around 7per cent in the period 2012 – 2022 (CEA, 2015).

The graph, in Figure 6.9, indicates the rate of growth of electricity demand, shown by the CAGR schedule, has a downward trend over the 10 years as projected. The trend indicates that unmet demand is falling as access to electricity improves, but gross demand for electricity for pumping is still increasing. Thus, agriculture demand for power is an identified driver for the sector.

6.3.4 Energy Demand for Industries

The industrial sector is also a major driver of energy demand. The World Energy Outlook (2015) estimates energy demand in the industrial sector to increase by 4.4 per cent per annum from 2015 till 2040.

Figure 6.9: Electricity Consumption by Agricultural Pump Sets with CAGR, 2012-2022

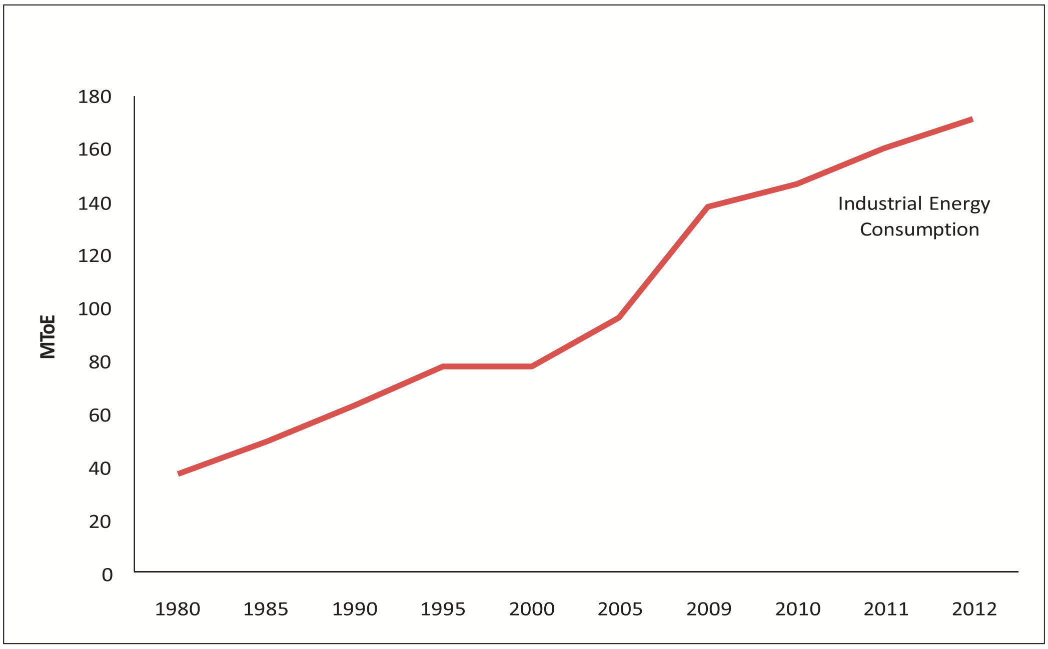


Source: Central Electricity Authority, 18th Electric Power Survey 2013

Industries is projected to consume over 50 per cent of total energy produced by 2040. Figure 6.10 shows trends of industrial energy consumption in India in the last three decades.

Electricity generated from coal being major source of energy for the industrial sector, would eventually also be the major polluter of the environment. The westernized model of industrialisation was based on consuming energy from fossil fuels which led to environmental degradation. The Indian industrialisation have also experienced a high demand in energy consumption within the period of 1980-2012, if precautionary measures are not take, then the progress of Indian industries would put the environment at stake.

Figure 6.10: Industrial Energy Consumption in India in Million Tonnes of Oil Equivalents, 1980-2012



Source: Ministry of Petroleum and Natural Gas, 2013

6.3.5 Energy Cost and Global GHG Emissions

The rising cost of energy as electricity is driving the need for a low carbon alternative that is more efficient and cheaper. In India the agriculture sector used 22 per cent of total electricity but accounted for only 8 per cent of the revenue in 2014 (Bhandari, 2015). This subsidy provided to farmers have simultaneously caused increase in prices for other sectors. Agricultural users pay less than Rs 2 per unit, while industrial and commercial users pay upwards of Rs 6 per unit and Rs 7 per unit.

Additionally, with the rising pressure from the international community for India to reduce its GHG emissions, even though India has a growing population and booming economy has slightly drifted the energy source towards renewable or clean sources of energy. This is driving the shift towards a greater percentage of solar in India.

6.3.6 Transportation

India has one of the largest transport systems in the world, serving over a billion people on a land area of 3.3 million km^2 (Census, 2011). The transport sector in India consumes about 14 per cent of the total energy consumption, at 75 Mtoe in 2013 (IEA, 2015). The transport sector is heavily dependent on fossil fuels such as oil and gas, and it is one of the largest energy consuming sectors. According to the Ministry of Petroleum and Natural Gas, the sector consumes one third of petroleum products. Within this sector, road transport is the largest consumer followed by rails, which runs on electricity produced by coal fired power stations, followed by aviation and shipping sector. Land transport in India is dominated by liquid fuels mainly from coal and oil, however some electricity is used by rail and metro. At present in India very little renewable energy transportation is present. Aviation also uses jet fuel or aviation gas while marine transport heavy fuel oil such as diesel.

However, as per the India Energy Outlook (2015), consumption changes spurred by the increase in diesel prices relative to those of other fuels have led to reduce in demand, as well as pushing consumers to switch alternate fuels, or even opt for more efficient technologies.

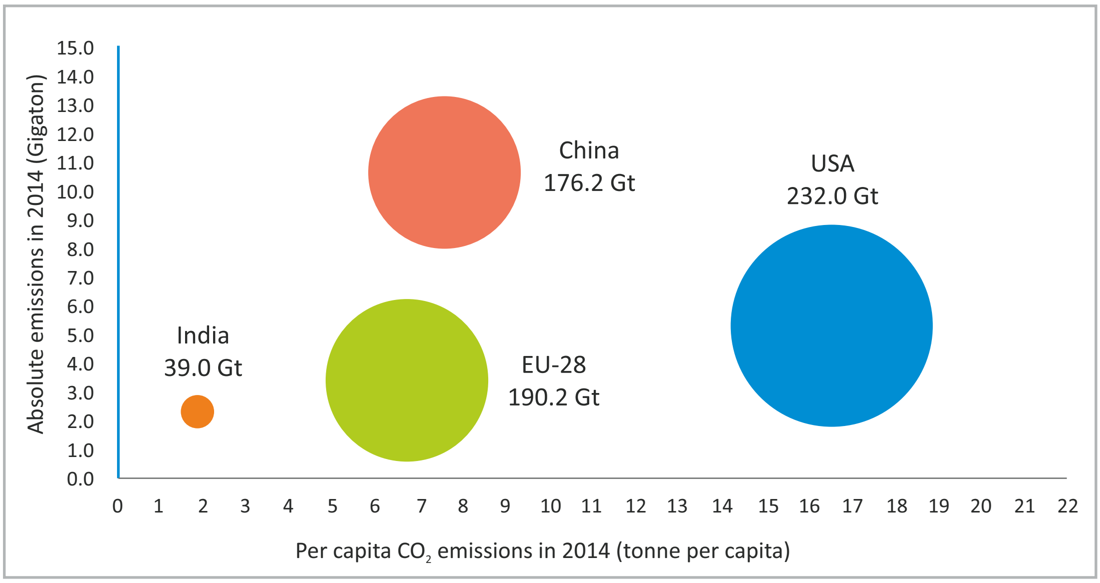
6.4 IMPACTS

Some of the consequences arising out of mismanagement and mishandling of energy resources have in its wake several serious impacts on the environment.

6.4.1 Climate Change

Climate change is a change in global or regional climate pattern. In the year 2015, two important

Figure 6.11: Absolute and Per Capita CO_2 Emissions of Select Economies in 2014



Note: *Width of the bubbles indicates the total emissions between 1970 and 2014 for the respective countries and have been indicated beside the bubbles.*

Source: Based on PBL Netherlands Environmental Assessment Agency data used in 'Trends in Global CO2 Emissions 2015 Report' international climate change agreement were negotiated with the participation by 195 nations, represented by their national leaders: climate change agreement under the UNFCCC in Paris and the adoption of Sustainable Development Goals. Greenhouse gases (GHG) released from anthropogenic emissions has been a major trigger for climate change (IPCC, 2014). CO_2 emissions from combustion of fuels in the energy sector are the largest contributor to GHG emissions, and in the view of a global emissions scenario these emissions are distributed very unequally among different countries.

The agreement places emphasis on concepts like sustainable lifestyles approach along with climate justice; for the first time agreement brings together all nations for a common cause under the UNFCCC. The agreement focuses on a major global effort to counter climate change, by restraining the increase in the global average temperature to well below 2°C above pre- industrial level and on driving efforts to limit it even further to 1.5°C.

Figure 6.11 indicates if historical emissions are reduced and current levels considered, both in terms of absolute and per capita emissions, India is extremely far away from the three major CO_2 emitters in the developed world. China in 2014 was at the top, in terms of absolute emissions, while in terms of per capita emissions, the USA was at the top. In comparison with US and China and other developed countries, India ranks very low in terms of per capita emissions in the world .

India, if compared in terms of equity and differentiated responsibilities at different levels of development, then it is lowest among the four; and, the USA has the highest per capita CO_2 emissions and per capita income.

Although, India is far behind in terms of per capita income and per capita CO_2 emissions; but its economy is growing at a rapid pace, at present largely based on the consumption of fossil fuels. If the trend in consumption of fossil fuels continues to power the economic growth of the country, then it could become one of the largest emitters and a major contributor to the climate change.

India is also on path to get 100 per cent electricity for its people, therefore, at this juncture it is important to identify and implement a strong policy framework to increase the share of renewables in the future energy mix.

India is on a path of economic progress, and to power the growth, the country requires vast reserves of energy. Energy from renewables has the potential to minimize climate change, and eventually save the environment from the concentration of air pollutants.

6.4.2 Impact on Air Quality

Besides air pollution in cities and elsewhere in India due to energy creation by use of fossil fuel, there is also a risk of indoor air pollution. The use of biomass fuels in the country is widely prevalent in the rural areas, especially as a medium for cooking. In addition to biomass, coal and kerosene are also widely used, in various inefficient devices for cooking and space heating. The result is one of high levels of indoor air pollution. In addition to cooking, lighting and space heating, there are two other offenders in the form of bio- aerosols suspended particulates containing living organisms, or were emanated by other living organisms, as well as use of building materials such as asbestos.

A study seeking to quantify exposures to respiratory particulate matter (RPM) found concentrations of 500 mg/CuM 2,000 mg/CuM during cooking in households that were using biomass. The same study concluded that there could be 2 million premature deaths that could be attributable to indoor air pollution, with diseases such as pneumonia (44 per cent), COPD (54 per cent) and lung cancer (2 per cent) (Gupta, 2013).

According to World Health Organisation Chronic Obstructive Pulmonary Diseases (COPD) in rural India, are rampant and over 15 million persons could be mildly to severely affected. Women are the worst suffers of impacts from indoor air pollution, as they are mostly involved in household chores including cooking food using fossil fuels. The emissions are extremely harmful for their health and have the potential to ill-impact their reproductive and care giving roles. Indoor air pollution is detrimental to health of the environment along with human lives; the emissions released lead to concentration of air pollutants.

6.4.3 Impact on Water Sources and Water Quality

Coal is the most abundant fuel resource in India, however it is also among the most polluting. While mining of coal uses a lot of water. Large and deep opencast mines usually have great impact on the hydrologic regime of the region (Singh, n.d.). Further, energy and water are interlinked with complex and dynamic interactions, and vulnerability in one could directly translate to disruptions in the other. Surface water pollution emanating from coal mines are blamed for the deterioration of the water quality in Singrauli Industrial Area of Madhya Pradesh, one of the richest coal belt in India (Dubey et al, 2012).

Additionally, the large hydropower projects do have some environmental impact, that is, submergence of land, leading to loss of flora and fauna and displacement of communities. Although projects only catering to hydro power needs, may cause little submergence and displacement. These can be further mitigated by small hydropower projects.

6.5 RESPONSES

To combat rising demand from the energy sector, as well as seeking to remain climate and environmentally sustainable, Government of India has come forward with a variety of responses. Different aspects of the sector are governed by different ministries and bodies like Ministry of Power, Ministry of Coal, Ministry of New and Renewable Energy, Central Electricity Authority, Central Electricity Regulatory Commission etc. Together these cover and are attempting to address major barriers to the field: investments in renewable energy (RE) policy, exploiting the potential for development of RE technologies, taking the lead in energy efficiency solutions for households and commercial buildings, efficiency in public utilities, power distribution companies (DISCOMS) and industry.

6.5.1 Rural Electrification

On rural electrification, the current definition (Ministry of Power, 2005) defines an electrified village as:

- Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti/hamlet where it exists. (For electrification through Non-Conventional Energy Sources a Distribution transformer may not be necessary).
- Electricity is provided to public places like Schools, Panchayat, Office, Health Centers, Dispensaries, and Community Centres etc.
- The number of households electrified should be at least 10 per cent of the total number of households.

A national rural electrification programme was launched namely RGGVY or Rajiv Gandhi Grameen Vidyutikaran Yojana, launched in 2005, later renamed to Deen Dayal Upadhyay Grameen Jyoti Yojana (DDUGJY) in 2014.

Under DDUGJY, projects were financed up to 90 per cent by the central government, while the rest was provided by Rural Electrification Corporation (REC) as a soft loan. However, the RGGVY was more extensive than intensive. As the Planning Commission study seems to indicate, RGGVY managed to achieve 53 per cent success in terms of intensification of electrified villages (Evaluation report on RGGVY, 2014). In addition to rural electrification, the DDUGJY sought to improve power distribution to agriculture by separation of feeders for agricultural and non-agro activities. Figure 6.12 demonstrates the pace of village electrification carried out by the programmes. As one can observe, village electrification was at its peak performance in the first five to six years between 2005 and 2011, after which it has maintained steady growth for a few years before picking up again in the final year.

In parallel with RGGVY, Ministry of New and Renewable Energy launched the Remote Village Electrification Programme (RVEP) and the Village Electricity Security Programme (VESP), the aim utilizing renewable energy technologies to provide energy access to remote villages with small-scale off-grid systems. A majority of Indian villages are without power, providing access to energy from fossil fuels is a major concern for the state of the environment, as more and more emissions would increase concentration of air pollutants.

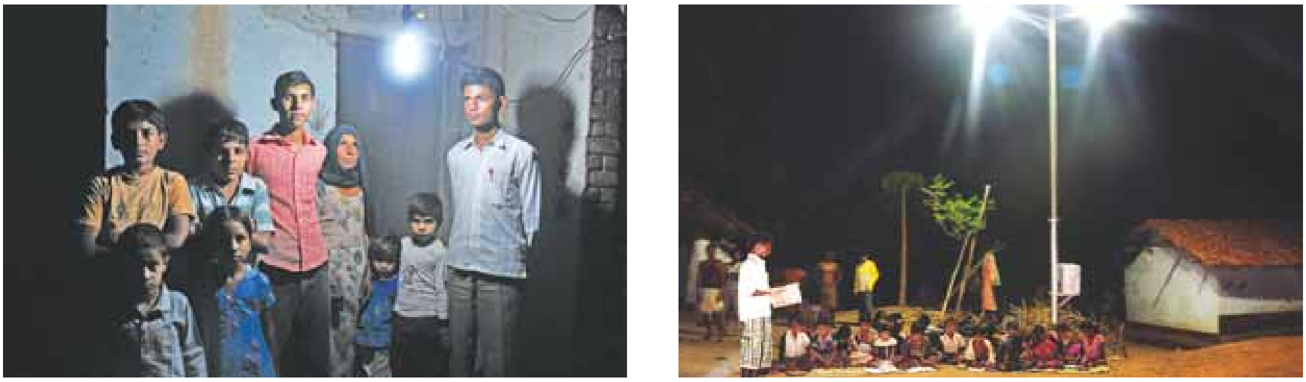


Photo 6.6: Rural electrification of a village under DDUGJY

6.5.2 Improving Distribution Efficiency and Management

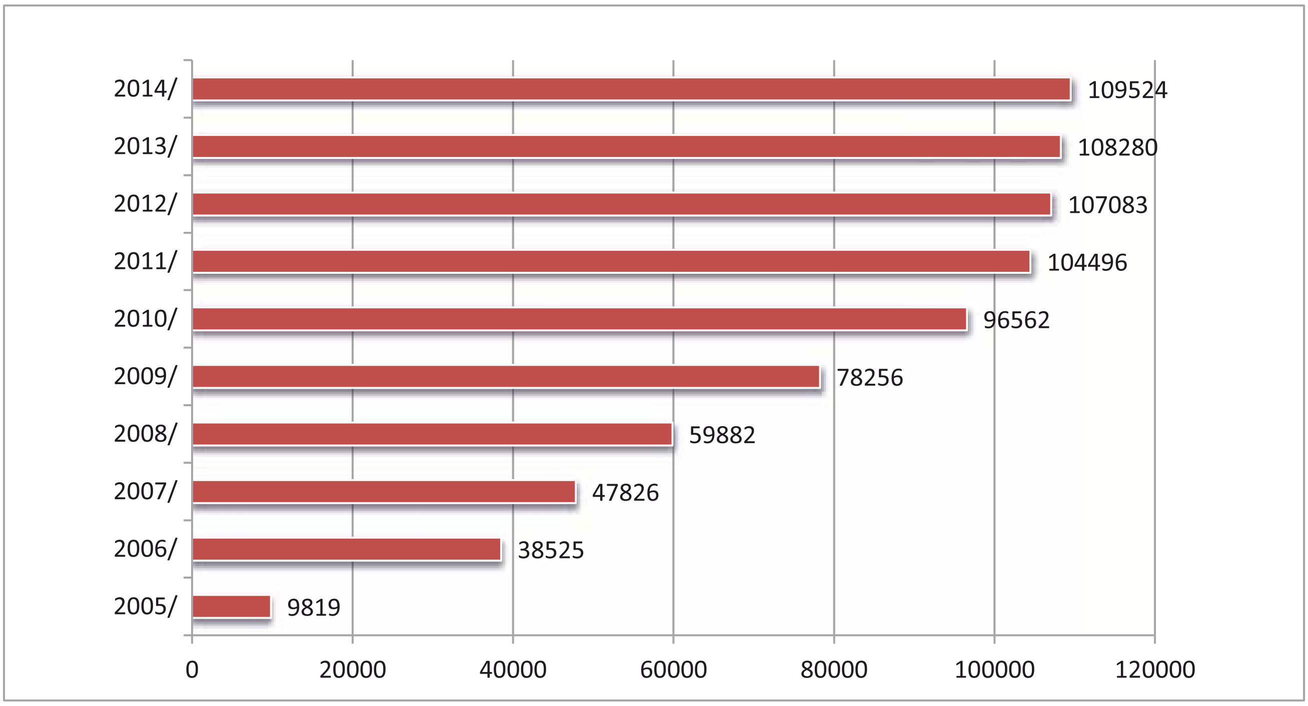
Ujwal DISCOM Assurance Yojana (UDAY)

In collaboration with DDUGJY, the national government has introduced an innovative scheme for financial turnaround of DISCOMs. The scheme, (UDAY), seeks to improve financial performance of state-owned distribution companies, most of which are not in sound financial health. It is commonly understood that state-owned DISCOMs suffer from poor billing, metering and collection (BMC) efficiencies, leading to poor accrual. Further, higher aggregate technical and commercial (ATC) losses weakens financial position of the DISCOM.

The UDAY scheme seeks to introduce better financial prudence at the level of the DISCOM. While the UDAY scheme does provide a bailout to the weak financial conditions of the state owned DISCOMs, it does not address the fundamental weakness in revenue generation for these agencies. Moreover, UDAY would at best be a long-term solution to the financial problems of the DISCOMs, whereas setting up distribution franchisees would have a more powerful impact within a short term.

Besides UDAY, some of the other recent schemes were launched by the GoI, such as the National Electricity Fund and the Financial Restructuring Scheme, to address distribution management include.

Figure 6.12: No. of Villages Electrified under Deen Dayal Upadhyay Grameen Jyoti Yojana (DDUGJY) or Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)



Source: Rural Electrification Corporation Annual Report 2015

Integrated Power Development Scheme (IPDS)

This scheme was approved in 2014 with a total outlay of Rs 32,612 crores. The objectives of the scheme are:

- Strengthening of sub-transmission and distribution networks in the urban areas;
- Metering of distribution transformers / feeders / consumers in the urban area.
- IT enablement of distribution sector and strengthening of distribution network

6.5.3 Promotion of Renewable Energy

The renewable energy sector in India, which was primarily driven by wind power till the turn of the millennium received a significant boost around 2009-10, with the initiation of the National Action Plan on Climate Change and in sync with the global spurt in renewables.

The graph 6.13 shows the spurt in renewable energy installed capacity, especially since 2009-10, with the formation of the NAPCC and the initiation of the Jawaharlal Nehru National Solar Mission (JNNSM) (discussed below). The following sections discuss individual sub-sectors in greater detail.

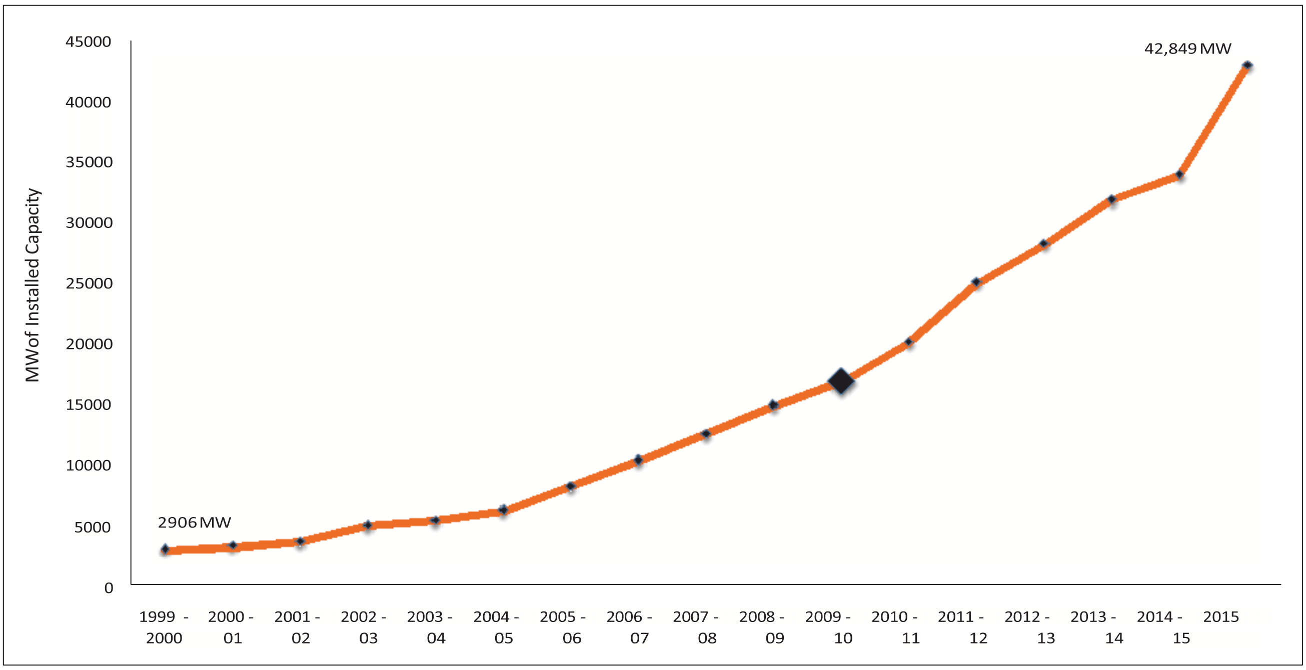
6.5.4 Reducing Dependence on Biomass Fuels

This forms one of the important parts of the government's renewable energy programme. The Special Project on Cookstove (SPC) initiated during 2009-10 seeks to ascertain the status of various types of biomass improved cookstoves being developed and promoted and to identify ways and means for the development and expansion of the deployment of improved biomass cookstoves. The cleaner combustion in these devices will also greatly reduce greenhouse pollutants. Some of the key initiatives include: National Biomass Cookstoves Initiatives (NBCI) launched in 2009 and the Unnat Chulha Abhiyan Programme from 2014. The government also seeks to leverage the potential of carbon finance alternative for reducing the price of improved biomass cookstoves for low-income households (MNRE, n.d.)

6.5.5 Reducing Transmission & Distribution Losses

The Government of India under Deen Dayal Upadhayay Gram Jyoti Yojana (DDUGJY) developed a framework for strengthening and augmentation of

Figure 6.13: Growth in Renewable Energy in India, 1999 – 2015



Source: Ministry of New and Renewable Energy Annual Report 2014 – 2015 sub- transmission and distribution infrastructure for rural area. The scheme is focused at: renovation and modernization of existing sub- stations and lines, erection of High Transmission lines for reorientation/re-alignment including augmentation of existing lines, High Voltage Distribution System etc., therefore investing in the overall infrastructure development of the power sector to transmit reliable and quality power along with loss reduction. Government could also look at establishing micro-grid and off-grid network.

6.5.6 E-Waste Recycling

The current spate of rapid growth in the electronic industry led to the generation of large quantities of electronic waste (e-waste) including solar panels; recognized as one of the fastest growing waste streams worldwide e-waste accumulation is a crisis, as it is unregulated, and if the recycling process is not regulated, then it could lead to major environmental problems endangering human health.

The Ministry of Environment, Forest & Climate Change (MoEF&CC) has formalized the E-Waste Management Rules. The rules were developed from the E-Wastes (Management and Handling) Rules, 2011. The ministry emphasized on empowering State Pollution Control Board (SPCB) and Centre Pollution Control Board (CPCB), as the government agency to drive the change in the management of e-waste. India is the fifth largest producer of e-waste in the world. Nearly 18.5 lakh metric tonne of electronic waste is produced each year, with telecom equipment alone accounting for 12 per cent of the e-waste.

The Comptroller and Auditor- General's (CAG) in 2010 identified 4 lakh tonnes of electronic waste are generated in the country annually. E-Waste in India, a report tabled in the Lok Sabha in 2011, categorized solar cells as an environmental hazard due to its Arsenic content; and its recycling in an environmentally sustainable manner is a difficult process. Central Pollution Control Board (CPCB) estimated India's E-waste at 1.47 lakh tonnes or 0.573 MT per day. The CPCB indicated that the pollutants or toxins in e-waste are majorly found in the circuit boards, batteries, plastics, and LCDs (liquid crystal displays).

6.6 CONCLUSION

The Indian energy sector is at a crossroads today. Greenhouse gases emissions leading to climate change is a serious concern threatening planetary system. To counter climate change, and ensure a strong framework for sustainable development for future generation, it is important to invest in cleaner and efficient energy alternatives. India, being perceived as one of the largest economy in the future; energy will be at the core of its growth. Though, the per capita energy consumption still lagging behind major developed countries, the trend would reverse as India's continues on the path of economic development. If fossil fuels continue to play a major role in the energy mix, then the concentration of air pollutants would increase, contributing to climate change. The future energy demand trends developing from the existing status invokes the need to create an institutional framework focused at energy planning to achieve energy security. In order to optimize its use in the future without deteriorating the health of the environment, and integrated and updated database of production and consumption of different fossil fuel sources, such as, coal, crude petroleum, natural, gas and electricity, is required to streamline energy planning. It is also essential to have good energy statistics, leading to development of an efficient monitoring of energy generation from various sources, along with losses and damages done to the environment by various processes.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 7

INDUSTRY AND MINING

Key Messages

- *The rising trend of industrial production has contributed to resource scarcities and degradation of environmental quality by overloading natural sinks with wastes and pollutants.*
- *Most of the manufacturing industries are categorized as Micro, Small and Medium Enterprises (MSME) and they contribute to 70 per cent of the total industrial pollution load of India.*
- *Non-compliance with regulations making it mandatory to adopt pollution control technology has been increasing in cement, iron and steel and sugar industries and in distilleries and power plants.*
- *Unsustainable extraction of natural resources have been causing damage to land, water and air and the wellbeing of people.*
- *Response measures that have been taken are geared towards improving efficiencies to maximize output with minimum waste and damage through the use of clean technologies and recycling of secondary raw materials.*
- *Inclusion and promotion of Resource Efficiency (RE) policies in national agenda is creating a facilitative environment for the adoption of recycling technologies and the decoupling of economic growth from environment degradation.*

7.1 INTRODUCTION

The industrial sector has been the growth engine of economies since the advent of the Industrial Revolution. On the other hand, it has also marked the beginning of environmental pollution and climate change. Rampant industrial production has a direct negative impact on air, water and land and, hence affects human health and well-being. Therefore, it is imperative for a growing economy like India to focus on sustainable growth of the industrial sector addressing major environmental impacts.

The economic survey report by the Ministry of Finance states that the global financial crisis in 2008-09 slowed industrial production growth in India to 2.5 percent. However, mining and manufacturing led the recovery of industrial production growth starting from 2011-12. As a result, the Government of India has launched several programs and initiatives such as Make in India, labor-sector reforms, ease of doing business, E-biz project, skill development, streamlining environment and forest clearances.

As per the Index of Industrial Production (IIP) which provides quick estimates of the performance of key industrial sectors, the industrial sector in India broadly comprise mining and quarrying, manufacturing, construction and electricity, gas etc. (Ministry of Finance, 2015). The mining sector is at the core of infrastructure, manufacturing and basic industries. India is a mineral rich land, producing as many as 94 minerals including four fuel minerals, 10 metallic minerals, 19 non-metallic, 52 minor minerals and nine atomic minerals (IBM, 2015). Thus, mining as a sector assumes an important space in the Indian economy, even though the sector contributed only 2.3 per cent of the Gross value added (GVA) share as seen in 2014-15.

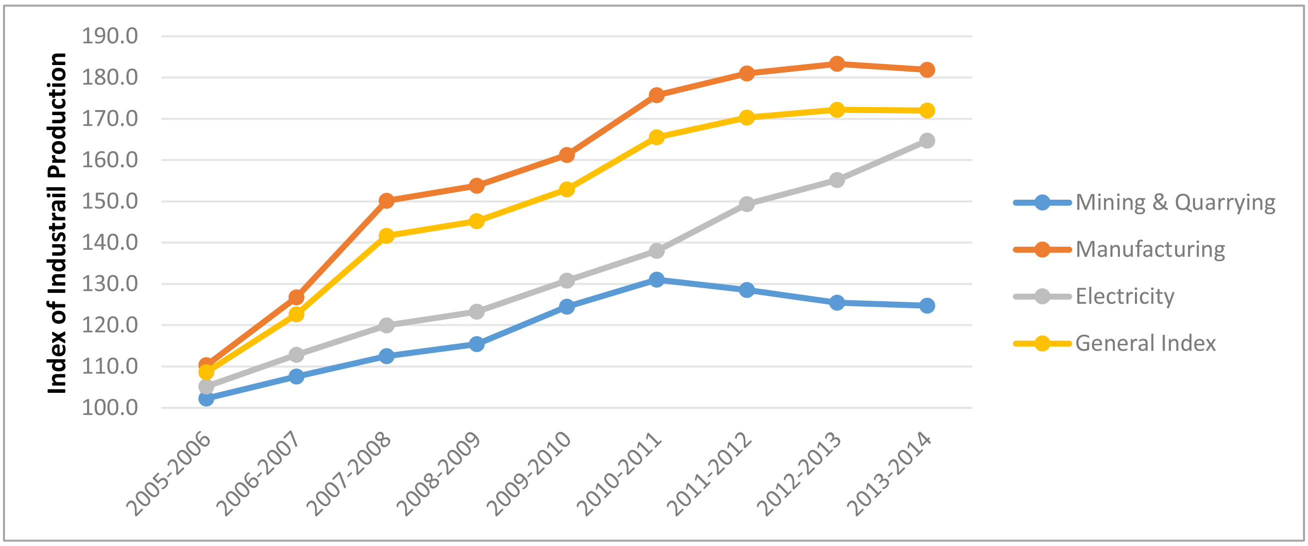
This chapter focuses on mining, manufacturing and the construction sector. Energy is discussed in detail in chapter 6.

7.2 STATUS

Indian industries have grown remarkably in the last two decades spurred on by the economic liberalisation and subsequent reforms. With growing trends of population, and increase in industrial production due to rising levels of consumption per capita, the demand for fuel, water, and other natural resources have increased tremendously. The rising trends of industrial production can have adverse effects on the natural resources and environment, leading to resource scarcities and degradation of environmental quality by over loading natural sinks with wastes and pollutants (MOSPI, 2015).

The manufacturing sector has grown at a faster rate than mining (Figure 7.1). The mining sector growth was mainly on account of higher coal production, while the manufacturing sector was propelled by the higher production of industry groups like furniture, apparel, dressing material and dyeing of fur; motor vehicles, trailers & semitrailers; chemicals and chemical products; refined petroleum products and nuclear fuel.

Figure 7.1: Annual Averages – Index of Industrial Production (Base: 2004-05=100)



Source: Central Statistics Office, Ministry of Statistics and Program Implementation (MOSPI)

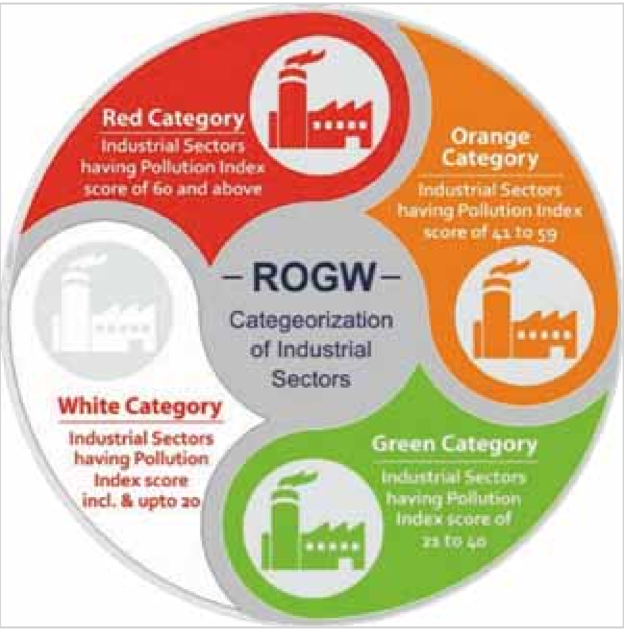
Post a slump in the first half of this decade, the mining sector over the last couple of years has also shown a positive growth trend. However, the value of mineral production shows a negative trend. The underlying cause of the poor performance has been considerable deceleration in investment particularly by the private corporate sector during 2011-12 and 2012-13; a trend that appears to be continuing during 2013-14 (MOSPI, Statistical Year Book, 2015). It is important to note that decline in mining and quarrying has led to tepid growth of the manufacturing sector, thus, establishing a dependence of manufacturing on mining and quarrying.

Construction formed the majority of the additional to fixed capital (58.6 per cent) followed by Machinery & Equipment (35.6 per cent) in 2013-14. The erection of dwelling units has added to income and employment significantly during the period of construction, and has generated large forward and backward linkages through creation of demand in the input sectors and real estate services (Department of Economic Affairs, 2015).

7.2.1 Status of Polluting Units in the Manufacturing Sector

Manufacturing is one of the most resource intensive and polluting sectors. The cost of environmental damage caused by the manufacturing sector is estimated to be $32 billion as per National Productivity Council (Planning Commission, 2012). Most of the manufacturing industries fall under Micro, Small and Medium Enterprises (MSME), and assumes prime importance due to the quantum of units that fall under this sector. The MSMEs act as ancillary units to large industries and accounts for about 45 per cent of the manufacturing output, and around 40 per cent of the total exports of the country (MSME, 2015). The Comprehensive Environmental Pollution Index (CEPI) developed by the CPCB undertook a nationwide environmental assessment of Industrial Clusters. Various dimensions of environment including air, water, land, hazardous wastes generated and consumption of resources were captured by the index. Industrial clusters with a CEPI greater than 70 were identified as critically polluted. Within a respective environmental component i.e air, water and land, a sub-index score (Table 7.1) of more than 60 shows a critical level of pollution, whereas a score between 50-60 shows a severe level of pollution with reference the respective environmental component. About 60 types of industrial sectors are identified as 'Red', 83 industrial sectors as 'Orange' and 63 sectors as 'Green' by CPCB. The White category contains 36 industrial sectors which are practically non-polluting and do not need a "Consent to Operate''. Red category industries are not normally permitted in ecologically fragile areas / protected areas (MoEF&CC, 2016).

Figure 7.2: CPCB categorised industrial sectors based on the pollution index



Source: Central Pollution Control Board ENVIS Center

The increasing number of industries, and the accompanying non-compliance with the environmental standards is a major reason for concern. Besides the main manufacturing unit that is registered and being monitored, the performance of the remaining value / supply chain both upstream and downstream for contribution of environmental pollution also requires attention.

In 2014, CPCB identified 3,266 highly polluting, 17 categories of industries out of which 2328 are complying, 571 industries are non-complying and 367 industries have been closed down. The number of industries that have ensured compliance and non-compliance with regulations; and the other industries that have been closed down due to ineffectiveness in adopting cleaner production processes are shown in Figure 7.4.

Comparative analysis on compliance status of 17 categories of highly polluting industries for the period between 2010 and 2014, indicate that 71 per cent of the total industries have adequate pollution control

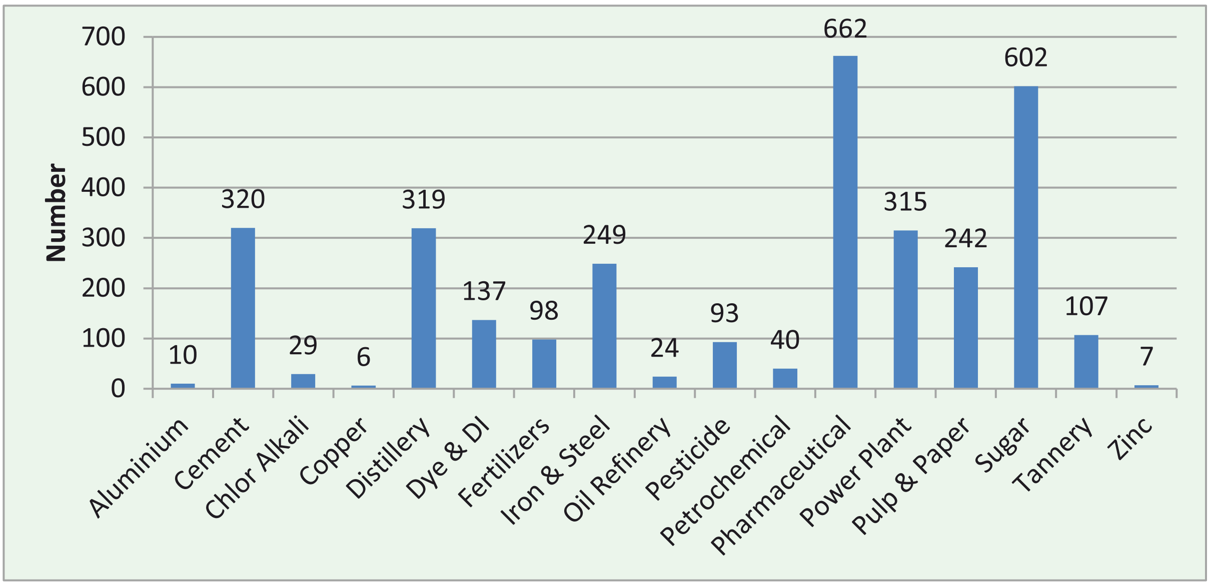
Table 7.1 : State-wise list of Critically Polluted Industrial Clusters/Area Showing Sub-index Scores for Each Environmental Component

State	Clusters	Industrial Clusters/ Areas	Air	Water	Land	CEPI	Status
Andhra Pradesh	2	Vishakha patnam	38.00	43.00	43.00	52.31	An-Wn-Ln
		Patancheru-Bollaram	62.50	67.25	43.00	76.05	Ac-Wc-Ln
Chhattisgarh	1	Korba	59.50	47.00	50.50	69.11	As-Wn-Ls
Delhi	1	Nazafgarh drain basin	56.88	57.50	60.50	73.42	As-Ws-Lc
Gujarat	6	Ankaleshwar	67.50	68.75	57.75	80.93	Ac-Wc-Ls
		Vapi	51.75	79.50	54.75	85.31	As-Wc-Ls
		Ahmedabad	49.75	60.50	46.00	69.54	An-Wc-Ln
		Vatva	43.00	80.00	40.00	83.44	An-Wc-Ln
		Bhavnagar	30.75	57.50	40.50	62.79	An-Ws-Ln
		Junagarh	42.75	40.00	43.00	52.75	An-Wn-Ln
Haryana	2	Faridabad	46.00	67.50	40.50	73.55	An-Wc-Ln
		Panipat	48.25	76.00	45.50	81.27	An-Wc-Ln
Jharkhand	1	Dhanbad	50.50	47.00	63.00	71.78	As-Wn-Lc
Karnataka	2	Mangalore	54.75	58.25	41.00	67.62	As-Ws-Ln
		Bhadravati	37.38	35.50	35.50	45.27	An-Wn-Ln
Kerala	1	Cochin, Greater	48.00	45.50	42.00	57.94	An-Wn-Ln
Madhya Pradesh	1	Indore	65.00	70.50	43.00	78.75	Ac-Wc-Ln
Maharashtra	5	Chandrapur	51.75	50.50	75.50	81.90	As-Ws-Lc
		Dombivalli	51.00	64.50	43.00	72.29	As-Wc-Ln
		Aurangabad	56.75	55.50	50.50	68.87	As-Ws-Ls
		Navi Mumbai	47.00	66.00	43.00	72.87	An-Wc-Ln
		Tarapur	58.00	63.00	48.00	73.30	As-Wc-Ln
Odisha	3	Angul Talchar	61.75	60.50	48.00	72.86	Ac-Wc-Ln
		Ib valley	48.00	48.00	47.00	59.73	An-Wn-Ln
		Jharsuguda	65.00	50.50	47.00	73.31	Ac-Ws-Ln
Punjab	2	Ludhiana	49.50	68.00	48.75	75.72	An-Wc-Ln
		Mandi Gobind Garh	55.00	67.00	60.50	77.98	As-Wc-Lc
Rajasthan	3	Bhiwadi	62.75	46.00	46.00	70.63	Ac-Wn-Ln
		Jodhpur	57.50	50.50	69.00	78.00	As-Ws-Lc
		Pali	54.00	72.50	68.75	82.71	As-Wc-Lc
Tamil Nadu	4	Vellore	59.75	71.50	48.00	79.67	As-Wc-Ln
		Cuddalore	45.50	53.50	60.50	70.12	An-Ws-Lc
		Manali	55.50	69.00	48.00	77.26	As-Wc-Ln
		Coimbatore	32.38	48.00	30.50	53.14	An-Wn-Ln
Uttar Pradesh	6	Ghaziabad	69.50	76.00	48.75	84.13	Ac-Wc-Ln
		Singrauli	68.00	70.50	63.50	83.24	Ac-Wc-Lc
		Noida	50.00	72.50	45.00	78.69	As-Wc-Ln
		Kanpur	55.00	64.50	40.00	72.31	As-Wc-Ln
		Agra	57.00	55.00	49.50	68.71	As-Ws-Ln
		Varanasi-Mirzapur	44.00	47.00	42.50	56.91	An-Wn-Ln
West Bengal	3	Haldia	48.75	50.00	47.50	61.58	An-Ws-Ln
		Howrah	43.00	51.00	48.00	61.11	An-Ws-Ln
		Asansol	47.38	40.50	40.50	56.01	An-Wn-Ln
Ac = Air critical ; As = Air severe ; An = Air normal; Wc = Water critical ; Ws = Water severe ; Wn = Water normal;Lc = Land critical ; Ls = Land severe ; Ln = Land normal							

Note: The data presented in the table is from the year 2015.

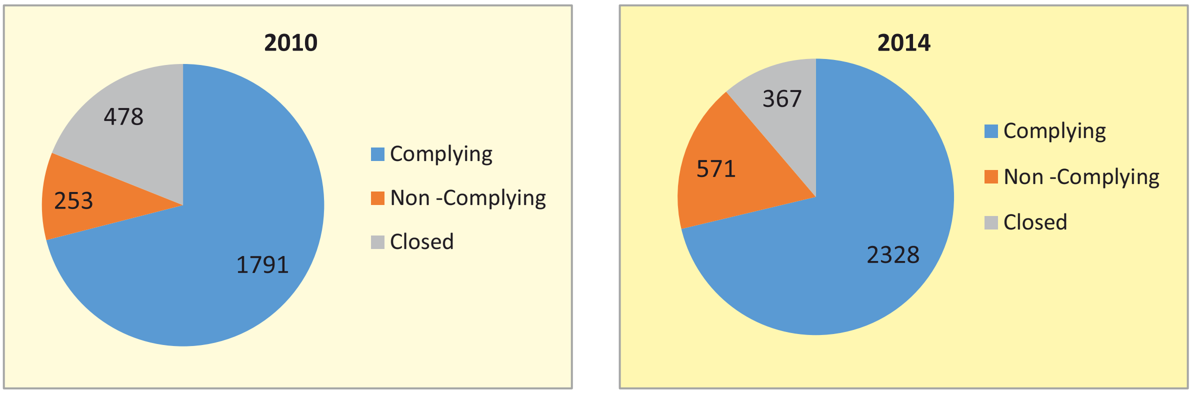
Source : Central Pollution Control Board, 2016

Figure 7.3: Number of Units for Each of the 17 Highly Polluting Industries



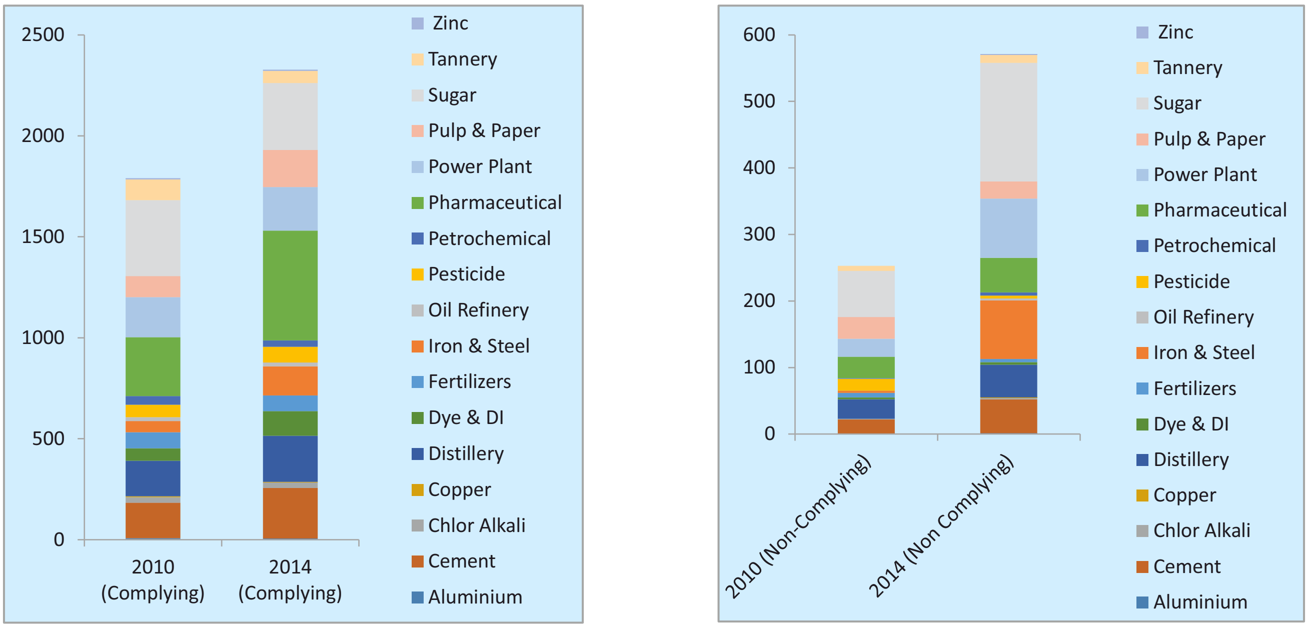
Source: Planning Commission, 2012

Figure 7.4: Compliance Status of 17 Highly Polluting Industries in 2010 and 2014



Source: Planning Commission, 2012 and ENVIS Centre-WWF India, 2014

Figure 7.5. Compliance Status of 17 Categories of Highly Polluting Industries



Source: Planning Commission, 2012 and ENVIS Centre - WWF India, 2014 facilities to ensure compliance with regulations, and this trend remains unchanged in the same period. However, the percentage of non-compliance has increased from 10 per cent in 2010 to 17 per cent in 2014. From sector-wise Compliance Status as shown in Figure 7.5, it is pertinent to mention that the non-compliance with regulations mandating pollution technology has been increasing in cement, distilleries, iron and steel, power plant and sugar industries .

As of the last count, there are 3,260 highly polluting industries of which only 929 industrial units have installed pollution control devices, and 920 industrial units have installed 24X7 Real Time Monitoring Systems (MoEF&CC, 2015). Figure 7.3 gives number of units for each of the 17 highly polluting industries. It is important to note that most manufacturing industries have the highest number of polluting units.

7.2.2 Environmental Issues with MSMEs

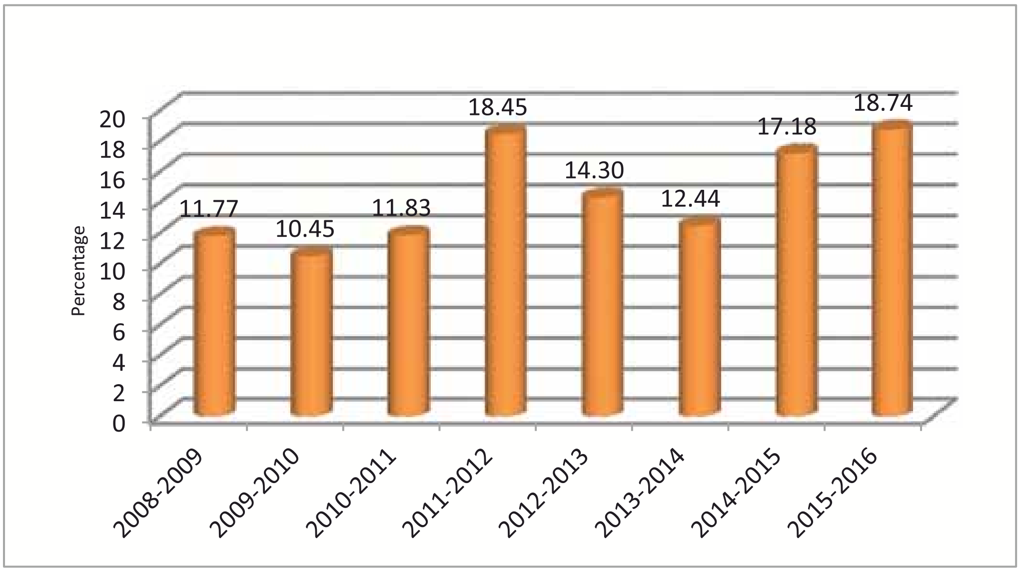
MSMEs play a pivotal role in driving the Indian economy. With a vast diversity in terms of its size, level of technology employed, range of products and services provided and target markets, the sector is engaged in manufacturing of over 6,000 products ranging from traditional to hi-tech items. Remarkable highlights in the recent times include MSME tool rooms providing at least ten components which were used in India's Mangalyaan mission. With over 46 million units based throughout the geographical expanse of the country, the sector is poised for rapid growth, and presents an opportunity for integration across all industry sectors.

In the recent years, MSME sector has consistently registered higher growth rate compared to the overall industrial sector. The annual growth rates of MSMEs can be seen in Figure 7.6, and observations from the graph highlighting the constant growth rate of around 11 per cent every year till 2010-11. However, recent data for 2015 has shown impressive year-on-year growth of 18.74 percent (MSME, 2015).

MSMEs have a major contribution in manufacturing industries upstream and downstream value chains. From an environmental perspective, it could have a profound impact, as MSMEs are often equipped with obsolete, inefficient, and polluting technologies and processes. It is estimated that 70 per cent of the total industrial pollution load of India is attributed to MSMEs (Planning Commission, 2012).

Regulatory mechanisms put forward by CPCBs, and respective State Pollution Control Boards to ensure compliance are poorly suited for MSMEs, as they are tailored more towards larger industries, impeding compliance for MSMEs. Major barriers towards adoption of environmental and social responsibilities include insufficient technology, expertise, training and capital and lack of initiatives tailored for small companies (UNEP, 2003).

Figure 7.6: Annual Growth Rate of MSMEs

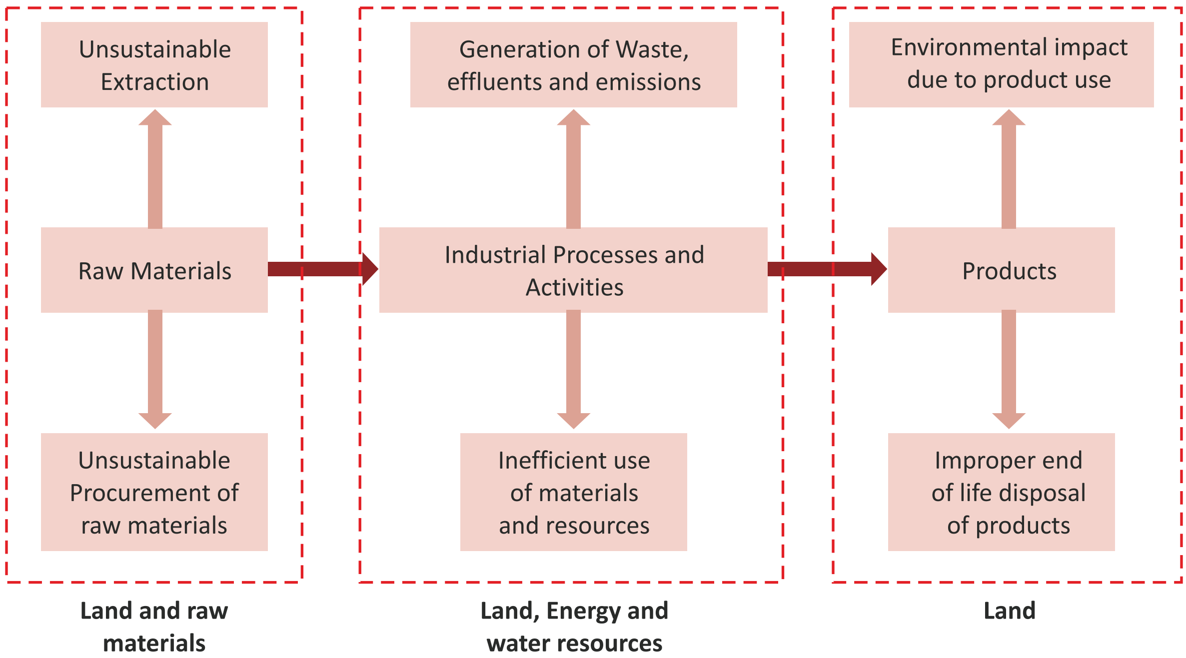


Source: Ministry of MSMEs, 2015

Environmental Impact of Construction Sector

The interlinkages between industries and the environment are exemplified by the construction industry. Sand is an important component of concrete, the mainstay of buildings today. Extensive and injudicious mining of sand from river beds has led to severe conflicts damaging natural drainage patterns and environmental flows. Rampant extraction has created resource scarcities in many parts of the country and compelled some states to ban its mining. Prices have risen, directly impacting the productivity of construction. This has forced the industry to look at alternatives like manufactured sand from stone quarries.

Figure 7.7: Pressures Exerted on the Environment by the Industry Sector



Source: Adapted from Planning Commission, 2012

7.3 PRESSURES

The previous section has established that environment and industrial growth are closely linked when it comes to the manufacturing sector. Manufacturing is vital for the sustainable growth of an emerging economy like India. Natural resources provide the basic inputs for industries in terms of materials, water and energy, and land to establish industry. Supporting economic growth requires large reserves of natural resources which exerts pressure on limited resources leading to multiple impacts on the environment. This challenge comes full circle with industries being impacted by subsequent resource scarcities.

The first point of interaction of the industry with the environment is during the procurement of raw materials like metals, minerals, food, fibre, etc. The activity is closely linked to environmental and social issues throughout the lifecycle from exploration, till the mine is closed. Over-exploitation and unsustainable practices in mining are responsible for damage to land, water, air and people. Industry has the potential to upset the delicate ecological balance of an area. The use of hazardous chemicals lead to contamination of the surrounding air, water and land, releasing sludge, leachates and noxious emissions damaging the biodiversity of the area.

Extraction and mining of natural resources has a series of environmental impacts ranging from deforestation and land degradation to groundwater/ surface water pollution , and occupational health and safety concerns due to the emissions.

7.3.1 Rising Consumption of Raw Materials

In the manufacturing sector material security is vital to its survival and growth. In India, the material and energy cost share for the selected subsectors in manufacturing is 71 per cent. These subsectors include food products, beverages, rubber and plastic products, fabricated metal products, machinery and equipment, furniture and other manufacturing sectors (IGEP, 2013). With manufacturing based job creation as the current focus, it is to be anticipated there will be an increase in extraction of materials.

Consumption of important minerals by various industries is constantly increasing annually. The total tally of mineral consumption increased to 965 million tons in 2013-14 from 940 million tons in 2011-12 (IBM, 2016). This tally included minerals such as bauxite, iron ore, limestone etc. which are consumed by important manufacturing sectors in India.

Besides these minerals, energy critical metals and technology metals like Germanium, Gallium, Osmium, Indium, Selenium, Cobalt, Niobium, Beryllium, Tantalum, Wolfram, Bismuth, etc. and rare earth metals, which have a wide application in electronics industry are emerging as critical inputs. (Planning Commision, 2011). Sustainability challenges at both the extraction and the production step of industries need to be addressed to ensure sustainable growth in the industrial sector.

7.3.2 Land Management and Land Use Change

Land is a very important though often neglected resource when discussing industries. It is a natural, immovable and non-renewable resource. The most direct linkage of land with industries is its acquisition for industries. Currently, industrial utilisation of land is estimated to be two to four percent of total land available in India. Even with increased industrial activities in the future, it is expected that there would be sufficient land for all users, including industry (Planning Commission, 2013).

Land in India has a special significance because it carries a huge tangible and emotional value for owners, and also for those whose livelihoods depend on it. Thus, land acquisition for industries has diverse social implications associated with it. Relocation and rehabilitation of both the people and the land is imperative.

Mining is associated with the land. Many of India's mineral reserves are in areas under forest cover. In Korba, Chhattisgarh, the largest coal-producing district, forests cover 51 per cent of the geographical area. Of the six major mining districts in Madhya Pradesh – Katni, Rewa, Satna, Shahdol, Sidhi and Chhindwara (except Rewa) have more forest cover than the national average. In Sidhi and Chhindwara it is 85 and 80 per cent more respectively. Angul the largest coal producing district in Odisha has 42 per cent area under forests. Overall, the total forested area in the 50 major mineral-producing districts is 18 per cent of India's total forest cover (Bhushan, Hazra, & Banerjee, 2008).

Many other forests cover are part of the watersheds of our major river systems. Over 80 per cent of the coal in Jharkhand and substantial portion of the Raniganj coalfields in West Bengal lie within the Damodar river basin. The Mahanadi-Brahmani basin holds all the coal reserves of Odisha. In Rajashtan, mica is distributed around the rivers Sambhar, Luni and Chambal (Bhushan, Hazra, & Banerjee, 2008). Thus, if not properly managed, mining in India may cause significant damage to our forest and water systems.

The land-use pattern undergoes a change due to the use of land for mining, dumping, and associated activities. It begins with the removal of vegetation and displacement of local populations. The topography, land form and subsequently drainage patterns of the area undergo alterations due to excavation leading to open pits and dumping of overburden rock mass in the form of land heaps. The land-use in the surrounding areas may get affected due to the impacts of mining on water regime. Leachates from overburden dumps and rock masses, and polluted water from the pits affect the characteristics of the top-soil affecting the land-use (CPCB, 2007).

Small and isolated deposits of minerals are scattered all over the country, leading to small scale or artisanal mining. With modest demand on capital expenditure and short-lead-time, they provide employment opportunities for the local population. However, due to diseconomies of scale, they could also lead to sub-optimal mining and ecological disturbance (Planning Commission, 2012).

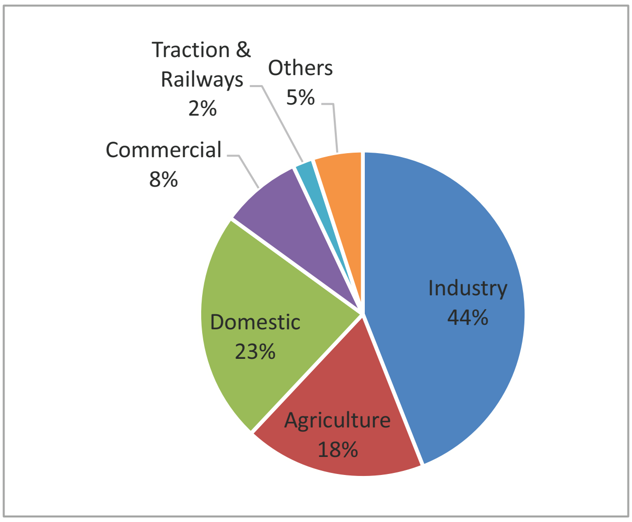
7.3.3 Rising Energy Demand

Energy is a key resource input required at all the stages of the industrial lifecycle; however material extraction and production processes are more energy intensive. In 2007, the industrial use of energy in India stood at 150 million tonnes of oil equivalent (Mtoe), accounting for 38 per cent of the country's total energy use. Though India is the fourth largest consumer of global industrial energy, surpassed only by China, the United States and Russia, its share is only 5 per cent of the total (Planning Commission, 2013).

The electricity consumption in the Industry sector has increased at a much faster pace as compared to other sectors during 2005-06 to 2014-15 with CAGRs of 10.69 per cent. The annual energy consumption by industries in the last decade has increased by 64 per cent. Industry also accounted for the largest share in final consumption of electricity in 2014-15 (MOSPI, 2016).

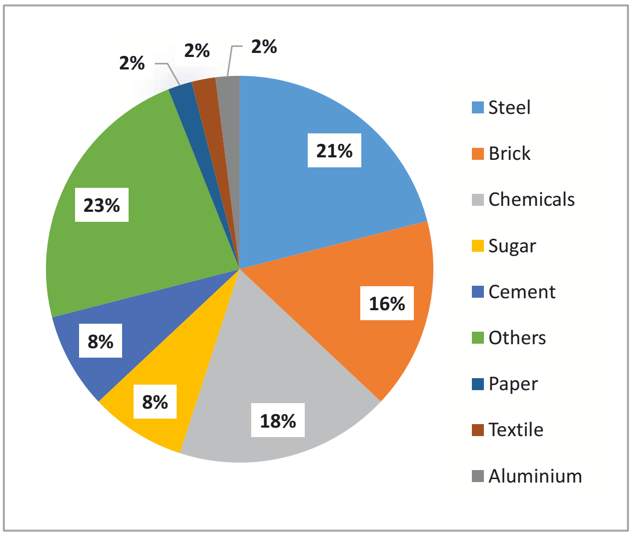
Industries' share in final consumption is expected to rise above 50 per cent by 2040. Industrial energy use is buoyed by substantial growth in output of steel, cement, bricks and other building materials, and by the expansion of domestic manufacturing. Energy demand has traditionally been dominated by the buildings sector (which includes residential and services), although demand in industry has grown more rapidly since 2000, overtaking buildings as the main energy user in 2013. (IEA, 2015).

Figure 7.8: Sector Wise Consumption of Electricity in India



Source: Ministry of Statistics and Programme Implementation, Energy Statistics, 2016

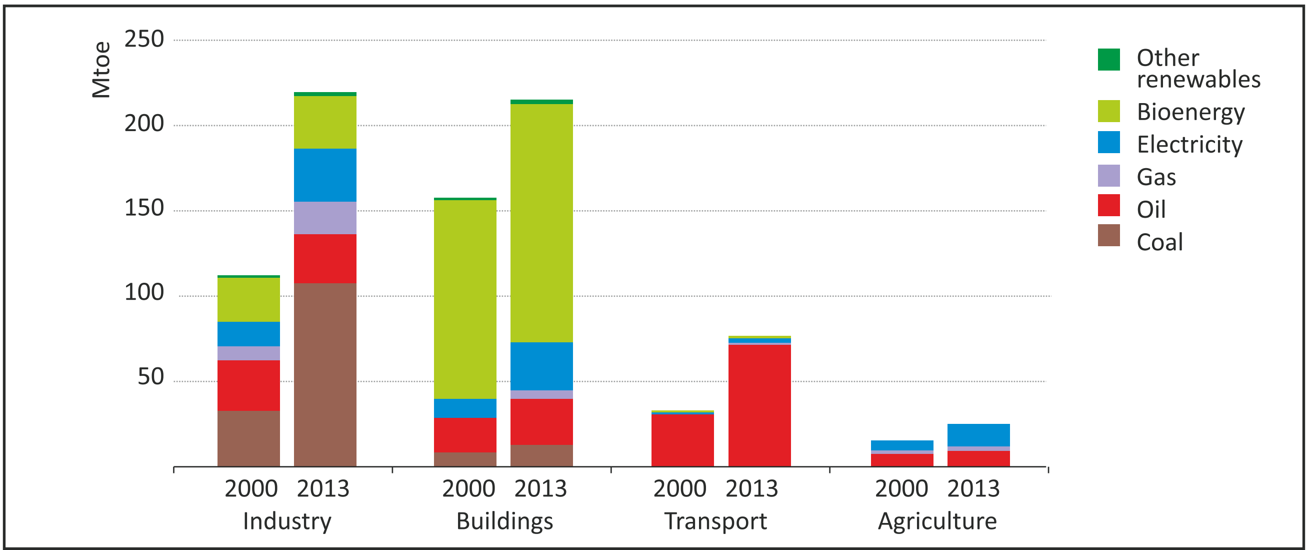
Figure 7.9: Current Industrial Energy Consumption by Sector



Source: International Energy Agency, 2015

Figure 7.9 shows the sector wise industrial energy consumption; it can be seen that Iron and Steel, Cement, Chemicals and Petrochemicals, Pulp and Paper and Aluminium, are the five most energy intensive industrial sectors, accounting for 56 per cent of India's industrial energy consumption in 2007. The Compound Annual Growth Rate (CAGR) of the energy consumption of manufacturing industries in India from 1990 to 2008 was 9.8 per cent (Planning Commission, 2013). Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity as seen in Figure 7.10. Large expansion in the energy-intensive sectors, including a tripling in steel production, is one component. Nonetheless, consumption levels of cement and steel are still relatively low for a country of India's size and income levels. Consumption of cement is around 220 kilograms per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1770 kg per capita) (OECD/IEA, 2015). Steel consumption is at 217 Kg per capita, again low as compared to china which is at 510 Kg per capita (Ministry of Steel, 2015). The energy intensity of Indian industries has shown a decreasing

Figure 7.10: Energy Demand by Fuel in Selected End-use Sectors



Source: International Energy Agency, 2015

trend; however, this trend needs to be accelerated and policy interventions may be required to overcome the challenges the industry face as a result of global energy and emission linked constraints (Planning Commission, 2013).

7.3.4 Rising Water Demand

Industries are the second largest user of water after agriculture, accounting for about eight per cent of the current water use. With rapid industrialisation and urbanisation, the water requirement for energy and industrial use is estimated to rise to about 18 per cent (191 BCM) of the total requirements in 2025 (CPCB, May 2013). With its increasing population and industrial activity, India is moving towards perennial water shortages. Groundwater has emerged as an important source to meet the water requirements of industries.

7.4 IMPACTS

This section focuses on impacts of industries and mining on air, water, land, health, social well-being and climate change.

7.4.1 Air Pollution

Industrial air pollution is particularly important to consider as the emitted pollutants do not remain concentrated in the areas around the industry but spread with wind polluting the ambient air in areas downstream as well.

Photo 7.1: Exhaust from industrial processes causing air pollution

Combustion of primarily fossil fuels in the production process of industries leads to the emission of carbon dioxide (CO_2), sulphur dioxide (SO_2), suspended particulate matter (SPM), oxides of nitrogen (NO_2) and greenhouse gases (GHGs). The emissions depend on the composition of the fuel as well as the efficiency of the industrial plant. Process based reactions also results in emissions. These include the gases mentioned along with hazardous substances like SF6, HFCs, CFCs, Cyanide, lead, fluoride, chlorine, mercury, asbestos, etc.

Air quality monitoring studies shows that SPM levels in most urban areas are considerably higher than the acceptable level as per the National Ambient Air Quality Standards. It is important to note that apart from industries, vehicular pollution is also a significant contributor to air pollution. These emissions contribute to a wide range of health and environmental impacts including deterioration of air quality, toxicological stress on human health and ecosystems, photo oxidation formation (smog), stratospheric ozone depletion, climate change, degradation of air resources and noise among others. Besides emissions, mining operations generate noise and fugitive dust. Mining dust is known to cause problems like silicosis, asbestosis, cataract and pneumoconiosis. Also, methane emissions from mining contribute to global warming.

7.4.2 Water Pollution

Poor or improper discharge management systems could lead to generation of highly toxic and organic wastewater with toxic chemicals such as mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As) etc. into the rivers which kills fish and other aquatic life besides being toxic to human beings. An estimated 501 MLD of industrial effluent is discharged into River Ganga by number of industries. CPCB estimated that there are 764 Grossly Polluting Industries (GPIs) discharging wastewater to main stem of River Ganga. Sugar, Distilleries, Pulp and Paper, Tanneries and Textiles were found to be the major industrial sectors responsible for pollution in Ganga (CPCB, 2013). Another concern is the entry of heated water from industries and power generation plants that results in a decrease in the oxygen concentration and subsequent decay of organic matter and loss of biodiversity.

Water bodies near mines get polluted due to erosion and leaching from the overburden dumps and mining areas, discharge of pumped mine water, effluents, oil and grease, solid waste disposal sites, and other activities in the vicinity of the water bodies. This is aggravated in the rainy season due to surface run-off. Associated activities cause changes in ground water flow patterns, and the hydrodynamic conditions of recharge basins, lowering of water table, reduction in volumes of subsurface discharge to water bodies/rivers, disruption and diversion of water courses/drainages pattern, contamination of water bodies, affecting the yield of water from bore wells and dug wells etc. (CPCB, 2007). Acid mine drainage is caused when sulphide minerals in mine seams are exposed to air and mine water, eventually leading to dissolution and release of toxic metals into other water bodies.

Photo 7.2: Industrial effluents causing water pollution

Delhi-Mumbai Industrial Corridor (DMIC)

Delhi - Mumbai Industrial Corridor Project is India's most ambitious infrastructure programme aiming to develop new industrial cities as "Smart Cities" and converging next generation technologies across infrastructure sectors. An investment of USD 100 billion is supporting the development of 8 industrial regions / cities.

About 35-40 per cent projects are trunk infrastructure projects for which funds are provided by Government of India through DMIC Trust. The balance 60-65 per cent projects are being structured under Public Private Partnership (PPP).

Other Industrial Corridors being developed in the country include

- Chennai-Bengaluru Industrial Corridor
- East Coast Economic Corridor Project
- Amritsar Kolkata Industrial Corridor
- North East Myanmar Industrial Corridor
- Bangalore-Mumbai Economic Corridor Project

Source: http://www.dmicdc.com

7.4.3 Land Contamination and Hazardous Waste

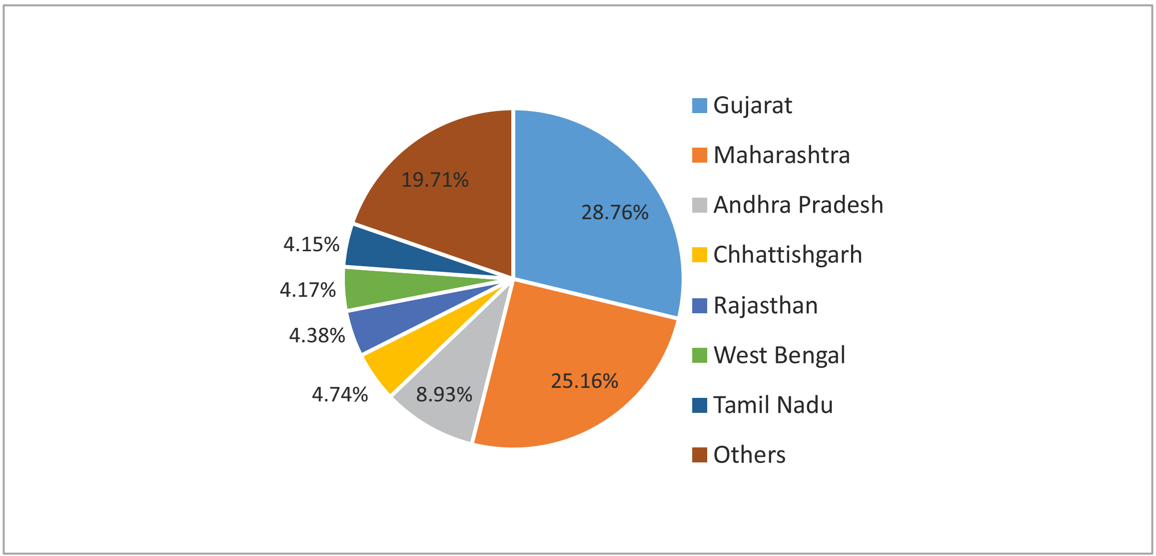
The site of the industry determines its interaction with the other settlements, and land uses in the vicinity. Results from research studies indicate that effluents and other waste materials from industries contribute to significant alteration of soil quality. In 2009, there were an estimated 36,165 hazardous waste generating industries, generating 6.2 million tonnes of hazardous wastes every year (CPCB, 2010). In 2015, the number of industries generating hazardous waste increased to 42,429 generating 7.8 million tonnes of hazardous waste annually (CPCB, 2015). Seven states are responsible for generating 80.29 per cent of country's total HW. Gujarat and Maharashtra also lead in the wasteland filled contributing to 40.58 per cent and 20.83 per cent of the total land disposable HW, and account for 62.87 per cent of country's total incinerable hazardous waste.

The Common Treatment Storage and Disposal Facilities (TSDF) developed for the disposal of land disposable waste have increased from 25 operational facilities in 10 states in 2009 (CBCB, 2010) to 28 operational facilities in 17 states with a cumulative capacity of 32 million tons for secure landfills and about 0.18 million for incineration. There are deficiencies in generation (0.61 million tons) and treatment capacity of incinerable hazardous waste (CPCB, 2015).

Mining activity often leads to environmental problems like land degradation in open-cast mining and land subsidence in underground mining. Overburden is the natural rock and soil that sits above and around the ore body that needs to be removed to allow access to the ore. Scientific methods to remove overburden are not followed, leaving considerable abandoned areas in dilapidated conditions. High stripping or overburden to ore ratio makes managing the waste a difficult issue. According to the data generated by the Indian Bureau of Mines, average stripping ratio for limestone mines in India is 1:1.05. Indian bauxite has a stripping ratio of around 1.2. For iron ore mines, the stripping ratio ranges around 2-2.5 (Sahu, H. B., & Dash, S., 2011). Goa has a relatively high overburden to ore ratio (of an average of about 2.5 to 3:1) in iron ore mines, and thus generates a large quantity of waste material. The waste dumps in most cases are outside mines due to small lease areas. Surface runoff from these dumps affect agricultural land in the surrounding villages and water bodies through siltation (Institute for Studies in Industrial Development, 2012). In the state of Goa alone, there are over a 100 acres of land that are unproductive and is used as dump storage for over 700 Million Metric Tonnes of waste (DoM, 2013).

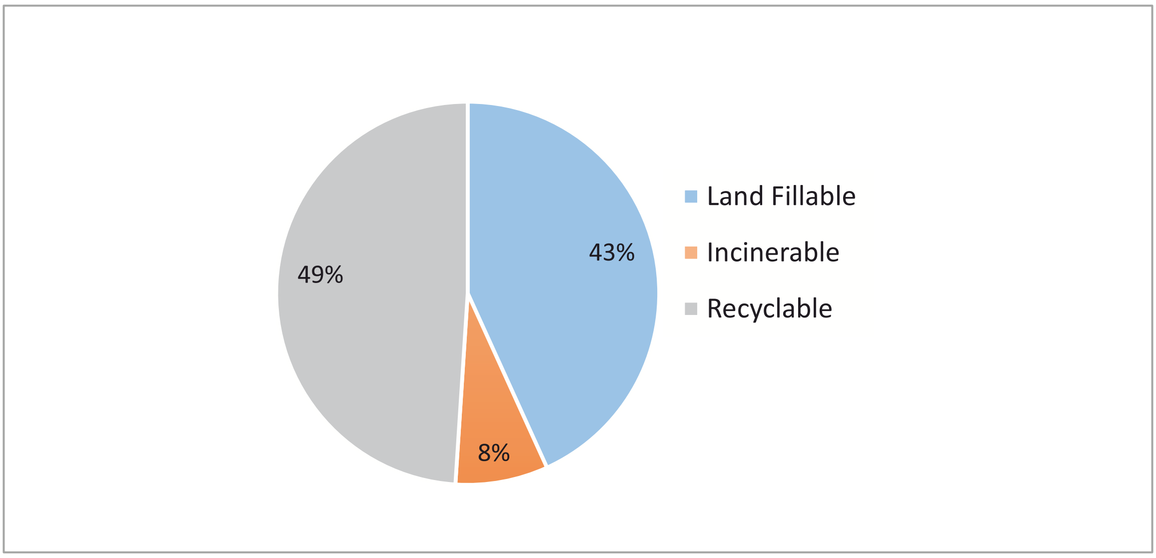
Open-cast mining in areas with actual forest cover leads to deforestation. The major adverse impacts are loss of habitat, biodiversity, rare flora & fauna, other aquatic life, migration of people, wildlife and overall

Figure 7.11: Distribution of Hazardous Waste in India



Source: Central Pollution Control Board, 2015

Figure 7.12: Characteristics of Hazardous Waste in India



Source: Central Pollution Control Board, 2015

disruption of the ecology of the area. A study in mining blocks of Keonjhar, Odisha, highlights these impacts. The land use pattern surrounding the mines has changed rapidly in the study area involving loss of forest cover and degradation of agricultural land; and an abrupt increase in waste land.

Apart from inadequate efforts at land reclamation and afforestation in the mining areas, over burden and poor management of mines has also resulted in the land use change. Also, soil quality of agricultural land has been affected adversely due to the deposit of ore dust generated from the nearby mines. Mining and consequent deforestation and heavy vehicular traffic carrying mineral ores have led to destruction of elephant habitats and corridors, leading to increased human-animal conflict and reduction in the elephant population in Keonjhar (Vasundhara, 2008).

Another concern is the rampant and often illegal mining of sand and stone (Aggregate) from riverbeds. Sand and gravel contributed 17.5 per cent to the value of minor minerals in 2014-2015 (Ministry of Mines, 2016). The demand is expected to more than double by 2020 to reach 1.4 billion tonnes (The Freedonia Group, 2013). Increasing demand due to the construction boom, coupled with easy availability, and limited government oversight has given rise to a thriving illegal trade in sand. It is primarily river sand that is used for construction purposes, and its mining has harmful impacts. The Supreme Court recently warned that riparian sand mining is undermining bridges, disrupting ecosystems, and harming wildlife all over the country (Beiser, V., May, 2015). River sand mining can damage private and public properties as well as aquatic habitats. Excessive removal of sand may significantly distort the natural equilibrium of a stream channel. Removing sediment from the active channel bed in river interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream and induces channel adjustments extending considerable distances beyond the extraction site. As the hydrological system is altered, local groundwater is affected, which leads to water scarcities; affecting agriculture and local livelihoods (MoEF&CC, 2016).

Illegal mining has forced several state governments and the National Green Tribunal to impose bans on sand mining across the country and issue warnings to defaulting states including Rajasthan, Uttar Pradesh, Haryana, Delhi, etc. Such bans have created a demand and supply gap, resulting in price spikes and often a thriving black market (Nagrath, 2015).

7.4.4 Impacts on Health and Social Wellbeing

Mining and quarrying are important sectors in the economy providing jobs and employment especially in rural areas where most mineral deposits are found. Once a reserve is discovered, and a mine is established, there is a ripple effect in the area, bringing investment to the region; the value of land increases, there is an influx of people and businesses, etc. It brings about infrastructural development, i.e. roads are constructed, schools and hospitals are established, and communication facilities are developed etc., which tend to improve the quality of life of the complexes. The local people are exposed to development, and aspirations of the overall community development in the mining complexes gets enhanced (CPCB, 2007).

Mining involves clearing the surface to reach the mineral reserve. This entails the removal of people, buildings and vegetation across the mine and associated areas. People living in these designated areas generally depend directly on land for their livelihood. Thus, people lose both home and livelihood, a huge cost in the pursuit of mineral resources.

Most mineral rich states in India suffer from the resource curse. It is also known as the paradox of plenty, that translates to areas with an abundance of natural resources, specifically non-renewable resources like minerals and fuels, tend to have less economic growth, less democracy, and worse development outcomes than areas with fewer natural resources. Jharkhand, Chhattisgarh and Odisha which are among the most mineral rich states, have low per capita incomes, higher levels of poverty, lower growth rates and higher levels of infant and maternal mortality compared to less endowed states. Research states that not only do local communities in mining areas remain poor, their vulnerability increases due to displacement and environmental degradation. Around 60 per cent of the 50 major mining districts are among the 150 most backward districts in the country (Bhushan, Hazra, & Banerjee, 2008).

People seek employment in the mining region specially for economic opportunities. The development of industries and its associated activities in the area increase the level of the economic activities manifolds. Increased industrial and economic activities generate more money and increase the buying power of the people directly and indirectly associated with these activities. This leads to an increase in the cost of living, which adversely affects the other people, including local people, who are not associated with these activities (CPCB, 2007).

The annual rate of criminal acts for every legitimate mine in the country is recorded at 30 (HRW, 2012). Another issue with mining, is the failure of key regulatory mechanisms to ensure legal mine operators comply with the law and respect human rights (HRW, 2012). In iron mining areas of Goa and Karnataka, for example, reports have cited extensive evidence of water pollution, toxic waste and health problems resulting from metallic dust.

Deterioration of health is a major problem for local people, as the resettlement sites are situated close to mining projects, resulting in respiratory diseases.

Table 7.2. Notified Diseases Connected with Mining Operations

Year	Notified Diseases
1952	Silicosis Pneumoconiosis
1956	Manganese Poisoning - Nervous type
1986	Asbestosis Cancer of lung or the stomach or the pleura and peritoneum (i.e. mesothelioma)
2011	Noise Induced Hearing Loss Contact Dermatitis caused by direct contact with chemicals Pathological manifestations due to radium or radioactive substances

Source: Ministry of Labour and Employment, 2011

Impacts of Mining

- Land disturbance and change in land use pattern
- Affecting floral and faunal habitat
- Disturbing the natural watershed and drainage pattern of the area
- Disturbing the aquifer causing lowering of the water table
- Air pollution due to dust and noxious fumes
- Water pollution due to surface run off, spoil dumps, seepages/overflow from tailings dam leads to siltation of surface water bodies and blanketing the agricultural fields
- Noise and ground vibrations due to blasting
- Displacement of people
- Loss of livelihood
- Change in population dynamics
- Water Scarcity
- Increase in cost of living
- Health Impacts

Source: Central Pollution Control Board, 2007

Health impacts can range from mild irritations like watery eyes, coughing and wheezing to respiratory distress resulting in development of diseases such as asthma, bronchitis, emphysema, heart disease and cancer. Ill-health causes the locals to spend most of their earnings towards medical treatment (Ministry of Tribal Affairs, 2014).

Many research studies have been conducted to draw out the correlations between mining and the impact on the health of workers as well as the local communities. Table 7.2 shows the list of diseases that have been notified as diseases connected with mining operations.

Photo 7.3: Effects of global warming as a result of GHG emissions

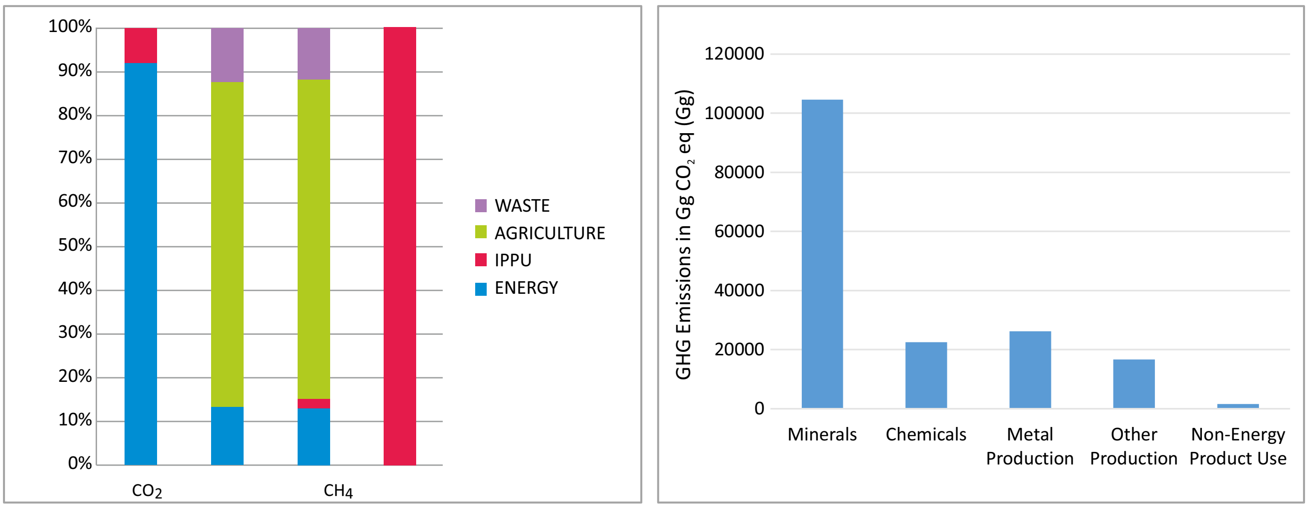
7.4.5 Climate Change

As per the national GHG inventory for the year 2010, India emitted 2,136.84 million tonnes of CO_2 equivalent greenhouse gases. The energy sector which includes electricity production, fuel combustion in industries, transport and fugitive emissions, contributed 71 per cent to the total emissions, and was the top emitter of GHG emissions in 2010. Industrial Processes and Product Use (IPPU) contributed eight per cent to the total GHG emissions. Further, the industrial process and product use sector emitted 1.43 Gg of fluoroform (HFC-23), 2.13 Gg of tetrafluoromethane (CF_4), 0.58 Gg of hexafluoroethane (C_2F_6) and 0.0042 Gg of sulphur hexafluoride (SF_6) which together amount to 36,027.53 Gg CO_2eq emissions (MoEF&CC, 2015). The inventory includes:

- Mineral industries — Cement, lime, glass and ceramics.
- Chemicals — Ammonia, nitric acid production, carbide production, titanium dioxide production, methanol production, ethylene, ethylene dichloride (EDC) and vinyl chloride monomer (VCM), ethylene oxide, acrylonitrile, carbon black, soda ash production and caprolactam.
- Metal production — Iron and steel, ferro-alloys production, aluminum, lead, zinc, and magnesium
- Other production — Production of halocarbons HFC-134a and HFC-23 and consumption of SF_6.
- Non-energy product use — Use of lubricants and paraffin wax.

Mineral industries dominate the GHG emissions in the sector as seen in Figure 7.13

Figure 7.13: Distribution of GHG Emissions in 2010: by Sectors (left); by Categories of IPPU Sector (right)



Source: Ministry of Environment, Forest and Climate Change, 2015

7.5 RESPONSES

Improving resource and energy efficiency of the sector is imperative to growth and sustainability. While we drive growth in the economy, we have to be cognizant of the fact that sustainability needs to be a key principle going forward. This is reflected in the various initiatives undertaken by the Government and industries in India.

7.5.1 Industrial Policies

The National Manufacturing Policy envisions that the growth of the manufacturing sector has to be made sustainable, particularly ensuring environmental sustainability through green technologies, energy efficiency, and optimal utilisation of natural resources and restoration of damaged / degraded eco-systems (Department of Economic Affairs, 2015). It also specifies that Environmental Clearances for National Investment and Manufacturing Zones (NIMZ) units under the EIA Notification, 2006, shall be considered on a high priority, and the units thereon will be exempted from public hearing provided under the EIA Notification, 2006. Further, facilitative instructions and guidelines may be issued at the Central and State level from time to time aiming at promotion of NIMZ investment while safeguarding environmental integrity. Environmental and water audits will be mandatory for industrial and institutional units in NIMZs.

A technology acquisition and development fund has been proposed to promote appropriate technologies, creation of a patent pool and the development of domestic manufacturing of equipment, used for controlling pollution and reducing energy consumption. Incentives for green technology and practices include: subsidies and tax rebates for technology for controlling pollution, reducing energy consumption and water conservation and recycling (DIPP, 2011).

The National Mineral Policy, 2008, proposed a framework of sustainable development which takes care of bio diversity issues, and ensures that mining activity takes place along with suitable measures for restoration of the ecological balance. The NMP 2008 mandates all mining to be undertaken as per the Sustainable Development Framework with the objective that miners leave the mining area in better ecological shape than found. Thus, it lays down guidelines for mining activities that prohibit operations in ecologically fragile and biologically rich areas; advocate leases be granted only with a proper mining plan, promote reclamation programmes and beneficiation; and agglomeration techniques to improve mine productivity as well as protect interests of indigenous populations (Ministry of Mines, 2008).

Industries have an important role in the State Action Plans on Climate Change. The Assam plan focuses at identifying opportunities for improving water and energy efficiency in industries. Chhattisgarh plans examine ways of incentivising such investments (taxes, subsidies and measures to improve access to capital) and linking it to initiatives such as energy efficiency projects, through which economic gains could accrue; and to build adequate linkages with financial institutions; build capacities of industrial establishments in the ability to access and absorb technological information about available options. Gujarat planned energy efficiency initiatives for industry through technology development, demonstration and deployment with a focus on MSMEs. The policy framework revisions seek to address barriers like conflicting market signals, limited capital availability, inadequate information flow, lack of expertise, inadequate workforce capabilities, performance risks and costs for new technology, insufficient capital allocation for upgrades, and counterproductive policies.

The Maharashtra plan recommends a combination of regulatory and market-based measures to encourage water recycling and reuse by industries. The focus of Andhra Pradesh is to enforce ‘cleaner production processes’ and waste minimisation across industries, minimize environmental damage and install pollution control measures. Odisha is developing GHG profiles of major industrial clusters, emphasising on waste, water and energy efficiency. It aims to develop emission targets for thermal power plants. (MoEF&CC, 2016).

7.5.2 Pollution Control Initiatives

The government has undertaken multitude of programs to mitigate industrial pollution. Some of the highlights are discussed below.

- Clean Ganga Action plan: While a comprehensive plan has not been launched, entry level activities are already underway. After identifying water polluting industries in Ganga basin, CPCB has prepared sectors specific plans for prevention and control of pollution in river Ganga from five key industrial sectors viz. Distilleries, Pulp and Paper, Sugar, Tanneries and Textiles. CPCB has issued directions to the states under Water (Prevention and Control of Pollution) Act, 1974, and Air (Prevention and Control of Pollution) Act, 1981, to achieve Zero Liquid Discharge (ZLD) in a fixed time (ENVIS CENTRE CPCB, 2015).

- India Water Tool (IWT): An India-specific, free, online tool, which helps companies understand potential water availability and quality risks across their India sites, co-chaired by ACC and PwC, with Infosys as the technology partner. Since its launch in 2007, the Global Water Tool has been updated twice and has been used by more than 300 companies (World Business Council for Sustainable Development, 2013).
- Central Pollution Control Board has set up national air quality monitoring network with the help of State Pollution Control Boards. The network consist of 346 stations covering 130 Cities, 26 States and 4 Union Territories. The parameters are Sulphur Dioxide, Oxides of Nitrogen and Respirable Suspended Particulate Matter. It is expected that there will be 104 observations in a year taken twice a week, 24 hourly at uniform level.
- The MoEF&CC directs mining projects to monitor and display key parameters like ambient air quality parameters (SPM, RSPM and NOx for open-cast mines), vibration, quality of discharge water (TDS, DO, pH, TSS, Cr+6) and plantation (number of trees planted, calendar-year-wise and area covered). Small mines are recommended to form a cooperative and monitor environmental parameters as a group (MoEF, 2009).
- Environmental Impact Assessment: Mining projects of major mineral with more than 5ha lease area need a clearance before they start operation. Though, it ignores smaller mines which are rampant across the country and touted to be major causes of pollution and environmental degradation.
- Under the Air Act, Water and Environment Act, all polluting facilities are legally required to obtain authorization from their respective SPCB consent (permit) to establish (CTE), and then consent to operate (CTO). Also, quarterly reports on water and air pollution are obtained from specified industries (including mining) and registers are maintained in SPCBs showing pollution with reference to standards. In spite of these legal provisions, there is a laxity in compliance mainly due to the lack of resources and capacity in the regulatory agencies to monitor compliance (Institute for Studies in Industrial Development , 2012).

Table 7.3 presents some of the measures mining facilities have undertaken to manage air pollution.

There are also initiatives at the state level that promote eco-friendly technology use in industries. The Bihar State Pollution Control Board and the Department of Environment and Forests set up an Inter Departmental Task Force (TF) on Accelerating Cleaner Production Systems in the Building Materials Sector in Bihar in June 2012 with a mandate to recommend, monitor and advise on use of low carbon technologies and building materials in Bihar, to ensure savings of coal and soil and reduce pollution from the operation of existing brick kilns.

The Gujarat Pollution Control Board (GCPB) with help from the University of Chicago reformed their environmental audit system. The new guidelines require environmental auditors to be randomly assigned to industrial plants, and have their work double-checked for accuracy. The pilot study found that making environmental auditors more independent improved the accuracy of audit reports on plant pollution. In response, audited industrial plants reduced their pollution emissions (Rosenbaum, 2015).

7.5.3 Energy Efficiency Initiatives

A reduction of emission intensity of GDP by about 12 per cent between 2005 and 2010 has been achieved against India's voluntary pledge to reduce the emission intensity of its GDP by 20-25 per cent by 2020, compared with the 2005 level. (MoEF&CC, 2015). An analysis tracking a transition from the Baseline Inclusive Growth (BIG) to Low Carbon Inclusive Growth (LCIG) scenario indicates a reduction in 63 billion kWh of electricity, 741 MT of coal, 3 MT of petroleum products and 7 billion cubic meters of natural gas. Thus, there is considerable scope for energy savings in industries (Planning Commission, 2014).

The industry sector has already made significant advances in the conservation of energy. Government policies, campaigns by industry associations and strategic decisions by firms have all contributed to

Table 7.3: Air Pollution Control Measures Adopted in Mines

Potential Sources of Air Pollution	Magnitude of Air Pollution	Control Measures
Drilling	High dust generation Risk of occupational hazard.	Wet drilling technology or dry drilling fitted with bag filter. Driller shall be equipped with closed cabin personal protective gear to reduce occupational hazard.
Blasting	High dust generation (Impact lasts for short period)	By improvising blasting technique and adopting controlled blasting methods. Water spray prior to blas ting. No blasting should be allowed in the areas close to human habitation. Rock breakers should be employed instead of blasting
Loading material on dumper	Air emission	Air conditioned cabin for loading operator Water spray on mineral ore / overburden material prior to loading.
Transportation	High dust potential	Both dumper and conveyor transportation. Provision for automatic water sprinkle system on permanent road and water spray by tankers on temporary road. Covering of the material with turpentine in case of long haulage or in case the road is passing through in close proximity of habitation Green belt of trees with good footage on both side of haul road. Provision of water spay on the dumper to arrest fine dust before it is transported to crusher.
Crushing of ore	High potential of dust and occupational hazard	Automatic water spray in crusher hopper and unloading point. Suitable enclosure for the conveyor system. Provision of bag filter in crusher unit. Barrier in form of greenbelt all around the vicinity of the crusher to trap fugitive dust.
Storage of ore	High potential and occupational hazards	Covered storage yards with greenbelt of adequate width all around

Source : Ministry of Environment, Forest and Climate Change, 2010

sizeable improvements in the intensity of energy use in industries. The major energy consuming sectors implemented varied measures, such as, promotion of fuel-efficient practices and equipment, replacement of old and inefficient boilers and other oil operated equipment; and fuel switching and technology upgradation (MoEF&CC, 2015).

Implementig energy efficiency policies for SMEs is difficult due to their diverse nature, lower awareness, the perceived risk of some efficiency technologies, lack of capital and high transaction costs. The Bureau of Energy Efficiency has targeted industrial clusters, where SMEs have based themselves around locally available resources. In these clusters, energy use assessments, efficiency manuals and capacity building are provided to particularly energy intensive SMEs, such as the food, brick or textile companies, with the objective of saving 1.8 Mtoe in 2016/2017. Financial assistance and low-interest loans, partially funded by development banks are available for selected energy efficiency measures and management systems in SMEs (OECD/IEA, 2015).

The main policy driver, the National Manufacturing Policy coupled with National Mission on Enhanced Energy Efficiency (NMEEE), introduced the Perform, Achieve and Trade (PAT) scheme in 2012, estimated to lead to a cumulative energy savings of 6.7 Mtoe in the first round of the PAT cycle by 2015. It specifies energy saving targets for 478 facilities with an energy consumption of more than 30 thousand tonnes of oil equivalent (ktoe) (lower for some industries) in the thermal power, aluminium, cement, chlor-alkali, fertiliser, iron & steel, paper and textiles industries. The companies account for 164 Mtoe of energy consumption (54 percent of India's total). Each company is subject to an energy consumption reduction target calculated using production and annual energy consumption data over five years (2006-2010) submitted by designated consumers, who receive tradable, certified energy savings credits if they hit efficiency gains beyond their targets.

In parallel, the central government promotes complementary actions aimed at correcting market failures in the adoption of environment-friendly technologies. In particular, it subsidizes manufacturing firms by a linked capital subsidy scheme to mitigate the high upfront costs of new technologies that aim to replace old machines with less energy intensive technologies. These subsidies reduce the payback period for energy saving investments, which would otherwise average about three years. Even before the end of the first PAT pilot period, results were encouraging (UNIDO, 2015). In 2013, an industry survey by the Confederation of Indian Industries of 55 Indian companies producing 10 per cent of India's total emissions and 45 per cent of its industrial emissions, revealed that 93 per cent of these companies were implementing emission reduction initiatives. These companies together were cutting 2.5 million metric tonnes of carbon dioxide equivalent annually (Clough, J., 2015).

The second cycle of the PAT scheme is in progress, and includes more companies by lowering the consumption threshold and adding three additional industries: railways, electricity distribution companies and refineries. Both the ZED and PAT schemes, are part of India's Intended Nationally Determined Contribution (INDC) towards reductions in greenhouse gas emissions as part of its global commitment of reducing the emissions intensity of its GDP by 20-25 per cent, over 2005 levels, by 2020.

7.5.4 Resource Efficiency Initiatives

The 'Make in India' campaign with Zero Effect, Zero Defect (ZED) is a policy initiative to rate Medium and Small Industries on quality control and certification for energy efficiency, enhanced resources efficiency, pollution control, and use of renewable energy, waste management using ZED Maturity Assessment Model. The scheme, launched in 2015, envisages coverage of about one million medium and small enterprises.

Developing countries like India need to address the disproportionate and steadily increasing share of natural resources required to support changing lifestyles, as well as raw material for industrial production. With a growing economy, India is expected to have the world's third largest consumer group by the year 2020, with a consumption share of 13 per cent. With rising consumption levels, India is already facing supply constraints and import dependence of key materials in certain sectors. The demand for resources in the future will be increasingly huge and may eventually lead to worsening of impact on economy, environment, and access to resources, if not addressed in a timely manner.

In order to tackle this challenge, the Indian Resource Panel (InRP) was formed in the 2015 under the stewardship of the Ministry of Environment, Forest

Measures for Reduction of Emission Intensity in Major Industries

Iron and Steel Industry

1. A shift in the technology-mix of the iron and steel sector towards more efficient processes
2. Diffusion of energy efficient technologies into the sub-processes of various process routes
3. Coke dry quenching/ Waste heat recovery systems for coke moisture reduction and power generation
4. Utilisation of renewable energy in specific process/ plant/colony applications
5. Increased use of waste heat/process gas as alternate fuels
6. Increased scrap utilisation
7. Improving quality of coal/coke before its use in the industry
8. Low carbon captive power generation using process gas

Cement Industry

1. Diffusion of energy-efficient technologies in various sub processes of cement manufacture.
2. Waste heat recovery systems for moisture reduction in coal, raw materials and for power generation.
3. Utilization of renewable energy in specific process/plant/colony applications.
4. Increased use of waste as alternate fuels, rationalizing the various policies that regulate this activity.
5. Increased blending using fly ash from thermal power plants and granulated blast furnace slag from steel plants, and the increased use of composite cements.
6. Improving quality of coal before its use in the industry.
7. Low carbon captive power generation.
8. Increase of blended cements in the public procurement process.

Source: 12th Five Year Plan

and Climate Change (MoEF&CC). The ministry will partner with other relevant ministries of the Government of India, private and public enterprises towards creation of a facilitative environment for recycling to promote sustainability and decouple growth from environment degradation. Its primary purpose is to prepare a strategic roadmap for utilisation of secondary resources for meeting the developmental needs. India is the first country to constitute a National Resource Panel (Press Information Bureau, 2015). The InRP is looking at barriers and measures to promote resource efficiency. An excellent example to mainstream the use of waste material to improve industry energy and resource efficiency, that is, the use of fly ash in cement manufacturing.

The Sustainable Development Framework (SDF) was specially tailored to the Indian context to allow for the government to balance environmental and social interests of the nation, with mining priorities in the longer term (Ministry of Mines). It was developed taking into consideration the work done, and being done, in International Council of Mining and Metals (ICMM) and International Union for the Conservation of Nature and Natural Resources (IUCN). The SDF defines sustainable development in the mining sector as mining that is financially viable; socially responsible; environmentally, technically and scientifically sound; with a long term view of development; uses mineral resources optimally; and, ensures sustainable post-closure land uses. It provides a path towards achieving sustainable development aided by guidance steps, measurable outcomes and reporting, and assurance based on a set of principles that form the core of the Sustainable Development Framework (Environmental Resources Management, 2011)

The Ministry of Environment, Forests and Climate Change developed Sustainable Sand Mining Management Guidelines, 2016 to ensure that sand and gravel mining is done in environmentally sustainable and socially responsible manner. It recommends that sand and aggregate mining, and quarrying should be done only after sound scientific assessment and adopting best practices to limit the impact on the environment. It also promotes greater use of substitute material (manufactured sand, artificial sand etc.) and construction technology, and sustainable use of the resource which could drastically reduce adverse impact of mining on the environment. District authorities have been given the power to grant clearances and stop illegal mining. Monitoring of mined out materials will be undertaken to prevent excess of mining beyond clearance capacity (MoEF&CC, 2016).

Resource Recovery

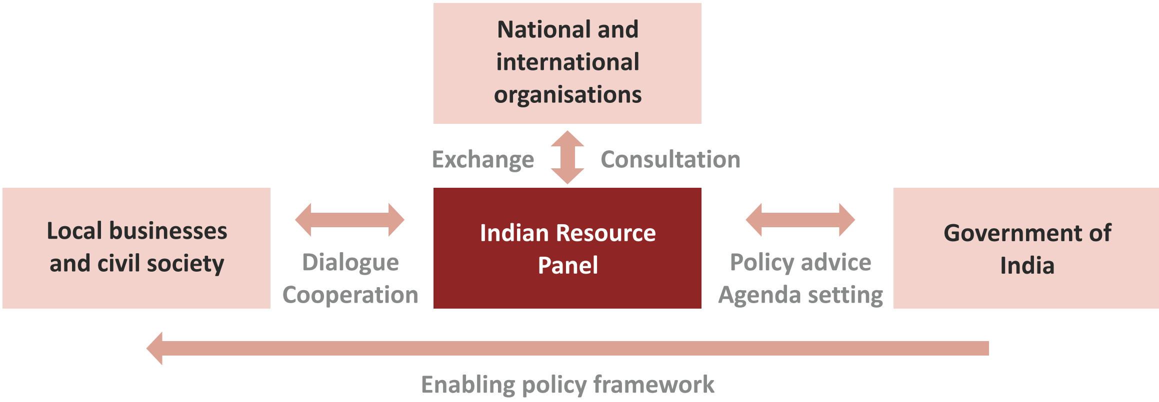
India can hope to recover over 1.5 million tonnes of steel scrap, 180,000 tons of aluminum scrap and 75,000 tons each of recoverable plastic and rubber from scrapped automobiles by the year 2020.

Source: PIB, 2015

The Sustainable Mining Initiative (SMI) was established in 2009 to address environmental and social issues related to mining industry, and to maximize the contribution of the mining sector to the cause of sustainable development in the country. A total of 10 leading Indian mining companies came together to start SMI, and now act as its governing council. SMI is aligned with the proposed Mines and Minerals Development and Regulation (MMDR) Act of 2011, which advocates for the mining industry to operate within a sustainable development framework.

The Pradhan Mantri Khanij Kshetra Kalyan Yojana (PMKKKY) implemented by the District Mineral Foundation (DMF) aims at the welfare of areas and people affected by mining operations. It seeks to minimize/mitigate the adverse impacts, during and after mining, on the environment, health and socio-economics of people in mining districts, and to ensure long-term sustainable livelihoods for the affected people in mining areas. At least 60 per cent of PMKKKY funds will be utilized for drinking water supply, environment preservation and pollution control measures, health care, education, welfare of women, children, aged and disabled people, skill development and sanitation. Up to 40 per cent of the PMKKKY funds will be utilised for physical infrastructure, irrigation, energy and watershed development and any other measures for enhancing environmental quality in the mining district. State Governments of Chhattisgarh, Goa, Karnataka and Telangana have established DMFs, and notified the rules in this regard. Other States are also in the process of establishing DMFs and making rules in this regard (Ministry of Mines, 2016).

Figure 7.14 : Framework of the Indian Resource Panel



Source: Indo-German Environment Partnership Program, 2015

Portland Pozzolana Cement

Portland pozzolana cement (using fly ash as pozzolana) can be manufactured either by integrating Portland cement clinker, fly ash and gypsum or by intimately and uniformly blending Portland cement and fly ash (IS : 1489-1976). The notification on fly ash utilization was first issued in the year 1999 and since then, the fly ash utilization in the country has increased from 13.51 per cent up to 57.63 per cent in the year 2013-14 (MoEF&CC, 2015). In year 2013, about 41 per cent of total fly ash generated was used by cement industries in the country. This is a success story of resource efficiency in India and the standard issued by BIS allowing up to 35 per cent of fly ash in cement manufacturing has played a crucial role. Further, it is observed that at some places, where the quality of limestone permits, up to 45 per cent fly ash can be used (CPCB, 2015).

7.5.5 Mine Closure Initiatives

The Indian Bureau of Mines has issued guidelines on Mine Closure Plans, and all mines are expected to submit Progressive and Final Closure plans based on them. Historically, when an ore body got exhausted, mines were closed and abandoned. Today mine closure normally requires the reclamation and rehabilitation of the land in and around the mine concerned. The closure process, therefore, must take care that the environmental problems arising during mining operations and those likely to arise during the post-closure scenario are comprehensively addressed. Also the socio-economic issues of mine closure, and its impact on local communities, workers and their families and the local economy need to be assessed and managed (Institute for Studies in

Star Rating of Mines

Ministry of Mines initiated a 'Star Rating' system for mine leases taking initiatives for implementation of Sustainable Development Framework (SDF). The rating system gives 1 to 5 stars to the mine leases. Best performing leases gets 5 stars. The assessment is done on following parameters,

- The management of impact by carrying out scientific and efficient mining.
- Addressing social impacts of our resettlement and rehabilitation requirements for taking up mining activities.
- Local community engagements and welfare programmes.
- Steps taken for progressive and final mine enclosure.
- Adoption of international standards.

Initially mine leases of major minerals operational for 180 days in the year of reporting will be eligible for star rating. The star rating is awarded after due inspection by IBM officials. At the time of writing this report IBM has released a notification with star rating evaluation template and a web portal for online filling and submission of the template.

Source: Ministry of Mines, Notification No.- 31/4/2016-M.III, Dated 23rd May 2016

Industrial Development, 2012). As per the IBM (Guidelines for preparation of Mine Closure Plan, 2016), closure plans need to include detailed proposal on reclamation and rehabilitation of mined-out land; air, water and waste quality management; top soil and tailing dam management; disposal of mining machinery; safety and security; disaster management and risk assessment for accidents; infrastructure stability and maintenance in case of future utilisation or decommissioning plan and, care and maintenance during temporary discontinuance.

It needs to encompass an ongoing programme designed to return the reclaimed mine sites to their previous natural state thereby recreating habitat or making these available for agriculture or for establishing public facilities such as sports and educational institutions, as has happened in Sesa Goa's Sanquelin mine in South Goa, India.

Another case of rehabilitation success was achieved at a lignite mine-disturbed area, near village Giral, Rajasthan. Efforts included backfilling abandoned pits with mine spoil and covering the backfilled-surfaces with fresh topsoil to a thickness of about 0.3 m micro-catchment rainwater harvesting; soil profile modification; plant establishment and selection of appropriate germplasm material (trees, shrubs and grasses). Preliminary results indicate that the resulting vegetative cover will be capable of self-perpetuation under natural conditions while at the same time meeting the land use requirements of the local people (Sharma, 2004).

Reclaimed Mine of Sanquelim

Sesa has developed a Bamboo Setum (a garden of Bamboos) in the reclaimed mine of Sanquelim. Exhausted mining pit has been converted to a pond for pisciculture and horticulture species of the Goan region (cashew, mango, coconut, jackfruit etc.) have been grown on waste dumps along with spice plantations and medicinal plants. These are irrigated by rainwater harvested in the mining pits. Athletic facilities like playgrounds (on mine rejects dump), football academy (renovating employee quarters on exhausted Sanquelim mine) and even a technical/industrial training school (renovated mine workshop) have been established on the reclaimed land.

Source: Sesa Goa Limited, 2012 & Institute for Studies in Industrial Development, 2012

The National Mineral Development Corporation is setting up a 0.3 million tonne pig iron plant for the utilisation of tailings. The Kudremukh iron ore company has formulated a project to reclaim 117 million tonne of tailings to recover 21 million tonnes of concentrates (TERI, 2001). Inactive overburden dump slopes in the Halki Mines of JK Cement are stabilized with *Aloe Vera* saplings to arrest soil erosion, and to mitigate dust from the dump area (IBM, 2016).

While instances of appropriate mine closure and rehabilitation are far and few between; there is added pressure from the Government to insist on developing and subsequently implementing scientific mine closure plans.

7.6 CONCLUSION

Neither the importance nor the impacts of industries can be ignored. With the present development path charted out for India, industries both construction and manufacturing assume an important role in delivering jobs and economic growth. In the same vein, the potential impacts of mismanaged industrial growth on the health of the people and environment cannot be ignored. There is widespread recognition of this duality, prompting action at various levels.

At the national level, sustainable management of resources that drive industries like raw materials, energy, land and water, has made its way into mainstream industrial policies. 'Make in India', the flagship national programme promoting industrial growth in India, places emphasis on use of green technology as well as audits to monitor and mitigate environmental impacts of industries. The Sustainable Development Framework and the National Mineral Policy, 2008, present a platform for the mining sector to improve productivity and efficiency in an eco-friendly and scientific manner; promoting sustainable growth of the sector that will benefit the economy without adverse impacts on the planet.

Globally the Sustainable Development Goals identify 'Industries' as a key area of intervention. Goal 9 seeks to build resilient infrastructure, promote sustainable industrialization and foster innovation. It builds on the principle that economic growth, social development and climate action are heavily dependent on investments in infrastructure, sustainable industrial development and technological progress. Thus in the face of a rapidly changing global economic landscape and increasing inequalities, sustained growth must include industrialization that makes opportunities accessible to all people, and supported by innovation and resilient infrastructure (UNDP, 2016).

The sector also has the potential to contribute to other goals. Industrialization's job multiplication effect has a positive impact on society; with every job in manufacturing creating 2.2 jobs in other sectors (UNDP, 2016). Thus, it directly contributes to the SDG Goal 8 to provide decent work and economic growth; and Goal 1 to end poverty. Industrial outputs can also play a big role in meeting some other goals in terms of providing tools and means to provide health care (Goal 3), quality education (Goal 4), clean water and sanitation (Goal 6) and sustainable communities (Goal 11). Appropriate energy and resource management in industries promotes the cause of responsible consumption and production (Goal 12) and climate action (Goal 13).

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 8

URBANISATION

Key Messages

- *Unplanned, rapid urbanisation is the prime cause behind air pollution, depleting water resources, congested built environment and above all, growing waste in urban agglomerates.*

- *Increase in the number of densely populated urban centers is causing the extraction and use of natural resources beyond their carrying capacities.*

- *High rate of urban migration is leading to creation of slums without basic amenities and this is emerging as a stress point for environmental quality.*

- *Current pattern and pace of urbanisation is leading to loss of green spaces. With growing trend in concrete based urban infrastructure, reduction in green spaces and increase in use of air conditioning, pockets of heat islands are being formed, affecting the local micro-climate.*

- *The creation of waste processing and recycling infrastructure for both solid and liquid waste is not commensurate with the rate at which the generation of wastes is growing and needs immediate attention.*

- *Some promising initiatives for urban renewal have been made pertaining to basic service delivery and environment restoration.*

8.1 INTRODUCTION

Urbanisation is the process where an increasing percentage of population lives in cities and suburbs. This process is often linked to industrialisation, as large numbers of people leave farms, to work and live in cities. Over the past hundred years, urbanisation has increased rapidly to the point that sustainable urban development has emerged as a major challenge. Today, more than half of the world's population lives in cities. (United Nations, 2015)

At the turn of the 19th century, urban population represented 3 per cent of the total world population, 13 per cent at the beginning of the 20th century, and 28.1 per cent by the second half of the 1900s. By this time, urban centres across the world faced acute problems of congestion, sanitation, poor infrastructure, vehicular traffic, water and energy loss, and the heat island effect. Together these factors create immense stress on the environment as increased concretisation – mainly to cater to housing needs – and coverage of open spaces and vegetation, meant less evaporation and more surface heat. Vehicles, industry, and domestic HVAC (Heating, ventilation and air conditioning) caused city temperatures to be 1-6 degrees warmer than surrounding landscapes. Rapid industrialization i.e. the creation of jobs, led to mass migration from rural to urban areas. This amounted to unprecedented pressures on the limited capacity of the existing infrastructure. Now, there was more pressure on services like housing, transport, and sanitation. To cater to the needs of a rising population, the production of goods increased exponentially leading to the release of large amount of waste and pollutants from polluting – but increasingly required – industries. All of this resulted in larger urban settlements that were mired in unending environmental problems.

8.2 STATUS

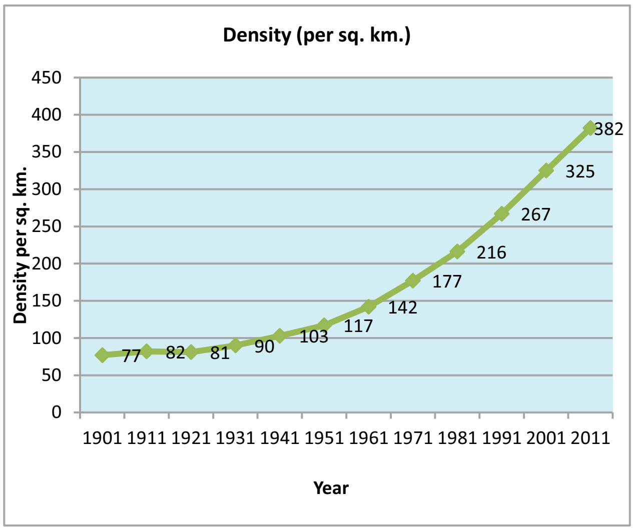
8.2.1 Population Density

Population density of a country has a direct relationship with the quality of life of its citizens. As land is fixed and immobile, the consistent increase in population on per unit of land increases the pressure on land and other facilities. According to Census 2011, the population density of India is 382 persons per sq.km. Mumbai has the highest density followed by Kolkata, Delhi and Chennai, having higher density than national average of 382 people per sq.km.

Although the growth in population densities does not correlate directly with urbanisation per se, it is nevertheless, a pointer of how India is becoming more and more congested over time.

The Table 8.1 shows ten most congested urban districts in India as per Census 2011. As one would expect, these districts spread across the metropolises of Delhi, Mumbai, Kolkata, Chennai and Hyderabad, are the largest urban centres in India (Demographia World Urban Areas: 12th Edition: 2015).

Figure 8.1: Trends in Population Density 1901-2011



Source: Census of India 2011

Table 8.1: India's 10 Most Congested Urban Districts

S.No.	District Name	Population (per sq. km)
1	North East Delhi	36,155
2	Central Delhi	27,730
3	East Delhi	27,132
4	Chennai	26,553
5	Kolkata	24,306
6	Mumbai Suburban	20,880
7	Mumbai City	18,652
8	West Delhi	18,563
8	Hyderabad	18,172
10	North Delhi	14,557

Source: Census of India 2011

8.2.2 Planning of Urban Areas

Urban Agglomerations (UA): There were 384 urban agglomerations in 2001, which increased to 474 in 2011, with the inclusion of 137 new UAs and

Table 8.2 : Statewise Urban Population Density in India

2599 - 11297	Chandigarh, Delhi
1103 - 2598	Lakshadweep, Daman & Diu, Pondicherry
415 - 1102	Punjab, Tamilnadu, Haryana, Dadra & Nagar Haveli, Uttar Pradesh, Kerala, West Bengal, Bihar
17 - 414	Arunachal Pradesh, Andaman & Nicobar, Mizoram, Sikkim, Nagaland, Manipur, Himachal Pradesh, Jammu & Kashmir, Meghalaya, Chhattisgarh, Uttarakhand, Rajasthan, Madhya Pradesh, Odisha, Andhra Pradesh, Telangana, Karnataka, Tripura, Maharashtra, Goa, Assam, Jharkhand

Source: Census of India- 2001, 2011

Table 8.3: Class wise number of CTs in 2001 and 2011

Class	2001	2011
1	1	20
2	11	54
3	56	583
4	101	1,148
5	103	1,713
6	40	364

Source: Census of India 2011

elimination of 35 UAs, which were present in the 2001 list but not in 2011 data.

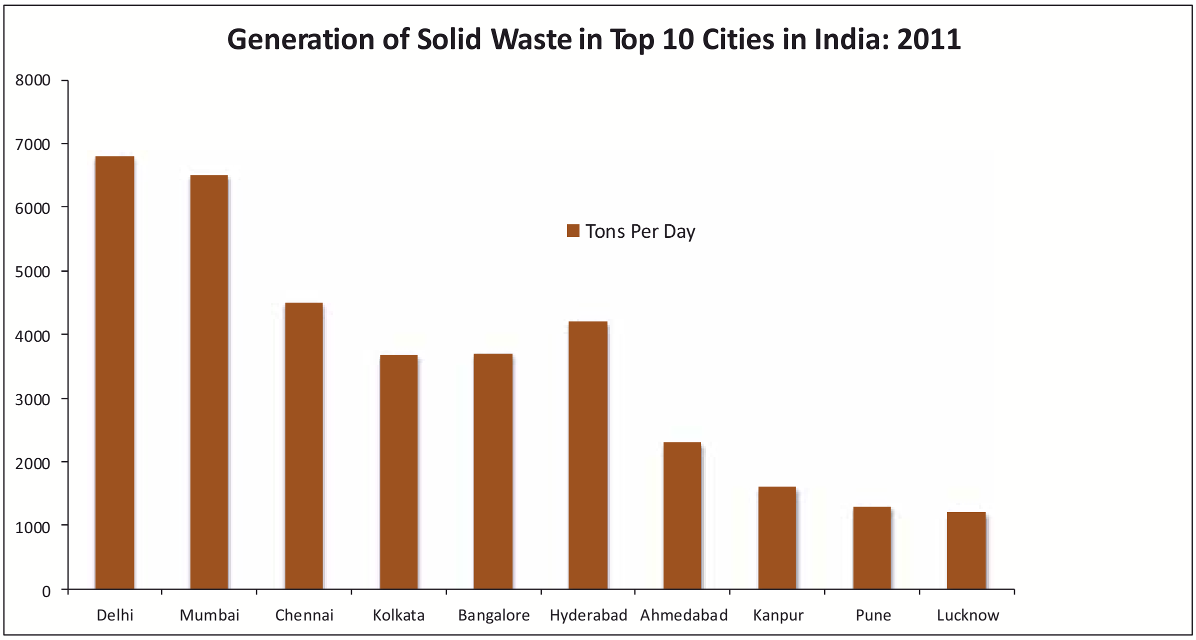
Census Towns (CT): There were **1,362 CTs** in 2001 to 3,894 in 2011. The unexpected increase in the number of CTs in the last census has brought them back in the spotlight. The new CTs account for almost **30 per cent** of the urban growth in last decade, with large inter-state variations. (Census 2001, 2011)

The changes in the number of CTs between census periods can happen in many ways, e.g., an increase due to reclassification of villages and outgrowth areas (OG), and rarely, from Statutory Towns (ST) into Census Towns (CT), and a decrease due to de-notification of existing CTs to villages, re-classification or amalgamation of existing CTs into Statutory Towns (ST) .

8.2.3 Waste Management

62 million tonnes of waste is generated annually in urban India at present, out of which 5.6 million tonnes is plastic waste, 0.17 million tonnes is biomedical waste, hazardous waste generation is 7.90 million tonnes per annum and 15 lakh tonne is e-waste. The per capita waste generation in Indian cities ranges from 200 grams to 600 grams per day. The figures below show the largest urban centers in India in terms of daily waste generation, as along with selected Indian cities (MoEF&CC, 2015).

Figure 8.2: Ranking of Top 10 Cities in India according to Solid Waste Generation



Source: Central Pollution Control Board (2013)

Delhi and Mumbai have daily generation of waste in excess of 6,500 tonnes per day (TPD), while cities like Lucknow and Surat have daily generation of 1,200 TPD. Although there is considerable variance, average waste collection stays roughly similar across the country at around 450 gm per capita per day.

Waste generation in metro cities has grown rapidly. The rise in urban population and it's increasingly consumerist behavior along with the growth of malls and use of paper and plastic bags – replacing the traditional cloth bag, have increased the waste produced in a typical household.

Since 1988, generation of waste has increased in major metro cities, and a sharp increase was observed in Delhi. It may be noted that since 2004-05 the growth in Delhi has taken place mostly around the suburbs, and in the National Capital Region (most of which are administratively under their respective urban local bodies and not under Delhi per se).

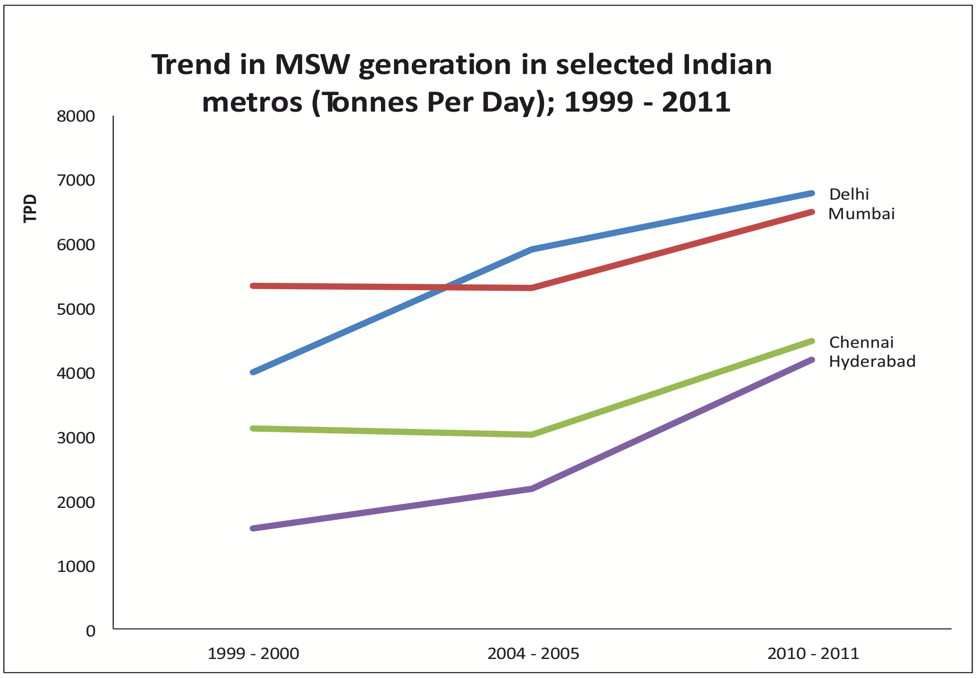
The Figure 8.2 suggests, solid waste generated in these randomly selected state capitals have grown significantly over the past decade. Given the large number of small and medium cities (Tier II to Tier VI), this steady rise in waste generation is also indicative of a rising menace, having potential to threaten the ecological balance of India's urban centers in both present and future.

High trajectories of growth was observed for solid waste generation in smaller cities like, Ludhiana (north), Nagpur (central), Indore (west), Vadodara (west) and Coimbatore (south). While Ludhiana has had spurt of growth in MSW generation between 1988 and 2004-2005; cities like Vadodara have seen the spurt between 2004-05 and 2010. Other cities like Indore and Coimbatore demonstrate a steady, almost lineal growth pattern.

The composition of urban MSW in India is 54 per cent organics, 17.5 per cent recyclables (paper, plastic, metal, and glass) and 27.71 per cent of moisture. The average calorific value is 7.3 MJ/kg (1745 kcal/kg). (MOSPI, 2015) The composition of MSW in the North, East, South and Western regions of the country varied between 50-57 per cent of organics, 16-19 per cent of recyclables, 28-31 per cent of inert, substances chemically not reactive, and 45-51 per cent of moisture. The calorific value of the waste varied between 6.8-9.8 MJ/kg (1,620-2,340 kcal/kg) (Sustainable Solid Waste Management in India, 2012).

By 2013-14, a total of 85 landfills have been constructed across the country in the states of Uttar Pradesh, Jharkhand, West Bengal, Haryana, Goa, Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu, Chandigarh, Jammu and Kashmir, Rajasthan, Meghalaya, Maharashtra and Manipur in North-

Figure 8.3: Trend in Municipal Solid Waste Generation



Source: CPCB Surveys carried out in 1988 - 2000 (Environment Protection Training and Research Institute), 2004 - 2005 (The National Environmental Engineering Research Institute) and 2010 - 2011 (Central Institute of Plastics Engineering & Technology), reproduced in, 'the Status Report on Municipal Solid Waste Management, Central Pollution Control Board (2013)

Eastern India. In addition, initiatives have been taken to set up landfills in 242 Urban Local Bodies, while as many as 1,285 new landfill sites have been identified.

An increasing trend in terms of processing of solid wastes, including through pits or vermi-compost, conversion of solid waste into compost, could be seen. The trend also reflects increase in organic farming, which in turn seeks to replace chemical fertilisers, with compost and other forms of bio-fertilisers. In India a total of 588 Urban Local Bodies have been set up for waste processing (compost and / or vermi-compost plants). It appears that smaller ULBs (with waste generation within 5-15 TPD) have had greater success in using their organic wastes to generate compost, which are sold to farmers.

On the contrary, large scale waste-to-energy projects have not experienced similar success. The major reasons lay in complications in segregation of waste, which is not well managed in typical Indian households. This often makes segregation difficult and expensive. As a result, waste to energy projects experience frequent disruptions in operation and it makes the venture less commercially viable. Presence of inorganic and toxic elements in processed waste also affects the overall performance of the processing unit. Consequentially, most waste-to-energy projects are in the MW scale: units that are capital intensive and have lower returns on investments and higher operational expenses. As per information available for 2013-14, compiled by CPCB, municipal authorities have set up 553 compost and vermi-compost plants, 56 bio-methanation plants, 22 RDF plants and 13 waste to energy (W to E) plants in the country. (MoEF&CC, 2015)

The inefficient management of waste begins when it is collected at the household level using manual labour; then dumped at nearby locations, without any segregation. It leads to concentration of the wastes at a certain neighbourhood, and deters its proper processing and disposal.

A total of 12,7486 TPD of municipal solid waste is generated in India, and nearly 75-80 per cent of this waste gets collected. Nearly 22-28 per cent of the collected waste is processed and treated. (MoEF&CC-2015) This small proposition of treatment may be attributed to the lack of primary and secondary treatment facilities at the regional and local levels.

Goa emerges as one of the pioneering states in MSW management, with nearly 100 per cent collection and treatment. Andhra Pradesh is able to treat about 80 per cent of the collected waste. States like Bihar and Lakshadweep, in contrast, do not perform as effectively, with negligible collection and treatment of solid waste reported.

Electronic and electrical equipment contain different hazardous materials which are harmful to human health and environment. Many substances used in the manufacturing of electronic equipment are hazardous in nature. Central Pollution Control Board (CPCB) in 2005, estimated 1.46 lakh ton of e-waste generation in the country which has exceeded to eight lakh ton by 2012. According to a report by the United Nations University, 'The Global E-waste Monitor 2014', India witnessed the quantum of 15 lakh tonnes of e-waste generation. The state of Maharashtra generates the maximum amount of waste electrical and electronic equipment at 20,270 tonnes, annually. (E-waste in India, 2011). The number of registered dismantlers and recyclers in the country have increased from 81 to 151 during last three years, which is not enough to deal with the increasing quantity. The combined capacity of these 151 dismantling and recycling units located in 13 states is 446,855 metric tonnes per annum. Despite the release of guidelines by concerned government bodies, most of the e-waste is still in the confinements of the informal sector, where it is segregated and scrapped to recover certain metals that can be lucratively recycled. Only 30 per cent of e-waste is disposed and rest remains are casually disposed, leaching toxins into the surroundings.

8.2.4 Access to Sanitation

Access to sanitation is one of the important elements of basic urban services.

Reports published by the planning commission and nodal ministries indicate that while Indian cities produce 40,000 million litres of sewage every day, barely 20 per cent of it is treated. Further, only 2 per cent of our urban areas have both sewerage systems and sewage treatment plants.

In terms of sewerage systems, nearly 81.4 per cent of urban households in India have access to toilet facilities within their premises. Of the remaining 18.6 per cent of urban households that do not have an access to a toilet facility, nearly 32 per cent use public toilets and the remaining 68 per cent defecate in open.

Nearly 80 per cent of the urban households with toilet facilities are connected to a flush or pour flush toilet. Faecal matter from about 1.2 per cent of the households is disposed via open drains. A small proportion of urban population (0.5 per cent) uses a human or animal serviced facility.

The CPCB estimates that many urban residents use toilets that are not connected to sewerage networks but only to soak pits. Further, 75-80 per cent of water pollution (by volume) arises out of domestic sewerage.

A city based ranking on sanitation, conducted by Ministry of Urban Development survey in 2009-10 (the latest one) depicted that no city could reach 'green' status (accorded for a clean and healthy city).

Table 8.4: Toilet Facilities

Categories	Number of Households
Toilet facility within the premises	64,162,118
No toilet within premises	14,703,818

Source: Census of India 2011

Chandigarh came closest (at 73.48 out of 100), and only four cities were in the 'blue' zone.

In the case of India, poor sanitation and open defecation have caused an overwhelmingly unhygienic environment and a variety of widespread health problems.

In India, there are more people who openly defecate on a regular basis than live in the entirety of Africa. Out of the 1.2 billion inhabitants, 103 million lack safe drinking water and 802 million lack any sanitation services. Diseases linked to poor sanitation and hygiene lead to substantial loss of life and potential. It is estimated that one in every ten deaths in India is linked to poor sanitation and hygiene. Diarrhoea, a preventable disease, is the largest killer and accounts for every twentieth death. Around 450,000 deaths were linked to Diarrhoea alone in 2008, of which 88 per cent were deaths of children below five. Monetized economic losses linked to poor sanitation in 2006 was of the order of Rs. 2.4 Lakh Crore (US$ 53.8 billion), or Rs. 2,180 (US$ 48) per person. This works out to 6.4 per cent of Gross Domestic Product (WSP, 2010). The poor are worst affected by the erratic water supply and sanitation services. Water related diseases result in disproportionately high

Photo 8.1: Toilets built under Swachh Bharat Mission

Table 8.5: Type of Sanitation Facilities

Types of Facility	Urban Households	Proportion of Households with Toilet Facilities (in per cent)
Flush/Pour Flush Toilet Connected to:		
Piped Sewer System	25,775,247	32.7
Septic tank	30,087,437	38.2
Other system	1,372,544	1.7
Pit Latrine		
With slab/ventilated improved pit	5,066,323	6.4
Without slab/ open pit	530,820	0.7
Night Soil disposed into open drain	842,643	1.2
Service Latrine		
Night soil removed by human	208,323	0.3
Night soil serviced by animal	178,782	0.2

Source: Census of India 2011

medical expenses as well as infant mortality, which is compounded by the location of slums and poor settlements along the drainage lines, that receive the sewage from the rest of the city. Also, since the poor predominantly depend on contaminated groundwater for water supplies without treatment, their vulnerability to water borne diseases are higher. They also suffer disproportionally during water crisis periods due to elite capture of centralized supplies.

The challenge of sanitation in Indian cities is acute. With poor sewerage networks, a large number of the urban slums still depend on public toilets. Many public toilets have no water supply while the outlets of many others with water supply are not connected to the city's sewerage system. Only 13.5 per cent of the sewage from Indian cities was treated, and the rest untreated sewage leads to pollution of land and water-bodies. The actual treatment was estimated at 72.2 per cent of the sewage collected which implies that only about 20 per cent sewage generated was treated before disposal in Class I cities and Class II towns (CPCB, 2010).

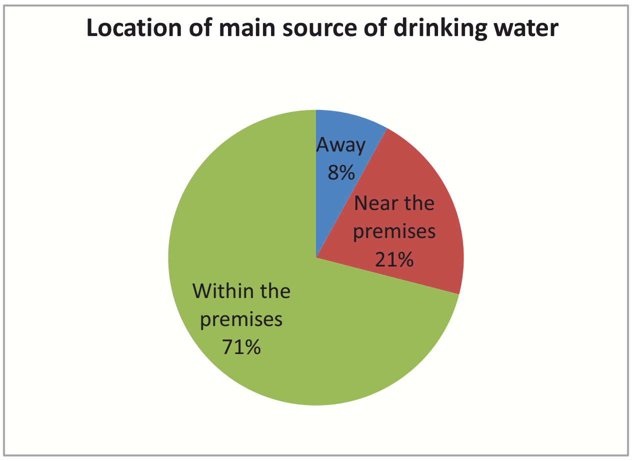
8.2.5 Water Resources and Management

Availability and access to a reliable source of water supply is a necessity for healthy habitation. In urban India, 71 per cent of the population (~56 million) has the main source of water supply located within the premises. 8 per cent (~6.3 million) of the population travels more than 500 meters for accessing water supply source.

88 per cent of the population (48.8 million) has access to treated water supply from source, as per Census 2011 data. This is an achievement in ensuring health for urban dwellers.

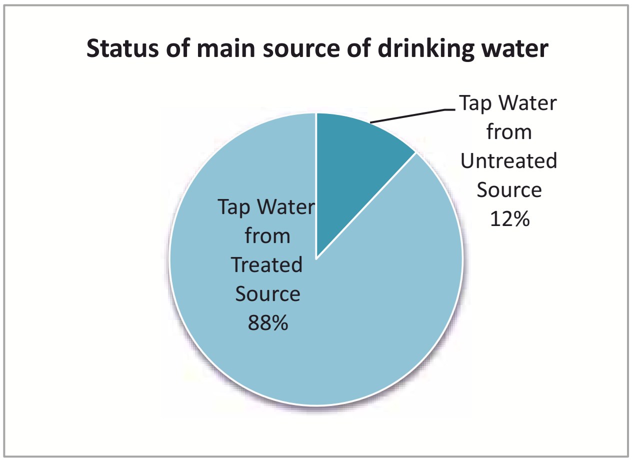
The key challenges faced in the management of the water quality in India are temporal and spatial variation of rainfall; uneven geographic distribution of surface water resources; persistent droughts; overuse of ground water and contamination; drainage salinization and water quality problems due to treated, partially treated and untreated wastewater from urban settlements, industrial establishments and runoff from irrigation sector besides poor management of municipal solid waste and animal dung. It is estimated about 15,644 million liters per day (MLD) of domestic wastewater gets generated per annum from 35 million plus cities. Only 51 per cent of sewage gets treated, whereas 60 per cent of industrial waste is treated out of the 13,468 MLD industrial wastewater. In view of population increase, demand of freshwater for all the uses will be unmanageable. It is estimated that the projected wastewater from urban centers may cross 1,00,000 MLD by 2050 and the rural India will also generate not less than 50,000 MLD in view of water supply designs for community supplies in rural areas. However, waste water management is not addressed at that pace. Most human activities whether domestic, agricultural or industrial have an impact on water, and the ecosystems. World Health Organization statistics indicate that half of India's morbidity is water related. Water borne diseases can be, to a large extent, controlled by managing human consumption and

Figure 8.4: Location of Main Source of Drinking Water



Source: Census of India 2011

Figure 8.5: Status of Main Source of Drinking Water



Source: Census of India 2011

production patterns. It is therefore pertinent to have an understanding of human activities, including water management initiatives, and their impacts on water and the environment. (CPCB 2012)

8.3 PRESSURES

Historically, the growth of industries has led to the growth of cities. As a result of industrialisation, people started moving towards industrialised areas in search of employment, resulting in growth of towns and cities. In India, urbanisation was led by industrial concentrations around the ports, which led to the birth of cities such as Kolkata, Chennai and Mumbai. However, today as per the 2011 census there are 7,935 urban centres in the country.

The main drivers behind urbanisation in India are expansion in government services, high rate of rural-urban migration due to better income generation opportunities and social factors in urban areas. Migration and urbanisation were also driven by societal change. In the past 100 years, Indian societies have increasingly redefined their perceptions of accomplishments in terms of access to material goods (Manchanda, Abidi and Mishra: Assessing Materialism in Indian urban youth). Social factors such as better standards of living including access to improved health and education, need for status etc., induce people to migrate to cities. Population increase has been the significant factor in the urbanisation of India, as it has been rising over one per cent per year over the last 100 years; though some decline has been witnessed in population growth rate, but still it is high.

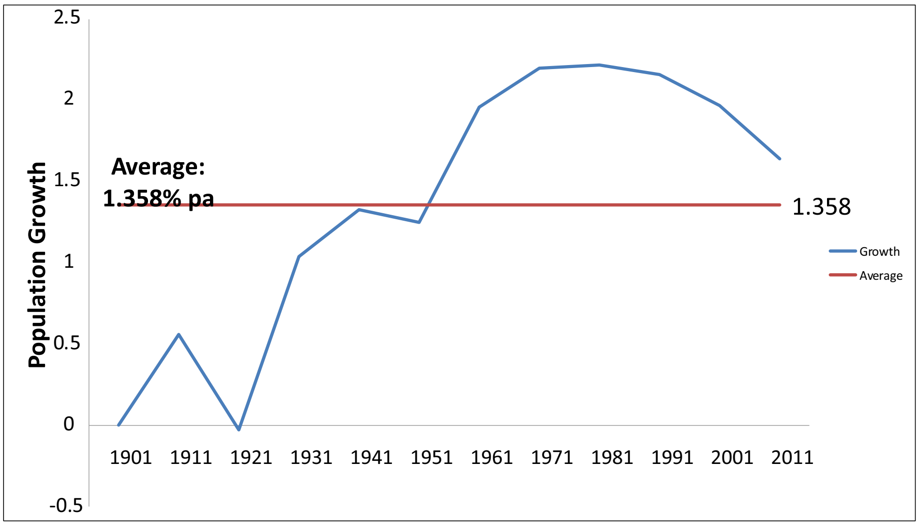
8.3.1 Urban Population Growth

Indian cities make up almost 40 per cent of the world's 100 most densely populated urban areas. According to the World Bank, Indian cities like Mumbai, Kolkata, Chennai and Delhi are among the top 20 most densely populated cities in the world. It shows the extent to which Indian cities have dominated the global urban landscape indicating the long-term unsustainability of India's cities, and thus signifying a clear and pressing need to manage urban environments. Since 1911, India has a decennial growth rate of 1.48 per cent per annum. Post-independence there was a spurt in growth rates, with improvement in health infrastructure leading to lower death rates, from 1951 to 2001. The population growth rate remained around or over two per cent per annum; still a large amount of migration was witnessed during this period. Post 2001, however, there was a reduction in decennial population growth rates from 1.87 per cent in 2001 to 1.64 per cent in 2011. Still, India does not compare well with similar countries like China (where population growth has stayed around the 0.5 per cent per annum compared to India at around 1.5 per cent per annum).

The percentage of urban population has increased by 50 per cent from 1951 to 1991 i.e. from 17.3 per cent to 25.73 per cent. The 1981-2001 decade is considered as a benchmark for urbanisation because of the newly introduced liberalization policies, which opened the market and various investment opportunities widening the economies of scale.

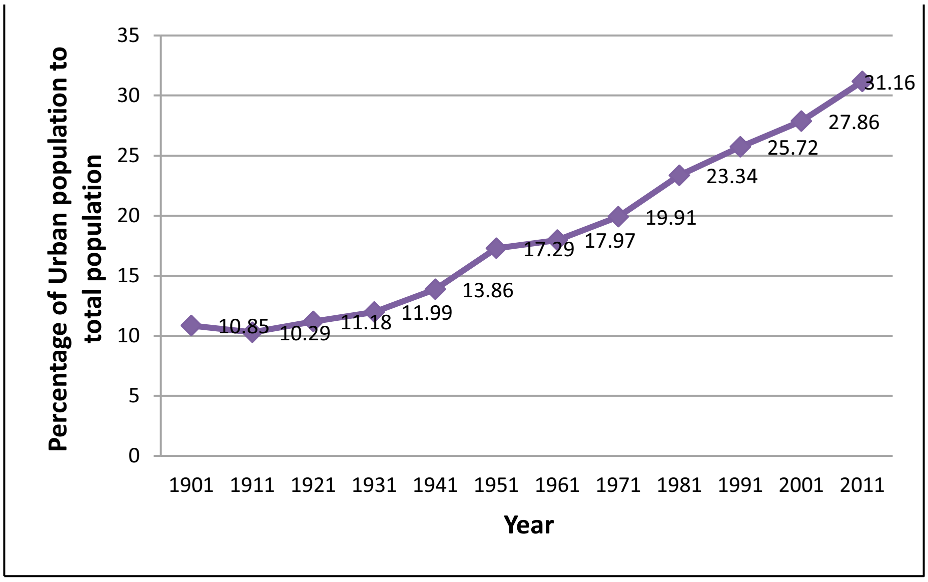
According to Census (2011) and Ministry of Urban Development, in the past decade (2001 – 2011) 2,774

Figure 8.6: Annual Exponential Population Growth Rate for India (1901-2011)



Source: Census of India 2011

Figure 8.7.: Share of Urban Population in Total Population in India; 1901 -2011



Source: Census of India 2011

urban areas were added. The spate of urbanisation resulted in demand of basic services like food, health and housing.

8.3.2 Rural Urban Transformation

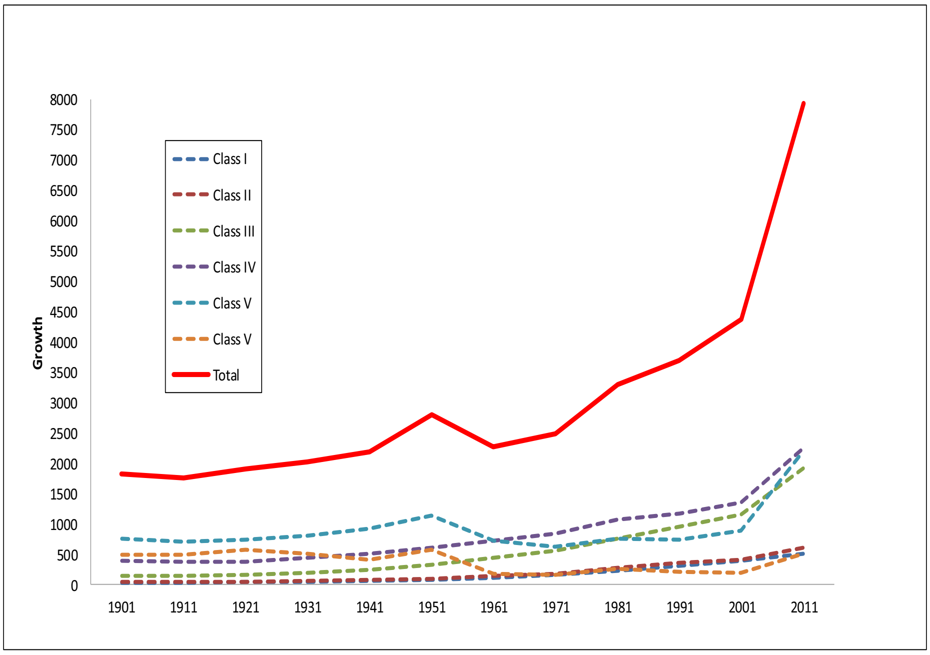
In India not only cities are growing in number but rural communities are also adopting urban culture. It is a well-known fact that compared to 1901 (over a century ago), the share of the Indian population living in cities has shot up from about 11 per cent to 31.16 per cent, due to various reasons which would be mentioned in this study later. (Census, 2011).

A strong trend towards urbanisation since independence led to the growth in Class III, Class IV and Class V cities. Typically, these are outgrown villages of the pre-independence era.

Societal changes have also influenced urbanisation in a significant manner. Over the past 100 years, communities have adopted a consumerist lifestyle. It has impacted the need to acquire assets and enjoy a lifestyle that in turn requires greater access to infrastructure in terms of electricity, roads, telecommunication, and consumer goods and services; prompting individuals and communities to adopt a more urbanised lifestyle.

Urban centres in India have increased considerably in last decade; increase in the numbers of Class I and Class II cities, with considerable change from Class III

Figure 8.8: Growth of Type of Cities in India 1901-2011



Source: Census of India 2011, National Institute of Urban Affairs

to Class VI, is basically due to classification of villages to census towns and allocation of new urban centre in these classes.

According to the International Institute of Population Sciences and primary Census data for 1981-2011, the contribution of natural increase in urban population is actually falling over time. However, this is more than an offset by other factors, such as rural to urban migration and the demarcation of erstwhile rural areas.

It is a fact that Indians living in urban areas tend to have a lower rate of population growth, therefore, if rural to urban migration could reduce then the net impact of urbanisation on the environment would be decidedly lower.

The natural increase in urban populations has declined from a peak of 62 per cent during 1981-91 to 44 per cent during 2001-2011. Yet, the natural increase added a population of about 40 million in urban areas during 2001-2011, thus rest of urban growth of 66 per cent is contributed by net rural-urban classification of town cities and not only rural-urban migration. It is generally agreed that employment and economic reasons, lead to urban migration. Total employments emerging from migration constitute over 50 per cent of the total migration, for males. For females the number was negligibly small at three per cent, though. The data is presented in table 8.7.

Table 8.6: Size Class of Urban Centres in India (2001 and 2011)

Category / Class of City	Population Band
Class I	1,00,000 and above
Class II	50,000 – 99,999
Class III	20,000 – 49,999
Class IV	10,000 – 19,999
Class V	5,000 – 9,999
Class VI	Less than 5,000

Source: Census of India 2011

8.3.3 Urban Habitat

The increase in growth in the number of people residing in urban India, led to an inevitable growth in housing demand. To provide an estimate, the total number of census houses (Census 2011) in India was a staggering 330.83 million. Of this, 110.13 million households were in urban areas, while 220.68 million were in rural areas. The figure 8.10 provides information on the growth in urban housing from 1971 to 2011.

Scenario of Slums in India

The Indian Census defines a slum as "residential areas where dwellings are unfit for human habitation" because they are dilapidated, cramped, poorly ventilated, unclean, or "any combination of these factors which are detrimental to safety and health". Slums cover all 7,935 statutory towns in India. One of

Figure 8.9: Factors for Urbanisation 1981-2011

Source: Emerging Patterns of Urbanisation (Figures developed in the report using data from Census Reports for 1981 – 2011). Produced in Economic and Political Weekly, August 2011 XLVI, No. 34

Table 8.7: Reasons for Migration to Urban Areas

Reasons	Male Percentage			Female Percentage		
	1993	1999–2000	2007-2008	1993	1999–2000	2007-2008
Employment	41.5	51.8	52.7	4.8	3.0	2.6
Family related	28.3	26.6	26.6	81.2	88.5	80.2
Studies / Education	18.0	6.0	6.8	7.0	1.3	2.2
Others	12.2	15.6	13.9	7.0	7.2	15.0
Total	**100**	**100**	**100**	**100**	**100**	**100**

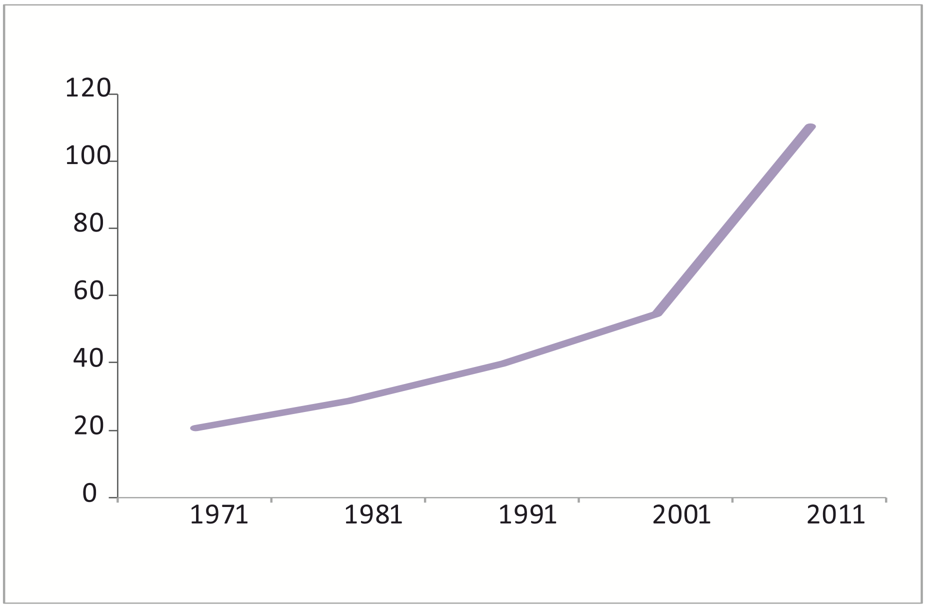
Source: National Sample Survey Office 63rd Round-2008

the most striking features of urbanisation in any developing country is the existence of slums. Nearly 32 per cent of towns in India report the existence of slums, and 17.4 per cent of the total urban population in India resides in these slums. The number of residents in Indian slums is expected to cross the 100 million mark by 2017 (projected to reach 104.7 million individuals). Although slum populations were assessed for the first time in Census 2001, there are unofficial estimates of slum populations for 1981 and 1991. While the 1991 figure is pegged at 27.8 (as estimated during Census 2001), slum population in 1991 is estimated at 46.26 million inhabitants. As per Census 2011, there are 67.4 million people living in slums in India, constituting 13.8 million households.

The population living in slums in India is expected to exceed 300 per cent cumulative growth between 1981 and 2017 (27.8 to 104.7 million). As per Census 2011, the state of Andhra Pradesh had the maximum proportion of its urban population (nearly 35.7 per cent) living in slums. In contrast, Kerala had the least proportion of urban slum dwellers (1.5 per cent).

With over 11 million of its residents in slums, Maharashtra has the highest slum population; 4.6 million of them in ‘identified’ slums. Andhra Pradesh follows with over 10 million in slums, and West Bengal and Uttar Pradesh have over six million slum residents each. Over one million of Delhi’s 1.7 million slum residents live in ‘identified’ slums.

Figure 8.10: Growth in Urban Households in India (1971-2011)



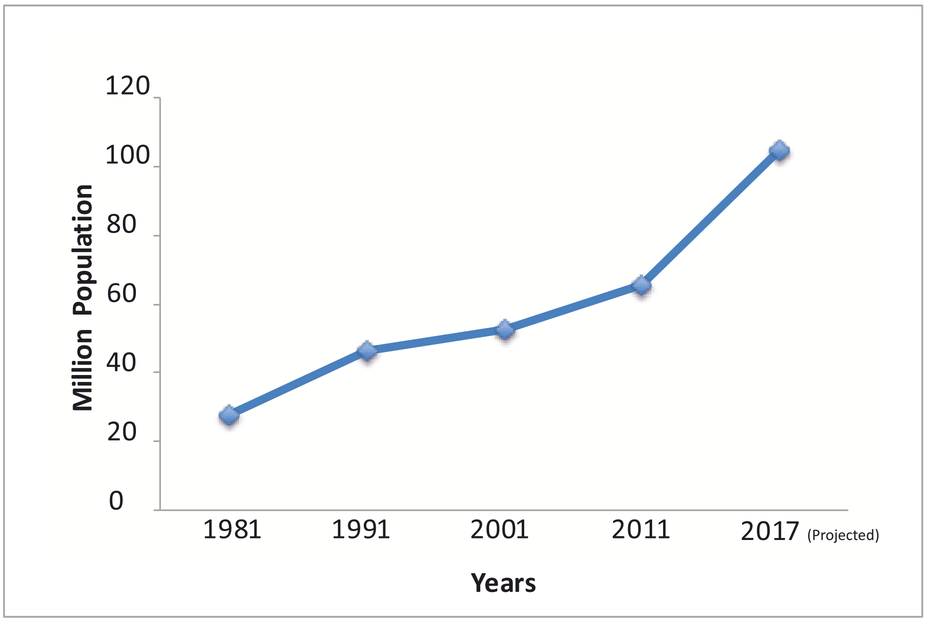
Source: Census of India 2011

Table 8.8: Slum Household Profile of India - 2011

Number of Towns			Urban Households	Slum Households	
Total Towns	Statutory Towns	Slum Reporting		Number in Lakh	Percentage
7,833	4,041	2,543	788.7	137.5	17.4

Source: Census of India 2011

Figure 8.11: Growth of Slums in India: 1981-2017 (Projected)



Source: Census of India 2011, State of Slums in India: A Statistical Compendium (2013), produced by National Buildings Organisation (NBO), Ministry of Housing and Urban Poverty Alleviation.

Photo 8.2: Slums develop due to lack of housing facilities in Urban Areas

The Slum Challenge

Indian Slums are categorized based on whether they are recognised by the state government (notified) or not (not notified). The survey of NSSO shows that non-notified settlements have weaker infrastructure for basic facilities than notified slums.

According to the NSSO survey, only 19 per cent of urban Indian slums have private toilets along with shared toilets, available for their residents. In 50 per cent of the slums, the prevalent form of sanitation for residents is public or community toilet blocks. This is the most practical solution in settlements where water and sewerage connections have limited reach and additional space availability constraints are encountered.

8.3.4 Construction & Demolition Waste

Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges and dams.

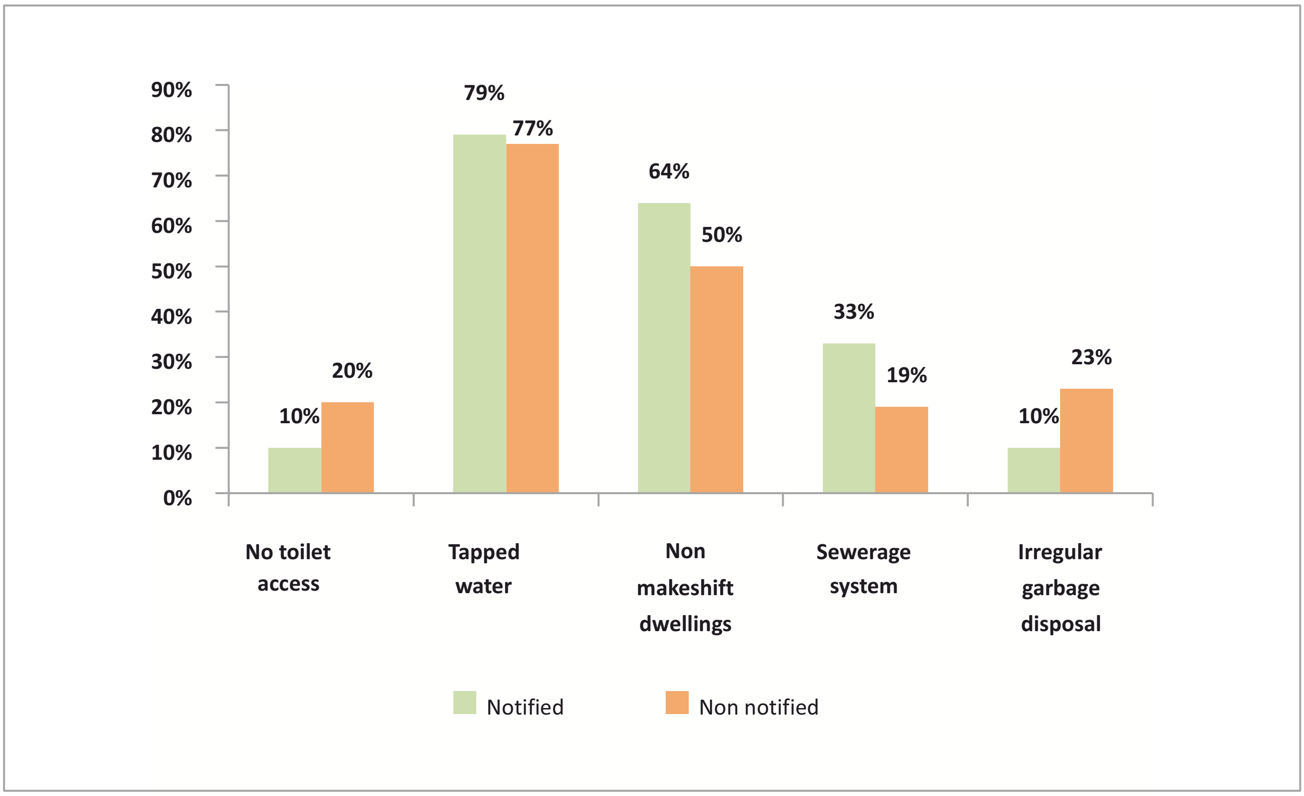
The correlation between urban population and C&D waste generation is depicts a strong correlation overall. Plausible explanations can be found for many of the outliers based on a national survey. In Bengaluru, population is relatively high but C&D waste generation is comparatively low. This can probably be explained by the lack of data available on the C&D waste generated in the city. Hence an estimate of 25 per cent of total MSW generated is used. Conversely, Kolkata has a relatively higher waste generation compared to its population; this may be due to accurate records available on C&D waste disposal in the municipal landfill. Another departure from the trend is Chennai. The recorded waste generated here is 2,500 tonnes per day, as high as Mumbai. This can be attributed to the fact that currently a detailed study is underway in Chennai, hence more than usual data is being collected. Unlike other places where estimates are based on data collected (or estimated) for final disposal, the Chennai estimate is based on actual generation potential.

8.3.5 Transportation

One of the associated fallouts of rise in population density levels in urban areas is a rise in the number of vehicles on the road. India has experienced a tremendous increase in the total number of registered motor vehicles. The total number of registered motor vehicles increased from about 0.3 million as on 31st March, 1951 to 158.5 million as on 31st March, 2012. The total registered vehicles in the country grew at a Compound Annual Growth Rate (CAGR) of 10.5 per cent between 2002 and 2012 (Ministry of Road Transport and Highways - 2013).

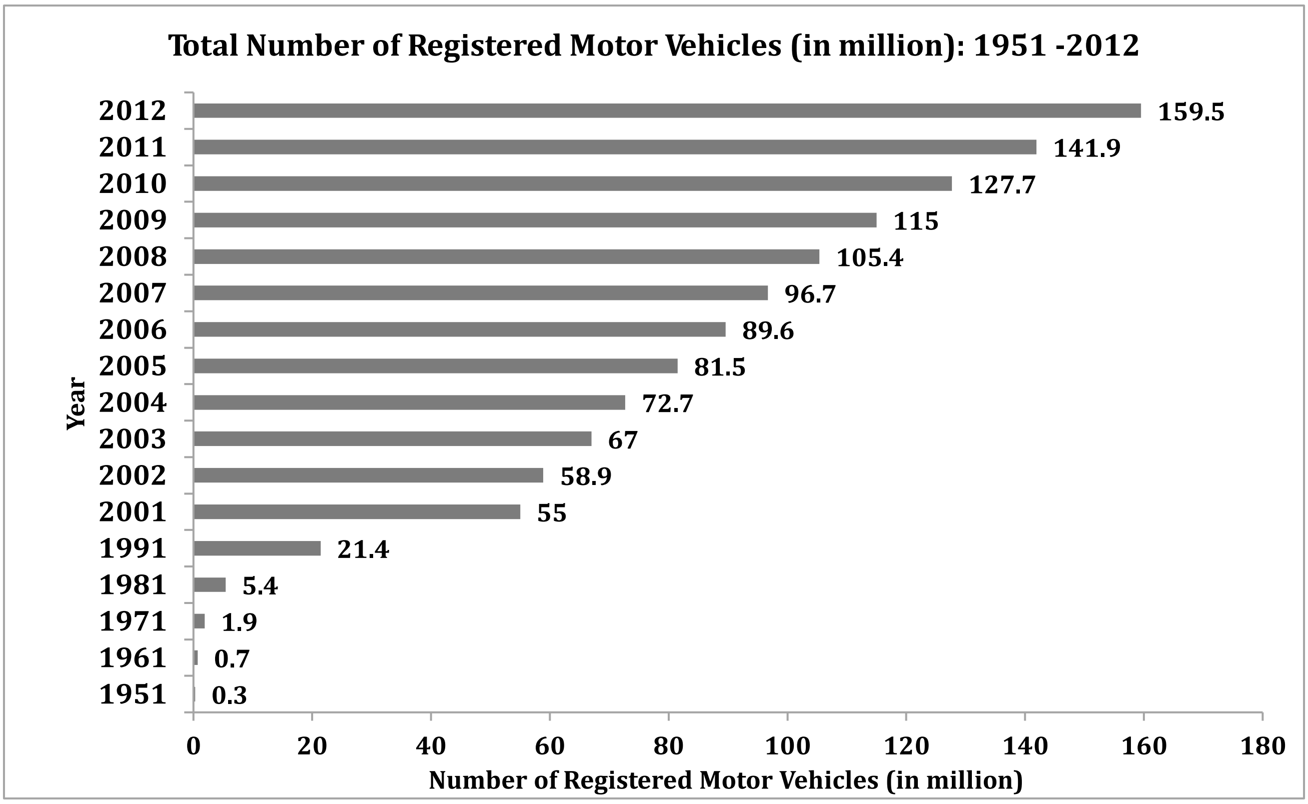
There has been a significant progress as far as urban transportation is concerned. Over the past 10 years Indian cities have experienced rapid motorisation. With impetus provided by the JNNURM, there has been a sharp rise in the number of cities that have their own local bus networks. Compared to 17 cities that had bus networks, the JNNURM introduced

Figure 8.12: Slums with Access to Basic Services



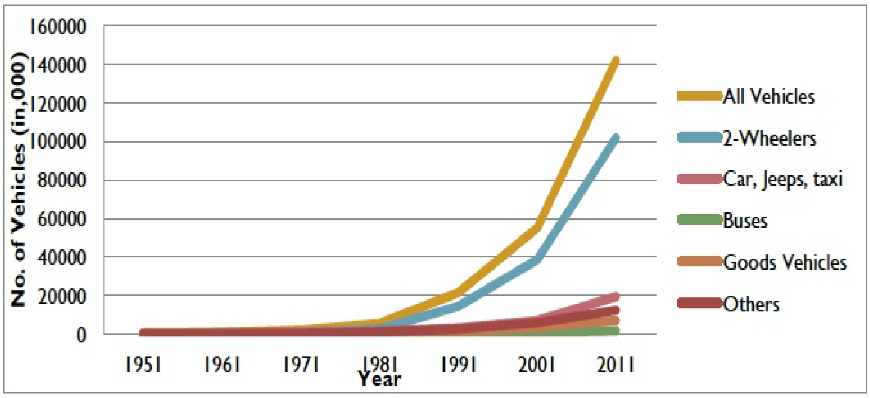
Source: National Sample Survey Office 68th round

Figure 8.13: Number of registered vehicles in India 1951 – 2012



Source: Annual Report of Ministry of Road, Transport and Highways, 2013

Figure 8.14: Growth in Type of Vehicles



Source: Review of Urban Transport in India: Centre for Technology Science and Policy

measures for city bus services in as many as 100 cities. (Development of Urban Public Transport: MORTH).

The Working Group on Urban Transport for the 12th Five Year Plan (2012 – 2017) Planning Commission observes the following:

- Investment in quality public transport and non-motorised transport are (very) low;
- The number of private vehicles (two wheelers and cars) are expected to grow more than three times in the period 2012 – 2021
- The increase is partly due to absence of a credible and efficient public transport system.

Emissions from Different Types of Vehicles

The road transport sector accounts for a share of 4.8 per cent in India's GDP (Ministry of Road Transport and Highways 2011). Two wheelers (mainly driven by two stroke engines) account for approximately 72 per cent of the total vehicular population. The motorisation rate in India is 26 vehicles per 1000 population, and this is lower than many developing countries in the world; but over the last three decades, the number of motor vehicles has been doubling against a 2-5 per cent annual growth rate in Canada, the US, the UK and Japan (Ministry of Road Transport and Highways).

Among different types of vehicles, trucks and lorries contribute to 28.8 per cent CO_2 (70.28 Tg), (tera gram), 38 per cent NOx (0.86 Tg), 27.3 per cent SO_2 (0.18 Tg) and 25 per cent PM (0.03 Tg), which constitute 25 per cent of the total vehicular emissions in India. Similarly, two wheelers are a major source of CO (0.72 Tg; 23.7 per cent), CH_4 (0.06 Tg; 46.4per cent), and HC (0.46 Tg; 64.2 per cent) and buses are emitting NOx (0.68 Tg; 30.7 per cent) and PM (0.03 Tg; 20.5 per cent).

Vehicular emissions vary with type, efficiency and the type of fuel used. Emission analysis based on the vehicle type reveals that bus and Omni buses contribute higher CO_2 (CO_2: 86.5 per cent, NO_x: 2.28 per cent) as compared to two wheelers (CO_2: 86.8 per cent, CO: 7.18 per cent, HC: 4.6 per cent), passenger light motor vehicles (CO_2: 86.8 per cent, CO: 7.6 per cent, NO_x: 1.8 per cent), cars and jeeps (CO_2: 88.8 per cent), taxi (CO_x: 84.6 per cent, SO_2: 4.68 per cent), Trucks and Lorries (CO_2: 87.6 per cent, NO_x: 1.2 per cent), goods light motor vehicles (CO_x: 88.4 per cent), and trailers and tractors (CO_2: 88.4 per cent) (CPCB 2010).

Two wheelers, combined with cars (four wheelers, excluding taxis) (personal mode of transportation) account for approximately four-fifth of the total vehicular population. The problem has been further compounded by steady increase in urban population from approximately 17 per cent to 31.16 per cent during 1951-2011, and larger concentration of vehicles in these urban cities especially in four major metros namely, Delhi, Mumbai, Chennai and Kolkata, which account for more than 15 per cent of the total vehicular population of the whole country. The vehicular population in more than 40 other metropolitan cities (with human population more than 1 million) accounted for 35 per cent of the country. Further, 25 per cent of the total energy (of which 88 per cent comes from oil) is consumed by the road sector only. Vehicles in major metropolitan cities were estimated to account for 70 per cent of CO, 50 per cent of HC, 30-40 per cent of NO_x, 30 per cent of SPM and 10 per cent of SO_2 of the total pollution load of these cities, of which, two-third is contributed by two wheelers alone. The high level of concentration of pollutants damage the environment, and are responsible for respiratory and other air pollution related ailments including lung cancer, asthma etc., which is significantly higher than the national average.

Table 8.9: Emissions from Different Vehicle Types in India (Gigagrams)

Categories	CO_2	NO_x	SO_2	PM	HC
Bus	28,748.16	678.73	78.24	31.36	51.72
Omni Bus	8,508.42	200.53	23.45	8.28	15.11
Two wheeler	8,701.08	62.15	4.25	16.36	464.48
LMV (Passenger)	4,378.10	82.83	2.11	14.52	10.16
Cars and Jeeps	23,801.22	22.14	5.67	3.22	28.01
Taxi	2,367.08	5.68	117.03	0.80	1.48
Trucks and Lorries	70,288.82	858.51	183.73	38.2	118.68
LMV (goods)	44,654.58	110.84	123.04	17.33	12.13
Trailers and Tractors	46,563.85	115.68	128.3	18.08	12.65
Total	5,705.22	64.54	32.18	3.88	8.86

Source: Central Pollution Control Board Status of the vehicular pollution control programme in India, 2010

Table 8.10 Composition of Vehicle Population (per cent of total)

Year	4 Wheeler	Goods vehicles	Other vehicles	2 Wheeler	Buses	Total (Million)
2004	13.0	13.0	8.4	71.4	1.1	72.7
2005	12.7	12.7	8.1	72.1	1.1	81.5
2006	12.8	12.8	8.8	72.2	1.1	88.6
2007	13.1	13.1	8.7	71.5	1.4	86.7
2008	312	13.2	8.6	71.5	1.4	105.3
2008	13.3	13.3	8.4	71.7	1.3	111.5
2010	13.5	13.5	8.6	71.7	1.2	127.7
2011	13.6	13.6	8.5	71.8	1.1	141.8

Source: Road Transport Year Book 2012

8.4 IMPACTS

The impact of urbanisation on the environment could have far-reaching consequences, which calls for awareness, early assessment and positive remedial action.

The areas where adverse impacts are documented include improper waste management, unchecked growth in construction sector including the real estate, pressure on natural resource base (surface water, ground water and free space for greening etc), growth of slums and deterioration in air quality due to vehicular emissions and particulate emissions from construction.

8.4.1 Impact on Transportation linked Pollution

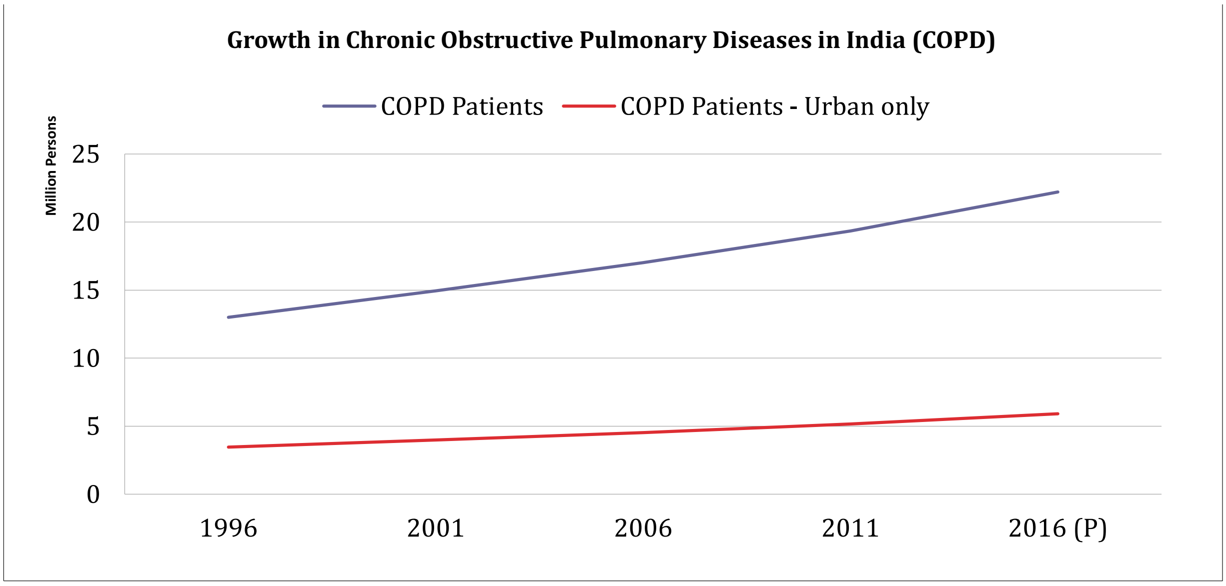
Impact of high use of personal modes of transportation, especially cars and two-wheelers, leads to higher emissions affecting urban air quality, as well as congestion on urban roads. While there are very few studies made on the impact of vehicular congestion on Indian roads; available secondary information seems to indicate urban transportation speeds of as low as 10 km/hour, observed in Kolkata's Central Business District area. Further, it is well known that vehicular emissions increase with decreasing speeds, so at 10 km/h a vehicle could emit five times or more as compared to when the vehicle is in its "optimum speed zone", associated with maximum mileage. The emissions are high at lower as well as high speeds, however at higher speeds engine uses more fuel, yet it does not emit more CO_2 (and other pollutants) as compared to when the speeds are lower than 20 miles/hour. (Central Pollution Control Board (2013)

Thus, there is conclusive evidence on how emissions are related to congestion on the roads. Other factors associated with urban transportation that could affect the urban environment are:

- Vintage: An older vehicle is more likely to have a weaker environmental performance compared to a newer vehicle. This is especially relevant to Euro compliant engines that are associated with superior environmental performances;
- Weight of the vehicle. A heavier vehicle is usually associated with poorer energy performance
- Engine and vehicle maintenance
- Ambient oxygen availability: in many cases in a congested road the less ventilated parts of the city, the car often does not have the quantity of oxygen required for optimal combustion, leading to unburnt fuel that contributes to poor environmental performance and high emissions of particulates, especially $PM_{2.5}$, $PM_{5.0}$ and PM_{10}

The following sections discuss urban air quality in greater detail.

Figure 8.15: Growth in Chronic Obstructive Pulmonary Diseases



Source: World Health Organisation, 2011

8.4.2 Impact on Air Quality and Health

Urban air quality may be broadly measured in terms of presence of pollutants such as oxides of Sulphur (SO_x), Nitrogen (NO_x) and particulate matter (PM). The CPCB conducted a detailed study covering 46 cities with million plus population in 2013 in terms of observed values for SO_x, NO_x and PM_{10} (particulates sized 10 micron or more). The results were published in various analytical reports including their Annual Report 2014-2015. Overall, results indicate improvement in presence of SO_x, which could directly be attributed to improvements in vehicular engine design and introduction of BS-IV standards, which are largely derived from the corresponding Euro standards. Introduction of low sulphur diesel is also a reason. Other contributing factors could be the increase in use of natural gas (LPG and CNG), and gradual replacement of coal by other options for domestic cooking. In terms of NO_x emissions, these are also perceived to be stable at acceptable levels, which again could be a direct result of improvements in vehicular engine performance.

However, the performance of particulates across the majority of stations monitored shows a rather alarming trends. Out of 46 cities monitored, 42 cities have reported levels exceeding the National Ambient Air Quality Standards. Of them, as many as 28 have reported PM_{10} concentrations that are at critical levels, while another twelve are at level 'high' and two at 'moderate' (CPCB - Annual Report: 2013-14)

Lung Disorders

Deterioration in air quality ranks among the serious impacts of urbanisation over the past few decades. The National Air Quality Index for 85 cities, measured in as many as 225 locations for the month of June 2015, provides a strong basis for analysis of urbanisation and its impact on ambient air quality.

As per the AQI, 34 per cent of the monitoring stations revealed moderate air quality, which is interpreted as "breathing discomfort to children, older adults and persons with lung or heart diseases". With as much as one-third of all locations surveyed indicating moderate air quality, this is indeed cause for concern.

The causes for concern are several: however, one of the critical impacts of deteriorating air quality can be seen on lung ailments, generically termed as Chronic Obstructive Pulmonary Disorder or COPD. Data produced by the National Commission on Macro-economics and Health from 1996, projected up to 2016, has provided actual data for people affected by COPD. Data showed 13 million individuals in India

Photo 8.3: Landfill site in Delhi

suffering from COPD in 1996, and by 2006 this figure rose to 22.21 million individuals. Of this, the share of urban residents affected by COPD rose from 3.46 to 5.81, which is an almost 80 per cent rise, between 1996 and 2006. The figure 8.15 charts the course of COPD patients, and provides separate trend estimates for urban populations. It indicates a perceptible growth in urban COPD, although rural COPD is still higher.

Unplanned growth affecting ground water levels, lack of drainage infrastructure leading to surface water and ground water contamination – depletion of Ground Water levels is a clear impact.

8.4.3 Impact on Health and Sanitation

One of the most persistent and emerging crises at the global scale is the outbreak of dengue haemorrhagic fever. From being almost non-existent prior to the 1970's, dengue fever is now a global threat. An estimated 500,000 dengue patients require hospitalisation every year, while a 2013 report the estimated the apparent burden of dengue fever to affect as much as 380 million people worldwide with an 85 per cent credible interval of 284-528 million people). The bulk of apparent cases was in Asia (66.8 million out of a possible 86 million, roughly 70 per cent), followed by Africa (15.7 million) and the Americas (13.3 million).

The outbreak of dengue fever and its rapid rise can be significantly attributed to climate change, together with poor management of water and sanitation, which explains the outbreak of dengue in cities. Temperature is known to play a role in adult vector survival, and increases in temperature may result in increased survival and/or migration of vectors into previously non-endemic areas, thereby explaining the spread of dengue fever across regions over the past 50 years. Specifically the Aedes mosquito's propagation habits are climate dependent, so meteorological factors play an important role in the outbreak of dengue epidemics globally (Epidemiology of Dengue: Past, Present and Future Prospects, by Murray, Quam and Wilder-Smith).

In India as well, the incidences of dengue are on the rise over the past decade, although the intensity is not as high as other nations in Asia and Latin America (Brazil, for instance, typically has over 1.5 million dengue cases a year). Incidence of dengue cases in India has also grown rapidly since 2007 (with the exception of 2011, although mortality rates have started to come down due to advancements in awareness and treatment. However, the menace of the disease is spreading to other Tier II, III and IV cities of the country. For instance, states like Arunachal Pradesh, Odisha and Madhya Pradesh, which recorded 0, 0 and 3 cases in 2008, now have 156, 2,028 and 138 cases respectively (State-Wise Dengue Cases and Deaths in India, 2012).

8.4.4 Climate Change

While links between climate change and urbanisation is well documented through global literature, specific references to Indian cities discuss the issue more in the light of adaptation rather than mitigation. Recent papers on the subject, considering the case studies of Delhi and Mumbai, seem to focus more on the need to adapt to climatic changes, especially manifested through sudden and dramatic changes in precipitation levels (rainfall/snow), which could lead to associated spikes in vector-borne diseases, especially dengue fever in the case of Indian cities.

Heat Island Effect

The term "heat island" describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with one million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

The phenomenon of urban heat islands is recognised as a direct consequence of urbanisation. Like many other cities in developing countries, Delhi and Mumbai have more than doubled in size and population in the past 25 years as rural migrants have flooded in.

Artificial urban surfaces such as concrete and asphalt act as a giant reservoir of heat, absorbing it in the day and releasing it at night. Pollutants from nose-to-tail traffic add to the heat and, in a vicious cycle, people turn to air conditioning, which pumps out yet more heat and pollutants, so increasing climate-changing emissions, which lead to warmer global conditions.

The report titled, 'Economic Impacts of Climate Change in Mumbai ' assesses impacts of climate change for Mumbai along similar lines (temperature and precipitation changes leading to diseases and erratic rainfall), estimating a staggering USD 560 billion in damages to India's financial capital owing to climate change, by 2050.

Transportation is a major source of greenhouse gases emissions. This aspect has also been outlined in New Delhi's State Action Plan on Climate Change, which has estimated 46 per cent emissions from only road transportation for 2007-08. While such detailed studies may not be available for other Indian cities, the role of transportation in precipitating urban climate change is more likely to be significant.

The three main direct impacts of climate change on urban India would be disruption of life from floods, water scarcity and morbidity and mortality due to hot and cold waves. The coastal cities are also likely to face additional stress due to sea level rise and possible increase in frequency of cyclonic storms. These direct impacts can cause disruptions in urban economies for days to weeks or months at a time. Some of the issues like water scarcity already exist due to rapid urbanisation and climate change will only amplify these issues. The urban storm water drainage modifications have been causing water logging in areas earlier not known to be prone, as in case of Powai area of Mumbai. The main indirect impacts would include changes in vector borne diseases, seasonal stresses on energy systems due to temperature increase. Climate change impacts water supply systems with unpredictable precipitation patterns and increased competition over limited resources by upstream use. Floods and other rapid events disrupt other infrastructure like electricity and transport, which can result in huge losses and take weeks and months to recover.

8.4.5 Depletion of Groundwater

With 50 per cent of Indian urban population dependent on groundwater for daily needs, the resultant demand on groundwater is significant.

Data from a 2011 report published by the Central Ground Water Board (CGWB), Ministry of Water

Photo 8.4: Loss of Green Spaces due to Increasing Urban Infrastructure

Resources, indicates that total annual groundwater draft is 245 billion cubic metres (BCM). Of this, as much as 81 per cent (222 BCM) is used for irrigation. Thus only eight per cent is left for urban and industrial use, implying stretched resources (Dynamic Ground Water Resources of India, as of March 2011. Central Ground Water Board, published July 2014).

A study conducted by the Indian Council for Research on International Economic Relations (ICRIER) in May 2015, (focused on ground water depletion in 28 cities), concluded that dependence on groundwater in India, is expected to remain high and/or increase further, due to contamination in surface water resources (rivers etc.) and easy access to groundwater resources. However, as urban populations increases, there is an increasing pressure on groundwater resources: as one digs deeper, fluoride and possible arsenic contamination is present. Worse, ground water resources get depleted faster than they could be recharged by poor quality surface water resources. Finally, climate change impacts exacerbate all the above conditions with higher rates of evapo-transpiration and uncertainties in rainfall and temperature patterns.

A perceived lacuna in this respect, which has been indicated by several reports, is that monitoring and planning for India's urban groundwater resources is a challenge, in view of a lack of effective regulation governing urban groundwater use, as well as weak compliance with existent laws. An important development has been reflected in the form of an overhauling the existing institutional framework that today comprises of the Central Water Commission and the Central Ground Water Board members. The report, presented in July 2015, recommended a paradigm shift in approach for groundwater management through improved management efficiency of resource, as opposed to enhanced supply.

8.4.6 Loss of Green Spaces

Increasing rate of urbanisation results in expansion of land area as it spreads to the adjoining regions including green and forest area. India has witnessed a vital change in its land cover due to increasing rate of urbanisation. According to a study by Indian Institute of Science, land use could be categorised into two groups "Urban or Built up", which includes residential and industrial areas, paved services and "Mixed pixels with built up area" meaning built up area which contain areas of any other three categories- water which includes tanks, lakes, reservoirs and drainages; vegetation which includes forest and plantations and others; including rocks, quarry pits, open grounds at building sites, building roads, valley zones and parks.

Kolkata has an urban population of 14.1 million, making it India's third largest city. Urban built up area has increased 180 per cent from 1990-2010. In 1990 2.2 per cent of the land was built up; in 2010, 8.6 per cent and is predicted to go up to 51 per cent by 2030. Hyderabad city had a population of 10 million in 2014, whereas urban built up area has risen to 400 per cent from 1998-2008. In 1998, 2.55 per cent of land was built up. In 2009, 13.55 per cent is predicted to rise to 51.27 per cent till 2030.

City of Ahmedabad is the sixth largest city of India and third fastest growing city, its urban built up area has risen by 132 per cent from 1990-2010. Its built up area in 1990 was 7.03 per cent of land, in 2010 it was 16.34 per cent and is predicted to rise to 24.3 per cent till 2024. Bhopal, one of the greenest cities of India with population of 1.6 million has clear concretizing trends. In 1992, 66 per cent of the city was covered with vegetation (82 per cent in 1977) which is down by 21 per cent and still is falling. Traditionally, India's fastest growing city has been Bangalore and it has been found that 584 per cent increase in built up area, with vegetation declining by 665 and water bodies by 94 per cent (Indian Institute of Science, 2012).

8.5 RESPONSES

Concerted action on the urban environment took place since the 1990s, with the creation of the Urban Development Authorities to strengthen urban local bodies (Municipal Authorities). As a pan Indian movement, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) has been one of the pioneering programmes targeted at the urban sector. The JNNURM spanned across seven years from 2005 to 2012, and it was further extended by two years to 2014. The following section introduces various government initiatives in greater detail.

8.5.1 Jawaharlal Nehru National Urban Renewal Mission

The core mission behind JNNURM was the holistic and sustainable development of cities, which was to be achieved primarily through the empowerment of

Urban Local Bodies. The aim was to promote reforms in urban governance and service delivery, and provide reform-linked financial assistance to support development in infrastructure and service capabilities. The Mission was supported by two sub-missions and in turn by two sub-schemes. The Mission has actively advocated the role of Public Private Partnership (PPP). With the launch of JNNURM, both the macro-environment as well as project-level micro environment has become more and more congenial for PPPs in the urban sector. Development of water, sanitation, and solid waste management infrastructure under this project aimed the overall urban environmental quality and public health of Indian cities along with upgrading the parameters of quality of life like housing, natural environment, health, recreation and leisure time, social belonging, community life, public services and transport, which includes water and other basic services for mobility and connectivity.

8.5.2 National Urban Sanitation Policy 2008

The National Urban Sanitation Policy (NUSP), launched in 2008 aims to address issues like open defecation and strengthening of local to national institutions, to address urban environment governed by dynamics of climate change and mass migration.

8.5.3 Recent Initiatives

A plethora of activities have been launched under flagship programmes, namely Swachh Bharat (Clean India) Mission, Smart Cities Programme and so on. However, these schemes have been launched in 2014-2015, and as such there is little scope to provide any detailed evaluation of their impacts. However, some salient features of the schemes are outlined below, especially to link these national schemes to the issue of urban environmental concerns.

Swachh Bharat Mission

Swachh Bharat Mission (SBM) was launched on 2nd October, 2014 with a vision to improve urban environment, primarily to address open defecation and management of waste. The programme has been launched with a target date for completion in 2019. It would cover 1.04 crore households, provide 2.5 lakh seats of community toilets, 2.6 lakh seats of public toilets and solid waste management facility for all towns. Community toilets are being proposed in residential areas, where it is difficult to construct individual household toilets; public toilets will be constructed in designated locations such as tourist places, markets, bus stations, near railway stations and places of public recreation wherever required.

National Transport Policy 2014

National Transport policy was launched with a focus to bring about comprehensive improvements in urban transport services and infrastructure. The policy focus is on moving people by strengthening urban transportation in India, rather than adding vehicles on road.

Transport sector is the second largest consumer of energy in India. The growth of transport not only increases pressure on the limited non-renewable energy resources and increase in foreign exchange outgo but also considerably increases environmental pollution. Increasing car dependence in India especially in the urban areas is most visible at the local level – vehicular emissions causing air pollution, noise pollution, and corresponding health effects. Increasing energy consumption, operational pollution, land intrusion and congestion are some of the areas of concern. Therefore, the policy aims at increasing the use of green energy sources, energy efficiency and environmental protection.

Smart Cities Programme

According to a NITI Aayog report on Smart Cities, 2015, the mission aims to create economically competitive, environmentally and socially sustainable cities and urban settlements primarily with technological interventions. The nature of interventions required for meeting these goals might need alteration with changing time and context. Efforts towards achieving these goals need to be cognizant of main drivers and influencing factor for cities.

The objective of the Smart Cities Programme is to provide core infrastructure for a city and provide clean and sustainable environment, through implementation of smart solutions. Core infrastructure elements in a smart city would include improvement in water and electricity service delivery, efficient urban mobility etc. The objectives of the Smart Cities Mission that would contribute towards achieving the definition could be articulated as: 1) Strengthening urban management systems through an effective monitoring and evaluation platform; 2) Enhancing the capacity of urban institutions through easily accessible tools and guidance; 3) Pushing a decentralisation agenda by strengthening avenues for citizen participation; 4) Reducing conflict in the urban environment by treating cities as spaces through a seamless and responsive planning and policy framework; 5) Targeting inclusive and equitable urbanisation by enhancing livability conditions across all segments of a city (Bhattacharya, 2015).

Smart Cities should integrate waste management, energy and water management.

Rajiv Awas Yojana (RAY)

RAY was launched in 2011 with an aim of making "Slum Free India with access to basic infrastructure, amenities and housing in slums". The plan facilitates expansion of linkages for urban poor by creation of affordable housing stock. This will strengthen institutional, capacity building and resource networks at state and municipality level mainly for BSUP (Basic Services for urban Poor).

8.6 CONCLUSION

Rapid rise in the number of cities from 5,161 in 2001 to 7,935 in 2011 has been witnessed in India; highest growth took place in the number of census towns from 1,362 in 2001 to 3,884 in 2011.

Despite being ascertained as cities, most of the cities in India are still falling within the administrative framework of rural local bodies. The cities either they do not fulfil the criteria of towns or lack in development aspects, which makes them eligible for financial assistance or grants that an urban area is eligible for. The major recommendation for this problem at hand is to redefine the criterion for determining a city in the first place, and then to reconcile the effects of previous cities determination.

60-70 per cent of the total urbanisation in India has been concentrated in Class I cities, due to excessive migration and employment opportunities into these cities from rural areas in search of a better life. This massive population pressure that occurs in the cities have multi-faceted consequences, the major one being providing for the basic needs of the population. This complementarily increases the pressure on land, resources and equally distributed urbanisation. Thus, regional disparities to the urbanisation scenario in India could be witnessed by comparing HDI to the urban rate of a state. Example: Gujarat is 42.46 per cent urbanized but its (SHDI) State Human Development Index is 0.527 which is same as the country of Zambia (India Human Development Report: Planning Commission: 2011), (UNDP, 2009).

62 million tonnes of waste is generated in urban India annually; most of it does not have a dumping site, some of the dumping sites like Bhalswa, Ghazipur in Delhi are open without proper treatment; and they release methane in environment, which have a high contribution in spreading diseases and other hazardous diseases. People residing in the vicinity are most likely to be effected by landfill sites. The Government has started taking this issue seriously and have initiated to resolve the issue.

One of the Sustainable Development Goals (SDGs) that are part of the 2030 Agenda, i.e. SDG 11, aims at ensuring the development of sustainable cities and communities, in particular by ensuring access to safe and affordable housing, upgrading slum settlements, investing in public transport, creating green public spaces, and improving urban planning and management in a way that is both participatory and inclusive. The Indian Government has launched flagship programmes like AMRUT, HRIDAY, NLURM etc to achieve the targets set by United Nations till 2030.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 9

ENVIRONMENTAL POLLUTION

Key Messages

- *Environmental pollution has emerged as a major public health concern in the country.*

- *Environmental pollution has had serious impacts on human productivity and economic growth.*

- *Rapid and unplanned urbanisation and unregulated industrial growth are the key drivers of environmental pollution today in the country.*

- *Various steps have been taken by Government to reduce pollution in the country, including policy interventions, awareness generation, capacity building and the enforcement of a stringent regulatory regime.*

9.1 INTRODUCTION

While India is on a path of fast development, the challenge at its hand is to contain associated pollution. To this end, as a first step, significant efforts were made to enhance quality and frequency of environmental data collection systems in the country. Due to unchecked urbanisation and unregulated industrialisation and infrastructure development, our land, water and air resources are being contaminated rapidly. Increasing population and the consequent requirement of resources for a decent lifestyle has exerted excessive burden on our natural resources, most of which carry beyond their capacity of self-regeneration. Our rivers receive more sewage than they can handle. Dump sites are over flowing and the air quality of some of the Indian cities has a dubious distinction of being the most polluted in the world. India falls short on both awareness of its citizens as well as on environmental compliance front too. Even when effective regulations are declared by the government, the stringency with which they are followed on ground is insufficient to bring about any positive change. Key concerns are deterioration of air quality due to emissions from transportation, agricultural residue burning and industrial sources: deterioration of both surface and ground water due to open dumping of solid and liquid wastes without proper treatment. This chapter takes stock of the status of environmental quality with reference to air, water, noise and solid waste.

9.2 STATUS AND PRESSURES

9.2.1a Urban Air Quality

Air pollution generated by human activities adversely affects the lives of people and causes great economic damage to ecosystems and society. Rural to urban migration, growth in mobility demands, demands for power and industrial production, burning of agri-wastes and increasing ambient noise has led to deterioration of ambient air quality across urban and peri-urban areas.

During the last two decades India has seen rapid economic growth and urbanisation. The number of urban centres in the country has risen sharply. There are now 46 million-plus cities in the country that accommodate residents in relatively smaller regions. Higher population densities not only lead to enormous demand for resources but also degradation of environmental quality.

26.18 per cent of India's urban population relies on solid fuels like firewood, crop residue, coal, lignite and cow dung for cooking and lighting purposes (Census of India 2011) whereas globally, 40 per cent of the population, about 3 million people, use the mentioned solid fuels for cooking and lighting (WHO, 2015). These solid fuels are major emitters of particulate matter and oxides of Nitrogen.

CPCB implements the National Air Quality Monitoring Programme to monitor PM_{10}, NO_2 and SO_2 across monitoring stations all over the country. As per data recorded by the CPCB monitoring stations in 2012, Gwalior reported the highest PM_{10} value at an annual average 329 μg/m^3 of all Indian cities. The second highest was reported in Raipur at 305 μg/m^3, followed by Delhi at 286 μg/m^3, clearly implying that many Indian cities exceed the permissible limits (National Ambient Air Quality Status and Trends - 2012, CPCB, August 2014).

Along with ambient air quality, indoor air quality too has been a cause of concern in rural as well as urban areas with the exposure of large population to harmful pollutants. Especially women and children are more vulnerable due to higher exposure to dangerous levels of emissions resulting from cooking and domestic lighting based on bio-mass, dung, and kerosene burning.

Besides the levels of SO_x, No_x and particulate matter in ambient air, another area of concern is the increase in ambient noise levels in public places. Noise levels from various sources such as industrial and construction activity, fire-crackers, public address systems, music systems, vehicular horns, generator sets etc. are on the rise.

Ambient Air Quality Trends

Residents of urban settlements are exposed to increasingly higher levels of particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and ozone. While SO_2 levels have declined in recent years, levels of all other pollutants routinely exceed the National Ambient Air Quality Standards (NAAQS). Many cities still face unhealthy levels of several pollutants. In over half the cities monitored as part of the National Air quality Monitoring Programme (NAMP), levels of PM_{10} are critical, and over two-thirds exceed the mandated safe levels of 60 μg/m^3. PM_{10} trends for Indian states are graphically depicted in Figure 9.1 and show repeated exceedance from mandated safe levels in 2015. The NO_x levels have begun to increase in several cities and available data from Delhi shows frequent violation of ozone standards as well.

Estimation of emission loads is an essential step in order to approximate the share of various sources in the total emission load in a region. It also helps in understanding the potential of various strategies in reducing the emission loads in a region. However, there has been a gap in data availability for emission loads in different Indian cities.

The National Ambient Air Quality Monitoring (NAAQM) programme was started in 1984 with 7 stations. Subsequently the programme was renamed as National Air Quality Monitoring Programme (NAMP). Steadily, the air quality monitoring network was strengthened by increasing the number of monitoring stations from seven in 1984 to 591 in 2014-2015 (Fig 9.2). Tables 9.2 a and 9.2 b depict the Air Quality Index of a few Indian cities with more number of days concentrated in the 'moderate' to 'very poor' category of air quality index.

In 2011, The National Summary Report on 'Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Six Indian Cities', published by CPCB found vehicular sources to be the primary contributors of PM_{10} and $PM_{2.5}$ pollutant levels. The study found levels of PM_{10} and $PM_{2.5}$ in the ambient air to be significantly high irrespective of locations, with winter conditions especially critical. Significant quantities of sulfates and nitrates were found in the air indicating an important contribution of secondary particles. NO_x levels are another emerging problem and Elemental Carbon (EC) to Organic Carbon (OC) ratio (EC/OC) is found to be high for most cities. This indicated pollution from diesel/coal/biomass/ garbage combustion.

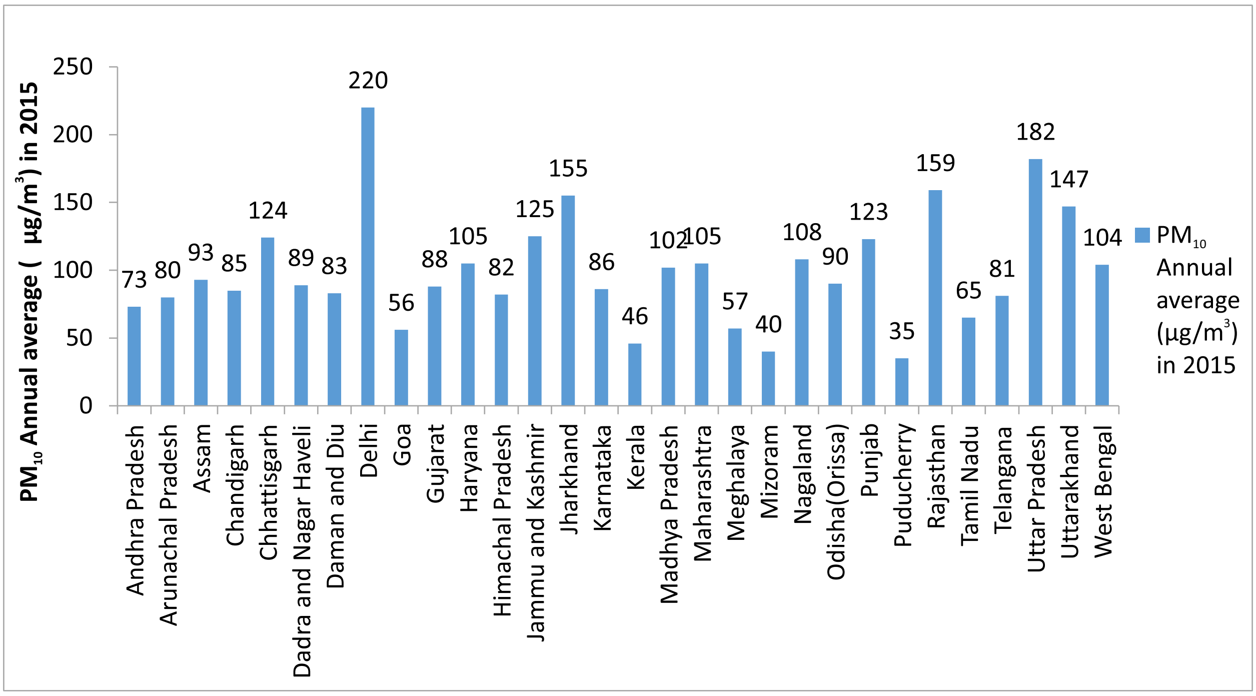
In the year 2014, out of 46 cities with a million-plus population, 28 cities exceeded the NAAQS with respect to PM_{10}. None of the cities exceeded the standard limit (Table 9.1) with respect to SO_2. Sulphur dioxide levels have also risen due to combustion of Sulphur containing fuels. It contributes to formation of acid rain and may also lead to high probability of respiratory problems in humans.

The 2015 data from the cities being monitored by CPCB indicates a further rise in all key parameters. The figures indicate that very few major cities have a significant number of days with 'satisfactory' air quality, and the number of days having 'poor' or 'very poor' air quality are also high (Table 9.2).

Urban Noise Pollution

Urbanisation and industrialisation lead to another growing concern, that of noise pollution. Acceptable range of noise levels that can be tolerated without long term impacts as prescribed by CPCB are seen to be violated across metropolitan areas as the data

Figure 9.1: PM_{10} Trends in States



Source: Central Pollution Control Board indicates. Noise is generated from different indoor and outdoor sources such as industries, transport vehicles, construction activities, generator sets and fire crackers.

The standards are given by Central Pollution Control Board in order to maintain the sound levels of the specified areas. The extent of violation with respect to prescribed standards helps decision makers to take immediate actions and create public awareness.

There are violations of average noise pollution standards set up by Central Pollution Control Board in a majority of cases in metropolitan cities with respect to standards given in table 9.3. Both increase in vehicular traffic and industrialization lead to increased level of noise pollution.

Indoor Air Quality Trends

The statistics state that $PM_{2.5}$ is found in high amount in the indoor air of Indian cities. Spatially, highest concentration of $PM_{2.5}$ is found in Punjab, Uttar Pradesh and Haryana as a consequence of the high usage of solid fuels.

Household air pollution generated from the usage of

Major Causes of Air Pollution in India

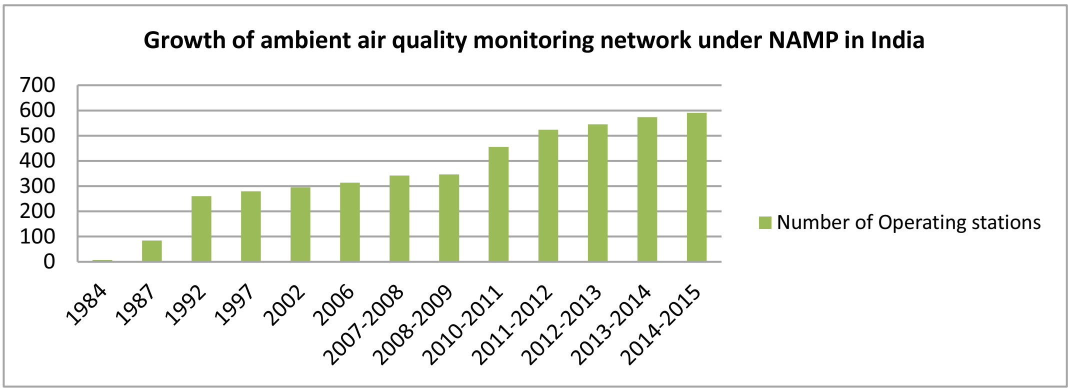
As on January 2015, coal fired thermal power plants account for 60.72 per cent of India's total power generation, according to data available from Central Electricity Authority (CEA). Coal based thermal power plants happen to be leading emitters of SO_2 and NO_2.

Private and commercial vehicles in Indian cities account for 66.28 per cent of the total consumption of diesel (Petroleum Planning and analysis Cell, Petroleum Ministry). Low standards for vehicle emissions and fuel have resulted in increased level of Nitrogen and Sulphur oxides.

As per Census 2011, 87 per cent of rural households and 26 per cent of urban households depend on biomass which is a leading cause of indoor air pollution and is responsible for respiratory and pulmonary health issues in approximately 400 cities and towns.

The percentage of rural households using kerosene as primary source of energy for lightning is almost 30 per cent. Kerosene lanterns used in rural areas are a primary source of emission of black carbon soot and cause significant health impacts particularly in the case of women and children (WHO).

Figure 9.2: Growth in Number of Ambient Air Quality Monitoring Stations



Source: Annual Report 2014-15, Published by Central Pollution Control Board

Table 9.1: Standards of National Air Quality Monitoring Programme (NAMP)

Pollutant	Time Weighted Average	Industrial/Residential/Rural and other areas (µg/m³)	Ecologically Sensitive area notified by Central Government (µg/m³)
SO_2	Annual	50	20
	24 hours	80	80
PM_{10}	Annual	60	60
	24 hours	100	100
NO_2	Annual	40	30
	24 hours	80	80

Source: Central Pollution Control Board

Table 9.2 a: Showing AQI Categorization for the Month of October 2015 in Selected Cities in India

City	Number of days with specified air quality in October 2015					
	Good (0-50)	Satisfactory (51-100)	Moderate (101-200)	Poor (201-300)	Very Poor (301-400)	Severe >401
Delhi	-	1	2	17	19	-
Mumbai	-	11	15	4	-	-
Agra	-	-	9	15	-	-
Bengaluru	2	13	13	-	-	-
Chennai	9	20	8	-	-	-
Ahmedabad	-	1	7	10	2	1
Hyderabad	-	4	17	8	1	-

Table 9.2 b: Showing AQI Categorization for the Month of November 2015 in Selected Cities in India

City	Number of days with specified air quality in November 2015					
	Good (0-50)	Satisfactory (51-100)	Moderate (101-200)	Poor (201-300)	Very Poor (301-400)	Severe > 401
Delhi	-	-	-	2	20	8
Mumbai	-	7	14	-	-	-
Agra	-	-	1	11	15	3
Bengaluru	8	18	1	-	-	-
Chennai	1	13	14	-	-	-
Hyderabad	-	15	14	1	-	-
Lucknow	-	-	-	3	10	10

Note: Figures denote the number of days in the month; total days per month for which data is tabulated may vary if AQI wasn't generated/recorded on certain days.

Source: AQI Bulletin, Sep-Dec 15, CPCB

solid cooking fuel, is primarily due to inefficient combustion of fuel in the typical household stoves. Hundreds of different chemical substances are emitted during the burning of solid biomass, in the form of gases and particles. In addition to small particles, carbon monoxide and nitrogen oxides regulated in India as outdoor pollutants, are also emitted. Data indicates upto 48 per cent of our population used solid bio-fuels for cooking till 2011; of these 62 per cent are in rural areas and 20 per cent are urban residents (Table 9.4).

As of October 2015, the LPG profile published by the Ministry of Petroleum and Natural Gas indicates less than one crore customers (urban and rural) using cooking gas. This indicates a strong dependence on solid biofuels and kerosene for cooking.

9.2.1b Pressures contributing to Urban Air Pollution

Urban vehicular growth, increase in industrial activity, demand for electric power that is being addressed by diesel generators and combustion of municipal wastes and agri-residues are major causes of air pollution today.

Vehicular Growth

Transport sector is a significant contributor in emission estimates of cities. Major Indian cities attribute automobiles as the primary sources of air pollution. Source apportionment studies conducted in the six major cities of the country have shown that transport has significant contribution to the $PM_{2.5}$ and NO_x concentrations.

Table 9.3: Permissible Limits for Ambient Noise Levels

Area Code	Category of Area zone	Limit in * dB (A) Leq	
		Day Time	Night Time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

Source: CPCB, 2014.

Note: dB (A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.*
-- A "decibel" is a unit in which noise is measured.
-- "A", in dB (A) Leq denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.
-- Leq : It is an energy mean of the noise level over a specified period

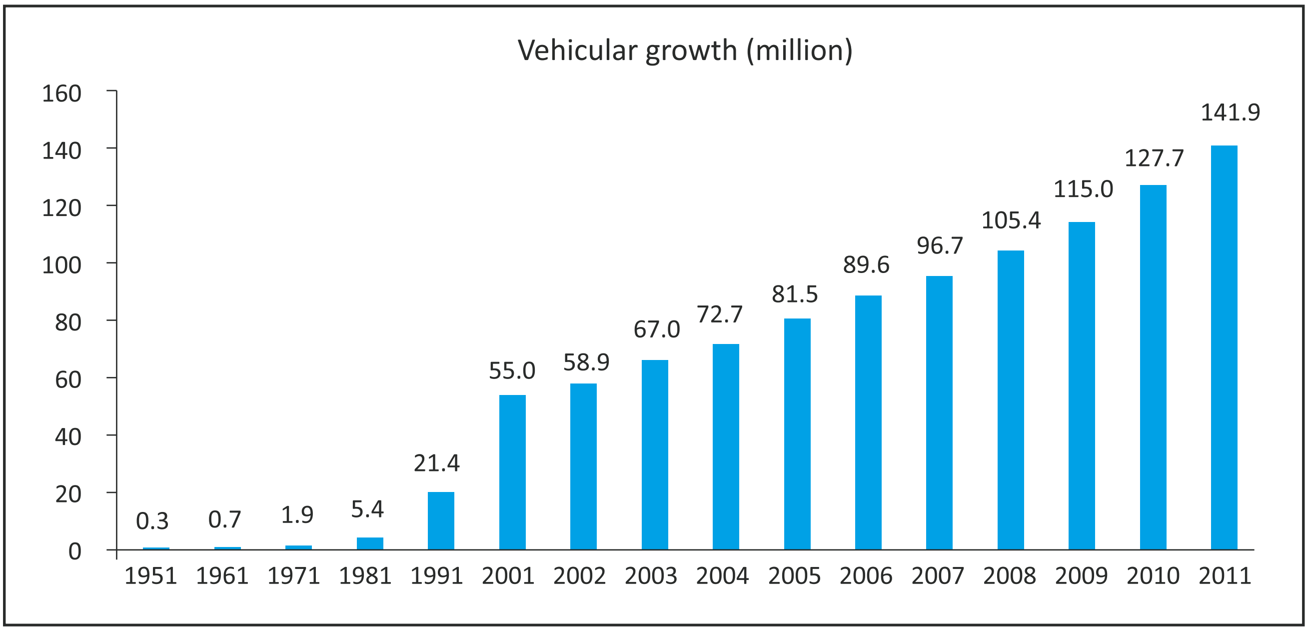
Table 9.4: Types of Solid Fuels and Percentage of Indian Population Using These

Population	Percentage of population using			
	Firewood	Crop residue	Coal / Charcoal	Cow dung
Percentage of total population	48.99	8.85	1.45	7.95
Percentage of rural population	62.55	12.33	0.77	10.87
Percentage of urban population	20.12	1.45	2.89	1.72

Source: Census of India, 2011

Motor vehicle growth rate has been concentrated in the major cities. From the year 1991 there has been tremendous vehicular growth. The total number of motor vehicles increased from 55 million in 2001 to 141.9 million in 2011 (Ministry of Road Transport and Highways), i.e. an average growth rate of 9 per cent per year. Some analysts predicted that India's motorization rate will continue to grow at a rate of to 40 vehicles per 1000 till 2020. This issue of vehicular growth has also been discussed in chapter 8 (Urbanisation).

Figure 9.3: Annual Vehicular Growth in India



Source: MoRTH, SIAM

Increase in Industrial Activity

The rapid growth in the industrial, power, and transportation sectors nationally, teamed with growing planned and unplanned urbanisation in India presents a cause for concern, specifically seen from the perspective of air quality deterioration.

Studies have shown a strong correlation between high levels of PM_{10} and SO_2, and proximity of the cities to coal fired power plants. With substantial growth in coal-based power predicted even in the most conservative of scenarios, and lax standards to address stack emissions, this is a problem that is only going to worsen with time. During 2009-10, there was a comprehensive assessment of 88 prominent industrial clusters based on CEPI (Comprehensive Environmental Pollution Index). Out of identified 88 prominent industrial clusters, 43 industrial clusters in 17 States having CEPI score of 70 and above are identified as 'Critically Polluted Industrial Clusters'.

Burning of Agricultural Residue

Another unaddressed yet significant contributor to air pollution in India is poor management of agro-wastes, especially agriculture residue burning. Ambient air quality of human habitations in close proximity to agricultural farms shows sharp deterioration especially when coupled with temperature drop and windless days during post-harvest seasons. Agri-waste management through the practice of burning the crop stubble that remains after harvesting to clear the fields for the next crop, has become a common practice in large parts of Haryana and Punjab. Every year between October and November, seven to eight million metric tonnes of paddy residue is burnt, releasing highly polluting, particulate matter laden smoke into the air, which includes NO_X, SO_2, CH_4, CO_2, $PM_{2.5}$, N_2O and CO. Such pollutants are proven aggravators of asthma and related respiratory disorders.

At the national level, approximately 361.85 MT crop residue is generated every year from cereal crops, followed by 122.37 MT/year from fiber crops, 107.5 MT/year from sugarcane and 28.72 MT/year from oil seed crops (Table 9.5). From this, 131.86 MT of crop residue was burnt during 2008-09 (as calculated using IPCC coefficient).

States generating the highest quantity of residue from cereal crops are Uttar Pradesh, Punjab, West Bengal and Andhra Pradesh, and consequently are major

Photo 9.1: Proximity of thermal power plants to residential areas is a threat to air quality and public health

contributors to burning residue. The bar chart in Figure 9.4 shows the quantity of crop residue generated and burned in 11 major agricultural states (cereals, oilseeds, fiber crops and sugarcane) in 2008-09 (Jain et al, 2014).

The burning activity may also be contributing to high PM_{10} levels in the states of Punjab and Haryana, which report among the highest values at 204 and 187 microgram per cubic meter respectively. (CPCB Annual Report 2014-15).

9.2.2a Solid Wastes Generation and Management

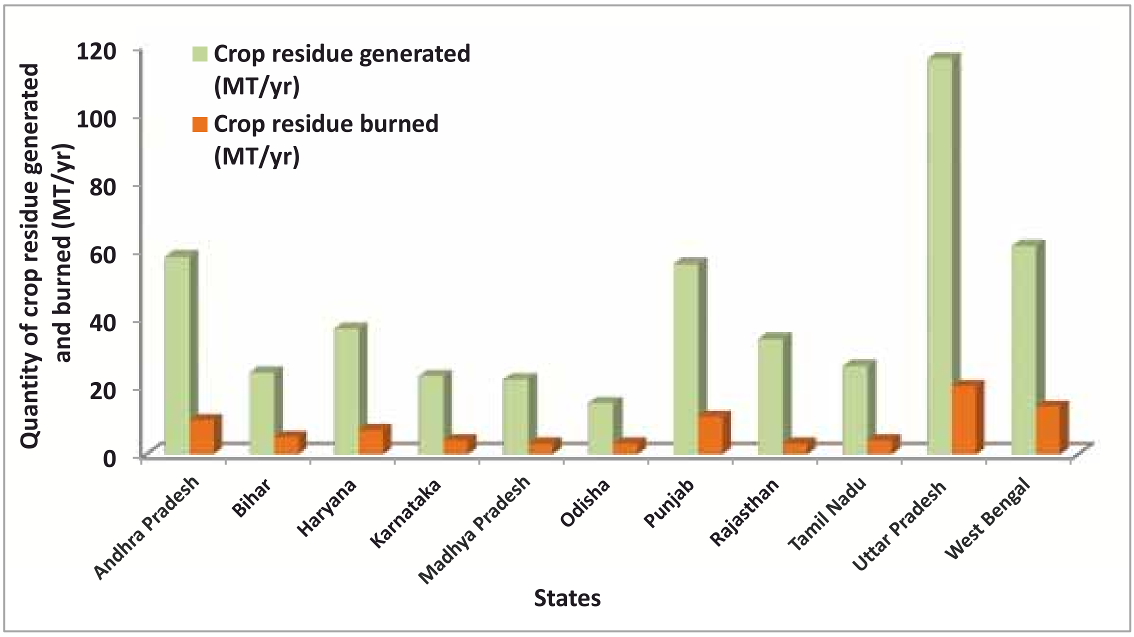
As per the Indian Census of 2011, 31.16 per cent of the Indian population, about 377 million people live

Table 9.5: Crop Residue Generated and Burned in Various Indian States

States	Cereal Crops (MT/yr)	Fiber Crops (MT/yr)	Fiber Crops (MT/yr)	Sugarcane (MT/yr)	Residue burned (calculated using IPCC coefficient)
Andhra Pradesh	33.07	16.07	2.50	5.80	1.00
Arunanchal Pradesh	0.56	0.000	0.06	0.01	0.16
Assam	8.15	2.01	0.29	0.41	2.65
Bihar	19.87	3.27	0.20	1.87	5.21
Chhattisgarh	8.87	0.01	0.11	0.01	2.39
Goa	0.24	0.00	0.01	0.02	0.17
Gujarat	8.18	28.62	5.06	5.85	9.63
Haryana	24.73	7.58	2.15	1.93	6.85
Himachal Pradesh	1.95	0.00	0.01	0.02	0.25
Jammu & Kashmir	2.76	0.00	0.11	0.00	0.47
Jharkhand	7.34	0.00	0.09	0.13	1.90
Karnataka	11.73	3.55	0.81	8.80	5.52
Kerela	1.14	0.01	0.00	0.10	0.55
Madhya Pradesh	16.05	3.51	2.13	1.12	3.86
Maharashtra	8.75	19.51	0.57	22.87	10.96
Manipur	0.78	0.00	0.00	0.01	0.21
Maghalaya	0.44	0.13	0.01	0.00	0.14
Mizoram	0.10	0.00	0.00	0.01	0.03
Nagaland	0.89	0.01	0.06	0.07	0.21
Odisha	13.38	0.56	0.16	0.24	3.84
Punjab	45.58	9.32	0.08	1.76	13.30
Rajasthan	22.19	2.96	9.26	0.15	4.27
Sikkim	0.14	0.00	0.01	0.00	0.02
Tamil Nadu	11.69	0.78	1.56	12.37	5.57
Tripura	1.22	0.02	0.00	0.02	0.63
Uttar Pradesh	72.02	0.04	2.48	41.13	22.38
Uttarakhand	2.40	0.00	0.03	2.11	1.07
West Bengal	37.26	24.43	0.95	0.62	14.85
A&N Islands	0.04	0.00	0.00	0.00	0.01
D & N Haveli	0.05	0.00	0.00	0.00	0.01
Delhi	0.17	0.00	0.00	0.00	0.04
Daman & Diu	0.01	0.00	0.00	0.00	0.00
Pondicherry	0.10	0.00	0.00	0.06	2.11
All India	**361.85**	**122.37**	**28.72**	**107.50**	**131.86**

Source: Emission of Air Pollutants from Crop Residue Burning in India. Aerosol and Air Quality Research, 2014

Figure 9.4: Comparative Figures of Crop Residue Generated and Burnt in Some Indian States



Source: Emission of Air Pollutants from Crop Residue Burning in India. Aerosol and Air Quality Research, 2014

Reports by NASA as reported in the Down to Earth Magazine, 2015 indicate wide spread burning of paddy residue in fields across Punjab and Haryana. In the early winter season, low wind intensity and low temperatures result in most of the particulate matter at low levels. Coupled with vehicular emissions, this gives rise to smog with dangerous levels of $PM_{1.0}$ to $PM_{2.5}$ (Image released by NASA when its Moderate Resolution Imaging Spectroradiometer (MODIS) aqua satellite passed over Punjab on 29 October, 2015).

in cities and towns. Trends suggest that 50 per cent of India's population will live in the urban areas by 2050. Large urban agglomerations face challenges of effective waste management with the quantities being beyond the assimilative capacity of the indigenous infrastructure and management capacities of environmental sinks. More than 81 per cent of the total Municipal Solid Waste (MSW) in India is generated in the Class I cities of the country (Swachh Bharat Mission: Solid Waste Management Manual, 2016). This is predicted to go up from the current per capita generation of 0.2-0.6 kg (CPHEEO manual) in typical Indian cities in the coming years. The rural areas see significantly less generation and better management of waste, though the market invasion by plastic has been quite a contributor to pollution in such areas too.

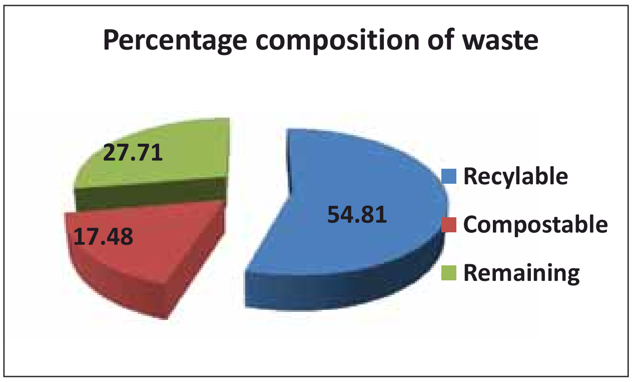
Municipal Solid Waste commonly known as 'garbage' is generated at household, commercial and institutional levels in urban areas. Its composition is heterogeneous, consisting of food waste, plastics, packaging and glassware. Apart from municipal solid wastes, biomedical, hazardous, construction and demolition, and plastic wastes are generated in amounts proportional to the population of the area. These are not considered as part of municipal wastes. However, often times these may be mixed up in the domestic wastes being managed by municipalities. The changing composition of waste, in addition to poor awareness and implementation of laws, is a limiting factor to proper waste management. Discarded batteries from automobiles and various electronic/electrical gadgets, waste/used oils largely generated from service stations and other uses (transformer oil, hydraulic machines etc.) are substances that need to be dealt with caution and care.

The municipal solid waste which is not recycled ends up in landfills and some finds way in vacant unused plots, roadsides and in drains. The compostable waste and combustible waste in some of the landfills are used to produce manure and to convert to Refuse Derived Fuel (RDF) for use in boilers/cement plants to recover energy. Construction and demolition waste generally ends up in municipal solid waste landfills and low lying areas. The recycling of such waste has now been started. Plastic wastes received along with municipal waste are picked up by rag-pickers in an unhygienic manner and channelized for recycling in the unorganized sector.

Municipal Solid Waste, Plastic and E-waste

Decadal data from 59 Indian cities indicates that daily waste generation of 39,031 TPD (tonnes per day) in

Figure 9.5: Percentage Composition of MSW in Indian Cities



Source: Compendium of Environment Statistics India, Ministry of Statistics and Programme Implementation, 2015

2001 has increased to 81,073 TPD in 2011, i.e., by 207 per cent. Almost all cities with population above 1 million generate more than 1000 TPD of waste (Compendium of Environment Statistics India, 2015). These include Agra, Ahmedabad, Bangalore, Coimbatore, Hyderabad, Jaipur, Kanpur, Kochi, Ludhiana, Pune, Surat and Vishkhapatnam.

Cities with populations ranging from 8-15 million (Census of India, 2011) such as Chennai (6,118 TPD), Delhi (11040 TPD), Mumbai (11,124 TPD) and Kolkata (11,520 TPD) generate more than 5000 TPD of municipal solid waste. The generation has further increased to 1,27,486 TPD in 2013 (Annual Report, CPCB) of which roughly 75 per cent is collected and 22-28 per cent of the collected waste is treated.

To cater to the enormous amount of waste generated, there are only a total of 76 registered landfill sites in the country. Most landfills are non-scientific, rudimentary dump sites, posing grave threats to the land and water resources in the vicinity (Compendium of Environmental Statistics, MoSPI, 2015). These may be overflowing, openly burned to reduce volume or constantly leaking leachates into the underlying land. The rest of the MSW rots unattended on road sides and vacant plots of land. Bhubaneswar is the only city in India which has four landfill sites, whereas Delhi, Dhanbad, Faridabad, Greater Mumbai and Jaipur have three dedicated sites each. Rest of the cities all over the country have a single landfill site each, which is often over-exerted. 1285 new landfill sites have been identified across the country (Press Information Bureau, MoEF&CC).

There is a vast variation in the characteristics and composition of waste being generated in Indian cities. Figure 9.5 gives an indication of the composition of wastes being generated from Indian urban homes and commercial establishments. Data from 59 major cities in the country indicates that the compostable waste varies anywhere from 29.60 per cent (Daman) to 65.02 per cent (Amritsar) of the total. To tackle this, composting and vermi-composting plants have been set up in the states of Andhra Pradesh (32), Chhattishgarh (15), Delhi (3), Goa (5), Haryana (2), Gujarat (86), Himachal Pradesh (13), Karnataka (5), Kerala (29), Madhya Pradesh (4), Maharashtra (125), Meghalaya (2), Orissa (3), Punjab (2), Rajasthan (2), Tamil Nadu (3), Tripura (13), Uttarakhand (3) and West Bengal (9) (Status Report on Municipal Solid Waste Management, CPCB). It may be noted that segregation of wastes and composting of bio-degradable component at household and/or

Overflowing Dumpsites in Delhi

One of the most populous Indian cities, Delhi generates a massive amount of solid waste every day. In the absence of requisite and competent waste management processes in place, a major portion of this waste ends up in the city's dump sites at Ghazipur, Okhla and Bhalswa. The sites have been operational since 1984, 1996 and 1994 respectively. Some of these are still being illegally used by the local authorities due to lack of alternative sites for landfilling/dumping. Nearly 8000 tonnes of waste is dumped into these sites daily, leading to overflowing piles and frequent cases of methane catching fire in the garbage stacks.

Such unmanaged dump sites are also known to heavily contribute to environmental pollution by releasing toxic gases and leachates into the surroundings.

Source: Department of Environment, Delhi Government

neighbourhood level is negligible. While a significant amount of paper and plastic segregation at household level through informal sector does take place, the recyclable fraction for example, spanning from 10.91 per cent in Chandigarh to 36.65 per cent in Shimla, finds its way into general waste stream, making it laborious to segregate and channelize to the right kind of processing and/or disposal units. On an average 54.81 per cent of the waste generated in an Indian city is recyclable, making recycling a lucrative option if practiced correctly (Compendium of Environment Statistics India, 2015). The 3Rs (Reduce, Reuse and Recycle) philosophy is gaining prominence in the public eye and may help us manage our trash dumps efficiently in the future.

Plastic is another bane of the modern civilization. India annually consumes 12 million tonnes of plastic products every year as of 2012, out of which a huge 50-60 per cent ends up in disposal bins. India's per capita consumption of plastic is about 6-7 kg per annum. The biggest consumers of plastics are developed countries like the US and Europe using upto 109kg/person and 65kg/person respectively (Potential of Plastics Industry in Northern India, FICCI 2014). India's consumption is way less than developed countries, but poor management makes it a cause of concern. The majority of plastic that finds its way into waste streams consists of plastic carry bags, packaging, disposable water bottles, containers and household materials. An important fact that needs mention here is that there are no reliable records of data on plastic waste generated and disposed in India. Additionally, the percentage composition of plastic waste in municipal waste of different cities ranges from 3.10 per cent in

Chandigarh to 12.47 per cent in Surat (Status of implementation of Plastic Waste Management, 2015).

E-waste, another growing component of waste in urban areas includes electrical and electronic equipment, whole or in part, discarded as well as rejects from manufacturing or defurbishment and repair processes. These range from refrigerators, washing machines, computers, printers, televisions, mobiles, ipods, batteries etc.; many of which contain toxic materials and trace elements.

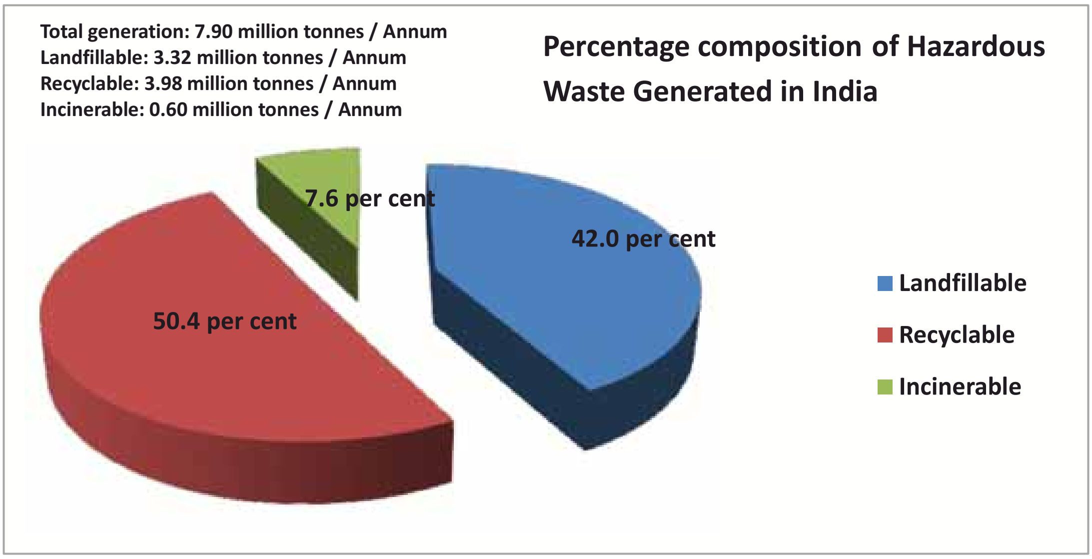
Central Pollution Control Board (CPCB) in 2005 estimated 1.46 lakh tonnes of e-waste generation in the country which was expected to exceed 8 lakh tonnes by 2012. According to a report by the United Nations University, 'the global e-waste monitor 2014', India has witnessed generation of 17 lakh tonnes of E-waste in 2014. The state of Maharashtra generates the maximum amount of waste electrical and electronic equipment at 20,270 tonnes annually (e-waste in India, 2011).

A growing stream of e-waste with hazardous substances, such as mercury, is that of spent and spoilt fluorescent and CFL light bulbs and tubes from households, commercial and institutional sources. The CFL industry is growing by a huge 50 per cent or more annually with no scientific mechanisms to safely dispose them once they become dysfunctional (Report of Task Force on Environmentally Sound Mercury Management in FL Sector). Guidelines of disposal and management being inadequate and collection systems almost non-existent for these very common household items, they find their way into domestic waste streams handled by rag-pickers and garbage collectors in an unscientific manner.

The number of registered dismantler/recyclers in the country has increased from 91 to 151 during last three years, which is insufficient to deal with the quantity of e-waste generated. The combined capacity of these 151 dismantling /recycling units located in 13 states is 446,855 metric tonnes per annum. Despite the release of guidelines by concerned government bodies, most of the e-waste is still in the confinements of the informal sector, where it is segregated and scrapped to procure certain metals that can be lucratively recycled. The remains are then casually disposed, leaching toxins into the surroundings (Ministry of Environment, Forest and Climate Change, 2015).

The notification of E-Waste (Management & Handling) Rules 2011 came into force in May 2012, and is based on the Extended Producer Responsibility (EPR) principle, thus making it the responsibility of the producer to collect and process the electronics once out of function. A period of one year was provided to the stakeholder, especially the producers, to set up systems and infrastructure for an effective take back programme and further channelization of e-waste. Unfortunately, there is not much progress on the take back system till now.

Figure 9.6: Percentage Composition of Hazardous Waste Generated in India



Source: Existing Scenario of Hazardous Waste Management in India, Central Pollution Control Board, 2009

Table 9.6: Number of TSDFs, Secured Landfills and Incinerators in Different States and UTs

State/UT	Integrated TSDFs	Exclusive Common Incinerators	Exclusive Common Secure Landfills (ESCLs)
Andhra Pradesh	1	-	-
Gujarat	4	1	4
Haryana	1	-	-
Himachal Pradesh	-	-	1
Karnataka	-	5	1
Kerala	-	-	1
Madhya Pradesh	1	-	-
Maharashtra	3	-	1
Odisha	-	-	1
Punjab	-	-	1
Rajasthan	-	1	2
Tamil Nadu	1	-	-
Telangana	1	-	-
UP	2	1	1
Uttarakhand	1	-	-
West Bengal	1	-	-
Daman, Diu, Dadra & Nagar Haveli	1	-	-
TOTAL	**17**	**8**	**13**

Source: Central Pollution Control Board 2014-15, Annual Report

Hazardous Substances

A significant challenge in waste management has resulted from the shift in natural to synthetic products that include paints, petrochemicals, dyes, metals, pharmaceuticals etc. The production of these synthetics requires a variety of chemicals that are processed and modified generating wastes that can neither be biologically handled nor completely segregated by current known technological processes. As per the Hazardous Waste (Management, Handling & Trans boundary Movement) Rules, a major quantity of hazardous waste is generated by the 36 processes recognized under Schedule I of the said rules, which include metal and petrochemical refining, production of dyes and paints, etc.

As per the latest reports by CPCB, there are about 42,429 (Annual Report, 2014-15) hazardous waste generating industries in the country, letting out 7.90 Million Tonnes of such waste per annum (Fig 9.6).

In industrial areas, both hazardous and non-hazardous wastes are generated, many of which have recycling potential. While hazardous wastes are regulated as per Rules under Environment Protection Act 1986, non-hazardous waste either remains unregulated or becomes part of consent conditions under the Water and Air Acts.

A meaningful quantity of this hazardous waste can potentially be recycled and put to use, circling back into production streams. The table below indicates the number of waste treatment/ disposal facilities in different states in India, indicating the poor infrastructural capacity with respect to the amount of waste generated. Many recycling and waste disposal facilities have come up in various states (Table 9.6); however, more facilities are still required to cater to the entire waste stream generated within each State/UT. The high volume, low affect waste such as fly ash, phospho-gypsum, red mud, jarosite, slags from pyro-metallurgical operations, mine tailings and ore beneficiation rejects, which are excluded from category of hazardous waste, are required to be managed as per guidelines issued by Central Pollution Control Board.

Biomedical Waste

According to the annual report information for the year 2014 of the CPCB's Hazardous Waste Division that also handles bio-medical waste, there are 1,69,913 Health Care Facilities (HCFs) with a cumulative bio-medical waste generation of about 495.3 tonnes/day in India. Of these, 1,18,964 HCFs have obtained authorization under the Bio-Medical Waste (BMW) Rules. There are 191 Common bio-medical waste treatment facilities (CBWTFs) in operation (33 under construction in 2014), while 21,491 HCFs have captive biomedical waste treatment and disposal facilities. The common and captive facilities together are only able to treat and dispose off 461.9 tonnes of biomedical waste from 495.3 tonnes generated everyday. About 5980 HCFs/CBWTFs were found violating the provisions of the BMW Rules (Status and Issues on implementation of Bio-medical waste Rules, 1998 and as amended, 2015).

The remaining is still a huge amount that lays piled up across open areas, hospital surroundings or lands up untreated with municipal solid waste. Out of the total, 11,690 HCFs have obtained authorisation under the Biomedical Waste (Management and Handling) Rules, 1998 and amendments made thereof. The new rules called Bio-Medical Waste Management Rules, 2016 have come up for effective implementation.

The States of Arunanchal Pradesh, Goa, Mizoram, Nagaland and Sikkim, and the union territories of Andaman and Nicobar, and Lakshadweep Islands are yet to develop their own CBWTFs.

9.2.2b Pressures contributing to Waste Accumulation

Increasing Population

The waste management issues in India have gone up in the last decade and can be attributed to a number of factors. The major underlying factor is increased urban population and the consequent desire for modern lifestyles. The urban population in India has gone up a staggering 31.8 per cent from 28,61,19,689 in 2001 to 37,71,06,125 in 2011 (Census of India, 2011). More people flock to the urban centers for better livelihood opportunities and better health and education facilities, exerting immense pressure on the city's infrastructure and making it a challenge to manage the waste. More industries and production centers come up to support the material needs of the inhabitants, exerting the waste management system of the city.

A desire for better lifestyles has resulted in greater resource consumption and consequent higher amounts of waste generated. There is an increasing trend of e-waste generation year after year due to increasing obsolence rate of electronic products, and similarly there is an increase in the biomedical waste generated owing to an increase in the number of HCUs (1044 new units added in 2014).

Evolving Profile of Waste Generation

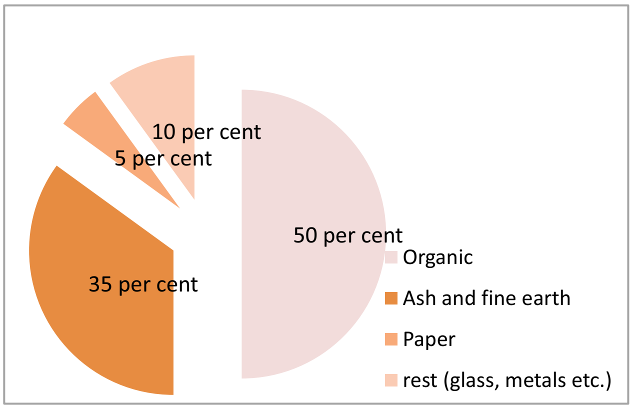
The changing dynamics of the type of wastes is also a deterrent in effective management of waste. More non-biodegradable components require better segregation and recycling or processing than biodegradable materials. The composition of MSW at generation sources and collection points in India is observed to mainly consist of a large organic fraction (40-60 per cent), ash and fine earth (30-40 per cent), paper (3-6 per cent) and plastic, glass and metals (each less than 1 per cent) (Swachh Bharat Mission: Solid Waste Management Manual, 2016). A typical composition in an Indian city is graphically represented in Figure 9.7.

Inadequate and Non-Scientific Management of Wastes

Ineffective and non-scientific management of waste is the root cause as to why India struggles with huge piles of waste in landfills. A state-wise list on generation of municipal waste indicates that 82 per cent (1,17,644 TPD) of the waste is collected and only 23 per cent (32,871 TPD) is treated. Maximum amount of solid waste generated is in the state of Maharashtra (26,280 MT) whereas only 56.60 per cent (14,900 MT) is collected and 17.88 per cent (4,700 MT) is treated. Similarly, Tamil Nadu which only treats 11 per cent (1,607 MT) of its total waste (Compendium of Environment Statistics India, 2015).

It is also estimated that the Urban Local Bodies spend about Rs. 500 to Rs. 1500 on a tonne of solid waste for collection, transportation, treatment and disposal. About 60-70 per cent of this amount is spent on street sweeping of waste, 20 to 30 per cent on transportation and less than 5 per cent on final disposal of waste, which shows that hardly any attention is given to scientific and safe disposal (Solid Waste Management Compendium, 2016, CPHEEO).

Figure 9.7: Composition of MSW in a Typical Indian City



Source: Swachh Bharat Mission: Solid Waste Management Manual, Ministry of Urban Development, 2016

Environmental Quality Monitoring

The Central Pollution Control Board over the years has been strengthening its systems for real-time environmental quality monitoring, regulatory compliance checks and creating infrastructure for scientific processing and disposal of waste. Some of these initiatives are illustrated below:

- Number of air quality monitoring stations has increased from seven in 1984 to 591 in 2014-15. This network is spread across 29 states and 5 Union territories.
- As a part of the National Water Quality Monitoring Network, the number of monitoring stations has grown from 1700 stations in 2009-10 to 2500 in 2011-12. Water quality of 445 rivers is recorded by the network.
- Final guidelines on Implementation of E-waste rules, 2016 highlight the importance of extended producer responsibility and define the process for its implementation.
- The CPCB is also proactive in cancelling registrations of Lead acid battery importers due to non-compliance of safe handling and management guidelines.
- 1285 new landfill sites have been identified for construction of scientific landfills and waste treatment centers.

Photo 9.2: Disposal of unsegregated waste causes land pollution

Photo 9.3: Advanced infrastructure is required for scientific treatment and disposal of municipal solid waste

9.2.3a Water Quality and Management

Water quality and pollution of water sources is a critical concern for India. According to the India Infrastructure report (2011), over 70 per cent of the surface water and an increasing quantum of ground water sources are contaminated much above acceptable standards by organic and inorganic pollutants. Although water is a renewable resource, increasing demand by a growing population, agriculture and industry requirements, and inadequacy of management and treatment systems, both natural and man-made, have resulted in a steady decline in freshwater availability. Pollution loads in many of the monitored sources exceed the natural regenerative capacities of the sources and sinks and therefore along with quantity of water demanded by competing uses, the quality of available water stands threatened too.

The extent of water quality is determined by the BOD and pathogenic bacterial contamination on the one hand and by the extent of salinity and toxic minerals such as mercury, arsenic, fluorides and iron on the other. These make the water unfit for consumption by humans and animals and even unfit for agriculture and industry applications.

A study by the CPCB in 2009 and further validated in an updated report in 2012, indicated that microbial contamination was the major form of surface water pollution in India, to which domestic sewage contributes heavily. Nearly 64 per cent of the surface water observations had BOD levels less than 3mg/l, while 17 per cent observations fell into a category with BOD levels as high as 6mg/l and more. Apart from poorly treated sewage, over burdening of the river bodies lacking enough water to accommodate or dilute the discharged waste, also contributes to higher BOD levels (Water Quality Status Report, CPCB, 2012).

Standards for Drinking Water in India

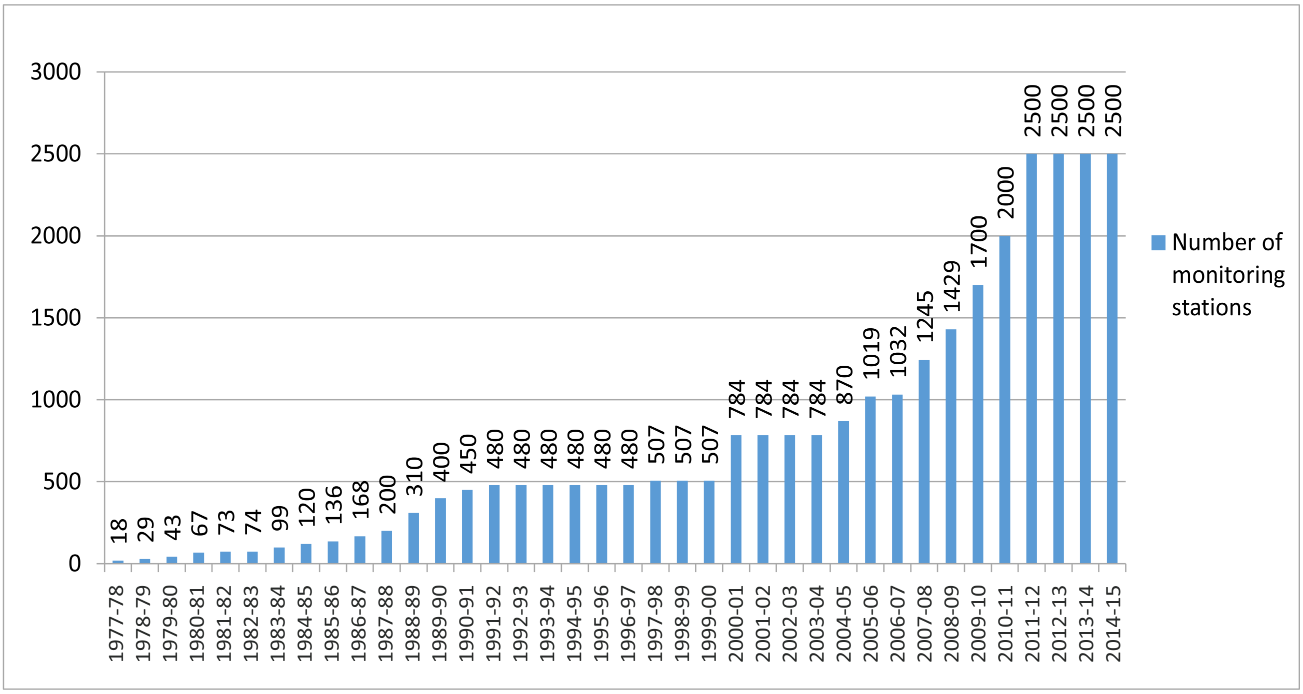
Parameter	Standard
Odour:	unobjectionable
pH:	6.5 - 8.5
Total Dissolved Solids:	500 mg/L
Hardness:	300 mg/L
Alkalinity:	200 mg/L
Iron:	0.3 mg/L
Chloride:	250 mg/L
Flouride:	1 mg/L
Arsenic:	0.05 mg/L
Lead:	0.01 mg/L
Mercury:	0.001 mg/L

Source: IS 10500:2012, Bureau of Indian Standards

Water Quality and Standards

The Bureau of Indian Standards sets permissible limits for different parameters affecting water quality in the country, thus recognising them as safe for the

Fig 9.8: Year-Wise Growth of Monitoring Network in India



Source: Central Pollution Control Board, 2015

Polluted Stretches based on BOD Levels

Priority Class I BOD levels >30mg/l

Priority Class II BOD levels 20-30mg/l

Priority Class III BOD levels between 10-20 mg/l

Priority Class IV BOD level between 6-10mg/l

Priority Class V BOD levels between 3-6 mg/l

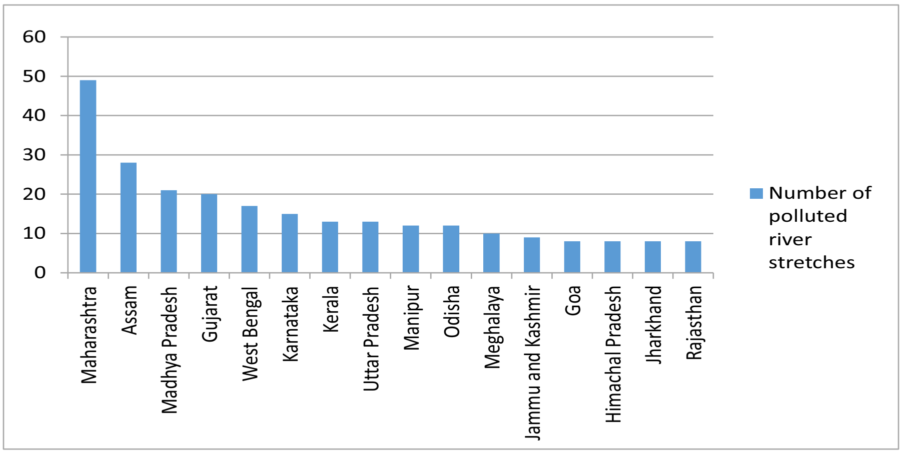
intended purpose. There are specified standards for water intended for drinking, recreation, domestic and industrial uses.

According to the Central Pollution Control Board, the monitoring infrastructure that consists of water quality monitoring stations has grown over the years and now covers all aquatic sources in the country. The number of monitoring stations has grown rapidly from 1,429 in 2008-09 to 2,500 in 2014-15 (Figure 9.8). We are now able to track the quality of ground water as well as river and surface water bodies much better; though data indicates that water quality issues persist and have in fact grown (Water Quality Status Report, CPCB, 2012).

Pollution of Rivers and Surface Water

Organic matter and bacterial contamination from human and animal excreta continue to dominate the water pollution problem of rivers and surface waters as indicated by the 2012 monitoring results obtained under the National Water Quality Monitoring Programme. The CPCB Annual report, 2015, has

Fig 9.9: State-wise Categorization of Polluted River Stretches in India



Source: Central Pollution Control Board, 2015

The Choked Yamuna

According to CPCB standards, the water quality of Yamuna falls under category 'E' which makes it fit only for recreation and industrial cooling. Pollution of the Yamuna from untreated wastewater/domestic sewage discharge from Delhi-NCR, Mathura and Agra has rendered the river unfit for any use. Over the last decade, dissolved oxygen (DO) levels have plummeted to zero and BOD levels, which should ideally be about 3mg/l, range from 4 to 29 between the stretches in Delhi, indicating that the river can barely support life. The Yamuna Action Plan has not been able to contribute to visible betterment in the river's water quality.

Source: (International Journal of Environmental Sciences, 2014 and Central Pollution Control Board)

Table 9.7: Number of Observation Wells in Indian States

State	No. of observation wells
Andhra Pradesh	981
Arunanchal Pradesh	19
Assam	381
Bihar	373
Chhattisgarh	516
Goa	53
Gujarat	966
Haryana	426
Himachal Pradesh	85
Jammu & Kashmir	206
Jharkhand	208
Karnataka	1,499
Kerala	864
Madhya Pradesh	1,325
Maharashtra	1,496
Manipur	25
Maghalaya	38
Mizoram	NA
Nagaland	17
Odisha	1,214
Punjab	261
Rajasthan	1,373
Sikkim	NA
Tamil Nadu	906
Tripura	42
Uttar Pradesh	1,218
Uttarakhand	44
West Bengal	909
A&N Islands	63
D & N Haveli	10
Delhi	87
Daman & Diu	4
Pondicherry	15
All India	**15,640**

Source: Central Ground Water Board

indicated that 275 rivers of the 445 monitored are polluted. The classification is based on mainly the BOD levels in water. Among the 302 identified polluted river stretches in the 275 rivers, 34 fall in Priority Class I, 17 in Class II, 36 in Class III, 57 in Class IV and 158 in Class V. The largest numbers of polluted stretches lie within the state of Maharashtra with Assam, Madhya Pradesh and Gujarat following closely (Figure 9.9). The most polluted rivers on specific stretches are Vashishtha, Kalinadi, Damanganga, Markanda, Sukhna, Mithi, Musi, Tambirapani, Bhavani, Yamuna and Umkhrah, whereas Mahi, Narmada, Brahmaputra and Beas are relatively clean with respect to organic and bacterial pollution.

The remaining states each have five or less polluted stretches, although the severity of pollution may not be appropriately reflected in the numbers for example, Delhi has just one river, the Yamuna, which is severely polluted and a single polluted stretch in the figure does not indicate the plight of the river. Statistics indicate that indicate that major towns (650) and metropolitan cities are located along the majorly polluted rivers, indicating the imbalance between urban centres and management of natural water systems.

Many water bodies in the Indian subcontinent are also under the pressure of eutrophication due to increased discharge of inorganic and organic dissolved and suspended materials which support propagation of algae and plant life due to higher NPK content from domestic and industrial sewage. Lack of quantitative data on parameters like eutrophication and organic content in rivers may be a hindrance in proper planning by experts and in effective river management strategies.

Table 9.8: Districts having Arsenic in Groundwater in Different States in India

State	Districts having As >0.05mg/litre
Assam	Dhemaji
Bihar	Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Katihar, Khagaria, Kishanganj, Lakhiserai, Munger, Patna, Pumea, Samastipur, Saran, Vaishali
Chhattisgarh	Rajnanadgaon
Uttar Pradesh	Agra, Aligarh, Balia, Balrampur, Gonad, Gorakhpur, Lakhimpur, Kheri, Mathura, Muradabad
West Bengal	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Praganas, South 24 Praganas

Source: Groundwater Quality in Shallow Aquifers of India, Central Ground Water Board, 2010

Major metropolitan cities such as Delhi, Kolkata, Hyderabad, Bengaluru and Mumbai also have a similar situation. Urban population in India has gone up from 27.81 per cent in 2001 to 31.16 per cent in 2011 (Census of India 2011), pressuring the river systems that support urban centres. Many severely polluted water bodies are near major population centres of the country.

Ground Water Contamination

In India, over 80 per cent of the rural population and 50 per cent of the urban population uses ground water for domestic purposes. Such a high dependence on ground water for domestic consumption as well as agriculture and industry make this source important from the perspective of quality management. Trends indicate that a large proportion of ground water in country is polluted and lost for use.

The Central Ground Water Board monitors the chemical quality of ground water in the country once in a year (April/May) through a network of 15640 observation wells. The state-wise distribution of observation wells being monitored by CGWB is given in the Table 9.7.

Apart from these observation wells, the quality of ground water from unconfined aquifers is also being monitored through various studies such as ground water management studies and special studies taken up in different areas by the Board as per its Annual Action Plans.

Ground water quality is monitored for salinity (through electrical conductivity), chlorides, fluorides, iron, arsenic and nitrates by the Central Ground Water Board. In addition, CPCB through its network of 807 points monitors groundwater with respect to temperature, pH, DO, Conductivity, BOD, Nitrate, Nitrite, Total Coliform (TC) and Faecal Coliform (FC).

Arsenic: Arsenic levels above 0.05 mg/litre are considered harmful and not permissible for domestic consumption. However, in some regions in Rajasthan, the absence of alternate source of drinking water has influenced the relaxation of the standards from permissible limits of 0.01 mg/l to 0.05 mg/l. High arsenic content in ground water affects the human, animal, soil and plant systems. As many as 96 districts in 12 States have been affected by high arsenic contamination in ground water. 70.4 million people in 35 districts alone have been exposed to groundwater arsenic. Over one lakh deaths and 2 to 3 lakhs of confirmed cases of illness have reportedly been caused by arsenic contamination of ground water (Ground Water Quality Scenario in India, 2014-15).

In West Bengal, 79 blocks in 8 districts have arsenic beyond the permissible limit of 0.01 mg/L and about 16 million people are in risk zone. The most affected districts are on the eastern side of Bhagirathi River in the districts of Malda, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas and western side of the districts of Howrah, Hugli and Bardhman. Arsenic in ground water is reported mainly in the intermediate aquifer in the depth range of 20-100m. The deeper aquifers are free from arsenic contamination. Apart from West Bengal, Arsenic contamination in ground water has found in the states of Bihar, Chhattisgarh, Uttar Pradesh and Assam. Arsenic in ground water has been reported in 12 districts In Bihar, 5 districts in UP and one district each in Chhattisgarh and Assam. The occurrence of Arsenic in the states of Bihar, West Bengal and Uttar Pradesh is in alluvium formation but in the state of Chhattisgarh, it is in the volcanics exclusively confined to N-S trending Dongargarh-Kotri ancient rift zone. It has been reported in Dhemaji district of Assam. Table 9.8 depicts the occurrence of Arsenic in ground water in some States of India.

Very high arsenic concentration is reported in the mining areas of Rajasthan in Western India especially around mining areas of Khetri Copper Complex and Zawar mines in Jhunjhunu and Udaipur district respectively. This problem is also frequent in Bihar mining belts where it has contaminated ground water resources.

Fluoride Contamination: The Bureau of Indian Standards recommends an upper desirable limit of concentration of fluoride in drinking water as 1.0 mg/l of F. This may be relaxed to 1.5 mg/l of F in case no alternative source of water is available. Water with fluoride concentrations of more than 1.5 mg/l in water is unsafe and not suitable for drinking purposes. The 2010 Central Ground Water report of shallow aquifers indicates that the majority of country's observation wells show fluoride concentrations well within acceptable levels. However, fluoride levels in drinking water in 14 states of India, have been detected to be above permissible levels. These locations are found in the States of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Rajasthan, Chattisgarh, Haryana, Odisha, Punjab, Haryana, Uttar Pradesh West Bengal, Bihar, Delhi, Jharkahnd, Maharashtra, and Assam.

Trends indicate that extent and concentration of fluoride concentrations in drinking water has increased over time. Some estimates indicate that up to 65 per cent of the rural population of India is exposed to fluoride risk.

Iron: High concentration of Iron in ground water has been observed in more than 1.1 lakh habitations in the country. The highest value (49 mg/L) has been found at Bhubaneswar. Ground water contaminated by iron has been reported from Assam, West Bengal, Orissa, Chhattisgarh, and Karnataka. Localized pockets are observed in states of Bihar, UP, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu, Kerala and North Eastern States.

Nitrates: The most common contaminant identified in ground water is dissolved nitrogen in the form of nitrate (NO_3). The direct source of nitrates in ground water are mainly nitrogen sources on the land surface. These could be shallow subsoil zones where nitrogen rich wastes are buried through the nitrate in wastes or fertilizers.

Nitrates also originate through conversion of organic nitrogen due to the processes of ammonification and nitrification. An important step in the nitrogen cycle, the biological oxidation of ammonia or ammonium to nitrite and then to nitrate. This is related to the capacity of soil micro-organisms to convert ammonia to nitrate to provide growing plants with the assimilable form of nitrogen.

Nitrate contamination is especially found in shallow aquifers. The range commonly reported for ground water is not limited by solubility constraints. Very shallow ground water in highly permeable sediment or fractured rocks commonly contains considerable dissolved oxygen and in these hydrological environments, nitrate commonly migrates large distances from input areas. The source is mainly from agricultural activities.

In India, high concentration of nitrate (more than 45 mg/l) has been found in many districts of Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu, Rajasthan, West Bengal and Uttar Pradesh. The highest being 3080 mg/L has been reported in Bikaner, Rajasthan.

Salinity: Inland salinity in ground water is prevalent mainly in the arid and semi-arid regions of Rajasthan, Haryana, Punjab and Gujarat and to a lesser extent in Uttar Pradesh, Delhi, Madhya Pradesh Maharashtra, Karnataka, Bihar and Tamil Nadu. About 2 lakh sq.km has been estimated to be affected by saline water with electrical conductivity more than 4000 µS/cm. There are several places in Rajasthan and southern Haryana where EC values of ground water are higher than 10000 µS /cm making water non-potable. Inland salinity is also caused due to surface water irrigation As per recent assessments, about 2.46 Mha of the area under surface water irrigation projects is water logged or threatened by water logging.

Withdrawal of fresh ground water from coastal aquifers may result in inequilibrium, therefore resulting in intrusion of saline water in coastal aquifers. The Indian subcontinent has a dynamic coast line of about 7500 km length. It stretches from Rann of Kutch in Gujarat to Kanyakumari in the south and northwards along the Coromandal coast to Sunderbans in West Bengal. In India, salinity problems have been observed in a number of places in the coastal areas. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol-Chorwad-Porbander belt along the Saurashtra coast. In Orissa in an 8-10 km wide belt of Subarnrekha, Salandi, Brahamani outfall regions in the proximity of the coast, the upper aquifers contain saline horizons decreasing landwards. Salinity ingress is also reported in Pondicherry region, east of Neyveli Lignite Mines.

The level of vulnerability is higher in areas where all the above mentioned pollutants are present in the ground water.

9.2.3b Pressures acting upon Water Resources

Water quality deterioration is driven by several factors. The increasing pressures of human sewage, waste water and solid waste, inadequacy of treatment infrastructure and pollutants leaching from unsanitary land fills is a major concern in urban areas. Besides these, agricultural runoffs with high concentrations of fertilizers and flood irrigation and chemicals from industrial sources as a result of non-compliance of industrial waste management guidelines, excessive drawing of ground water and changes in precipitation pattern, all increase the pollutant load in water sources.

Pressures of Sewage, Waste Water and Solid Wastes

As per the latest estimate of Central Pollution Control Board, about 38,000 million litres of wastewater is generated in the country everyday (CPCB). Only 27 cities across the country have primary treatment facilities and 49 have both primary and secondary treatment facility.

A large part of un-collected, un-treated wastewater finds its way to surface water bodies or is accumulated in the city itself forming cesspools. In almost all urban centres cesspools exist. These cesspools are good breeding ground for mosquitoes and also source of groundwater pollution. Wastewater accumulated in these cesspools percolates and pollutes groundwater. Conventional septic tanks and other low cost sanitation facilities are still prevalent in many urban areas. These are poorly maintained and become major sources of groundwater pollution. In smaller cities and towns, even septic tanks do not exist and human excreta is directly let out into open drains that drain into rivers and streams. In many urban areas groundwater is only source of drinking and a large population is exposed to the risks of water borne diseases of infectious or chemical nature.

The gap between generation and treatment of sewage results in the high level of BOD in water bodies as evident in the water quality reports across river stretches and surface water bodies.

In addition, urban solid waste management systems and infrastructure currently is unable to handle the large volumes of municipal wastes being generated. The mixed nature of urban waste finding its way into large, unscientifically managed land-fills leads to toxins leaching into the ground and enhance pollutant levels in groundwater. The practice of segregation of wastes at source that would result in significant reduction of what goes into a land-fill, is not practiced at the city level in any Indian city.

An assessment and feasibility study of 24/7 water provision in 15 Class A cities of Maharashtra by the CEPT University (2013) indicated that poor supply infrastructure coupled with pressure changes in water pipelines leads to ingress of leaking sewage from sanitation lines into drinking water system. The under-pricing of domestic water has been attributed to poor revenues and inadequate maintenance and subsequent deterioration of the supply infrastructure. In many dense urban habitations untreated waste water from domestic sources often finds its way into surface and ground water courses. This waste water contains high organic pollutant loads. With many of these habitations dependent on ground water for domestic purposes, this is a huge health hazard.

Unregulated Industrial Effluent Discharge into Ground Water and River Systems

In India, industries are the second largest consumers of water after agriculture. Waste water from chemical

Photo 9.4: Water Pollution due to direct discharge of effluents

processes in industries lands up in rivers and surface water bodies increasing the chemical loads with long lasting human and environmental health impacts. This is mainly a case of non-compliance rather than lack of knowledge or availability of infrastructure. Many industries even in the region covered by the Ganga Action Plan do not have adequate effluent treatment facilities and have been reported to be discharging upto 501 MLD of effluent into the river (ENVIS Centre, CPCB). The Central Pollution Control Board has identified 17 highly polluting industries, the majority of which are manufacturing industries and now placed in the red category. Major polluting industries are sugar mills, distilleries, leather processing industries and thermal power plants. CPCB issued guidelines to 3377 industrial units falling under 17 categories of highly polluting industries for installation of online monitoring systems. Out of these, 2140 units have complied to the directions (CPCB, 2015). The issue has been covered in detail in the Industries and Mining chapter, which also addresses the effects of mining on water resources.

Maharashtra has the maximum number of industries which do not comply to the standards (Figure 9.10). The situation is equally grim in most parts of the country and demands stricter implementation of laws.

Overdraw due to Irrigation

Two-thirds of India's farm production comes from one-third of its land which is irrigated. The rest is from rainfed areas that employ large populations. In order to meet the increasing demand for food and farm employment, India has to enhance productivity in both irrigated and rainfed areas. For the agricultural sector, water and electricity for irrigation are subsidized for political reasons. This leads to wasteful flood irrigation rather than adoption of more optimal practices such as sprinkler and drip irrigation. Cropping patterns and farming practices also do not necessarily encourage the judicious use of water. Conservative estimates indicate that the same quantity of irrigation water used today can irrigate double the current area with optimized irrigation and farming practices. With limited revenues and budgetary support, the state engineering departments are unable to operate and maintain the irrigation systems efficiently, leading to increasing deterioration of the structures and systems over time. Consequently, there are further water losses due to breaches and seepage, resulting in water logging and salinity. Water quality is further affected due to the overuse of chemical fertilizers and pesticides which are not entirely used by the plants and land into rivers as constituents of surface runoff. This section has been elaborated in the Agriculture chapter.

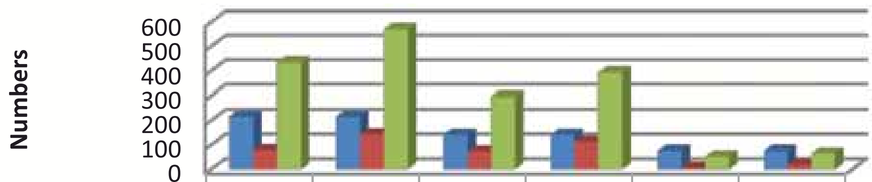
Fertiliser dependent agricultural practices also contribute excess of Nitrates, Phosphates and Potash salts into the water discharge, which pollute water by increasing eutrophication and accumulation in shallow aquifers. Figure 9.11 shows the top five nitrate affected states in India.

Changing Rainfall Patterns

A change in precipitation patterns (Figure 9.12) is another contributor to water stress in India. As

Figure 9.10: Polluting Industries Discharging their Effluents into Rivers and Lakes

Status of Polluting industries discharging their effluents into rivers and lakes



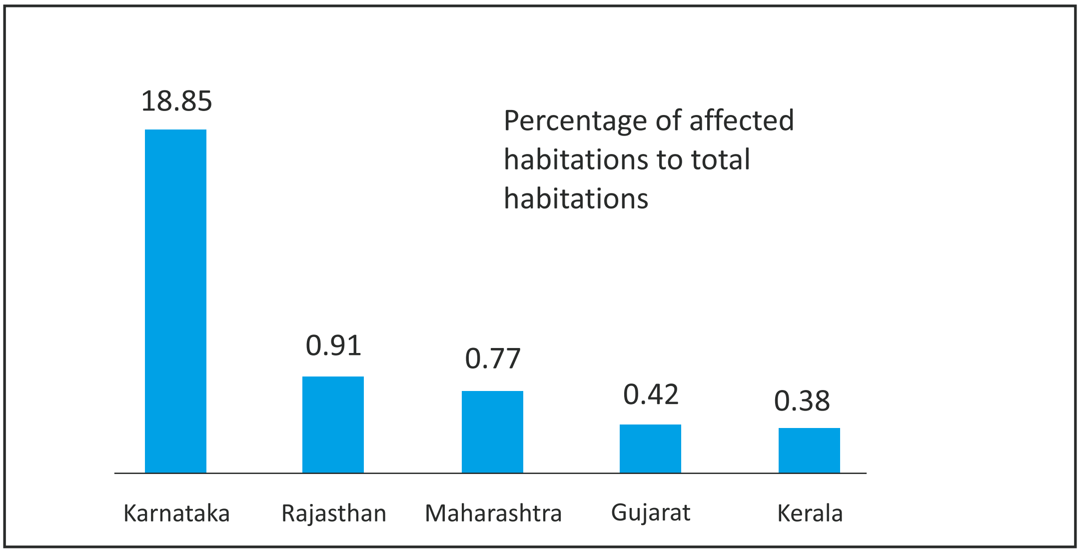
	Total		Complying		Not Complying	
	2010	2011	2010	2011	2010	2011
Maharashtra	214	214	139	139	73	73
Haryana	76	142	71	112	4	17
Uttar Pradesh	432	569	294	391	49	62

Source: Central Pollution Control Board, 2015

Tanneries in Uttar Pradesh

Majority of the industries have not installed boards depicting the name of industry, environmental and hazardous wastage usage. Effluent treatment plants for majority of units are inadequate capacity and poor maintenance. Design of clarifiers is most faulty with respect to retention time and is not appropriately synchronised with pumping rate leading to high TSS in waste water.

Figure 9.11: Nitrate Affected States in India



Source: Data originally from The Ministry of Drinking Water and Sanitation (2011) as accessed in Water in India report, The United Nations Childrens' Fund (UNICEF), 2013 indicated in the figure below, many Indian states face the issue of deficient rainfall, Bihar facing the maximum threat, followed by Uttar Pradesh, Assam and Haryana. Reduced rainfall inhibits self-regeneration capacity of polluted water sources. Even when total rainfall remains the same nationally, the number of rainy days has decreased whilst the intensity has gone up, resulting in higher surface water runoff and reduction in absorption of rainwater by the soil. This runoff water gets into the sewage system and consequently needs to be treated as discharge. It increases dilution in the rivers for only a limited time, while most of the year concentrations of chemical and organic wastes in streams and rivers continue to rise.

9.3 IMPACTS

Air and water pollution, and solid waste accumulation have become amongst the most pervasive of health hazards today. It would not be wrong to say that a majority of human diseases originate from pollution of land, water and air.

Human health impacts and demands on waste and pollutant management have a consequential impact on the economy. Environmental pollution is thus both a public health concern as well as an economic efficiency issue. Finally, polluted water-bodies and atmosphere have cascading negative impact on the ecology, flora and fauna of a bio-region.

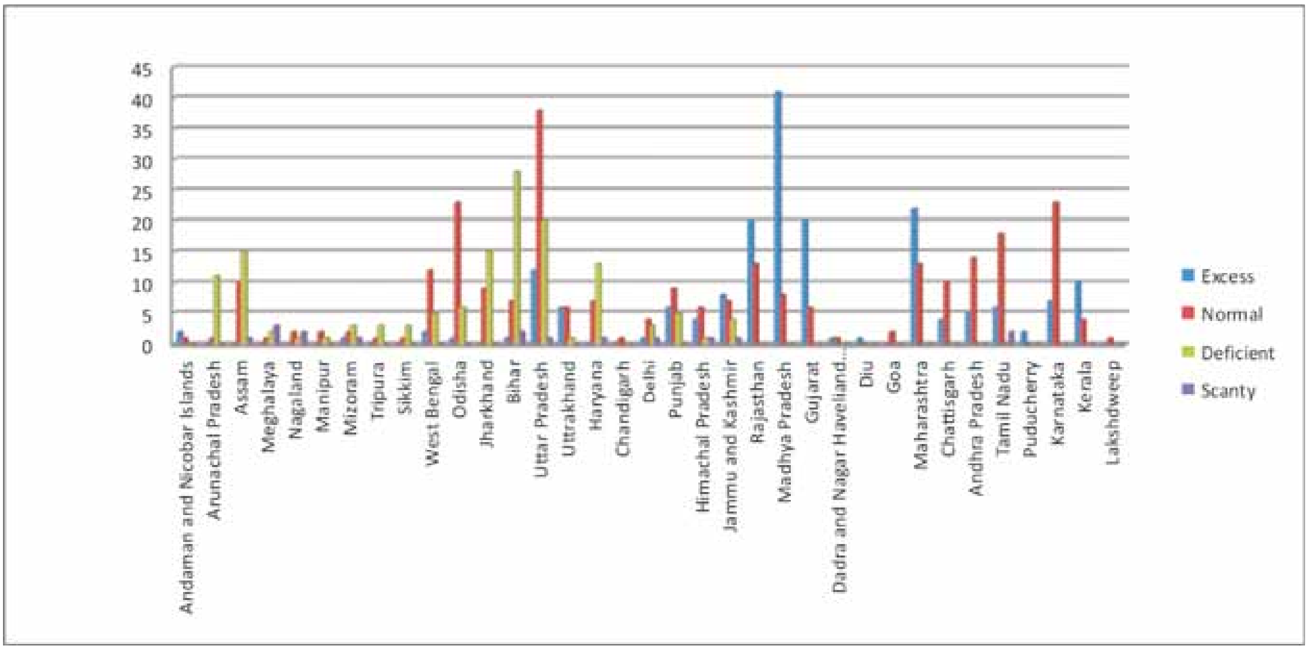
9.3.1 Impact on Public Health

The compounding effects of indoor and outdoor air pollution, water quality deterioration and waste accumulation have severe impacts on both human and environmental health.

Impact on Respiratory Health: Studies across the world and also in India prove that outdoor and indoor air pollution is a serious environmental risk factor that causes or aggravates acute and chronic diseases and has been identified as the fifth highest cause of morbidity in India (Atkinson et al. 2011). Globally, over 7 million deaths in the world were attributed to the combined impact of ambient (3.7 million) and household (4.3 million) air pollution (WHO, 2015).

The WHO tracks and monitors four health related pollutants, namely Particulate Matter (PM_{10} and $PM_{2.5}$) Nitrogen dioxide, Sulphur dioxide and Ozone, although other pollutants also impact human health and environment (WHO, 2006). The Central Pollution Control Board (CPCB) in India, under its National Air Quality Monitoring Programme (NAMP) focuses on three major pollutants viz. PM_{10}, Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) for regular monitoring at all locations. Other parameters like $PM_{2.5}$ (Particulate Matter having an aerodynamic diameter less than or

Figure 9.12: Rainfall Status in States and Union Territories



Source: Indian Meteorological Department, Ministry of Earth Sciences equal to 2.5 µm), Carbon monoxide (CO), Ammonia (NH_3), Lead (Pb), Ozone (O_3), Benzene (C_6H_6), Benzo (a) pyrene {B(a)P}, Arsenic (As) and Nickel (Ni) are being monitored at selected locations and are slowly being added to the monitoring network under NAMP.

CPCB gives ambient air quality data in different cities of India. Only 31 cities meet the standard of 60 µg/m^3 for PM_{10} out of 204 cities for which data exists. Almost all the cities in India except for Dombivali (52) and Ulhasnagar (46) lie below the permissible limit of 50 µg/m^3 for SO_2. There are 9 cities which exceed the permissible limit of 60 µg/m^3 for NO_2. A correlation drawn between HDI (poverty), and PM_{10} and $PM_{2.5}$ indicates that poor and developing economies have relatively worse air quality parameters. This would also indicate that people with already vulnerable health are further compromised due to high amounts of pollutants in their atmosphere (Air Pollution Health Discussion Paper, TERI).

The current standards for atmospheric particulate matter as set by the CPCB are higher than the WHO norms. Almost 80 per cent Indian cities regularly violate PM_{10} norms (CPCB, 2012). The percentage distribution of deaths across states attributable to ambient particulate matter pollution in India, indicates ischemic heart disease, and cerebrovascular and chronic obstructive pulmonary diseases as the major killers (figure 9.13).

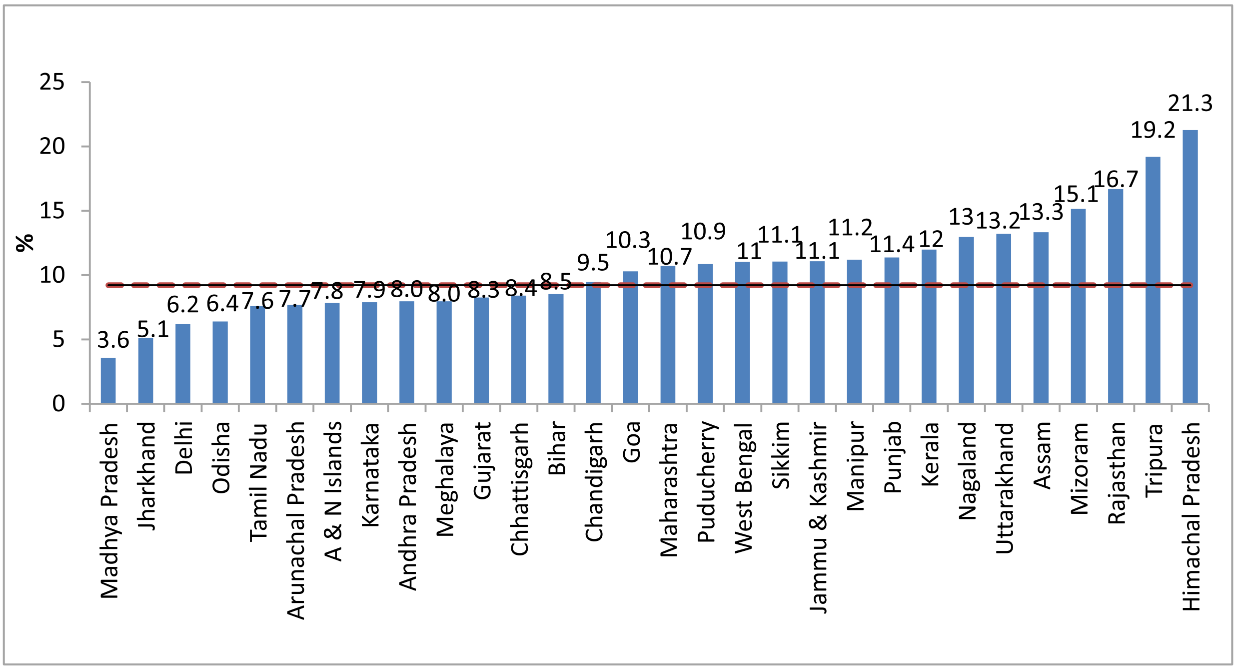
Studies by the WHO and Harvard University suggest that high exposure to $PM_{2.5}$ leads to increase in cardio-pulmonary mortality and cancer (WHO, 2013).

It is therefore important that $PM_{2.5}$ is also measured in all locations. The studies also concluded that even small improvements in $PM_{2.5}$ levels could yield significant health benefits. And, while small reductions in pollution in cleaner cities result in large health benefits, less cleaner cities would have to bring down their pollution to much lower levels for relative benefits to be discernable.

Children are especially susceptible to the effects of air pollution because their lungs are still developing. Relative to their body weight, children eat, breathe, and drink more than adults do. So children take in higher concentrations of any toxins in their food, water or air. Children also spend more time out of doors than adults, with more intense physical activity, causing them to breathe more deeply. A six city study conducted in India showed that child morbidity significantly increases with the increase in ambient air pollution (Ghosh and Mukherjee 2010). The six cities considered in the city were Chennai, Delhi, Hyderabad, Indore, Kolkata and Nagpur.

Indoor air quality has emerged as one of the most important issues of environment and health worldwide. Household air pollution (HAP) due to biomass cooking fuel use is an important risk factor for a range of diseases, especially among adult women who are primary cooks (Lim et al 2010). Use of

Figure 9.13: State-wise Percentage of Deaths due to Respiratory Diseases



Source: Central Bureau of Health Intelligence, India (2013) biomass fuel leads to harmful health effects due to incomplete combustion and emission, of a large number of air pollutants such as carbon monoxide (CO), sulphur dioxide (SO_2), respirable particulate matter ($PM_{2.5}$ and PM_{10}), poly cyclic aromatic hydrocarbon (PAH), benzene, and metals like lead and copper. Several studies have linked biomass cooking fuel with adverse pregnancy outcomes such as pre-term births, low birth weight and post-neonatal infant mortality.

Auditory Disorders: Excessive and prolonged exposure to high noise levels have been found to have harmful impacts on human psychological wellbeing and health (OECD, 2014). The adverse health effects of noise are auditory disorders such as hearing impairment, tinnitus, ear ache, noise induced hearing loss, and non-auditory manifestations which include headache, psychological disturbances manifested by irritability, inability to concentrate on one's work thereby reducing work efficiency, disturbance in sleep and rest, and interference with speech communication.

Auditory morbidity is a serious issue which should not be neglected. It can lead to miscommunication, accidents, loss of livelihood, etc. Studies have also reported hypertension to be associated with noise exposure. Noise exposure among vulnerable groups, such as children, is an area of major concern. A study conducted in Odisha found that, though people experienced noise induced symptoms such as headache, bad temper, hearing problem, loss of concentration, and sleep disturbance, they were unaware of the ill-effects of noise on health.

As per the Global Burden of Disease Report 2004 of the World Health Organization, the global prevalence of moderate to severe hearing loss (41 decibels or greater) was 278 million, and mild hearing loss (26-40 decibels) was 306 million. In India, the prevalence of hearing loss was estimated to be 63 million (6.3 per cent). It is a common cause of years lived with disability.

Water Borne Diseases and Health Impacts: Water borne diseases are of the greatest concern in India where one-third of all deaths of children under five years of age are due to diarrhoea and pneumonia (India: Country Profile of Maternal, New-born & Child Survival, April 2010, UNICEF). Further, UNICEF reports indicate that even though child mortality has come down globally, almost 90 per cent of child deaths from diarrhoeal diseases are directly linked to contaminated water, lack of sanitation, or inadequate hygiene. Approximately 50 per cent of all under-five deaths are reported from five countries: India, Nigeria, Democratic Republic of the Congo (DRC), Pakistan and China. India (24 per cent) and Nigeria (11 per cent) account for more than one third of all global under five deaths. Water pollution and poor sanitation have been directly linked to this high mortality rate.

Delhi Smog 2016

The plight of the city in the days following Diwali has been talked about the world over, with citizens expressing anger over the exacerbating air quality of the region. In addition to the fireworks used around Diwali, the crop stubble burning in Punjab and Haryana has been a major contributor (about 70 per cent) to the thick black smog. In 2016, farmers burned approximately 32 million tonnes of paddy stubble at the end of October, to make way for the new crop. Despite National Green Tribunal's orders, the practise has not been sufficiently curbed. This is the worst recorded case over the last 5 years, with $PM_{2.5}$ levels exceeding 700µg/m^3.

Data source: Safar, Ministry of Earth Sciences, November 2016

Besides microbial infections due to unsafe water, other concerns are the increasing incidence of skeletal disorders, dental fluorosis, anaemia and genetic changes due to fluorides and arsenic poisoning.

India is amongst the worst affected countries with the largest number of people suffering from fluorosis. A study in the journal of water and health presented in 2006 indicated India as having the highest disease burden due to fluorosis (table 9.9). This was corroborated in 2013 in the International Journal of Research and Development on Health which suggested that in India, 62 million people including 6 million children are estimated to have serious health problems due to consumption of fluoride contaminated water. Data of 2013 indicates 15 states in India are endemic for fluorosis and 6 million (almost 10 per cent) of the total population affected by fluorosis comprises of children below 14 years of age.

High levels of Fluoride were reported in 230 districts of 20 States of India (after bifurcation of Andhra Pradesh in 2014). The population at risk (as per population in habitations with high fluoride) is 11.7 million as of 2014. Rajasthan, Gujarat and Andhra Pradesh are worst affected states. Punjab, Haryana, Madhya Pradesh and Maharashtra are moderately affected while Tamil Nadu, West Bengal, Uttar Pradesh, Bihar and Assam are mildly affected (Fluorosis, National Health Portal of India).

The first groundwater arsenic incident and its health effects in India were reported in 1976 in the Union Territory of Chandigarh (Occurence of High Arsenic Content in Ground Water, First Report, 2014). In 1982, groundwater arsenic contamination and reports of individuals suffering from arsenicosis emerged in West Bengal. Later on, groundwater contamination and the suffering of exposed individuals came to limelight in Bihar (2002), Uttar Pradesh (2003), Jharkhand (2004), and the Upper Ganga Plains of Uttar Pradesh (2009). In the Brahmaputra Plains, arsenic contamination was reported from Assam and Manipur between 2004 and 2006. The population of the 35 districts identified with ground water arsenic contamination in these six states is 70.4 million. (CGWB, 2014-15)

Arsenic contamination is by far the biggest mass poisoning case in the world putting 20 million people from West Bengal and Bangladesh at risk, though some other estimates put the figure at 36 million people (International Water Management Institute). Arsenic, fluoride and heavy metal contamination in ground water sources have health impacts such as damaged joints and bone deformities, yellowing of teeth and toxicological effects on genetic material in living organisms. Metals like chromium are also known carcinogens.

Vector Borne Diseases: Vector borne diseases, especially dengue and chikungunya, filariasis and leptospirosis are on the rise in urban areas. The breeding grounds for these vectors are mismanaged waste sites and solid waste accumulated in open sewers, drains and roadsides, where water collects and mosquitoes breed or rodents proliferate. Dengue is amongst the fasted growing vector disease. In India, dengue cases have been steadily rising with a dip only in 2011.

Exposure to Toxins in Waste Management

India struggles with proper management of its waste, especially e-wastes, hazardous wastes from industry and bio-medical wastes. Most e-waste lands up in the informal sector, where it is recycled without any consideration to health and environment. Open burning, acid baths, unventilated work spaces and crude handling of chemicals are typical of these operations, where susceptible groups like children and women are regularly employed. With no safety equipment at hand, the workers in some of the recycling hotspots spread all over the country are exposed to the toxic cocktails daily. The unregulated practices also release hazardous materials in air, water and soil, thereby endangering our environment. Despite government guidelines, toxic chemical products like discarded lead acid batteries and CFL lamps still end up in general waste piles.

E-waste generation is increasing by 10 per cent annually (E-waste in India, 2011). Around 25,000 workers, including children, are involved in crude dismantling units in Delhi alone where 10,000–20,000 tonnes of e-waste are handled every year by bare hands. Improper dismantling and processing of e-waste render it perilous to human health and our ecosystem. It also contains valuable non-renewable materials, hence, there is the necessity to recycle materials and reduce burden on mining of virgin materials. Recovery of these materials without any adverse impact on environment requires a set of complex operations and highly advanced technology. Some of these

Table 9.9: Estimated population affected by dental and skeletal fluorosis in selected countries (mid-point estimate)

Country	Population estimated to be suffering from (thousands)	
	Dental Fluorosis	Skeletal Fluorosis
Niger	159	41
Ethiopia	868	184
USA	0	0
Brazil	0	0
Peru	0	0
Saudi Arabia	263	35
Pakistan	2,234	517
Egypt	928	182
UK	0	0
Thailand	0	0
India	18,197	7,889
China	23,523	10,887

Source: An attempt to estimate the global burden of disease due to fluoride in drinking water, Journal of Water and Health, 2006 complexities and concerns for the environment, created conditions for the policy makers in many parts of the world to involve the producers/product manufacturers to own responsibility for the end-of-life disposal of these products and initiated introduction of a policy tool called the 'Extended Producer Responsibility' (EPR).

Biomedical waste when improperly disposed, poses health risk due to indiscriminate dumping and finding way into municipal waste dumpsites, leaching pathogens and chemicals into the surrounding land and water resources.

Another major impact stems from the inadequacy of hazadrous waste management facilities and indiscriminate dumping at many locations, because of which a number of hazardous waste dump sites have been contaminated. As per information available on the CPCB website, 35 locations spread across India have 71 hazardous waste contaminated sites. Contamination at most of the sites is owing to the presence of chromium, flouride, cyanide, heavy metals, mercury, lead and hydrocarbons.

9.3.2 Economic Loss and Inefficiency

According to a World Bank study in 2009, about 1100 billion INR (1.7 per cent of GDP) and more than 800 billion INR (1.3 per cent of GDP) were estimated as the annual cost of environment damage caused by ambient air pollution and household air pollution, respectively, in India (World Bank, 2009).

This indicates that about 52 per cent of the relative share of damage cost by environment category was due to ambient and household air pollution put together (World Bank 2013).

Data from the country's apex environmental regulator, the Central Pollution Control Board (CPCB), reveals that approximately 80 per cent of Indian urban agglomerations exceeded National Ambient Air Quality Standard (NAAQS) for Respirable Suspended Particulate Matter PM_{10} in 2010 (CPCB 2015). Estimates from the WHO suggest that 13 of the 20 cities in the world with the worst fine particulate $PM_{2.5}$ air pollution are in India, including Delhi, the worst-ranked city at number 7. The report suggests that air pollution also leads to a reduction in life expectancy. Using a combination of ground-level in situ measurements and satellite based remote sensing data, it has been estimated that 660 million people, over half of India's population or nearly every Indian (1,204 million people, or 99.5 per cent of the population), live in areas that exceed the Indian National Ambient Air Quality Standard for fine particulate pollution. Reducing pollution in these areas to achieve the standard would, increase life expectancy for these Indians by 3.2 years on average, for a total of 2.1 billion life years (Greenstone et al 2015).

Health impacts of Hazardous Components in E-waste:

Arsenic: Can affect skin and reduce nerve conduction velocity. May even trigger lung cancer.

Lead: Can affect kidneys, reproductive organs, brain and nervous connections.

Mercury: Affects central nervous system, kidneys and the immune system. It also impairs foetal growth when expecting mothers are exposed to it.

CFCs: Damage the ozone layer. Can cause skin cancer in humans and genetic disorders in other organisms.

Dioxins: Highly toxic and carcinogenic to humans and the environment alike.

BFRs (Brominated Flame Retardants): Can cause hormonal disorders in humans, and harm reproductive and immune systems.

Water borne diseases had a huge economic impact on the country which was roughly equivalent to the state income of Tamil Nadu in 2010 (Water and Sanitation Program, 2010, accessed in Water in India, UNICEF, 2013), making water pollution one of the biggest challenges India faces today- economically, environmentally and socially.

9.3.3 Impact on Environment

High BOD and low DO levels in water bodies are responsible for choking of underwater marine life, where instances of huge numbers of dead fish have been reported all over the country. At the most polluted stretches, most Indian rivers are unable to support any living organisms.

These toxins in the river water bio-magnify and accumulate over time and trophic levels, such that they occur in the highest concentrations at the terminal water body, having adverse impacts on the marine life and biodiversity.

Impacts of various kinds of pollution on specific environmental components have been elaborated in the Biodiversity, Marine and Coastal Ecology, Land and Forests, and Water chapters of this report.

9.4 RESPONSES

Environmental pollution and its management have been high on the agenda for the Ministry of Environment, Forests and Climate Change, Government of India. The Central Pollution Control Board serves as a field information source and also provides technical services to the Ministry on the provisions of the Environment (Protection) Act, 1986. As per CPCB (2013-14), municipal authorities have set up 553 compost and vermi-compost units, 56 biomethanisation plants, 13 waste to energy and 22 RDF plants across the country (Press Information Bureau). The Environment (Protection) Act of 1986 is an umbrella Act on all issues related to environmental protection and provides for the audit of all facilities that require permits under water pollution, air pollution and hazardous waste rules. Together, these laws enshrine the "polluter pays principle" into Indian environmental policy, and have evolved to include citizen suits, right to information, and incentives for pollution prevention.

Principal functions of the CPCB, as spelt out in the Water (Prevention and Control of Pollution) Act, 1974, and the Air (Prevention and Control of Pollution) Act, 1981, are: (i) to promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution, and (ii) to improve the quality of air and to prevent, control or abate air pollution in the country. The CPCB sets pollutant discharge standards from all discharge points including those from Sewage Treatment Plants and standards specific to different industries. The State Pollution Control Boards (SPCBs) have the mandate to monitor performance and take enforcement action.

The MoEF&CC also puts out policies and guidelines at the national level for various environmental management issues and monitors their implementation. In association with other ministries and relevant state governments, it sets in place the institutional mechanisms to deal with pertinent issues, for example, National Ganga River Basin Authority or the National Green Tribunal. The environment protection policies and guidelines are reviewed and revised from time to time, for example the Waste Management Rules 2016, brought together all the various types of wastes and their management under one umbrella with comprehensive measures for the management of urban solid wastes, plastic wastes, bio-medical, hazardous and e-wastes. Despite government bans on plastic carry bags in many towns and states, no serious implementation has been carried out.

9.4.1 Policy Initiatives for Management of Air Quality

Air Quality Management: The Air (Prevention and Control of Pollution) Act was enacted in 1981 and amended in 1987 to provide for the prevention, control and abatement of air pollution in India. Under the Act, standards, rules and guidelines for ambient and household air quality and management of air quality are enforced. State governments are empowered to take action to declare air quality control areas, take steps to implement guidelines and standards, monitor and track air quality and penal action in the case of non-compliance or set in place mechanisms for improving air quality parameters.

Central Pollution Control Board is executing a nation-wide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP). The network consists of 342 operating stations covering 127 cities/towns in 26 states and 4 Union Territories of the country.

The objectives of the NAMP are to determine status and trends of ambient air quality; to ascertain whether the prescribed ambient air quality standards are violated; to Identify Non-attainment Cities; to obtain the knowledge and understanding necessary for developing preventive and corrective measures and to understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated.

Under NAMP, four air pollutants viz., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM / PM_{10}) have been identified for regular monitoring at all the locations. The monitoring of meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality.

The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and

8-hourly sampling for particulate matter) with a frequency of twice a week, to have one hundred and four (104) observations in a year. The monitoring is being carried out with the help of Central Pollution Control Board; State Pollution Control Boards; Pollution Control Committees and National Environmental Engineering Research Institute (NEERI), Nagpur. CPCB co-ordinates with these agencies to ensure the uniformity, consistency of air quality data and provides technical and financial support to them for operating the monitoring stations. NAMP is being operated through various monitoring agencies. Large number of personnel and equipment are involved in the sampling, chemical analyses, data reporting etc. It increases the probability of variation and personnel biases reflecting in the data, hence it is pertinent to mention that these data be treated as indicative rather than absolute.

9.4.2 Policy Initiatives for Management of Solid Wastes

The National Waste Management Guidelines, 2016 are a comprehensive perspective towards waste reduction, recovery, reuse, recycling and scientific disposal. They bring together guidelines for the management and rules for the waste generators (both producers and consumers), municipal bodies and elated departments and ministries with respect to municipal solid wastes – domestic, construction and demolition, plastic wastes, e-wastes, bio-medical wastes and hazardous wastes under one umbrella.

The solid waste management rules, 2016 been revised after 16 years with due process of an expert Working Group of the ministry that drafted the rules and put it out for public review and suggestions, stakeholder consultations in New Delhi, Mumbai and Kolkata and consultative meetings with relevant Central Ministries, State Governments, State Pollution Control Boards and major hospitals.

The rules are applicable to municipal areas and extend to urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, airports, airbases, ports and harbours, defence establishments, special economic zones, State and Central government organizations, places of pilgrimage, religious and historical importance.

The rules now mandate waste generators, such as households, industries, hospitals and others to segregate waste into three categories – Wet, Dry and Hazardous Waste with a 'User Fee' to the waste collector and a 'Spot Fine' for littering and non-segregation. The rules require that segregated waste be channelized to generate wealth though recovery, reuse and recycling. Under the rules, integration of the present informal sector of rag pickers and waste collectors through local Civil Society Organisations and linking them to formal waste chains and to local bodies has been recommended.

In addition to very specific waste segregation rules for all domestic, institutional, commercial and industrial establishments, including events that generate wastes. The updated document has laid strict rules with respect to responsibility of producers of equipment or consumer products for wastes generated in their complete value chains including take-back of e-waste and labelling on disposal, collection systems for non-recyclable or non-biodegradable packaging material, awareness creation and systems for disposal of bio-wastes, for example from sanitary napkins.

Under the new rules, local bodies have the power to decide on user fees for the collection, processing and disposal of wastes from bulk generators. The generator will have to pay "User Fee" to the waste collector and a "Spot Fine" for littering and non-segregation, the quantum of which will be decided by the local bodies. There is "zero tolerance" for littering, burying and burning wastes stipulated in the rules.

The new rules give attention to composting and bio-methanation of organic wastes, requiring land area to be allocated in residential, industrial and commercial developments for the purpose. The Department of Fertilisers, Ministry of Chemicals and Fertilizers is required to provide market development assistance on city compost and ensure promotion of co-marketing of compost with chemical fertilisers, along with other support for the promotion of conversion of organic wastes into valuable compost. The compost standards have been amended to align with Fertiliser Control Order. They also encourage Waste to Energy plants in industrial units with mandated minimum consumption and utilisation of energy from these in industries and also facilitatory support from the MNRE to set up infrastructure and make appropriate power uptake arrangements by discoms. The rules have specified detailed location and management methods, including emission standards for landfill sites, and require local bodies to set up land fill sites for all cities with 1 million and above population, however they do not provide for a maximum limit of land fill area per capita which would have limited the scale of waste generated at settlement level.

A Central Monitoring Committee has been constituted under the chairmanship of Secretary, Ministry of Environment, Forest and Climate Change and members from different relevant ministries, representative of some local bodies, state pollution boards, experts and chambers of commerce to monitor the overall implementation of the Rules. The Waste management guidelines have also introduced a partnership with Swachh Bharat Abhiyaan.

It will take almost 4-5 years to see the drastic change in how the waste management regimes will work in India. The SWM Rules, 2016 raises our hopes in pushing for adoption of a decentralised mechanism for solid waste management. However, it would be challenging to see how segregation at source shall work on the ground. A massive awareness campaign in association with communities, NGOs, students and other stakeholders needs to be planned to push for better implementation of these rules. The Rules need to focus on making solid waste management a people's movement by taking the issues, concerns and management of solid waste to citizens and grass-roots.

9.4.3 Waste Water Management

There is no distinct, separate policy to deal with waste water management in the country and Water and Waste water management in India is dealt with separately. While the latest Water Policy of India 2012, does recognise the serious concern of waste water management leading to pollution of fresh water sources both ground and surface, it does not provide any specifics on legal frameworks or implementation mechanisms.

Water pollution concerns are governed by the following environmental legislations, pollution control acts, and rules and notifications: The Water (Prevention and Control of Pollution) Act (1974, amended in 1988); The Water Prevention and Control of Pollution) Rules, 1975; The Water (Prevention and Control of Pollution) (Procedure for Transaction of Business) Rules, 1975; The Water (Prevention and Control of Pollution) Second Amendment Rules, 1976; The Water (Prevention and Control of Pollution) Cess Act, 1977 as amended by Amendment Act, 1991; The Water (Prevention and Control of Pollution) Cess Rules, 1978 and The Water (Prevention and Control of Pollution) Amended Rules, 1989 (Water and waste water in India , 2011).

The Water (Prevention and Control of Pollution) Act of 1974 restricts discharges of pollutants to water

Photo 9.5: Waste water treatment plant

bodies and created Central and State Pollution Control Boards with authority to set standards and enforce water pollution rules. The Water (Prevention and Control of Pollution) Cess Act of 1977 established a levy on industries using water, using the funds thus generated to augment the resources of the Central and State Pollution Control Boards.

As per Water Act 1974, State Pollution Control Boards possesses statutory power to take action against any defaulting agency. The CPCB has developed discharge standards for 33 parameters under four categories: discharges to inland surface waters, in marine coastal areas, to public sewers, and on land for irrigation. Creation of sewerage infrastructure for sewage disposal is responsibility of State governments/urban local bodies, though their efforts are supplemented through central schemes such as National River Conservation Plan, National Lake Conservation Plan, AMRUT etc.

Urban sewage becoming one of the most pertinent issues with respect to waste water management, its improvement in the recent years has been dealt with through urban development and urban rejuvenation programmes. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) launched in 2005 for a period of seven years, and extended till 2014 was replaced by the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme. Waste water management is also a point of consideration in the smart city (area development) initiatives. The AMRUT programme has identified water supply, sewerage facilities and septage management and storm water systems amongst a host of other city level priorities (Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Mission Statement & Guidelines , June 2015).

Five hundred cities are to be taken up under AMRUT. These include all cities and towns with a population of over one lakh with notified Municipalities, including Cantonment Boards (Civilian areas), all Capital Cities/ Towns of States/UTs, all Cities/Towns classified as Heritage Cities by MoUD under the HRIDAY Scheme, 13 cities and towns on the stem of the main rivers with a population above 75,000 and less than 1 lakh, and 10 cities from hill states, islands and tourist destinations (not more than one from each State. The components of the AMRUT consist of capacity building, reform implementation, water supply, sewerage and septage management, storm water drainage, urban transport and development of green spaces and parks. During the process of planning, the Urban Local Bodies (ULBs) are expected to include some smart features in the physical infrastructure components. AMRUT has reiterated the provisions of the National Urban Sanitation Policy (NUSP) of 2008 to reuse wastewater as an important factor in helping to urban areas meet their environmental targets of water recycling and reuse as the preferred option to meet total water needs of a habitation. It recognises the service level benchmark of at least 20 percent of the waste water generated in ULBs to be recycled within the prescribed norms for recycled water for non-potable uses. If implemented, this would reduce environmental pollution due to waste water to some extent.

A directly relevant policy for wastewater reuse is the CPCB standards for land application of treated wastewater for irrigation. These provide industry specific standards for land application. However, according to a report by the GIZ, land application of wastewater for irrigation is almost completely unmonitored and unregulated given the inadequate resources of SPCBs who can barely monitor air and water discharges of regulated industries. Use of untreated or inadequately treated wastewater for irrigation may be widely practiced, often out of compulsion in peri-urban or water scarce areas, with questionable impacts on public health and the environment.

A serious concern is the industrial pollutants discharged from micro, small and medium enterprises (MSMEs). These account for a significant quantum of land, water and air pollution in India. They have little technical and financial resources to implement effective and economically viable effluent treatment solutions. The Common Effluent Treatment Plants (CETPs) for MSME industry clusters have been promoted to address this problem. A subsidy scheme to defray 50 per cent of capital cost for a CETP with equal contribution from both State and Central government has been instrumental to enable over 88 CETPs with a total capacity of 560 MLD covering over 10,000 industries to be set up by 2013. Since then the subsidy support has been increased to cover 75 per cent of Capital investment.

A remarkable initiative for managing river water pollution has been taken under the National Ganga River Basin Authority (NGRBA). Functioning under the ministry of Water resources, the mission of the NGRBA is to safeguard the drainage basin which feeds water into the Ganges by protecting it from pollution or overuse. The NGRBA has installed Realtime Water

Quality Monitoring Stations on river Ganga. It is taking steps to conduct intensive water quality monitoring in polluted stretches of the river, periodically assess the levels of pollution of drains falling into the river, conduct ground water quality monitoring along the districts adjacent to the river, assess the adequacy of common effluent treatment plants, evaluate the performance of sewage treatment plants and verify compliance of Grossly Polluting Industries.

9.5 CONCLUSION

Environmental pollution is fast becoming a major public health issue. Unmanaged wastes released into air, water and land systems are impacting human health with fatal consequences. Respiratory diseases due to deteriorating air quality, water borne diseases due to poor water quality and vector diseases festered by solid wastes have taken epidemical proportions in the past. Added to these are slow killers resulting from toxins such as arsenic and fluorides, and depressed immune systems due to high levels of SO_x, NO_x, PM_{10} and $PM_{2.5}$. There is evidence that environmental pollution is seriously impacting human productivity and economic growth. Absenteeism in schools and from work due to human health issues, costs of disease control and treatment and expenditures associated with fresh water resource sourcing from distant places for human consumption and industry applications are adding up. In addition the losses due to non-recovery of precious metals and the loss in potential wealth generation due to inadequate to poor recycling of wastes is another area which needs serious attention. Land loss in the increasing land-fills is a serious issue that needs to be addressed, especially in dense urbanized regions and those where urban rural continuum has reduced available land for waste management. The waste stream is a potential for new resources such as composts, construction materials, plastics etc. which is a tremendous economic opportunity not being tapped.

Rapid and unplanned urbanisation and unregulated industrial growth are the key drivers of environmental pollution today. Almost 50 per cent of India's population is expected to become urbanized in the next 30 years. The fastest growth is being seen in small and medium towns. Densities in urban areas are growing exponentially, while infrastructure to manage wastes is neither growing as fast, nor, in the absence of financial and technical capacities of local bodies being maintained and managed. This is resulting in the deterioration of existing infrastructure with very little new infrastructure being added. The separation of water supply and waste water management systems is an issue for example, that needs to be highlighted. Pressures due to industrial development are only going to increase in the future. With the emphasis on manufacturing for new job creation and supporting economic growth, new industries, especially small and medium scale industries, are expected to increase substantially. Already, management of wastes from the MSMEs is an issue of concern. The CETPs are not adequate and the capacities of existing MSMEs need to be addressed. These would increase the quantum of unregulated waste disposal unless, cluster development of MSMEs with mandatory CETPs is not considered. Managing wastes from urban, industrial and agricultural sources and containing air and water pollution has been an area of concern for both Central and State Governments since the early 1970s. A large number of policy measures, regulations, guidelines and institutional mechanisms have been put in place. The launch of National Air Quality Index points to the need for enhancing public awareness on the quality of air they are breathing. The Waste Management Rules 2016 are a comprehensive updation of many of the waste management measures and have raised hopes of both stakeholder engagement as well as technology and financial support towards addressing wastes in a pro-active manner. Water quality and its management remain an area of concern. Despite mechanisms such as the Ganga Action Plan and other major river basin management efforts, pollutant discharge into rivers by cities and industries is rampant. Compliance is a big concern, and at the same time capacities of municipalities and MSMEs to undertake adequate treatment of wastes remains poor. Pollution due to agricultural fertilizers is an area not adequately addressed, either in policy, regulation or public awareness.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

CHAPTER 10

CLIMATE CHANGE

Key Messages

- *India is experiencing increasing temperatures and erratic rainfall patterns. The last decade i.e. 2006-2015 was the warmest on record.*
- *India's per capita GHG emission is less than one-third of the global average per capita emission.*
- *The country is at risk directly from an increase in the frequency and intensity of extreme climate events. These are expected to have adverse social and economic impacts.*
- *India's response to climate change is dual. While it aims to reduce its GHG emissions, it is also preparing to adapt to the impending impacts of climate change. one on hand while prepare for the impacts on the other.*
- *Climate change is a major challenge for India and response at an appropriate scale is expected to require significant quantum of financial and technological resources.*

10.1 INTRODUCTION

Climate change is an over encompassing issue that affects all other areas in this report. The Inter-Governmental Panel on Climate Change (IPCC), that assesses on a comprehensive, objective, open and transparent basis the best available scientific, technical and socio-economic information on climate change from around the world, defines climate change as "a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity" while the United Nations Framework Convention on Climate Change (UNFCCC) defines it as a "change that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods."

Climate Change has emerged as a global challenge requiring an integrated global response based on the principles of equity and Common but differentiated responsibilities and respective capabilities (CBDR & RC). The cumulative accumulation of greenhouse gases (GHG) historically since the industrial revolution led by the developed world has resulted in the current problem of global warming. This is further compounded by the inadequate response of the developed countries even after the adoption of the United Nations Framework convention on Climate Change (UNFCCC) and delineation of obligations and responsibilities. As a result, an 'emission' ambition gap has been created calling for enhanced global actions to address it.

Since the mid 20th century the Earth's climate system has been warming. The IPCC in its recent report – the Fifth Assessment report (AR5) published in 2014 – has observed that there has been an increasing trend in the anthropogenic emissions of GHG since the advent of the industrial revolution, with about half of the CO2 emissions during this period occurring in the last 40 years. The period 1983-2012 is likely to have been the warmest 30 year period of the last 1400 years.

The World Meteorological Organisation (WMO) has indicated that the global average near-surface temperature for 2016 was the hottest on record as a result of the long-term rise in global temperatures, caused mostly by emissions of GHG from anthropogenic sources, combined with effects of a very powerful warming El Niño event. The global average temperature for the year was approximately 1.1°C above the 1850-1900 (pre-industrial era) average. Although in the current era, most of the temperature rise is attributed to anthropogenic factors such as Greenhouse gases, Deforestation, Land-use Change, Energy Usage, Vehicular Usage etc. Greenhouse gases (GHGs) are naturally present in the atmosphere, and are absorbed by the biosphere and oceans. However, a multitude of scientific studies have stated that it is extremely likely that increased GHG emissions are a cause for the current global warming, and carbon dioxide (CO_2) occupies the highest share (70 per cent) among them. Globally this CO_2 is increasing due to burning of fossil fuels (56.6 per cent) (IPCC, 2014).

Climate change is more than just global warming, and global temperature rise is one part of the multitude of its implications. Climate change impacts are varied and are additionally driven by natural and human factors. Projections show that the climate of the planet will continue to warm over the next century and the impacts thus experienced are also projected to increase.

The complete study of climate change in India, must begin by looking at the shifts in weather patterns over 30 year cycles and impacts of this change in India. In this chapter we explore India's contribution to global climate change as well as other natural drivers that add to climate change. The chapter would further elaborate on the impacts India is facing due the change in the climate and will look at India's strategy in response to address climate change, both in mitigation and adaptation.

It needs to be understood, while reading this chapter that climate change is a cross-cutting issue, and thus impacts and responses to climate change are presented in a number of other chapters of this report, namely Urbanization, Land and Forests, Coastal and Marine ecology, Biodiversity, Agriculture and Energy.

10.2 STATUS

India is disproportionately affected by climate change as compared to most of the developed countries in the world. More so if looked at in terms of emissions, the impact is much more severe on the poor and on climate sensitive sectors such as agriculture and allied activities. India's rapidly developing economy needs significant amount of energy to meet its inclusive development objectives in a sustainable manner, which in some way or the other, directly or indirectly leads to climate change issues.

The subcontinent is among the world's most disaster prone areas. Around 85 per cent of the area is vulnerable to one or multiple hazards. 23 states are subject to floods, and prone to flood disasters. India's annual average flood damage was INR 47.45 billion (USD 753.2 Million) during the period 1996-2005 (NATCOM II, 2012).

The India Meteorological Department (IMD) has a vast weather observational network with 675 stations all across India. IMD regularly collects data and manages it. They also provide weather forecasting and research as required.

In order to observe the state of climate the Global Climate Observing System (GCOS) developed Essential Climate Variables (ECVs). The variables are required to compare the current status and the historical status to present a complete picture. They are divided into three domains:

- **Atmospheric** – the variables under this range from air temperature, air pressure, precipitation rates, wind speed and direction, surface radiation to the concentration of the different GHGs.
- **Oceanic** – the variables measured are sea surface temperatures, sea level, sea ice, ocean currents.
- **Terrestrial** – It constitutes river discharge, ground water levels, lake water levels, land cover (including vegetation type), glaciers, etc. (UNFCCC, 2010).

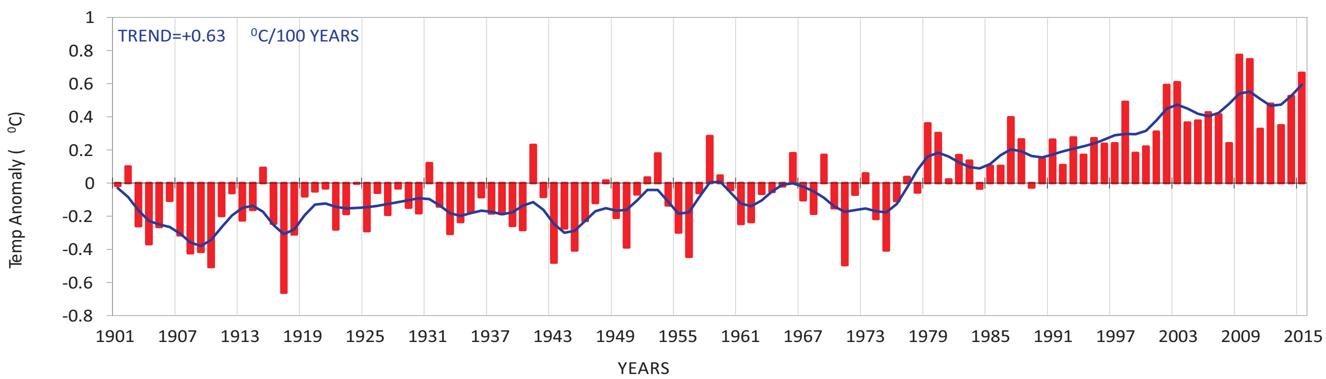
In India average temperatures have risen, while rainfall has remained highly variable with no clear trend. The climate change projections for India estimate that there might not be a significant drop in the monsoon rainfall except in the southern peninsula.

In few regions such as Marathwada in Maharashtra, Kashmir and Telangana, there have been extreme weather events like hailstorms, heat wave, and frost, along with unseasonal and erratic rains. These maybe attributed to climate change, and will be dealt in detail in the impact section.

India has a very dynamic climate due to its diverse and unique geography; from frigid Himalayas to the dry Thar Desert, and from semi-arid Bundelkhand region to the rain surplus Meghalaya. The Himalayas act as a barrier to prevent frigid katabatic winds into the subcontinent keeping it warm as compared to similar regions in the latitude. Temperatures for the Indian sub-continent show a strong gradient across regions and seasons, from very high temperatures in central India where the annual average temperatures exceed 42°C, to much cooler conditions in the northern parts of the country along the Nepal border. Similarly, precipitation also varies across the country and by seasons; measuring more than 2,818 millimeters per year in Assam, while annual precipitation can be less than 313 mm in the western state of Rajasthan.

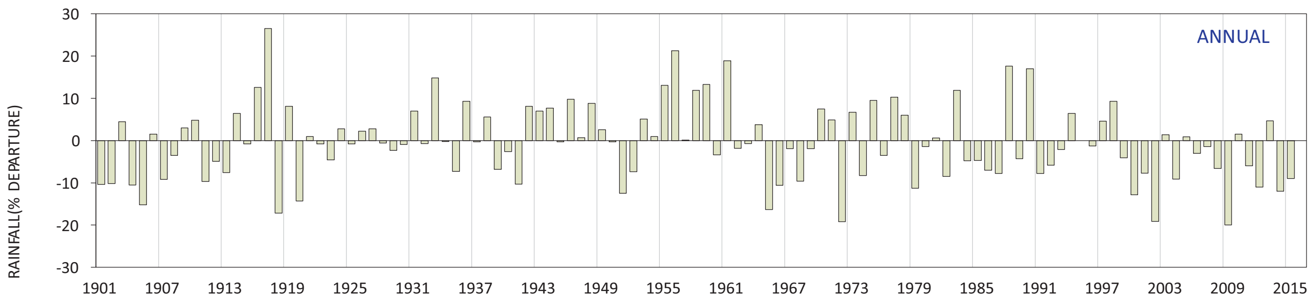
The Indian sub-continent covers a large range of climate zones and it sets it apart from the majority of other countries listed as developing nations in the UNFCCC. In order to assess the state of climate change in India this section delves on the change in

Figure 10.1: Observed temperature trend over India (1901-2015)



Source: India Meteorological Department, Annual Climate Summary, 2015

Figure 10.2: Trend in all India annual rainfall over the period (1901-2015)



Source: India Meteorological Department, Annual Climate Summary, 2015

temperature and precipitation, data availability, the observed trends and the projections for the future.

10.2.1 Changes in Temperature

The main physical impacts of climate change are temperature rise leading to change in precipitation and sea level rise due to polar and other snow melt. India's temperature has a distinct warming trend of 0.63 °C in 100 years from 1901 to 2015 (IMD, 2015). Climate during 2015 was significantly warm in respect of temperature. This warming is mostly constituted in the recent decade and due to post winter and monsoon seasons (NATCOM II, 2012). Between 1971 and 2007, the temperature has increased 0.2°C per decade, especially the minimum temperature. The All-India maximum temperature has an increase of 1.02°C per 100 years (NATCOM II, 2012). The IPCC (2014) predicts that by 2030, temperatures in India are set to rise by 1-4°C, with maximum increase in the coastal regions. For now the past decade (2006-2015) was the warmest on record with decadal mean temperature anomaly of 0.49°C (IMD, 2015). The IPCC (2014) predicts that by 2030, temperatures in India are set to rise by 1-4°C, with maximum increase in the coastal regions.

10.2.2 Changes in Precipitation

Rainfall in excess could cause floods or even droughts in scarcity. The Mahanadi river basin is assumed to have floods in September, and increased possibility of water scarcity in April (IPCC, 2014). Due to climate change rainfall in India has experienced an increase in mean and extreme precipitation during the summer season. India's precipitation is influenced by two rainy seasons out of which the South-West or summer monsoon brings 75 per cent of the country's annual rainfall. Annual variability in monsoon outset, seasonal rainfall distribution and intensity has a great impact on agriculture, power generation, ecosystems and water resources in India (MoEF&CC, 2015). The Himalayan region according to the IPCC (2014) will have the maximum increase in precipitation. The increase will cause weaker rainfall over central India and many other areas. Deciduous forests in India will change to evergreen ones due to increase in precipitation but human pressures such as deforestation will slow these changes (IPCC, 2014).

The trend of monsoon rains do not show any overall change in India, however, there are regional variations with increase in monsoon along the west coast and northwestern India. But an average of 0.4 mm/year decrease in rainfall is observed. A simple trend analysis of extreme rainfall shows that these occur mostly in the Western Ghats and North Eastern India over the period of 1951 to 2007. In 2014 and 2015 the rainfall average had a shortfall of more than 11 per cent as per the India Meteorological Department (IMD, 2015).

10.2.3 Future Projections of Climate Change

The report on climate projection, 'Climate Change and India: A 4×4 Assessment: A sectoral and regional analysis for 2030s' undertaken by Indian Network for Climate Change Assessment (INCCA) assessed the impacts of climate change over four climate-sensitive regions and provided regional climate change scenarios by using PRECIS. The climate change projections predicted that:

- There will be a 10 per cent increase in rainfall over central and peninsular India by 2030s. Further, there will be a 3-7 per cent increase in all-India summer monsoon rainfall.
- Annual mean surface air temperatures may rise by

2° C as per the projections of PRECIS in India.

- The climate model simulations also project that cyclonic disturbances will get more intense and change location towards South India via the Indian Ocean.
- Mean changes in temperature and rainfall are small, but individual simulations show large differences.

As per IPCC (2013) similar projections of rise in temperature and increase in summer monsoon precipitation is estimated. Further, IPCC predicts a loss of over USD 7 billion (around INR 42,749 crore) by 2030 in agriculture. This is in addition to worsening yields by 2050. The Indo-Gangetic Plains are highest at risk with significant reduction in wheat yields. From 2005 to 2014, in India there have been 16 major extreme climate events causing economic loss of USD 43,84,925 as per the International Disaster Database.

10.3 PRESSURES

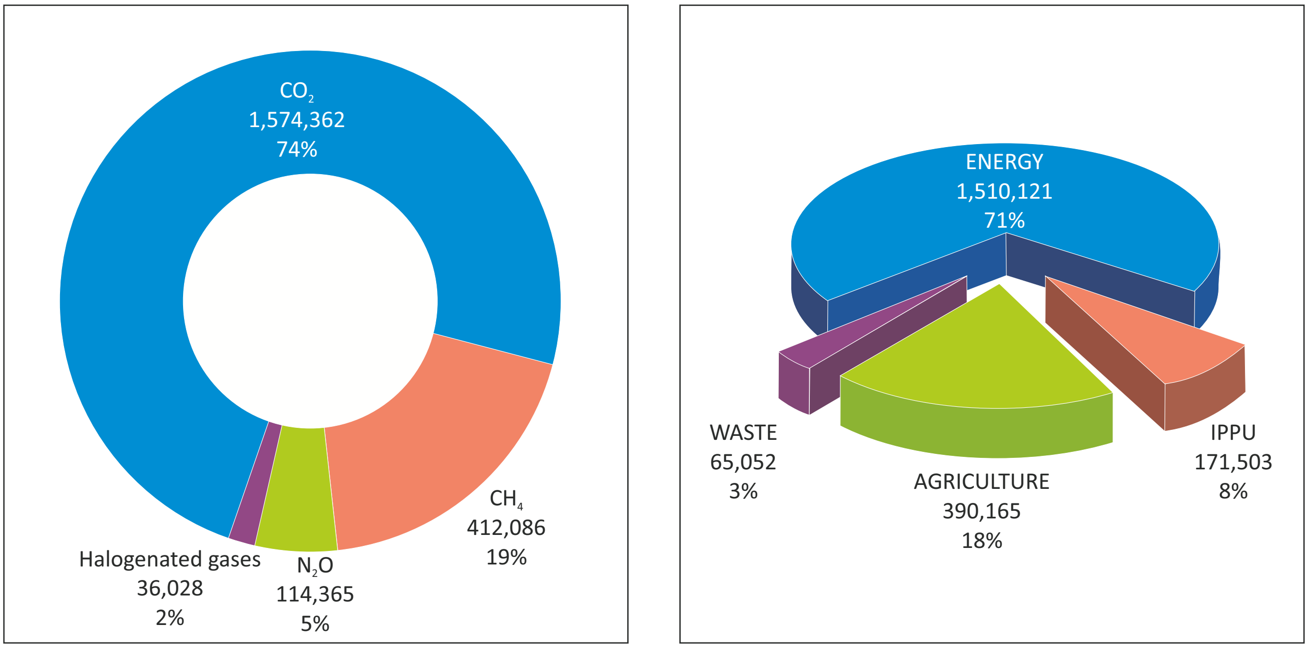
There are many drivers of climate change ranging from position of Earth's orbit to emissions of GHGs. The drivers of climate change could be divided into two – human induced or anthropogenic and natural drivers. Although, natural drivers of changing temperature are beyond control of any nation on Earth, the current change in as indicated earlier is human induced mostly. A complete study of the drivers and pressures on climate change would indicate that India does not contribute much towards climate change. It has not been a historical emitter of GHGs nor ozone depleting substances. Industrialized nations have a bigger responsibility towards climate change.

Anthropogenic Pressures

10.3.1 GHG Emissions

GHG emissions are considered as the main drivers of climate change today. A study of the GHG emission inventory highlights the contribution of India as a driver to global climate change. Energy needs are responsible for mostof the GHG emissions, this links it closely to the development pathway a nation takes. A complete GHG emission inventory would look at the emissions as well as their removal by sinks. Carbon links absorb GHGs and store in the form of carbon stock these are in the anthropogenic sense the forest sector. Including Land Use, Land Use Change and Forestry (LULUCF) is a GHG inventory sector that covers removals of GHGs resulting from direct human-induced land use, land-use change and forestry activities. CO_2 emissions mostly emanate from energy production, industrial processes and waste. Methane (CH_4) and Nitrous Oxide (N_2O) mainly emanate from agricultural activities. In 2010, 73 per cent of CH_4 and 75 per cent of N_2O has been emitted

Figure 10.3: GHG Emissions by Gas and by Sector, 2010 (Values in Gigagrams CO_2 equivalent)



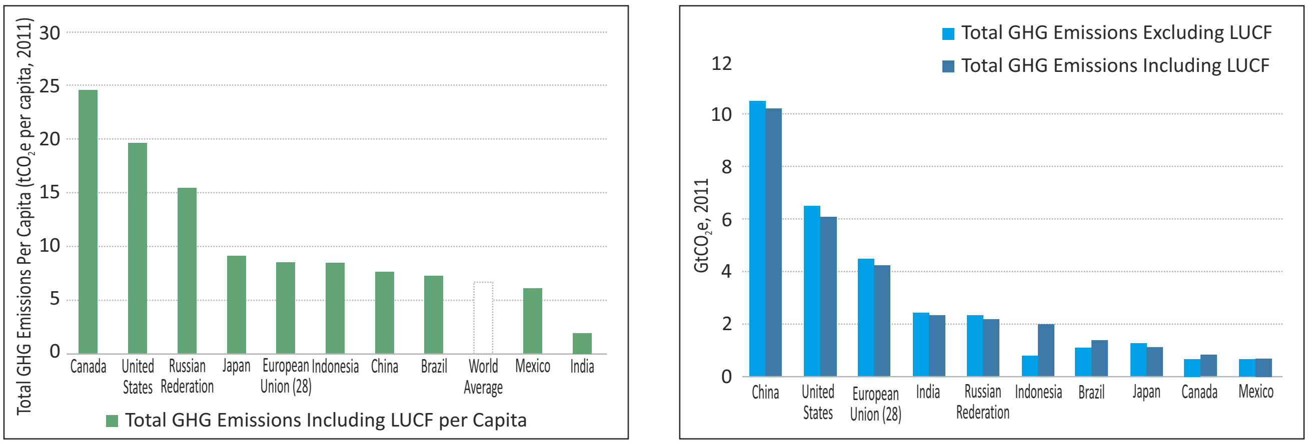
Source: Ministry of Environment, Forest and Climate change, 2015

Table 10.1: Greenhouse Gas Emissions, By Sectors, For India in 2010

Sectors	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC-134a	HFC 23	CF_4	C_2F_6	SF_6	CO_2 Equivalent
Energy	1,441,882.67	-	2,534.30	48.44	-	-	-			1,510,120.76
IPPU	132,479.47	-	22.97	8.11	-	1.43	2.13	0.58	0.0042	171,502.87
Agriculture	-	-	14,612.78	268.7	-	-	-	-	-	390,165.14
LULUCF	58,261.70	314,586.77	153.02	1.87	-	-	-	-	-	252,531.78
Waste	-	-	2,453.10	43.67		-	-	-	-	65,052.47
Memo Item (not accounted in total Emissions)	589,760.13	-	0.05	0.1	-	-	-	-	-	589,293.4
International Bunkers	3,627.13	-	0.05	0.1	-	-	-	-	-	3660.42
Aviation	3,281.64	-	0.02	0.09	-	-	-	-	-	3,310.64
Marine	345.49	-	0.03	0.01	-	-	-	-	-	349.77
CO_2 from biomass	586,133.00	-	-	-	-	-	-	-	-	586,133.00
Total without LULUCF (Gg)	**1,574,362.14**	**-**	**19,623.15**	**368.9**	**-**	**1.43**	**2.13**	**0.58**	**0.0042**	**2,136,841.24**
Total with LULUCF (Gg)	**1,632,623.84**	**314,586.77**	**19,776.18**	**370.8**	**-**	**1.43**	**2.13**	**0.58**	**0.0042**	**1,884,309.46**
GWP indexed multipliers of CH_4, N_2O, HFC -134a, HFC-23, CF_4, C_2F_6 and SF_6 are 21, 310, 1300, 11700, 6500, 9200, and 23900 respectively										

Source: Ministry of Environment, Forest and Climate Change, 2015

Figure 10.4: Country-wise Total GHG and GHG Per Capita Emissions



Source: World Resources Institute, 2014

from this sector and hydro chlorofluorocarbons were a by-product of the industrial processes (MoEF&CC, 2015). In India, equaling the global scenario, CO_2 is the most emitted gas with a 74 per cent share in 2010, while nitrous oxide has remained at similar levels throughout (MoEF&CC, 2015).

From the energy, industrial processes, product use, agriculture, and waste management sectors India emitted 1,523,777.44 Gg CO_2 eq. in 2000 (NATCOM II, 2012) . LULUCF, which is a carbon sink, included makes the total emissions drop to 1,301,209.39 Gg CO_2 eq. When compared to the latest emissions data in 2010 GHG emissions trend we see that it has increased 1,946,684.02 $GgCO_2eq$ without LULUCF.

Including LULUCF we see the total CO_2 equivalent to be 1,884,309.46. The detailed breakup of the latest GHG profile is in Table 10.1. Industrial Processes and Product Use (IPPU) contributes for 8 per cent of the total emission. Industries such as cement production, lime production, glass and ceramics added 171,502.87 Gg of CO_2eq in the year 2010.

As the table clearly shows that energy as a sector is contributing maximum as compared to other areas. GHG emissions in the energy sector are mostly because coal, gas and diesel being the major sources of power in India. India is home to around 24 per cent of the global population without access to electricity (304 million). Further it is inefficient in its energy usage as about 30 per cent of the global population relying on solid biomass for cooking are from India.

Lower emissions as per intensity of GDP would mean a cleaner development pathway. Since 2010 the population of India increased by 18 per cent while correspondingly the GHG emissions as per intensity of GDP have decreased by 12 per cent during 2005 to 2010 (MoEF&CC, 2015). This is important in the sense that it shows India is on track to meet its pre-2020 pledge without requiring offsets. It signals that the country will be ready to transition for the stringent, long-term emission reductions, as pledged for limiting warming to below 1.5°C in the Paris Agreement. The growth of the Indian economy and population after the Nationally Determined Contributions would be smoother in terms of facilitating mitigation by reducing locking-in of carbon and energy intensive infrastructure in the energy system and society (UNEP, 2015).

India's total contribution is only 4.6 per cent of total global emissions of CO_2 as compared to 17.3 per cent and 20.9 per cent of China and USA respectively (MOSPI, 2015). India does not contribute much to the total emission of CO_2 in the world in terms of per-capita (Figure 10.4). With respect to per capita emissions we stand at 140th rank globally indicating the low development and consumption levels (WRI, n.d). In 2011, the average annual energy consumption was only 0.6 tonnes of oil equivalent (toe) per capita as compared to the global average of 1.88 toe per capita (MOSPI, 2015). There are wide disparities among the people in India which are often not reflected in its per capita GDP of USD 1,408 per annum. Even though it is among the fastest

Table 10.2: Forest Coverage (2009 To 2013)

Physiographic Zone	Geographic Area (Km^2)	Year 2009 Area (Km^2)	2009 % of Geog. Area	2011 Area (Km^2)	2011 % of Geog. Area	2013 Area (Km^2)	2013 % of Geog. Area
Western Himalayas	329,255	8,091	2.46	7,859	2.39	9,035	2.74
Eastern Himalayas	74,618	324	0.43	356	0.48	448	0.6
North East	133,990	2,243	1.67	2,275	1.7	2,655	1.98
Northern Plains	295,780	9,473	3.2	9,366	3.17	8,609	2.91
Eastern Plains	223,339	5,444	2.44	5,168	2.31	4,722	2.11
Western Plains	319,098	7,497	2.35	7,038	2.21	6,245	1.96
Central Highlands	373,675	9,150	2.45	9,886	2.65	10,127	2.71
North Deccan	355,988	7,559	2.12	7,007	1.97	6,762	1.9
East Deccan	336,289	11,157	3.32	10,718	3.19	9,644	2.87
South Deccan	292,416	8,002	2.74	8,012	2.74	8,244	2.82
Western Ghats	72,381	3,847	5.31	4,083	5.64	4,189	5.79
Eastern Ghats	191,698	4,051	2.11	4,420	2.31	4,194	2.19
West Coast	121,242	9,427	7.78	8,863	7.31	10,391	8.57
East Coast	167,494	6,504	3.88	5,791	3.46	6,001	3.58
Total	**3,287,263**	**92,769**	**2.82**	**90,844**	**2.76**	**91,266**	**2.78**

Source: India State of Forest Report, Forest Survey of India, 2014 developing economies, the per capita electricity consumption is low at 917 kWh compared to the global consumption (GoI, 2015).

10.3.2 Land Use Change – Deforestation and Over-extraction of Resources

As per IPCC (2014) forests around the world store about 283 Gt of carbon in its biomass, 38 Gt in dead wood, and, 317 Gt in soils and humus. This acts as a great carbon stock. The carbon content in the forest ecosystems of about 638 Gt is more than the carbon content present in the atmosphere. The gross terrestrial uptake of carbon by forests is 2.4 Gt a year which a huge amount for sequestration. Increasing the tree cover and reduction in cutting of trees for paper, recycling of paper products and less usage, will also help in carbon sequestration in the long run as trees absorb a large amount of CO_2 from the atmosphere.

Forests act as great carbon sequesters and land-use change or diverting of forest land for non-forest use is a major impact factor for increase in atmospheric carbon. India is the 10th most forested nation in the world with 76.87 million ha of forest and tree cover. This makes it a big contributor as a global carbon sink. Increased urbanization and industrialization also contribute to deforestation and land-use change (GoI, 2015).

The overall percentage of forest cover has not changed much since 2009 to 2013; however we see there have been changes in the forest cover as per their physiographic zones (Table 10.2). The relationship between LULUCF and climate change has been established by various studies that concluded that land-use change has had greater effect on climate change than other ecological variables. Although most of the land-use change actions have little to do with climate, the human usage of land management will have ecological effects.

Wood additionally has a possibly noteworthy part to play in global warming adaptation, by ecosystem management benefits and giving livelihood alternatives. Deforestation and decimation of rainforests, is an immensely critical addition to atmospheric CO_2. Conversion of forest land for agricultural or other use of land purposes reduces the carbon stock.

Natural Pressures

This sections aims to look at the natural drivers of climate change in order to obtain a complete understanding of the global phenomenon which is also affecting India. It must be however, clearly understood that natural drivers are beyond human control. Climate change has been an ongoing phenomenon since millennia. The global climate is not controlled by a single factor - there are a number of influences that can cause change. Natural drivers are Oceans, Climate oscillations (El Niño), orbital eccentricity, earth's tilt, and sun heat magnetic variations to name a few and all play a role in influencing current change in global climate.

10.3.3 Orbital Variations

The National Research Council (NRC, 2012) report, 'The Effects of Solar Variability on Earth's Climate' concluded that the effects of solar variability are more regional than global. India is located above the equator in the tropics that receive very high solar radiation. Any change in solar variability then would invariably affect the South Asian subcontinent. Louisiana State University conducted a study that reported that the tilt of the Earth affects the rain in India and across the world. It is among the world's heaviest rain belt. The study showed that Earth's tilt shifts every 41,000 years and moves the clouds that cause rain (LSU, 2015).

The Earth's climate has also changed due its change in its orbit. A study of the glacial-interglacial cycles helps understand the evolution of Earth's climate since the past 10,000 years. Milankovitch Cycles are three dominant cycles in the form of variations in the Earth's eccentricity, axial tilt, and precession. Even though they are insufficient to explain the full range of climate change, they are a primary driver that must be accounted. The changing temperature of the planet between warm periods and ice ages is correlated strongly with Milankovitch cycles. These cycles impact the seasonality and location of solar energy around the Earth. Irregular climate cycles have been getting stronger in the past 10,000 years, becoming full-fledged glacial cycles roughly 2.5 million years ago since the Earth was formed. However, when we look at the current trend of global warming and rising temperatures it is clear that the radiative forcing or the change in energy in the atmosphere is beyond the natural cycle. This correlates to the relative spike in GHG production across the world and proves that the current rise in temperature is anthropogenic.

10.3.4 Changes in Ocean Currents

Oceans transport cold water and precipitation from poles to the equator and vice versa for warm water. These currents then regulate the global climate to balance out the solar radiation that reaches out to Earth's surface. The sun's radiation is the primary source of heat for the Earth. Any change in the solar activity would impact the Earth's climate even though it varies very less over a stable 11 year long pattern of solar cycles. Even though Earth receives only 0.1 per cent light emitted, its impact is very strong to alter the atmosphere by even pushing storms on the ground.

El Niño-Southern Oscillation cycle (ENSO) is a temperature anomaly commonly known as El Niño. These are fluctuations in temperature between the ocean and the atmosphere in the east-central Equatorial Pacific. El Nino is reflected by unusually warm water in the Pacific Ocean. When temperatures in the same region are near average or normal, it is known as ENSO neutral, which signifies that the oscillation is neither in a warm nor cool phase. El Niño and La Niña episodes last 9 to 12 months and rarely last for years. Due to complexity of weather models its effect on India is very probabilistic. El Niño could cause floods, droughts and epidemics in India.

Deep oceans have also absorbed a large amount of heat over the years causing climate measurement aberrations. The anthropogenic CO_2 is not causing surface warming as most of it is absorbed by oceans. Therefore the rate of increase in surface temperature is not proportional to the rate of CO_2 emissions. But it is equal to the total CO_2 added since the industrial revolution. The long term trends (30 years) are most accurate in order to measure temperature variation in climate science.

Water vapor is the most abundant greenhouse gas on Earth. The heat of the oceans escapes through water vapor. It absorbs the radiations from Sun and traps such heat in the atmosphere making the earth warmer. However, water vapor also contributes to cooling of the Earth by way of cloud formation.

10.4 IMPACTS

For a developing country like India, climate change is of a bigger concern than most nations across the world. India is among the most vulnerable nations to climate change, just after Bangladesh. In a list of nations considered at "extreme risk" from climate change, nearly the whole of India has a high or extreme level of sensitivity to global warming. This is exacerbated due to increasing population and further its important strain on natural assets. There is a high level of poverty, poor general wellbeing and reliance on agriculture by a significant part of the population that increases the negative impacts. Rainfall induced landslides will also increase in many regions of India especially the North-East.

However, still it is very difficult to associate a particular extreme weather event to climate change (IPCC, 2014). The science on such an attribution is still evolving. But there have been a series of extreme weather events in India, both sudden and slow, with increased intensity in the recent past that could be certainly co-relate to climate change and global warming. Climate change manifestations can be seen as physical and socio-economic impacts - directly impacted by floods, declining glaciers etc. or impacting resources and services that further disturb the socio-economic aspects of human wellbeing. These are discussed in detail below:

Physical Impact

Impact of Rapid Onset Climate Events

Rapid onset of climate events are frequently experienced as natural disasters. They arrive rapidly and sometimes with no warning such as floods and cyclones/ storms surges.

10.4.1 Increased Frequency of Floods

In between 2009-2014, floods occurred in 2009, 2011, 2012, 2013 and 2014. The states affected by floods were Andhra Pradesh, Karnataka, Odisha, Kerala, Delhi, Maharashtra, Tamil Nadu, Jammu and Kashmir and Uttar Pradesh. Impacts of climate change include sudden extreme rainfall causing overflow in rivers and inundation of cities. Cloudbursts have also become an additional impact of climate change especially in the northern region due to prolonged winters as per Defense Institute for High Altitude Research (DIHAR). An example of such an impact was the flash flood in Jammu and Kashmir in 2014, due to heavy rainfall for 30 hours. Some parts of the state experienced 650 mm of rainfall in 3 days. The state transitioned from being a 32 percen train deficit state to 18 per cent rain surplus state in 5 days. The rain inundated 557 Km^2 which is 3.5 per cent of the area of the state. The flood caused 284 deaths, over 22,00,000 people were affected and an estimated 7,00,000 were displaced. Estimated overall financial losses were over INR 1,00,000 Crores (as per NIDM).

On 16 June 2013, Uttarakhand suffered a mega disaster, one of the worst disasters in the living memory, causing widespread damage and destruction, besides heavy casualties. The entire State was hit by very heavy rainfall and flash floods. Though all the thirteen districts of the State were hit, five districts, namely Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi were the worst affected (NIDM, 2013).

10.4.2 Increased Frequency of Cyclones and Storm Surges

Another impact of climate change is storms of strong intensity called cyclones. Cyclones can have devastating impact on big cities like Mumbai and Chennai that face the sea. In the past cyclones have hit Vishakhapatnam and other regions on the Bay of Bengal side. Urban centers like Surat and ports like Kandla are also at risk due to cyclones. Frequency of cyclones would decrease by 2030s but there would be an increase in the intensity of cyclones. The coastal districts are vulnerable due to poor infrastructure and demographic development. About 8 per cent of the area in the country is prone to cyclone related disasters (MoEF&CC, 2015). Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private property and severe damage to infrastructure, thus seriously reversing developmental gains at regular intervals.

In a span of 6 years from 2009 to 2014, India witnessed 7 cyclones. Tropical cyclones similar to what India has experienced will be multiplied with risen sea levels (IPCC, 2014). The Eastern states such as Odisha, Tamil Nadu, Puducherry, West Bengal and Andhra Pradesh were severely affected. Cyclone Alia of 2009 hit coast of West Bengal which resulted in 149 deaths and tens of thousands stranded. In 2010, two cyclones Laila and Jal caused 104 deaths along with destruction of rice crop, mudslides and flooding in Andhra Pradesh. In 2011, Cyclone Thane made landfall in Tamil Nadu and Puducherry which disrupted agricultural crops and killed about 50 lives. Cyclone Nilam took over 100 lives in Andhra Pradesh and Tamil Nadu and caused heavy rainfall in 2012 (NIDM, 2013).

It is clearly known that India's coastal region especially on the Eastern Ghats is highly vulnerable to cyclones. The coasts in the states of Odisha and Andhra Pradesh are highly vulnerable to cyclones due to their locational and morphological settings. These are exposed to strong waves and high velocity winds. Better early warnings, effective mitigation programs and ground level educational enhancement/ awareness, effective planning and efficient management helped the State Government and others, in reducing the vulnerability of the population.

An example would be Cyclone Phailin. It caused extensive damage to infrastructure though there were a few casualties reported in Odisha. As reported by the Government of Odisha the disaster affected 13 million lives and 2,56,633 houses were damaged. Similarly, a severe Cyclone Hudhud struck the same eastern coast of India in 2014 in Andhra Pradesh. This was the first time that a cyclone of such intensity landed on an urban city leading to high degree of devastation. There were 61 human causalities and around 9.2 million people in 4 coastal districts were affected. A total of 1,12,850 houses were partially or fully damaged in the coastal areas of Vishakhapatnam district alone (NIDM, 2013).

Impact of Slow Onset Climate Events

Climate change induced environmental degradation, sea level rise; desertification and even drought are slow disasters. These are considered disasters in the sense that they cause damage and disruption to human wellbeing and the ecosystem.

10.4.3 Intensified Droughts

Besides floods and cyclones, drought has been another significant impact of climate change. Reduced rainfall is the prime reason for drought in India as most of the farmers engage in rainfed agriculture. The droughts experienced in 2009 because of weakest monsoon (experienced since 1972) affected North-Western and North-Eastern India.

We see from the trends is that severe drought have been increasing in recent years (Table 10.4). Although the average has remained nearly the same. Since 1970's the droughts severity has spiked with consecutive droughts. Prolonged drought has been observed in the Bundelkhand region of Uttar Pradesh

Table 10.3: Deaths as Per Disasters (2010 - 2014)

Causes	2010		2011		2012		2013		2014	
	Number of Deaths	% to total deaths	Number of Deaths	% to total deaths	Number of Deaths	% to total deaths	Number of Deaths	% to total deaths	Number of Deaths	% to total deaths
Avalanche	45	0.69	60	1.07	40	0.72	52	0.83	23	0.38
Cold and Exposure	937	14.5	849	15.1	997	17.9	946	15.1	913	15
Cyclone/ tornado	106	1.63	117	2.08	47	0.84	52	0.83	62	1.02
Earthquake	8	0.12	69	1.23	3	0.05	9	0.14	2	0.03
Epidemic	57	0.88	127	2.26	80	1.43	57	0.91	48	0.79
Flood	965	14.9	585	10.4	420	7.52	700	11.2	541	8.91
Heat Stroke	1,274	19.7	793	14.1	1,247	22.3	1,216	19.4	1,248	20.6
Landslide	347	5.35	302	5.37	282	5.05	264	4.21	499	8.22
Lightening	2,622	40.4	2,550	45.4	2,263	40.5	2,833	45.2	2,582	42.5
Torrential Rains	123	1.9	170	3.02	203	3.64	142	2.26	156	2.57
Total	**6,484**	**100**	**5,622**	**100**	**5,582**	**100**	**6,271**	**100**	**6,074**	**100**

Source: National Crime Record Bureau, Ministry of Home Affairs, 2015

and Madhya Pradesh, Maharashtra, Telangana and Andhra Pradesh in 2015. Maharashtra has experienced drought four times since 2008 till 2015. The Marathwada and Vidarbha regions were drought hit in 2015 effecting 9 million farmers - two third of total farmers of the state. Further, these droughts across India cause migration of rural people to urban areas of the state.

10.4.4 Intensified Desertification

The Ministry of Environment, Forest & Climate Change (MoEF&CC) as ratified signatory to the United Nations Convention to Combat Desertification since 1996, considers combating desertification and land degradation as one of its thrust areas. Desertification, Land Degradation and Drought (DLDD) are prevalent in India's arid, semi-arid and dry sub-humid drylands such as Rajasthan and Bundelkhand. These states are also among the most vulnerable in terms of people, livelihoods and ecosystems.

The Indian government with ISRO mapped desertification of the entire country using Indian Remote Sensing Satellites (IRS) data in Geographical Information System (GIS) environment. It found 32 per cent of its land under degradation and 25 per cent undergoing desertification (ISRO, 2016).

As per the Desertification Atlas of India (ISRO, 2016), in 2003-2005, 28.76 per cent (94.53 Mha) of the Total Geographic Area (TGA) was undergoing land degradation, it has increased to 29.32 per cent (96.40 Mha) of TGA (Figure 10.5). This was concentrated to the regions in Rajasthan, Maharashtra, Gujarat, Jammu & Kashmir, Karnataka, Jharkhand, Odisha, Madhya Pradesh and Telangana. Rest of the states in India adds to less than 1 per cent of the total desertification/land degradation. This is an increase of total 0.57 per cent of TGA between 2003-05 and 2011-13.

10.4.5 Increased Melting of Glaciers

As per the latest data there are 9575 glaciers in India. These are distributed among the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh (MOSPI, 2015). A glacial lake outburst flood (GLOF) is flooding that occurs when the dam containing a glacial lake bursts. Glaciers in Uttarakhand are at a high risk of GLOF as per a report by a Nepal based mountain development organization ('Formation of Glacial Lakes in the Hindu Kush-Himalayas and GLOF Risk Assessment') the glaciers in Himalayas are the lifeline of many rivers in northern India. The ice and snow deposits provide water supply for livelihoods, drinking and industrial needs. The recession of the glaciers will affect all the population in north India.

Glaciers in Himalayas and in the Karakorum Range on one hand, have remained same or even advanced on the other, some glaciers have receded. The most important concern due to deglaciation is the diminishing water flow. Increase in temperature leading to snow melt would threaten stability and reliability of Indus and Brahmaputra. These rivers are expected to see increased flows in spring, and, alteration of flows would impact irrigation, food production in the basins as well as millions of livelihoods.

The study, 'Himalayan Glaciers: A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change' confirmed the earlier studies by the government and inferred that it is not possible to conclude that glaciers in Himalayas are retreating abnormally due to global warming as a glacier melt is affected by a range of complex climate factors.

10.4.6 Impacts as Sea Level Rise and Coastal Erosion

Rising sea levels are a direct causal driver for coastal erosion. The coastal erosion in India could displace and affect the fisheries engaged economy. This would cause increased inland migration. Flooding of coasts can also damage coastal infrastructure. The region's most vulnerable to such an implication are Maharashtra, Goa and Gujarat (MOSPI, 2015).

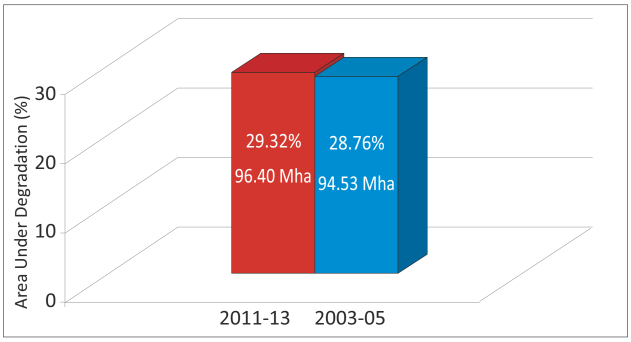
Sea level rise of 1-2 mm annually is expected all across the world as per IPCC (2014). This would cause salination in the fresh water sources in the coastal areas. It will decrease the soil fertility and inundate high density population areas. The most vulnerable areas in India are along the Western Ghats namely Khambat and Kutch in Gujarat, Mumbai, and parts of the Konkan coast and south Kerala. The deltas in the east coast are also threatened due to saline coastal groundwater by disturbing the irrigation and settlements in the region. Such an impact could cause a huge economic loss and impact economies of some states. Low lying coastal zones and flood plains in India is most at risk due to a high population density.

Table 10.4: Drought Years with Percentage Area of the Country Affected By Drought

Year	Moderate drought (%)	Severe drought (%)	Total (%)
1877	30.6	28.9	59.5
1891	22.4	0.3	22.7
1899	44.1	24.3	68.4
1901	19.3	10.7	30
1904	17.5	16.9	34.4
1905	25.2	12	37.2
1907	27.9	1.2	29.1
1911	13	15.4	28.4
1913	24.5	0	24.5
1915	18.8	3.4	22.2
1918	44.3	25.7	70
1920	35.7	2.3	38
1925	21.1	0	21.1
1939	17.8	10.7	28.5
1941	35.5	0	35.5
1951	35.1	0	35.1
1965	38.3	0	38.3
1966	35.4	0	35.4
1968	22	0	21.9
1972	36.6	3.8	40.4
1974	27.1	6.9	34
1979	33	1.8	34.8
1982	29.1	0	29.1
1985	25.6	16.7	42.3
1987	29.8	17.9	47.7
2002	19	10	29
2009	32.5	13.5	46

Source: India Meteorological Department; Disaster Management in India, Ministry of Home Affairs, 2011

Figure 10.5: Area under Land Degradation



Source: Indian Space Research Organisation, 2016

Sector Specific Impacts

10.4.7 Impact on Biodiversity

Understanding the progressing effects of environmental change on biological communities and ecosystems isessential to deal with climate change impacts. How natural surroundings are utilized, will influence the amount of that CO_2 is discharged in the atmosphere.

India is a very species rich country and contributes to about 6 per cent of the total biodiversity in the world. The impact of climate change on forests would manifest in the form of shifts in the boundaries of forest types, change in area etc. (MOSPI, 2015).

Species distribution and abundance is impacted by climate change. With change in seasonal events there will be likely changes in the composition of plant and animal communities. Altered water regimes, higher forest growth rate etc. aresome of the changes in the habitat and ecosystems that are possible and which can influence species distribution.

10.4.8 Impact on Human Settlements

India, as mentioned in the earlier sections, is a predominantly agriculture oriented economy. Changes in climate might affect hydrological balances and these will affect crop productivity. Other agricultural systems such as livestock production would also be affected by temperature and precipitation. The impact on human beings to such a change is uncertain and complex. Climate change would be added to the already present pressures on the Indian agriculture such as yield stagnation, land use, competition for land, water, etc.

Climate change variations would affect food production and will even impact fruits, vegetables, tea, coffee etc. There could be a loss of 10 to 40 per cent in production by 2100 according to the NAPCC (2008). Agricultural loss due to climate change in India is to be estimated at USD 7 billion by 2030. 10 per cent of the population would be directly affected by this. IPCC predicts that there will be a 51 per cent reduction of wheat yields in the Indo-Gangetic plains due to heat stress. The produce from India contributes to 15 per cent of the global wheat production (MOSPI, 2015).

Increased urbanization poses complex challenges in assessing the impacts of climate change. Growing population gets added to warmer days, increase in heat waves, increase in precipitation events, intense tropical activity, and increase in sea levels in some regions in exacerbating the existing stresses. Climate change effect on water supply system and drinking could lead to increase in demand. Erratic precipitation may disturb the annual charging thus leading to reduced water tables.

Socio - Economic Impact

10.4.9 Impact on Human Health

Direct impacts

In 2015, India also experienced an unusually high number of deaths due to heat waves during summer in several parts of the country these can be attributed to increase in global temperatures. High temperatures are usually associated with mortality rate and will have increased implications on outdoor workers due to air pollution. As per the International Disaster Database (2015), this heat wave was the fifth deadliest since 1900. The elderly, the young, and the individuals who work outside, including development workers are the most vulnerable of the population. Temperatures in the states of Odisha, Andhra Pradesh and Telangana went up till 45°C. Even inland states such as Jharkhand, the city of Daltonganj found the temperatures averaging 46°C. There was a similar heat wave in Andhra Pradesh in 2013 killing 20 people (NIDM, 2013).

Indirect Impacts

The impact of climate on vector species is related to increase in temperature and relative humidity. This helps it spread and enlarges the transmission windows. Vector borne diseases such as malaria, dengue and chikungunya have experienced a spike during such episodes of weather.

IPCC (2014) highlights that studies have been done that established the relation between increase in vector-borne diseases such as vaccine-preventable Japanese encephalitis, malaria and rainfall in India. Even the Chikungunya fever that was first reported in 1963 with continued transmission till 1973 followed by drop in cases, has now re-emerged since 2005 and spread rapidly till date (IPCC, 2014). Increase in temperature can greatly increase malaria transmission due to increased numbers of mosquitoes as per 'Climate change & infectious diseases in India: Implications for health care providers' (Dhara, J. Schramm, & Luber, 2013).

In UP there were a total of 609 deaths due to Japanese encephalitis in 2013. An equally high number of deaths were seen in Assam. The numbers of cases are increasing and awareness and education is the only key in control of this disease.

10.4.10 Impact on Water Resources, Water Supply and Sanitation

Climate change influences water resource at multiple levels. Water as a resource is most at risk whether in excess or in scarcity and it is the biggest link to equitable and inclusive development. It is very likely to impact on the quality, quantity and availability of water in India. The impact on the water sector is further compounded by additional drivers for example pollution generated by untreated wastewater combines with reduced river flows due to droughts thereby increasing pollution. Prime hazards for the sanitation and hygiene (WASH) sector would be experienced through erratic weather events, increased frequency of droughts, flash floods and heat waves. The direct impact will adversely affect quality and availability of drinking water, critical infrastructure and hygiene and sanitation services.

The World Bank Report (2011) on sanitation observed that the annual economic impact of inadequate sanitation in India in 2006 amounted to a loss of INR 2.4 trillion. The need and access to water and sanitation is also very closely linked to reducing vulnerability of women and children.

Water scarcity will also impact food production leading increased malnutrition in children and health issues for women. The primary necessity for adolescent girls and children to attend school or participate in the public sphere is the need for sanitation facilities. Girls require these facilities for specific needs, while in children, good sanitation levels ensure better immunity.

10.4.11 Gender Linked Impacts

Climate change impacts women and men differently. The rural women in India due to inadequate water spend a lot of time in fetching water for households. Women are systemically excluded from decision making processes on WASH when they are among the most affected across the world (Mahon & Fernandes, 2010). Women in India across the rural landscape are responsible for collecting water, and are also caregivers for the family members. Women in India spend 150 million work days per year to collect water each year (UNESCO, 2015). The adolescent female children have to share the burden of carrying water, leading to gender gaps in school attendance in India. Additionally, women and children are also more likely to die in the aftermath of extreme weather calamities such as flash floods.

The Indian government has seen a focus on women as a critical component to improve management or governance of water within an overall context of poverty alleviation. The gender gaps in literacy in Indian states are directly proportional to states vulnerable to climate and water-related stresses such as Bihar, Uttar Pradesh and Madhya Pradesh (NATCOM II, 2012). This means a direct correlation exists between state investments in girl's education to reduced vulnerability of people to climate change impacts.

10.5 RESPONSES

India's Climate Change Response Strategy India's response to climate change has been very varied and widely undertaken as part of the development policy. The response can be considered in two perspectives: Mitigation and Adaptation (refer text box). It aims to reduce carbon dioxide emissions on one hand while preparing to strengthen response to the adverse effects of climate change, on the other. India's contribution for combating climate change takes into account its historical commitment to conservation of nature as well as the imperatives of meeting the competing demands for resources for addressing the challenges of poverty eradication, food security and nutrition, energy, employment and sustainable urbanization to name a few. Additionally, the country has been an active and constructive participant in the search for solutions. The Government has taken several initiatives to address the issues related to climate change.

On international platform, India is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) which is the international treaty on climate change. The Paris Agreement on climate change was adopted under the UNFCCC on 12

December 2015, which is one of the most remarkable steps taken internationally to address the issue of climate change at global scale. It is a legally binding agreement that covers all countries, developed and developing, with the aim to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty. The Agreement acknowledges the development imperatives of developing countries and reflects the principle of equity and common but differentiated responsibilities and respective capabilities (CBDR & RC) under the Convention. All important elements of the Convention, including adaptation, loss & damage, finance, technology, capacity building and transparency of action and support, have been captured equally in the Agreement. Parties' contributions under the Paris Agreement, defined as 'Nationally Determined Contributions' (NDCs), are country driven and comprehensive. The Agreement mandates developed countries to provide financial resources to developing countries, and has evolved a new technology framework. India gained international interest in 2015, as in response to the decisions of the Conference to the Parties (COP decision 1/CP.19 and 1/CP.20) it submitted its Nationally Determined Contribution (NDC) to the UNFCCC on 2nd October, 2015, outlining the post-2020 climate actions intended to be taken under the Paris agreement. The eight goals put forth by India in its NDC are as under:

1. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
2. To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
3. To reduce the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level.
4. To achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
5. To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.
6. To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
7. To mobilize domestic and new and additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
8. To build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies.

Adaptation and Mitigation

Climate change mitigation are the efforts to prevent or reduce the emission of GHGs. The global consensus is that at current warming level, is caused to due human activities. Further, the impacts of climate change are already being felt in many parts of the world, through extreme weather events such as heat waves and droughts, extreme storms, pressure on water resources and crop yields, sea level rise etc.

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

The NDC centers around India's policies and programmes on promotion of clean energy, especially renewable energy, enhancement of energy efficiency, development of less carbon intensive and resilient urban centres, promotion of waste to wealth, safe, smart and sustainable green transportation network, abatement of pollution and India's efforts to enhance carbon sink through creation of forest and tree cover. Consistent with India's development agenda, including eradication of poverty and commitment to follow a sustainable low carbon development strategy, the contributions articulated in the INDC are comprehensive, balanced, equitable and pragmatic, addressing all elements of the Paris Agreement. India ratified the Paris Agreement on 2nd October, 2016, and is preparing a roadmap for achieving its eight internationally pledged targets on climate change as contained in the NDC document.

10.5.1 Mitigation

For the pre-2020 period, India declared a voluntary goal of reducing its emissions intensity of GDP by 20-25 per cent, over 2005 levels, by 2020, despite having no binding mitigation obligations as per the Convention. A slew of policy measures to promote sustainable development has resulted in the decline of emission intensity of our GDP by 12 per cent between 2005 and 2010. The United Nations Environment Programme (UNEP) in its Emissions Gap Report 2016 has recognized India as one of the countries on track to achieving its voluntary goal.

Between 2002 and January, 2016, the share of renewable grid capacity has increased over 13 times, from 2 per cent (3.9 GW) to around 16 per cent (50 GW). This will be significantly scaled up with the aim to achieve 175 GW renewable energy capacity by 2022 (including 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydro). India also anchored the launch of International Solar Alliance (ISA) jointly with the Government of France on the sidelines of 21st Conference of the Parties (COP 21) in Paris, France. This is an alliance of 121 solar resource rich countries lying fully or partially between the Tropic of Cancer and Tropic of Capricorn. It provides a common platform where global community including bilateral and multilateral organizations, corporate, industry, and stakeholders can make a positive contribution to the common goal of increasing utilization of solar energy in meeting energy needs of ISA member countries in a safe, convenient, affordable, equitable and sustainable manner. So far, 25 countries have signed the ISA Framework Agreement.

India's fundamental goal of mitigation in development is via universal energy access and energy security. The Indian government has promoted greater use of renewable energy through solar and wind power as well as improving energy efficiency by the Energy Conservation Act, to ensure minimum growth in carbon emissions. India's mitigation approach is informed by two approaches as its contribution to the international effort to curb global emissions and second, to manage its development and poverty eradication challenges. The mitigation actions can be broadly defined as:

- Clean and Efficient Energy System
- Enhancing Energy Efficiency in Industries
- Promoting Waste to Wealth Conversion
- Safe, Smart and Sustainable Green Transportation Network
- Planned Afforestation
- Abatement of Pollution

The above areas have been widely covered in the earlier chapters. Additional mitigation measures in the transport sector are broadly listed below:

- Auto Fuel Policy
- Corporate Average Fuel
- Consumption (CAFÉ) standards for Cars
- National Mission on Electric Mobility
- Mass Rapid Transit System
- Aviation and Shipping

10.5.2 Adaptation

The vulnerabilities in India are diverse due to its differences and

variations in ecosystems, climatic conditions etc. The schemes by the government of India focus on critical adaptation components, and are about 2.83 per cent of the GOP in 2009-2010 (INOC, 2015). The major focus of adaptation expenditure is on capacity building, poverty alleviation, health improvement and disease control and risk management.

It is a globally accepted fact that there needs to be a linkage between adaptation and mitigation actions for reducing and managing the risks of climate change and their successful implementation relies in relevant tools, appropriate governance structures and enhanced capacity to respond. In order to address the issue of climate change, various adaptation and mitigation measures have been taken up by the Government across sectors, including agriculture, water, health and sanitation, forest, coastal zone, urban development, energy, railways, disaster management etc. The Prime Minister's Council on Climate Change (PMCCC) and Executive Committee on Climate Change (ECCC) develop coordinated responses on issues relating to climate change at the national level, providing oversight for formulation of action plans in the area of assessment, adaptation and mitigation of climate change, and periodically monitor key policy decisions. A National Steering Committee in Climate Change (NSSCC) is in place to facilitate preparation and implementation of climate change projects/plans at the State level. At the sub-national level, each state has a nodal department on climate change for planning and implementing climate action.

Expenditure on human capabilities and livelihoods, viz. poverty alleviation, health improvement and disease control and risk management, constitutes more than 80 per cent of the total expenditure on adaptation in India.

Disaster Risk Reduction (DRR)

India has almost 85 per cent of its area vulnerable to some hazard or the other, making it among the most disaster prone areas in the world (INDC, 2015). Around 45.64 million hectares of land are subject to flood disasters. Before 2009, climate change and disaster management departments in India were working in relative isolation, but with the direction given by the National Policy on Disaster Management (2009) there is support for such integration between climate change adaptation and disaster risk reduction. India has a disaster risk reduction and response apparatus at national, state and district levels in order to reduce vulnerability, and to provide appropriate response, rehabilitation and reconstruction in case of disasters.

This integration in addition to the paradigm shift from a relief centric to a risk reduction approach has brought results in previous years. Cyclone Phailin affected livelihood of 13 million people in Odisha and Andhra Pradesh but no loss of life was recorded. Effective disaster planning, preparation and dissemination of early warning information led to minimal deaths in 2013 in the wake up a very severe cyclonic storm. This is in sharp contrast to the Super Cyclone in 1999 that killed 10,000 people in Odisha. The strategies for DRR ranged from early warnings and communications, construction and sustainable maintenance of multi- purpose cyclone shelter, improved access and evacuation, enhanced capacity and capability of local communities to respond to disaster (INDC, 2015).

The Government of India has also set up a National Disaster Relief Fund, financed through a levy of a cess at all levels. India has also put to work the Sendai

UN's 2030 Agenda for Sustainable Development - Goal 13: Take urgent action to combat climate change and its impacts*

The 13th Goal of the United Nation's Agenda for Sustainable Development Goal is on climate change actions. India is a signatory to the UN's 2030 Agenda for Sustainable Development. This multilateral commitment helps to create a guiding framework for development.

The NITI Aayog has entrusted the targets of Goal 13 to MoEF&CC. The targets under the goal are as below:

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

13.2 Integrate climate change measures into national policies, strategies and planning

13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

13.a Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly USD 100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible

13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

Framework for Disaster Risk Reduction that also helps India to link Adaptation, Disaster Risk Reduction and Loss and Damage.

10.5.3 Priority Flagship Programmes

There are few programmes that the government of India has specifically taken up in order to address climate change in India:

Climate Change Action Programme (CCAP)

MoEF&CC has implemented a scheme on climate action in order to build assessment capacities of climate change. The 12th five year plan allocated INR 290 crores to the scheme. CCAP includes National Carbonaceous Aerosols Programme (NCAP), Long Term Ecological Observatories (LTEO), and Coordinated Studies on Climate Change for North East Region (CSCCNER). These programmes focus on inventory of black carbon, long term monitoring of impacts of climate change on natural ecosystems and formulate adequate response measures to the challenges of climate change. Other components of the scheme include coordination of the National Action Plan on Climate Change (NAPCC), State Action Plan on Climate Change (SAPCC), international climate change negotiations, and other meetings.

National and State Action Plans on Climate Change

The current policy framework for achieving India's climate change goals includes the National Action Plan on Climate Change (NAPCC), which is the overarching policy framework for direct climate change interventions. The NAPCC is being implemented through eight National Missions, outlining priorities for mitigation and adaptation to combat climate change including Missions on Solar Energy, Enhanced Energy Efficiency, sustainable Habitat, Water, Sustaining the Himalayan Ecosystem, Green India, Sustainable agriculture and Strategic knowledge for Climate Change anchored by line Ministries. New Missions on Coastal Region, Health, and Waste to energy are also being set up. On similar lines states have also devised their State Action Plans on Climate Change (SAPCC). 32 states and Union Territories have submitted their SAPCC, which can be accessed online. The NAPCC strongly emphasizes on co-benefits of climate change adaptation and mitigation with development. The NAPCC mission envisioned a large goal beyond the developmental targets in order to influence institutions, policies, and program to co-benefit development and climate goals. Five approaches known as 'National Missions' on Agriculture, Water, Himalayan ecosystems, Forestry, Capacity building and Knowledge management are adaptation mechanisms. While the other three on solar energy, energy efficiency and sustainable habitat are focused on mitigation. These missions are constantly under review by the Prime Minister's Council on Climate Change. The missions are at different stages of implementation.

Developing Climate Resilient Urban Centers

Government of India, in order to improve the standard of living in urban spaces as well as improve the local environment in the cities launched a number of schemes for transformation and rejuvenation of urban areas including Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and National Heritage City Development and Augmentation Yojana (HRIDAY).

Among these Schemes the Smart Cities Mission focuses on core infrastructure solutions to increase "sustainable and inclusive development." It is aimed to create climate resilience and reduce carbon emissions in 100 cities in India. The government has also created National Industrial Corridors, to streamline environment and forest approvals, labour reforms that enable the ease of doing business and have kept climate change considerations in check. India has also focused on granting incentives to cities to take up waste to energy conversion projects.

Mainstreaming Climate Resilient Development

The report on 'Low Carbon Strategies for Inclusive Growth' (2014) by the Indian government focused on India's commitment to reducing emissions intensity of its economy and the voluntary measures it has promised to undertake before the international community (MoEF&CC, 2014). The report contained details of technology, policy and finance options required to pursue a low emission growth trajectory. The report also highlighted the need to create climate adaptation in agricultural practices and water resource utilization.

Resource Mobilisation

Developing countries such as India face enormous challenge to advance adaptation activities because of lack financial resources. Global estimates on adaptation cost as reported by The Adaptation Gap Report 2015 published by United Nation Environment Programme (UNEP) indicates two to three fold rise in cost, as compared to the current estimates made for 2030. Even though the international finance for adaptation has increased in recent times, current available public finance falls short of need.

Finance has always remained one of the key asks of India in climate negotiations. India's overall response is to acquire a comprehensive resource package. India is therefore committed to mobilizing the resources that are necessary for both mitigation and adaptation. These include financial resources, technical cooperation and technology transfers. At present India's current climate finance comes from budgetary sources. Most of the funds for adaptation and mitigation are built into schematic programmes. Additionally, India is moving towards using market mechanisms together with fiscal instruments and regulatory interventions to mobilize climate change finance.

India's INDC highlights that it will cost at least USD 2.5 trillion to implement at 2014-2015 prices (INDC, 2015). While it is considerably higher than many other developing nations, on a per capita basis the rough calculation is on par. Following are few of the climate finance options that India exercises:

10.5.4 Finance

The Government of India has set up dedicated funds and mechanisms at the national level for mobilizing financing for mitigation and adaptation respectively:

Cess on Coal

Indian government initiated Coal cess in 2010. The proceeds of coal cess forms National Clean Environment Fund (NCEF) to finance clean energy projects and research in the area of clean energy in the country. Coal cess makes renewable energy competitive by increasing cess on coal by INR 400 per tonne of coal produced domestically or imported. The total collection of INR 170.84 billion (USD 2.7 billion) till 2014-15 is being used for 46 clean energy projects worth INR 165.11 billion (USD 2.6 billion) (INDC, 2015).

National Adaptation Fund

National Adaptation Fund on Climate Change

Table 10.5: Sector Wise Approved CDM Projects

Name of Sector	Number of Projects
Afforestation and Reforestation	28
Agriculture	3
Chemical Industries	18
Construction	0
Energy Demand	224
Energy Distribution	9
Energy industries (Renewable/ Non-renewable sources)	2400
Fugitive emissions from fuel (Solid, oil and gas)	4
Fugitive emissions from production and consumption of halocarbons and Sulphur	6
Manufacturing Industries	241
Metal Production	4
Mining/Mineral Production	A
Solvent use	0
Transport	13
Waste handling and disposal	72
Total	**3,026**

Source: National Clean Development Mechanism Authority, GoI, 2015

(NAFCC) is a central scheme which was operationalised in 2015-16. The fund is meant to assist National and State level activities to meet the cost of adaptation measures in areas that are particularly vulnerable to the adverse impacts of climate change in sectors like agriculture, water, forestry etc. The Scheme has been taken as Central Sector Scheme with National Bank for Agriculture and Rural Development (NABARD) as the National Implementing Entity (NIE). Currently, 21 projects have been approved under NAFCC for which, an amount of Rs. 212.29 Crore has been released.

Clean Development Mechanism (CDM)

India has strengthened its position as a leader in terms of Host Country Approved CDM projects with 13.13 per cent share of the total certified emission reductions projects up to 2017. The total number of

CDM projects registered by India as per the National CDM Authority of India is 3026 up to June 2017 (Table 10.5). It has received further CDM Executive Board's registration under UNFCCC for over 1644 projects ranging over a wide range of renewable energy projects. Large number of CDM projects focused on wind, biomass, hydro and solar energy.

Other Financial Resource Mobilisation Measures

India has reduced its petroleum subsidy by 26 per cent over the past one year. It has further increased taxes on fossil fuels such as petrol and diesel moving India from a carbon subsidy to a carbon taxation regime. India has also initiated incentives for the forestry sector. The funds that will be provided to the states from the Central government would be based on 7.5 per cent of the area under forest cover in the states. This Indian government also has developed Tax Free Infrastructure Bonds (INR 50 billion) for clean and green energy.

10.5.5 Education

Climate change has cross-sectoral implications in India. It is important to understand the science as well as the concept behind it to find options to mitigate and adapt to it. This is fundamental to future development pathways of India. It is therefore important for the Indian society to include climate change into education and training curricula. Indian citizens would be better equipped to re-orient society towards social, economic and ecological sustainability if they are trained on climate change education. The Government of India has committed to spreading awareness about climate change education and strengthening the scientific knowledge on the issue. The National Mission on Strategic Knowledge for Climate Change (NMSKCC) was created to help develop knowledge systems on climate change and sustainable development. This mission also focused on dissemination of knowledge to improving capabilities in agriculture and other climate sensitive industries.

In the year 2015, 'Science Express Climate Action Special (SECAS)' train was designed on the theme of climate change. The objective was to increase the understanding on issues relating to climate change including, observed and anticipated impacts and different possible responses. The state-of-the-art exhibition aboard SECAS aimed to create awareness among various sections of society, especially students, as to how climate change can be combated through mitigation and adaptation. The train travelled across the country during 15 October 2015 to 07 May 2016, halting at 64 locations in 20 States, covering a distance of about 19,800 km. It received an overwhelming response and with over 23.24 lakh visitors (including 5,89,615 students; 30,120 teachers and 13,29,373 general visitors), SECAS became the biggest Climate Change Awareness Programme in the country. In view of the unprecedented response received by SECAS, the Science Express will be running again on the theme of climate change as SECAS II from 17 February to 08 September 2017, covering a distance of over 19,000 km, exhibiting at 68 stations across India.

The Government of India further set up 25 ENVIS centers as part of a dynamic network of numerous institutions that would help in accessing environmental information easily. These centers have government departments, institutions and various NGOs in the network.

10.5.6 Science and Technology

Research in climate change is a high priority R&D for the Government of India. India needs highly functional climate change science and technology platform to enable the development and implementation of appropriate actions to minimize the impacts of climate change. It has therefore set up the Indian Network on Climate Change Assessment (INCCA) in 2009. As a network based scientific program it assesses the drivers and impacts of climate change, estimates GHG emissions, capacity building to manage climate change risk and opportunities.

Technology transfer is an important component of the principle of common but differentiated responsibility. It is also a component of resource mobilization. Its presence in the climate change negotiations is driven by two mechanisms: Global Environment Facility (GEF), and projects funded under the CDM. India has been vocal on the issues of support in the form of technology transfer and development in the international negotiations.

10.5.7 Monitoring, Reporting and Verification

For effective implementation of the response to mitigate climate change impacts it is required that these are evaluated and monitored. On one hand, India must effectively engage in modelling climate change scenarios as well as monitoring its current status with respect to the subcontinent. On the other hand, India should monitor the responses in terms of adaptation and mitigation measures.

Measuring, reporting and verification were added to the agenda through the Bali Action Plan as it would enhance national action plans on climate change. Currently the measuring, reporting and verification (MRV) system in India is confined to financial and physical parameters due to lack of appropriate institutional mechanisms and capacity for domestic MRV systems (MoEF&CC, 2015). Even though India has been implementing a large number of programs in curtailing GHG emissions there are only a very few programmes involve systematic monitoring, evaluation and reporting. Few of them are listed below:

- MRV of Energy Efficiency: PAT (Perform, Achieve and Trade) Scheme
- Monitoring in Forest Sector
- MRV of Renewable Purchase Obligation (RPO)

The above systems in energy are market and trading based mechanisms while the forest area monitoring is done by latest remote sensing techniques, which is critical for implementing CDM and REDD+ (MoEF&CC, 2015).

10.6 CONCLUSION

Climate change is among the most far-reaching and urgent challenges India faces today, constituting additionallyto the environmental constraints that come up in social development and planning. The impacts of climate change as we have seen throughout the report vary across the country. These are majorly through change in long-term temperature and rainfall patterns. There is also projection of increase in extreme weather events including floods, droughts, sea level rise, and coastal erosion. The projected extended impacts of both weather changes and extreme weather events include those for agriculture, biodiversity, water and marine environment, health, livelihoods and infrastructure.

Every country around the world is developing its own adaptive responses to climate change and ensuring that it reduces its contribution to mitigating the emissions that are causing the change. It is a cross-generational challenge. Even though our responses may seem to have no significant consequences, we must recognize that climate change impacts will affect the future generations the most. Further, under the principles of climate justice and of equity and common but differentiated responsibilities it will require extensive international support and partnership.

In comparison to the impacts of climate change India is facing or will face the response required needs to be proportional. It will further require sustained effort and cooperation from all spheres of government, the private sector and civil society organizations in India. Additionally, the financial and technological needs for India are expected to be high, particularly in terms of adaptation. However, with a growing economy and fast moving development there are substantial opportunities for India to usher in a sustainable climate resilient and low-emissions society and economy through appropriate measures. With the signing of the Paris Agreement and UN's SDGs, India has committed strongly to building a climate-resilient nation for the current and future generations.

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Note: *Some of the references that have been used in the report may have been published or released in 2016 but it has been ensured that the data that was cited from such documents pertain to the time periods only upto 2015.*

APPENDICES

Apex Committee Meetings

First Apex Committee Meeting

Second Apex Committee Meeting

Third Apex Committee Meeting

Apex Committee

List of Participants

Shri. R H Khwaja, Chairman, Apex Committee, Former Secretary, Govt. of India

Prof. S P Gautam, Member, Apex Committee and Former Chairman, CPCB

Dr. Anandi Subramanian, Senior Adviser, MoEF&CC

Mr. M Peter Johnson, Member, Apex Committee, Statistical Adviser, MoEF&CC

Dr. M Salahuddin, Member Secretary, Director, MoEF&CC

Dr. A B Akolkar, Member, Apex Committee, CPCB

Dr. K Vijaya Lakshmi, Development Alternatives, New Delhi

Mr. Chandra Bhushan, Member, Apex Committee, CSE, New Delhi

Dr. Suneel Pandey, Member, Apex Committee, TERI, New Delhi

Dr. S M Iliyas, Former Director, NARM, IARI

Prof. L Kannan, Former Vice-Chancellor, Thiruvalluvar University

Dr. B Sengupta, Former Member Secretary, CPCB

Mr. Amit Mital, Central Water Commission, New Delhi

Ms. Bhawna Singh, Ministry of Rural Development, New Delhi

Mr. Chandra Shekhar, Central Energy Authority

Ms. Chhavi Pant Joshi, Ministry of Health and Family Welfare, New Delhi

Mr. D N Prasad, Ministry of Coal, New Delhi

Dr. Divya S Iyer, Ministry of Commerce, New Delhi

Mr. Gopal R Iyengar, Ministry of Earth Science, New Delhi

Mr. James Mathew, MoSPI, New Delhi

Mr. Jay Anand, Consultant, Chennai

Ms. Parvathy Nair Patel, CPHEEO

Mr. Peeyush Kumar, Ministry of Coal, New Delhi

Dr. R K Chaturvedi, Indian Institute of Science, New Delhi

Mr. R K Pachauri, Central Water Commission, New Delhi

Mr. Rajesh Kumar, Central Energy Authority

Mr. Rajiv Kumar, Central Water Commission, New Delhi

Mr. Rakesh Maurya, MoSPI, New Delhi

Mr. Rama Kant Singh, Department of Food and Public Distribution

Dr. Shahid Ali Khan, NHPC, New Delhi

Mr. Siyad N, Ministry of Commerce, New Delhi

Mr. Subhash Zadoo, Food Corporation of India, New Delhi

Mr. Subrata Halder, Ministry of Tourism, New Delhi

Ms. Sushmita Dasgupta, Ministry of Commerce, New Delhi

Dr. Vinita Arora, Coal India Limited, New Delhi

Dr. Alka Srivastava, Development Alternatives

Mr. Anand Kumar, Development Alternatives

Ms. Anindita Singh, Development Alternatives

Mr. Avanindra Kumar, Development Alternatives

Mr. Farhan, Development Alternatives

Ms. Kavya Arora, Development Alternatives

Mr. Mayukh Hajra, Development Alternatives

List of Acronyms

AMRUT	Atal Mission for Rejuvenating Urban Transformation
AQI	Air Quality Index
AYUSH	Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy
BCM	Billion cubic metres
BMW	Biomedical Waste
BOD	Biological Oxygen Demand
C&D Waste	Construction and Demolition Waste
CAGR	Compound Annual Growth Rate
CBD	Convention on Biological Diversity
CBWTF	Common Biomedical Waste Treatment Facilities
CEPI	Comprehensive Environmental Pollution Index
CFL	Compact Fluorescent Lamp
CGWB	Central Ground Water Board
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNG	Compressed Natural Gas
COPD	Chronic Obstructive Pulmonary Diseases in India
CPCB	Central Pollution Control Board
CSE	Centre for Science and Environment
CT	Census Towns
CuM	Cubic Metres
CWC	Central Water Commission
DIPP	Department of Industrial Policy and Promotion
DMF	District Mineral Foundation
DO	Dissolved Oxygen
DoM	Department of Mines
ENVIS	Environmental Information System
EPR	Extended Producer Responsibility
ESZ	Eco Sensitive Zone
E-Waste	Electronic Waste
FICCI	Federation of Indian Chambers of Commerce and Industry
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDI	Human Development Index
HVAC	Heating Ventilation and Air Conditioning
IBM	Indian Bureau of Mines
ICAR	Indian Council of Agricultural Research
ICMM	International Council of Mining and Metals
IEA	International Energy Agency
IIP	Index of Industrial Production
IMD	India Meteorological Department
INDC	Intended Nationally Determined Contributions
INR	Indian Rupees
IPCC	Inter-Governmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
IWMI	International Water Management Institute
IWT	India Water Tool
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
LPG	Liquified Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
Mha	Million Hectares
MLD	Million Litres per Day
MoEF&CC	Ministry of Environment, Forest & Climate Change
MoRTH	Ministry of Road Transport and Highway
MoSPI	Ministry of Statistics and Program Implementation
MoWR, RD & GR	Ministry of Water Resources, River Development & Ganga Rejuvenation
MRV	Measuring, Reporting and Verification
MSME	Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
MT	Metric Tonnes
Mtoe	Million tonnes of oil equivalent
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality Monitoring Programme
NAPCC	National Action Plan on Climate Change
NCIWRD	National Commission for Integrated Water Resource Development
NIH	National Institute of Hydrology
NO_x	Oxides of Nitrogen
NSSO	National Sample Survey Organization
NTCA	National Tiger Conservation Authority
OECD	Organisation for Economic Co-operation and Development
PA	Protected Areas
PM	Particulate Matter
PPP	Public Private Partnership

RSPM	Respirable Suspended Particulate Matter
SAPCC	State Action Plan on Climate Change
SBM	Swacch Bharat Mission
SDF	Sustainable Development Framework
SDG	Sustainable Development Goals
SHDI	State Human Development Index
SO_x	Oxides Of Sulphur
SPM	Suspended particulate matter ST Statutory Towns
TEEB	The Economics of Ecosystems and Biodiversity
TIFAC	Technology Information, Forecasting and Assesment Council
TPD	Tonnes per day
TSDF	Treatment, Storage And Disposal Facility
TSS	Total Suspended Solids
UA	Urban Agglomerations
UDD	Urban Development Department
ULB	Urban Local Bodies
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USD	US Dollar
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization WWF World Wildlife Fund
ZED	Zero Effect Zero Defect

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