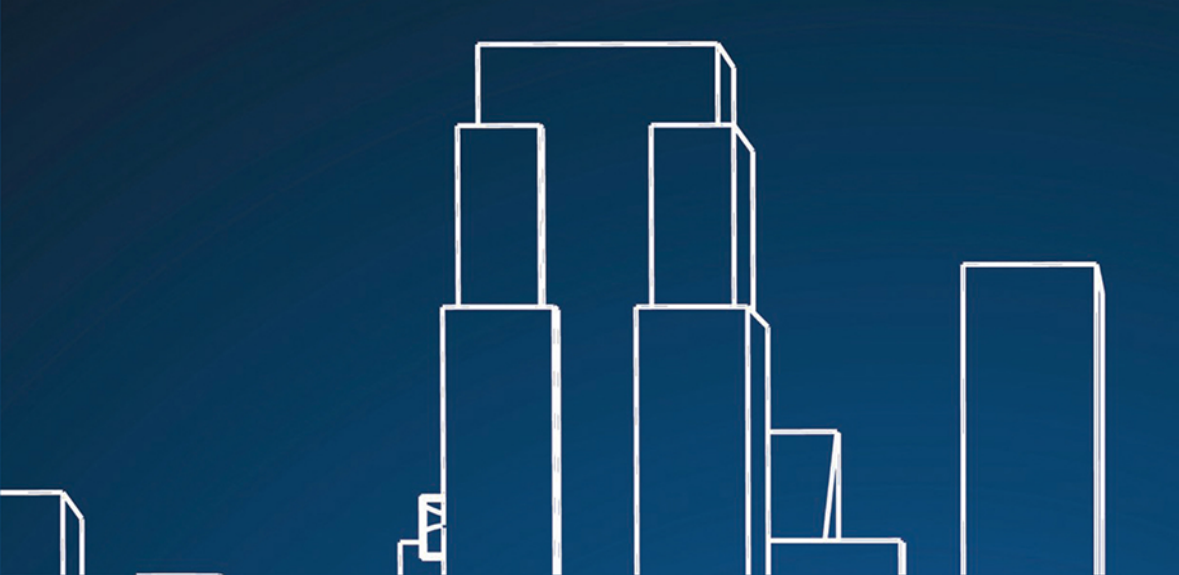




URBAN GREEN SPACE, HEALTH ECONOMICS AND AIR POLLUTION IN DELHI

Swati Rajput, Kavita Arora and Rachna Mathur



Urban Green Space, Health Economics and Air Pollution in Delhi

This book looks at the ecological stress on cities and engages with challenges of reducing vulnerabilities and risks of pollution on the health, well-being and livelihoods of people living in developing countries. Cities are the world's highest energy consumers and the biggest producers of toxic wastes and pollutants.

With an emphasis on the environmental issues facing the city of Delhi, the volume focuses on steps to preserve and manage the city's urban green spaces. It explores the concept of urban green spaces and their economic, social, health, and psychological significance in cities. Drawing from their fieldwork and research in Delhi, the authors identify the sources of pollution in the city and assess the role of urban green spaces in countering adverse effects. They further examine the relationship between green spaces and social and economic development, urban health, and urban governance. They highlight the good practices followed by other global cities. The volume also offers suggestions and policy recommendations to reverse and recover ecological balance in cities.

This book will be of interest to students and researchers of environment and ecology, public health, urban planning and governance, development studies, urban geography, urban sociology, resource management and health economics. It will also be useful for policymakers, and NGOs working in the areas of sustainability, urban planning and management and environmental preservation.

Swati Rajput is a faculty member in the Department of Geography, Shaheed Bhagat Singh College, University of Delhi. She has 20 years of experience teaching geography in Delhi University. Her subject expertise includes environment, agriculture, urban and tourism geography. She is the editor of the book, *Sustainable Smart Cities: Challenges and Future Perspective*. She was awarded as the National Resource Person in Social Sciences by the Ministry of Human Resource Development and United Nations FPA. She has contributed to various national and international books and peer-reviewed journals. She has also recorded various modules for e-PG Pathshala and Massive Open Online Courses (MOOC) (National Institute of Open School

[NIOS]) under a Ministry of Human Resource Development (MHRD) initiative. She is a Gold medallist (Delhi University) and rank holder throughout academics.

Kavita Arora is the author of a book *Indigenous Forest Management in Andaman & Nicobar Islands, India*. She has published her research in many reputed journals. She earned her Ph.D. in Political Geography from Jawaharlal Nehru University, New Delhi. She got Post -Doctoral Fellowship from Indian Council of Social Science Research (ICSSR), New Delhi and Rajeev Gandhi Institute of Contemporary Studies (RGICS), Rajeev Gandhi Foundation, New Delhi. She is currently working as an assistant professor of Geography at Shaheed Bhagat Singh College, University of Delhi, India. A political geographer with interests in development and environmental issues, her research focuses on forests, gender, indigenous knowledge, trans-border conservation and the socio-political dimensions of development.

Rachna Mathur is an assistant professor in the University of Delhi. She has been teaching economics for the last 13 years. She did her Ph.D. in Health Economics. Her areas of interest are health economics, money and financial markets and financial economics. She has published many research papers and presented papers in national and international conferences.

Urban Green Space, Health Economics and Air Pollution in Delhi

Swati Rajput, Kavita Arora and
Rachna Mathur

First published 2021
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

© 2021 Swati Rajput, Kavita Arora and Rachna Mathur

The right of Swati Rajput, Kavita Arora and Rachna Mathur to be identified as authors of this work has been asserted by them in accordance with sections 77 and 78 of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or reproduced or utilised in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

A catalog record has been requested for this book

ISBN: 978-0-367-35269-1 (hbk)

ISBN: 978-0-367-71021-7 (pbk)

ISBN: 978-0-429-34058-1 (ebk)

Typeset in Sabon
by SPi Global, India

Contents

<i>List of Figures</i>	<i>vi</i>
<i>List of Tables</i>	<i>viii</i>
<i>Preface</i>	<i>x</i>
<i>Acknowledgements</i>	<i>xiv</i>
Introduction	1
1 Urban green spaces: Concept and significance	8
2 Green spaces of Delhi: A journey from past to present	35
3 Level and extent of air pollution in Delhi	59
4 Health challenges in Delhi	89
5 Healthcare management: Investment and expenditure	107
6 Green health insurance for urban areas: Willingness to pay	139
7 Conclusion and suggestions	159
<i>Index</i>	<i>175</i>

Figures

I.1	Simplified model of linkage between green space, air pollution and health economics	2
1.1	Green spaces in world cities	22
1.2	Vertical green pillars along metro lines	26
1.3	Exhibition of kitchen garden practices	27
1.4	Migratory birds in Yamuna Bio-diversity Park in Delhi	28
1.5	Green cities and their remarkable features, as per the Economist Intelligence Unit	28
2.1	Green spaces in Delhi, 2002	49
2.2	Green spaces in Delhi, 2015	50
2.3	Green spaces in Delhi, 2018	50
2.4	Spatiotemporal change in agricultural land, parks and vegetation (including TOF) in 2002 and 2015	52
2.5	Location of selected parks in Delhi	53
2.6	NDVI for Delhi, 2016	54
2.7	NDVI for Delhi, 2018	55
2.8	Potential green spaces in Delhi, as proposed by several authorities	56
3.1	Registered private vehicles in million-plus cities, 2017	66
3.2	Registered vehicles in Delhi	67
3.3	Fuel utilisation in Delhi	68
3.4	Types of industries in Delhi	70
3.5	Distribution of factories	71
3.6	Industrial fuel consumption	71
3.7	Road length in Delhi	74
3.8	Delhi heat stress May 2000–2016	79
3.9	Temperature distribution in Delhi, 2016	80
3.10	Concentration of PM _{2.5} in Delhi	81
3.11	Concentration of PM ₁₀ in Delhi	82
3.12	Distribution of carbon dioxide in Delhi	83
4.1	Life expectancy in megacities of the world	91
4.2	Infant mortality rate in world megacities	92
4.3	Diseases in Delhi (zonewise) in per cent	97

4.4	Preference for environment friendly products	100
4.5	Preference of ecofriendly products and educational level	101
5.1	Vicious circle of health investment and management	108
5.2	Virtuous circle of health investment and management	109
5.3	Healthcare providers in India	111
5.4	Healthcare providers in urban and rural India	111
5.5	Investment on health in different plan periods (percentage of total plan investment)	114
5.6	Government expenditure on health as percentage of GDP in 12th Five-Year Plan	114
5.7	Health expenditure by healthcare providers in India	115
5.8	BRIC countries health expenditure per capita (US\$, 2015)	117
5.9	Government and voluntary health expenditure as percentage of GDP, 2017	118
5.10	OOP expenditure (as percentage of total current health expenditure) of major regions of the world, 2015	121
5.11	Percentage of OOP expenditure and percentage of government expenditure on health, 2015	122
5.12	Choice of hospitals for healthcare service by the people in Delhi	130
5.13	Income levels and choice of hospitals (percentage of respondents)	130
5.14	Number of earning members and choice of hospital	131
5.15	Level of education and choice of hospital	132
5.16	Monthly expenditure on preventive healthcare (rupees)	133
5.17	Willingness to pay for health insurance	133
5.18	Number of family members and WTP for health insurance	134
5.19	Frequency of occurrence of disease and WTP for health insurance	135
5.20	Level of education and WTP for health insurance	136
5.21	Family income and WTP for health insurance	136
6.1	Individuals' WTP for an improvement in health status from U_0 to U_1 while still maintaining the same level of well-being	141
6.2	Demand curve showing WTP for green insurance for given BIDS	153
6.3	Demand curve for amount respondents are willing to pay for green insurance	156
7.1	Green infrastructure, health economics and development	173

Tables

3.1	Impact of pollutants on trees and plants	63
3.2	Gases emitted by different types of industries in Delhi	69
3.3	Sources of PM10 and PM2.5	72
3.4	Health impacts of construction material	73
3.5	Selected heat stress indices temperature limits	78
3.6	Heat stress in Delhi, 2016	81
3.7	Temperature and pollution (PM2.5) regions of Delhi	85
3.8	Temperature and pollution (carbon dioxide) regions of Delhi	86
4.1	Report on National Air Quality Index and Health Impact, Central Pollution Control Board	93
4.2	Details of vector-borne diseases in Delhi, 2010–2018	94
4.3	Major cause of death in Delhi, 2018	94
4.4	Major environment problems in your area	96
4.5	Disease that family members suffer from	97
4.6	Types of preventive healthcare	98
4.7	Ecosystem services derived from green spaces	99
4.8	Test statistics for the regression model for the preference for EFP	102
4.9	Test statistics of the regression model of choice for EFP	103
4.10	Assessing the health satisfaction level (percentage of respondents)	105
5.1	Trends in centre–state share (Per cent) in total public expenditure on health	113
5.2	Public expenditure on health as percentage of GDP across World Bank income groups (2015)	116
5.3	Current health expenditure per capita (USD), 2015	116
5.4	Public expenditure on health as percentage of GDP for South East Asia Region (SEAR) Countries, 2015	117
5.5	Government and voluntary health expenditure as percentage of GDP, 2017	119
5.6	Breakdown of out-of-pocket payments by Indian households on healthcare (in percentage)	120
5.7	OOP expenditure (as percentage of current health expenditure in different countries) in 2017	123

5.8	Healthcare financing schemes, 2014–2015 (percentage of total)	124
5.9	Expenditure on health with reference to GSDP	127
5.10	Percentage of plan expenditure on health sector by Government of Delhi	128
6.1	Descriptions of variables for the study of WTP for green insurance	145
6.2	Classification table for binary logistic in Step 0 (initial step)	148
6.3	Variables in the equation	148
6.4	Variables not in the equation	148
6.5	Omnibus tests of model coefficients	149
6.6	Classification table for binary logistic WTP for green insurance	149
6.7	Model summary of binary logistic regression	150
6.8	Variables in the equation showing the determinants for participating in the green insurance scheme	151
6.9	Percentage of respondents willing to pay the proposed BID amount for green insurance in Delhi	152
6.10	Willingness to pay for green insurance for proposed BIDs	152
6.11	The amount respondents are willing to pay for green insurance, using the regression model	154
6.12	Test statistics of the amount respondents are willing to pay for green insurance, using the regression model	155
6.13	Amount respondents are willing to pay for green insurance, using the open-ended question	156

Preface

The human species has marked its presence on the Earth by reshaping the landscapes with numerous social and economic activities. Urbanisation is inevitable in the modern world. Cities have become symbols of human dominance and triumph. Agriculture and industry are two strong pillars of human establishment. Industrial development led to massive urbanisation worldwide. After the 1990s, tertiarisation shaped the emancipated megacities. The reckless behaviour of man has hampered the urban ecosystem by misusing and abusing the natural resources, especially in cities. Growth in number of cities and population residing in them has shown a drastic increase in the last century. Cities occupy nearly 3 per cent of the world's land and accommodate around 55 per cent of its population. The increase in concentration of population in limited areas has pressurised the natural biomes. Asia has some 48 per cent of its population residing in urban areas. India, China and Nigeria contribute to 37 per cent of urban population in Asia and Africa together. Tokyo is the world's largest city with an agglomeration of 38 million inhabitants, followed by Delhi with 25 million, Shanghai with 23 million, and Mexico City, Mumbai and São Paulo, each with around 21 million inhabitants. By 2030, the world is projected to have 41 megacities with more than 10 million inhabitants (UN, 2014). The huge increase of population in cities has led to contraction of agricultural land, forest land and other open spaces.

Green spaces are imperative for healthy growth of cities and its residents. Green spaces in cities have social, psychological and health impacts. These spaces are essential for the residents to breathe fresh and clean air. Trees are very important elements of the sustainable urban ecosystem. Due to various developmental activities like building of roads, rails, housing and commercial complexes etc, green spaces are reducing in the city and have become last in the priority list of the planners and policymakers. Cities are considered to be the engine of economic growth, but now they are turning into symbols of unsustainable growth, especially in the developing nations of Asia and Africa.

The Greenpeace Report, 2018, says that India has 22 of the 30 most polluted cities of the world, and Gurugram is reported to have the most

polluted air of the world. Coal burning and vehicular emissions are the most common and major contributors to air pollution in the Asian cities of India, Pakistan and China. The report adds that around seven million people die every year in the world due to air pollution.

According to Sandifer et al. in 2015, 'The roles of Urban Green Spaces in supporting biodiversity and the linkages among biodiversity, human health and ecosystem function have so far received insufficient attention'. This book tries to explore several aspects of the linkages between green spaces, air pollution and health in Delhi. Nearly 97 per cent of Delhi's population lives in its urban areas. Delhi has a population density of 11,297 persons per sq. km. It is considered to be among the most polluted yet greenest capital cities of the world. Twenty per cent of its area is vegetated, but even with the availability of 21 square metres of green area per person (Forest Survey of India, 2016), it has miserably bad air. Green spaces in Delhi have not been planned properly. Air pollution has become a major issue of concern. The residents of Delhi are breathing the worst quality air. The city lacks an effective plan to curb the issue. Numerous saplings were planted before the 2010 Common Wealth Games in South and South West Delhi, brought from different countries like China, Sri Lanka and Malaysia. Biodiversity parks and the city forest are also being created and maintained; yet, the citizens of Delhi suffer from numerous health ailments. Vehicular pollution, industrial pollution, pollution due to waste disposal and power generation are among the major culprits. The book begins with introducing the concept of green spaces and their significance. By focusing primarily on Delhi, the book covers a past-to-present journey of green spaces in it. It later discusses the challenge of depleting green spaces and increasing air pollution, by explaining the link between the two. The book also emphasises upon the financial and economic aspects linked to the human health level in Delhi.

The solution lies in adopting a holistic approach. The government is generally forming short-term policies and attempting to just bandage the wounds. It should rather focus on a pragmatic approach to build the policies and urban designs with an eco-friendly perspective. Residents are careless and authorities are not willing to invest in something which does not generate direct financial profit but rather demands investment. Sadly, we fail to understand that 'health is wealth'. A healthy nation can generate profits at much accelerated speed than an unhealthy nation. Delhi is the asthmatic capital of the world; the number of asthma patients has shown a nearly 300 per cent rise in the last few years. Residents have been paying a heavy cost of staying in a polluted and unhealthy environment. As a quick short-term measure, odd-even cars are supposed to ply on roads on odd-even dates, respectively. On high pollution alert days, residents are advised to stay indoors. A pollution holiday is declared by the government by shutting down the schools. Children are more vulnerable to such hazards. The health expenditure for both curative and preventive care is increasing day by day.

Delhi needs a huge health investment plan, where on the one hand, the focus should be on creating a sustainable environment and on the other hand, the government should sensitise and subsidise the adoption of green health insurance policies. The problem of air pollution, which is turning out to be more dangerous day by day, has to be addressed by making both short-term and long-term policies. There is a need to invest in establishing institutes that can impart training in urban and environmental engineering.

The book clearly restricts itself to a spatial and economic approach by incorporating various parameters of the issue of shrinking green spaces, air pollution and health. While writing this book, the authors came across several documents, reports, news coverage, media discussions, etc., all pinpointing the felling of trees, problem of air pollution and rising asthma cases in Delhi. Although it was very difficult to include all sources and related data, the book tries to include the authentic sources and impactful studies. The book is based upon both secondary sources and primary surveys. It is written in a systematic manner; it moves from a spatial approach to a historical journey, then the economic perspective and later it gives a technological insight. It focuses upon the concept and need of green spaces and the quantity of green spaces needed in urban areas. The book figures out the temporal changes in urban green areas from the early historical period to the present modern period. It includes both planned and natural green spaces and their interface with empires, planners, policymakers and the public. The book analyses and maps the level of air pollution in Delhi, based on data collection at various green and non-green spaces. It discusses the causes and consequences of depletion of green spaces and increasing air pollution. The hotspots in relation to temperature and pollution have been identified, tabulated and mapped by using the data collected by air quality monitors. The book also focuses on the extent of health issues and related health economics. Prevalence of pollution leads to the frequent occurrence of seasonal diseases like dengue, chikungunya, fever, common cold and cough, asthma, bronchitis, eye infections, and skin diseases, which have been causing a heavy burden of healthcare cost on an individual or a household. People are spending a huge amount of money on both preventive and curative costs. They pay a high cost for every single episode of hospitalisation or visit to the doctor. Heavy out-of-pocket expenditure on health is one of the important causes of poverty, which adversely affects access to healthcare. It is catastrophic to poor households and further impoverishes them. This study aims at converting this out-of-pocket expenditure into prepayment schemes through health insurance on the basis of willingness to pay, which will lower the financial burden of medical expenses, enabling access and protecting them from the economic ruin caused by high health expenditure. The study suggests the importance of insurance for health in the form of 'Green Health Insurance'. Green insurance products with a low

premium would help to finance seasonal diseases caused due to environment pollution, especially for the poor and workers from unorganised sectors in the urban areas.

The book thus tries to make the readers think from various perspectives of green spaces, air pollution and health in Delhi. The authors have made a genuine effort to demonstrate the extent of the issue and highlighted the solutions to it. There can be many more perspectives and approaches to understand the interface of green spaces, air pollution and health, that cannot be undermined; therefore, the authors have taken due care to maintain the relevance of their approach and respectfully leave the further scope of the multifarious ways to handle the issue. The book, on the one hand, emphasises the need of having green spaces and curbing air pollution in cities, and on the other hand, analyses the financial and economic perspective of managing the grim situation.

New Delhi, India

Acknowledgements

The authors are thankful to the University of Delhi for giving the opportunity and environment for conducting research under innovation project 2015. The authors extend special thanks to Dr. Bindhy Wasini Pandey, Associate Professor in Department of Geography, Delhi School of Economics, University of Delhi, for his mentorship. The authors are grateful to Dr. P. K. Khurana (former Principal) and Dr. Anil Sardana, the Principal, Shaheed Bhagat Singh College for their constant support and encouragement. The book is an outcome of sincere hard work put in by a group of undergraduate students, in the form of conducting field surveys and data collection, from Geography and Economics Department of the college namely, Shubham Saket, Sagar, Nupur Bhatia, Sachi Vohra, Tanvi Jindal, Pretty Pamei, Khuram Shabir, Prasun Bhowmik, Soumya Kumari, Mayank Garg, Shikhar Kumar, Sonali Chowdhury, Ngamgupou Thaimai, Shikha Barnwal, Sharad Yadav, Ankesh and Dr. Vijay Pandey (Assistant Professor). We are also thankful to the authorities and officials of Delhi for sharing the information and their views on concerned issues. The authors are indebted to the residents of Delhi for sharing their opinions on the issues examined. The authorities of Indian Agriculture Research Institute, PUSA; Yamuna Biodiversity Park; Aravalli Biodiversity Park; Association of Kitchen Gardens, Defence colony; etc also deserve heartfelt acknowledgment for their support. We are also grateful for the technical help extended by Dr. Rashmi Rani Anand (Assistant Professor) and Ms. Arifa Begum (Research fellow IIRS and ISRO). The authors are also thankful to Mr. Rahul Celly, research editor in print media and education, for his help in proofreading the work. The authors extend their gratitude to the reviewers for giving positive reports about the manuscript. The authors are thankful to Prof. Gunnar Magnus Johannesson, Professor at the Stockholm School of Economics, for giving his approval for using the figure of willingness to pay in the study. Last but not least, the authors are deeply thankful to their respective parents and families for their continuous support and encouragement.

Introduction

Cities in the world are struggling from various complex and diverse challenges. Megasettlements with serpentine transport and communication networks, inexorable construction work, industrial townships, etc., have on the one hand, ensured convenience and on the other hand, created spheres of bio-geo-chemical modified landscapes. Among the many challenges is the challenge of air pollution. In the cities, trees are being cleared and chemicals are penetrating the air from various sources every second. Removal of these chemicals from the air is a challenging task, which means that people in the cities breathe in this polluted air making them vulnerable to many health risks. These health issues besides having an impact on the body also have a financial cost. The cost of increasing air pollution and being unhealthy has to be borne by people living in these cities. It is therefore important to analyse and understand the relationship between green spaces and air pollution to manage health economics in urban areas (Figure I.1).

According to UNDP, cities of the world occupy 3 per cent of land but consume around 70 per cent of energy and are responsible for 70 per cent of carbon emissions. They contribute to around 90 per cent of the world's GDP. Sustainable growth and environment conservation have to be the ultimate goals for the survival of mankind on the Earth. Natural vegetation cover is the only saviour for sustainability, considering the fact that the process and pace of production cannot come to a standstill. Vegetation cover has to be planned smartly and has to be considered as an integral part of the development process.

Air pollution does not follow manmade national and international boundaries. Pollutants can be carried away by the air current to faraway places. The area which is the source of air pollution is the worst affected and its effect diminishes as we move away from its source. The land use changes of the city causes a slow and steady change in its microclimate. Excessive vehicular traffic, industrial and domestic effluents enter the air. The vapour, chemical and smog accumulates in the air just above the surface it becomes heavier, therefore, hindering the speed and process of air circulation thereby choking the cities. The horizontal movement of air and the development of

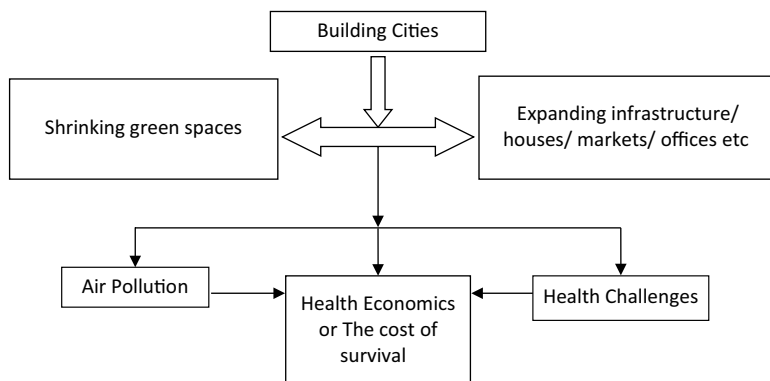


Figure 1.1 Simplified model of linkage between green space, air pollution and health economics.

Source: Authors

surface ozone is also common in the core of the city. The cities thus experience a phenomenon called ‘heat island’, especially in summers.

The harmful impact of various pollutants in the air is unequivocal. The United States Environmental Protection Agency has categorically mentioned that long-term or short-term exposure to fine particle pollution, also known as PM_{2.5} (Particulate Matter), can cause premature death, harmful effects on the cardiovascular system and asthma. Moreover, long-lived greenhouse gases which trap heat in the atmosphere including carbon dioxide, methane, nitrous oxide and fluorinated gases are released due to various diverse human activities (<https://epa.gov/>). According to USGC global monthly, average concentrations of carbon dioxide have risen steadily from 330 parts per million in 1980 to 407 ppm in 2018, an increase of more than 20 per cent in less than 40 years.

According to National Center of Biotechnology Information (NCBI), excessive breathing of CO₂ can lead to breathing troubles, increased heart rate, elevated blood pressure, etc. Nitrous oxide concentration in the air has also drastically risen in last 50 years. Presently, it is 329.9 parts per billion. According to NCBI, excessive exposure of nitrous oxide leads to high blood pressure, nausea, headache and breathing disorders.

India has nine out of the ten most polluted cities in the world. Researchers estimate that smog pollution killed around 1.24 million people in 2017. According to the American Thoracic Society, 2019, reductions in air pollution yield fast and dramatic impacts on health outcomes as well as decreasing morbidities.

Reducing air pollution and establishing sustainable cities can be achieved by building green spaces. Green spaces are semi-natural areas that not only have the environmental function of blocking noise, reducing carbon emissions and air pollution, conserving water and soil, adjusting the microclimate

and moderating temperatures, but also have the ecological functions of recovering fertility, preserving ecologically sensitive areas, providing the habitat and feeding spaces for various species and stabilising ecological systems. Moreover, it enhances environmental beauty and visual aesthetics. It also strengthens social cohesion and place identity within communities by providing environmental awareness, recreation and cultural exchange. Additionally, green spaces improve people's sense of satisfaction and happiness and reduce stress.

The United Nations Conference on Sustainable Development (UNCSD), Organization for Economic Co-operation and Development (OECD), UK government sustainable development framework indicator (UKSDI) and Towards Sustainable Europe all use green space as an important indicator for evaluating the sustainable development (Liu and Shen, 2014). A city devoid of quantity and quality of urban green spaces (UGS) becomes a concrete jungle or a polluted city vulnerable to calamities, with low liveability index. UGS provide benefits to the city that helps mitigate these negative effects (Ridder et al., 2004), and are valuable amenity–recreation venues, wildlife refuge and essential liveable-city ingredients (Jim & Chen, 2003).

Sustainable development goals and cities

According to World Health Statistics 2016, achieving a sustainable and healthy future for all requires action on air pollution, which is a major cause of morbidity and mortality globally. The new Sustainable Development Goals (SDGs) provide a massive opportunity for addressing air pollution and the related burden of increased health risks and diseases. The list of targets related to health, air pollution and sustainability includes:

SDG target 3.9, which calls for a substantial reduction in deaths and illnesses from air pollution

SDG target 7.1, which aims to ensure access to clean energy in homes

SDG target 11.2, which aims to provide access to safe, affordable, accessible and sustainable transport systems for all

SDG target 11.6, which aims to reduce the environmental impact of cities by improving air quality

WHO is currently involved in the development and monitoring of the following SDG indicators: Air pollution-related mortality (SDG 3.9.1); Access to clean energy in homes (SDG 7.1.2) and air quality in cities (SDG 11.6.2) (World Health Statistics 2017).

More than half of the world's people now live in urban areas and the proportion will rise to two-thirds by 2050; the urban population will reach 6.4 billion people by 2050, driven by high rates of urbanisation and population growth (United Nations, 2014). Understanding how health is affected by urban environments is therefore of the upmost importance.

A growing body of evidence shows a relationship between urban green spaces and reductions in several diseases, as well as improving people's health and well-being, especially for low-income and deprived urban populations (Mitchell and Popham, 2008; Maas et al., 2009; Mitchell et al., 2015). Lower exposure to green space has been associated with a number of lifestyle diseases such as obesity, Type II diabetes, osteoporosis and stress-related illnesses such as depression, heart diseases and mental fatigue (Ulrich et al., 1991; Mitchell and Popham, 2008). Evidence also shows that access to green space can promote physiological effects such as lower concentrations of cortisol, lower pulse rate and blood pressure, greater parasympathetic nerve activity and lower sympathetic nerve activity compared to urban environments (Park et al., 2007, 2010; Lee et al., 2011; Song et al., 2016). These studies suggest that green space may offer opportunities to buffer or mitigate health outcomes for urban populations (WHO, 2017).

There is disparity in health expenditure worldwide. More than half of the population in the world does not have access to formal social protection schemes (WHO, 2010). In India, the disparity on health care cost and expenditure done by the state is pretty evident. The high cost of frequently prevalent diseases caused due to pollution has to be borne by the people. This increases their out-of-pocket expenditure. The heavy financial burden of diseases becomes unbearable for middle class and low economic class people. At times, people have to sell their property or land or precious belongings, take loans or even make compromises related to the health and survival of the sick or the elderly. Where cities face constant and frequent cases of air quality or lifestyle health challenges, special health insurance products need to be built for these areas to minimise the out-of-pocket expenditure of the people.

Therefore, an analysis of linkages between air pollution, green spaces and health care cost is of great importance. Our health depends on our environment and we cannot ignore the environment while focussing solely on rapid urbanisation or the growth of our economies.

The book presents the relationship between urban green spaces, air pollution and health. The first chapter of the book highlights the concept of urban green spaces and their significant role in cities. The next chapter discusses the green spaces present in Delhi from past to present. The third chapter gives an insight into the extent of air pollution in Delhi by highlighting various causes. Lack of green spaces and high pollution levels are linked to various health challenges. Chapter 4 discusses the extent of health challenges with the help of primary and secondary data. Chapters 5 and 6 talk about the health economics, out-of-pocket expenditure and financial burden on the city dwellers because of the persistent environmental challenges. Concluding chapter discusses various good practices followed by different countries. It also focuses on the present policies and scope of such good practices in Delhi.

Research methodology and data analysis

The study covered in this book is based on both primary and secondary sources of data. The secondary sources include published reports of the World Health Organization (WHO), Census of India, Central Pollution Control Board (CPCB), Planning Commission of India, and National Health Estimates. The study also takes into consideration the data and papers published in renowned national and international journals and newspapers. The book incorporates the mapping of green spaces using Global Positioning System (GPS), satellite images and Geographic Information System (GIS).

To identify the green spaces, the study uses satellite images of Landsat (Landsat 7, October 2002 and Landsat 8, April 2016). Landsat 7 (2002) and Landsat 8 data (2016) with 30 metres of spatial resolution were taken into consideration. Landsat 7 bands: are Band 1 (Blue), Band 2 (Green), Band 3 (Red), Band 4 (NIR). Landsat 8 bands are Band 2 (Blue), Band 3 (Green), Band 4 (Red), Band 5 (NIR), Band 6 and Band 7, to make the bands composite. After getting the images geo-registered, a supervised classification technique was performed. After the Land Use and Land Cover (LULC) map preparation, Normalised Difference Vegetation Index (NDVI) was also calculated to understand the density of greenness. From the LULC map, the vegetation class was derived, coupled with Agricultural class and Park class. For validating the vegetation class, NDVI calculation was conducted, because NDVI is the most generalised index of plant 'greenness'. Hence, the output maps show the classes of vegetation, agriculture and parks for the years 2002 and 2015. A land use and NDVI map of 2016 was also prepared.

The study uses maps to show the variation in temperature and pollution level at different locations of Delhi. Besides maps, the study uses descriptive analysis by using relevant statistical diagrams like bar diagrams, pie diagrams and trend lines to represent the data.

The spatial analysis of temperature variation and air pollutants (mainly PM_{2.5}, PM₁₀ and CO₂) was done on the basis of data collected through manual air quality monitor (AQM). Data were collected at 35 different locations of the city. The sample was thus determined by keeping in view various sectors and green and non-green spaces of Delhi. Care was taken to identify the 35 locations in such a way that they covered various categories of land use like residential, commercial, market, traffic junctions, water bodies, and semi-natural areas like forest or ridge. The GPS instrument was also used in order to acquire the absolute location (cardinal points). Data were collected twice in the month of June, between 10th and 15th, 2016 (11:00 am to 3:00 pm). Data (temperature, PM_{2.5}, PM₁₀ and CO₂) were recorded at 35 selected locations and then mapped to check the relevant role of green spaces and type of economic activities in the extent of pollution. Data were also collected for temperature and relative humidity