state of environment report West Bengal

2016

West Bengal
Pollution Control Board

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The report has been prepared based on the information as available from various sources up to December 31, 2016. Subsequently Kalimpong, Jhargram and Paschim Barddhaman emerged as new districts.

Spellings of the districts have been used in accordance with the Administrative Atlas of India: Census of India 2011

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সত্যমেব জয়তে

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দমকল ও জরুরী পরিষেবা দপ্তর,
পরিবেশ দপ্তর ও অ..াবাসন দপ্তর
পশ্চিমবঙ্গ সরকার
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মহানাগরিক
কলকাতা পৌরসংস্থা

FOREWORD

It gives me great pleasure to learn that the West Bengal Pollution Control Board is bringing out the State of Environment Report of West Bengal 2016. During the last five years, the environmental conditions of the State have improved considerably through the untiring efforts and strict vigilance of the State Government and the support and cooperation of people across the State. Publication of this comprehensive report will contribute to promoting environmentally sustainable development of the State by raising awareness about the environment and helping policy makers in taking decisions that are environment friendly.

I congratulate the West Bengal Pollution Control Board in taking up this initiative. I hope the report will be widely circulated and will be of use to decision makers, researchers, students and the general public.

(Sovan Chatterjee)

Kolkata, May 16.5.2017

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PREFACE

The State of Environment Report–West Bengal (2016) provides a complete overview of the environmental scenario in West Bengal. It aims to serve as a reference document that will help environmental decision making while also providing useful information to researchers, non-governmental organisations and all those interested in the current state of our environment. The report covers key environmental issues that include land use, agriculture, forestry, biodiversity, industrial pollution, waste management, air quality and climate change.

I compliment the WBPCB for bringing out this report. I am confident that the information presented in this report will facilitate various stakeholders in taking informed decisions which will result in sustainable management of the State's environment and natural resources.

Kolkata, May 19, 2017

Arnab Roy

Acknowledgement

The state of West Bengal has been endowed with vast and rich environmental resources. The State offers wide topographic variety, large river network, dense forest areas, rich heritage of biodiversity and mineral resources. Protection of the environment and natural resource management has always been the major priorities of the State. During last six decades, growth of population has not only increased the density in this State but also put enormous pressure on its natural resources. Over exploitation of natural resources has been threatening the State's soil quality, water reserve, rich biodiversity and also the ambient conditions. Besides, increment in population density is also causing rapid urbanisation, obviously compromising environmental issues, resulting in creation of heat islands, change in rainfall pattern, water scarcity and pollution. The Department of Environment, Government of West Bengal and the West Bengal Pollution Control Board are relentlessly working to protect and safeguard the environmental condition of the State with active support from the line departments of the State Government, NGOs and various other stakeholders.

In order to facilitate environmental planning and policy formulation, a need was felt for a document that will provide all relevant information about the current state of our environment. It is with this objective that the West Bengal Pollution Control Board decided to prepare the State of Environment Report-West Bengal (2016) incorporating almost all related aspects of environment. There are twenty chapters in this report starting with West Bengal at a glance followed by demography, land and land use, soil, agriculture, forest and wild life, biodiversity, water resource, groundwater, wetlands and mineral resource of the State. The Report also covers major environmental challenges like climate change, industrial pollution management, solid waste management, bio-medical waste management, electronic waste management and urban waste water management. The major environmental regulations and salient orders of the Courts are also dealt in a separate chapter.

The task of preparation of State of Environment Report was taken up in early 2016. Although the change in district administrative boundaries in the State till 2016 viz., creation of Alipurduar district, have been considered while preparing the report, subsequent changes in the year 2017 could not be included at present.

Preparation of this Report could not have been possible without the active contribution of some eminent experts in respective fields who wrote the individual chapters and guided us throughout the process. I acknowledge the contribution of Shri Amarnath Goswami, Prof. Arunabha Majumder, Smt. Barna Majumdar, Shri Biswajit Mukherjee, Shri Bosista Kumar Sengupta, Shri Debanjan Gupta, Prof. Debasis Sengupta, Dr. Dipanjana Maulik, Shri Girija Sankar Chattopadhyay, Prof. Koushik Brahmachari, Prof. Nishith Kumar Pal, Prof. Pradip K. Sikdar, Prof. Rabindranath Majumdar, Shri Rohit Tiwari, IFS, Prof. Sampa Chakraborty, Smt. Sarmistha Kundu, Prof. Silanjan Bhattacharyya, Dr. Sharadindra Chakrabarti, Dr. Smarajit Jana, Dr. Subir Kumar Ghosh, Dr. Subrat Mukherjee, IFS, Shri Subrata Ghosh, Shri Sujit Choudhury, Shri Sujit Kumar Bhattacharya, Prof. Susanta Kumar Pal, Prof. Susmita Bhattacharya, Dr. Tapas Kumar Gupta and Dr. Ujjal Kumar Mukhopadhyay.

I also acknowledge contribution of Prof. Biswajit Ghosh, Energy Science and Technology, Jadavpur University, Kolkata; Shri Romit Mutsuddi, Advisor and Director, West Bengal Mineral Development and Trading Corporation Ltd., Kolkata; and Dr. Saktipada Gon Chaudhuri, Former Managing Director, West Bengal Green Energy Development Corporation Ltd. who provided important information required during preparation of this Report.

I would also like to thank Dr. Dhrubajyoti Ghosh, Dr. Ashok Kanti Sanyal and Prof. Sumana Bandyopadhyay for their help in reviewing the manuscripts.

The untiring efforts of Prof. Rabindranath Majumdar, Prof. Sampa Chakraborty and Prof. Debashis Gangopadhyay, in guiding the State Board from the initiation of this report till its completion are greatly acknowledged.

The sincere efforts of Dr. Ujjal Kumar Mukhopadhyay, Chief Scientist and Shri Debanjan Gupta, Senior Scientist of West Bengal Pollution Control Board, who have steered the entire project and also designed and prepared this report, are commendable.

Kalyan Rudra

Dr. Kalyan Rudra
Chairman
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Abbreviations and Units

Abbreviations

ABS	Access and Benefit Sharing
ADB	Asian Development Bank
ADDA	Asansol Durgapur Development Authority
AER	Agro-Ecological Regions
AESR	Agro-Ecological Sub-Regions
AETC	Auto Emission Testing Centre
AEZ	Agri-Exports Zones
AI	Artificial Insemination
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
A&OE	Administrative & Office Expenses
APCS	Air Pollution Control System
APEDA	Agricultural and Processed Food Products Export Development Authority
APMC	Agricultural Produce Market Committee
AQ	Abandoned Quarries
ARI	Acute Respiratory Infection
As	Arsenic
BaP	Benzo(a)Pyrene
BDA	Barddhaman Development Authority
BFR	Brominated Flame Retardant
bgl	Below ground level
BGREI	Bringing Green Revolution in Eastern India
BKTPP	Bakreswar Thermal Power Plant
BMC	Biodiversity Management Committee
BMW	Bio-medical Waste
BOD	Biochemical Oxygen Demand
BP	Before Paleosol
BPL	Below Poverty Line
BRGF	Backward Regions Grant Fund
BSI	Botanical Survey of India
BUR	Biennial Update Report
C_6H_6	Benzene
CAGR	Compound Annual Growth Rate
CBD	Convention on Biological Diversity
CBM	Coal Bed Methane
CBMWTF	Common Bio-medical Waste Treatment Facility
CCARI	Climate Change Adaptation in Rural India
CCIMS	Climate Change Information Management System
CDC	Centre for Disease Control
CEPI	Critical Environmental Pollution Index
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CETP	Common Effluent Treatment Plant
CFC	Chloro-Fluoro Carbon
CFE	Consent for Establishment
CFO	Consent for Operation
CGWB	Central Ground Water Board
CHWTSDF	Common Hazardous Waste Treatment, Storage and Disposal Facility
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
C/N	Carbon/Nitrogen
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COM	Cut-off Meander
CPA	Critically Polluted Areas
CPCB	Central Pollution Control Board
CRT	Cathode Ray Tube
CSR	Corporate Social Responsibility
CSS	Central Sector Scheme
C–Tech	Cyclic Activated Sludge Process
CVD	Cardiovascular disease
CW	Constructed Wetlands
CWC	Central Warehousing Corporation
CWMS	Centralized Wastewater Management System
DDT	Dichlorodiphenyltrichloroethane
DDUGJY)	Deen Dayal Upadhyaya Gram Jyoti Yojana
DFID	Department for International Development
DG	Diesel Generator
DISHA	Society for Direct Initiative for Social and Health Action
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
DoEn	Department of Environment
DoF	Department of Forest
DPR	Detailed Project Report
DPSCL	Dishergarh Power Supply Company Ltd.
DPSIR	Driving Force–Pressure–Status–Impacts–Response
DRCSC	Development Research Communication and Service Centre
DSDA	Digha Sankarpur Development Authority
DVC	Damodar Valley Corporation

DVD	Digital Versatile Disc
DWMS	Decentralized Wastewater Management System
EDC	Eco Development Committees
EIA	Environmental Impact Assessment
EKW	East Kolkata Wetlands
EMIS	Environment Management Information System
ENVIS	Environmental Information System
EoDB	Ease of Doing Business
EPA	Environment Protection Agency
EPR	Extended Producer Responsibility
ETP	Effluent Treatment Plant
E-W	East-West
F	Fluorine
FAB	Fluidized Aerobic Bed
FAO	Food and Agriculture Organization
FCC	Fecal Coliform Count
FCI	Food Corporation of India
Fe	Ferrum (Iron)
FMCG	Fast Moving Consumer Goods
FPC	Forest Protection Committees
FRLHT	Foundation for Revitalization of Local Health Traditions, Bengaluru
GAP	Ganga Action Plan
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEC-97	Ground Water Estimation Committee-1997
GHG	Green House Gas
GI	Geographical Indication
GIS	Geographical Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit, GmbH
GM	Genetically Modified
GoWB	Government of West Bengal
GoI	Government of India
GPI	Grossly Polluting Industries
GSDP	Gross State Domestic Product
GWP	Global Warming Potential
HAI	Hospital Associated Infection
HCU	Health Care Unit
HDA	Haldia Development Authority
HDI	Human Development Index
Hg	Hydrargyrum (Mercury)
HMA	Haldia Municipality Area
HMC	Howrah Municipal Corporation
HRD	Human Resource Development
HWDI	Heat Wave Duration Index
HYV	High Yielding Variety
IARC	International Agency for Research on Cancer
IAS	Invasive Alien Species
ICAR	Indian Council of Agricultural Research
ICC	Indian Chamber of Commerce
ICEF	India-Canada Environment Facility
ICT	Information and Communication Technology
IEC	Information-Education-Communication
IESWM	Institute of Environmental Studies and Wetland Management, Kolkata
IISER	Indian Institute of Science Education and Research, Kolkata
IITB	Indian Institute Technology, Bombay
IMD	Indian Meteorological Department
IMMW	Inland Man-made Wetlands
INCCA	Indian Network on Climate Change Assessment
IRDP	Integrated Rural Development Programme
IRGSSA	IRG Systems South Asia Private Limited
IRRI	International Rice Research Institute, Philippines
IRS	Indian Remote Sensing
ISOPOM	Integrated Scheme of Oilseed, Pulses, Oil Palm and Maize
IT	Information Technology
ITeS	IT enabled services
ITIS	Interagency Taxonomic Information System
ITK	Indigenous Technological Knowledge
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JFM	Joint Forest Management
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
JPOA	Joint Plan of Action
K	Kalium (Potassium)
KAP	Knowledge-Attitude-Practice
KEIIP	Kolkata Environmental Improvement Investment Programme
KMA	Kolkata Metropolitan Area
KMC	Kolkata Municipal Corporation
KMDA	Kolkata Metropolitan Development Authority
KMW&SA	Kolkata Metropolitan Water and Sanitation Authority
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LEL	Lower Explosive Limit
LGMP	Last Glacial Maximum Palaeosol
LGP	Length of Growing Period
LISS	Linear Imaging and Self Scanning Sensors
LUDCP	Land Use and Development Control Plan
MAB	Man and Biosphere
MBR	Membrane Bio Reactor
MBBR	Moving Bed Bio Film Reactor
MMWL	Man-made Water Logged
Mn	Manganese
MoEF	Ministry of Environment and Forests
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoFPI	Ministry of Food Processing Industries
MPCA	Medicinal Plants Conservation Area
MPCE	Monthly Per Capita Expenditure
msl	Mean Sea Level

MSMEs	Micro, Small and Medium Enterprises
MSP	Minimum Support Price
MSW	Municipal Solid Waste
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NAFCC	National Adaptation Fund Climate Change
NAPCC	National Action Plan on Climate Change
NASA	National Aeronautics and Space Administration
NATCOM	National Communication
NB	North Bengal
NC	Non-Compliance
NDITA	Naba Diganta Industrial Township Authority
NDOP	National Oilseed Development Project
NE-SW	North East-South West
NFSM	National Food Security Mission
NGO	Non-Government Organisation
NGT	National Green Tribunal
NH_3	Ammonia
Ni	Nickel
NIMZ	National Industrial Manufacturing Zones NMPB National Medicinal Plants Boards
NMSHE	National Mission for Sustaining Himalayan Ecosystem
NMW	National Water Mission
NO_2	Nitrogen Dioxide
NP	National Park
NPCB	National Project for Cattle and Buffalo Breeding
NPV	Nuclear Polyhedrosis Virus
NRCA	National River Conservation Authority
NREGS	National Rural Employment Guarantee Scheme
NRSC	National Remote Sensing Centre
N-S	North-South
NSDP	Net State Domestic Product
NSSO	National Sample Survey Organization
NTFP	Non-timber Forest Products
NTPC	National Thermal Power Corporation
NVBDCP	National Vector Borne Disease Control Programme
NW	National Waterway
NWMP	National Water Monitoring Programme
O_3	Ozone
ODF	Open Defecation Free
OL	Oxbow Lakes
O&M	Operation and Maintenance
OPP	Oilseed Production Programme
OPTP	Oilseed Production Thrust Programme
P	Phosphorus
P_2O_5	Phosphorus Pentoxide
Pb	Lead
PBB	Polybrominated Biphenyl
PBR	People's Biodiversity Register
PC	Personal Computer
PCB	Pollution Control Board
PCBs	Polychlorinated Biphenyls
PCC	Pollution Control Committee
PET	Potential Evapotranspiration
PHED	Public Health Engineering Department
PIC	Prior Informed Consent
PIL	Public Interest Litigation
PM2.5	Particulate Matter (size less than 2.5 μm)
PM10	Particulate Matter (size less than 10 μm)
PPC	Plant Protection Chemical
PPE	Plant Protection Equipment
PPP	Public Private Partnerships
PRECIS	Providing Regional Climate for Impact Studies
PSB	Phosphate Solubilizing Bacteria
PUC	Pollution Under Control
PVC	Polyvinyl Chloride
REE	Rare Earth Element
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RKVY	Rashtriya Krishi Vikash Yojana
RTA	Rapid Threat Assessment
RWH	Rain Water Harvesting
SAPCC	State Action Plan on Climate Change
SBM	Swachh Bharat Mission
SBR	Sequencing Batch Reactor
SBR	Sundarban Biosphere Reserve
SEIAA	State Environment Impact Assessment Authority
SEZ	Special Economic Zone
SHG	Self Help Group
SIFC	State Investment Facilitation Centre
SJDA	Siliguri-Jalpaiguri Development Authority
SLF	Sanitary Land Fill
SO_2	Sulfur Dioxide
SPCB	State Pollution Control Board
SPI	Seriously Polluting Industries
STP	Sewage Treatment Plant
STR	Sundarban Tiger Reserve
SWAT	Soil and Water Assessment Tool
SWID	State Water Investigation Department
SWM	Solid Waste Management
SWRE	School of Water Resource Engineering
TCC	Total Coliform Count
TCP	Traditional Commercial Practices
TGA	Total Geographical Area
TSS	Total Suspended Solid
TV	Television
UIDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
ULBs	Urban Local Bodies
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

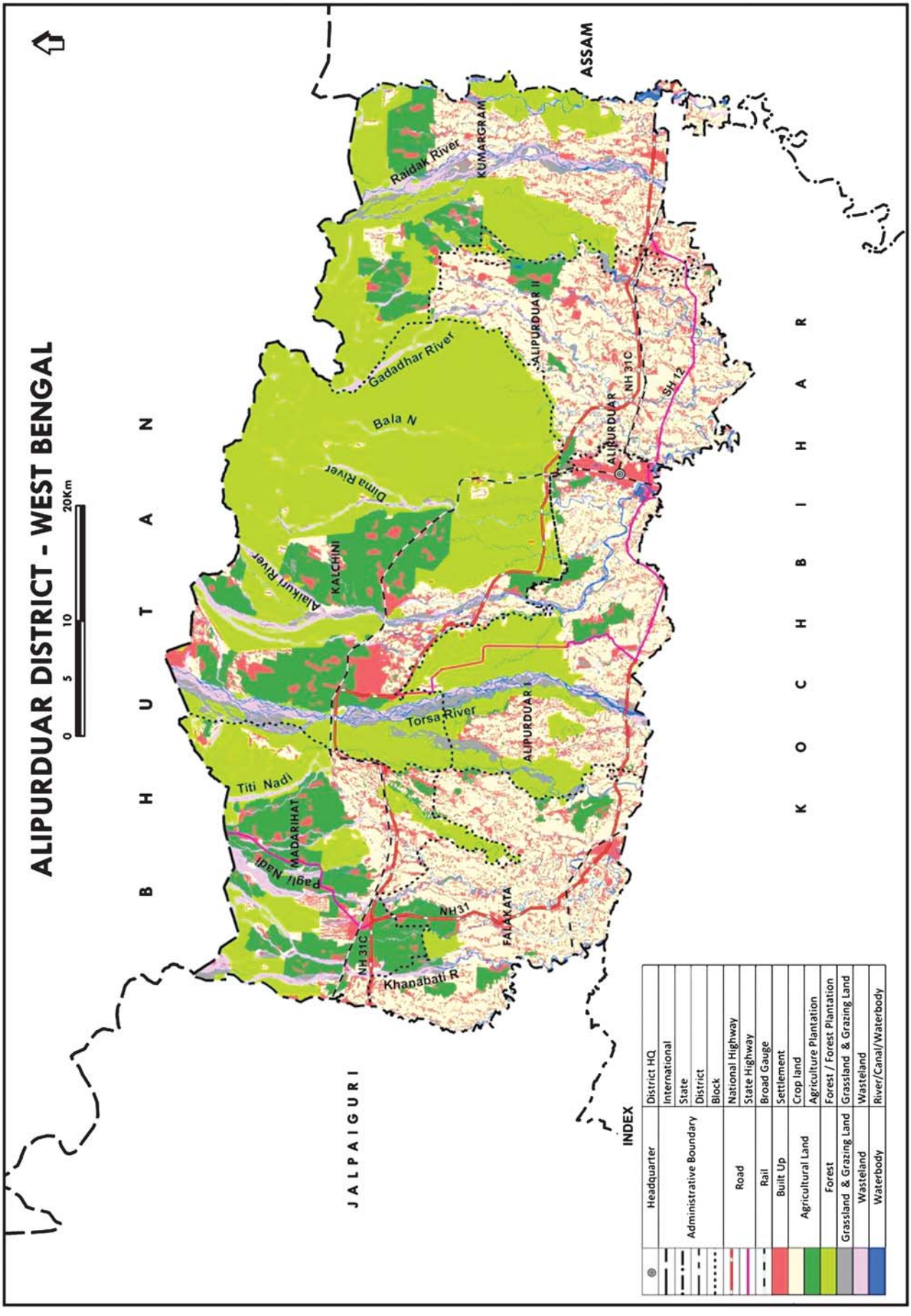
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UASB	Up-Flow Anaerobic Sludge Blanket Process
VRP	Varietal Replacement Programme
WB	West Bengal
WBBB	West Bengal Biodiversity Board
WBFD	West Bengal Forest Department
WBGEDCL	West Bengal Green Energy Development Corporation Ltd.
WBIDC	West Bengal Industrial Development Corporation Ltd.
WBMD&TC	West Bengal Mineral Development and Trading Corporation Ltd.
WBPCB	West Bengal Pollution Control Board
WBPDCL	West Bengal Power Development Corporation Ltd.
WBSEDCL	West Bengal State Electricity Distribution Company Limited
WBUA&FS	West Bengal University of Animal and Fishery Science
WBREDA	West Bengal Renewable Energy Development Agency
WHO	World Health Organisation
WLS	Wild Life Sanctuary
WLW	Wild Life Wing
WPA	The Indian Wildlife (Protection) Act, 1972
WSWL	Wetlands Seasonal Waterlogged
WWF	World Wide Fund for Nature
WWF-ER	World Wide Fund for Nature, Easter Region
ZLD	Zero Liquid Discharge
ZSI	Zoological Survey of India

Units

bcm	Billion cubic metre
cm	Centimetre
cumec	Cubic metre per second
cusec	Cubic feet per second
Gg	Giga gram = 109 gram
$GgCO_2$	Giga gram Carbon Dioxide
g	gram
ha	Hectare
kcal/kg	Kilo calorie per kilogram
kg/cap/day	Kilogram per capita per day
kg/ha	Kilogram per hectare
kg/ha/yr	Kilogram per hectare per year
kg/m^3	Kilogram per cubic metre
KLD	Kilo litres per day
km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometre
Kmph	Kilometre per hour
m^3	Cubic metre
mcm	Million cubic metre
m/day	Metre per day
m^2/day	Square metre per day
m^3/hr	Cubic metre per hour
mg/l	Milligram per litre
m.ha.m.	Million hectare metre
mcm	Million cubic metre
mg/kg	Milligram per kilogram
mg/l	Milligram per litre
m ha	Million hectare
MKWH	Million kilo watt hour
MLD	Million litres per day
mm	Milimetre
mm/year	Milimetre per year
MPN	Most Probable Number
MT	Metric Ton
MTA	Metric Ton per annum
MT/day	Metric Ton per day
MW	Mega Watt
µg/g	Microgram per gram
µg/l	Microgram per litre
$\mu g/m^3$	Microgram per cubic meter
sq km	Square kilometer
t	Ton
t/ha	Ton per hectare
ton/ha/yr	Ton per hectare per year
TPA	Ton per annum
TPD	Ton per day

District Maps of West Bengal

(As on December 31, 2016)


ALIPURDUAR DISTRICT - WEST BENGAL
0 5 10 20Km
B H U T A N
ASSAM
K O C H B I H A R
J A L P A I G U R I
Raidak River
KUMARGRAM
Gadadhar River
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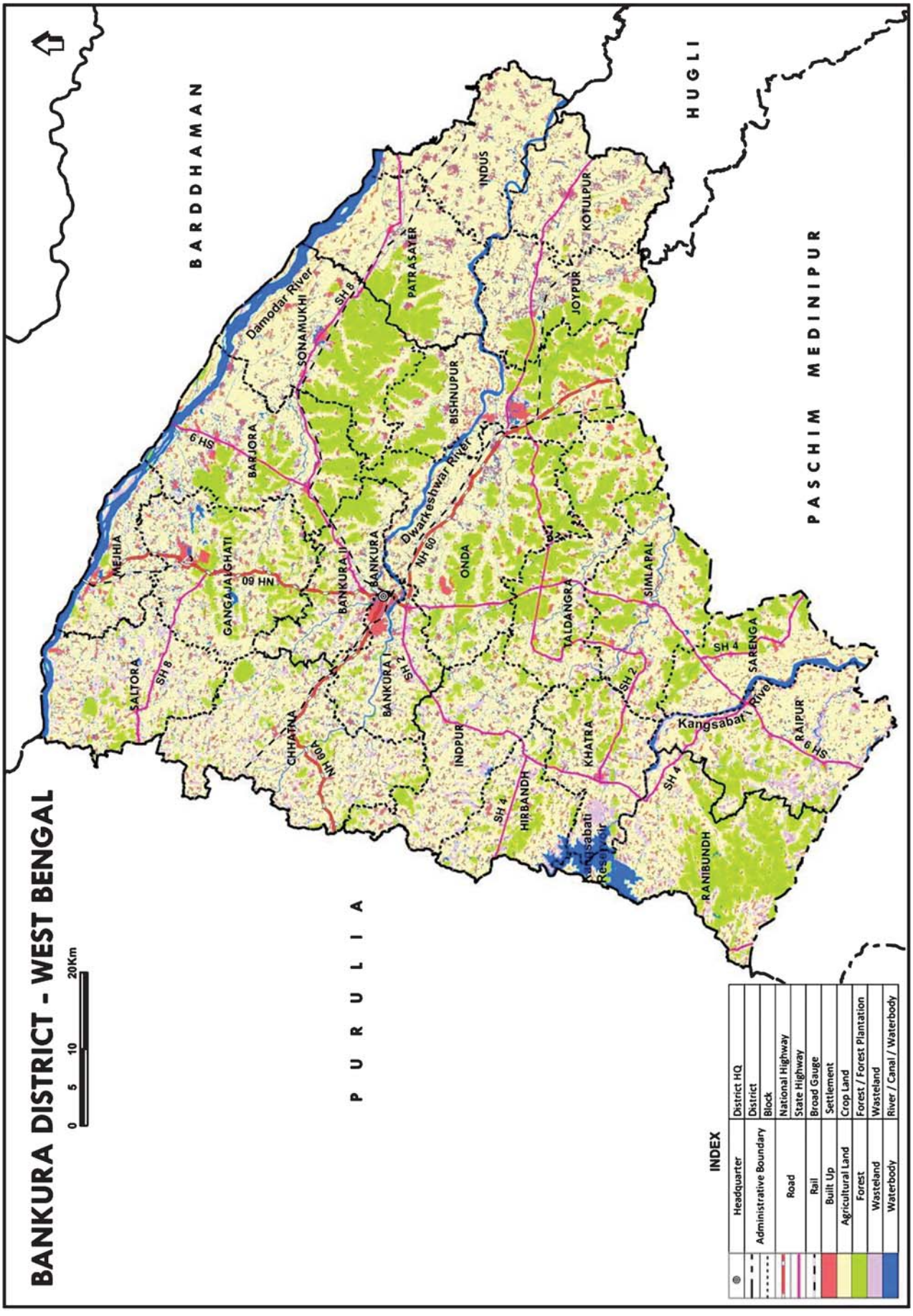
Administrative Boundary
International
State
District
Block
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop land
Agriculture Plantation
Forest
Forest / Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/Canal/Waterbody


BANKURA DISTRICT - WEST BENGAL
0 5 10 20Km
BARDDHAMAN
HUGLI
PASCHIM MEDINIPUR
PURULIA
MEJHIA
SALTORA
GANGAJALGHATI
BARJORA
SONAMUKHI
Damodar River
CHHATNA
BANKURA II
BANKURA
BANKURA I
Dwarkeshwar River
BISHNUPUR
PATRASAYER
INDUS
KOTULPUR
JOYPUR
ONDA
INDPUR
HIRBANDH
TALDANGRA
KHATRA
SIMLAPAL
SARENGA
RAIPUR
Kangsabati River
Kangsabati Reservoir
RANIBUNDH
6 HS
SH 8
SH 2
SH 4
NH 60
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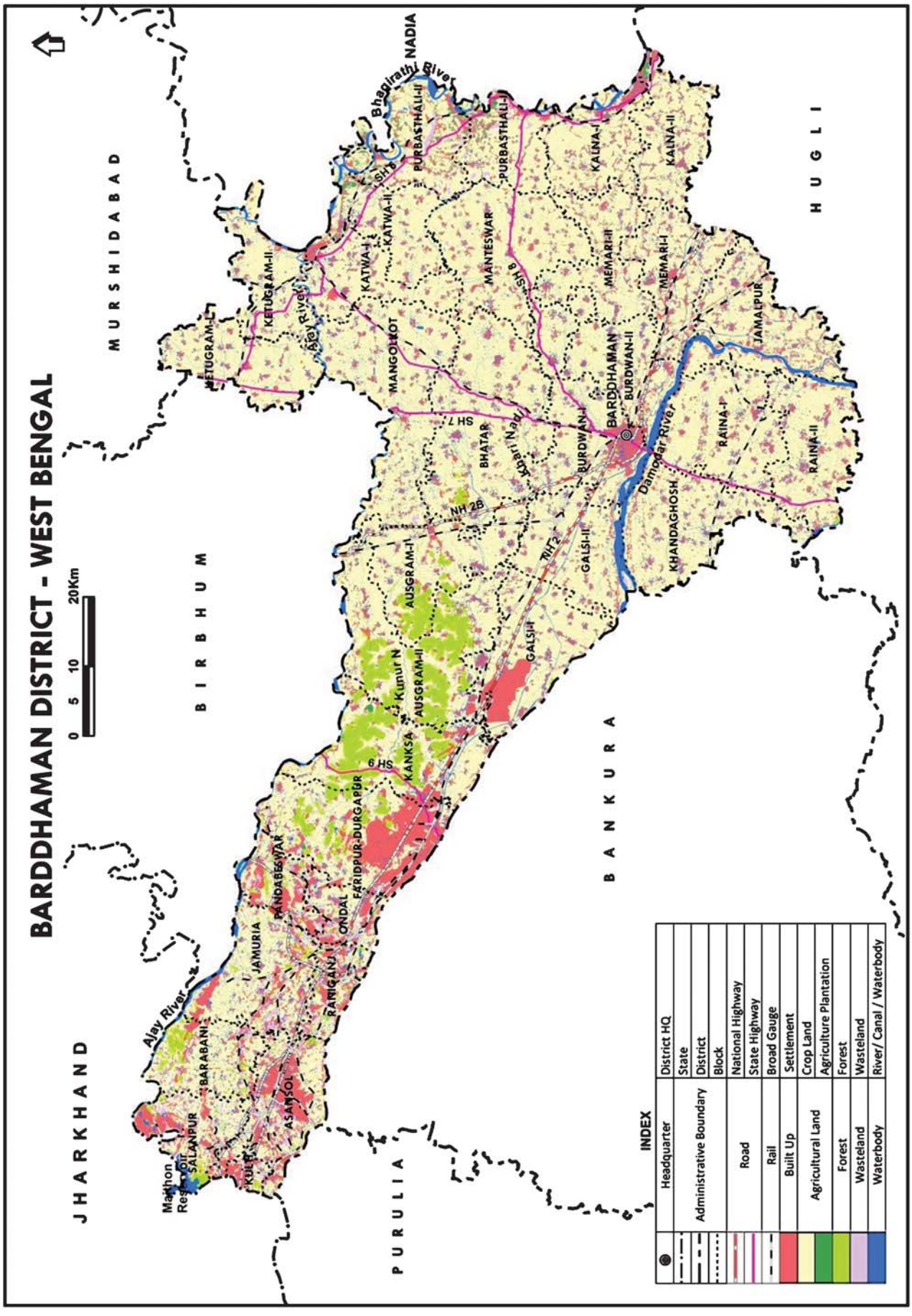
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Forest
Forest / Forest Plantation
Wasteland
Waterbody
River / Canal / Waterbody


BARDDHAMAN DISTRICT - WEST BENGAL
0 5 10 20Km
MURSHIDABAD
BIRBHUM
BANKURA
HUGLI
PURULIA
JHARKHAND
NADIA
Bhagirathi River
Ajay River
Damodar River
Kunur N
Khari Nadi
Maithon Reservoir
BARDDHAMAN
BURDWAN-I
BURDWAN-II
KETUGRAM-I
KETUGRAM-II
KATWA-I
KATWA-II
MANGOLKOT
PURBASTHALI-I
PURBASTHALI-II
MANTESWAR
KALNA-I
KALNA-II
MEMARI-I
MEMARI-II
JAMALPUR
RAINA-I
RAINA-II
KHANDAGHOSH
BHATAR
GALSI-I
GALSI-II
AUSGRAM-I
AUSGRAM-II
KANKSA
FARIDPUR-DURGAPUR
ONDAL
RANIGANJ
PANDABESWAR
JAMURIA
ASANSOL
KULTI
SALANPUR
BARABANI
SH 6
SH 7
NH 2B
NH 2
6 HS
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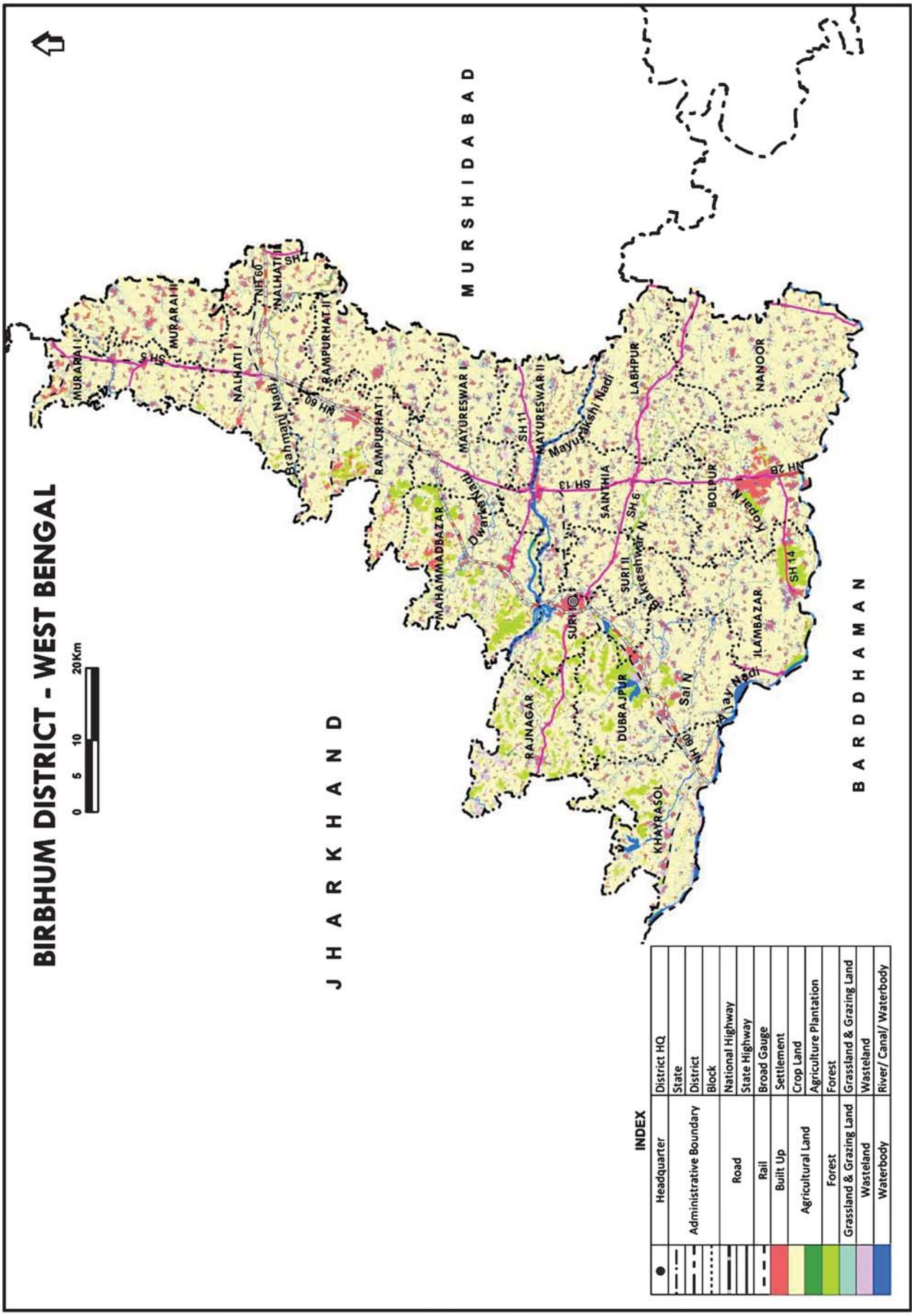
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest
Wasteland
Wasteland
Waterbody
River/ Canal / Waterbody


BIRBHUM DISTRICT - WEST BENGAL
0 5 10 20Km
MURSHIDABAD
JHARKHAND
BARDDHAMAN
MURARAI I
MURARAI II
NALHATI I
NALHATI II
RAMPURHAT I
RAMPURHAT II
MAYURESWAR I
MAYURESWAR II
MAHAMMADBAZAR
SURI I
SURI II
SAINTHIA
LABHPUR
BOLPUR
NANOOR
ILAMBAZAR
RAJNAGAR
DUBRAJPUR
KHAYRASOL
Brahmani Nadi
Mayurakshi Nadi
Dwarkeshwar N
Tarakeshwar N
Sai N
Ajay Nadi
Kopai N
NH 60
NH 28
SH 5
SH 7
SH 11
SH 13
SH 6
SH 14
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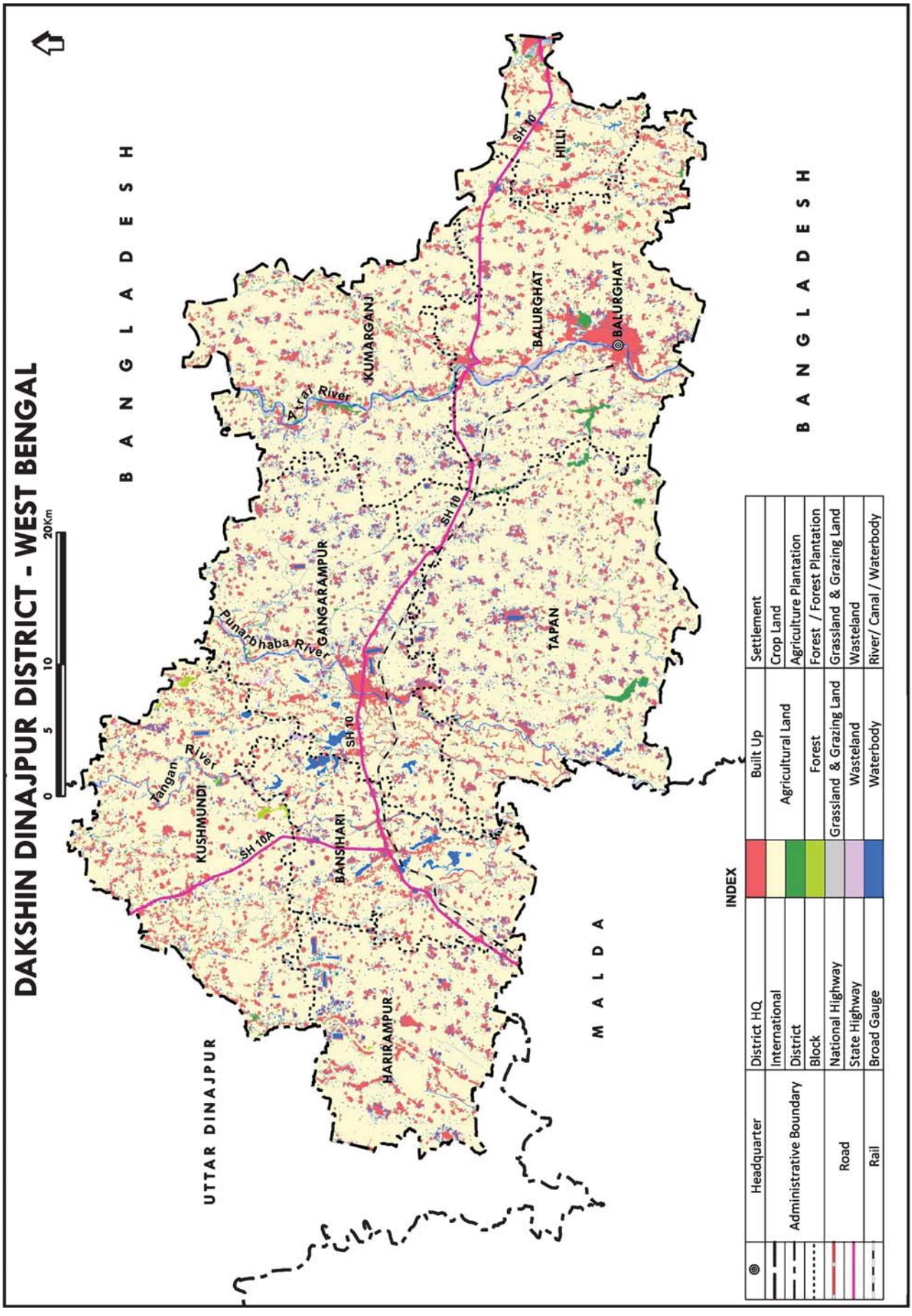
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal/ Waterbody


DAKSHIN DINAJPUR DISTRICT - WEST BENGAL
0 5 10 20Km
BANGLADESH
UTTAR DINAJPUR
MALDA
BANGLADESH
KUMARGANJ
BALURGHAT
HILLI
TAPAN
GANGARAMPUR
BANSHARI
HARIRAMPUR
KUSHMUNDI
Tangan River
Punarbhaba River
Atrai River
SH 10
SH 10A
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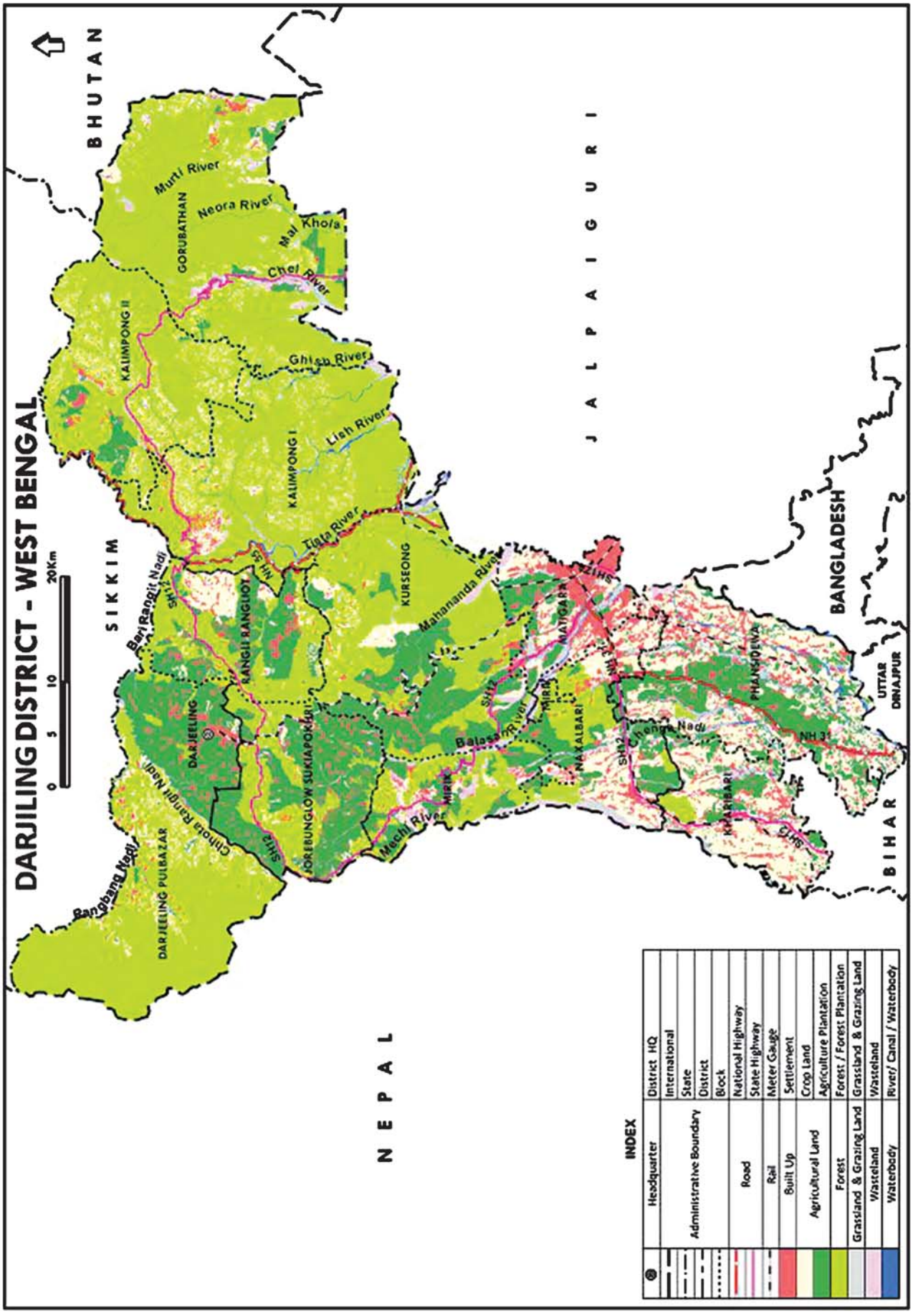
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest / Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal / Waterbody


DARJILING DISTRICT - WEST BENGAL
BHUTAN
SIKKIM
NEPAL
BANGLADESH
BIHAR
JALPAIGURI
UTTAR DINAJPUR
0 5 10 20Km
Murti River
Neora River
Mal Khola
Chel River
Ghish River
Lish River
Tista River
Mahananda River
Balasan River
Mechi River
Chenga Nadi
Bari Rangit Nadi
Chhota Rangit Nadi
Rangbang Nadi
GORUBATHAN
KALIMPONG II
KALIMPONG I
KURSEONG
RANGLI RANGLIOT
DARJEELING
DARJEELING PULBAZAR
JOREBUNGLOW SUKIAPOKHRI
MIRIK
NAXALBARI
MATIGARA
PHANSIDEWA
KHARIBARI
NH 31
NH 55
SH 12
SH 2
SH 13
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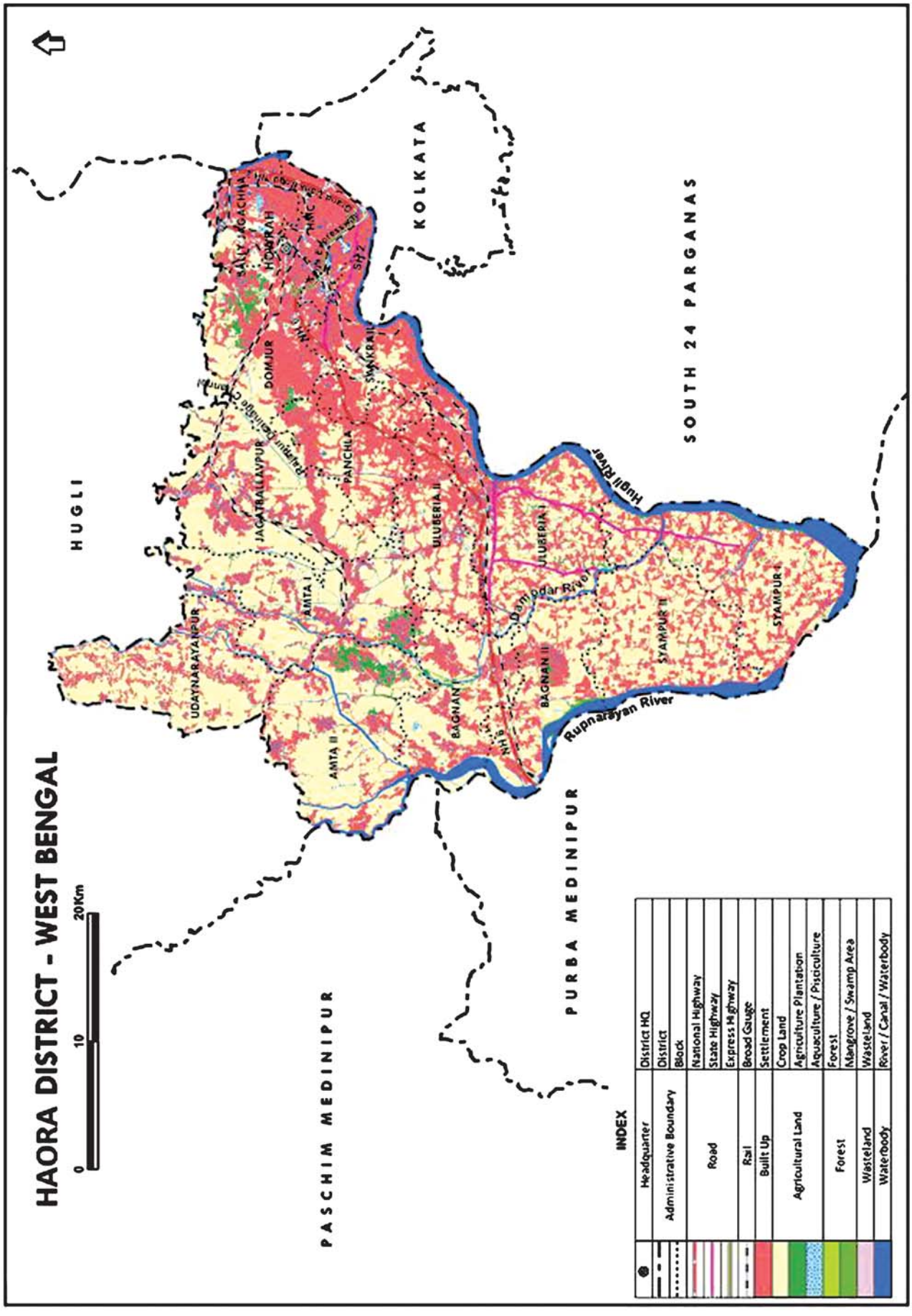
Block
Road
National Highway
State Highway
Rail
Meter Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest / Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal / Waterbody


HAORA DISTRICT - WEST BENGAL
0
10
20Km
HUGLI
KOLKATA
SOUTH 24 PARGANAS
PASCHIM MEDINIPUR
PURBA MEDINIPUR
SALKIA
JAGACHHA
HOWRAH
DOMJUR
SANKRAIL
JAGATBALLAVPUR
PANCHLA
ULUBERIA II
ULUBERIA I
AMTA I
AMTA II
UDAYNARAYANPUR
BAGNAN
BAGNAN II
SYAMPUR II
SYAMPUR I
Hugli River
Damodar River
Rupnarayan River
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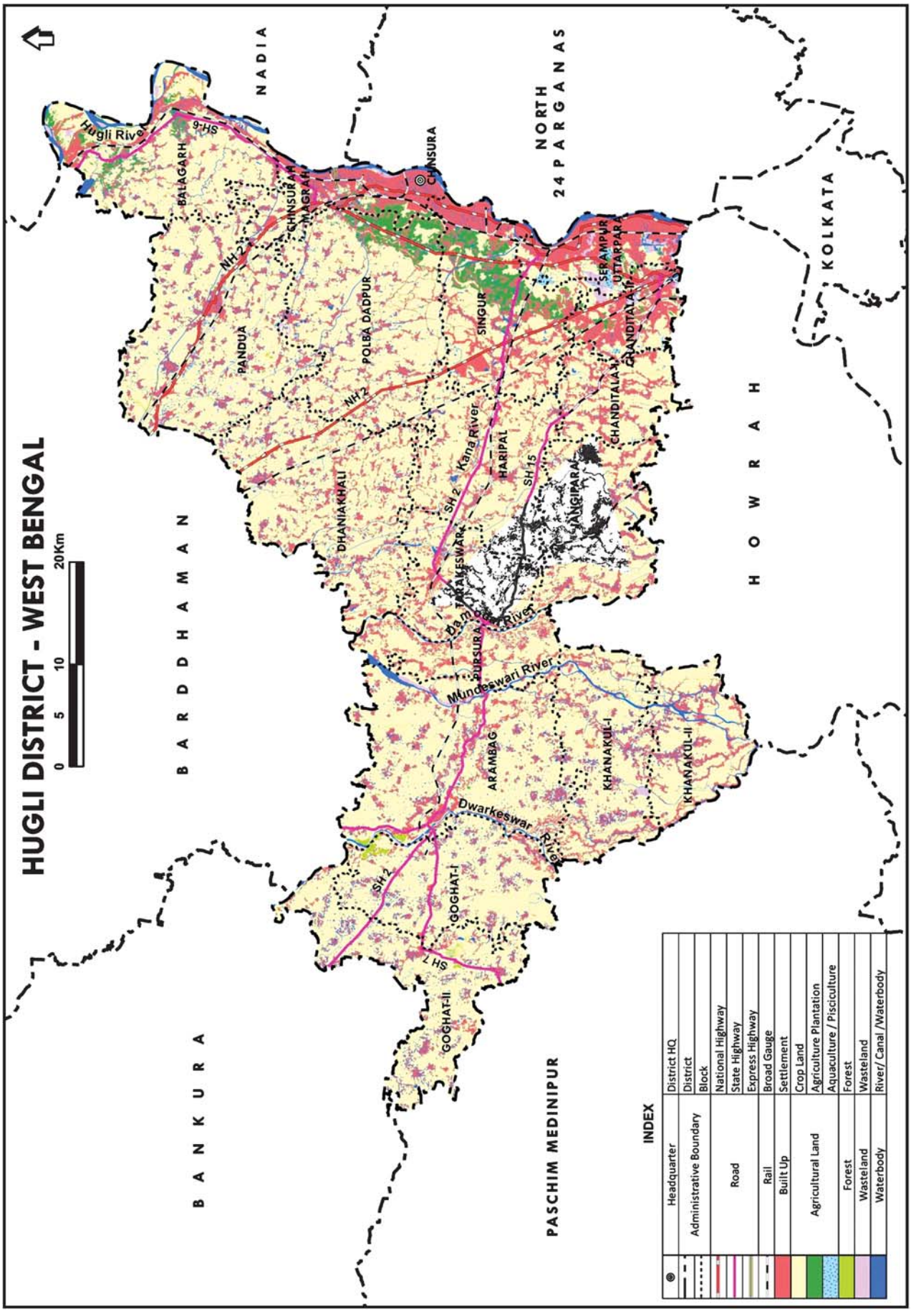
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest
Mangrove / Swamp Area
Wasteland
Wasteland
Waterbody
River / Canal / Waterbody


HUGLI DISTRICT - WEST BENGAL
0 5 10 20Km
NADIA
NORTH 24 PARGANAS
KOLKATA
HOWRAH
BARDDHAMAN
BANKURA
PASCHIM MEDINIPUR
Hugli River
SH-6
BALAGARH
KHINSURA
MAGRAH
CHINSURA
NH 2
PANDUA
POLBA DADPUR
SINGUR
SERAMPUR
UTTARPARA
CHANDITALA-II
CHANDITALA-I
DHANIAKHALI
Kana River
HARIPAL
SH 2
SH 15
TARAKESWAR
JANGIPARA
Damodar River
PURSURA
Mundeswari River
ARAMBAG
KHANAKUL-I
KHANAKUL-II
Dwarkeswar River
GOGHAT-I
GOGHAT-II
SH 7
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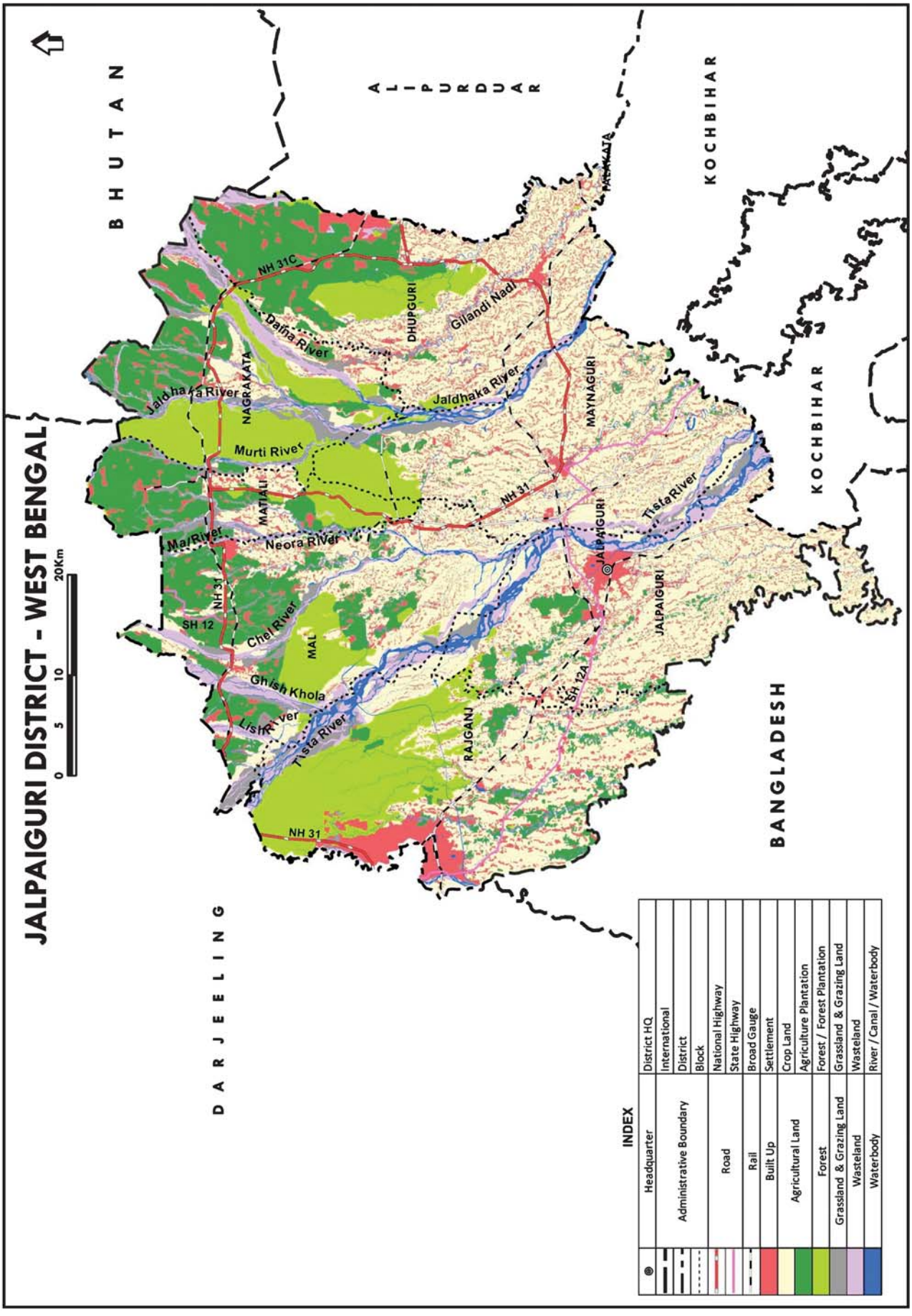
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest
Wasteland
Wasteland
Waterbody
River/ Canal /Waterbody


JALPAIGURI DISTRICT - WEST BENGAL
BHUTAN
ALIPURDUAR
KOCHBIHAR
KOCHBIHAR
BANGLADESH
DARJEELING
NH 31C
Daina River
DHUPGURI
Gilandi Nadi
Jaldhaka River
NAGRAKATA
Jaldhaka River
Murti River
MATIALI
MAYNAGURI
NH 31
Tista River
JALPAIGURI
JALPAIGURI
Ma River
Neora River
NH 31
SH 12
Chel River
MAL
Ghish Khola
Lish River
Tista River
RAJGANJ
SH 12A
NH 31
0 5 10 20Km
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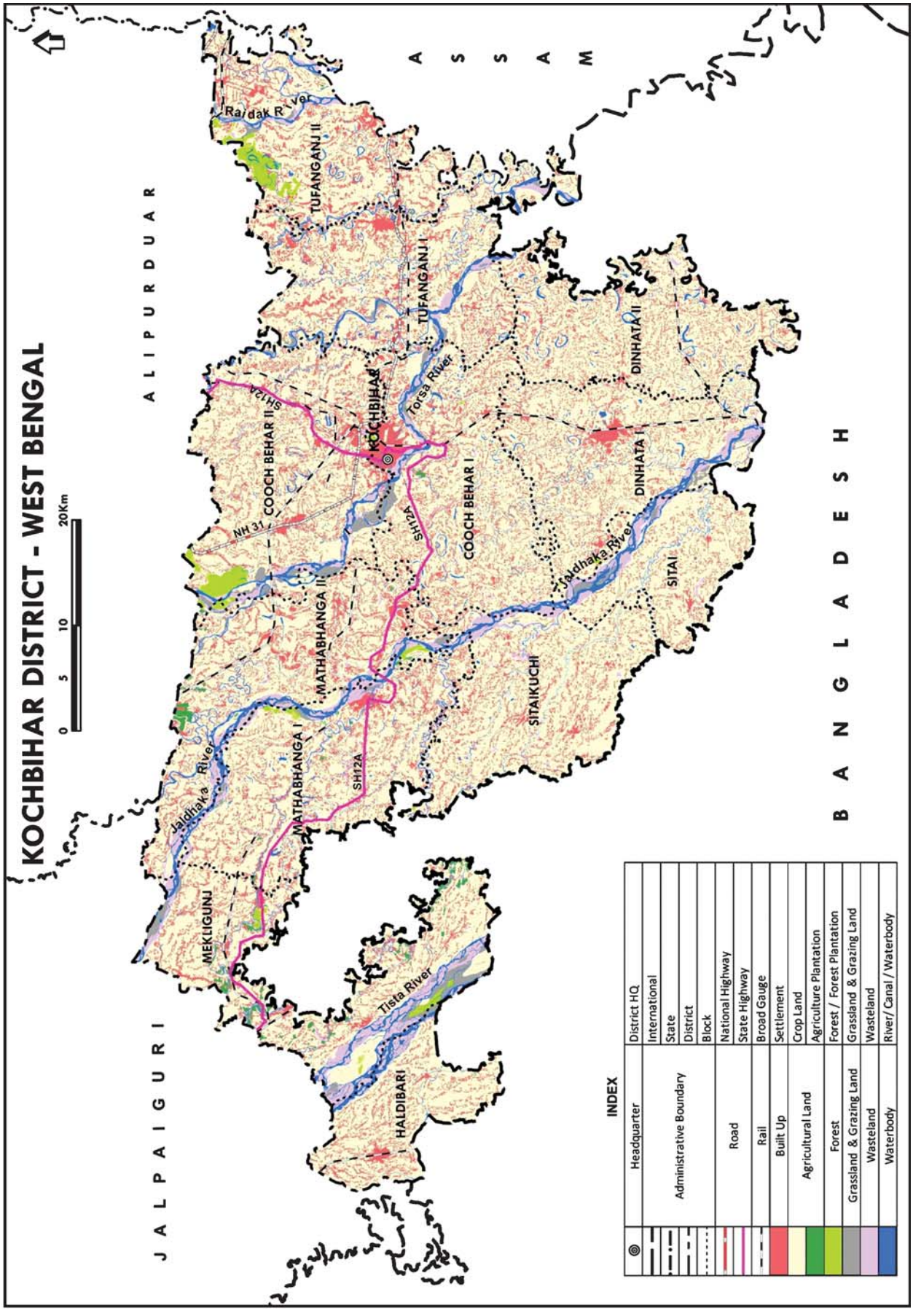
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest / Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River / Canal / Waterbody


KOCHBIHAR DISTRICT - WEST BENGAL
0 5 10 20Km
A S S A M
B A N G L A D E S H
A L I P U R D U A R
J A L P A I G U R I
Raidak River
TUFANGANJ II
TUFANGANJ I
DINHATA II
DINHATA I
KOCHBIHAR
Torsa River
SH12A
COOCH BEHAR II
COOCH BEHAR I
NH 31
MATHABHANGA II
MATHABHANGA I
SITAIKUCHI
SITAI
Jaldhaka River
MEKLIGUNJ
Tista River
HALDIBARI
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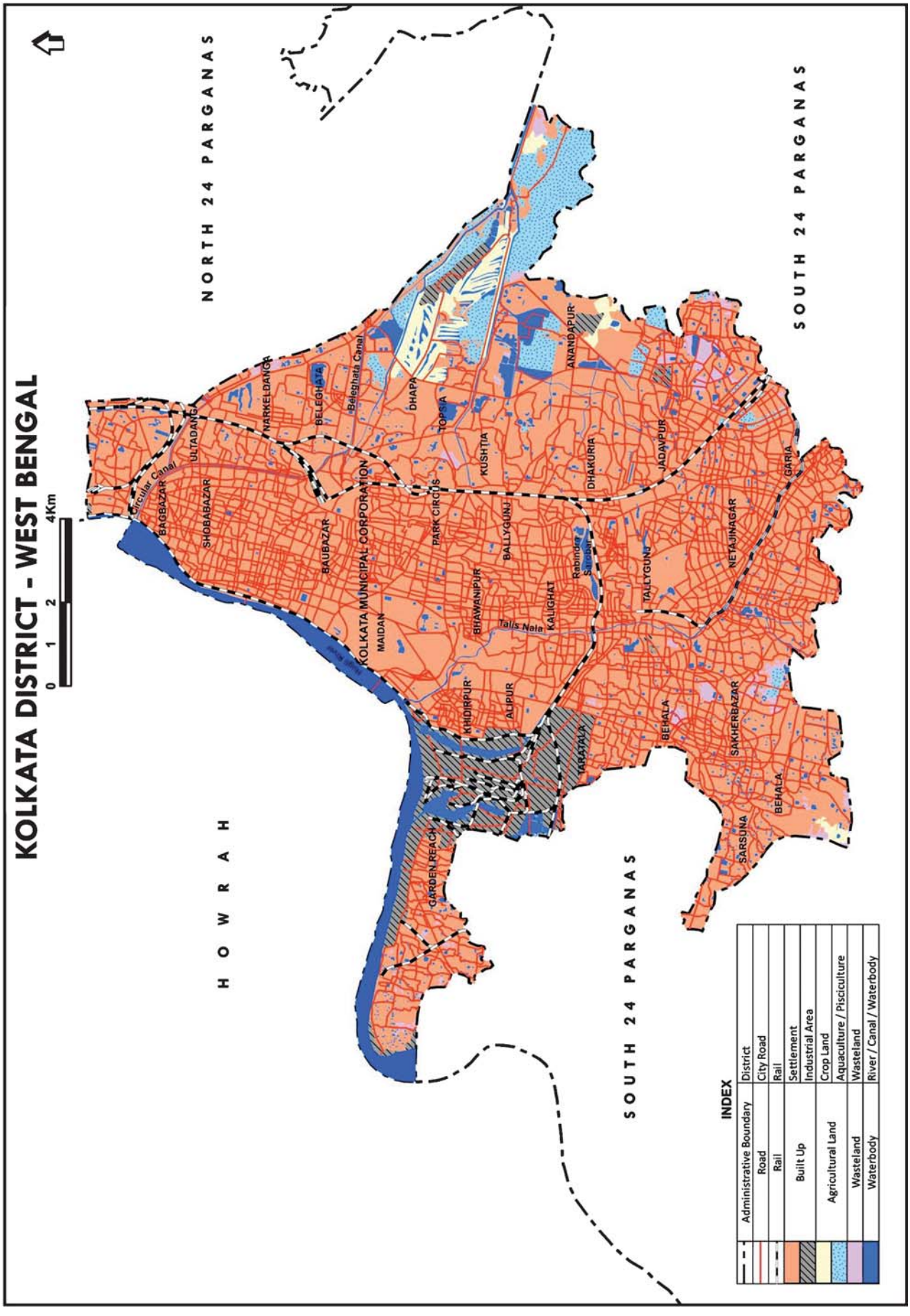
District
Block
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest / Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal / Waterbody


KOLKATA DISTRICT - WEST BENGAL
0 1 2 4Km
NORTH 24 PARGANAS
SOUTH 24 PARGANAS
HOWRAH
SOUTH 24 PARGANAS
Circular Canal
BAGBAZAR
SHOBABAZAR
ULTADANGA
NARKELDANGA
BELEGHATA
Beleghata Canal
DHAPA
TOPSIA
KUSHTIA
ANANDAPUR
DHAKURIA
JADAVPUR
GARIA
BAUBAZAR
KOLKATA MUNICIPAL CORPORATION
MAIDAN
PARK CIRCUS
BALLYGUNJ
Rabindra Sarovar
TALLYGUNJ
NETAJINAGAR
BHAWANIPUR
Tolis Nala
KALIGHAT
KHIDIRPUR
ALIPUR
TARATALA
BEHALA
SAKHERBAZAR
GARDEN REACH
SARSUNA
BEHALA
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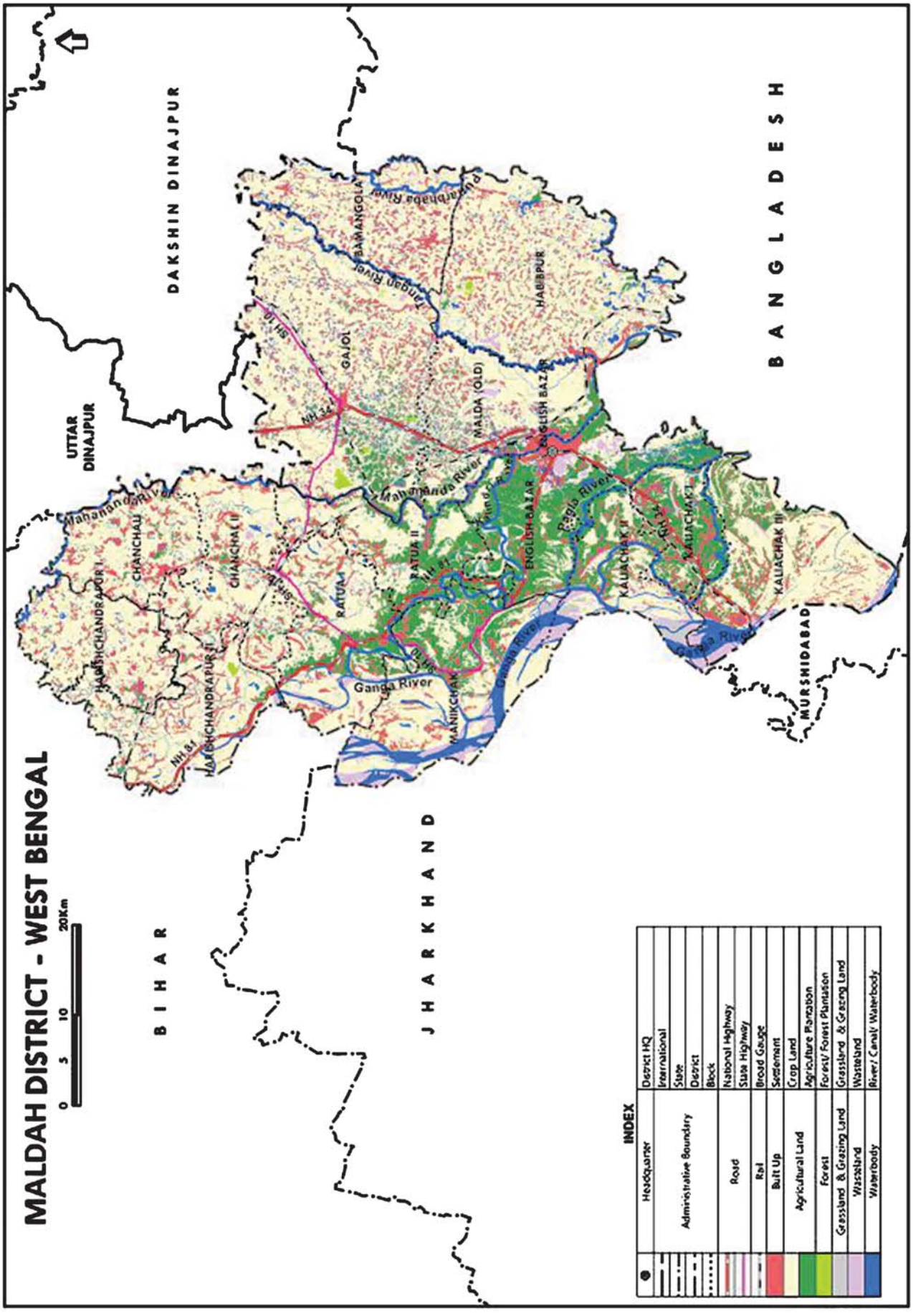
City Road
Rail
Rail
Built Up
Settlement
Industrial Area
Agricultural Land
Crop Land
Aquaculture / Pisciculture
Wasteland
Wasteland
Waterbody
River / Canal / Waterbody


MALDAH DISTRICT - WEST BENGAL
0 5 10 20Km
DAKSHIN DINAJPUR
UTTAR DINAJPUR
BIHAR
JHARKHAND
BANGLADESH
MURSHIDABAD
HABIBPUR
BAMANGOLA
GAJOL
MALDA (OLD)
ENGLISH BAZAR
RATUA
RATUA II
KALIACHAK I
KALIACHAK II
KALIACHAK III
CHANCHAL
CHANCHAL II
HARISCHANDRAPUR I
HARISCHANDRAPUR II
MANIKCHAK
Mahananda River
Mahananda River
Pagla River
Ganga River
Ganga River
Ganga River
NH 34
NH 81
SH 10
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Block
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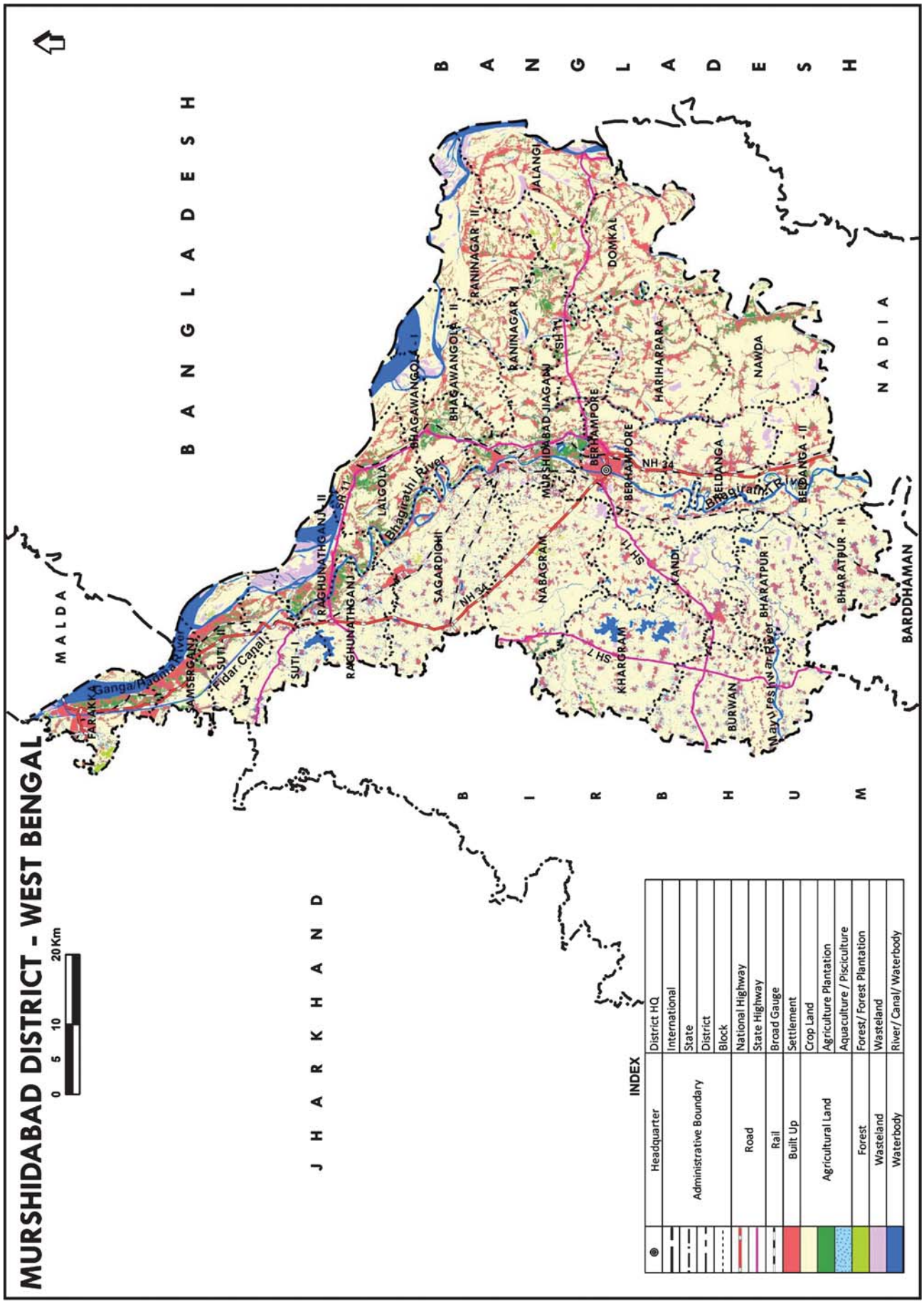
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest/ Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal/ Waterbody


MURSHIDABAD DISTRICT - WEST BENGAL
0 5 10 20 Km
B A N G L A D E S H
M A L D A
J H A R K H A N D
B I R B H U M
B A N G L A D E S H
N A D I A
BARDDHAMAN
FARAKKA
Ganga/Padma River
SAMSERGANJ
SUTI - II
Fidar Canal
SUTI - I
RAGHUNATHGANJ - II
RAGHUNATHGANJ - I
SR 11
LALGOLA
Bhagirathi River
BHAGAWANGOLA - I
BHAGAWANGOLA - II
SAGARDIGHI
NH 34
NABAGRAM
KHARGRAM
SH 11
SH 7
RANINAGAR - II
RANINAGAR - I
MURSHIDABAD JIAGANJ
BERHAMPORE
JALANGI
DOMKAL
HARIHARPARA
KANDI
BURWAN
Mayurakshi River
BHARATPUR - I
BHARATPUR - II
BELDANGA - I
BELDANGA - II
NAWDA
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Road
National Highway
State Highway
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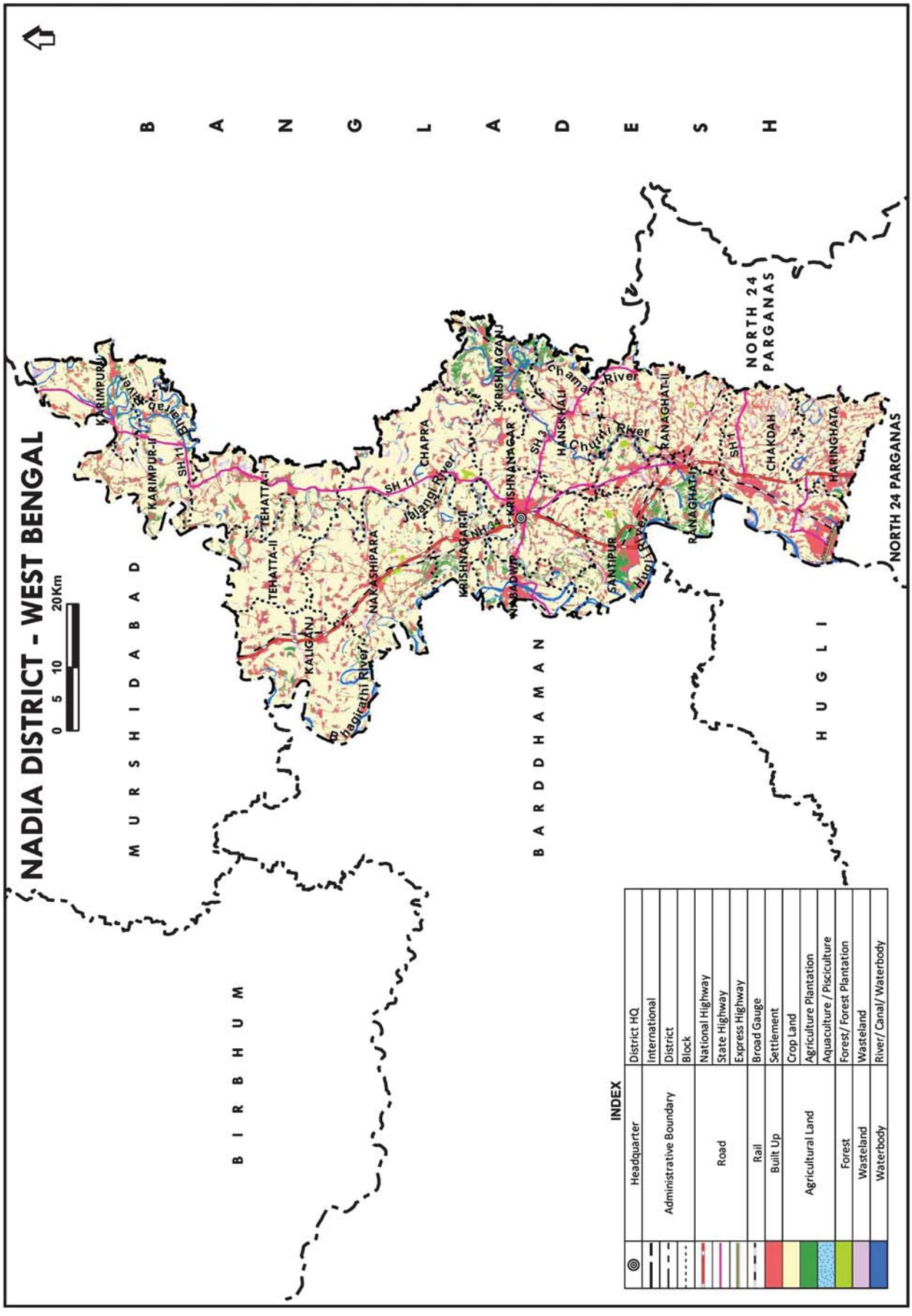
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest/ Forest Plantation
Wasteland
Waterbody
River/ Canal/ Waterbody


NADIA DISTRICT - WEST BENGAL
0 5 10 20Km
B A N G L A D E S H
M U R S H I D A B A D
B I R B H U M
B A R D D H A M A N
H U G L I
NORTH 24 PARGANAS
NORTH 24 PARGANAS
KARIMPUR-I
KARIMPUR-II
TEHATTA-I
TEHATTA-II
KALIGANJ
NAKASHIPARA
CHAPRA
KRISHNAGAR-I
KRISHNAGAR-II
KRISHNAGAR
NABADWIP
HANSKHALI
SANTIPUR
RANAGHAT-I
RANAGHAT-II
CHAKDAH
HARINGHATA
Bhairab River
Bhagirathi River
Jalangi River
Churni River
Hooghly River
SH 11
NH 34
SH 3
SH 1
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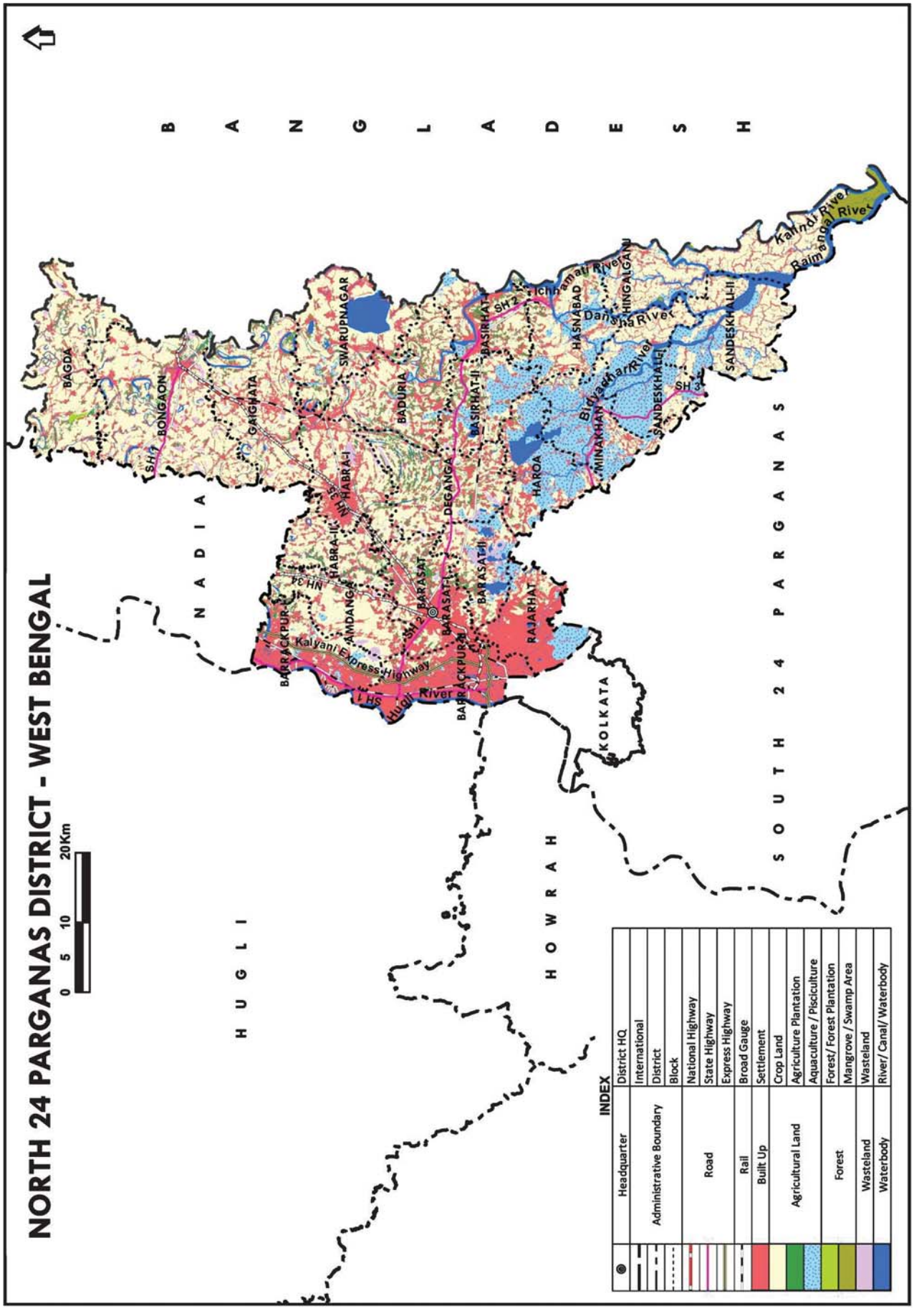
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest/ Forest Plantation
Wasteland
Waterbody
River/ Canal/ Waterbody


NORTH 24 PARGANAS DISTRICT - WEST BENGAL
0 5 10 20Km
B A N G L A D E S H
N A D I A
H U G L I
H O W R A H
S O U T H 2 4 P A R G A N A S
KOLKATA
BAGDA
BONGAON
GAIGHATA
SWARUPNAGAR
BADURIA
HABRA-I
HABRA-II
AMDANGA
BARRACKPUR-I
BARRACKPUR-II
BARASAT
BARASAT-I
BARASAT-II
DEGANGA
BASIRHAT-I
BASIRHAT-II
HAROA
RAJARHAT
HASNABAD
HINGALGANJ
MINAKHAN
SANDESKHALI-I
SANDESKHALI-II
Kalyani Express Highway
Hugli River
Ichhamati River
Dangha River
Bidyadhari River
Kalindi River
Raimangal River
SH 1
SH 2
SH 3
NH 34
NH 35
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National Highway
State Highway
Express Highway
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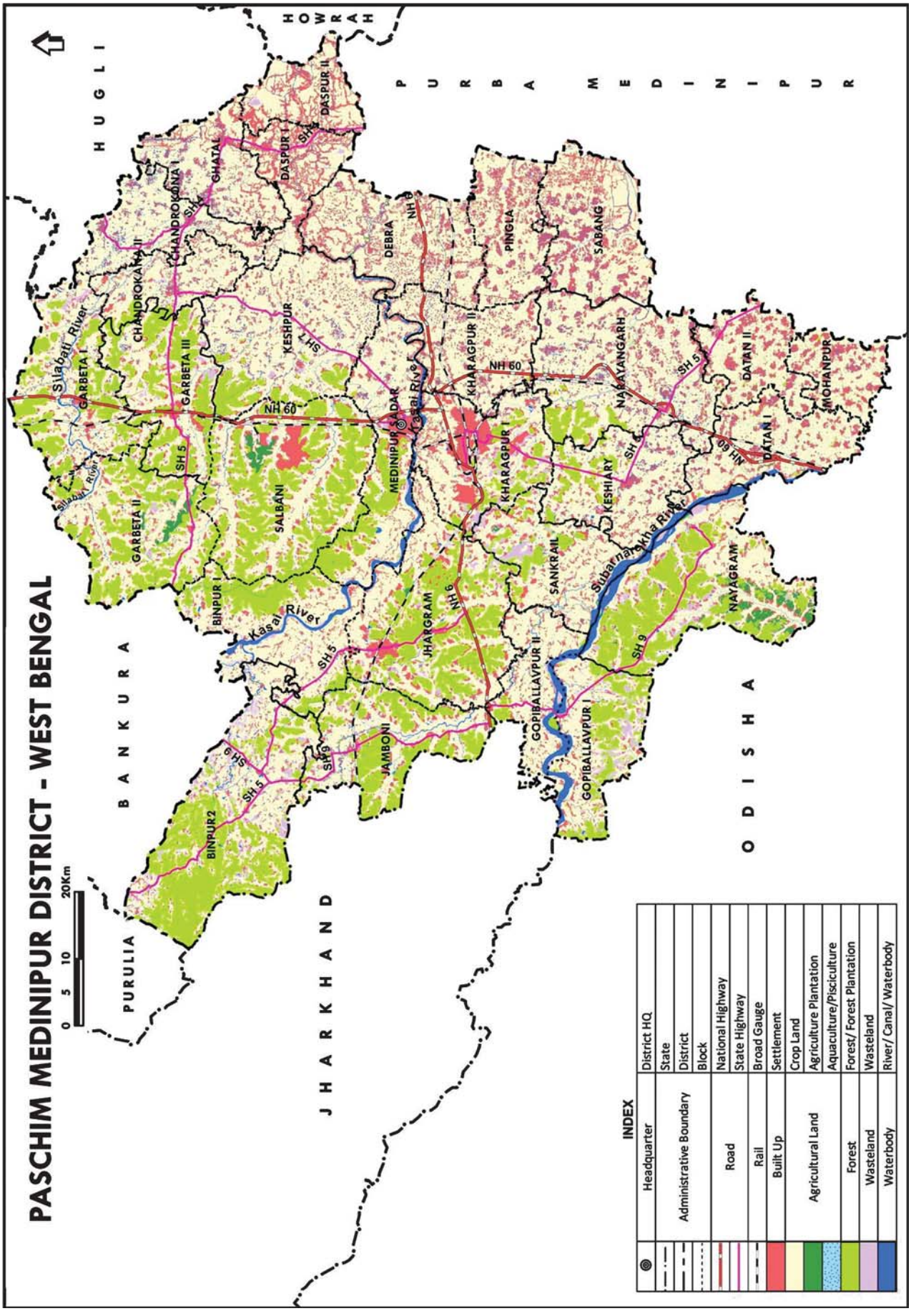
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest/ Forest Plantation
Mangrove / Swamp Area
Wasteland
Wasteland
Waterbody
River/ Canal/ Waterbody


PASCHIM MEDINIPUR DISTRICT - WEST BENGAL
0 5 10 20Km
HUGLI
HOWRAH
PURBA MEDINIPUR
BANKURA
PURULIA
JHARKHAND
ODISHA
Silabati River
Kasai River
Subarnarekha River
GARBETA I
GARBETA II
GARBETA III
CHANDRAKONA I
CHANDRAKONA II
GHATAL
DASPUR I
DASPUR II
KESHPUR
SALBANI
BINPUR I
BINPUR2
DEBRA
PINGLA
SABANG
KHARAGPUR I
KHARAGPUR II
MEDINIPUR SADAR
NARAYANGARH
KESHIARY
SANKRAIL
JHARGRAM
JAMBONI
GOPIBALLAVPUR I
GOPIBALLAVPUR II
NAYAGRAM
DATAN I
DATAN II
MOHANPUR
NH 60
NH 6
SH 5
SH 9
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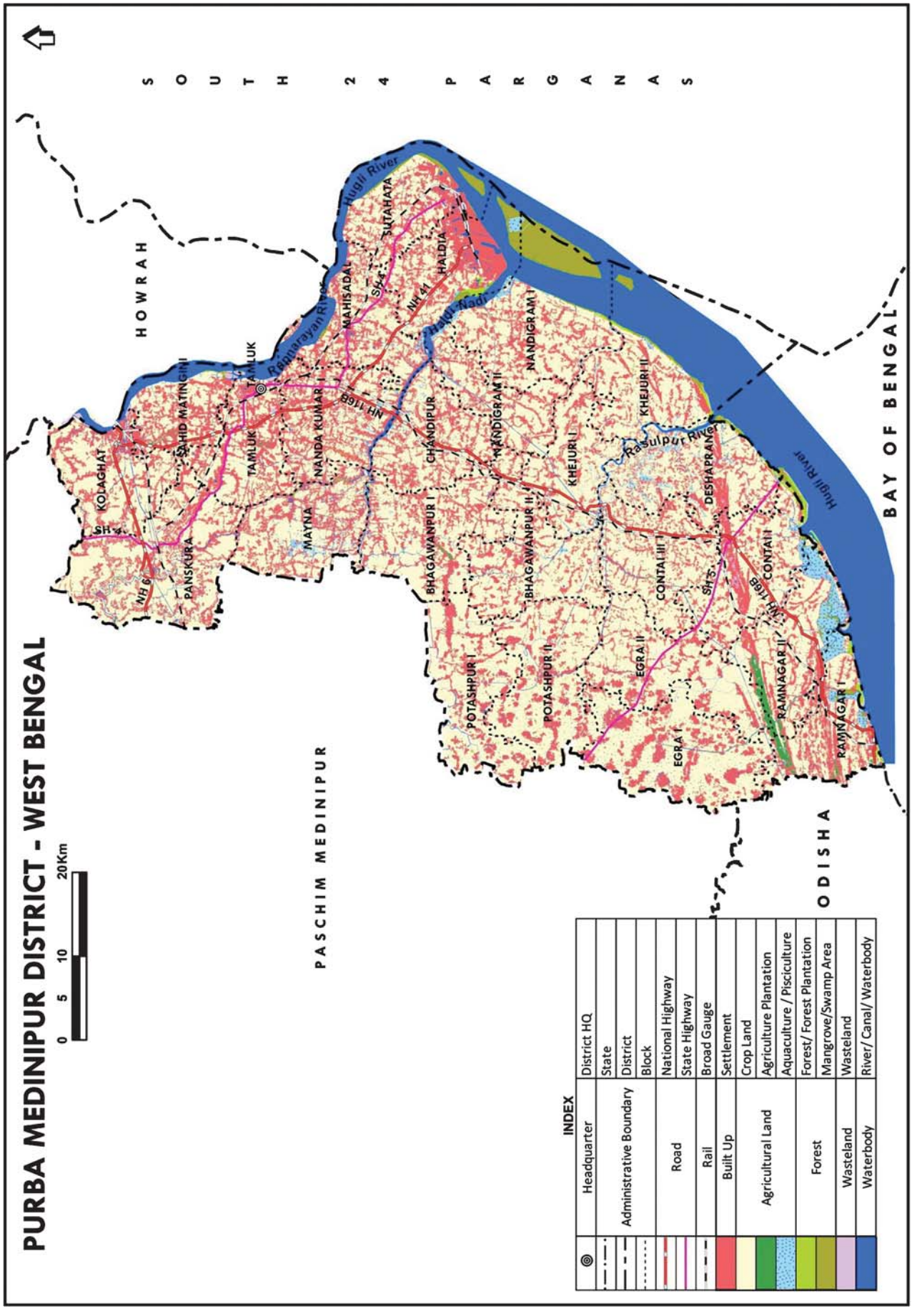
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture/Pisciculture
Forest
Forest/ Forest Plantation
Wasteland
Waterbody
River/ Canal/ Waterbody


PURBA MEDINIPUR DISTRICT - WEST BENGAL
0 5 10 20Km
HOWRAH
SOUTH 24 PARGANAS
PASCHIM MEDINIPUR
ODISHA
BAY OF BENGAL
Hugli River
Rupnarayan River
Haldi Nadi
Rasulpur River
KOLAGHAT
SAHID MATINGINI
TAMLUK
PANSKURA
MAYNA
NANDA KUMAR I
MAHISADAL
SUTAHATA
HALDIA
CHANDIPUR
NANDIGRAM II
NANDIGRAM I
BHAGAWANPUR I
BHAGAWANPUR II
POTASHPUR I
POTASHPUR II
KHEJURI I
KHEJURI II
EGRA I
EGRA II
CONTAI III
CONTAI I
DESHAPRANA
RAMNAGAR I
RAMNAGAR II
SH 4
NH 6
NH 116B
SH 5
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State Highway
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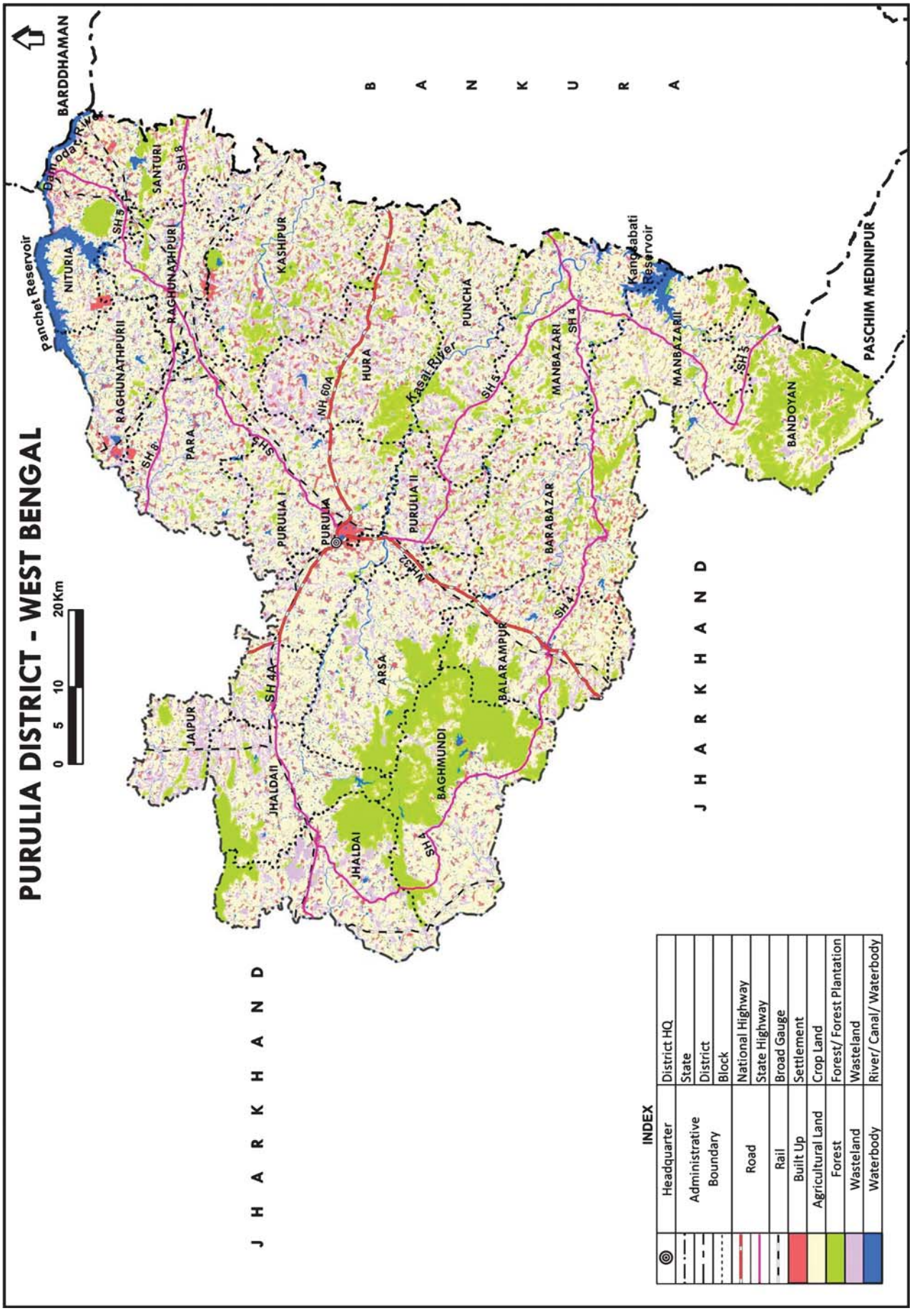
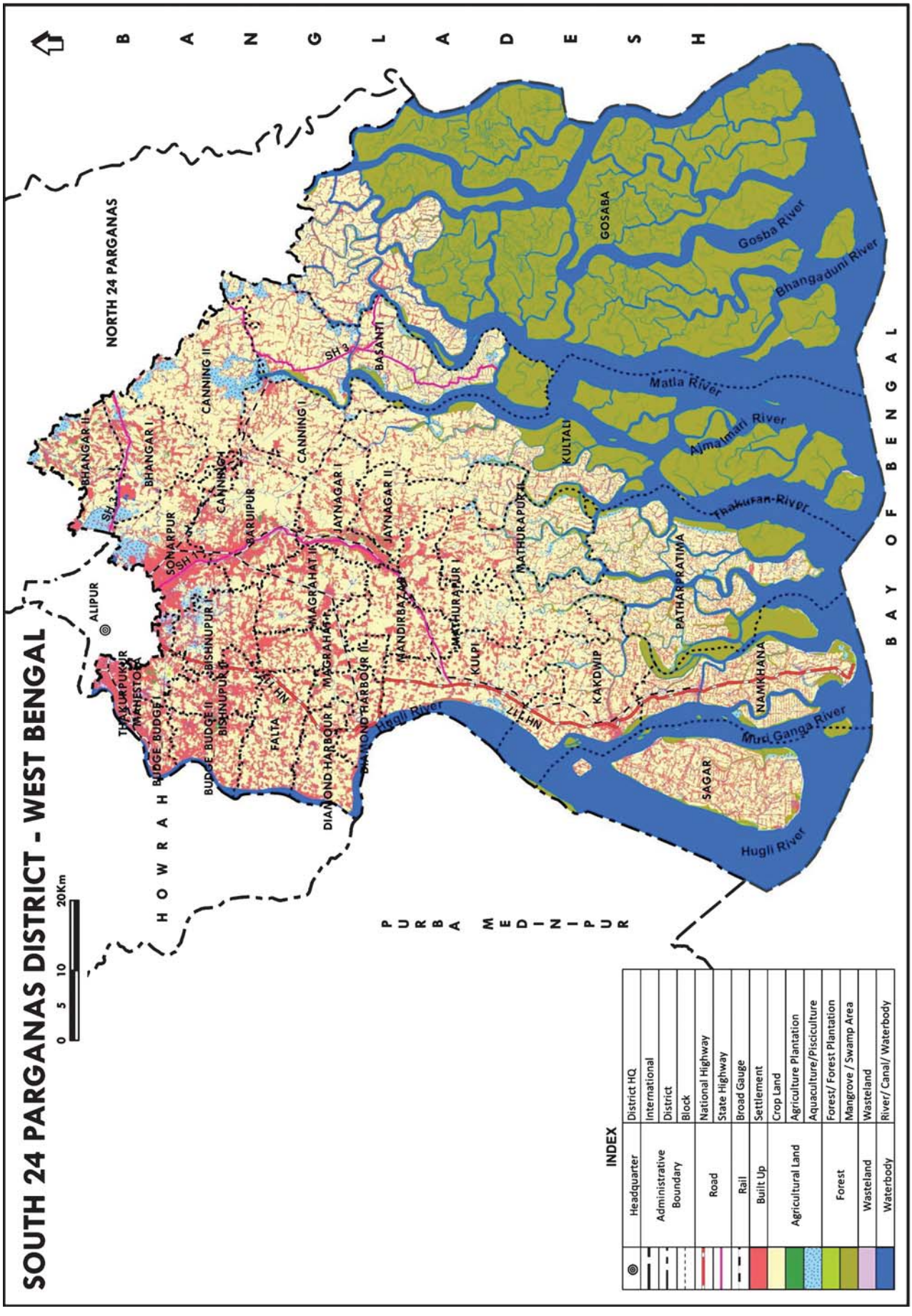
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture / Pisciculture
Forest
Forest/ Forest Plantation
Mangrove/Swamp Area
Wasteland
Waterbody
River/ Canal/ Waterbody


PURULIA DISTRICT - WEST BENGAL
0 5 10 20 Km
BARDDHAMAN
Panchet Reservoir
Damodar R.
NITURIA
SANTURI
SH 8
RAGHUNATHPURII
RAGHUNATHPUR I
KASHIPUR
PARA
SH 6
SH 5
NH 60A
HURA
Kasai River
PUNCHA
PURULIA I
PURULIA
PURULIA II
NH 32
BARABAZAR
MANBAZARI
SH 4
Kangsabati Reservoir
MANBAZARII
SH 3
BANDOYAN
PASCHIM MEDINIPUR
B A N K U R A
JAIPUR
SH 4A
JHALDAII
JHALDAI
ARSA
BAGHMUNDI
BALARAMPUR
J H A R K H A N D
INDEX
Headquarter
District HQ
Administrative Boundary
State
District
Block
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Forest
Forest/ Forest Plantation
Wasteland
Wasteland
Waterbody
River/ Canal/ Waterbody


SOUTH 24 PARGANAS DISTRICT - WEST BENGAL
0 5 10 20Km
NORTH 24 PARGANAS
B A N G L A D E S H
H O W R A H
P U R B A M E D I N I P U R
B A Y O F B E N G A L
ALIPUR
THAKURPUKUR MAHESTOLA
BUDGE BUDGE I
BUDGE BUDGE II
BISHNUPUR I
BISHNUPUR II
SONARPUR
BHANGAR I
BHANGAR II
CANNING II
CANNING I
BARUIPUR
FALTA
DIAMOND HARBOUR
MAGRAHAT I
MAGRAHAT II
JAYNAGAR I
JAYNAGAR II
MANDIRBAZAR
MATHURAPUR I
MATHURAPUR II
KULPI
KAKDWIP
KULTALI
PATHARPRATIMA
NAMKHANA
SAGAR
BASANTI
GOSABA
SH 1
SH 2
SH 3
NH 117
Hugli River
Muri Ganga River
Thakuran River
Matla River
Almalmari River
Gosba River
Bhangaduni River
INDEX
Headquarter
District HQ
Administrative Boundary
International
District
Block
Road
National Highway
State Highway
Rail
Broad Gauge
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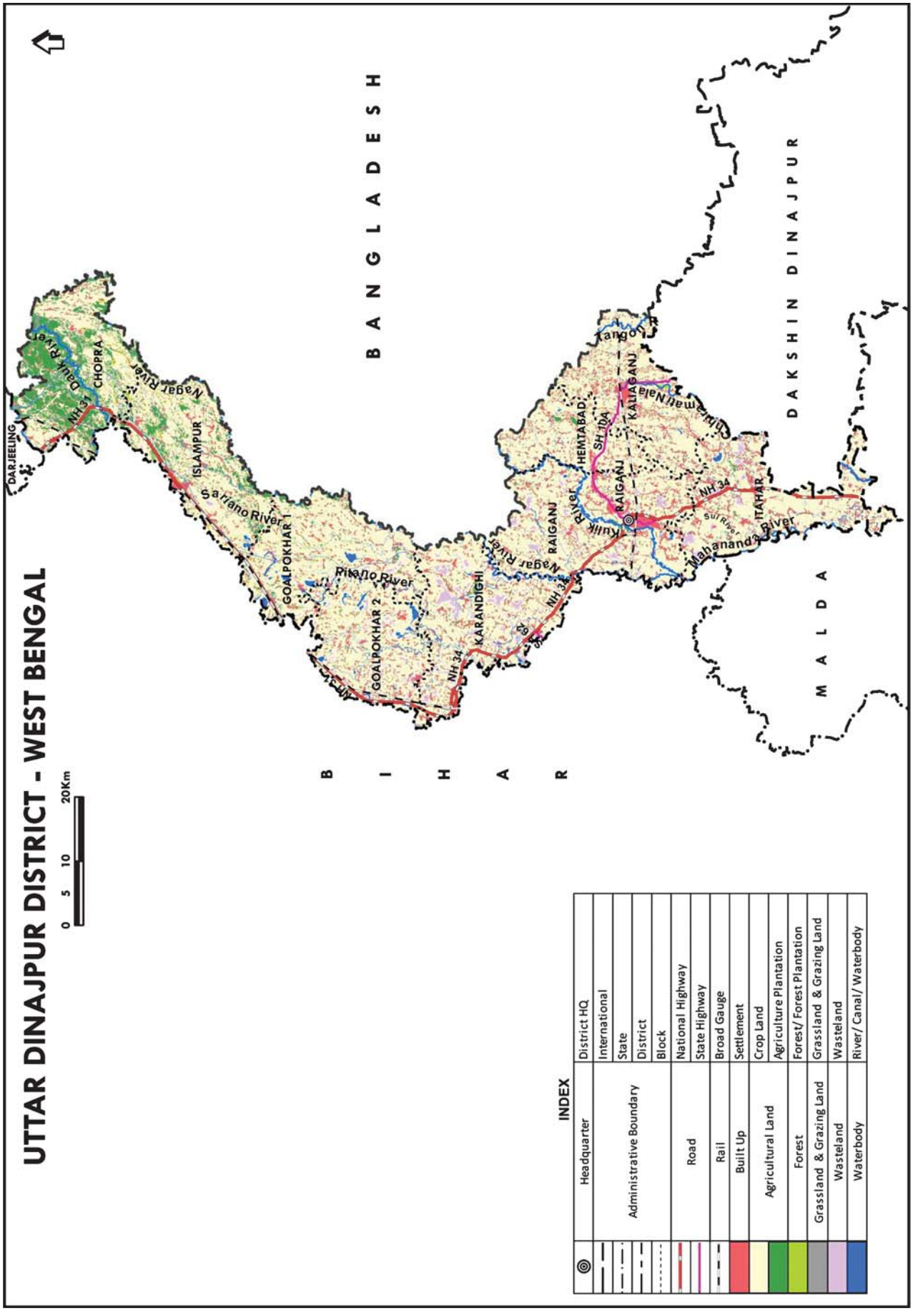
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Aquaculture/Pisciculture
Forest
Forest/ Forest Plantation
Mangrove / Swamp Area
Wasteland
Waterbody
River/ Canal/ Waterbody


UTTAR DINAJPUR DISTRICT - WEST BENGAL
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INDEX
Headquarter
District HQ
Administrative Boundary
International
State
District
Block
Road
National Highway
State Highway
Rail
Broad Gauge
Built Up
Settlement
Agricultural Land
Crop Land
Agriculture Plantation
Forest
Forest/ Forest Plantation
Grassland & Grazing Land
Grassland & Grazing Land
Wasteland
Wasteland
Waterbody
River/ Canal/ Waterbody
BANGLADESH
BIHAR
DAKSHIN DINAJPUR
MALDA
DARJEELING
CHOPRA
ISLAMPUR
GOALPOKHAR 1
GOALPOKHAR 2
KARANDIGHI
RAIGANJ
HEMTABAD
KALIAGANJ
ITAHAR
Dauk River
Nagar River
Sarano River
Rirano River
Kulik River
Mahananda River
Sui River
Dhamali Nala
NH 37
NH 34
SH 10A

Chapter 1

West Bengal – *at a glance*

The state of West Bengal, the fourth largest state of India covering an area of about 88,752 sq km, is the home of about 91.28 million populations as per census of 2011. The State is sharing borders with countries of Bangladesh, Nepal and Bhutan and other Indian states of Odisha, Jharkhand, Bihar, Sikkim and Assam. West Bengal is the only state of India that extends from the Himalaya in the north to Bay of Bengal in south. About 31.87 per cent of total population of the State lives in urban areas and remaining 68.13 per cent in rural areas.

West Bengal offers wide topographic diversity and intricate drainage network of the Ganga, the Brahmaputra and the Subarnarekha river basins. The State can distinctly be divided into three geographical units. The Ganga divides the State into two unequal hubs - the North and South Bengal. The State has 20 administrative districts. The North Bengal with seven districts covers 21,855 sq km and renders home to 17,211,010 persons. The remaining thirteen districts of South Bengal can further be subdivided into two geographical units taking Bhagirathi-Hugli river as the demarcating line. The western Rarh region covers an area of about 46,418 sq km and supports a population of about 42,677,166 while the eastern deltaic plain covers 20,484 sq km and population living thereon is 31,387,939.

Major administrative reforms

With the Indian independence in 1947, West Bengal emerged as a new state when Dinajpur of undivided Bengal was bifurcated into two parts, a district named as West Dinajpur was added to India, and its eastern counterpart was included in the erstwhile East Pakistan (now Bangladesh). Similarly, Nadia was divided into two parts and the western part was added to West Bengal as Nabadwip district, but it was again renamed as Nadia district in 1948. The royal state of Koch Bihar was merged with India in 1949 and was declared as a new district of West Bengal in 1950. Thus in 1951, West Bengal had altogether 15 districts.

In 1954, Chandannagore, a former French colony was merged with Hugli district. The Manbhum district of Bihar was included to West Bengal as Puruliya and the total number of districts increased to 16. In 1983, the adjoining municipalities namely Garden Reach, South Suburban and Jadavpur were

TABLE 1.1 Geographical units and population distribution in West Bengal

Geographical units	Area	Population (2011)
North Bengal	21850 km^2 (25%)	17211010 (19%)
Western Rarh	46418 km^2 (52%)	42677166. (47%)
Eastern Plain	20484 km^2 (23%)	31387939 (34%)
Total	**88752 km^2**	**91276115**

Source: Calculated based on Census 2011

included into Kolkata Municipal Corporation. In 1986, the district of 24 Parganas was divided into two parts - the North 24 Parganas and South 24 Parganas.

The administrative reform continued in 1992 when West Dinajpur was divided into Uttar and Dakshin Dinajpur and again in 2002 when Medinipur was bifurcated into Purba and Paschim Medinipur. On 25 June 2014, Jalpaiguri district has been bifurcated to create the Alipurduar district - the 20th district of West Bengal. Since then the number of districts in West Bengal is altogether twenty. It should be mentioned here that while making the demographic projection, the present territorial boundaries were notionally considered effective since 1951.

The Himalaya in the north
Source: Kalyan Rudra

Physical features

The state of West Bengal shows widely varying physical features starting from green and picturesque mountain with deep precipitous valley in the north, plains of Doors and Terai, relatively high Barind tract, undulating lateritic plateau in the south-west and extensive alluvial plain stretching from North to South Bengal. Broadly speaking, the state is occupied by three physiographic divisions - mountain, plateau and plain. However, these three units are further subdivided into several subunits.

Physiography of North Bengal

In North Bengal, the Himalaya rises abruptly from the boulder-strewn undulated plains. This mighty mountain system, having a length of about 2,500 km, between the lofty peaks of Nangaparvat to Namchabarwa and covering 250-300 km wide expense, borders the Indian subcontinent in the north and separates it from rest of Eurasia. The Singalila range marks border of West Bengal with Nepal and Phalut is the highest point of West Bengal. The four major Himalayan rivers namely Torsa, Tista, Jaldhaka and Mahananda with their numerous tributaries debouch on the plain and the abrupt decline of slope leads to the deposition of coarse sediment along the foothill areas and thus numerous fans have been formed. These fans extend southward up to 66 m contour having their apex at 300 m contour. One can find sorting of sediment from coarse to fine in a north-south direction. The alluvial plain of North Bengal is found between 66-27 m contour. This plain has been formed by the deposition of finer fluvial sediments. In Dakshin Dinajpur and north-east Malda, the older ferralitic deposits are known as Barind. The archaeological sites of Gaur, Pandua and Bangarh are found in this tract. The meander belt of Ganga, which extends for about 10 km from both the bank lines is

covered with most recently deposited silt and is known as *diyera*.

Physiographic units of Rarh

The Rarh Bengal lies to the west of Bhagirathi and extends up to the south-western border of West Bengal with Jharkhand. This geographical unit can be subdivided into five physiographic units (Table 1.2).

The word *rarh* has been corrupted from Sanskrit word *roorha* meaning rough or uneven. The course of Damodar up to Barddhaman and extending further east through its moribund distributary called Gangur upto Kalna may be treated as the dividing line between northern and southern *Rarh*. This ancient landmass has evolved through protracted sub-aerial denudation and the topography is a combination of ridge or hill, dome-shaped residual mounds and extensive fluvial plains. The western Archaean shield plunges under recent alluvium approximately to the east of 87^0E meridian but extends further east up to the line connecting Medinipur, Galsi and Jangipur. The thickness of sediment increases from 900 m along the western border of West Bengal to about 8,182 m below Kolkata. The plateau proper, which is enclosed by 120 m contour, is virtually the extension of Chotanagpur plateau. This is clearly discernible in Puruliya. The Ajyodha Pahar is the classical example of residual hill or monadnock. This plateau proper was covered with dense tropical forest and was known as 'Jangal Mahal' during British rule. Now the area has been extensively deforested and degraded.

The area lying between 120-36 m contours is known as plateau fringe. The rivers like Mayurakshi, Brahmani, Dwaraka, Ajoy, Damodar, Dwarakeswar, Silai and Kansai have curved wide valleys and interfluves between two rivers have been identified as spurs. These spurs are further dissected by transverse tributaries joining the trunk streams from both sides.

TABLE 1.2 Physiographic units of Rarh

Sl	Physiographic Units	Elevation
1	Plateau Proper	120 m and above
2	Plateau Fringe	36-120 m
3	Marginal Plain	18-36 m
4	Flood Plain(meander belt)	18 m contour to western bank-line of Bhagirathi
5	Coastal Plain	< 3 m

The tributaries receive numerous rills, gullies, and secondary tributaries especially from the lateritic tracts. These tributaries are mostly ephemeral in nature.

The area between 36-18 m contour line is known as Piedmont plains. Here the rivers are sluggish and the wide valleys are choked with sands. The lean season's feeble flows often disappear below the blanket of sand. The major rivers flow through the sandy beds in extremely sinuous course. The piedmont plain merges imperceptibly with the meander-belt of Bhagirathi.

Eastern Deltaic Plain

The area lying between Bhagirathi-Hugli in the west, Ganga-Padma in the north, Indo-Bangladesh border in the east and Bay of Bengal in the south is popularly known as deltaic West Bengal. Some experts believe that the true delta extends westwards and northwards beyond the Bhagirathi-Hugli and the Ganga-Padma and the area is described as the Ganga-Brahmaputra delta. Despite the debate over the geographical extension of delta, the area lying to the east of Bhagirathi has been divided into three segments namely moribund, matured and active delta. The active delta is also the Sundarban and enclosed by 3 m contour. It can be otherwise delineated by a line joining the northern limit of tidal invasion through creeks. In this active delta marine and fluvial land building processes are juxtaposed The Bay

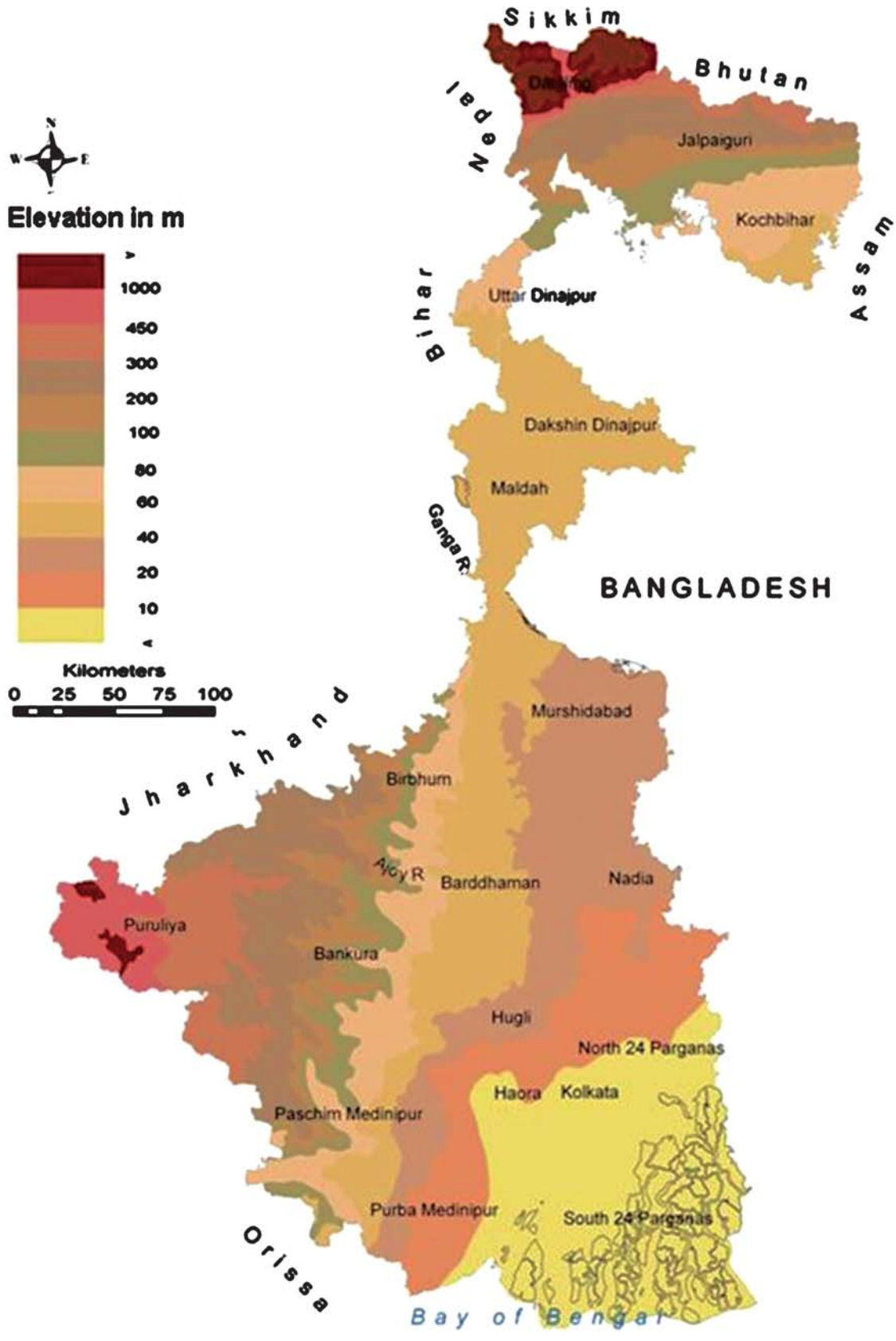

FIGURE 1.1 West Bengal contours and elevation

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

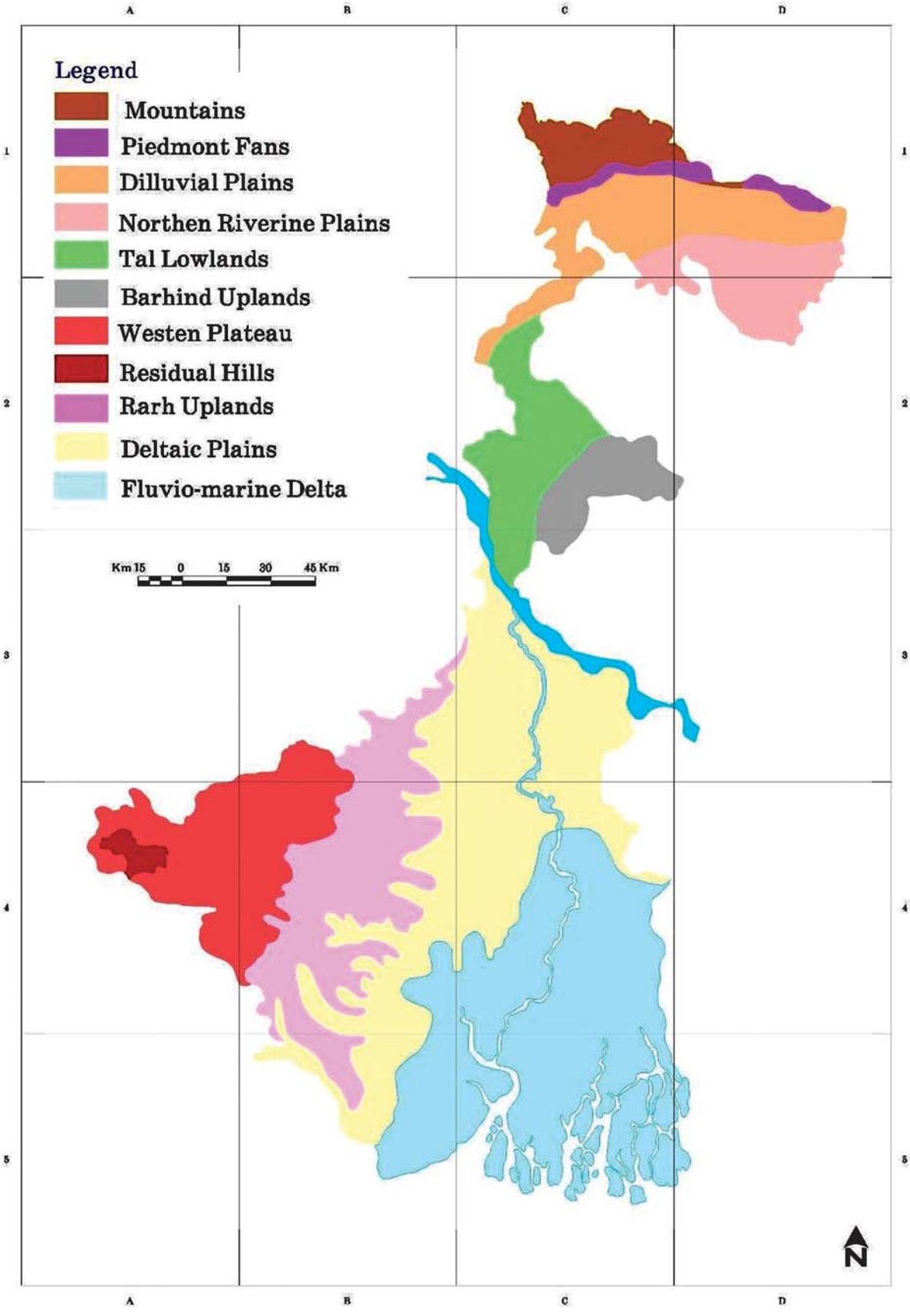

FIGURE 1.2 West Bengal physiographic regions

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

of Bengal achieved its present level about 7,000 years BP after protracted glacial period when sea-level receded further south and extensive coastal areas were exposed. Since then, delta building has been continuing through the complex processes of tidal intrusion, spill-over of silt laden water, auto-compaction of newly deposited sediments and flushing of sediment through the submarine canyon or swatch of no ground. However, since second half of the 18th Century, due to premature reclamation of large part of western Sundarban through embanking the creeks, the spill-over of silt-laden water was restricted and thus the delta building was impaired.

The area lying to the south of Jamuna, a moribund channel that once connected Bhagirathi with Ichhamati and north of 3 m contour line may be conveniently identified as mature delta. It is the area built up by Bhagirathi and its distributaries but there is hardly any difference in geomorphological characteristics of mature delta and its counter part - the moribund delta. Only major difference is that the mature delta has regional slope towards south-east as indicated by the flow of rivers like Suti, Bidyadhari, Noai and Ichhamati and moribund delta has the slope towards south-west as indicated by the flow of Jalangi and Mathabhanga-Churni. Both these parts of delta are having many wetlands scattered over Murshidabad, Nadia, North and South 24 Parganas and may be treated as areas of incomplete morphogenesis. The northern segment is more prone to flood because of its location in between Bhagirathi and Ganga-Padma. The Bansloi, Pagla, Mayurakshi and Ajoy are also responsible for recurrent flood in moribund delta.

Kalindri river
Source: Kalyan Rudra

Climate

The State of West Bengal, geographically located between $20^0$30'16"N to $27^0$16'17"N latitude, is characterized by striking climatic variation. The topography and latitudinal extent exert influence on temperature and rainfall pattern in different parts of West Bengal. Therefore, the plains, plateaus and the Himalaya are distinctly different in their climatic characteristics.

The four seasons cyclically rotates over West Bengal. These are:

(a) Winter: December to February;
(b) Summer: March to May;
(c) Monsoon: June to September;
(d) Retreating Monsoon or Autumn: October and November

Since the agriculture is the largest consumer of water, the Department of Agriculture, Government of West Bengal has linked three principal cropping seasons with corresponding meteorological seasons: (a) Summer corresponding with pre-Kharif or Boro cultivation; (b) Monsoon with Kharif (dominated by Aman cultivation); and (c) Retreating Monsoon with Rabi.

Temperature

The latitudinal extension of West Bengal imparts less influence on the temperature pattern of the State than topography. The summer temperature in Darjiling varies

between 14^{0}C in Sandakphu to 23^{0}C in foothills. The mercury goes up to about 27^{0}C in Jalpaiguri and goes down to 23^0-24^{0}C in Uttar Dinajpur. The average summer temperature in Dakshin Dinajpur is between 26^0-27^{0}C and that in Maldah is between 27^0-28^{0}C. The entire South Bengal experiences scorching summer having temperature of about 29^{0}C but the coastal Purba Medinipur records less summer temperature around 20^{0}C due to maritime influence.

The average winter temperature in Darjiling is observed to be between 9^0-14^{0}C and that in Jalpaiguri is 17^0-19^{0}C. The temperature declines to 12^0-16^{0}C in Uttar Dinajpur and stands between 17^0-19^{0}C in Dakshin Dinajpur and Maldah. The temperature varies between 20^0-21^{0}C in western Rarh and fluctuates between 21^0-22^{0}C in Kolkata, South 24 Parganas and Purba Medinipur.

Rainfall

The annual rainfall in different districts of West Bengal varies widely. The Jalpaiguri (including Alipurduar) records highest rainfall in the State amounting about 3,899 mm, followed by Koch Bihar (3,302 mm) and Darjiling (3,141 mm). Amongst the districts of South Bengal Nadia recorded lowest rainfall (1,309 mm) followed by Puruliya (1,329 mm), Barddhaman (1,349 mm), and Bankura (1,360 mm), Birbhum (1,387 mm).

The statement of annual rainfall is not enough to appreciate the water-scenario of the districts. The two districts having same amount of annual rainfall may differ in number of rainy days. The skewed rainfall pattern causes more runoff and less infiltration. A late monsoon cloudburst generating torrential rainfall may invite flood and consequent disaster.

The annual average number of rainy days in West Bengal is 79. However, in case of North Bengal, it is 88 and that for South Bengal it is 79. The average annual rainfall is not the assured rainfall, which can be taken for planning of water management. Secondly, the number of meteorological stations in West Bengal is 26 only and those are located far away from each other and many districts have only one station. The data recorded at those stations do not necessarily represent districts' scenario. So the rainfall and the evaporation data were rationalized using advanced statistical methods (Kernel smoothing) to have a better understanding of the rainfall received by each district and subsequent evaporation loss from those areas. An estimate of annual precipitation in West Bengal calculated using 110 years of precipitation data (1901-2010) from IMD is shown in Table 1.5.

TABLE 1.3 Annual precipitation in West Bengal

Districts	Annual precipitation (mm)
Darjiling	3141
Jalpaiguri	3899
Alipurduar	3899
Koch Bihar	3302
Uttar Dinajpur	1567
Dakshin Dinajpur	1711
Maldah	1491
Murshidabad	1402
Birbhum	1387
Barddhaman	1349
Nadia	1309
North 24 Parganas	1613
Hugli	1471
Bankura	1360
Puruliya	1329
Purba Medinipur	1621
Paschim Medinipur	1535
Haora	1621
South 24 Parganas	1771
Kolkata	1686
West Bengal	1795

Source: Calculations from the model described in Rudra (2012), adapted to latest precipitation data (1901-2010) from IMD

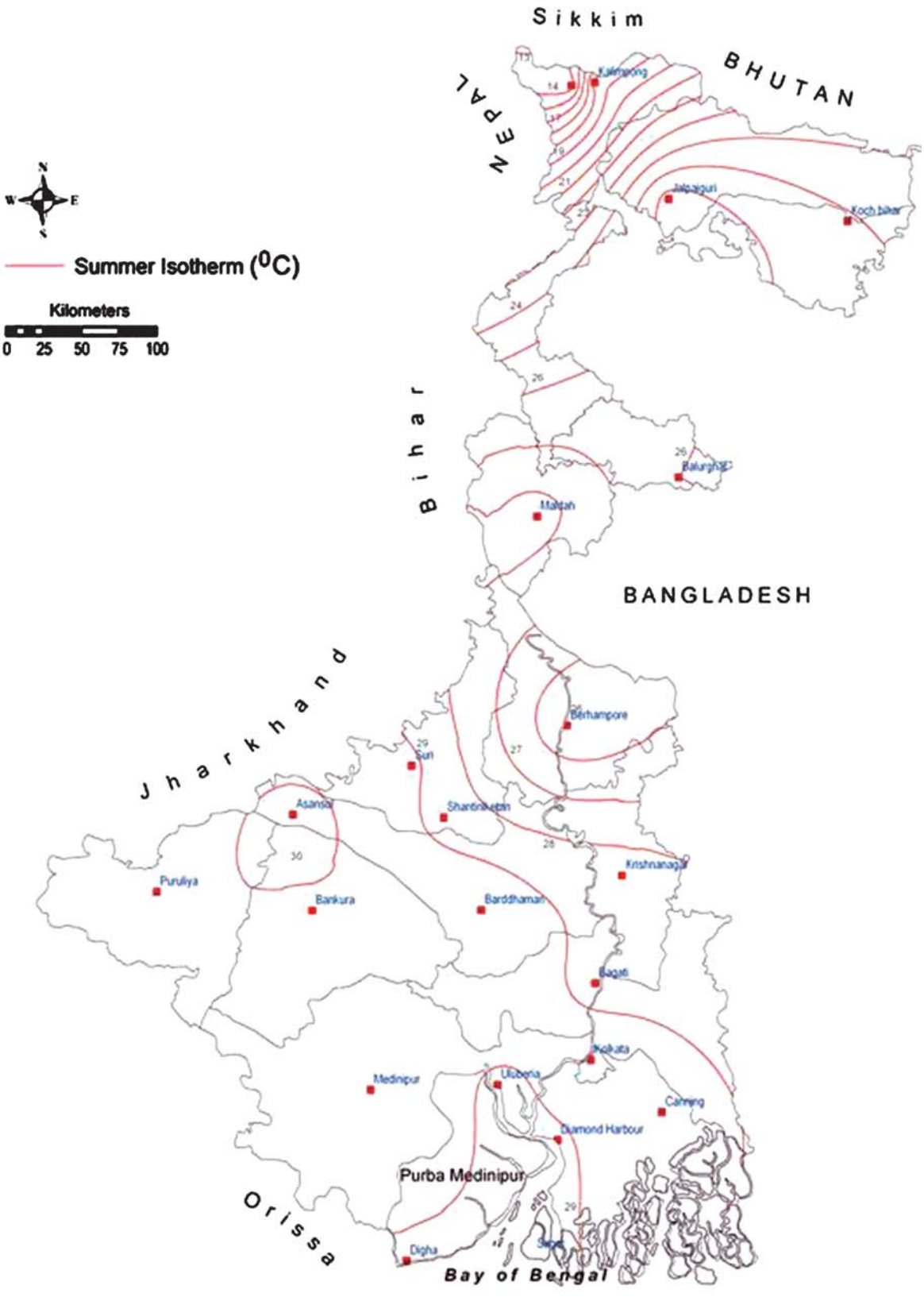

FIGURE 1.3 West Bengal summer isotherm

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

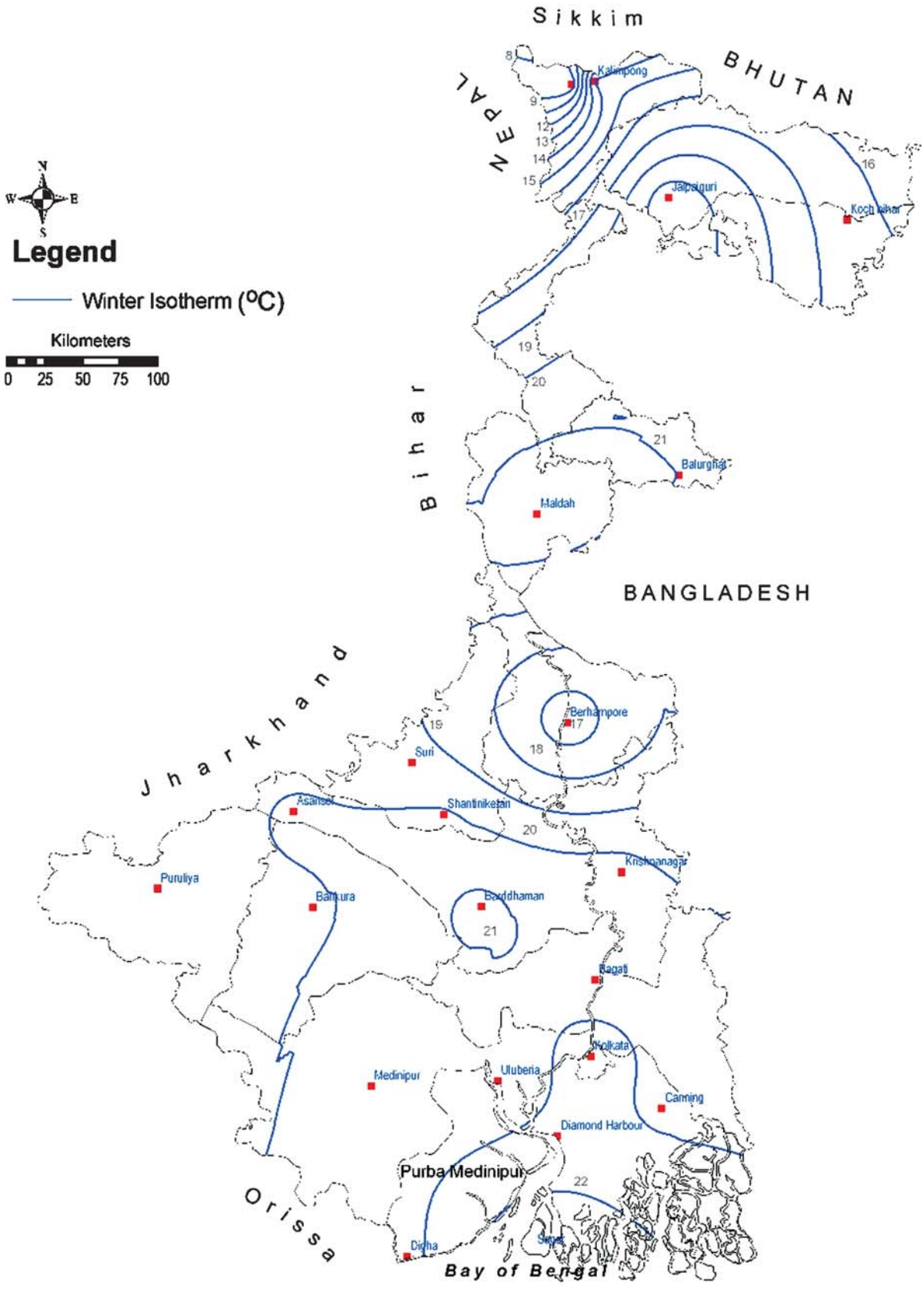

FIGURE 1.4 West Bengal winter isotherm

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

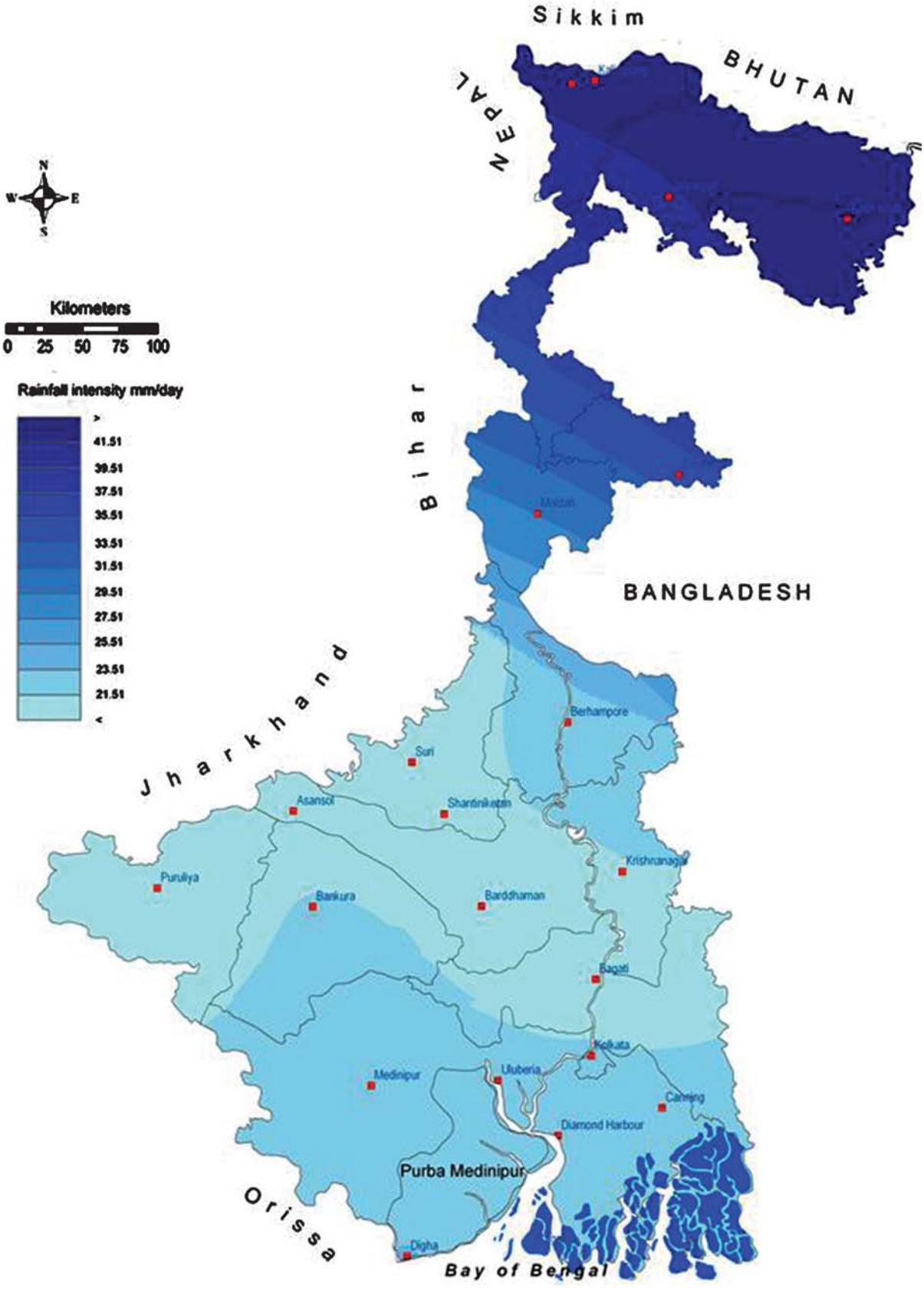

FIGURE 1.5 West Bengal monsoon rainfall intensity

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

Land

In West Bengal, due to high population density (1,028 per sq km.), the pressure on land in West Bengal is immense and majority of the population is dependent primarily on agriculture. Recent State's land use pattern shows that 60.2 per cent of land is used for agriculture and 4.02 per cent land is current fallow. However, over time the 'net sown area' has been reduced from around 63 per cent in 1999-2000 to around 60 per cent in 2013-2014 and the current fallows have increased from about 2.4 per cent to about 4 per cent during the same period. There is a reduction of 1.4 per cent of agricultural land and the 'area not available for cultivation' has increased from about 19 per cent to about 21 per cent. Thus it is evident that the land use pattern in the State has been changed during last fifteen years with decreased agricultural area and increase in settlement area. This is a natural precursor to development of infrastructure and urbanization. Notable is the fact that urbanization and other non-agricultural activities have been slow in comparison to the average growth of population, both in terms of absolute numbers and density, as this land use class shows a marginal increase of 2.16 per cent. Though this indicates low level of urbanization, it also bears a crucial indication for the ecological character of the land – this inadvertently implies an environmental benefit of sorts.

Soil

The soil in West Bengal varies widely from Himalaya to the Bay of Bengal. Physiographically the soil of the State can be classified into several groups depending on their texture, structure, colour, porosity and nutrient content. Broadly speaking, the soils of Rarh tract lying to the west of Bhagirathi-Hugli are mostly lateritic or red soil. The soils along the eastern deltaic tract and along the western flood plain are younger alluvium. In the southern littoral tract of Sundarban, the soil is saline due to recurrent submergence during high tide.

In the high Himalaya, the soil is coarse and said to be mountain. But along the foothill, the soil is classed as terai, which is coarse grained and having low water holding capacity. The water infiltrates quickly in this soil. Further south, soil is again classed as younger alluvium but grains are coarser than southern deltaic Bengal. In north-eastern corner of Maldah and in Dakshin Dinajpur, there is a patch of older alluvium, popularly known as Barind.

The texture and structure of the soil are two important factors controlling runoff-infiltration ratio. It has been observed that in lateritic area, the hard crust does not allow easy infiltration and generate more runoff. In the Rarh uplands, the presence of a rock layer in the subsurface does not allow the infiltration of water into the deeper aquifer.

District wise soil fertility map shows that soils of Purba and Paschim Medinipur, North and South 24 Parganas are low, while soils of Darjiling, Jalpaiguri, Kooch Bihar, Puruliya, Hugli and Nadia are medium in soil nitrogen content. With respect to available phosphate content, soils of Puruliya and Purba Medinipur are low, soils of Darjiling, Jalpaiguri, Koch Bihar, Maldah, North 24 Parganas, South 24 Parganas and Paschim Medinipur are medium, and soils of Hugli are high. If the potassium content in soil is considered, in eight districts (Darjiling, Maldah, North 24 Parganas, South 24 Parganas, Hugli, Puruliya, Purba Medinipur and Paschim Medinipur) potassium content is medium, and soils of Jalpaiguri and Koch Bihar are rated as low.

The effective soil depth plays an important role in crop selection as it governs root development and also moisture and nutrient supply to the plants. There are five depth classes of which three influences crop growth and selection of crops. Only 5.3 per cent of total geographical area of

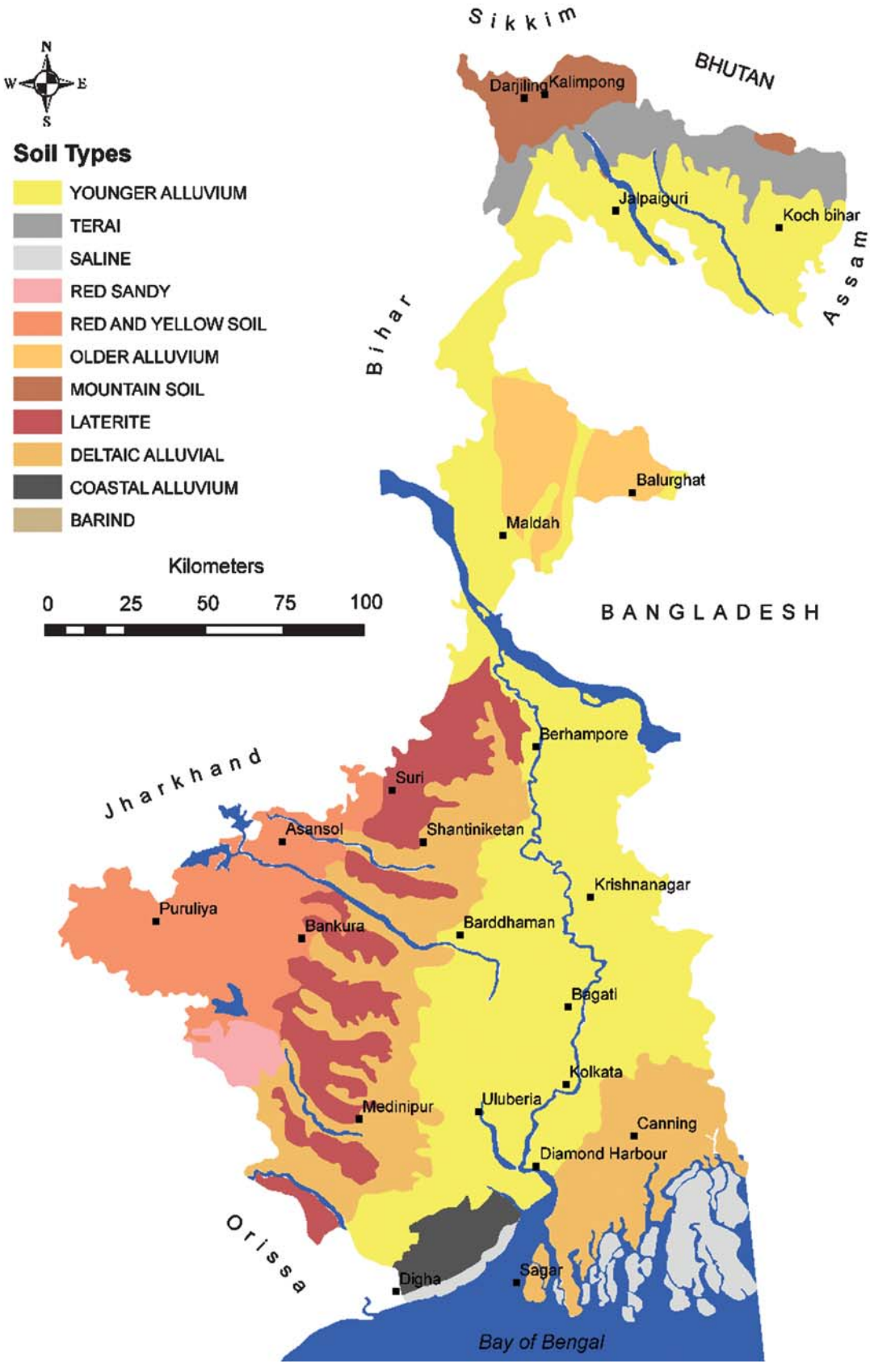

FIGURE 1.6 West Bengal soil types

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

the State has limiting soil depth and rest (94.7%) area is free from soil depth related problem.

The major problems of the soil degradation in West Bengal are due to water/wind erosion and deterioration of soil properties including physical deterioration in the form of waterlogging, flooding and chemical deterioration as salinization. About 30.9 per cent of total geographical area in West Bengal is degraded due to one of the above problems. About 19.7 per cent area in the districts of Puruliya, Bankura and Darjiling is affected due to loss of top soil by water erosion; while 3.2 per cent of area in the districts of South 24 Parganas and Purba Medinipur is degraded due to soil salinity and 6.9 per cent of area in North and South 24 Parganas, Medinipur, Hugli, Nadia and Maldah districts is degraded due to waterlogging for a significant period.

Natural vegetation

West Bengal has 13.38 per cent area (11,879 sq km) under forest. Out of the total recorded forest area of the State, 59.38 per cent area is under Reserved Forest areas and 31.75 per cent area is under Protected Forest areas. The remaining forest area is Unclassed State Forest.

The forest types differ spatially depending on many geographical factors like, latitude, altitude, rainfall, temperature, relative humidity, slope and soil. Wide variety of climatic conditions, soil characteristics, the State forest reserves can be broadly divided in to eight major forest types: Tropical semi-evergreen forests, tropical moist deciduous forests, littoral and swamp forests, tropical dry deciduous forests, sub-tropical broadleaved hill forests, montane wet temperate forests, Himalayan moist temperate forests and sub-alpine forests. West Bengal is the only the state in India having both coastal and alpine ecosystems and it harbours and sustain varied flora and fauna, including many rare and endangered species. The State has 53 per cent of bird species, 47 per cent of mammals, 32 per cent of reptiles and 21 per cent of angiosperms recorded in India. For protection of this unique biodiversity, the State has five national parks, fifteen sanctuaries, two tiger reserves, two elephant reserves, and one biosphere reserve.

Forest and wildlife management in the State aims at conservation of forests and biodiversity while being responsive to the livelihood needs of forest dependent people. To this end, a number of afforestation and conservation schemes are being implemented in the State.

River network

The West Bengal is the land of rivers. An intricate network of three major river basins (the Ganga, Brahmaputra and Subarnarekha) drain this State. The rivers of West Bengal and their basin areas are shown in Table 1.6.

North Bengal rivers deposits sediment load on the foothill
Source: Kalyan Rudra

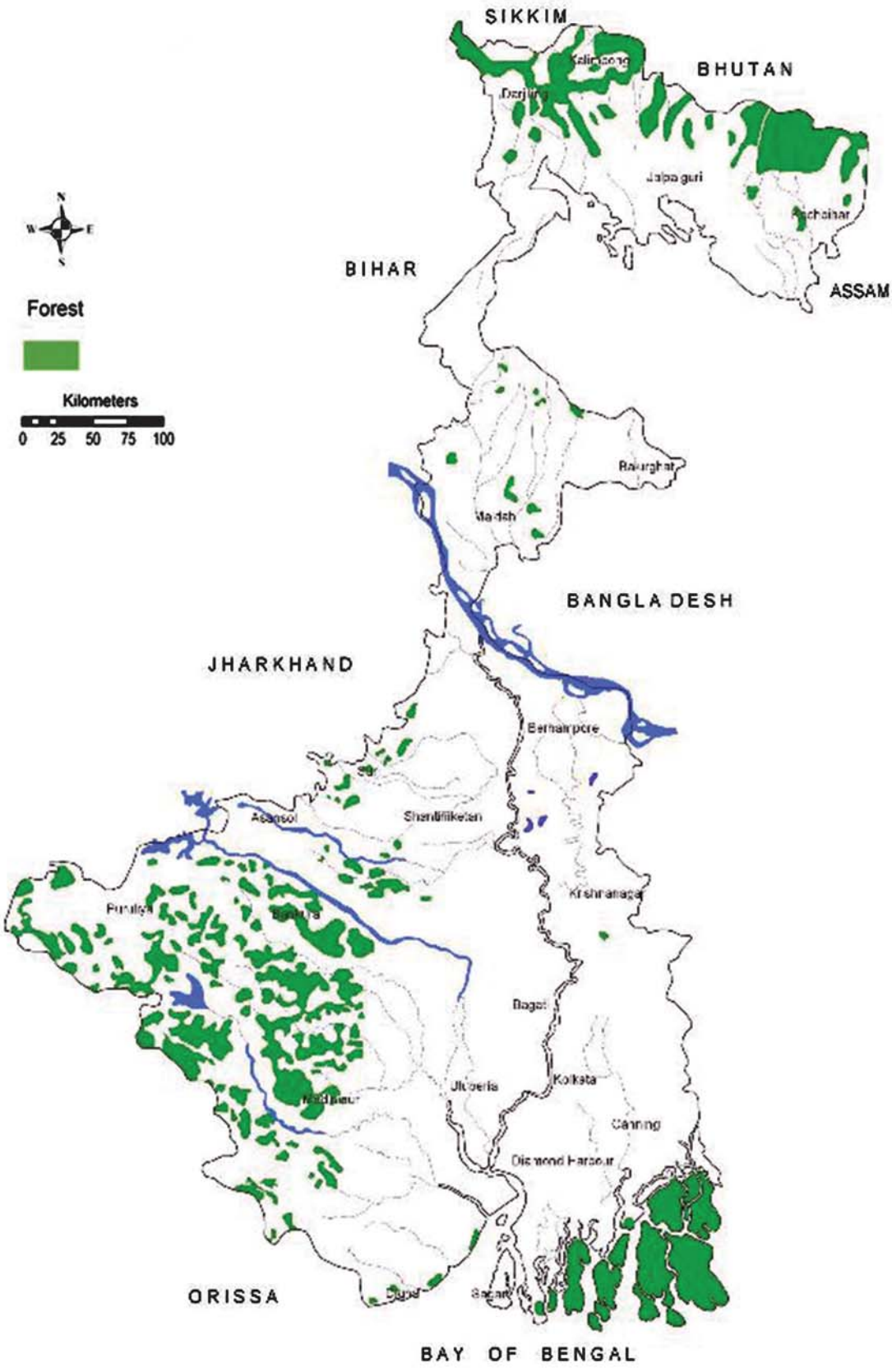

FIGURE 1.7 West Bengal forest cover

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

Rivers of North Bengal

The North Bengal is drained by six major rivers having the sources in the Himalaya beyond the northern border of West Bengal and they flow southward across Indo-Bangladesh border either into the Ganga or Brahmaputra. Five rivers drain into the Brahmaputra and only Mahananda drains to the Ganga.

The drainage map of North Bengal has changed appreciably during the known historical period. The Tista earlier discharged into Ganga through Karatoya, Atryee and Punarbhava. However, during the devastating flood of 1787, the mighty river migrated eastward to join the Brahmaputra at Bhairabbazar. Some experts believe that the east ward migration of Tista was due to the slow subsidence along the course of Brahmaputra or Jamuna in Bangladesh (Hirst, 1915; Morgan and McIntire, 1959). However, all rivers of North Bengal have been clogged with boulders, pebbles and sand and tend to alter their courses during monsoon months.

TABLE 1.4 Rivers and their basin area in West Bengal

Basin	Area in WB (km^2)	Area outside WB (km^2)
Raidak-Torsa	4063	7846
Jaldhaka	4140	880
Tista	3571	8588
Mahananda	7348	11887
Jamuna-Nagar	2728	8100
Feeder Canal-Bagmari	314	204
Bansloi	391	531
Pagla	364	914
Mayurakshi	9800	2200
Ajoy	3017	2983
Gangur-Banka-Khari	3280	-
Saraswati	1910	-
Damodar	6878	14622
Rupnarayan	11293	-
Kasai_Haldi	9332	-
Rasulpur	1674	-
Pichhabani	814	-
Subarnarekha	3720	15580
Bhairab-Gobra-Jalangi	4709	-
Mathabhanga-Churni	1699	-
Jamuna-Ichhamati	2309	-
Tidal creeks	5398	-
Total Area	**88752**	**74335**

Ganga-Bhagirathi system

The river Ganga enters the state dashing the Rajmahal hill of Jharkhand and flows about 80 km upto Farakka where a mighty barrage tames the river since 1975 to resuscitate the navigational status of the port of Kolkata by inducing 40,000 cusec of water into the Bhagirathi-Hugli river. The Ganga flows about 102 km between Farakka and Jalangi and approximately delineates Indo-Bangladesh border. The skewed hydrograph of the Ganga at Farakka, stratigraphy of bank, which is composed mostly of unconsolidated sand, and the influent-effluent seepage of water are the major causes of bank failure. The structural measures like construction of spur or bank revetments with boulders are expensive measures but do not offer guarantee against erosion. However, the gnawing Ganga renders thousands of people homeless every year and rehabilitation of those erosion-victims is serious challenge for the Government of West Bengal.

The river Bhagirathi takes off from the Ganga at a village called Mithipur (Murshidabad district), about 2 km. north of Jangipur or about 40 km to the south-east of Farakka Barrage. It flows southward for about 500 km and ultimately discharges into the Bay of Bengal at Gangasagar. The 280 km. stretch of river below Nabadwip is tidal. This tidal reach of river is known as Hugli. The Jalangi and Churni are two offshoots of Ganga-Padma and exceptionally flow southwest to join Bhagirathi at Mayapur and Payeradanga respectively. These two rivers drain an area of about 6408 sq km from Murshidabad and Nadia. Both Jalangi and Mathabhanga-Churni are now beheaded

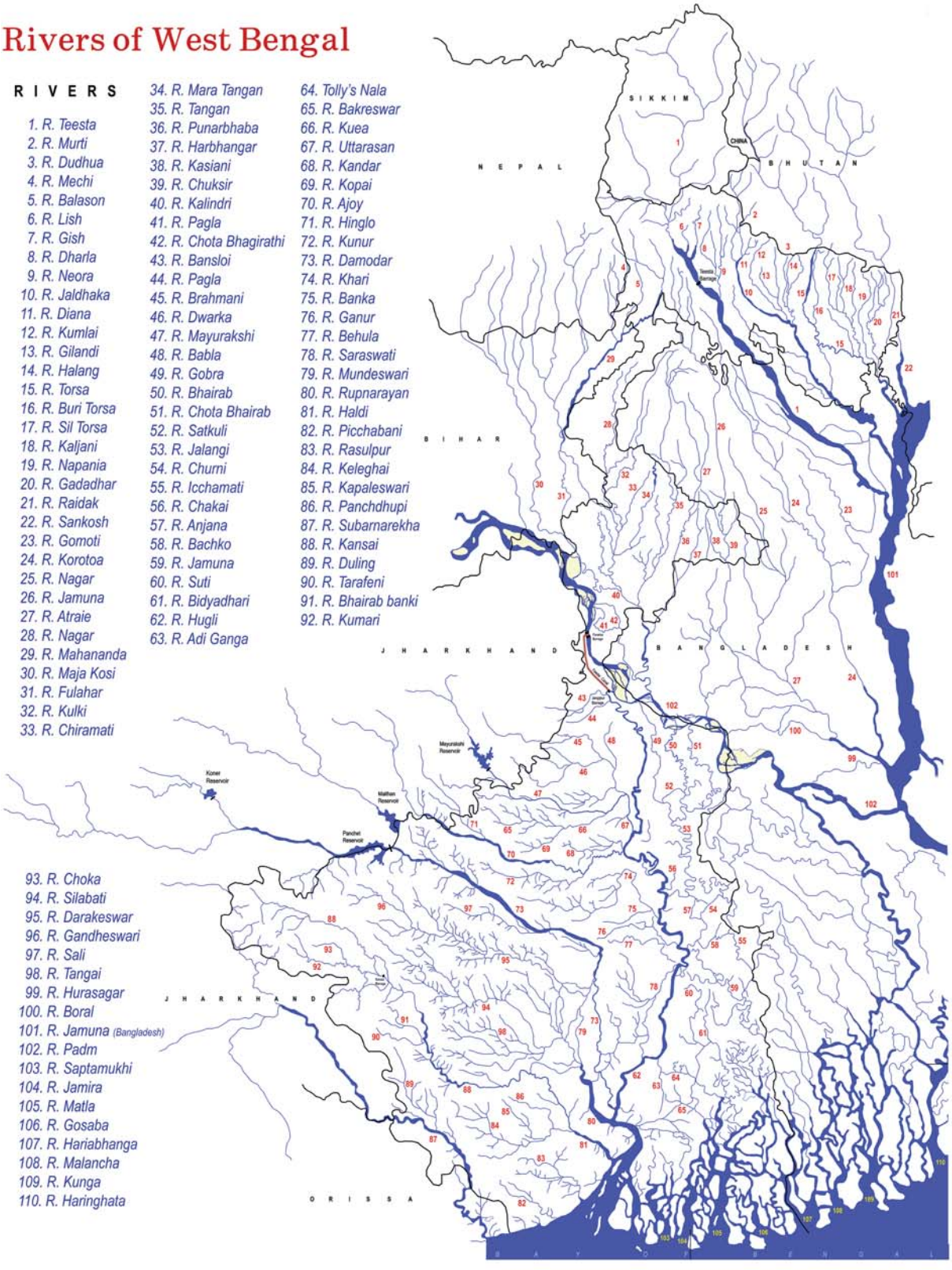

FIGURE 1.8 Drainage map of West Bengal

Source: Atlas of Changing River Courses in in West Bengal, Kalyan Rudra, 2012

from their feeder and do not get any upstream water supply during lean months. The Mathabhanga is bifurcated into two channels namely Churni and Ichhamati at Majhdia (Nadia). While Churni flows west, the Ichhamati flows south towards Sundarban.

In Murshidabad and Nadia, the Bhagirathi oscillates continuously within its meander-belt and many human settlements have so far been wiped out. Even the site of famous Nabadwip is also at peril. The nature of bank failure along the Bhagirathi is same like that in Maldah and Murshidabad. The Bhagirathi threw off three distributaries namely Saraswati, Hugli and Jamuna at Tribeni, which literally means three braids of hair. The popular Hinduistic belief is that three major rivers - Ganga, Jamuna and Saraswati joined together at Allahabad and as such it is known as *yuktabeni*. The same three rivers were branched off at Tribeni, which is *muktabeni*. However, the present moribund channel of Saraswati flows about 77 km through Hugli and Haora districts and again joins the parent river at Sankrail. The port of Satgaon or Saptagram developed on the eastern bank of Saraswati during mediaeval period. The Jamuna flowed eastward from Tribeni and joined Ichhamati at Charghat of North 24 Parganas.

River Hugli and Rabindra Setu
Source: Kalyan Rudra

Western tributaries

The Bhagirathi-Hugli is the only branch of the Ganga having some tributaries. These are Pagla, Bansloi, Mayurakshi, Ajoy, Khari-Banka, Damodar, Rupnarayan, Kansai - Haldi, Rasulpur and Pichhabani. All these rivers except last two originate from uplands of Chotanagpur and flows eastwards or south-eastwards into Bhagirathi.

Since these rivers are exclusively rainfed, many of them go dry during lean months. The western plateau is the upper catchments of all major tributaries to Bhagirathi and the areas are regionally covered with lateritic and red soil. Geomorphologically, the catchments have three segments. The upper part is the area of erosion with an adjoining area of sediment transfer and finally the lowermost area of deposition. All major rivers have formed para-deltas before their outfalls into the Bhagirathi and the plains lying to the west of it (*i.e.* Bhagirathi) is a series of coalescing deltas.

The catchment areas of these rivers have been extensively deforested due to expansion of agricultural land and growth of

Western tributaries deposit substantial sediment load on rarh plain
Source: Kalyan Rudra

human settlements. The increasing sediment load has been the major cause of decay of rivers, which are now choked with sand and silt. The combined catchment areas of these tributaries are about 70,551 sq km and about 30 per cent area of that lies in the Jharkhand.

Tidal creeks of Sundarbans

The Sundarbans is an area of incomplete morphogenesis. An area covering 4,267 sq km with numerous tidal creeks, intricate interlacing drainage, dense mangrove forest has marked it as a distinctive geographical region within the Ganga-Brahmaputra delta. Indian Sundarban expands over 9,630 sq km and delineated by Dampier and Hodges line in the north, Ichhamati-Hariabhanga in the east, Baratala estuary in the west and the Bay of Bengal in the south. Out of 13 creeks six have flown through Indian territory. These are Saptamukhi, Jamira, Matla, Bangaduni, Gosaba and Baratala. The large part of Sundarban is only three metres above mean sea level and tidal fluctuation is more than five metres. The extensive area goes under water during high tide. Since the second half of the eighteenth century, premature land reclamation started in Sundarban by the British rulers. The extensive areas were deforested; creeks and rivers were embanked to restrict the spill over of saline water into the flood plain. This impaired the delicate hydro-geomorphology of the delta. Since the spill over into the flood plain was restricted, uninterrupted sedimentation on the creeks and rivers led to the gradual decay of drainage system. Presently, drainage congestion and resultant water logging threaten the human settlement of Sundarbans.

Estuarine mangoves of Sundarbans
Source: Arjan Basu Roy

Mineral resource

West Bengal is dominantly (75% of the total area) underlain by soft rocks and the rock formations vary in age from Pre-Cambrian to Tertiary. The major land mass is covered by Quaternary formation. West Bengal has mineral reserves for coal, apatite, china clay, fire clay, dolomite, feldspar, quartz, iron ore, granite, silica sand etc. West Bengal is a major apatite reserve of the country and apatite is available in Puruliya and Bankura districts. The State possess about 16 per cent china clay reserve of the country spread over Bankura, Birbhum and Barddhaman districts. Besides these two, coal is available in Barddhaman, Bankura, Birbhum, Puruliya and Darjiling districts and fireclay in Bankura, Birbhum, Barddhaman and Puruliya districts, Other minerals available in the State are dolomite, feldspar, granite, lead-zinc, quartz, silica sand, limestone, barytes, manganese ore, copper, gold, kyanite, pyrite, titanium, dolomite, tungsten, vermiculite, sillimanite etc.

The value of mineral production in West Bengal in the year 2013-14 was Rs. 4,374 crore and the State accounted for about 2 per cent of the value of mineral production in the country (Indian Minerals Yearbook, 2014 (Part-I), State Reviews: West Bengal, Indian Bureau of Mines, Ministry of Mines, Govt. of India). Coal accounted for 93 per cent of the value of mineral production in the State. During 2013-14, the production of quartzite in the State increased by

TABLE 1.5 Mineral production in West Bengal, 2011-12 to 2013-14 (P) (Excluding Atomic Minerals)

(Value in Rs. '000)

Mineral	Unit	2011-12			2012-13			2013-14 (P)		
		No. of Mines	Quantity	Value	No. of Mines	Quantity	Value	No. of Mines	Quantity	Value
Coal	'000 t	100	24230	80662100	101	26467	108398800	100	28244	40794000
Natural Gas (utilised)	m cu m	-	84	604239	-	107	884904	-	166	1372841
Apatite	t	1	136	295	1	-	-	1	-	-
Felspar	t	*	5031	1947	*	13560	5148	*	19842	4622
Fireclay	t	6	82423	7974	6	99088	16489	6	95504	18278
Kaolin	t	11	92148	37249	13	98061	69047	8	90137	57654
Quartz	t	4	16084	5000	3	30262	9370	3	35521	12545
Quartzite	t	-	-	-	1	300	90	1	7090	2008
Silica Sand	t	1	51130	21730	1	71752	30908	1	62415	26786
Moulding Sand	t	1	30	5	1	305	82	1	490	134
Sulphur#	t	-	31749	-	-	36382	-	-	41901	-
Minor Minerals@	t	-	-	1455113	-	-	1455113	-	-	1455113
All Minerals	**-**	**124**	**-**	**82795652**	**127**	**-**	**110869951**	**121**	**-**	**43743981**

Note: The number of mines excludes minor minerals.
*associated with other minerals
Recovered as by-product from oil refinery.
@ Figures for earlier years have been repeated as estimates, wherever necessary, because of non-receipt of data.
Source: Indian Minerals Yearbook, 2014 (Part-I), State Reviews: West Bengal, Indian Bureau of Mines, Ministry of Mines, Govt. of India

manifolds, while the production of natural gas, feldspar, quartz, sulphur and coal has also increased compared to 2012-13. The number of reporting mines in West Bengal in 2013-14 was 121 for all minerals.

Energy scenario

West Bengal is a power surplus state and is in a position to export power to other states after meeting its internal demand fully. Thus the surplus power is banked with the power deficit states and is returned to West Bengal in the critical summer months. The per capita energy consumption of the State is below the national average. The power generation scenario in the State is given in Table 1.6 in respect of installed capacity of power generation and energy generation. At present, the State is significantly dependent on coal based thermal power plants. About 97 per cent power (in terms of energy) of the State comes from coal based thermal power stations and remaining 3 per cent power comes from other sources. Most of the hydro electric power plants of the State are located in the North Bengal except the Puruliya Pumped Storage scheme with a capacity of 900 MW. Besides, there are some captive thermal and biomass power plants in the State which have not been included with the total installed capacity.

Although the State has adequate capacity to generate quality electricity, it is important to strengthen the transmission and distribution network in the State for making power availability across the State, especially in rural Bengal.

According to the information available from the Department of Power and Non-conventional Energy Sources, Government of West Bengal, under Special BRGF Scheme (*Sabar Ghare Alo*) all household electrification works have been completed in Jalpaiguri, Alipurduar, Uttar Dinajpur, Dakshin Dinajpur, Maldah, Birbhum, Bankura,

TABLE 1.6 Installed capacity and generation of energy by Power Plants in West Bengal (Excluding NTPC)

Description	1980-81	1990-91	2000-01	2010-11	2011-12	2012-13
Installed capacity (MW)						
Total	2081.01	3271.06	5769.07	8441.83	9173.23	10569.37
Steam (Thermal)	1856.15	3042.38	5426.37	7298.20	8026.40	9428.00
Oil (Diesel)	26.35	22.37	18.00	0.82	0.82	0.82
Hydro (Hydel)	98.51	106.31	224.70	242.81	246.01	236.55
Gas	100.00	100.00	100.00	-	-	-
Pump Storage	-	-	-	900.00	900.00	900.00
Energy generated (MKWH)						
Total	6260.65	10304.19	22446.91	44432.94	47960.65	52233.15
Steam (Thermal)	5831.79	9933.15	21995.28 *	43142.91	86644.32	50877.95
Oil (Diesel)	16.75	0.52	0.50	0.88	0.47	0
Hydro (Hydel)	232.61	346.96	444.83 @	410.27	549.45	555.87
Gas	179.50	23.56	6.30	-	-	-
Pump Storage	-	-	-	878.88	766.41	797.50

Note :Installed Capacity at the end of the period i.e. as on 31st March.
* Including DVC's Hydel generation
@ Excluding DVC's Hydel Generation.
Source: Statistical Abstract 2013

Purba Medinipur and Paschim Medinipur districts. Household electrification works for Puruliya, Murshidabad and South 24 Parganas districts will be completed in early 2017. Moreover, under the RGGVY (XIIth Plan) electrification of BPL households in the remaining districts have been taken up. A new program under *Sech Bandhu* (DDUGJY) have been started for providing access to power for all households and also to improve the overall distribution infrastructure for round the clock power supply in rural areas of West Bengal. Grid power has been extended to Gosaba island in the Sundarban and all households in Sagar Island have been electrified.

The State is blessed with abundant sources of renewable energy in the form of solar, wind, biomass, biogas, hydro, tidal etc. Renewable energy is going to be the major source of energy in future and is closely associated with energy efficiency, energy conservation and climate change issues etc. The West Bengal Renewable Energy Development Agency (WBREDA) and the West Bengal Green Energy Development Corporation Ltd. (WBGEDCL) are working with various renewable energy sources. WBREDA has done a number of pioneering work in the field of renewable energy particularly in remote areas of the State.

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Milestones in Forestry, Directorate of Forests, Govt. of West Bengal, July 2014

Chapter 2

Demography

According to the nationwide census conducted in 2011, over 91 million people were living in West Bengal as of March 1, 2011. West Bengal is the fourth most populous state of India behind Uttar Pradesh, Maharashtra and Bihar. West Bengal had been the most densely populated state in the country (in terms of 'population density' or average number of persons living per square kilometre of area) as per the 1991 and the 2001 census. In the 2011 census, this State was found to have the second highest population density, behind Bihar. The density was found to be about 1,028 persons per sq km, which was almost three times the national average (368 persons per sq km). A demographic profile of the twenty districts of West Bengal is given in Table 2.1.

It is seen that the most populous districts are North and South 24 Parganas, Barddhaman and Murshidabad. Figure 2.1 gives a visual comparison of the populations of the districts, along with the rural/urban break-up. Apart from Kolkata, the districts of North 24 Parganas and Haora are found to have urbanisation above 50 per cent (that is, more than half of the population of these districts live in urban areas).

The population densities of all the districts except Kolkata are shown in Figure 2.2, along with the decomposition by caste. The corresponding bars for the entire State and the country are shown alongside. North 24 Parganas, Haora and Hugli, where the urban agglomeration around Kolkata has extended, have the highest population density. The least densely populated districts of Bankura and Puruliya also have population density higher than that of India. The percentage of scheduled tribe population is the largest in Alipurduar and Darjiling, while that of scheduled castes is the largest in Koch Bihar and Jalpaiguri.

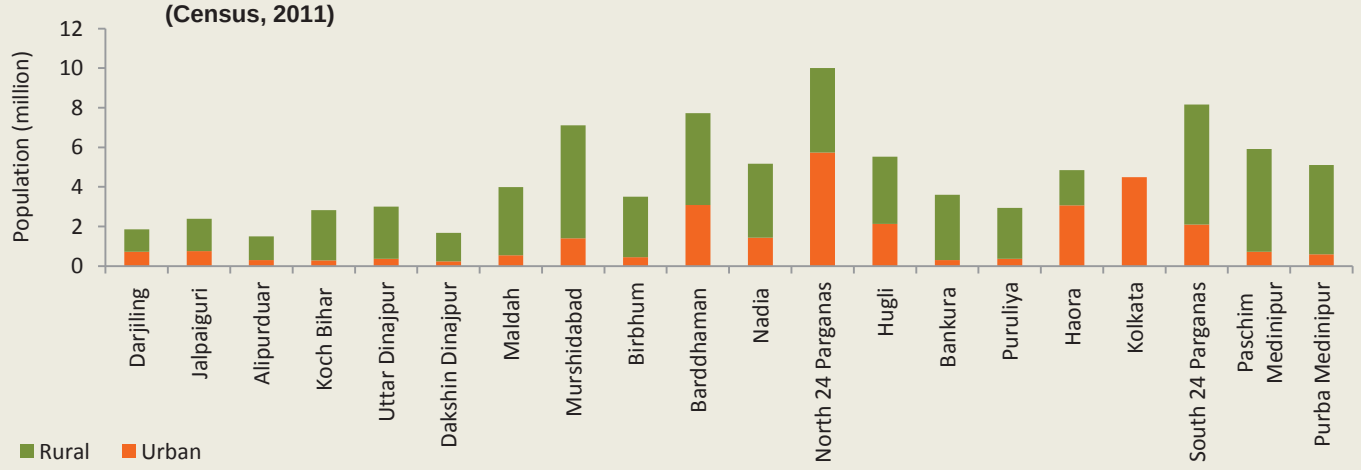
The sex ratio (number of females per 1,000 males) in West Bengal is marginally higher than the national value. The variation across the districts is shown in Figure 2.3. The urban sex ratio is generally smaller than rural sex ratio in India, which is partially due to male members of the family flocking to urban areas for work. This pattern is visible in West Bengal too, and is most notable in Kolkata, Alipurduar, Uttar Dinajpur and Maldah. In Koch Bihar, Dakshin Dinajpur and Murshidabad, the urban sex ratio by far exceeds the rural sex ratio.

TABLE 2.1 Population summary of the districts of West Bengal (Census, 2011)

Region	Population	Population density (persons per sq km)	Urbanisation (%)	SC (%)	ST (%)	Literacy rate (%)	Sex ratio	SC sex ratio	ST sex ratio	0-6 year children (%)	0-6 year sex ratio
Darjiling	1846823	586.5	39.4	17.2	21.5	79.6	970	965	1015	10.5	953
Jalpaiguri	2381596	700.0	31.6	42.1	14.7	73.4	956	942	1010	12.1	956
Alipurduar	1491250	527.9	20.6	30.6	25.6	73.0	948	942	991	11.6	954
Koch Bihar	2819086	832.3	10.3	50.2	0.6	75.5	942	941	931	12.2	948
Uttar Dinajpur	3007134	957.7	12.0	26.9	5.4	60.1	939	932	990	16.1	953
Dakshin Dinajpur	1676276	755.4	14.1	28.8	16.4	73.9	956	944	995	11.2	957
Maldah	3988845	1068.5	13.6	20.9	7.9	62.7	944	931	993	15.3	950
Murshidabad	7103807	1334.3	19.7	12.6	1.3	67.5	958	951	972	14.3	968
Birbhum	3502404	770.6	12.8	29.5	6.9	70.9	956	953	1024	12.8	959
Barddhaman	7717563	1098.7	39.9	27.4	6.3	77.2	945	960	1009	10.8	951
Nadia	5167600	1315.9	27.8	29.9	2.7	75.6	947	938	978	10.2	960
North 24 Parganas	10009781	2445.0	57.3	21.7	2.6	85.0	955	945	972	9.6	956
Hugli	5519145	1752.7	38.6	24.4	4.2	82.6	961	974	1024	9.7	952
Bankura	3596674	522.6	8.3	32.7	10.3	71.0	957	979	1010	11.6	949
Puruliya	2930115	468.1	12.7	19.4	18.5	65.4	957	953	989	14.0	953
Haora	4850029	3306.1	63.4	14.8	0.3	83.9	939	959	945	10.8	962
Kolkata	4496694	24306.5	100.0	5.4	0.2	87.1	908	889	865	7.5	933
South 24 Parganas	8161961	819.5	25.6	30.2	1.2	78.6	956	946	971	12.6	963
Paschim Medinipur	5913457	631.2	12.2	19.1	14.9	79.0	966	979	1001	11.6	963
Purba Medinipur	5095875	1081.2	11.6	14.6	0.5	87.7	938	943	969	11.5	946
West Bengal	91276115	1028.4	31.9	23.5	5.8	76.3	950	951	999	11.6	956
India	1210854977	368.3	31.1	16.6	8.6	73.0	943	945	990	13.6	918

Source: Primary Census Abstract, 2011. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district. The area of Kalchini block of Alipurduar district, for which a gross underestimate is given in the Handbook, has been adjusted for consistency with the aggregate areas and the map given there. The population density of Alipurduar reflects this adjustment.

FIGURE 2.1 Population in the districts of West Bengal, with rural/urban composition (Census, 2011)



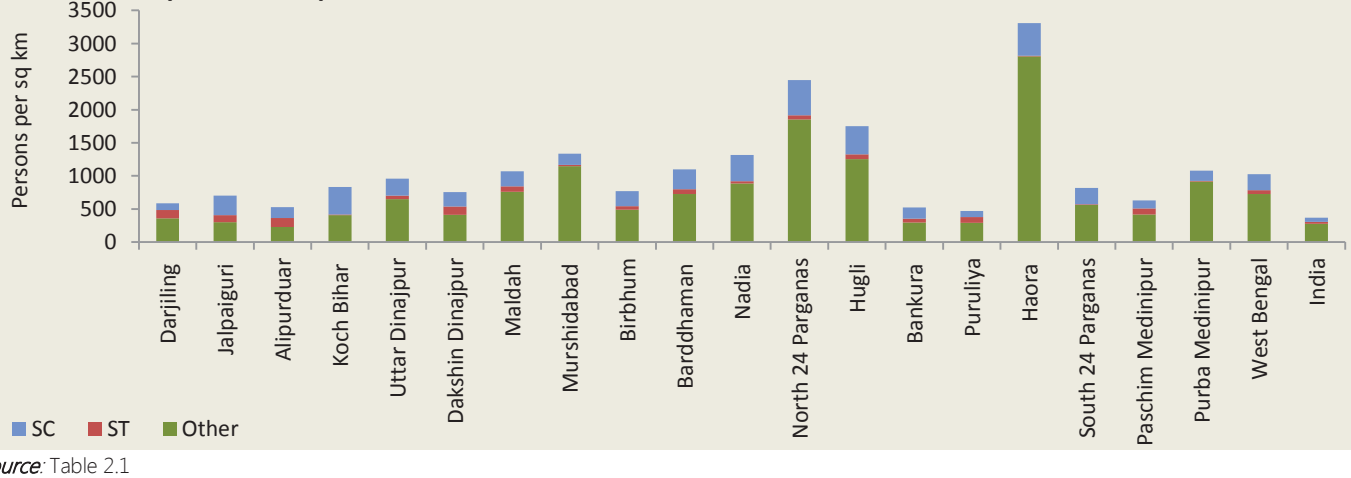
Source: Table 2.1

TABLE 2.1 Population summary of the districts of West Bengal (Census, 2011) (contd..)

Region	Rural							Urban						
	Population	0-6 year children (%)	SC (%)	ST (%)	Literacy rate (%)	Sex ratio	0-6 year sex ratio	Population	0-6 year children (%)	SC (%)	ST (%)	Literacy rate (%)	Sex ratio	0-6 year sex ratio
Darjiling	1118860	11.3	20.1	28.5	74.3	973	965	727963	9.1	12.7	10.8	87.5	966	930
Jalpaiguri	1628791	12.8	46.9	20.0	69.6	954	958	752805	10.6	31.5	3.1	81.5	961	951
Alipurduar	1183704	12.0	33.4	30.7	70.0	961	956	307546	9.9	20.0	6.0	84.5	899	944
Koch Bihar	2529652	12.6	53.4	0.7	73.2	939	949	289434	8.8	22.0	0.4	88.4	974	937
Uttar Dinajpur	2644906	16.7	28.0	6.0	56.0	941	953	362228	11.8	18.4	1.2	80.3	921	955
Dakshin Dinajpur	1439981	11.8	30.6	18.6	70.1	952	957	236295	7.9	18.0	3.2	88.7	979	958
Maldah	3447185	15.4	22.3	8.9	59.4	949	960	541660	14.5	12.5	1.2	76.6	913	882
Murshidabad	5703115	14.3	12.8	1.5	65.3	955	968	1400692	14.3	12.1	0.4	71.8	974	970
Birbhum	3052956	13.1	30.6	7.6	69.1	955	962	449448	10.5	22.0	2.2	81.1	963	934
Barddhaman	4639264	11.0	32.9	8.2	72.6	954	962	3078299	10.4	19.2	3.6	81.5	932	935
Nadia	3728727	10.9	30.6	3.2	70.8	941	962	1438873	8.3	28.2	1.4	85.4	964	953
North 24 Parganas	4277619	11.5	29.3	4.6	77.4	947	960	5732162	8.1	16.0	1.2	88.9	961	951
Hugli	3390646	10.3	31.1	6.2	78.5	968	954	2128499	8.7	13.6	0.8	86.9	950	948
Bankura	3296901	11.9	33.5	11.1	68.9	956	947	299773	9.0	22.9	1.1	84.4	968	965
Puruliya	2556801	14.3	19.2	20.8	62.7	960	956	373314	12.1	20.7	2.4	76.2	936	933
Haora	1775885	11.6	23.0	0.2	80.0	953	965	3074144	10.3	10.1	0.4	85.2	932	960
Kolkata	0	--	--	--	--	--	--	4496694	7.5	5.4	0.2	86.3	908	933
South 24 Parganas	6074188	13.3	34.0	1.5	75.7	954	964	2087773	10.5	19.2	0.3	82.7	961	957
Paschim Medinipur	5190771	11.9	19.9	16.4	76.9	965	962	722686	9.4	13.0	3.7	86.0	974	972
Purba Medinipur	4503161	11.6	15.0	0.5	86.8	939	945	592714	10.7	11.5	0.7	88.6	929	958
West Bengal	62183113	12.6	27.5	7.8	72.1	953	959	29093002	9.5	15.0	1.5	84.8	944	947
India	833748852	14.6	18.5	11.3	67.8	949	923	377106125	11.5	12.6	2.8	84.1	929	905

Source: Primary Census Abstract, 2011. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

FIGURE 2.2 Population density in the districts of West Bengal, with caste composition (Census 2011)



Source: Table 2.1

FIGURE 2.3 **Sex ratio in rural and urban areas of the districts of West Bengal (Census 2011)**

Source: Table 2.1

TABLE 2.2 **Age distribution of male and female populations of West Bengal (Census, 2011)**

Region	Male						Female					
	Percentage of persons in age range (years)					Median age	Percentage of persons in age range (years)					Median age
	0-6	7-18	19-45	46-60	60+		0-6	7-18	19-45	46-60	60+	
Darjiling	10.57	24.14	45.02	13.39	6.88	26	10.37	23.69	47.01	12.63	6.30	26
Jalpaiguri & Alipurduar	11.91	24.83	43.62	13.64	6.00	25	11.94	25.02	44.87	12.32	5.85	25
Koch Bihar	12.20	24.94	42.75	13.81	6.30	25	12.27	24.84	43.76	12.54	6.59	25
Uttar Dinajpur	16.02	29.86	38.20	10.88	5.04	21	16.27	29.77	38.98	10.01	4.97	20
Dakshin Dinajpur	11.23	25.69	42.83	13.82	6.43	25	11.24	25.02	44.41	12.67	6.66	26
Maldah	15.23	28.68	39.91	11.12	5.06	22	15.32	28.46	40.68	10.24	5.30	21
Murshidabad	14.20	27.80	41.06	11.51	5.43	22	14.35	27.45	41.41	10.65	6.14	22
Birbhum	12.79	25.32	42.94	13.36	5.60	25	12.84	24.23	43.93	12.68	6.32	25
Barddhaman	10.76	22.61	45.54	14.52	6.56	27	10.83	22.29	46.39	13.38	7.10	27
Nadia	10.10	22.62	45.23	14.60	7.45	28	10.24	22.41	45.90	13.07	8.39	27
North 24 Parganas	9.58	21.01	45.35	15.54	8.52	29	9.59	20.91	46.87	14.07	8.57	28
Hugli	9.71	20.82	45.36	15.91	8.19	30	9.62	20.72	46.73	14.31	8.61	29
Bankura	11.69	23.62	43.64	13.90	7.15	26	11.59	22.49	43.94	13.42	8.56	27
Puruliya	14.04	25.36	41.06	12.59	6.94	25	13.99	24.29	41.42	12.61	7.69	25
Haora	10.67	21.91	45.87	14.23	7.32	28	10.92	22.14	46.54	12.80	7.59	27
Kolkata	7.49	17.97	46.65	17.71	10.18	32	7.69	18.06	47.54	16.46	10.25	31
South 24 Parganas	12.54	24.54	44.13	12.25	6.53	25	12.63	24.59	44.70	11.31	6.76	25
Paschim Medinipur	11.64	23.60	43.73	13.93	7.09	26	11.58	22.96	45.22	12.59	7.64	26
Purba Medinipur	11.49	23.64	44.39	13.03	7.45	26	11.59	23.61	45.19	12.05	7.56	26
West Bengal	11.57	23.75	43.87	13.81	6.99	26	11.64	23.50	44.80	12.69	7.36	26
India	13.81	26.05	41.49	11.83	6.83	24	13.45	24.91	42.05	12.13	7.45	25

Source: Census of India, 2011, Table C-13 for West Bengal and India

The overall sex ratio among the scheduled tribe communities of most of the districts is close to 1,000, as found elsewhere in India.

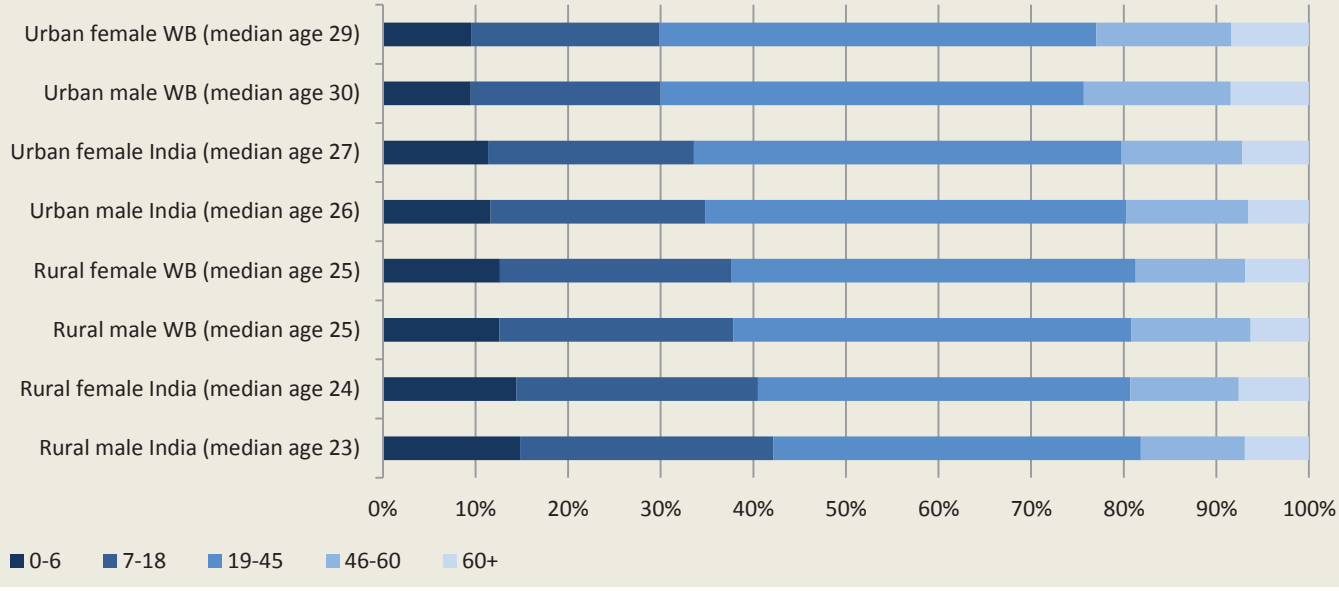
The sex ratio in the country has been found to have improved in successive rounds of census since 1991. However, the sex ratio among children of 0-6 years of age (905) is much lower than in the general population (929). This disturbing pattern is not there in West Bengal. Table 2.1 shows that the sex ratio among this group of children in all the districts is consistently far above the national level.

The very young population (0-6 years) of West Bengal is a smaller proportion of the general population (11.6%) compared to the national average (13.6%). This two per cent gap is present both in rural and urban areas. In the urban areas of West Bengal, this percentage is lower (9.5%) than in the rural areas (12.6%). This pattern persists across all the districts except Murshidabad, where the rural and urban percentages are very similar.

The distribution of the male and female population over different ranges of age is shown in Table 2.2, together with the median ages. It can be observed from this table that the districts of Uttar Dinajpur, Maldah and Murshidabad have the youngest population (for both males and females) in the State, as there are large proportions of people in these districts who belong to the younger age ranges, and the median age is also small. All the other districts generally have an older population than India as a whole. Kolkata has the oldest population of both males and females.

There is also a considerable difference between the age distributions in rural and urban areas. Figure 2.4 shows the age distributions in West Bengal and India by gender and residence. The rural populations are found to be younger than the corresponding urban populations.

FIGURE 2.4 Age distributions of different sections of the people of West Bengal and India (Census, 2011)



Source: Census of India Table C-13 for West Bengal and India.

Literacy

Table 2.1 shows that according to the 2011 census, the average literacy rate in West Bengal (76.3%) is higher than in the country (73.0%). The gap is higher in the rural areas. The district-wise rural and urban literacy rates are shown in the clustered bar chart of Figure 2.5. The urban literacy rate is above 80 per cent in all the districts except Murshidabad, Maldah and Puruliya. The rural literacy rate is below 80 per cent in all the districts except in Purba Medinipur. Uttar Dinajpur and Maldah has rural literacy rate below 60 per cent.

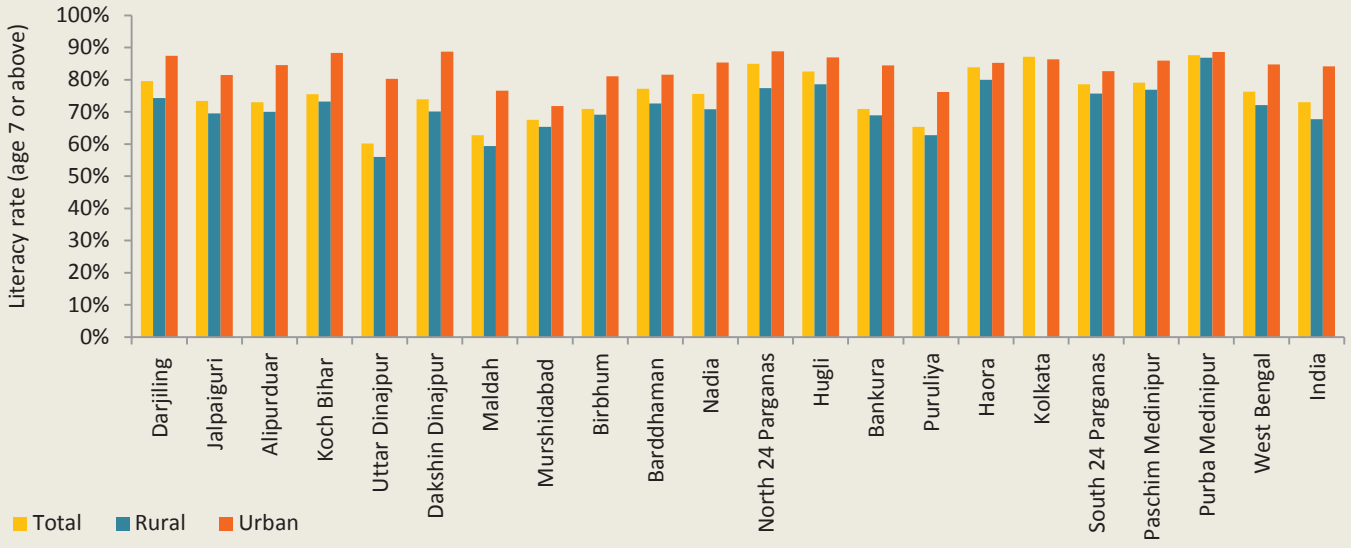
Table 2.3 shows the literacy rates by gender, and a comparative bar chart is given in Figure 2.6. It is clear that there is across-the-board gap between male and female literacy, which is most pronounced in Bankura and Puruliya. Elsewhere the gender gap is less than the national average (16.2%).

TABLE 2.3 Gender specific literacy rates in the districts of West Bengal (Census, 2011)

Region	Literacy rate (%)	Male literacy rate			Female literacy rate			Gender gap in literacy		
		Total (%)	Rural (%)	Urban (%)	Total (%)	Rural (%)	Urban (%)	Total (%)	Rural (%)	Urban (%)
Darjiling	79.6	85.6	81.8	91.4	73.3	66.6	83.5	12.3	15.2	7.9
Jalpaiguri	73.4	80.1	77.3	86.1	66.4	61.4	76.8	13.8	15.9	9.3
Alipurduar	73.0	79.7	77.3	88.4	66.0	62.4	80.2	13.7	14.9	8.1
Koch Bihar	75.5	80.7	79.4	91.6	68.5	66.5	85.0	12.2	13.0	6.6
Uttar Dinajpur	60.1	65.5	62.8	83.9	52.2	48.7	76.3	13.3	14.1	7.6
Dakshin Dinajpur	73.9	78.4	76.1	91.8	67.0	63.8	85.5	11.4	12.3	6.3
Maldah	62.7	66.2	64.2	78.9	57.0	54.3	74.0	9.3	9.9	4.9
Murshidabad	67.5	69.9	68.4	76.2	63.1	62.0	67.3	6.9	6.4	8.9
Birbhum	70.9	76.9	75.6	86.0	64.1	62.3	76.0	12.8	13.2	10.0
Barddhaman	77.2	82.4	79.1	87.3	69.6	65.9	75.3	12.8	13.3	12.0
Nadia	75.6	78.8	74.8	88.9	71.0	66.7	81.6	7.8	8.1	7.3
North 24 Parganas	85.0	87.6	81.9	91.8	80.3	72.6	85.8	7.3	9.3	5.9
Hugli	82.6	87.0	84.8	90.5	76.4	72.1	83.1	10.7	12.7	7.4
Bankura	71.0	80.0	79.1	90.1	60.1	58.3	78.5	20.0	20.8	11.6
Puruliya	65.4	77.9	76.8	84.6	50.5	48.1	67.1	27.3	28.8	17.5
Haora	83.9	87.0	84.7	88.2	79.4	75.0	82.0	7.5	9.8	6.2
Kolkata	87.1	88.3	--	88.3	84.1	--	84.1	4.3	--	4.3
South 24 Parganas	78.6	83.3	82.1	86.8	71.4	68.9	78.4	11.9	13.2	8.3
Paschim Medinipur	79.0	85.3	84.5	90.4	70.5	68.9	81.3	14.8	15.6	9.1
Purba Medinipur	87.7	92.3	92.2	92.9	81.4	81.0	84.0	11.0	11.2	8.9
West Bengal	76.3	81.7	78.4	88.4	70.5	65.5	81.0	11.2	12.9	7.4
India	73.0	80.9	77.1	88.8	64.6	57.9	79.1	16.2	19.2	9.7

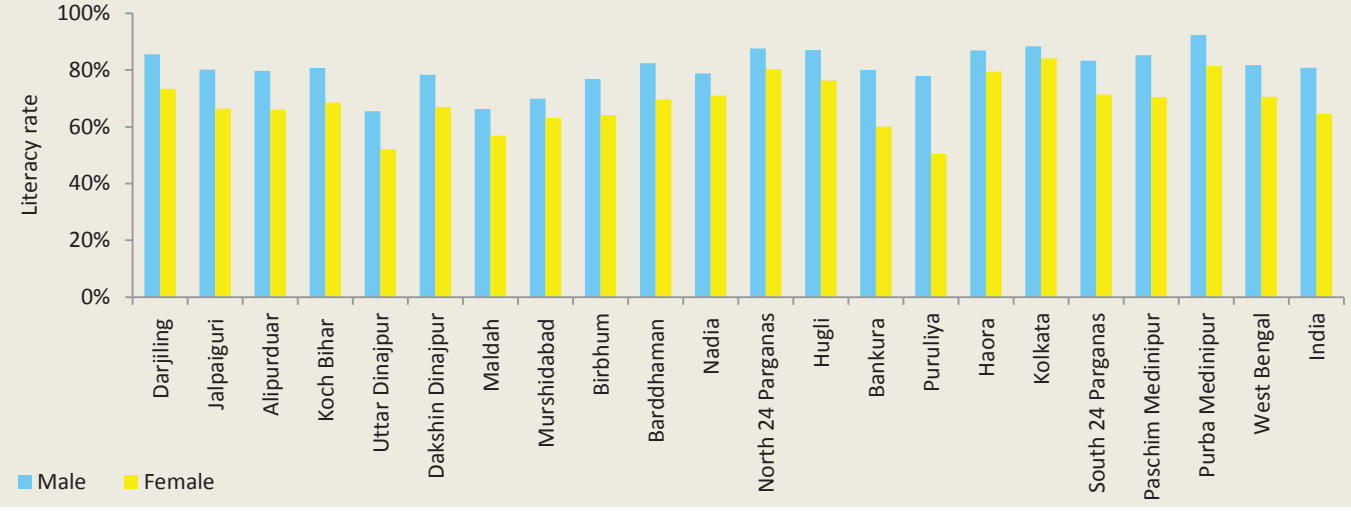
Source: Primary Census Abstract, 2011. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

FIGURE 2.5 Literacy rates in rural and urban areas of the districts of West Bengal (Census, 2011)



Source: Table 2.1

FIGURE 2.6 Male and female literacy rates in the districts of West Bengal (Census, 2011)



Source: Table 2.3.

Religion

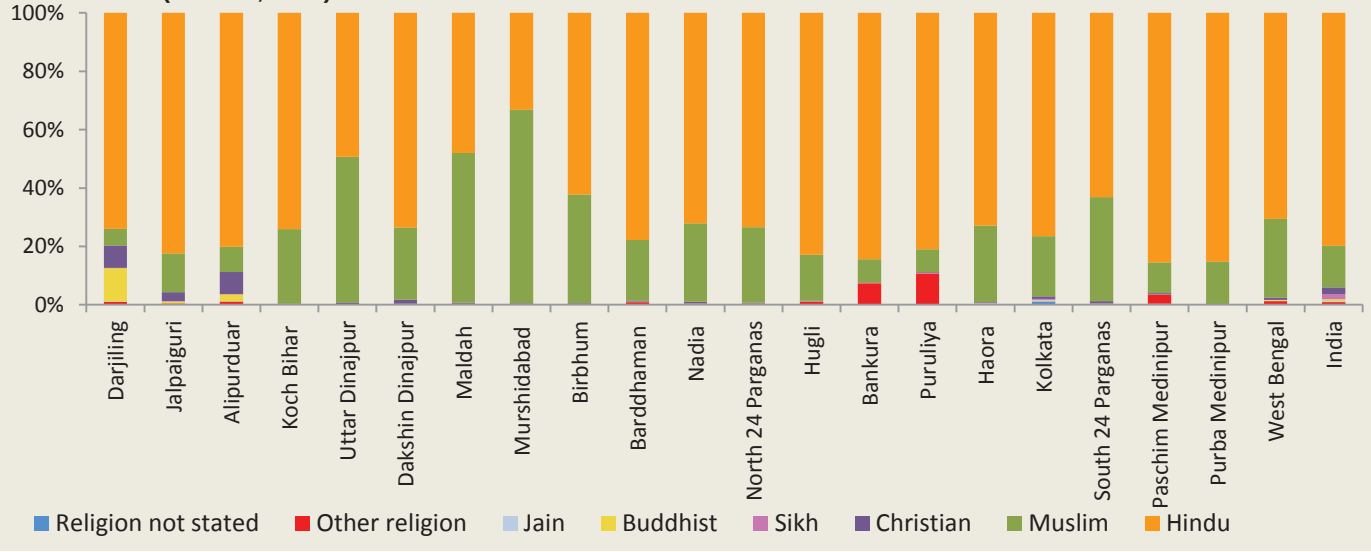
The numbers of followers of different religions in the districts of West Bengal are listed in Table 2.4, and the corresponding distributions shown in the composite bar chart of Figure 2.7. It is seen that as of 2011, the majority of the population in most of the districts are hindu, while the muslim religion is most popular in Mursidabad, Maldah and Uttar Dinajpur. There is a significant presence of christians in Darjiling, Alipurduar and Jalpaiguri. Buddhists are most prominently present in Darjiling and Alipurduar. The prevalence of 'other religion' in Puruliya, Bankura and Paschim Medinipur is accounted for mostly by the tribal population present there. More than 1 per cent of the population of Kolkata declined to state their religion.

TABLE 2.4 Number of persons of West Bengal having different religions (Census, 2011)

Region	Hindu	Muslim	Christian	Sikh	Buddhist	Jain	Other religions	Religion not stated
Darjiling	1366681	105086	141848	2032	209240	1840	15523	4573
Jalpaiguri	1962679	315478	74188	1064	15358	596	8950	3283
Alipurduar	1194102	130339	112091	1930	35318	865	14866	1739
Koch Bihar	2087766	720033	4122	449	445	1869	158	4244
Uttar Dinajpur	1482943	1501170	16702	477	432	1324	1622	2464
Dakshin Dinajpur	1232850	412788	24794	276	148	323	2786	2311
Maldah	1914352	2045151	13209	747	359	639	7929	6459
Murshidabad	2359061	4707573	18102	766	348	3037	7429	7491
Birbhum	2181515	1298054	10906	582	258	1152	6051	3886
Barddhaman	6008472	1599764	21220	16675	1602	1674	44968	23188
Nadia	3728482	1382682	33835	849	514	281	16893	4064
North 24 Parganas	7352769	2584684	26933	9394	5818	4452	2930	22801
Hugli	4574569	870204	7300	2662	1730	2160	49050	11470
Bankura	3033581	290450	3865	386	260	2904	260694	4534
Puruliya	2373120	227249	8646	622	209	3052	309029	8188
Haora	3535844	1270641	8666	4380	1258	9699	1265	18276
Kolkata	3440290	926414	39758	13849	4771	21178	1452	48982
South 24 Parganas	5155545	2903075	66498	2783	2494	972	6065	24529
Paschim Medinipur	5056953	620554	23287	2854	2019	1550	184278	21962
Purba Medinipur	4343972	743436	2648	746	317	574	359	3823
West Bengal	64385546	24654825	658618	63523	282898	60141	942297	228267
India	966257353	172245158	27819588	20833116	8442972	4451753	7937734	2867303

Source: Census of India, 2011 census data, population enumeration data, Data on religion (TableC-01). The block/ town level data for the erstwhile Jalpaiguri district, available in this table, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

FIGURE 2.7 Distribution of the population of West Bengal by religion (Census, 2011)



Source: Table 2.4.

Language

During the census of 2001, people were asked about their mother tongue. The summary of those data remains the latest state-specific information available on the subject. Table 2.5 gives a list of languages in decreasing order of the number of speakers. Alongside the number of speakers, the proportion of all speakers of that language in India who reside in West Bengal are calculated. This proportion shows the importance of West Bengal with respect to that language. It is seen from the table that West Bengal is an important habitat for people with mother tongue Bengali, Koda/Kora, Nepali, Santali and Lepcha. This is in spite of the fact that the actual number of people with Koda/Kora and Lepcha as mother tongue is very small. The most common mother tongues in West Bengal are Bengali, Hindi, Santali, Urdu and Nepali, in that order.

State-specific information about the number of people speaking a second or a third language is not available in an organized form in the 2001 census data. Table 2.6 summarizes the 1991 data on additional languages spoken by those who named one of the five most popular languages of West Bengal as their mother tongues. For each of the five mother tongues, the number and percentage of bilingual and trilingual persons are also mentioned. Every bilingual person was asked to name a second language, and a third one where applicable. The frequency and percentage of popular second languages are shown in the table. For the third language, only the name of the language is mentioned. It is found that over 90 per cent of the Bengali speakers speak only Bengali. About three-quarters of the speakers of Hindi, Nepali and Urdu are monolingual. In contrast, the majority of the Santali speakers are either bilingual or trilingual. Half of them speak Bengali.

While some individuals may learn several languages as a matter of their liking, the extent of multilingualism cannot vary too much from one large group to another because of voluntary choices alone. There has to be a matter of compulsion behind more multilingualism in one group in comparison to others. A person belonging to the linguistic majority of the State would not feel compelled to learn another language in order to carry out day-to-day activities, while a person belonging to a linguistic minority may feel otherwise. Indeed, at the national level, it was found

TABLE 2.5 Most popular 21 mother tongues in West Bengal (Census, 2001)

Language	Language type	Number of speakers	Share of West Bengal among all speakers of this language in India (%)
Bengali	Scheduled	68369255	82.01
Hindi	Scheduled	5747099	1.36
Santali	Scheduled	2247113	34.73
Urdu	Scheduled	1653739	3.21
Nepali	Scheduled	1022725	35.61
Telugu	Scheduled	208769	0.28
Kurukh/ Oraon	Non-scheduled	201309	11.49
Oriya	Scheduled	186391	0.56
Punjabi	Scheduled	67952	0.23
Munda	Non-scheduled	61862	13.18
Gujarati	Scheduled	46926	0.10
Bodo	Scheduled	37654	2.79
Koda/ Kora	Non-scheduled	33218	77.20
Mundari	Non-scheduled	32571	3.07
Maithili	Scheduled	22064	0.18
Tamil	Scheduled	20238	0.03
Malayalam	Scheduled	17043	0.05
English	Non-scheduled	15681	6.92
Marathi	Scheduled	15176	0.02
Lepcha	Non-scheduled	14731	29.10
Rabha	Non-scheduled	10967	6.66
Other scheduled languages	Scheduled	21602	0.03
Other non-scheduled languages	Non-scheduled	122112	0.39
Total		**80176197**	**7.79**

Source: Census of India, Census 2001 data online, Languages and mother tongues.

during the 2001 census that 88 per cent of Hindi-speakers, the largest linguistic group, are monolingual, about 80 per cent of the Bengali speakers (including those residing outside West Bengal) are monolingual, while less than half of the Santali, Nepali, Urdu, Kurukh/Oraon and Munda speakers are monolingual (*see Census of India, Census 2001 data online, C-series: Social and cultural tables*). Thus, the pattern seen in West Bengal in 1991 was no different from the national pattern in 2001. Interestingly, Hindi, Nepali and Urdu speakers of West Bengal have a moderately high percentage of monolinguals, which may be due to their living in linguistically homogeneous clusters. The speakers of Santali and other adivasi languages are apparently more fragmented. These groups live mostly in rural areas, and sometimes in and around forests. The extremely high percentage of multilingual people among these groups indicates a form of stress, which may be indirectly linked to stress on the environment.

TABLE 2.6 Five most popular mother tongues in West Bengal, by second and third languages spoken (Census, 1991)

Language	Number of people with this language as mother tongue	Number of people speaking only this language	Number of people speaking exactly one other language	Number of people speaking two or more additional languages	Second language of speakers of this language	Number of speakers of these two languages	Third languages mentioned by speakers of these two languages
Bengali	58541519 (100%)	52912962 (90.4%)	3853144 (6.6%)	1775423 (3.0%)	English	4438559 (7.6%)	Hindi
					Hindi	1190008 (2.0%)	English
Hindi	4479170 (100%)	3375155 (75.4%)	936364 (20.9%)	167651 (3.7%)	Bengali	775966 (17.3%)	English
					English	283257 (6.3%)	Bengali
					Nepali	44792 (1.0%)	
Santali	1858010 (100%)	900499 (48.5%)	929259 (50.0%)	28252 (1.5%)	Bengali	929514 (50.0%)	English, Hindi
					Hindi	18580 (1.0%)	
					English	9417 (0.5%)	
Nepali	860403 (100%)	657175 (76.4%)	125228 (14.6%)	78000 (9.1%)	Hindi	142624 (16.6%)	English, Bengali
					English	34604 (4.0%)	Hindi
					Bengali	26000 (3.0%)	Hindi
Urdu	1455649 (100%)	1084793 (74.5%)	286456 (19.7%)	84400 (5.8%)	Hindi	155447 (10.7%)	Bengali, English
					Bengali	118188 (8.1%)	Hindi, English
					English	53551 (3.7%)	Hindi, Bengali
					Arabic/Arbi	43670 (3.0%)	

Source: eCENSUSIndia, Issue 19, 2003.

Population trends

The population of West Bengal, enumerated in the successive rounds of census after independence, are shown in Table 2.7. Over this span of six decades, the population of West Bengal has risen 3.47 times, whereas the national population has risen by a factor of 3.35 only. Much of the rise in West Bengal took place in the early decades after independence and was fuelled by migration from neighbouring states and East Pakistan/Bangladesh.

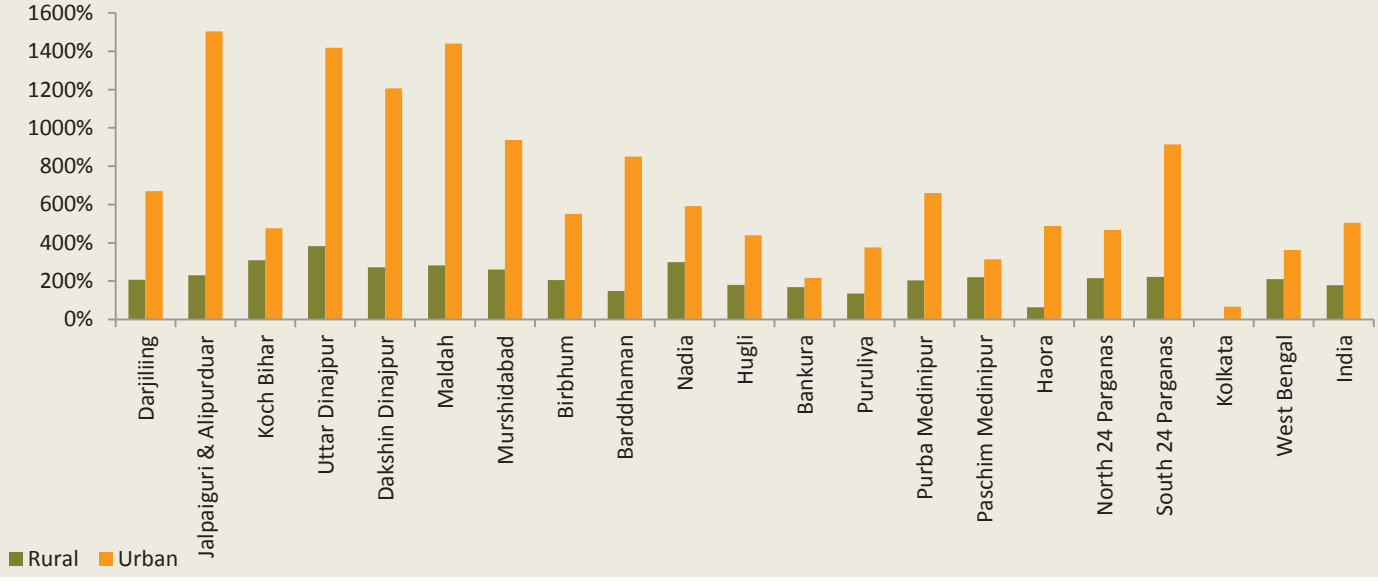
The populations of the districts during these rounds of census are summarized in Table 2.8. The overall growth of population in the districts from 1951 to 2011 is depicted in Figure 2.8. In the case of a district that did not exist in 1951, the growth of the present district during the period prior to its formation is assumed to be equal to the growth of the parent district during that period. It may be observed that many of the border districts (e.g., Jalpaiguri, Alipurduar, Maldah, Uttar and Dakshin Dinajpur) have witnessed a dramatic rise in the urban population. As for the rural population, the rise has been the largest in Uttar and Dakshin Dinajpur, Koch Bihar, Nadia and Maldah, which are also border districts.

TABLE 2.7 Population of West Bengal and India in successive rounds of census after independence

		1951	1961	1971	1981	1991	2001	2011
West Bengal	Total	26299980	34926279	44312011	54580647	68077965	80176197	91276115
	Rural	20018338	26385439	33344988	40133926	49370364	57748946	62183113
	Urban	6281642	8540840	10967023	14446721	18707601	22427251	29093002
India	Total	361088090	439234771	548159652	683329097	846302688	1028610328	1210854977
	Rural	298644381	360298168	439045675	523866550	628691676	742490639	833748852
	Urban	62443709	78936603	109113977	159462547	217611012	286119689	377106125

Source: Census of India, 2011: India at a glance, Census of India, 2011 Census data: Population enumeration data, Statistical Abstracts of West Bengal, 2013, Table 2.5, Census of India, 1971, Series 22, West Bengal Part IIA, Census of India, 1981, Series 1, Part IIB(i), adjusted with District Statistical Handbooks 2004.

FIGURE 2.8 Overall growth of population in the districts of West Bengal from 1951 to 2011



Source: Tables 2.7 and 2.8.

TABLE 2.8 Population in the districts of West Bengal in successive rounds of census after independence

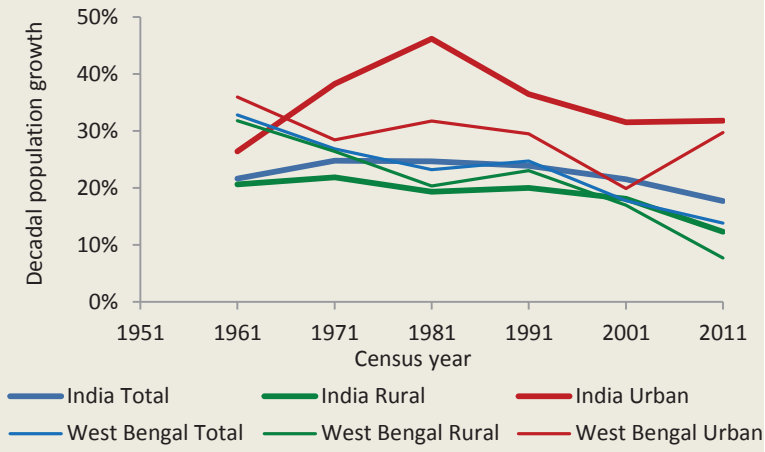
District	1951		1961		1971		1981		1991		2001		2011	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Darjiling	365136	94481	480003	144637	601565	180212	742116	282153	903859	396060	1088740	520432	1118860	727963
Jalpaiguri	850602	66145	1235478	123814	1582079	168080	1903650	311221	2342296	458247	2794291	606882	1628791	752805
Alipurduar													1183704	307546
Koch Bihar	618769	50180	948360	71446	1317531	96652	1649383	122260	2001648	169497	2253537	225618	2529652	289434
Uttar Dinajpur	934942	41940	718220	56267	1021453	85697	1312798	127277	1644070	252975	2147351	294443	2644906	362228
Dakshin Dinajpur			506608	42702	664744	87993	823423	141449	1066383	164225	1306324	196854	1439981	236295
Maldah	902419	35161	1171138	50785	1544631	68026	1934675	97196	2450495	186537	3049528	240940	3447185	541660
Murshidabad	1580832	134927	2094546	195464	2691779	248425	3351534	346018	4245802	494347	5133835	732734	5703115	1400692
Birbhum	997896	68993	1345389	100769	1651137	124772	1922296	173533	2326101	229563	2757002	258420	3052956	449448
Barddhaman	1867726	323941	2521539	561078	3024184	891990	3414219	1421169	3927613	2122992	4348466	2547048	4639264	3078299
Nadia	936055	208101	1398355	315338	1812211	418059	2324384	639869	2980279	871818	3625308	979519	3728727	1438873
Hugli	1210165	394839	1652005	579283	2111846	760270	2506777	1050529	2996979	1358251	3354227	1687749	3390646	2128499
Bankura	1224641	94618	1542356	122157	1879304	151735	2193568	181247	2572587	232478	2957447	235248	3296901	299773
Puruliya	1090627	78470	1267538	92478	1470508	132367	1687039	166762	2014571	210006	2281090	255426	2556801	373314
Haora	1089053	522320	1213385	825092	1403753	1013533	1628068	1338793	1880530	1849114	2121109	2151990	1775885	3074144
Kolkata	0	2698494	0	2927289	0	3148746	0	3305006	0	4399819	0	4572876	0	4496694
North 24 Parganas	3243340	1216152	4282958	1997957	5479162	2970320	6569957	4169482	3551581	3730300	4083339	4850947	4277619	5732162
South 24 Parganas									4954653	760377	5820469	1086220	6074188	2087773
Paschim Medinipur	3106142	252880	4007569	334286	5089091	420156	6170039	572757	3918712	567567	4575651	617760	5190771	722686
Purba Medinipur									3592205	253428	4051232	366145	4503161	592714

Source: 1991-2011 source: Statistical Abstracts of West Bengal, 2013, Table 1.5; population of Medinipur for 1991, 2001 apportioned to Purba and Paschim Medinipur as per Tables 2.3 of District Statistical Handbooks 2004. 1951-1971 source: Census of India, 1971, Series 22, West Bengal Part IIA, Census of India, 1981, Series 1, Part IIB(i), adjusted with District Statistical Handbooks 2004.

The decadal growth rates implied by Table 2.7 are plotted in Figure 2.9. It is seen that both rural and urban growth rates in West Bengal had consistently declined till 2001. The rural growth rate in West Bengal declined more sharply from 2001 to 2011 than in the previous decade. However, the urban growth rate took a dramatic upward turn, which by far surpassed the corresponding national trend. This is indicative of a massive spate of movement from rural to urban areas of West Bengal.

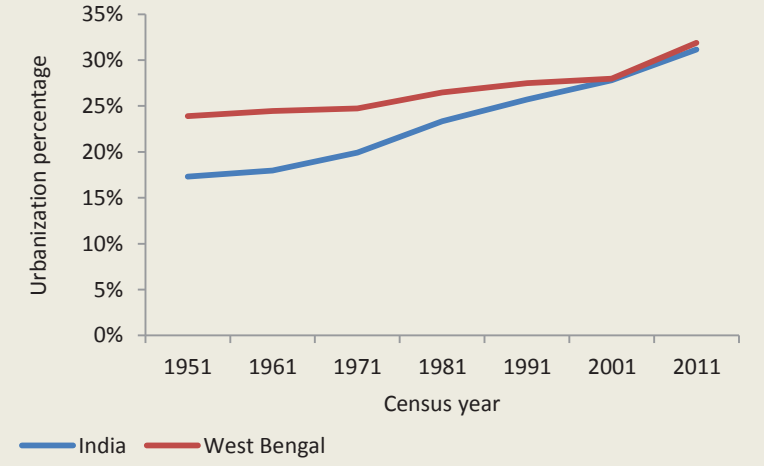
Evidence of this movement is also apparent from the trend of urbanization (urban population divided by total population) in successive rounds of census, plotted in Figure 2.10. West Bengal has traditionally been more urban than the rest of the country. The gap almost vanished in 2001. However, in 2011, urbanisation of West Bengal was found to have risen rapidly, in sharp contrast with the earlier rounds of census.

FIGURE 2.9 **Decadal growth rates of population in West Bengal and India over seven rounds of census**



Source: Table 2.7.

FIGURE 2.10 **Urbanization percentage in West Bengal and India over seven rounds of census**



Source: Table 2.7.

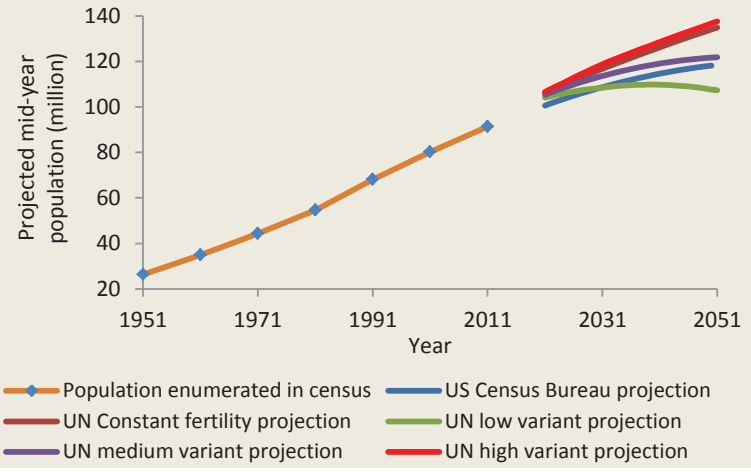
Projections till 2051

Projections of total population of different countries are regularly made and updated by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. The United States Census Bureau also maintains an International Data Base where such projections are regularly updated. These projections, downloaded on 1 March, 2016, were adapted to arrive at projections for the population of West Bengal. For this purpose, the fact used is that the State's share of the national population (as evident from Table 2.7) has declined gradually over the last five rounds of census. A straight line fit of this percentage share data was extended into the future to arrive at projections of the State's population from those of the national population.

Figure 2.11 shows the graph of these projections till 2051. There are four versions of the UN projection, corresponding to different scenarios. According to projections of the State's population based on the UN medium and low variant projections indicate that the population of West Bengal would reach a peak of about 125 million at around the middle of the twenty-first century, before starting to decline.

Separation of the projected total population into rural and urban components would require projections of the urbanization percentage. Since the urbanization at West Bengal in the recent rounds of census have been close to the national level, the

FIGURE 2.11 Five different Projections of total population of West Bengal till 2051



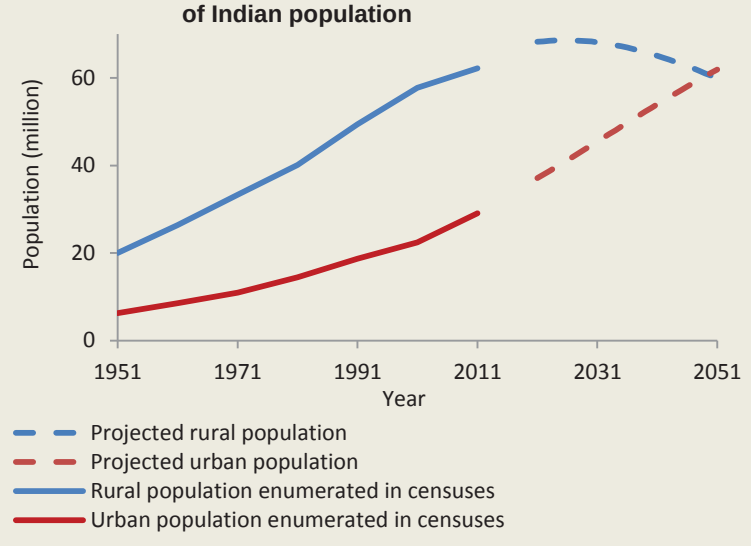
Source: Analysis made exclusively for this report, from projections of population of India given by UN Population Project and US Census Bureau, and West Bengal's share of Indian population in 1971, 1981, 1991, 2001 and 2011, given in Table 2.7.

TABLE 2.9 Projected urbanization percentages in India in future census years

Year	2021	2031	2041	2051
Projected urbanization in India (%)	35.2	40.0	45.3	50.8

Source: Analysis made exclusively for this report, from projections of urbanization percentage of India given in World Urbanization Prospects: The 2005 Revision.

FIGURE 2.12 Projections of the rural and urban populations of West Bengal, based on the UN medium variant projection of Indian population



Source: Analysis made exclusively for this report, from projections of urbanization percentage of India given in World Urbanization Prospects: The 2005 Revision.

projections of the urbanization rate of India given by the UN Population division (World Urbanization Prospects: The 2005 Revision) have been used directly for West Bengal. The projections at five year intervals were linearly interpolated to obtain projections for in between years (Table 2.9).

The projected rural and urban populations of West Bengal, obtained as indicated above from the UN medium variant projection of the total population (plotted in Figure 2.11), are shown in Figure 2.12. According to this projection, the census of 2021 may be the last occasion when the rural population will be seen to rise. After that, a steady decline is expected. There would probably be a corresponding upsurge in the urban population, which will rise steadily till 2051 and continue to rise after surpassing the rural population.

While choosing a model for district-wise projections, it may be noted that the population of Kolkata appears to have reached a steady state. The twists and turns in the population data for the other districts across the seven rounds of census have been very haphazard. On the other hand, the shares of districts in the rural and urban populations of the State, after leaving out Kolkata from the calculations, have remained somewhat steady. Therefore, the population of Kolkata is projected by its last enumerated value, and apportioned the rural and urban populations of West Bengal into the districts in terms of their shares observed in the 2011 census. These projections are reported in Table 2.10. According to these projections, North 24 Parganas, the most populous district, may have a population of 17.5 million by 2051. This corresponds to a population density of about 4,274 per sq km, which is four times the 2011 population density of West Bengal. Haora, the smallest district in terms of area (leaving aside Kolkata), is likely to have a population of 8.9 million by 2051. This means a population density of 6,056 per sq km, which is about six times the 2011

TABLE 2.10 Projected rural and urban populations in the districts of West Bengal in future census years

Population	Rural population (million)				Urban population (million)				Total population (million)			
	2021	2031	2041	2051	2021	2031	2041	2051	2021	2031	2041	2051
Darjiling	1.228	1.226	1.171	1.078	0.966	1.212	1.464	1.699	2.193	2.438	2.635	2.776
Jalpaiguri	1.787	1.785	1.704	1.569	0.998	1.253	1.514	1.757	2.786	3.038	3.218	3.326
Alipurduar	1.299	1.297	1.238	1.140	0.408	0.512	0.619	0.718	1.707	1.809	1.857	1.858
Koch Bihar	2.776	2.772	2.646	2.437	0.384	0.482	0.582	0.675	3.160	3.254	3.229	3.112
Uttar Dinajpur	2.902	2.898	2.767	2.548	0.480	0.603	0.729	0.845	3.383	3.501	3.496	3.393
Dakshin Dinajpur	1.580	1.578	1.506	1.387	0.313	0.393	0.475	0.551	1.893	1.971	1.982	1.938
Maldah	3.783	3.777	3.606	3.321	0.718	0.902	1.090	1.264	4.501	4.679	4.696	4.585
Murshidabad	6.258	6.249	5.967	5.494	1.858	2.332	2.818	3.269	8.116	8.581	8.784	8.762
Birbhum	3.350	3.345	3.194	2.941	0.596	0.748	0.904	1.049	3.946	4.093	4.098	3.990
Barddhaman	5.091	5.083	4.854	4.469	4.083	5.125	6.193	7.183	9.174	10.209	11.046	11.652
Nadia	4.092	4.086	3.901	3.592	1.908	2.396	2.895	3.358	6.000	6.481	6.796	6.949
North 24 Parganas	4.694	4.687	4.475	4.121	7.603	9.544	11.531	13.376	12.297	14.231	16.007	17.497
Hugli	3.721	3.715	3.547	3.266	2.823	3.544	4.282	4.967	6.544	7.259	7.829	8.233
Bankura	3.618	3.612	3.449	3.176	0.398	0.499	0.603	0.700	4.015	4.112	4.052	3.875
Puruliya	2.806	2.801	2.675	2.463	0.495	0.622	0.751	0.871	3.301	3.423	3.426	3.334
Haora	1.949	1.946	1.858	1.711	4.077	5.118	6.184	7.174	6.026	7.064	8.042	8.884
Kolkata	0.000	0.000	0.000	0.000	4.497	4.497	4.497	4.497	4.497	4.497	4.497	4.497
South 24 Parganas	6.665	6.655	6.355	5.851	2.769	3.476	4.200	4.872	9.434	10.132	10.555	10.723
Paschim Medinipur	5.696	5.688	5.431	5.000	0.959	1.203	1.454	1.686	6.654	6.891	6.884	6.687
Purba Medinipur	4.941	4.934	4.711	4.338	0.786	0.987	1.192	1.383	5.727	5.921	5.904	5.721
West Bengal	68.233	68.134	65.055	59.899	37.120	45.450	53.977	61.893	105.353	113.583	119.032	121.792

Source: Analysis made exclusively for this report, from projections of population of India given by UN Population Project, West Bengal's share of Indian population in 1971, 1981, 1991, 2001 and 2011, given in Table 2.7, and projections of urbanization percentage of India given in World Urbanization Prospects: The 2005 Revision.

population density of West Bengal and sixteen times the 2011 population density of India. By 2031, the population density of South 24 Parganas, the district that includes most of the mangrove forests of Sundarbans, is likely to exceed the 2011 population density of West Bengal. The consequent level of stress on land, water resources and the environment would be much more severe than what has ever been experienced in the region.

Livelihood

For the purpose of census, those who were engaged in economic activity for more than 180 days during the preceding year are called main workers, those who worked for less than 180 days are called marginal workers and those who did not work at all are called non-workers (*for exact definitions, see Census of India 2011 Meta Data*).

Unpaid work such as household chores is not counted as economic activity. The number of persons in each of these categories in each district of West Bengal, as found in the census of 2011, is reported in Table 2.11. It turns out that West Bengal has a fewer percentage of female main workers (4.39% of the population) than the national average (7.38%) and a larger percentage of female non-workers (39.91%) than the national average (36.14%). Housewives who do not get paid for their household work fall into this category. The decomposition of the entire population of the districts in terms of male and female main workers, marginal workers and non-workers is shown in the composite bar chart of Figure 2.13, together with the corresponding decomposition for West Bengal and India. In Puruliya and Purba Medinipur, the percentage of male main workers is below 20 per cent and the percentage of male marginal workers is above 10 per cent. The largest percentage of female main workers is in Darjiling and the largest number of female marginal workers is in Puruliya.

TABLE 2.11 Number of main/ marginal workers and non-workers in the districts of West Bengal (Census, 2011)

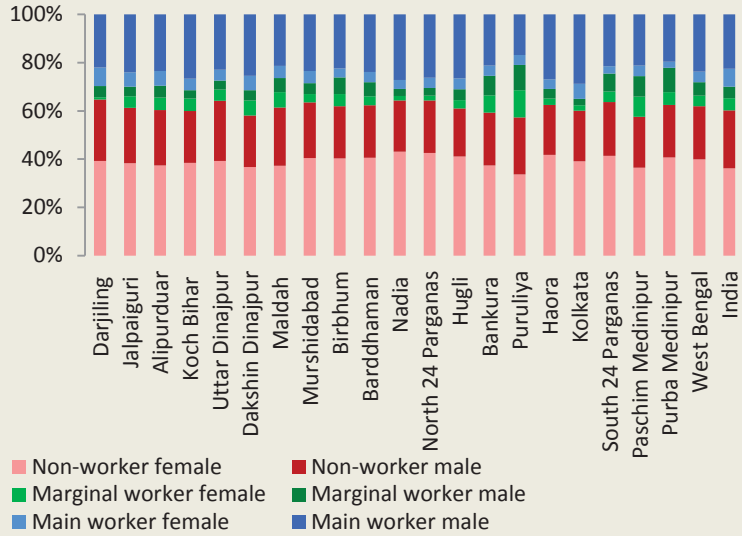
Region	Male population				Female population			
	Main worker	Marginal worker	Non-worker	Total	Main worker	Marginal worker	Non-worker	Total
Darjiling	396341	83245	457673	937259	136514	67626	705424	909564
Jalpaiguri	572500	95919	549113	1217532	140050	112373	911641	1164064
Alipurduar	349682	73260	342590	765532	91533	77593	556592	725718
Koch Bihar	749848	95460	606234	1451542	136509	146160	1084875	1367544
Uttar Dinajpur	688769	110858	751439	1551066	135573	140426	1180069	1456068
Dakshin Dinajpur	427578	71982	357639	857199	98892	104535	615650	819077
Maldah	851932	234529	965080	2051541	199063	252323	1485918	1937304
Murshidabad	1662624	323043	1641897	3627564	359459	244781	2872003	3476243
Birbhum	785648	244122	761150	1790920	127196	174637	1409651	1711484
Barddhaman	1838681	454402	1673806	3966889	328061	290107	3132506	3750674
Nadia	1405191	148899	1099678	2653768	190689	97828	2225315	2513832
North 24 Parganas	2630907	314282	2174200	5119389	424723	201712	4263957	4890392
Hugli	1463433	250175	1101045	2814653	251212	188050	2265230	2704492
Bankura	762088	288734	787273	1838095	154305	261093	1343181	1758579
Puruliya	493232	308022	695742	1496996	120166	328222	984731	1433119
Haora	1304435	193735	1002649	2500819	191832	129843	2027535	2349210
Kolkata	1294266	118200	944300	2356766	282153	101121	1756654	2139928
South 24 Parganas	1748714	607857	1817207	4173778	254971	352952	3380260	3988183
Paschim Medinipur	1252207	505151	1250527	3007885	258341	493460	2153771	2905572
Purba Medinipur	1000203	515893	1113738	2629834	127109	267115	2071817	2466041
West Bengal	21678279	5037768	20092980	46809027	4008351	4031957	36426780	44467088
India	273209976	58729899	291330383	623270258	89355595	60593398	437635726	587584719

Source: Primary Census Abstract, 2011. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

For the purpose of census, economic activities are divided into four broad categories (*see Census of India 2011 Meta Data*). Cultivators are those who supervise or direct cultivation in own/leased/ sharecropped land, while also possibly engaging in the act of cultivation of different crops (excluding planation crops like tea, coconut, betel-nut, etc.). Agricultural labourers are those who participate in cultivation in exchange for wages in money or kind. Household industrial workers are those who work in an industry conducted by one or more members of the household at home (or within the village in rural areas and within the precincts of the house in urban areas). Household industries relate to production, processing, servicing, repairing or making and selling (but not merely selling) of goods (e.g. production of flour, milking, husking, grinding of herbs, production of pickles, manufacture of country liquor, ice cream, soda water etc., production of bidi, textile cotton, jute, wool or silk, manufacture of wood/wood products, paper/paper products, leather/leather products, making foot wear from torn tyres and other rubber footwear, manufacture of toys, paints, colours, matches, fireworks, perfumes, ink etc., service and repairing of cycle, rickshaw, boat or animal driven carts etc.). Persons engaged in any other type of work (*eg,* government servants, municipal employees, teachers, factory workers, plantation workers, those engaged in trade, commerce, business, transport, banking, mining, construction, political or social work, priests, entertainment artists, etc.) are classified as other workers.

Among the persons who are main or marginal workers, the numbers of persons engaged in different types of economic activities, for every district, the state of West Bengal and India, are reported in Table 2.12. The decomposition of the workforce into these types is shown in Figure 2.14.

FIGURE 2.13 Composition of the urban population of the districts of West Bengal in terms of work status (Census, 2011)



Source: Table 2.11.

The profile of livelihood varied widely across the districts. The proportion of cultivators is the largest in three districts of North Bengal (Koch Bihar, Uttar and Dakshin Dinajpur), and the smallest in Haora. In the latter district, there is a large percentage of household industrial workers (mostly male but many females too). In Murshidabad, there are a large percentage of female household industrial workers (larger than the male contingent). Other workers have a large presence in Darjiling, North 24 Parganas and Kolkata. As in many districts of the State, cultivators constitute a far smaller part of the West Bengal workforce than in India as a whole.

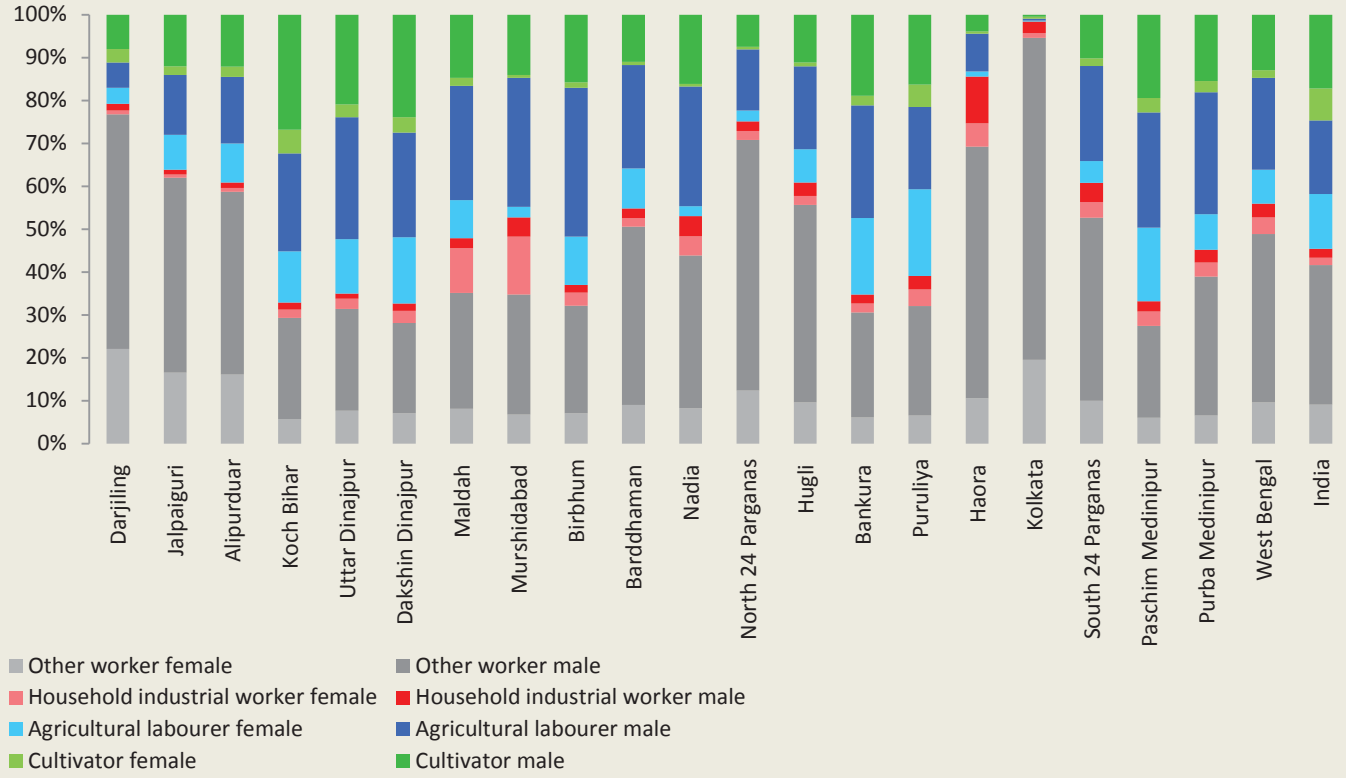
Table 2.13 shows the trend in the number of main workers, marginal workers and non-workers over the census years 1991, 2001 and 2011. The most notable growth has taken place in the number of marginal workers from 1991 to 2001, largely due to the implementation of the National Rural Employment Guarantee Scheme (NREGS). The growth has taken place across all the districts. Except for Puruliya and

TABLE 2.12 Number of workers in different occupations in the districts of West Bengal (Census, 2011)

Region	Male workers (both main and marginal)					Female workers (both main and marginal)				
	Cultivator	Agricultural labourer	Household industrial worker	Other worker	Total	Cultivator	Agricultural labourer	Household industrial worker	Other worker	Total
Darjiling	54694	40368	10667	373857	479586	21484	25673	5912	151071	204140
Jalpaiguri	111085	128773	10316	418245	668419	18045	74960	7114	152304	252423
Alipurduar	71516	91812	7333	252281	422942	14286	54127	5327	95386	169126
Koch Bihar	302745	257425	19269	265869	845308	62052	134450	21324	64843	282669
Uttar Dinajpur	225240	305965	12699	255723	799627	32137	136363	25279	82220	275999
Dakshin Dinajpur	167964	171590	12294	147712	499560	25312	108342	19996	49777	203427
Maldah	226131	409334	35922	415074	1086461	29051	136425	160765	125145	451386
Murshidabad	363528	779842	117511	724786	1985667	17548	62452	348496	175744	604240
Birbhum	210206	461340	24005	334219	1029770	17048	150170	41057	93558	301833
Barddhaman	319113	700508	64799	1208663	2293083	23053	272674	59759	262682	618168
Nadia	297055	513300	86650	657085	1554090	11687	42834	82488	151508	288517
North 24 Parganas	266507	509401	81434	2087847	2945189	21551	89638	74328	440918	626435
Hugli	239530	415950	66624	991504	1713608	20150	167430	45204	206478	439262
Bankura	276981	385049	29999	358793	1050822	32742	262325	31387	88944	415398
Puruliya	203535	239738	39043	318938	801254	65265	252467	48517	82139	448388
Haora	71163	160530	198995	1067482	1498170	9412	21132	98779	192352	321675
Kolkata	8156	8773	47799	1347738	1412466	7883	3615	20639	351137	383274
South 24 Parganas	302118	655262	133787	1265404	2356571	53232	151300	107189	296202	607923
Paschim Medinipur	486821	674153	58535	537849	1757358	85447	431048	84067	151239	751801
Purba Medinipur	295953	543701	57002	619440	1516096	49262	158603	61814	124545	394224
West Bengal	4500041	7452814	1114683	13648509	26716047	616647	2736028	1349441	3338192	8040308
India	82762934	82742337	9776530	156658074	331939875	36045846	61591353	8561638	43750156	149948993

Source: Primary Census Abstract, 2011. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

FIGURE 2.14 Composition of the workers (including both main and marginal workers) in the districts of West Bengal in terms of nature of work (Census, 2011)



Source: Table 2.12.

Medinipur, the growth has been much steeper than the growth at the national level. Interestingly, Kolkata (a completely urban district) has had a thirteen-fold increase in the number of marginal workers during this period. The number of main workers in Puruliya has steadily declined from 1991 to 2011. There has been a decline in the number of main workers in Bankura too. The number of non-workers has risen faster than the population in these two districts from 2001 to 2011.

Table 2.14 shows the total percentage of workers, including main and marginal workers, to the total population of West Bengal and India, as found in 1991, 2001 and 2011. There has been steady rise in the percentage. The overall rise has been faster in West Bengal than in India, though the State generally has a smaller percentage of workers. The lag is mostly due to smaller participation of women in economic activities. The percentage of workers among rural women of West Bengal is generally higher than in urban women, but much smaller than that percentage among rural women in other parts of India. The urban women in West Bengal have had a small but rapidly rising participation in the workforce, as in the rest of the country.

The higher percentage of workers in the population tells only a part of the story. If one looks at the percentage of main workers among all workers of West Bengal, reported in Table 2.15, then a steady decline from 1991 to 2011 is observed. This decline is across the board (male and female, rural and urban) and is sharper than the decline at the national level. In fact the proportion of main workers to the total population has also declined from 1991 to 2011 – both in West Bengal and India. This fact strongly indicates that people are finding it more difficult to engage fully in economic activities.

TABLE 2.13 Change in the number of workers in the districts of West Bengal, 1991-2011

Region	1991			2001			2011		
	Main workers	Marginal workers	Non-workers	Main workers	Marginal workers	Non-workers	Main workers	Marginal workers	Non-workers
Darjiling	438248	6599	855072	478851	90591	1039730	532855	150871	1163097
Jalpaiguri	882769	63563	1854211	1025433	277703	2098037	712550	208292	1460754
Alipurduar							441215	150853	899182
Koch Bihar	663424	34458	1473263	754311	212394	1512450	886357	241620	1691109
Uttar Dinajpur	623267	37256	1266206	716483	219041	1506270	824342	251284	1931508
Dakshin Dinajpur	399523	19143	782258	471187	141541	890450	526470	176517	973289
Maldah	834408	80419	1722205	967143	373563	1949762	1050995	486852	2450998
Murshidabad	1424489	69156	3246504	1672311	332863	3861395	2022083	567824	4513900
Birbhum	777482	69666	1708516	831699	296798	1886925	912844	418759	2170801
Barddhaman	1798130	56716	4195759	1902334	548907	4444273	2166742	744509	4806312
Nadia	1109831	20366	2721900	1405724	209981	2989122	1595880	246727	3324993
North 24 Parganas	2053312	42181	5186388	2623352	364808	5946126	3055630	515994	6438157
Hugli	1331144	24977	2999109	1528040	331447	3182489	1714645	438225	3366275
Bankura	921591	85656	1797818	944216	483056	1765423	916393	549827	2130454
Puruliya	786425	173539	1264613	645506	481982	1409028	613398	636244	1680473
Haora	1065322	20115	2644207	1224972	213902	2834225	1496267	323578	3030184
Kolkata	1444968	7335	2947516	1623779	93955	2855142	1576419	219321	2700954
South 24 Parganas	1491195	125689	4098146	1678130	564630	4663929	2003685	960809	5197467
Paschim Medinipur	2535520	396892	5399500	2530112	1220945	5859731	1510548	998611	3404298
Purba Medinipur							1127312	783008	3185555
West Bengal	20581048	1333726	46163191	23023583	6458107	50694507	25686630	9069725	56519760
India	285932493	28198877	524436566	313004983	89229741	626375604	362565571	119323297	728966109

Source: 1991 data are from Economic Review: 2007-08, Government of West Bengal. 2001 data are from Census of India, 2001 Census Data Online. 2011 data are from Primary Census Abstract. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the rest of the Jalpaiguri district.

TABLE 2.14 Percentage of workers to population in West Bengal and India, 1991-2011

Region		Persons (%)			Male (%)			Female (%)		
		1991	2001	2011	1991	2001	2011	1991	2001	2011
India	Total	37.46	39.10	39.80	51.55	51.68	53.26	22.25	25.63	25.52
	Rural	39.98	41.75	41.83	52.48	52.11	53.03	26.67	30.79	30.03
	Urban	30.17	32.25	35.31	48.94	50.60	53.76	9.17	11.88	15.44
West Bengal	Total	32.19	36.77	38.08	51.40	53.99	57.07	11.25	18.32	18.08
	Rural	33.18	37.90	38.73	52.09	54.09	57.19	13.07	20.86	19.35
	Urban	29.59	33.85	36.69	49.64	53.74	56.84	6.21	11.57	15.35

Source: Primary Census Abstract and Economic Review 2007-08, Government of West Bengal.

Thus, the increased participation of the general population in economic activity has mostly been through part time engagement. The NREGS has been a major vehicle of providing part time work to rural people.

From Table 2.15 it is not clear whether the decline in the percentage of main workers is because of a genuine decline in the numbers of the same or because of the fast rise in the number of marginal workers. In order to examine this, the growth of marginal and main workers in the rural areas during the decades 1991-2001 and 2001-2011 have been compared with the rural population growth rate during the same period in Table 2.16. The massive growth in the number of marginal workers during 1991-2001 is contrasted by the negative growth in the number of main workers, which is more negative than the national average.

The changes have been less dramatic in the decade 2001-2011. However, the decadal growth rate in rural male main workers in West Bengal has been less than half of the rural male population growth rate and also less than the growth rate of rural male main workers at the national level. The growth rate of rural female main workers has continued to be negative.

The district-wise decomposition of all workers (including main and marginal workers) into different professions is given in Table 2.17. The aggregate percentage of cultivators and agricultural labourers among all main and marginal workers for the different districts are shown in Figure 2.15.

TABLE 2.15 Percentage of main workers to total workers in West Bengal and India, 1911-2011

		Persons (%)			Male (%)			Female (%)		
		1991	2001	2011	1991	2001	2011	1991	2001	2011
India	Total	91.02	77.82	75.24	98.79	87.32	82.31	71.60	57.27	59.59
	Rural	89.26	73.94	70.50	98.63	85.04	78.51	69.62	54.07	55.59
	Urban	97.76	90.83	87.65	99.28	93.27	90.50	88.65	79.31	76.96
West Bengal	Total	93.91	78.09	73.90	98.56	87.08	81.14	70.75	49.74	49.85
	Rural	92.27	73.58	68.47	98.25	84.59	76.99	66.88	43.52	42.06
	Urban	98.79	91.11	86.17	99.38	93.33	90.05	93.33	79.57	70.94

Source: Primary Census Abstract and Economic Review 2007-08, Government of West Bengal.

TABLE 2.16 Decadal growth rates in population, marginal workers and main workers, 1991-2001 and 2001-2011: rural regions of West Bengal and India (in percentage)

		Population (%)		Marginal workers (%)		Main workers (%)	
		1991-2001	2001-2011	1991-2001	2001-2011	1991-2001	2001-2011
India	Persons	19.22	12.29	202.06	27.37	-3.01	7.28
	Male	18.78	12.10	1190.07	63.90	-1.66	5.32
	Female	19.68	12.49	108.85	6.08	-6.81	12.79
West Bengal	Persons	16.97	7.68	356.45	31.30	-6.17	2.38
	Male	16.41	7.53	966.36	69.82	-3.91	3.45
	Female	17.57	7.84	220.13	2.61	-18.15	-3.33

Source: Primary Census Abstract and Economic Review 2007-08, Government of West Bengal.

TABLE 2.17 Percentage of all workers in four specific groups of professions, 1991, 2001 and 2011: districts of West Bengal

Region	Cultivator (%)			Agricultural labourer (%)			Household industrial worker (%)			Other worker (%)		
	1991	2001	2011	1991	2001	2011	1991	2001	2011	1991	2001	2011
Darjiling	24.74	15.49	11.14	11.82	10.25	9.66	0.62	2.78	2.42	62.82	71.48	76.77
Jalpaiguri	29.35	20.71	14.02	16.94	17.66	22.12	1.13	2.06	1.89	52.59	59.56	61.96
Alipurduar			14.49			24.65			2.14			58.72
Koch Bihar	48.18	37.43	32.34	26.04	29.53	34.74	2.31	4.06	3.60	23.47	28.98	29.32
Uttar Dinajpur	41.72	29.58	23.93	37.35	39.66	41.12	1.58	3.68	3.53	19.35	27.08	31.42
Dakshin Dinajpur	44.76	30.98	27.49	32.04	36.23	39.82	2.50	4.85	4.59	20.69	27.94	28.09
Maldah	34.58	20.83	16.59	34.63	30.72	35.49	3.55	15.61	12.79	27.24	32.84	35.13
Murshidabad	31.47	18.71	14.71	29.29	28.02	32.52	13.64	20.40	17.99	25.60	32.87	34.77
Birbhum	34.54	23.12	17.07	37.39	36.95	45.92	3.60	6.48	4.89	24.47	33.45	32.12
Barddhaman	21.81	14.76	11.75	30.70	29.94	33.43	2.93	4.95	4.28	44.56	50.35	50.54
Nadia	29.34	19.83	16.76	27.48	23.24	30.18	7.35	11.41	9.18	35.83	45.51	43.88
North 24 Parganas	17.10	10.07	8.07	17.19	13.62	16.77	2.24	4.44	4.36	63.47	71.87	70.80
Hugli	21.12	14.95	12.06	26.62	24.31	27.10	2.94	5.17	5.19	49.32	55.57	55.65
Bankura	40.80	30.83	21.12	33.67	35.26	44.15	3.44	5.85	4.19	22.09	28.07	30.54
Puruliya	49.49	31.28	21.51	25.46	36.03	39.39	2.77	7.49	7.01	22.29	25.20	32.10
Haora	10.73	5.21	4.43	14.76	10.18	9.98	3.63	11.52	16.36	70.88	73.09	69.23
Kolkata	0.15	0.37	0.89	0.21	0.25	0.69	0.49	3.06	3.81	99.16	96.32	94.61
South 24 Parganas	27.75	16.15	11.99	29.82	26.04	27.21	4.19	6.07	8.13	38.23	51.74	52.68
Paschim Medinipur	42.13	28.12	22.81	25.40	31.79	44.05	4.85	7.40	5.68	27.63	32.69	27.46
Purba Medinipur			18.07			36.76			6.22			38.95
West Bengal	28.40	19.18	14.72	24.56	24.97	29.32	3.90	7.37	7.09	43.13	48.48	48.87
India	38.72	31.65	24.65	26.09	26.55	29.95	2.38	4.22	3.81	32.81	37.59	41.59

Source: 1991 data are from Economic Review: 2007-08, Government of West Bengal. 2001 data are from Census of India, 2001 Census Data Online. 2011 data are from Primary Census Abstract. The block level data for the erstwhile Jalpaiguri district, available in the District Census Handbook of Jalpaiguri, was used to obtain separate figures for the newly created Alipurduar district and the truncated Jalpaiguri district. 1991 percentages are computed on the basis of main workers only.

It may be observed that the percentage of cultivators has reduced in all the districts. Even when the cultivators are considered together with the agricultural labourers (both main and marginal workers), their percentage among all workers has gone down drastically. The sharpest decline happened during the decade 1991-2001, when there was proliferation of NREGS in West Bengal. Going by this percentage for 2001 and 2011, it can be safely concluded that agriculture no longer provides the means of livelihood to the majority of the workforce in West Bengal.

Another change observed from Table 2.17 is that the combined percentage of agricultural labourers and other workers has steadily increased at the expense of cultivators and household industrial workers. Thus, there has been a clear shift towards wage-earning jobs and away from the type of work where one would be in charge of expenses, profits and risks of the economic activity. A weaker level of engagement with work might be linked with weaker ties with the environment.

During the 2011 census, the marginal workers and non-workers were asked

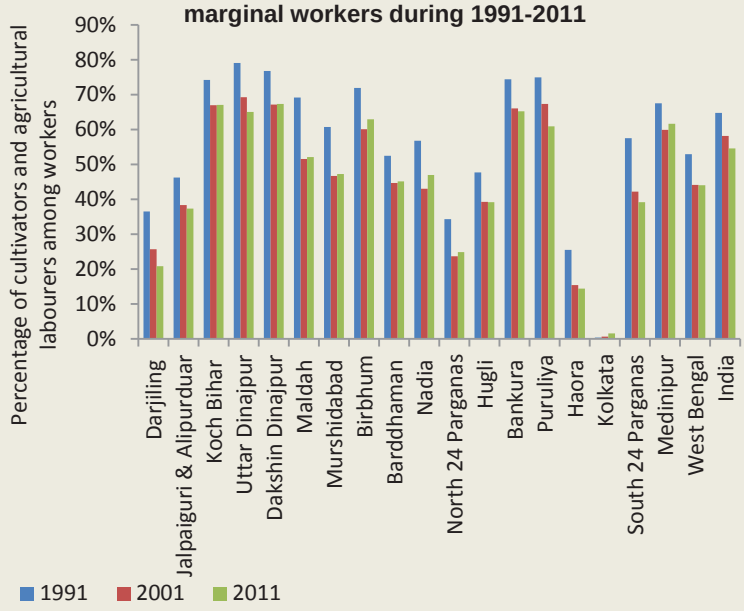
whether they were seeking work/available for work. A large number of people, amounting to 21 per cent of the entire population of West Bengal, answered in the affirmative. While the question is not ideal for assessing the unemployment rate, the response may be used for comparison. Only 10 per cent of the people of India had declared themselves as seeking or available for work (*see Primary Census Abstract*). It would be safe to say that there is more demand for paid work in West Bengal than in the rest of the country.

Migration

As already mentioned, the sharp rise in the decadal growth rate of the urban population of West Bengal from 2001 to 2011, observed in Figure 2.9, together with the continued decline in the growth rate of the rural population, is indicative of urban migration. In order to put this fact into perspective, the decadal growth rate (2001-2011) of the populations of Class I cities of West Bengal has been plotted against their population size, in Figure 2.16. The population is shown along the horizontal axis, in logarithmic scale.

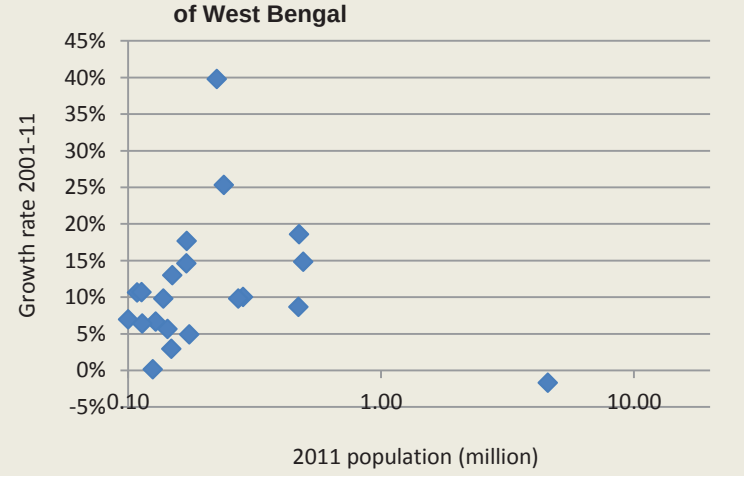
It may be noted that except for two cities that had growth rates of 40 per cent (Englishbazar urban agglomeration) and 25 per cent (Habra urban agglomeration), all the other cities had growth rates below 20 per cent. On the other hand, the urban population of West Bengal grew by 30 per cent during the same decade. Therefore, it is the smaller towns and cities that must account for this phenomenal growth rate. The growth has happened all over the State. Except for Kolkata, Paschim Medinipur and North 24 Parganas, the urban growth rate in all the districts during this decade has been more than 20 per cent. This could not have happened without a widespread pattern of net migration from villages to towns during this decade. In India, there is no system of regularly tracking and quantifying the movement of people. During the census of 2001, some data were collected in this regard. People were asked whether they had been living since birth in their place of enumeration. Those who did not, fell in the category of migrants. This definition includes people who had migrated several decades ago. They were asked what had been their places of birth and earlier

FIGURE 2.15 **Decline of percentage of cultivators and agricultural labourers among all main and marginal workers during 1991-2011**



Source: Table 2.17.

FIGURE 2.16 **Decadal growth rate (2001-2011) of the populations of the Class I cities of West Bengal**



Source: Cities having population 1 lakh and above, Census 2011, updated from West Bengal Population Census data 2011.

residence, for how long they have been living in the place of enumeration, the reasons of their migration, and several related questions. While the information collected in this manner is not adequate for calculating the rate of migration from one place to another, it may be used to form an idea about the composition of a population in a particular region in terms of those who have been living there since birth and those who moved there at some point of time.

The numbers of migrants of different origins in West Bengal and India recorded during the census of 2001 are shown in Table 2.18.

The numbers reported in Tables 2.7 and 2.18 imply that out of every 1,000 persons enumerated during the 2001 census, about 313 were 'migrants'. The corresponding number for West Bengal is 306 per 1,000 persons. However, the composition of this number tells a different story. Out of every 1,000 migrants found in West Bengal, the last place of residence of 103 persons was another country. The corresponding count for India is only 16 per every 1,000 migrants. West Bengal has witnessed a steady influx of persons from East Pakistan/Bangladesh for many decades. The above count aggregates over all those persons who have resided in a place continuously after having migrated sometime before 2001. It does not reflect recent migration.

A composite bar chart of male and female migrants in West Bengal and India at the time of the census of 2001 is given in Figure 2.17. It is seen that female migrants outnumber males, and that the share of out-of state migrants is less in West Bengal than in India. International migrants have a more visible presence in West Bengal than in the rest of the country.

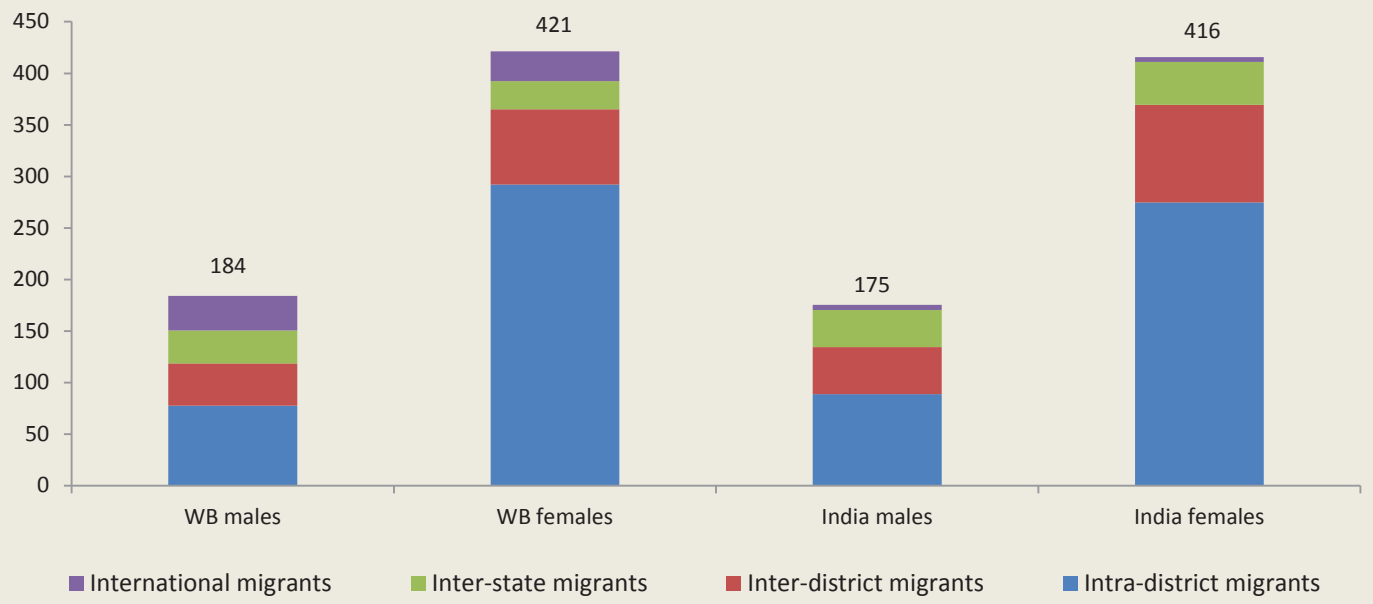
The largest three contributions of migrants from other countries and other states are listed in Table 2.19. Bangladesh has been the most frequently cited place of last residence, followed by Bihar and Jharkhand.

TABLE 2.18 Numbers of migrants of different origins (Census, 2001)

Region	Migrant category	Migrants by place of birth			Migrants by place of last residence		
		Persons	Males	Females	Persons	Males	Females
West Bengal	Intra-district migrants	14526298	2892376	11633922	15335448	3223488	12111960
	Inter-district migrants	4556260	1597360	2958900	4720177	1690345	3029832
	Inter-state migrants	2491932	1352219	1139713	2457162	1330989	1126173
	International migrants	3090393	1636343	1454050	2584806	1390023	1194783
	Unclassifiable	37	22	15	36	21	15
	Total migrants	24664920	7478320	17186600	25097629	7634866	17462763
India	Intra-district migrants	181799637	42781678	139017959	193592938	47337924	146255014
	Inter-district migrants	76841466	24778327	52063139	74626322	24241706	50384616
	Inter-state migrants	42341703	19675774	22665929	41166265	19098082	22068183
	International migrants	6166930	3174717	2992213	5155423	2683914	2471509
	Unclassifiable	421	194	227	402	183	219
	Total migrants	307150157	90410690	216739467	314541350	93361809	221179541

Source: Census of India, 2001 Census Data Online: Migration data.

FIGURE 2.17 **Number of migrants (per 1,000 persons) found in West Bengal and in India and their composition (Census, 2001)**



Source: Table 2.18.

Turning to domestic migrants residing in West Bengal, their composition by gender and the place of residence on the day of enumeration has been examined. This composition (in terms of the place of last residence) is given in Figure 2.18. The largest contingent of these migrants comprises females residing in rural areas. Most of them have migrated from elsewhere within the district, presumably on account of marriage. The urban female migrants have a larger share of those from other districts.

The majority of the 'migrants' recorded during the census are not recent migrants. This fact is amply borne out by Figure 2.19, which shows the number of migrants by the duration of their residence at the place of enumeration.

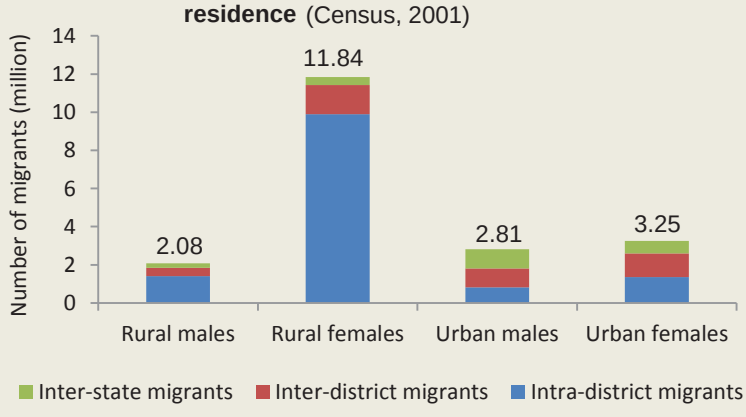
Figures 2.18 and 2.19 also show that the migration data are dominated by women having migrated within the district and/or people having migrated 10 years ago or earlier. In order to gain insight into more recent movements, the reasons for migration of people who migrated less than five years ago are shown in Figure 2.20.

TABLE 2.19 **Numbers of migrants, from top three countries and top three states, living in West Bengal (Census, 2001)**

	Migrants from	Persons	Males	Females
Foreign country	Bangladesh	2528993	1361863	1167130
	Nepal	37928	18930	18998
	Pakistan	6170	3385	2785
Other state	Bihar	1123729	685189	438540
	Jharkhand	441058	158995	282063
	Uttar Pradesh	298356	184056	114300

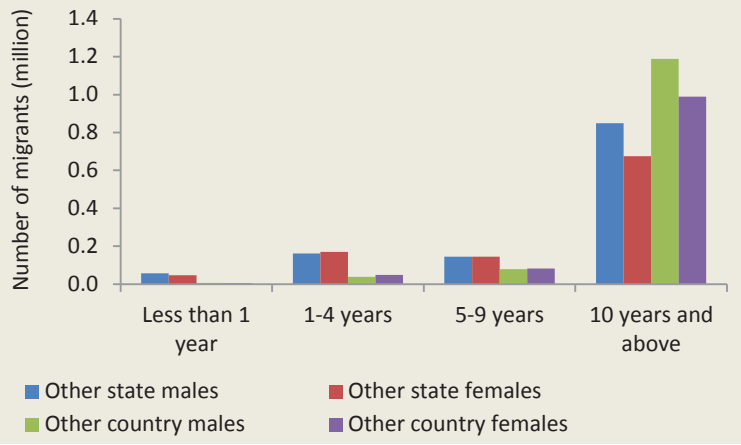
Source: Census of India, Census Data Online: Migration data.

FIGURE 2.18 **Number of domestic migrants found in West Bengal, and their composition, by current place of residence** (Census, 2001)



Source: Census of India, Census Data Online: Migration data.

FIGURE 2.19 Number of migrants found in West Bengal by duration of stay at current place of residence (Census, 2001)



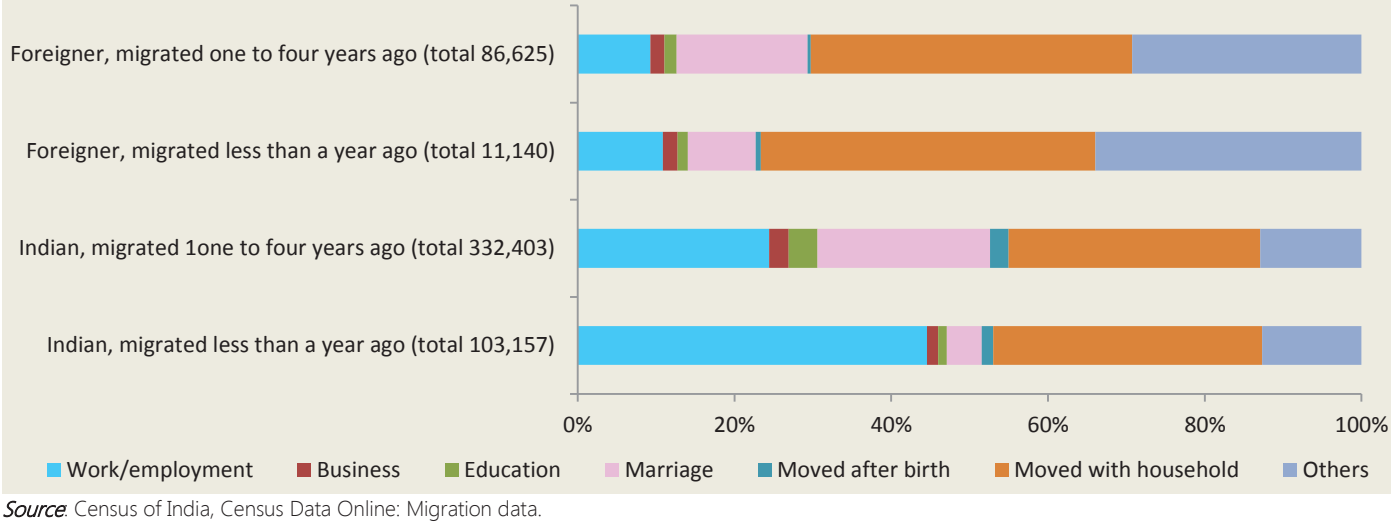
Source: Census of India, Census Data Online: Migration data.

It is seen that migrants from other states have a different pattern of reasons than those from abroad. For the latter group, the predominant reason is movement with household and other reasons not listed here. For the inter-state migrants, particularly those who migrated recently, were motivated by work/employment. Marriage has been a major cause for inter-state migrants to West Bengal, who have been residing there for one to four years.

In a 2007-08 survey conducted by the National Sample Survey Organization (NSSO), the respondents were divided into five equal groups in terms of their monthly per capita expenditure (MPCE). Figure 2.21 gives the decomposition of the migrants (as defined in Census 2001), in terms of the five percentile classes of MPCE. It may be observed that the female migrants have almost equal representation from the five MPCE percentile classes, with marginally higher representation from the higher expenditure percentile classes. Among the male migrants, there was larger representation from the higher expenditure groups. This effect was more pronounced among rural males than urban males, and less pronounced in West Bengal than in India as a whole.

The NSSO survey also shed light on the flow of people across rural and urban areas. Figure 2.22 shows the break-up of domestic migrants found in West Bengal and India in terms of four types of flow: rural to rural areas, rural to urban areas, urban to rural areas and urban to urban areas. Among females, the majority of the migration has taken place from one rural area to another. This type of migration was more prevalent in West Bengal than in India

FIGURE 2.20 Reasons of migration cited by recent migrants (those who migrated less than five years prior to enumeration) into West Bengal (Census, 2001)



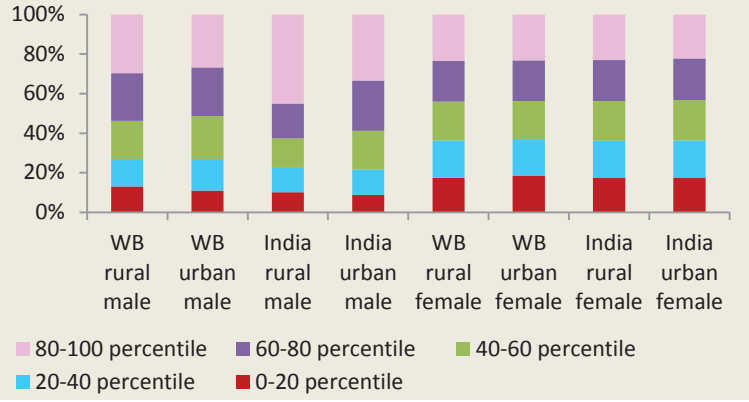
Source: Census of India, Census Data Online: Migration data.

as a whole. For both male and female migrants, migrants from rural to urban areas by far outnumber migrants from urban to rural areas. However, the share of migrants from rural to urban areas was more for India as a whole than for the state of West Bengal. This finding is consistent with the fact that urbanization percentage has not increased as rapidly in West Bengal as in the rest of India (Figure 2.10). Finally, the cases of males migrating from one urban area to another have been more prevalent in West Bengal than in the rest of the country.

During the 2001 census exercise, people originating from West Bengal were also enumerated elsewhere. Table 2.20 shows their count as well as the age profile. Figure 2.23 gives a pictorial representation. The pool of migrants is found to be dominated by those of age 25 to 59. Women outnumber men in the age groups of 25 and above. The duration of stay of migrants originating from West Bengal are displayed in Figure 2.24. This distribution is more evenly spread than that of Figure 2.19.

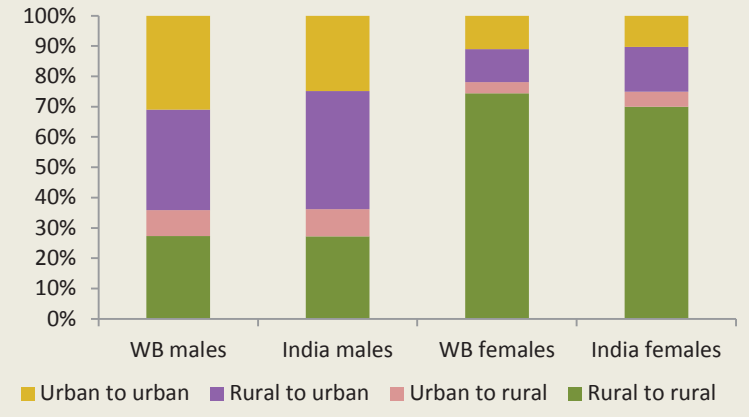
The reasons for migration given by the relatively recent migrants from West Bengal are shown in Figure 2.25. Women appear to have migrated mostly on account of marriage and movement with household.

FIGURE 2.21 Composition of migrants in West Bengal and India in terms of expenditure groups: 2007-08



Source: Migration in India: 2007-2008 (NSSO report)

FIGURE 2.22 Types of domestic migrants found in NSSO survey of 2007-08



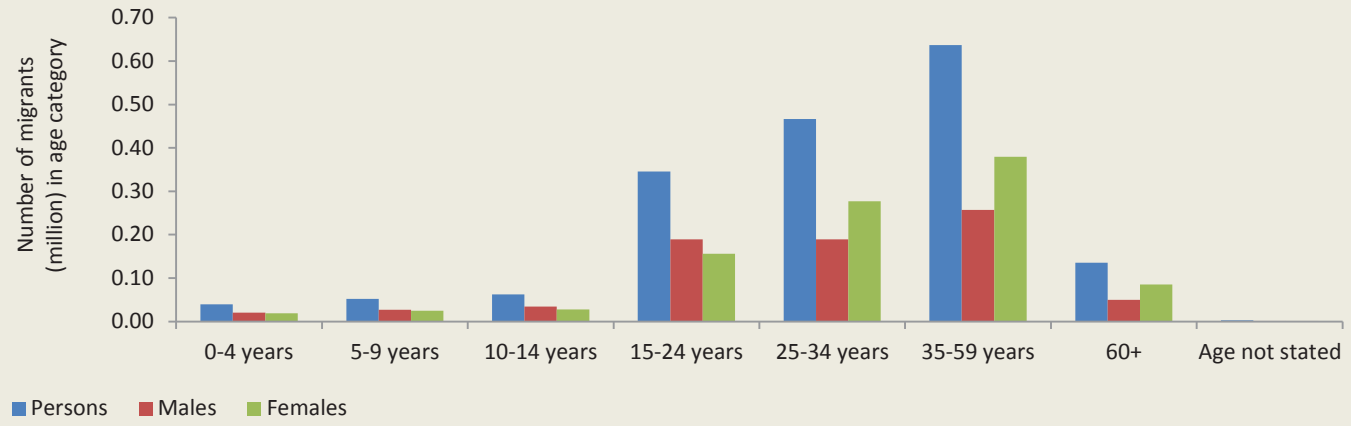
Source: Migration in India: 2007-2008 (NSSO report)

TABLE 2.20 Number of migrants enumerated outside West Bengal during Census 2001, who had mentioned West Bengal as their last place of residence, by age group, gender and present residence

Age-group	Place of enumeration								
	Total			Rural			Urban		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
0-4 years	39528	20302	19226	10874	5451	5423	28654	14851	13803
5-9 years	52463	27361	25102	13721	6971	6750	38742	20390	18352
10-14 years	62497	34431	28066	15640	8271	7369	46857	26160	20697
15-24 years	345367	189086	156281	113400	40810	72590	231967	148276	83691
25-34 years	466192	189208	276984	177855	43546	134309	288337	145662	142675
35-59 years	636622	257012	379610	248791	63083	185708	387831	193929	193902
60+	135121	49625	85496	57824	14823	43001	77297	34802	42495
Age not stated	2558	1411	1147	782	359	423	1776	1052	724
All ages	1740348	768436	971912	638887	183314	455573	1101461	585122	516339

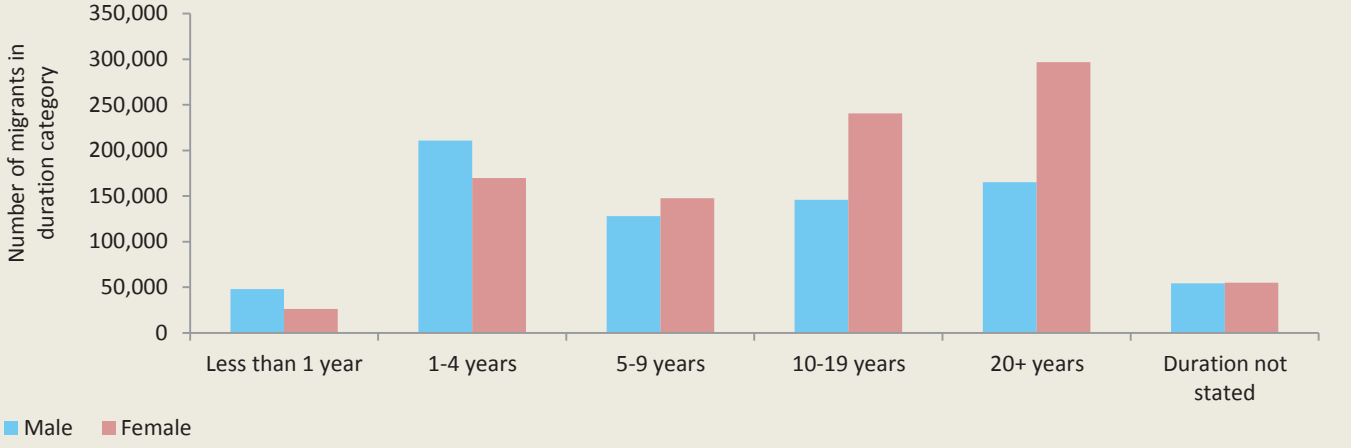
Source: Census of India, 2001: D-Series Tables.

FIGURE 2.23 **Number of migrants belonging to different age groups, enumerated outside West Bengal, who had mentioned West Bengal as their last place of residence (Census, 2001)**



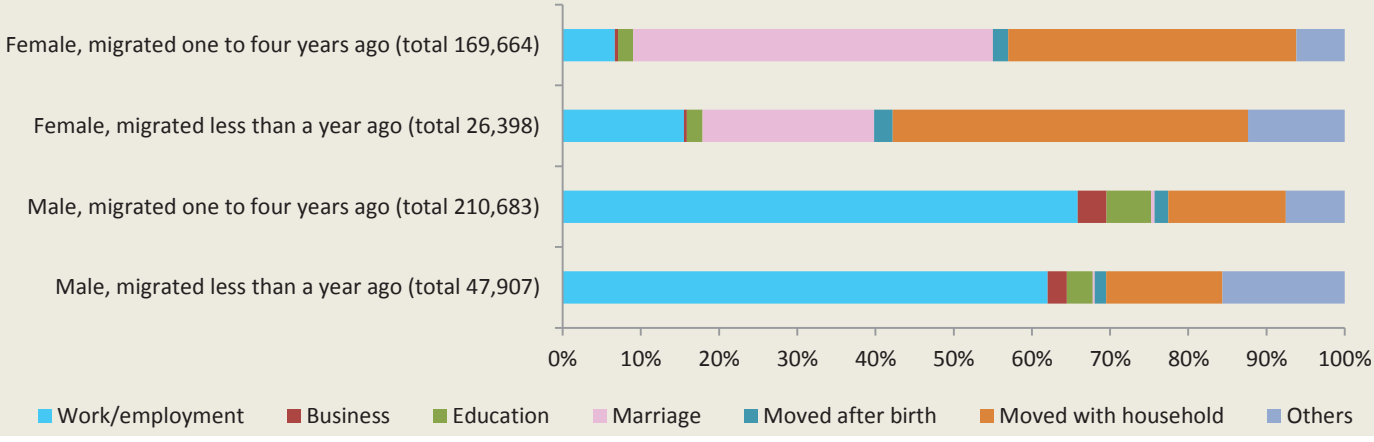
Source: Table 2.20.

FIGURE 2.24 **Number of migrants out of West Bengal, by duration of stay at place of enumeration (Census, 2001)**



Source: Census of India, 2001: D-Series Tables.

FIGURE 2.25 **Reasons of migration cited during Census 2001 by relatively recent migrants (those who migrated less than 5 years prior to enumeration) out of West Bengal**



Source: Census of India, 2001: D-Series Tables.

Those who moved in the year preceding the census, moved mostly with the household. For men, the dominating factor has been work or employment.

The NSSO survey of 2007-08 revealed the domestic destinations of out-migrants from West Bengal. It turned out that out of 1,000 migrants out of West Bengal, as many as 944 relocated elsewhere in West Bengal, 11 went to Maharashtra, 9 went to Uttar Pradesh, 7 went to Delhi, 4 went to each of Bihar and Orissa, 3 went to each of Punjab and Rajasthan, 2 went to each of Gujarat and Andhra Pradesh, and 11 went to other states.

It transpires from Table 2.18 that over 5.5 million people enumerated during the census of 2001 have stated that they have migrated to West Bengal from outside the boundaries of the State. Out of this total, about 2.5 million people were domestic migrants. In contrast, during the same census, about 1.7 million people enumerated outside the State said that they had migrated there from West Bengal. This indicates that there might be a net migration into the state of West Bengal – even in terms of state-to-state movements (i.e., not counting migration from other countries). The NSSO survey also suggests that interstate migrations in India are estimated to have led to a net influx of 13.44 persons per 1,000 persons in West Bengal. However, like the census exercise, the NSSO survey also used a very inclusive definition of migrants, and as a result migrants from recent and distant past were mixed up. The samples were also dominated by women relocating after marriage. The current migration rates would be known precisely if a properly designed study is conducted.

Tailpiece

While the overall outlook for population growth in West Bengal is not very discouraging (with UN medium variant projection predicting that the population would reach its peak at about 125 million by the middle of the twenty-first century), there are possibilities of fundamental changes in various aspects, with uncertain consequence. Agriculture is no longer the profession of the majority of workers of West Bengal. People are rapidly moving away from agriculture but not finding full-time work. Professions like cultivation and household industrial work are giving way to wage-earning jobs. There is widespread net migration from rural to urban areas – both from within the State and from outside the State. The rural population is about to reach a turning point. Haora and North 24 Parganas are now predominantly urban, and the other districts are set to follow suit. The urbanization is happening mostly in the smaller towns and cities, which are not geared to handle a rapid influx of residents. Arranging resources such as clean water and waste management will be some of the issues that planners have to grapple with. Meanwhile, stress on the mostly rural adivasi tribes is showing in a subtle way: their native language is proving to be inadequate for basic existence. Other forms of stress from the multitude of rapid changes that are about to take place in West Bengal would no doubt have their impact on the local environment. Understanding the nuances of these changes would be the key to facing them adequately.

Acknowledgement: *The author thanks Prabir Chaudhury for drawing his attention to the NSS Report No. 533 on migration and also for discussion on the content of that report. Anwesha Haldar's help in assessing and rationalizing the block areas of the bifurcated Jalpaiguri district is acknowledged. Finally the comments from Rabin Majumdar and Kalyan Rudra on a preliminary draft of the chapter, which led to significant improvement, are gratefully acknowledged.*

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Chapter 3

Land and Land Use

The total area of West Bengal is 88,752 sq km It is the thirteenth largest State in India covering 2.7 per cent area of Union of India and in terms of population it is the fourth largest State having 7.5 per cent population of the country with over 91.28 million population. The State is situated in a very diverse geographical background from Himalayas in the north to Bay of Bengal in the south and Chhotonagpur plateau in the west and the large stretches of eastern and central parts of West Bengal are in the fertile Gangetic plain. The 2011 census shows that West Bengal is the second most densely populated State in India after Bihar (Delhi has not been taken into consideration). The State population density is 1,028 per sq km compare to national population density of only 328 per sq km. It is evident that the pressure on land in West Bengal is immense due to huge population and majority of the population is dependent on primary sector economy mainly agriculture. The pressure on agricultural land is increasing as out of the total 9.12 crore population of West Bengal, 68.1 per cent are from rural areas and 31.9 per cent are from urban areas.

Rapid rise in population in the last one century, and its developmental needs have led to the conversion of of large tracts of forests to agricultural land and to other land uses. The recent land use in the State shows that 60.2 per cent of land is used for agriculture, keeping 4.02 per cent under current fallow, totalling 64.22 per cent of land being used for agricultural purposes. The forest cover in West Bengal is sparse around 13.5 per cent of the total area, whereas at all India level, forest cover is over 20 per cent. Ideally it should have been around 33 per cent of the geographic area (National Forest Policy, GoI). With high population density, around 21.25 per cent of West Bengal area are not available for cultivation primarily for urban centres, rural settlements, industrial sectors, roads and sundry other uses; remaining 0.9 per cent land remains uncultivated excluding current fallow (Table 3.1).

With population growth and urbanisation, the overall state wise changes in land use land cover is noticeable during last 15 years. From 2000 to 2014, the Bureau of Applied Economics and Statistics, Department of Statistics and Programme Implementation data shows the changes (Table 3.1) (Figure 3.1).

The agricultural land change has taken place over time, the 'Net Sown Area' has been reduced from around

TABLE 3.1 Land use classification in West Bengal

Classification	1999-2000	2006-2007	2013-2014
Total geographic area	8875.2	8875.2	8875.2
Total reporting area *	8689.0 (100%)	8684.1 (100%)	8684.1 (100%)
(a) Net area sown	5471.7 (62.97%)	5296.0 (60.98%)	5233.7 (60.27%)
(b) Current fallows	208.2 (2.40%)	341.2 (3.93%)	349.3 (4.02%)
(c) Forests	1191.9 (13.72%)	1173.7 (13.52%)	1173.6 (13.52%)
(d) Area not available for cultivation Δ	1658.9 (19.09%)	1754.3 (20.20%)	1845.7 (21.25%)
(e) Other uncultivated land excluding current fallows **	158.1 (1.82%)	118.7 (1.37%)	81.6 (0.94%)

* Excluding Kolkata Metropolitan District.
Δ Area under non-agricultural uses, barren and unculturable land.
** Area under permanent pastures & and other grazing lands, land under misc. tree groves not included in net area sown, culturable waste lands, fallow lands other than current fallows

FIGURE 3.1 Land use classification in West Bengal

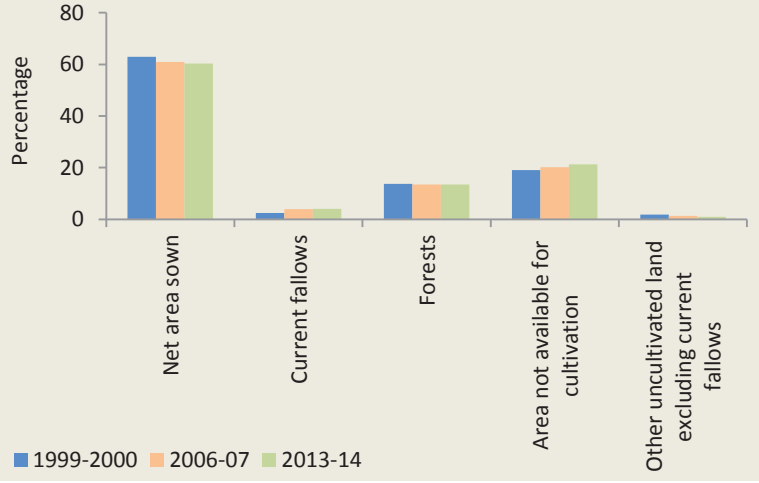


TABLE 3.2 Land use class in West Bengal

Land use	Area (%) of total area
Built up	17.60
Agriculture	61.45
Forest	10.70
Barren uncultuable wasteland & Grass grazing	2.18
Wetlands and water bodies	8.08
Total	**100**

63 per cent in 1999-2000 to around 60 per cent in 2013-14. During the same period current fallows have increased from around 2.4 per cent in 1999-2000 to around 4 per cent in 2013-14. There is a total reduction of 1.4 per cent of agricultural land. During this period with increasing population pressure, the 'area not available for cultivation' has increased from around 19 per cent to around 21 per cent. On the other hand during the same period 'other uncultivated land excluding current fallows' has reduced from 1.82 to 0.94 per cent. From the above, it is evident that at state level, there are changes in land use land cover with reduction of agricultural area and increase in built up/settlement area in urban and rural areas and development associated infrastructure like transportation, commercial and industrial use etc.

The NRSC 2008 Land use Land Cover map prepared based on IRS LISS III data at 1:50,000 scale shows a detailed land use class, (Table 3.2). The land use land cover data shows 17.60 per cent built up, 61.45 per cent agricultural land, 10.70 per cent forest cover and 8.08 per cent is wetlands and water bodies (Table 3.2). Out of 17.60 per cent built up area, 14.93 per cent is rural built up area and balance 2.67 per cent is urban built up area.

This also shows that over 8 per cent area in 2008 were under wetland and water bodies which are very significant in Gangetic West Bengal. It also shows that the majority of the wetland water bodies are concentrated in North and South 24 Parganas. With rapid urbanisation in South Bengal, along with agricultural land many wetland and water bodies are getting filled up and used as built up area or for infrastructure development. The forest cover mapped through satellite images shows 10.70 per cent area, which is 2.82 per cent less than the Bureau of Applied Economics and Statistics 2006-07 data of 13.52 per cent forest area. May be part of forest area has come under NRSC's barren unculturable wasteland and grass grazing category.

District land use land cover

The overall land use land cover pattern of West Bengal is different from the land use land cover pattern of individual districts located in different geographic condition. The land use pattern data clearly shows the distribution of various categories of land use. Districts in South Bengal in and around Kolkata are having highest share of land use area 'not available for cultivation' category (Table 3.3) (Figure 3.2). Haora, Hugli, North 24 Parganas districts are having more than 30 per cent of land under this category. This is mainly due to high concentration of urbanisation in and around Kolkata Metropolitan Area. Barddhaman is the other district having over 30 per cent land under this category mainly due to Asansol Durgapur Development Area settlements and its associated industrial belt and mining areas. The concentration of urban areas and settlements in Haora district is highest after Kolkata; the land category area 'not available for cultivation' in Haora is over 36 per cent of the total area whereas Uttar Dinajpur is having lowest, only 10 per cent area under 'not available for cultivation'. Dakhsin Dinajpur follows Uttar Dinajpur, with least urbanisation in terms of area. In North Bengal, Maldah and Koch Bihar is having

TABLE 3.3 District-wise land use statistics of West Bengal: 2013-14

District	Area in Ha*	Area not available for cultivation (%)Δ	Other uncultivated land excluding current fallows (%) ƭ	Area under forest (%)	Current fallows (%)	Net area sown (%)
Barddhaman	698762	30.71	0.84	3.03	0.47	64.94
Birbhum	451118	22.49	0.71	3.51	0.80	72.49
Bankura	687998	23.72	0.71	21.65	5.03	48.89
Purba Medinipur	396594	26.07	0.55	0.23	0.24	72.91
Paschim Medinipur	928581	17.34	1.04	18.52	7.50	55.61
Haora	138676	36.61	0.86	0.00	2.53	60.00
Hugli	313379	31.02	0.76	0.17	0.22	67.83
North 24 Parganas	386524	32.65	1.17	0.00**	5.96	60.23
South 24-Parganas	948710	15.29	0.42	44.93	1.25	38.11
Nadia	390655	22.83	0.77	0.31	0.75	75.34
Murshidabad	532499	24.95	0.39	0.14	0.16	74.36
Uttar Dinajpur	312466	10.09	1.06	0.19	0.08	88.58
Dakshin Dinajpur	221909	14.71	0.76	0.42	0.02	84.09
Maldah	370862	21.91	0.90	0.45	14.13	62.60
Jalpaiguri	622700	15.05	0.80	28.75	1.45	53.96
Darjiling	325469	12.81	2.23	38.28	4.69	42.00
Koch Bihar	331565	19.70	2.38	1.28	0.25	76.38
Puruliya	625646	18.33	1.64	12.00	18.63	49.41
West Bengal (excluding Kolkata)	8684113	21.25	0.94	13.52	4.02	60.27

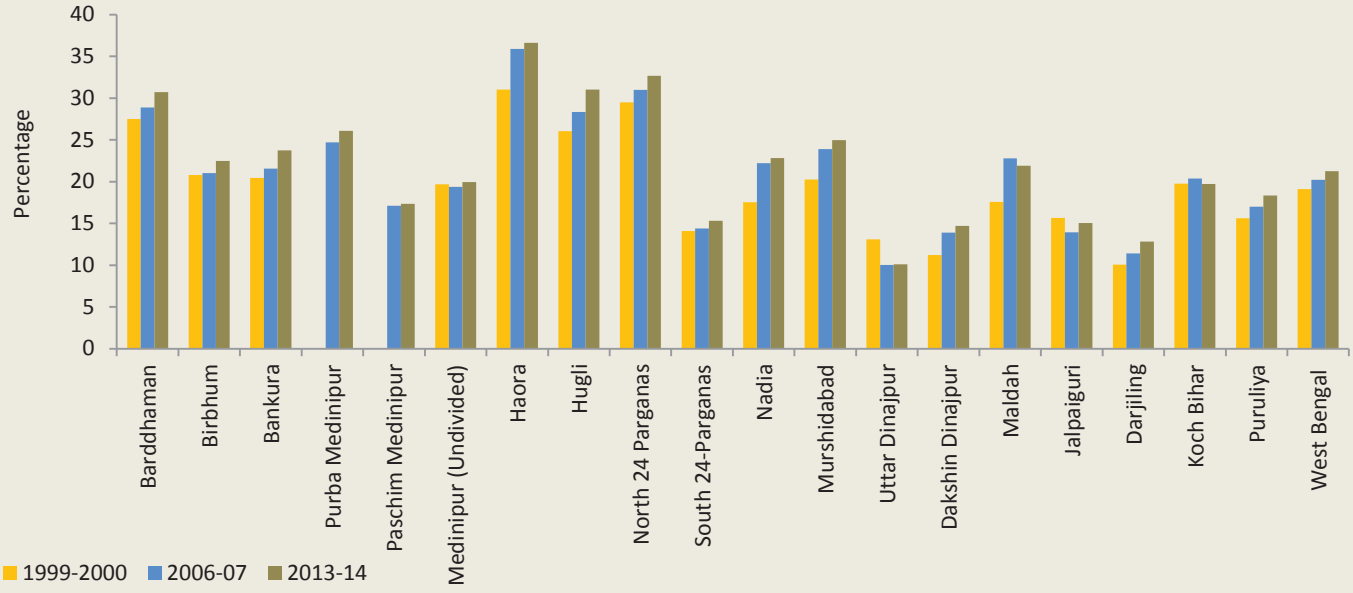
* According to village papers

** North 24 Parganas forest area has been added with South 24 Parganas forest area

Δ Area under non-agricultural uses, barren and unculturable land.

ƭ Area under permanent pastures and other grazing lands, land under miscellaneous tree groves not included in net area sown, culturable waste lands, fallow lands other than current fallows

FIGURE 3.2 Area not available for cultivation



highest land use under this category, around 22 per cent and 20 per cent respectively. In South Bengal, South 24 Parganas, due to its location and physiography, shows relatively less urbanisation trend with only 15 per cent land under this category.

West Bengal's 13.52 per cent forest areas are mainly located in South and North 24 Parganas, Darjiling, Jalpaiguri, Bankura, Paschim Medinipur and Puruliya districts. Over 95 per cent of the total West Bengal forest areas are present in these eight districts. In other districts, land area wise very small percentage is covered under forest in which Haora, Hugli, Nadia, Murshidabad, Uttar Dinajpur and Purba Medinipur shows no or very little forest area coverage.

In terms of agricultural area, land under net area sown category; Uttar and Dakshin Dinajpur is having largest district wise land use share with over 80 per cent of land followed by Koch Bihar, Nadia, Murshidabad, Purba Medinipur, Birbhum and Hugli. All these districts are part of Ganga Basin area with fertile agricultural land. Darjiling in Himalayas and South 24 Parganas with Sundarban forest and estuary shows lowest agricultural areas 42 per cent and 38 per cent of district areas under this category.

It is to be noted that Puruliya is having largest area, 18.63 per cent of total district land under current fallows followed by Maldah with 14.13 per cent land under current fallow. Other western districts with relatively less irrigation facilities like Paschim Medinipur and Bankura are also having large portion of area 7.5 per cent and 5 per cent respectively under current fallow, (Table 3.3).

District land use changes

The changes of land use land cover pattern over time shows that although urbanisation is growing but growth pattern is also different in different districts in West Bengal.

Area not available for cultivation

Area not available for cultivation, which are mostly used for built up settlement and transport area, indicative of urbanisation shows over all state level 2 per cent

increase during 2000-2014 period. It is noticed that during this period, the maximum conversion of other land category to this category took place in the four South Bengal districts namely Haora, Hugli, North 24 Parganas and Barddhaman. Haora has shown maximum changes from 31 per cent in 2000 to over 36 per cent in 2014. Other districts, which show relatively larger share and growth in this category of land use, are located in South Bengal namely Murshidabad, Nadia, Bankura, Purba Medinipur and Birbhum. During 2000-2014, South 24 Parganas, Uttar Dinajpur, Koch Bihar, Jalpaiguri and Paschim Medinipur show minimum land use changes to this category indicates the rate of urbanisation is relatively slow in these districts - particularly Uttar Dinajpur and Paschim Medinipur show very little change towards this direction. Maldah shows very sharp growth in this category of land use from 2000-2007, but between 2007 and 2014 the negative growth is noticed (Figure 3.2).

The urban land use pattern is changing at a very fast rate in urban local body and municipal corporation areas. It is important to incorporate land use planning in the planning process. The current legal framework of Town and Country Planning Act, 1979 accepted in 1982, covers designated 'Development Areas' administered by specially constituted development authority viz., Kolkata Metropolitan Development Authority (KMDA), Asansol Durgapur Development Authority (ADDA), Barddhaman Development Authority (BDA), Siliguri-Jalpaiguri Development Authority (SJDA), Haldia Development Authority (HDA), Digha Sankarpur Development Authority (DSDA). Such authorities are given responsibility to prepare land use plan and maps to control the process of development. These are called Land Use and Development Control Plan (LUDCP). But for majority of 125 urban local bodies and municipal corporations, such planning process has been handed over to them in the form of Development Plan. Majority of these local urban bodies has prepared second generation Development Plan.

Agricultural land

The overall district wise percentage of net area sown is highest in Uttar Dinajpur. It shows distinct increase of this area from 2000 to 2007, but 2007 onwards there is no change in net area sown. This is due to conversion current fallows between 2000 and 2007 (Figure 3.4). In all other districts except Koch Bihar, the agricultural land remains static or decreases during 2000-2014 (Figure 3.3). Koch Bihar also shows the decrease of current fallows during that period.

During the period 2000-2007, positive changes of current fallows are noticed in western districts like Puruliya, Paschim Medinipur and Bankura. Maldah also shows large increase in current fallows during 2000-2007 (Figure 3.4). But from 2007 to 2014, except Puruliya and Paschim Medinipur, all the above districts show reduction of current fallows.

In many districts, conversion from current fallows to agricultural land has taken place but districts like Barddhaman, Nadia, Haora, Hugli show reduction of net area sown as well as current fallows which can only attributed to adding these lands to 'area not available for cultivation' i.e. due to the effect of urbanisation in these districts (Figure 3.3 & Figure 3.4).

Forest area

Forest area does not show any significant changes during 2000-2014 period in the districts where the forests are present (Figure 3.5).

Other uncultivated land excluding current fallows

Reduction of 'other uncultivated land excluding current fallows' is noticeable during 2000-14. In West Bengal it reduced to half from 1.82 per cent to 0.94 per cent

FIGURE 3.3 Net area sown

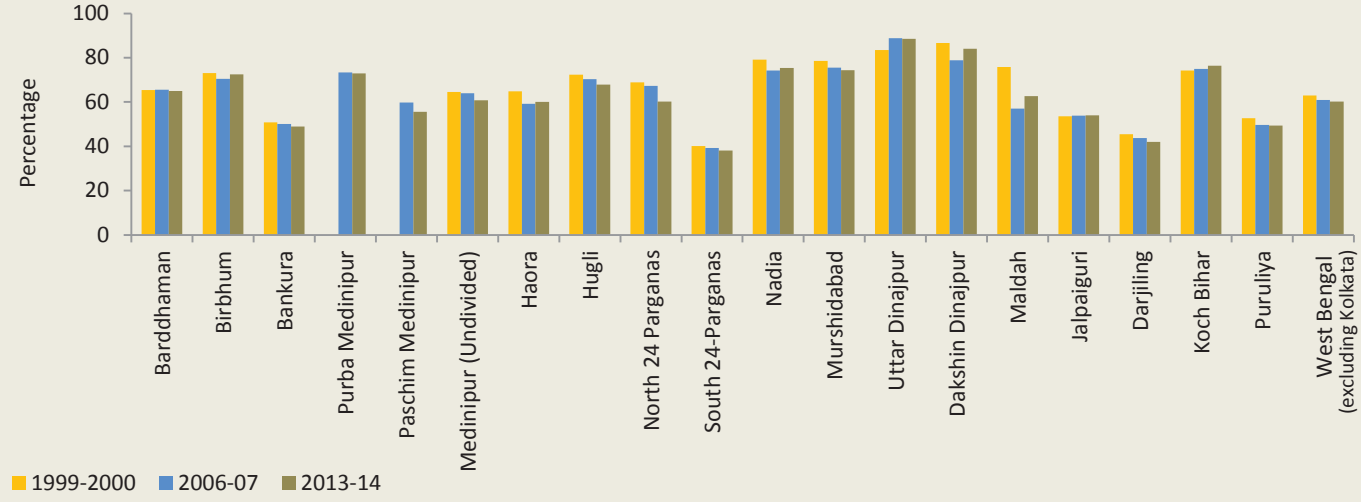


FIGURE 3.4 Current fallows

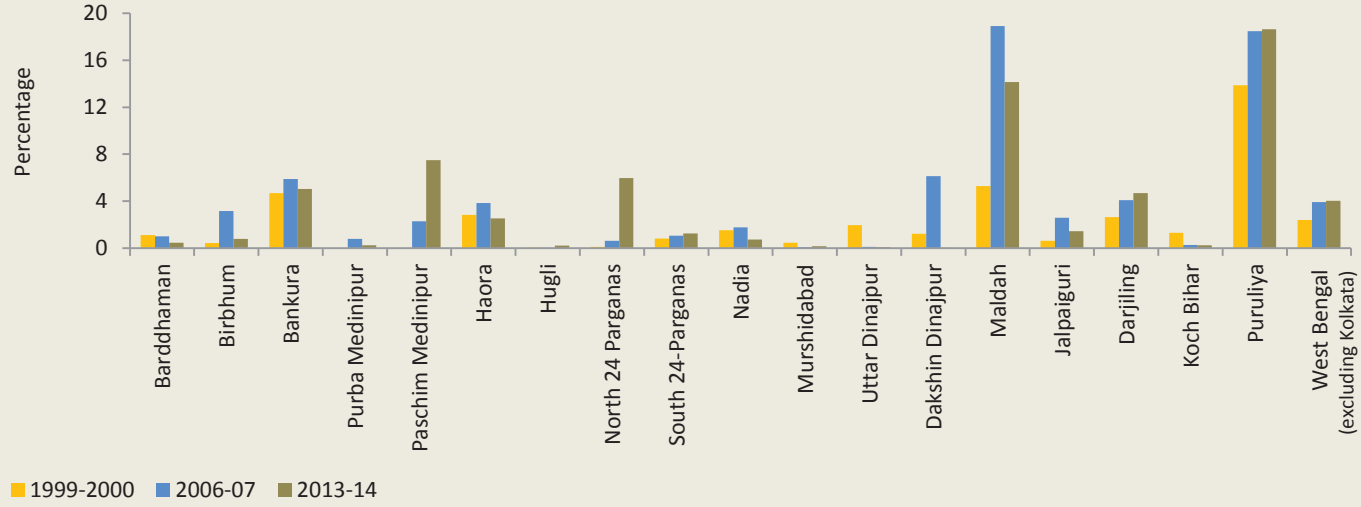


FIGURE 3.5 Area under forest

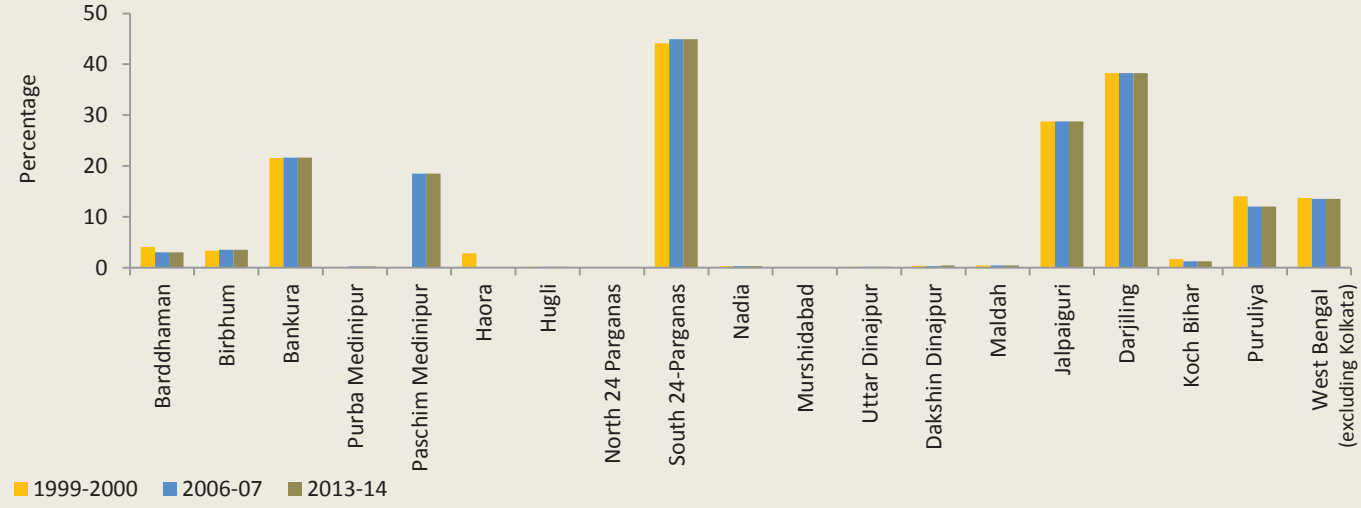
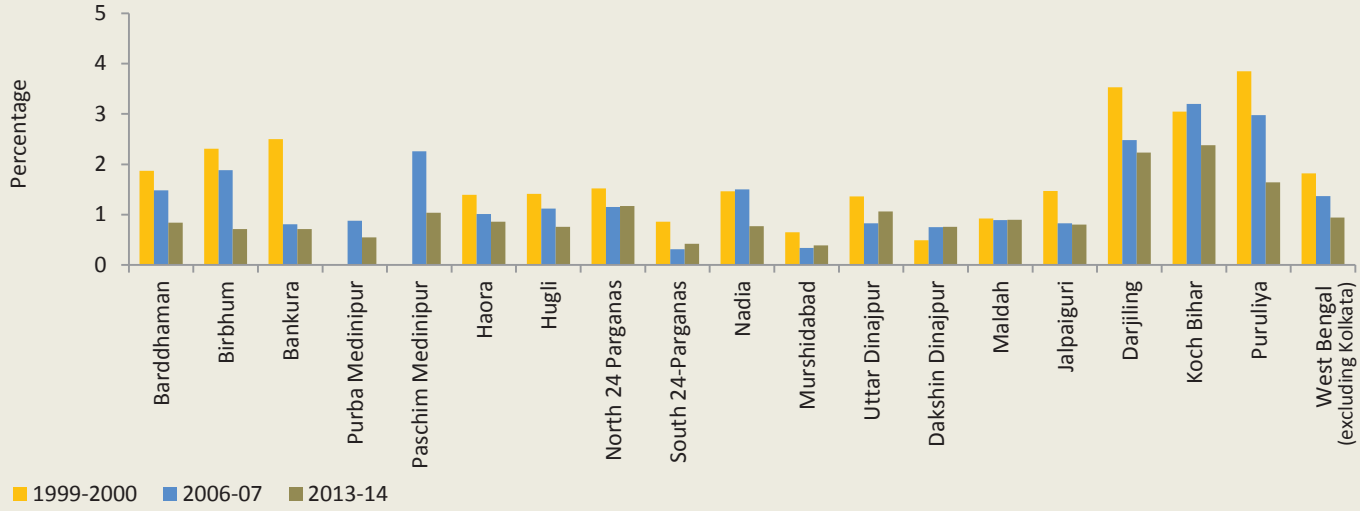


FIGURE 3.6 Other uncultivated land excluding current fallows



during this period (Figure 3.6). All the districts show reduction of this category land and the most noticeable changes are in Puruliya and two North Bengal districts namely, Darjiling and Koch Bihar. Across West Bengal, conversion of this category to land for built up, settlement and infrastructure can be noticed.

Conclusion

The overall land use land cover changes show increase in lands not under cultivation primarily for settlement and built up area and slow reduction of agricultural land. Both these changes are noticeable in South Bengal districts mainly on both sides of river Bhagirathi.

This trend needs to be properly assessed and monitored with the context of climate change. Large parts of South Bengal particularly in and around Kolkata city is vulnerable to the effects of climate change. Climate change resilient land use practices needs to be adopted to counter the threat of climate change.

Chapter 4

Soil

West Bengal is a state of eastern India lying between 20^{0}31' and 27^{0}14'N latitude and 85^{0}51' and 89^{0}53'E longitude with diverse physiography of high peaks of Himalayas in the northern extreme to low lying coastal regions in the south and regions of plateau and alluvial plain intervening in between. It covers an area of 88,752 sq km (34,257 sq mile) comprising 20 administrative districts namely, Barddhaman, Bankura, Puruliya, Birbhum, Purba Medinipur, Paschim Medinipur, Hugli, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas, Kolkata, Haora, Maldah, Uttar Dinajpur, Dakshin Dinajpur, Jalpaiguri, Alipurduar, Koch Bihar and Darjiling. The State supports approximately 7.54 per cent population (91.28 million as per Census, 2011) on only 2.7 per cent of the country's geographical area (Statistical Abstract 2013, Govt. of West Bengal).

Physiography

Physiographically the State is broadly divided into three regions, viz (i) Eastern Himalayas (in the north), (ii) Eastern or Chhotonagpur Plateau, and (iii) Alluvial and Deltaic Plains (Figure 4.1).

Eastern Himalayas (in the north): The Eastern Himalayas includes mountainous terrain of Darjiling and northern fringe of Jalpaiguri districts. Primarily, this is a forest area extending down to foot hills and is dotted with terraced lands under cultivation and tea gardens. Rivers like Tista, Mahananda, Jaldhaka and Torsha originating from snow-clad rain-fed Himalayas with their tributaries run in south-east direction and bring down parent material to form central alluvial plain of the State, but disposing much of the finer fractions to Bangladesh.

Eastern or Chhotonagpur Plateau: The western part of the districts of Birbhum, Barddhaman, Bankura, Paschim Medinipur, and almost entire Puruliya representing the eastern fringe of Vindhya ranges are undulating terrains dotted with small hills like Ajodhya and Susunia. Soils of this region are reddish in colour with an occurrence of granite, mica and gneissic rocks. Most of the rain-fed rivers like Damodar, Ajoy, Kansabati, Mayurakshi, Dwaraka, etc. originating from the Vindhya hills run down in south-east direction and ultimately discharging their contents into the river Ganges.

Alluvial and Deltaic Plains: About two-third area of the State is under this region. Vast stretches of this flat land are formed in the east and south of the State with alluvial deposits brought down by the rivers originating from the

FIGURE 4.1 Physiographic map of West Bengal
Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

Himalayas and hills of Vindhya ranges are called Bengal basin. It comprises both older and newer alluvium, although it is difficult to draw a distinct line of separation between these two. The river Ganga bifurcates into two main tributaries, viz Padma and Bhagarathi in the area between Rajmahal in Bihar and Murshidabad in West Bengal and starts developing Bengal basin. The river Ganga and its tributaries meanders severely leaving meandering scar on the flood plain and/or deltaic plain in extreme south of South 24 Parganas and south-eastern part of Purba Medinipur. Some areas are so low-lying as to receive tidal inundations daily. Numerous islands of different size and shape scattered in the Bay fringes. A large part of landmass adjoining Bangladesh and extending up to the Bay is under reserve forest (Sundarbans).

Agro-ecological sub-regions of West Bengal

A proper understanding of natural resources is essential for sustainable agricultural development of a State. Adequate information on the requirement of crops, soil types, their distribution and agro-climatic conditions are prerequisite for efficient crop planning in an area. The delineation of homogenous agricultural environment, called agro-ecological regions (AER) on the basis of soil characteristics, landforms, climate and biodiversity help in better crop selection, agro-technology transfer for sustainable land use. The National Bureau of Soil Survey and Land Use Planning has delineated 20 agro-ecological regions in the country superimposing length of growing period (LGP) and bioclimatic map on soil physiographic map. The LGP is the period (days), when precipitation exceeds 50 per cent of potential evapotranspiration (PET) plus time required to evapotranspire 100 mm of stored moisture from the deep soil layers or simply the period when both soil water and temperature permit crop growth. On the other hand, moisture index, thermal efficiency and summer concentration values act as a basis for determining bioclimate of an area. Agro-ecological regions are further refined to agro-ecological sub-regions (AESR) on the basis of LGP of 30 days interval starting from LGP of 60 days (Velayutham *et al.*, 1999). The soils of West Bengal are under into six agro-ecological sub-regions (Figure 4.2).

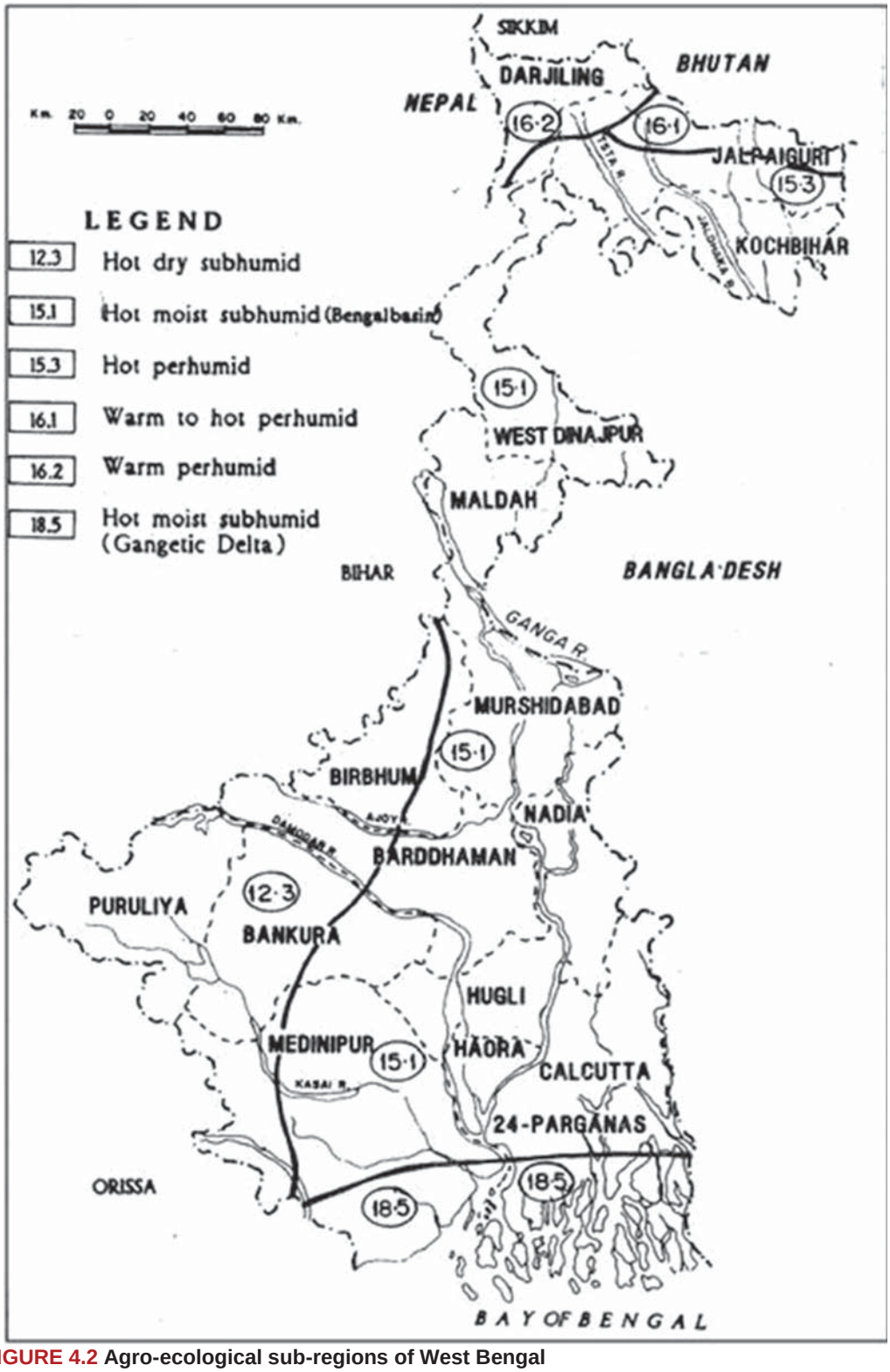


FIGURE 4.2 Agro-ecological sub-regions of West Bengal

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

In the legend (say, 12.3) the first numeral (12) represents the agro-ecological region [here, Eastern Plateau (Chhotanagpur) and Eastern Ghats, hot sub-humid ecoregion], while second numeral (3) represents the sub-region (LGP of 150-180 days) of this AER. The 12th AER has three sub-regions. Climate and characteristics and distributions of dominant soils under each sub-region have been discussed in Table 4.1.

TABLE 4.1 Description of Agro-ecological sub-regions of West Bengal

AESR (No.)	Soil type	Climatic factors	Soil characteristics	Area (% of State TGA*)	Distribution
Soils of Warm Perhumid AESR (16.2)	Brown forest soil of the Himalayas	Warm perhumid characterized by mild summers and cold winters associated with high rainfall. LGP more than 300 days	Soils of steep hill slopes are shallow, excessively drained with severe erosion hazard. Soils of foothill slopes and valleys are moderately deep, well drained, and loamy with moderate erosion hazard. Soils are low in water holding capacity, moderate to high in organic matter and available potash, but low in available phosphorus. Low soil pH leads to Fe, Mn and Al toxicity, but deficiency of Mo and B in some areas.	0.26 m ha (2.9)	Mountainous region of Darjiling district
Soils of Warm to Hot Perhumid AESR (16.1)	Tarai soils of Himalayan foothills	Warm summers, cool winters with high rainfall (>3000 mm). 270-300 days LGP	Partly developed and/or show beginning of profile development with young alluvium and with materials on alluvial fans of foothills. Soils are shallow to moderately deep and in some places deep with medium to fine texture. Severe flood hazard and runoff problem. Soils are low in water holding capacity, strongly to moderately acidic while at places neutral to mildly alkaline in reaction, high in undecomposed organic matter due to low decomposition rate; low in available N and P, but moderate to high in K.	0.17 m ha (1.9)	Northern fringe of Jalpaiguri and part of Koch Bihar district
Soils of Hot Perhumid AESR (15.3)	Alluvial plains of Teesta, Torsa, Mahananda, etc.	Warm summers, mild winters associated with high rainfall (>3000 mm). LGP 270-300 days	Soils developed in recent alluvium mostly occur in flood plains. These are moderately deep to deep, coarse to fine loamy in texture, imperfectly and/or poorly drained but at places are well drained, subject to moderate flood hazard. Slightly acidic to neutral while in some places slightly alkaline. Soils are low in cation exchange capacity, base saturation percentage, water holding capacity and available N.	0.85 m ha (9.6)	Koch Bihar, southern part of Jalpaiguri and Islampur subdivision of Uttar Dinajpur
Soils of Hot, Moist Subhumid AESR (15.1)	Indo-Gangetic alluvial plain (Bengal Basin)	Moist subhumid climate characterized by dry and hot summers and mild winters, medium rainfall (1389-1908 mm). LGP 210-240 days.	Soils formed from the alluvium deposited by the Ganga, its tributaries and rivers originating from Chhotonagpur plateau are deep, coarse to fine-loamy in texture, moderately well drained to well drained, but at places, are poorly drained. Soils are neutral to slightly alkaline in reaction with high base saturation. Soils on low-lying areas in the old flood plain show some degree of profile formation under high water table and reduced soil condition. These are imperfectly to poorly drained, slightly acidic to slightly alkaline in soil reaction with medium base saturation. Soils are low in N, medium in P and K.	4.93 m ha (55.7)	Indo-Gangetic plain covering districts of Maldah, southern part of Dakshin Dinajpur, Mushidabad, Nadia, Haora, Hugli, northern part of 24-Parganas, eastern part of Barddhaman, Birbhum, Bankura and eastern part of Medinipur
Soils of Hot, Moist Subhumid AESR (18.5)	Saline soils	Moist subhumid climate characterized by hot summers and mild winters. The mean annual rainfall covers 80-90 per cent of the annual PET**. LGP 240-270 days	Soils are deep, fine-loamy to fine in texture, imperfectly to poorly drained with moderate to very strong salinity hazards. They are neutral to slightly alkaline in reaction, rich in bases and, in general, have exchangeable sodium percentage (ESP) below the critical value (15%). Soils are rich in organic matter and medium in NPK.	0.68 m ha (7.6)	Coastal parts of 24 Parganas (North and South) and Purba Medinipur
Soils of Hot, Dry Subhumid AESR (12.3)	Alluvium of Peninsular rivers	Dry subhumid climate characterized by dry and hot summers and mild winters. Annual rainfall ranges from 1307 to 1392 mm covering 80 to 90 per cent of annual PET. LGP ranges from 150-180 days	Soils formed with alluvial deposits of rivers originating from Chhotonagpur plateau. Gently sloping and/or gently undulating land. Soils are well drained containing basic and ferruginous concretions, deep, loamy to clayey in texture. Low in organic matter, low to medium in N and P, while moderate to high K content.	1.98 m ha (22.3)	Puruliya, western part of Barddhaman (Asansol), Bankura, Birbhum (Suri), Pashim Medinipur (Jhargram)

*TGA-total geographical area; **PET-potential evapotranspiration

Land use

The state of West Bengal is densely populated; eventually there is tremendous pressure on limited land resources. About 68.0 per cent of the population lives in villages where agriculture is the prime mean of livelihood. The present land use scenario is illustrated in Table 4.2 and Figure 4.3.

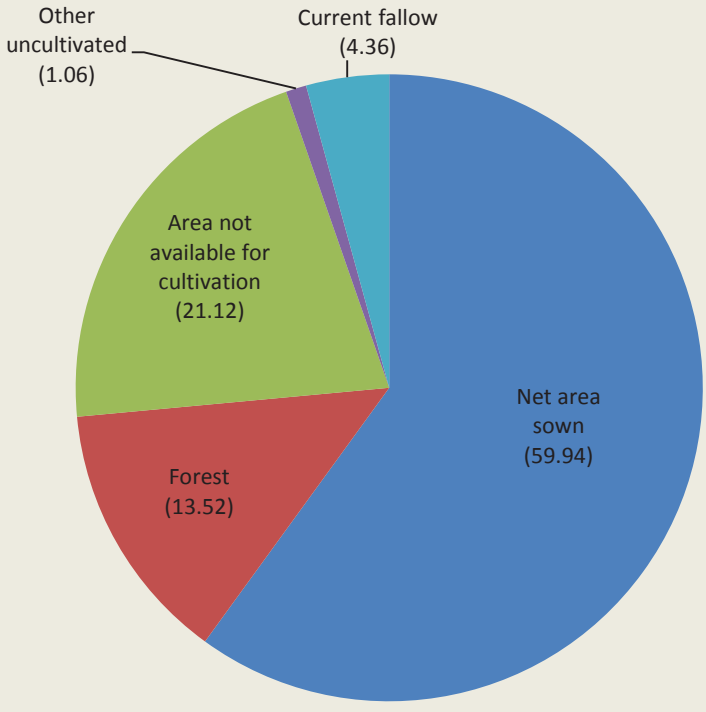
The data in Table 4.2 and Figure 4.3 reveal that about 59.94 per cent of reporting area is net sown area and of which only 21.17 per cent area is under government canal irrigation facility. The forest land occupies 13.52 per cent while 21.12 per cent of reporting area of the State is not available for cultivation. The cropping intensity computed as percentage of gross cropped area to net cropped area of the State is 182.

TABLE 4.2 Land utilization pattern of West Bengal in 2012-13

Land use	Area (m ha)
Total geographical area	8.875
Reporting area (excluding Kolkata)	8.684
Net area sown	5.205
Forest	1.174
Area not available for cultivation	1.834
Other uncultivated land excluding fallow land	0.092
Current fallow	0.379
Gross cropped area	9.459

Source: Statistical Abstract 2013, Govt. of West Bengal

FIGURE 4.3 Land use of West Bengal (2012-13) (in %)



Soil fertility

Although, the available nutrients' status of a soil is not an intrinsic property, their evaluation is needed to make sound fertilizer recommendation for maximum crop production with minimal or no environmental pollution. Indian Institute of Soil Science, Bhopal (2005) has evaluated available N, P and K status of soils of ten districts (Darjiling, Jalpaiguri, Koch Bihar, North and South 24 Parganas, Hugli, Nadia, Purba and Paschim Medinipur and Puruliya) of this State using GIS technology. Soil fertility map of different districts is prepared after categorization of area on the basis of percent sample falling in different categories. For example, more than 50 per cent samples in deficient category as low, 25-50 per cent samples in deficient category as medium and less than 25 per cent samples in deficient category as high.

District wise soil fertility map shows that soils of Purba and Paschim Medinipur, North and South 24 Parganas are low, while soils of Darjiling, Jalpaiguri, Koch Bihar, Puruliya,

TABLE 4.3 Rating chart for available N, P and K in soil

Fertility level	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
High	>450	>90	>350
Medium	>280-450	>45-90	>200-350
Low	Up to 280	Up to 45	Up to 200

Hugli and Nadia are medium in available nitrogen (Figure 4.4).

With respect to available phosphate content soils of Puruliya and Purba Medinipur are low, soils of Darjiling, Jalpaiguri, Koch Bihar, Maldah, North 24 Parganas, South 24 Parganas and Paschim Medinipur are medium, and soils of Hugli are high, while the report on soils of other districts of the State is still unavailable (Figure 4.5).

With respect to available potassium content of soils of West Bengal reveals that out of ten districts, soils of eight districts (Darjiling, Maldah, North 24 Parganas, South 24 Parganas, Hugli, Puruliya, Purba Medinipur and Paschim Medinipur) are medium, and soils of Jalpaiguri and Koch Bihar are rated as low (Figure 4.6).

Usually, the fertilizer dose is increased or decreased by 30-50 per cent of general recommendation (medium category) for soils graded as low or high category, respectively.

However, district wise no comprehensive data on secondary or micronutrient status of soils of West Bengal is available.

Problem in soils of West Bengal

The soil resource mapping of West Bengal has brought out some of salient land characteristics within different agro-ecological sub-regions. The extent and distribution of limiting soil attributes important for different land use such as soil depth, soil erosion, drainage, and salinity are discussed below:

Soil depth

The effective soil depth not only governs the root development but also is a source of moisture and nutrient supply to the plants. Thus, the effective soil depth plays a vital role in selection of crops to be grown in an area.

There are five depth classes of which three influences crop growth and selection of crops. Only 5.3 per cent of total geographical area has limiting soil depth and rest (94.7%) area is free from soil depth related problem (Table 4.4).

TABLE 4.4 Soils under limiting depth classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Very Shallow (0.25 cm)	Hot Subhumid (12.3)	Puruliya	30.7	0.3
Shallow (25-50 cm)	Warm Perhumid (16.2)	Part of Darjiling	15.4	0.2
	Hot Subhumid (12.3)	Puruliya, Medinipur, Bankura	303.0	3.4
Moderately Shallow (50-75 cm)	Warm Perhumid (16.2)	Part of Darjiling	109.8	1.2
	Hot Subhumid (12.3)	Parts of Medinipur, Barddhaman, Birbhum, Puruliya, Bankura	15.4	0.2
Total			**474.3**	**5.3**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

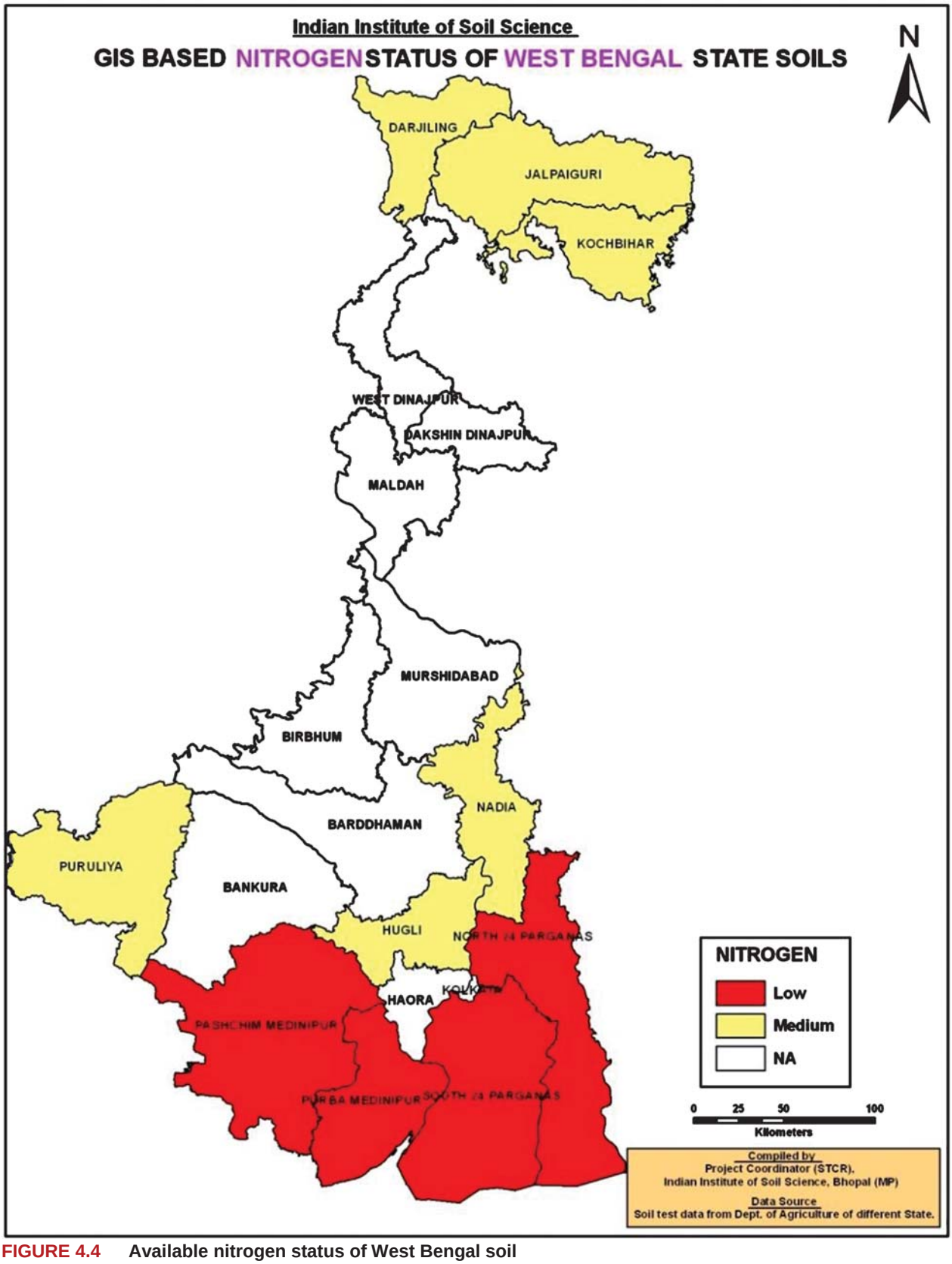


FIGURE 4.4 **Available nitrogen status of West Bengal soil**

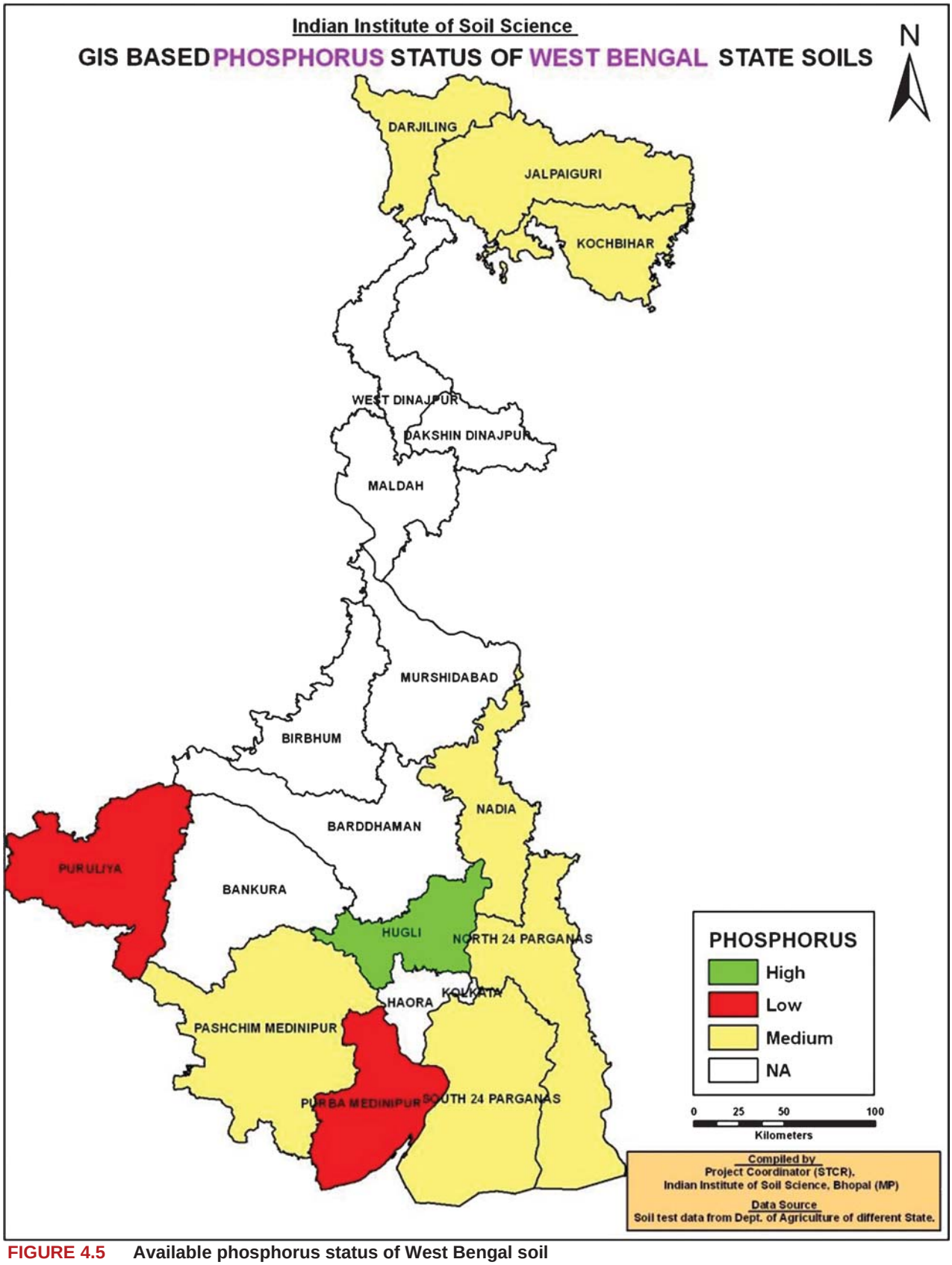


FIGURE 4.5 **Available phosphorus status of West Bengal soil**

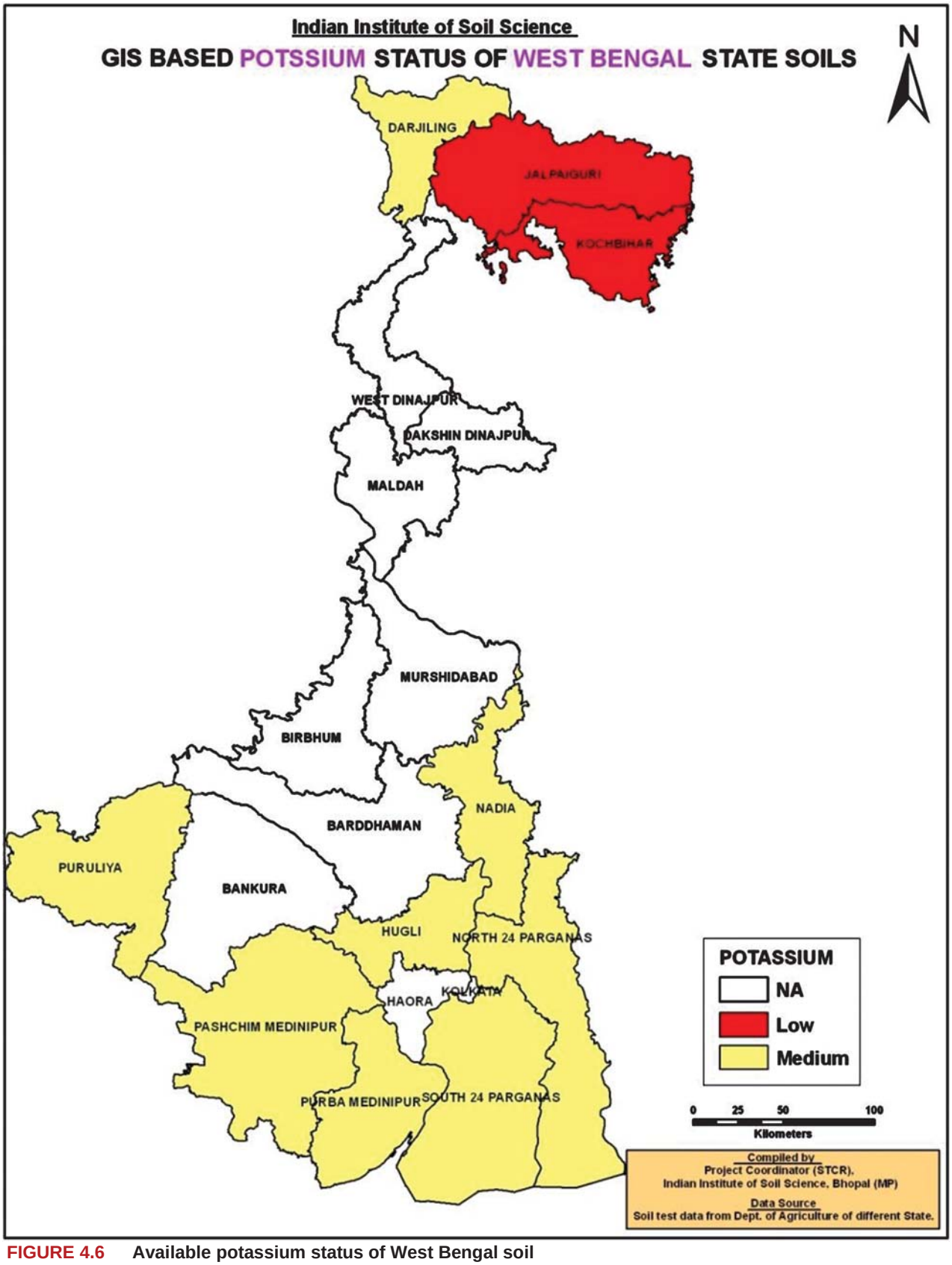


FIGURE 4.6 **Available potassium status of West Bengal soil**

Drainage

Drainage refers to internal drainage through the soil profile. It is governed by soil texture, structure, landform and depth of water table. Soils of West Bengal are grouped into six drainage classes, of which four have been found to adversely affect the soil and crop management. The extent and districts affected by these drainage classes are discussed in Table 4.5. Nearly half of the total geographical area of the State suffers from various degree of drainage problem, but rest half has the normal soil drainage.

Soil erosion

In West Bengal, soil erosion means erosion by water which is the major soil degradation factor in hilly areas of Darjlling and undulating terrains of south-western plateau. Out of four erosion classes identified, two require immediate soil and water conservation measures. The areas affected by these two classes are described in Table 4.6. About 15.2 per cent of total geographical area requires soil and water conservation measure to prevent soil degradation by water erosion. However, 84.5 per cent of total geographical area has no soil erosion related problem.

TABLE 4.5 Soils under limiting drainage classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Very Poorly Drained	Hot Subhumid (15.1)	Part of Medinipur, Hugli, South 24 Parganas	173.4	1.9
Poorly Drained	Hot Perhumid to Subhumid (15.3 & 15.1)	Parts of 24 Parganas, Nadia, Murshidabad, Jalpaiguri, Koch Bihar, Maldah, Medinipur, Haora, Hugli	2453.3	27.6
Imperfectly Drained	Hot Subhumid (15.1)	Parts of Barddhaman, Birbhum, Hugli, Dakshin Dinajpur, Maldah, Medinipur, Puruliya	1747.6	19.7
Excessively Drained	Warm Perhumid (16.2)	Parts of Darjiling and Jalpaiguri	56.1	0.6
	Hot Subhumid (12.3)	Parts of Bankura and Puruliya	8.6	0.1
Total			**4439.0**	**49.9**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

TABLE 4.6 Soils under limiting erosion classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Severe	Warm Perhumid (16.2)	Part of Darjiling	37.0	0.4
	Hot Subhumid (12.3)	Western part of Puruliya, Birbhum, Bankura, and Medinipur	20.4	0.2
Moderate	Hot Subhumid (12.3 & 15.1)	Western part of Barddhaman, Birbhum, Bankura, Medinipur, Murshidabad, Maldah, Dinajpur (Uttar and Dakshin), Koch Bihar and entire Puruliya	1137.1	12.8
	Warm Perhumid (16.2)	Part of Darjiling and Jalpaiguri	166.0	1.8
Total			**1360.5**	**15.2**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

Texture

Soil texture is an intrinsic permanent attribute of the soil and plays an important role in crop production starting from seed germination to crop maturity. Among the textural classes, those adversely affect crop growth are sandy, gravelly loam and clayey. The extent and districts affected by these textural classes are described in Table 4.7. About 23.2 per cent of total geographical area is either too light or too heavy textured to affect crop growth and selection of crop, while soil texture of 76.8 per cent area is good enough for crop growth.

Waterlogging

Waterlogging refers to the soil condition whereby the soil becomes saturated with water within the depth of root zone for a significant period. Waterlogging may occur due to high water table or submergence by rainwater or both. It is one of major physical deterioration which adversely affects the yield and quality of crops. Crop yield and selection of crop of about 14 per cent area of the State are influenced by waterlogging. However, rest 86 per cent area is free from such problem (Table 4.8).

TABLE 4.7 Soils under limiting textural classes (surface soil)

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Sandy	Hot Subhumid (18.5)	Coastal part of Medinipur	13.7	0.2
Gravelly loam	Warm Perhumid (16.2) Hot Subhumid (12.3)	Part of Darjiling, Paschim Medinipur, Bankura, Puruliya	488.4	5.5
Clayey	Hot Subhumid (15.1)	South 24 Parganas, Purba Medinipur, Barddhaman, Murshidabad, Nadia	1550.7	17.5
Total			**2052.8**	**23.2**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

TABLE 4.8 Soils under limiting waterlogging classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Moderate	Hot Perhumid (15.3)	Koch Bihar, Jalpaiguri	111.3	1.2
	Hot Moist Subhumid (15.1)	Dakshin Dinajpur, Medinipur, Barddhaman, Birbhum, Murshidabad	337.5	3.8
Slight	Warm Perhumid (16.2) Hot Perhumid (15.3)	Darjiling, Jalpaiguri, Koch Bihar	189.8	2.1
	Hot Moist Subhumid (15.1)	Dakshin Dinajpur, Maldah, Murshidabad, Birbhum, Barddhaman, Medinipur, Hugli, Nadia, Haora	618.5	6.9
Total			**1257.1**	**14.0**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

Flooding

Flooding is considered as a serious limitation for crop production in Indo-Gangetic plains of West Bengal. The area affected by surface flooding is given in Table 4.9. Therefore, crop planning as well as crop yield of nearly 22 per cent of total geographical area are regulated by surface flooding, while rest is safe from flooding.

Salinity

Salinization is a major mean of chemical degradation of land. In West Bengal, salinization is exclusively due to tidal inundation of costal land. Management of saline soil includes removal of soluble salts from root zone and thereafter maintenance of salt level of crop root zone at a desired level.

Out of five soil salinity classes, three classes severely hinder crop growth. The areas affected by salinity are given in Table 4.10. Only 4.26 per cent area is affected by salinity problem and requires soil management involving removal of soluble salts from root zone. However, vast majority (95.7 per cent) of soils of West Bengal is normal with regard to soluble salt content.

Soil contamination with heavy metals and Fluoride

In West Bengal groundwater in 12 districts (out of 20 districts) and 111 blocks (out of 341 blocks) is under the risk of arsenic contamination (Figure 4.7). Continuous withdrawal and deposition of arsenic contaminated groundwater (<0.01 mg/l As is the permissible limit for irrigation water set by WHO and FAO, the USA and European Union) for irrigation purpose may lead to increase soil arsenic level beyond the maximum acceptable limit for agricultural soil (20 mg/kg) recommended by the European Union and can affect the food chain cultivated in those areas. Although,

TABLE 4.9 Soils under limiting flooding classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Moderate	Hot Perhumid (15.3)	Parts of Jalpaiguri, Koch Bihar, Uttar Dinajpur	112.0	1.3
	Hot Subhumid (15.1)	Parts of Uttar Dinajpur, Maldah, Murshidabad, Nadia, Barddhaman, 24 Parganas, Medinipur	931.2	10.5
Severe	Hot Subhumid (15.1)	Parts of Hugli, Medinipur, Murshidabad, Nadia, 24 Parganas	907.2	10.2
Total			**1950.4**	**22.0**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

TABLE 4.10 Soils under limiting salinity classes

Class	AERS (No.)	Distribution	Area affected ('000 ha)	% of TGA
Very Strong	Hot Subhumid (18.5)	Parts of South 24 Parganas, Purba Medinipur	241.0	2.7
Strong	Hot Subhumid (18.5)	Parts of South 24 Parganas, Purba Medinipur	5.7	0.06
Moderate	Hot Subhumid (18.5)	Parts of South 24 Parganas, Purba Medinipur	131.0	1.5
Total			**377.7**	**4.26**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

detail study on arsenic contamination in soils of West Bengal has not been done, soil arsenic concentration in agricultural land soils (10.7 mg/kg) is higher compared to the fallow land (5.32 mg/kg). Arsenic concentrations (11.5 and 28.0 mg/kg, respectively) are high in those agricultural land soils of Domkol, Murshidabad where irrigation groundwater contains high As (0.082 and 0.17 mg/l, respectively) (Roychowdhury *et al.*, 2002). Sarkar *et al.* (2012) also reported that application of 1,200-1,400 mm water contaminated with As ranging from of 0.1-0.35 mg/l adds 120-420 mg arsenic per sq m with each cropping of summer rice making the soil as a secondary source of arsenic pollution.

Contamination of soils in and around open cast mines of Raniganj area of Barddhaman with mine waste indicates cadmium pollution of native soil and facilitates its entry in the food chain (Sadhu *et al.*, 2012). Effect of long-term irrigation with sewage water in soils and crops grown along the water channel running eastward of Kolkata also reveals severe cadmium pollution in soils, and higher concentration of lead, cadmium and nickel in number of vegetable crops beyond their permissible limits (Saha *et al.*, 2015).

The problem of high fluoride concentration (>1.5 mg/l) in groundwater resources has become one of the most important toxicological and geo-environmental issues in India. In West Bengal, 225 villages in 43 blocks of 7 districts (Birbhum, Bankura, Puruliya, Maldah, South 24 Parganas, Dakshin Dinajpur and Uttar Dinajpur) are identified as endemic for fluorosis (Figure 4.8) and people in these regions are at risk of fluoride contamination (Haldar and Ray, 2014). The fluoride concentrations in the contaminated groundwater of those areas are as high as 1.06-1.75 mg/l (Datta *et al.*, 2014). Peninsular rivers like Damodar and Rupnarayan carried fluoride charged alluvium in West Bengal. Use of fluoride loaded groundwater for irrigation purpose

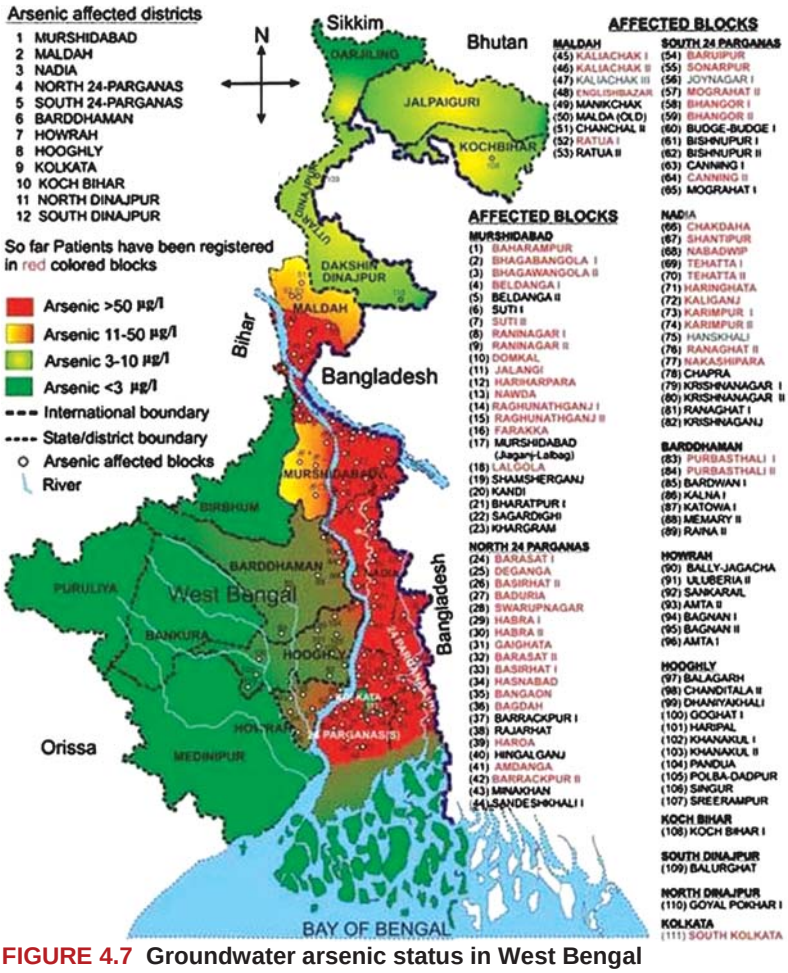


FIGURE 4.7 Groundwater arsenic status in West Bengal (till September 2006)

can build up fluoride concentration in soils as well as in crops grown in those areas beyond the threshold limit.

Soil degradation status of West Bengal

The major problems of the soils of West Bengal causing appreciable losses in soil productivity have been discussed in the preceding section. Soil degradation processes can basically be grouped into two categories: (i) soil loss as water/wind erosion and (ii) deterioration of soil properties. The second category of soil degradation includes physical deterioration in the form of waterlogging, flooding and chemical deterioration as salinization. Soil

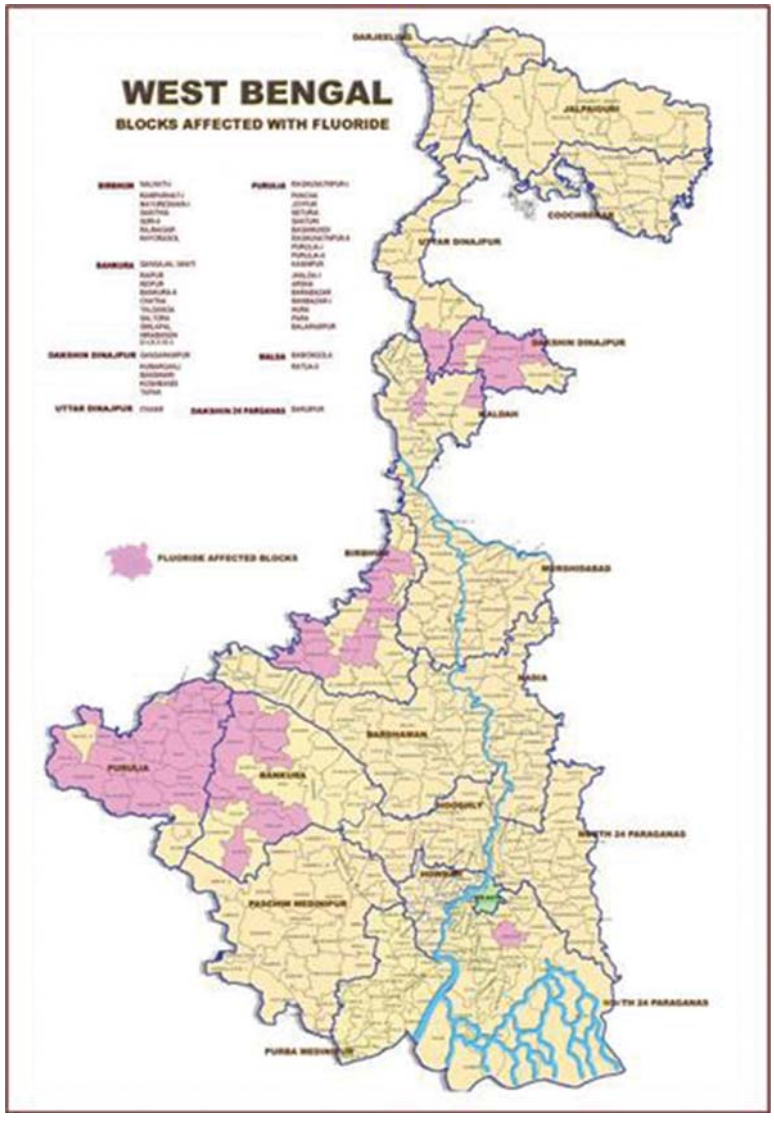


FIGURE 4.8 Fluoride affected blocks of West Bengal
Source: Public Health Engineering Department, Govt. Of West Bengal, 2014

degradation due to nutrient loss and/or depletion of organic matter has not been included in calculations to avoid overlapping as these areas have been included under water erosion.

The data in Table 4.11 depict that about 30.9 per cent of TGA in West Bengal is degraded due to one of the above problems. About 19.7 per cent area occurring mainly in the districts of Puruliya, Bankura and Darjiling is affected due to loss of top soil by water erosion; while 3.2 per cent of area occurring mainly in the districts of South 24 Parganas and Purba Medinipur is degraded due to soil salinity and 6.9 per cent of area occurring mainly North and South 24 Parganas, Medinipur, Hugli, Nadia and Maldah is degraded due to waterlogging for a significant period.

Potentiality of soils in West Bengal

The soil resource mapping of West Bengal has brought out some soil potentialities under each agro-ecological sub-region. The potentialities of soils primarily in relation to growing agricultural and horticultural crops are discussed below:

Soils of warm perhumid agro-ecological sub-region (No.16.2):

Acid soils rich in organic matter favour plantation of tea and horticultural crops like orange, pears, peech and plum. While, Darjiling tea is famous in international market for its flavour, Darjiling orange is also popular for its sweetness.

Soils of warm to hot perhumid agro-ecological sub-region (No.16.1)

Tarai soils are suitable for plantation of tea and pine apple. Establishment of more food processing units in this region can save perishable pine apple from wastage and increase the income of the farmers.

Soils of hot perhumid agro-ecological sub-region (No.15.3)

Major part of Duars favours growing of wetland crops, like jute and rice and tropical horticultural crops. While slightly alkaline upland soils are suitable for tobacco cultivation. Better processing for quality jute fibre along with central assistance on jute based industry can help the farmers to get better price for their produce.

TABLE 4.11 Status of soil degradation in West Bengal

Type of degradation		Degree of degradation ('000 ha) (%)				% of TGA
		Slight	Moderate	Strong	Extreme	
Water erosion		899.8 (10.1)	795.3 (9.0)	57.6 (0.6)	-	1752.7 (19.7)
Physical deterioration	Waterlogging	531.3 (6.0)	67.0 (0.8)	11.3 (0.1)	-	609.6 (6.9)
	Flooding	-	100.0 (1.1)	-	-	100.0 (1.1)
Chemical deterioration	Salinization+ Waterlogging	130.5 (1.5)	39.0 (0.4)	-	-	169.5 (1.9)
	Salinization + Flooding	-	-	113.0 (1.3)	-	113.0 (1.3)
	Wind erosion + Salinization	6.5 (0.01)	-		-	6.5 (0.01)
Total Degraded Area		1568.1 (17.6)	1001.3 (11.3)	181.9 (2.0)	-	2751.3 (30.9)
Wasteland not fit for cultivation		-	-	-	-	7.0 (0.1)
Stable Terrain under natural condition	Forest	-	-	-	-	333.4 (3.8)
	Mangrove vegetation	-	-	-	-	194.0 (2.2)
Land with no degradation problem		-	-	-	-	5329.6 (60.1)
Misc. area (road, river, habitation, etc)		-	-	-	-	260.0 (2.9)
Total Area		**-**	**-**	**-**	**-**	**8875.2 (100.0)**

Source: Soils of West Bengal: Their Kinds, Distribution, Characterization and Interpretation for Optimising Land use, 1992 (NBSS & LUP)

Soils of hot, moist subhumid agro-ecological sub-region (No.15.1)

Nutrient rich alluvial soils are suitable for most of the agricultural and horticultural crops keeping in view the landforms. Improved marketing facility and proper storing and processing of crops are the need of the farmers of this area.

Soils of hot, moist subhumid agro-ecological sub-region (No.18.5)

The area has the potential for saltwater pisciculture with prawns and other salt loving fish species, which can fetch more revenue from domestic and international markets.

Soils of hot, dry subhumid agro-ecological sub-region (No.12.3)

With suitable soil and water conservation measures like contour farming, water harvesting through excavating existing ponds and utilization of this water as live-saving irrigation during dry spell yield of crops like rice, wheat, mustard, groundnut can be increased under rain-fed situation.

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Chapter 5

Agriculture

The Indian Council of Agricultural Research (ICAR) has divided the country into 13 major and 127 micro level agro-climatic zones. Out of these, 3 regions are represented by the state of West Bengal; though the entire State has been divided into 6 agro-climatic zones, viz Hill Zone, Terai Zone, Old Alluvial Zone, New Alluvial Zone, Red Lateritic Zone and Costal Saline Zone on the basis of climatic factors, soil structure, texture, type, topography *vis-a-vis* ground water availability etc. An overview of these agro-climatic zones has been depicted in the Table 5.1. Out of these six agro-climatic zones Hill Zone, Terai Zone, Red Lateritic Zone and Coastal Saline Zone are identified to be stressed zones.

Agriculture is undoubtedly the backbone of the state of West Bengal, as the lion's share of the State's mammoth population depends directly or indirectly on it. It may not be irrelevant to mention that Agriculture in West Bengal is the livelihood of 65 per cent of the State's population living in the villages, with 95.4 per cent as small and marginal farmers who, besides sustaining their own families, are still feeding the rest Thirty five per cent of the population of our State having the second highest population density in the country and consequently minimum per capita share of land, being only 0.07 ha (700 square meter), for all material activities. The small and marginal farmers own 84 per cent of the land. Land reforms measures as well as modern agro-techniques *vis-à-vis* inputs and extensive use of major and minor irrigation systems had specific impact on the agricultural production of the State.

Since a number of decades the State occupies a prestigious position in the country. People get their food from agriculture in various forms *e.g.* cereals, pulses, fruits, vegetables etc. Many large and small scale industries depend on agriculture for their raw materials. Foreign trade also depends on it as it supplies a lot for exports. Thus, in brief, the fact is that the development of agriculture is the backbone of the State's economy. The importance of agriculture and allied sectors in the State's economy is reflected in its contribution of around 20 per cent in the Net State Domestic Product (NSDP) at constant (2004-05) prices. The employment support from the sector is nearly 39 per cent of total force and about 70 per cent are dependent on agriculture for their livelihood.

The average growth in different sectors during the period of last three five years plans is depicted below in the Table 5.2.

TABLE 5.1 Agro-climatic zones of West Bengal

Sl. No.	Agro-climatic zone	Area (ha)	Districts	Main Crops
1.	Hill Zone	2,42,779 (2.79%)	Darjiling (except Siliguri subdivision) and Northern part of Jalpaiguri	Maize, rice, different vegetables, potato, soybean, cardamom, ginger, medicinal plants, tea, orange etc.
2.	Terai Zone	12,14,880 (13.99%)	Darjiling (only Siliguri subdivision), Jalpaiguri, Alipurduar, Koch Bihar, Uttar Dinajpur (only Islamur subdivision)	Rice, jute, tea, pineapple, potato, pulses, oilseeds etc.
3.	Old Alluvial Zone	17,53,757 (20.20)	Dakshin Dinajpur and Part of Murshidabad, Bankura, Haora, Hugli, Burdwan, Birbhum, Paschim Medinipur and Purba Medinipur	Rice, wheat, maize, jute, mustard, niger, groundnut, sesame, linseed, lentil, blackgram, greengram, pigeonpea, vegetables etc.
4.	New Alluvial Zone	15,30,415 (17.62)	Nadia, Murshidabad, Maldah, Uttar Dinajpur, Barddhaman, Hugli, North 24 Parganas and Haora	Rice, wheat, maize, jute, greengram, blackgram, pigeonpea, lentil, rapeseed, mustard, groundnut, sesame, linseed, niger, vegetables etc.
5.	Red Lateritic Zone	24,84,244 (28.61)	Entire Puruliya and part of Barddhaman, Birbhum, Bankura, Purba Medinipur and Paschim Medinipur	Rice, maize, millets, vegetables, niger, toria, safflower, mustard, sesame, pulses, potato, vetiver, sabai etc.
6.	Coastal Saline Zone	14,56,879 (16.77)	Entire South 24 Parganas and part of North 24 Parganas, Haora and Purba Medinipur	Rice, chilli, vegetables, sunflower, sesame, watermelon, *Lathyrus* etc.

Data in parenthesis indicate the percentage of land under the concerned agro-climatic zones.

Sources: 1. Principles of Agronomy. S R Reddy (2010). Kalyani publishers. Ludhiana.
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3. Sahaj kathay bijnanbhittik chashbas. Gosthto Nayban (2008). Ananda Agency, Kolkata.

TABLE 5.2 Average growth in five year plan period

Sectors	Growth in plan periods (%)		
	Ninth plan (1997-2002)	Tenth plan (2002-2007)	Eleventh plan (2007-2012)
Agriculture and allied	3.29	1.63	2.76
Industry	6.64	8.01	5.08
Services	8.62	7.79	9.65
Total	**6.53**	**6.19**	**7.32**

Source: Bureau of Applied Economics and Statistics (BAE&S), Government of West Bengal, 2013

The State achieved significant growth in agricultural production over the past few years. It is now among the Country's top producers in a variety of agricultural produces like rice, jute, potato etc. The State produced 6.1 per cent of the total food grains in the country (State Economic Review, 2011-12). The Compounded Annualized Growth Rate (CAGR) of food grains production over the period 2001-02 to 2010-11 was 0.7 per cent. This indicates that food grains production is reaching a plateau. Total cultivable land in the State is 5.6 million hectares which is about 65.25 per cent of total geographical area of the State.

Land reforms and utilization of lands/land resource mapping

Land reforms system implemented in the State of West Bengal for past years has vitalized the rural economy to such an apex that it has attracted attention not only at national, but also at the international level. Distribution of ceiling surplus land to the landless and near landless people by the State Government with the active help of the Panchayati Raj institutions, recording Bargadars or sharecroppers providing them security of tenure with inheritance rights *vis-à-vis* providing small and marginal farmers

TABLE 5.3 Utilization of land in West Bengal ('000 ha)

Classification		Net area sown	Current fallows	Forests	Area not available for cultivation*	Other uncultivable land excluding current fallows**	Total reporting area***
1985-86	Area	5262	65	1186	1730	606	8849
	Percentage	59.5	0.7	13.4	19.6	6.8	100.0
1995-96	Area	5462	220	1196	1642	175	8695
	Percentage	62.8	2.5	13.8	18.9	2.0	100.0
2008-09	Area	5294	287	1174	1793	136	8684
	Percentage	61.0	3.3	13.5	20.6	1.6	100.0
2009-10	Area	5256	323	1174	1820	112	8685
	Percentage	60.5	3.7	13.5	21.0	1.3	100.0
2010-11	Area	4991	574	1174	1840	105	8684
	Percentage	57.5	6.6	13.5	21.2	1.2	100.0
2011-12	Area	5198	399	1174	1810	104	8684
	Percentage	59.85	4.59	13.5	20.84	1.19	100.0
2012-13	Area	5205	379	1174	1834	92	8684
	Percentage	59.93	4.36	13.5	21.1	1.05	100.0

Sources: West Bengal Statistical Handbook and District Handbook (2009)

It also includes barren and uncultivable land

** Area under permanent pastures & other gazing lands, land under miscellaneous trees, groves not included in net sown area, cultivable wastelands and fallow land other than current fallows.

*** Excluding Kolkata Metropolitan District.

TABLE 5.4 District wise Gross cropped area (GCA), net cropped area (NCA) and cropping intensity (CI) (in '000 ha)

District	2010-11			2011-12			2012-13		
	GCA	NCA	CI	GCA	NCA	CI	GCA	NCA	CI
Barddhaman	747.90	452.46	165	772.45	451.97	171	776.29	452.88	171
Birbhum	420.95	319.96	132	555.98	325.39	171	539.27	326.02	165
Bankura	321.58	264.09	122	504.06	329.28	153	504.30	331.19	152
Purba Medinipur	562.93	288.05	195	518.95	288.95	180	514.14	289.23	178
Paschim Medinipur	878.5	486.20	181	912.64	511.38	178	956.38	512.70	187
Haora	160.34	79.41	202	156.82	82.79	189	157.31	82.82	190
Hugli	542.68	212.41	255	520.74	211.27	246	527.63	212.09	249
North 24 Parganas	452.78	223.02	203	464.09	230.06	202	459.97	231.27	199
South 24 Parganas	513.60	358.40	143	539.71	359.30	150	530.20	360.57	147
Nadia	672.48	290.45	232	712.40	292.94	243	718.56	293.55	245
Murshidabad	866.92	395.96	219	892.44	395.27	226	914.80	396.12	231
Uttar Dinajpur	479.84	274.77	175	470.96	276.46	170	484.11	276.73	175
Dakshin Dinajpur	311.03	183.61	169	305.37	192.78	158	303.50	186.54	163
Maldah	426.70	217.98	196	438.77	231.07	190	457.41	231.08	198
Jalpaiguri	550.05	334.13	165	545.00	335.00	163	549.33	335.51	164
Darjiling	194.93	133.58	146	192.76	134.65	143	195.03	135.47	144
Koch Bihar	511.55	250.61	204	513.48	254.18	202	514.63	252.57	204
Puruliya	217.59	216.13	101	336.36	295.40	114	355.83	298.60	119
West Bengal	8832.35	4981.22	177	9352.95	5198.15	180	9458.68	5204.90	182

Source: Economic Review, Department of Agriculture, GoWB (2012)

with crucial non-land inputs like irrigation facilities, fertilizers, seeds, plant protection chemicals, soil and water conservation measures, credit facilities enormously changed the rural scenario of the State. The utilization of land in West Bengal is depicted in the Table 5.3.

Diversified crop production/crop resource mapping

The state of West Bengal is endowed with an enormous range of agro-climates and soil types to support diversified agriculture *vis-à-vis* multidisciplinary farming systems. In this context, intensive rather multiple cropping assumed great importance. It became an effective tool in increasing total production from a single piece of land as it increases net cropped area indirectly. Crop diversification in a cropping sequence on the same piece of land has been a very important tool in increasing per hectare net production from that very land.

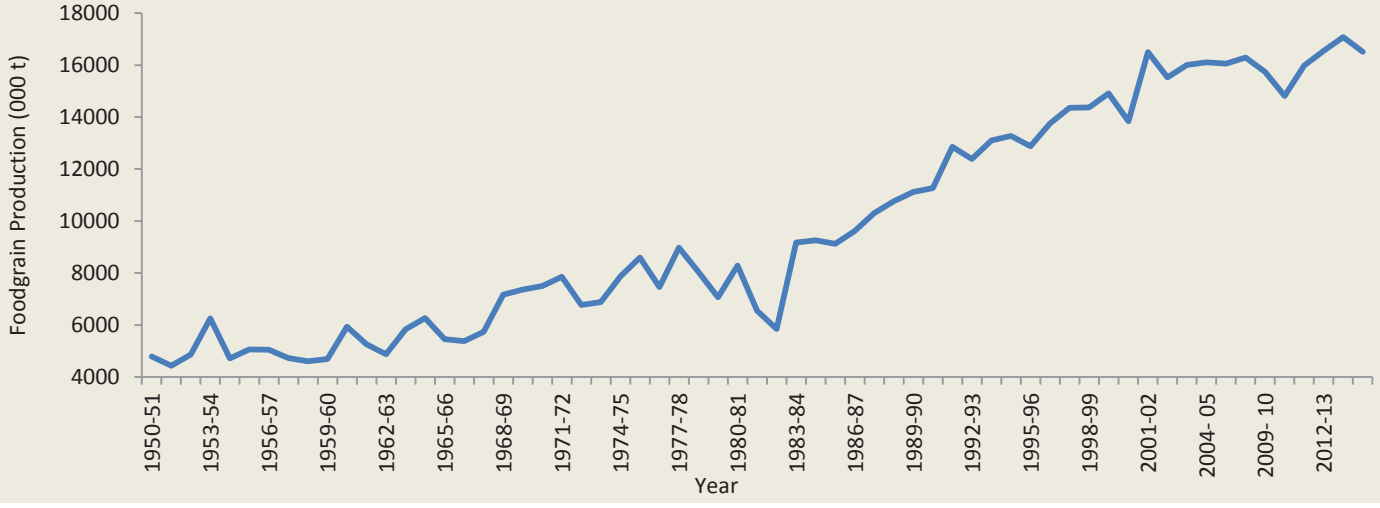
The cropping intensity which is the ratio of gross cropped area to net sown area along with the gross cropped area and net sown area of different district of West Bengal are presented in the Table 5.4.

State of agriculture in West Bengal

The total food grain production of West Bengal has increased from 4,788 thousand tonnes in the year 1950-51 to 16,547 thousand tonnes in the year 2012-13. It is clearly reflected from the graphics (Figure 5.1) that the State achieved to produce 3.45 times more cereals and pulses in the post-independence decades.

The cropping pattern in the State is changing steadily. While the acreage under pulses, oilseeds, vegetables and fruits have escalated significantly in the recent years. Cultivation of crops other than rice, like wheat, oilseed, maize, pulses etc. would help to meet the growing demand in the State for these crops as well as strengthen and broaden the value added chain by promoting food processing industries. The State Government is implementing a centrally sponsored scheme "Integrated Scheme of Oilseed, Pulses, Oil Palm and Maize" (ISOPOM) in order to increase the area and yield rate of these crops since 2004-05. From the year 2010-11 Pulses Development Programme has been dropped from ISOPOM as it was included under National Food Security Mission (NFSM) scheme.

FIGURE 5.1 Total food grains (cereals and pulses) production of West Bengal



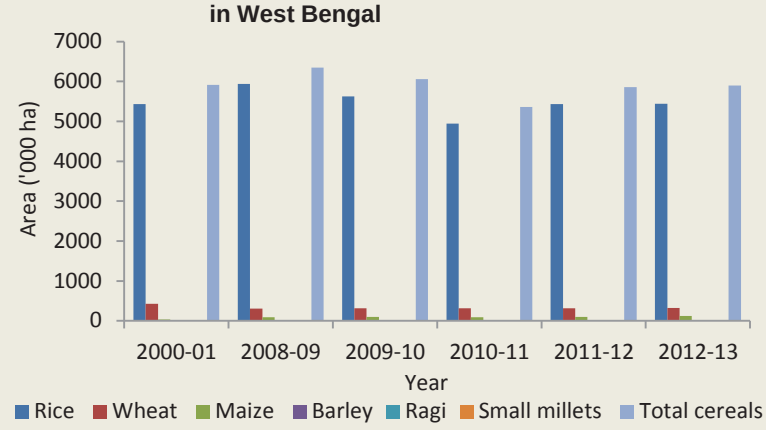
Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

Within the time span of 1980-81 to 2012-13 the total oilseed production of the State has augmented about by 5.6 times. The corresponding production values are 150.4 thousand tonnes and 854 thousand tonnes. Different developmental scheme such as National Oilseed Development Project (NDOP), Oilseed Production Thrust Programme (OPTP), Integrated Scheme on Oilseed, Pulses, Oil-palm and Maize (ISOPOM), Oilseed Production Programme (OPP) etc. have contributed a lot in this aspect.

The increase in area, yield rate and production of rice, wheat, maize, coarse cereals, oilseeds etc. are attributable to the interventions by the schemes like ISOPOM, NFSM etc. The dissemination of latest technologies by carrying out vast number of demonstrations and successful farmers' training programmes, bringing new potential crop varieties through minikit scheme in ISOPOM and distribution of agri-inputs like Plant Protection Chemicals (PPC), Plant Protection Equipment (PPE), seed bins, manual and power driven implements, Rhizobium/PSBs, NPV, micronutrients etc. are the key factors behind such success in the recent past.

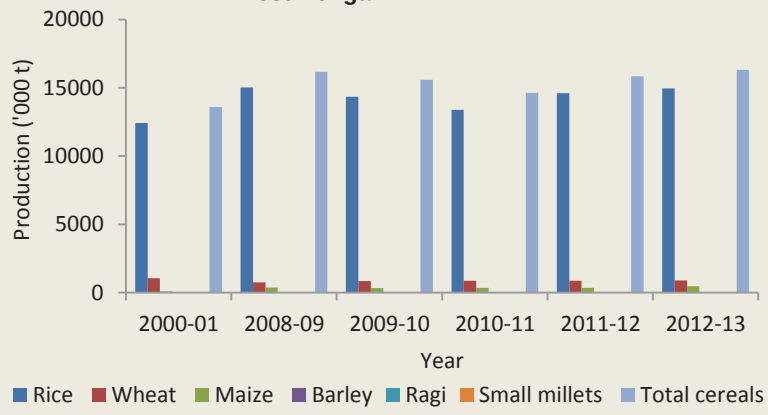
The name of the schemes like "Diversified cropping programme under Dry land/Rainfed condition" under State Plan, being implemented in drought prone/rainfed mono-cropped 59 Blocks of 5 districts *viz.* Puruliya, Bankura, Paschim Medinipur, Barddhaman and Birbhum located in the Red Lateritic agro-climatic region of the State, having low rainfall and low soil fertility, should also be mentioned. Multiple crop demonstration programme has been taken up under this scheme through demonstration on hybrid maize, groundnut, pigeonpea and other pulses during kharif (rainy) season in demonstration centres of 0.13 ha (1,333 sq m) each. The scheme like "Agricultural Development in Special problem Areas like Kanksa, Budbud, Ausgram, Gopiballlavpur, Ayodhya Hills etc." is going on in 20 underdeveloped tribal blocks of

FIGURE 5.2 (a) Cultivated area of different cereals in West Bengal



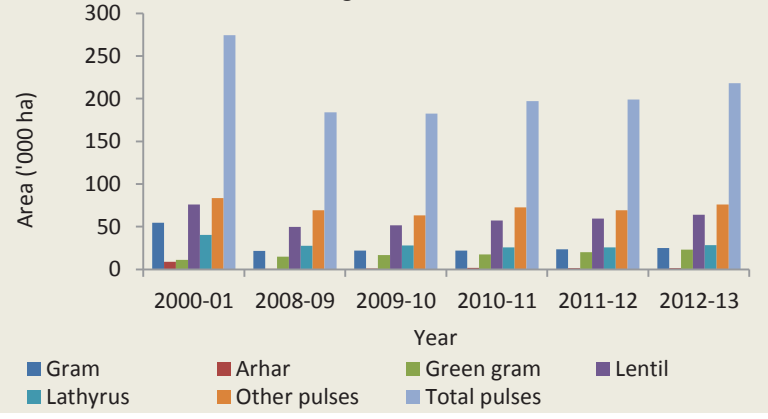
Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.2 (b) Production of different cereals in West Bengal



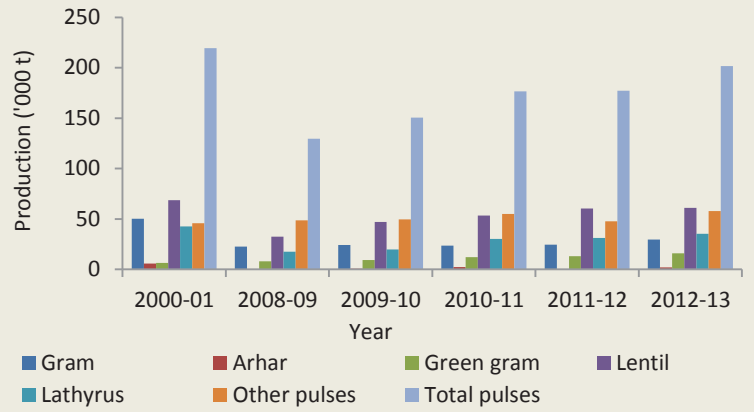
Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.3 (a) Cultivated area of different pulses in West Bengal



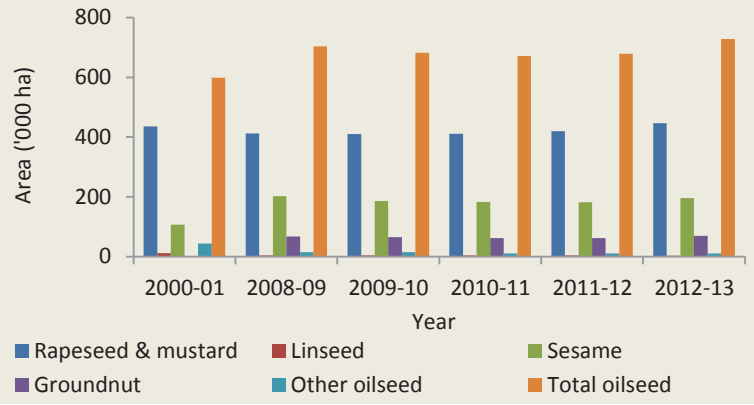
Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.3 (b) Production of different pulses in West Bengal



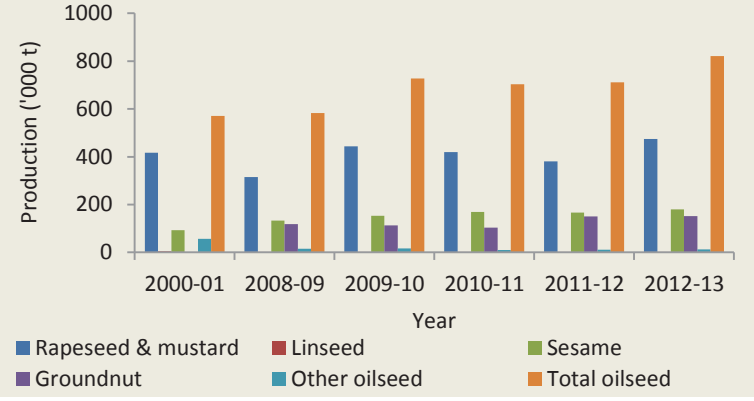
Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.4 (a) Cultivated area of different oilseeds in West Bengal



Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.4 (b) Production of different oilseeds in West Bengal



Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

four major districts in dry region *i.e.* resource poor areas of the State *viz.* Puruliya, Bankura, Paschim Medinipur and Barddhaman.

NFSM was launched in 13 districts of the State with the objective of 4 per cent enhancement in production by the end of the 11th Five year plan period by dint of replacement of old seeds by new HYV and hybrid seeds; restoring soil fertility by applying soil correcting chemicals (ameliorants), micronutrients, organic manures and biofertilizers; proliferating productive technology through demonstrations. The ultimate goal is to create rural employment and hence uplift of farm economy.

Focal objective of the flagship programme of the Additional Central Assistance Scheme e.g. Rashtriya Krishi Vikash Yojana (RKVY), launched in the State of West Bengal, was to incentivize the State to attain 4 per cent annual growth rate in agriculture and allied sectors. In "Bringing Green Revolution in Eastern India" (BGREI), the sub scheme under RKVY, 64 Block Demonstration Centres (1,000 ha each year for HYV and Hybrid paddy) and 3 Block Demonstration Centres (1,000 ha each for wheat) was allotted to the State. For holistic socio-economic development of farm sector and sustainable use of natural resources, Government of India has introduced Macro Mode Work Plan in agriculture.

State of horticulture in West Bengal

The Horticulture sector in West Bengal holds tremendous potential for larger production, area expansion, generation of self employment, processing, packaging, transportation, marketing and above all export. The State produces a considerable quantity of vegetables (13,875.51, fruits (3,172.5 thousand tones), flowers, spices, plantation crops (coconuts, cashewnut) etc. The total fruits and vegetables production

of West Bengal during the period of 1997-98 and 2011-12 is depicted in Figure 5.6 and Figure 5.7 respectively.

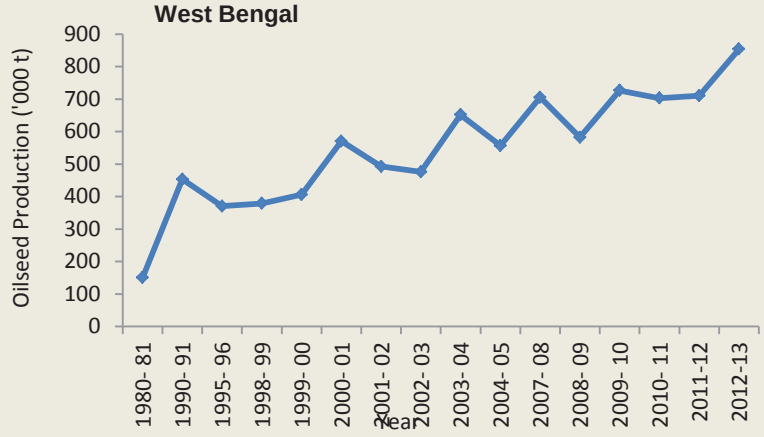
The schemes under State Plan, National Horticulture Mission, National Bamboo Mission, National Mission on Medicinal Plants, RKVY, Micro Irrigation, National Vegetable Initiative in Urban Clusters and above all mandates taken up by the Food Processing Industry and Horticulture Department as well as Directorate of Cinchona and other Medicinal Plants are showing enlightened horizon in this domain.

The major fruits are mango, pineapple, banana, litchi, orange, guava and papaya. Apart from those jackfruit, sapota, water chestnut, jamrul, pomegranate, ber, wood apple, java plum is also very important for their cultivation to meet the local demand. The Statistics of 2013-14 regarding the acreage, production and productivity of the major fruits is given below in the Table 5.5.

West Bengal occupies 9th position (Horticulture Division, Department of Agriculture and Cooperation) amongst the fruit producing states of the country having an acreage of 220.6 thousand ha it produced 3,172.5 thousand tonnes fruits (average yield being 14.4 tonnes/ha) during 2012-13. As a matter of fact it must be mentioned that even the marginal farmers of the State are now inclined to producing short duration fruits like papaya and banana. Some are getting good profit by producing strawberry at their fields. 'Lakshmanbhog', an elite mango variety of this State has secured the place in the list of exportable mango in the country. A considerable share of the farmers of Nadia, North and South 24 Parganas and Hugli have switched over from rice farming to orchard development for growing fruits especially banana, guava, ber (varied types), sapota, star apple etc. in the upland and medium upland situations.

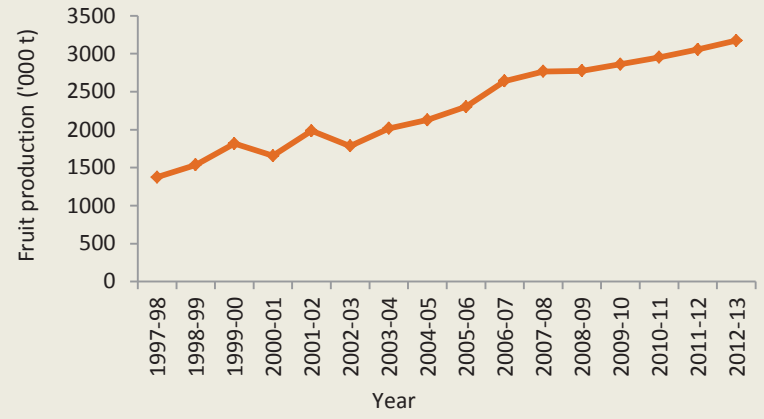
Healthy liaison amongst the fruit growers and exporters and offering special package including subsidy and technical supports for fruit orchard development from the

FIGURE 5.5 Total oilseeds production of West Bengal



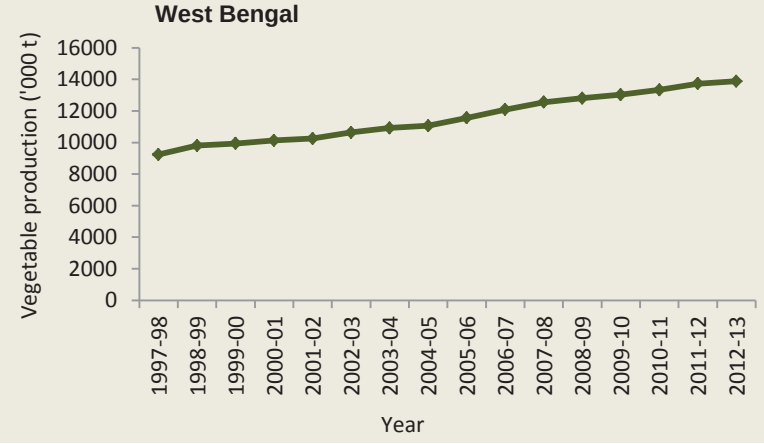
Source: Agricultural Statistics at a glance-2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.6 Total fruits production of West Bengal



Source: Horticulture Statistics Division (2016). Department of Agriculture and Cooperation, Govt. of India.

FIGURE 5.7 Total vegetables production of West Bengal



Source: Horticulture Statistics Division (2016). Department of Agriculture and Cooperation, Govt. of India.

TABLE 5.5 Area, production and yield of major fruits in West Bengal (2013-14)

Fruit	Area ('000 ha)	Production ('000 tonnes)	Yield ('000 t/ha)
Mango	93500	430,000	24.6
Banana	45500	109,700	24.1
Guava	14400	146,000	13.0
Litchi	9300	93,000	10.1
Papaya	11000	355,000	29.4
Pineapple	10700	316,000	29.5
Sapota	4200	45,400	10.4

Source: Horticulture Statistics Division (2016). Department of Agriculture and Cooperation, Govt. of India.

Government sector is an essential need at this moment. At the same time special emphasis should be given on the overall uplift of Food Processing units, Agri-export zones and Agro Food parks. All these issues if properly addressed may contribute successfully to bring the State at the top of the list of fruit growing states of India.

From the point of total vegetable production (including potato) the State occupies the 1st position amongst the vegetable producing states of India. But in the matter of productivity it occupied the 8th position (16.7 tonnes/ha being less than the national average yield of 17.34 tonnes/ha). Table 5.6 shows the estimated demand for vegetables in West Bengal during 2019-2021. Table 5.7 represents the first five districts producing vegetables (2012-13).

The major vegetables produced in the State are tomato, brinjal, green chilli, lady's finger, gardenpea, cucurbits, watermelon, cabbage, cauliflower, onion, garlic, pointed gourd, carrot, beet etc. Table 5.8 depicts some improved varieties of vegetables ideal for processing.

The Table 5.9 and Table 5.10 depict the fruits, flowers and spices having potentiality to be grown on commercial basis in different agro-climatic zones of West Bengal and different leading districts growing flowers in West Bengal.

TABLE 5.6 Estimated demand for vegetables in West Bengal

Time period	Population (crore)	Annual demand for vegetables (crore tonnes)
2005-06	8.18	0.88
2011-12	8.34	0.72
2020-21	10.34	1.04

Source: Adhunik Uddyan Bijnan Prajukti (2016), faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya

TABLE 5.7 Vegetable producing leading districts of West Bengal

District	Area ('000ha)	Production ('000 tonnes)	Productivity (tonnes/ha)
Murshidabad	87.28	1458.6	16.71
Nadia	84.43	1311.4	15.51
North 24 Parganas	71.56	1095.2	15.31
South 24 Parganas	75.29	1076.7	14.29
Hugli	54.04	683.8	12.65

Source: Annual Report (2015). All India Coordinated Research Project on Vegetable crops, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, west Bengal

Animal resources: past, present and future

The crop livestock system is one of the most important characteristics of Indian agrarian economy and livestock sector is the integral part of India's agriculture sector. Indian livestock sector provides sustainability and stability to the national economy by contributing to farm energy and food security. Livestock sector not only provides essential protein and nutrition to human diet through milk, eggs, meat and by-products such as hides and skin, blood, bone and fat etc., but also plays an important role in utilization of non-edible agricultural by-products. During the last decade, the annual growth rate of livestock production has maintained a steady growth of 4.8-6.6 per cent with a compounded growth rate of more than 5.0 per cent. In contrast, the crop production remained either stagnant or increased marginally. Therefore, the livestock sector has emerged

TABLE 5.8 List of vegetables with their varieties

Vegetable	Processed products	Improved/ Hybrid varieties
Tomato	Sauce, Ketchup, Chutney	Pusa Gourav, Pusa Upahar, Roma, Arka Sourav, Hybrid 2 & 4, Punjab Chauhara
Cauliflower	Pickles, Dried cauliflower	Pusa Snowball (KT-1 & KT-25)
Potato	Chips, Flakes, Fries	Kufri Chipsona 1&2
Chilli	Sauce	Pusa Sadabahar, Punjab Red, Pant C-1
Pumpkin	Sauce	Pusa Bikash
Carrot	Halua	Pusa Kesar, Pusa Mekhali
Onion	Flakes, Powder	Pusa Red, Pusa White Round/Flat
Bitter gourd	Pickle	Pusa Bisesh, Pusa Hybrid-1
Garden pea	Canned variety/Frozen variety	Pusa Pragati, Arkel
Ash gourd	Sweets/Pie	Pusa Shakti, Co-1

Source: Annual Report (2015). All India Coordinated Research Project on Vegetable crops, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, west Bengal

TABLE 5.9 Potential fruits, flowers and spices of different agro-climatic zones

Agro-climatic Zones of WB	Fruits	Flowers	Spices
Hill Zone	Orange, Strawberry etc.	Orchid, Gladiolus, Gerbera, Anthurium, Foliages, Cactus, Succulents, Different flowers	Black cumin, Fennugreek, Coriander, Chilli, Turmeric, Ginger, Large cardamom
Terai Zone	Pineapple, Jackfruit, Coconut, Arecanut, Banana etc.	Marigold, Tuberose, Foliages, fern, Gerbera in polyhouse etc.	Fennel, Coriander, Chilli, Turmeric, Ginger, Black pepper
New& Old Alluvial Zone	Mango, Guava, Papaya, Litchi, Banana etc.	Tuberose, Marigold, Roses, Jasmines, Dahlia, Gerbera, Anthurium, Gladiolus etc.	Black cumin, Fenugreek, Fennel, Coriander, Garlic, Black pepper, Chilli, Turmeric, Ginger
Red Lateritic Zone	Mandarins, Ber, Mango, Pomegranate, Guava, Grapes, Cashewnut etc.	Hibiscus, Roses, Marigold, Cactus, Succulents, Chrysanthemum, Gerbera in poly house, Anthurium etc.	Black cumin, Fennugreek, Coriander, Chilli, Turmeric, Ginger
Coastal Saline Zone	Coconut, Cashewnut, Sapota, Carambola, Karamcha etc.	Hibiscus, Marigold etc.	Black cumin, Fennugreek, Fennel, Coriander, Garlic, Chilli, Turmeric, Ginger

Source: Adhunik Uddyan Bijnan Prajukti (2016), faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya

TABLE 5.10 Flower growing areas of West Bengal (2012-13)

Districts	Area ('000 ha)	Loose flowers ('000 t)	Spiked flowers (crores)
Nadia	6.701	19.315	71.500
Purba Medinipur	5.326	14.931	63.998
Paschim Medinipur	3.682	8.134	54.232
Darjiling	1.653	0.513	24.833
North 24 Parganas	1.949	7.038	14.660
South 24 Parganas	2.131	7.110	15.748
Haora	1.332	3.352	3.696
Jalpaiguri	0.293	0.427	1.834
Uttar Dinajpur	0.233	0.777	1.219
Hugli	0.141	0.144	0.842

Source: Horticulture Statistics Division (2016). Department of Agriculture and Cooperation, Govt. of India.

FIGURE 5.8(a) **Cut flower production in West Bengal**

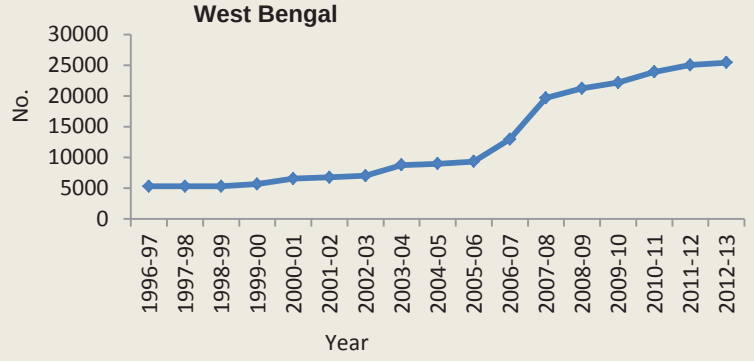


FIGURE 5.8(b) **Loose flower production in West Bengal**

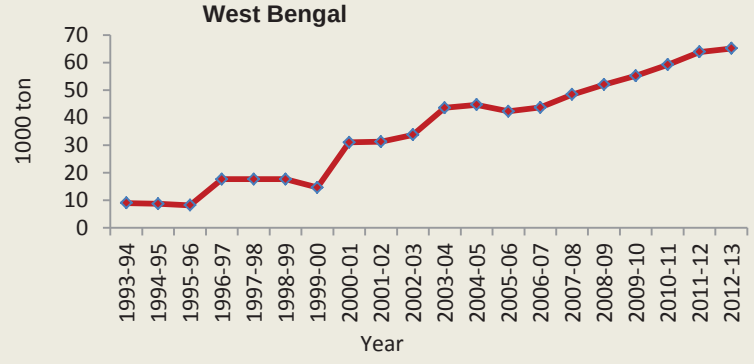


FIGURE 5.8(c) **Spices production in West Bengal**

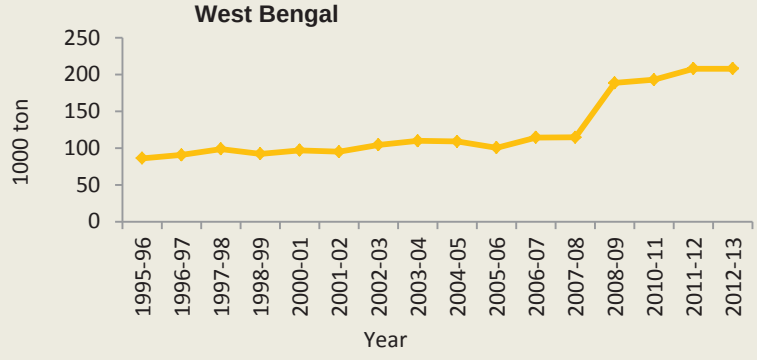
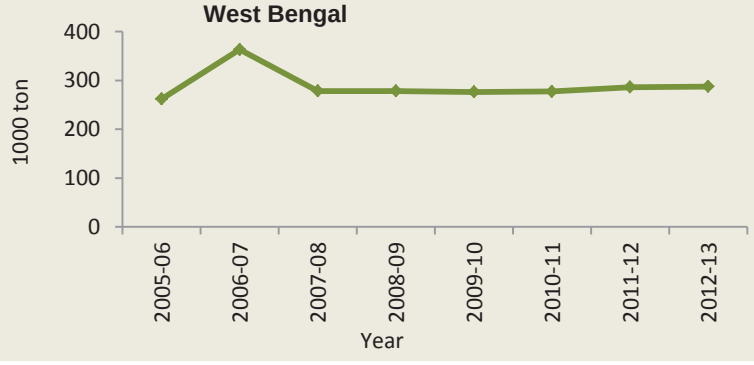


FIGURE 5.8(d) **Plantation crop production in West Bengal**



Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

as one of the key components of agricultural growth in India.

Animal husbandry is a vital sector of agricultural economy in the State also, which supports small and marginal farmers both economically and nutritionally, and plays a crucial role in generation of employment and augmentation of rural incomes. Concerted efforts combined with well planned schemes have strengthened this sector to a great extent. Combating the challenge of development of the poor quality, low productive non-descript livestock and poultry breeds of the State on one hand, generating rural employment in the primary sector along with creation of income opportunities in secondary and tertiary sectors in rural, semi-urban and urban areas, on the other have been successfully carried out. For this, the Animal Resources Development Department of Govt of West Bengal is pursuing an elaborate, dynamic and scientific policy in association with the State's unique three-tier panchayat system and municipal bodies. Increased production of milk, meat and eggs shows an improvement upon those of the previous years.

However, despite significant increase in the production of milk, meat and egg in the State in the last three decades, there is still a considerable gap between demand and supply of products of animal origin. In order to achieve high level of productivity from the bovine livestock in the State, constant care for genetic upgradation is being pursued. Since, 2001-02 a comprehensive centrally sponsored National Project for Cattle and Buffalo Breeding (NPCB) has been launched in the State with Paschim Banga Go-Sampad Bikash Sanstha as the State implementing agency.

The main achievement in this respect so far is extension of facilities like artificial insemination, veterinary first aid, deworming, vaccination of livestock and birds etc. to farmers' doorsteps through active and effective involvement of private workers named 'Prani-Bandhu'. This programme of

engaging 'Prani-Bandhu' has created a remarkable step-up in self-employment for the rural unemployed youths. At present nearly three thousand numbers of 'Prani-Bandhu' are working at Gram Panchayat level in the State. Consequently, the target is to double the number of 'Prani-Bandhu' who are private workers bestowed with the responsibility of reaching intensive vet care to farmers' doorsteps so that per 800 breedable bovine at least one 'Prani-Bandhu' is at work. The achievements of the 'Prani-Bandhu' in West Bengal can undoubtedly usher in an unbeatable example of successful self-employment not only in our State but also in India, at large.

Nationally, West Bengal holds the second position in fish production after Andhra Pradesh amongst leading fish producing states. With the expansion of fishery areas and development of management policy the fish production has increased from 370 thousand tonnes in the year 1980-81 to 1,490 thousand tones in the year 2012-13. South 24 Parganas is the leading district in fish production (Figure 5.9).

Over the last few years egg production of West Bengal has increased remarkably (Figure 5.10). The State produced 4,711 million eggs during the year 2012-13. It was about 2.06 times more than the egg production in the year 1990-91 (2,279 million eggs). South 24 Parganas ranks first in egg production followed by Murshidabad.

Meat production in the year 1990-91 was 695.7 thousand tonnes and 649.36 tonnes in the year 2012-13. The production declined enormously in the mid 90's; after that it increased gradually (Figure 5.11).

Dairy development

A network of three-tier co-operative system - Village Level Primary Milk Co-operatives, District Level Milk Unions and State Level Milk Confederation - under the overall guidance and control of the West Bengal Co-operative Milk Producers Federation

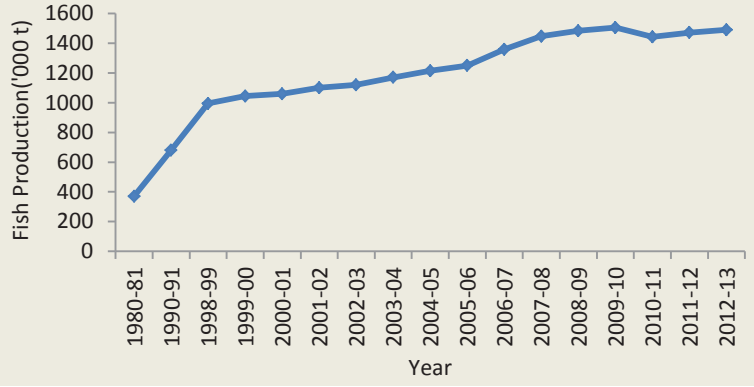
TABLE 5.11 Total number of livestock and poultry in West Bengal (2012)

Livestock/Poultry	West Bengal	India
Cattle	16514239	190904105
Buffalo	597379	108702122
Sheep	1076115	65069189
Goat	11505950	135173093
Pig	648111	10293695
Yak	1089	76662
Mithun	0	298264
Total Livestock[1]	30348280	512057301
Total Poultry[1]	52837576	729209320

1 Total livestock covers cattle, buffalo, sheep, goat, pig, Horses & Ponies, donkeys, camels, yak and mithun, and total poultry includes chicken, duck, turkey, quail, emu and other poultry species.

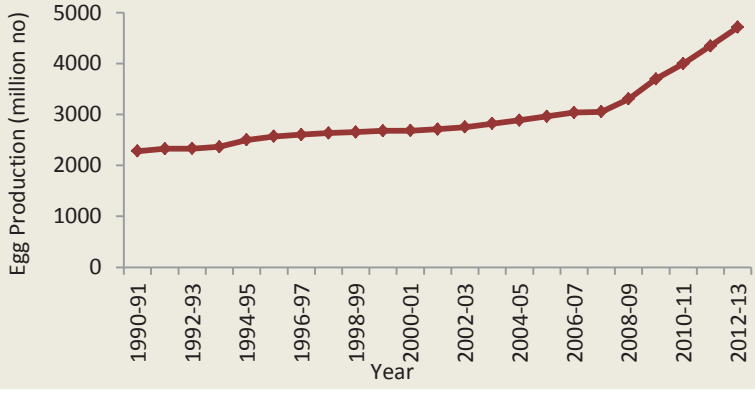
Source: 19th All India Livestock Census, 2012, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Govt. of India.

FIGURE 5.9 Total fish production of West Bengal



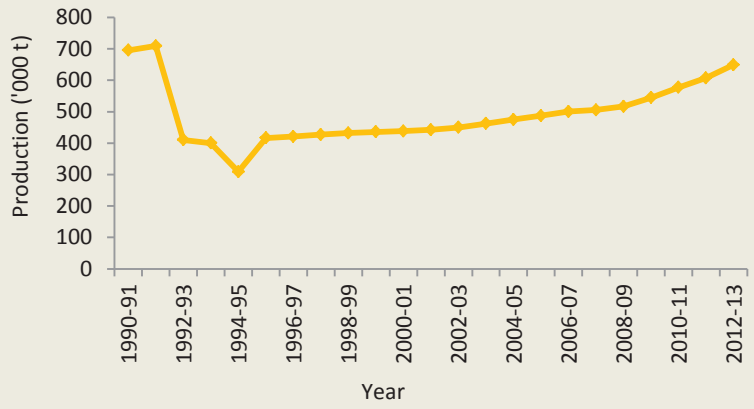
Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.10 Total egg production of West Bengal



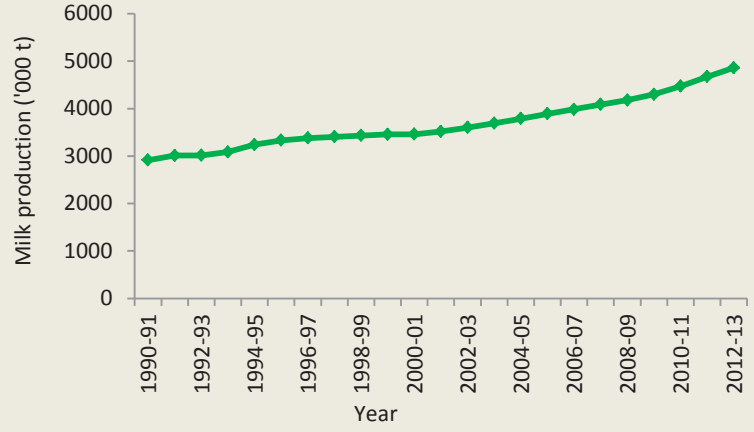
Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.11 Total meat production of West Bengal



Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

FIGURE 5.12 Total milk production of West Bengal



Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Govt. of India

Limited has been constituted with the objective of facilitating rural development by providing opportunities for self employment at village level, preventing migration to urban areas, introducing cash economy and opportunity for steady income. Inspired by the scope of self-employment till now more than three thousand primary milk co-operatives have been setup with a total membership of more than 0.2 million persons. The milk production pattern of West Bengal during last 20 years is given in Figure 5.12.

Self employment for women development

The Federation is also implementing Women Dairy Cooperative Project funded by the Ministry of HRD, Government of India and thus empowering women economically and socially. Nearly six hundred societies have been formed with the membership of fifty five thousand women members.

Poultry development

In order to augment egg and poultry meat production in the State for bridging the gap between requirement and supply, the State Government has taken up a two-pronged approach to increase egg production through promotion of large layer farms and secondly by promoting backyard poultry. In order to increase egg production in the organized sector, the State Government has introduced a subsidy scheme for development of layer farms in cage system. A 10 per cent subsidy on the capital investment for 10 thousand commercial layers subject to a limit of Rs. 0.5 million has been introduced. In the unorganized sector, the State Government has introduced a scheme to encourage backyard poultry amongst women members of self-help-groups (SHGs). The State Government had distributed huge number of chicks amongst women members of SHGs.

The potential of the food processing industry is explored in the State depending on certain pockets of agro-commodity exuberance. Infrastructural amenities like agri-marketing zone, cold-chain management system, multipurpose godown etc. are being provided accordingly. The three-tier panchayat system has been largely instrumental in bringing about success in all these aspects.

At present West Bengal is not self sufficient State in regards to production of milk, egg and meat. The present per capita production of milk is only 137 g daily and eggs 45 numbers in a year (2010-11). On the other hand, respective figures in India

are 281 g milk and 53 eggs. The National Committee of Human Nutrition recommended that we should consume at least 250 g milk daily and 180 eggs yearly per head. So there is a big gap between demand and availability of these animal products in the State.

Prioritization of Government interventions in Animal Husbandry in the state

1. Breed improvement through artificial insemination (AI), introduction/supply of quality animals;
2. Calf rearing as part of animal quality upgradation;
3. Promotion of green fodder cultivation on common lands, preservation of grazing land, through crop diversification and simultaneous strengthening of fodder seed production facilities;
4. Milk processing and marketing through dairy cooperatives and supply chain management through milk societies;
5. Promotion of low input technology poultry/duckery for the benefit of marginal farmers/landless rural poor/tribal habitations and also to meet the increasing local demand;
6. Prani-Bandhus (private AI worker) have done pioneering work in providing doorstep AI services in rural areas. Promotion of more number of Prani-Bandhus (at least one in every gram panchayat);
7. Awareness among farmers, especially in North Bengal to grow maize to meet ever increasing demand for feed.

Agri-marketing infrastructure of the state

There is a three-tier marketing system in West Bengal. It includes 3,260 primary rural haats/markets, 182 secondary markets, 34 secondary-cum-terminal markets and 12 large terminal markets and 279 wholesale markets. Most of the markets are privately owned. Besides these, there are haats and bazaars supervised by Panchayat Samiti and Regulated Market Committees. There are 43 regulated principal markets and 641 sub markets/yards in the State. Network of these haats and Agricultural Produce Market Committee (APMC) markets play a vital role in marketing of agricultural produce in the State. (Directorate of Agriculture Marketing, Govt of West Bengal, 2011-12)

The Government of West Bengal has initiated the administrative action to reform the APMC Act. Post implementation, it is expected to draw interest of large players in food processing who are keen to enter in direct arrangements with growers for sourcing of raw material.

Status of logistics and warehousing facilities

At present West Bengal State Warehousing Corporation is functioning with a network of 30 warehouses scattered all over the State of West Bengal except in the districts of Puruliya and Birbhum with a constructed capacity of 137,000 MT and a hired capacity of 80,000 MT The total effective storage capacity under Food Corporation of India (FCI) (owned and hired) in West Bengal as on February 2013 was 854,000 MT (including Sikkim) - out of this 94,000 MT was hired from Central Warehousing Corporation (CWC) and 19,000 MT from State Government.

Cold storages

State has approximately 431 potato cold storages with a total capacity of approximately 5,914,000 MT, 15 potato multi commodity combo cold storage in West Bengal with an estimated capacity of 180,000 MT. In addition, there are about 78 multipurpose cold storages with estimated capacity of 45000 million MT (Department of Agricultural Marketing, W.B, 2012-13). Out of these, about 413 cold storages belong to the private sector and about 50 belong to the cooperative sector. In terms of products,

more than 95 per cent of the cold storage capacity is utilized for potato.

Cold chain projects being implemented under MoFPI assistance

Under the Scheme for Cold Chain, Value Addition and Preservation Infrastructure, the Ministry of Food Processing Industries, GoI has approved five cold chain projects in the State which are in different stages of implementation.

Abattoirs/slaughter houses

The Ministry of Food Processing Industries has approved one abattoir project at Tangra, Kolkata with a total project cost of Rs. 284.5 million and with a capacity of 400-450 bovine per day. As per Agricultural and Processed Food Products Export Development Authority (APEDA), there are no approved abattoirs-cum-meat processing/ meat processing plant in West Bengal.

Status of West Bengal's food processing industry

Food processing units: Despite being a large producer of horticultural crops, the food processing in the State is still underdeveloped. The main processed products in the fruits and vegetables category are jams, jellies, pickles, sauce, canned sliced fruits and squash. The total employment in the sector was more than 250,000 during 2010-11. As per WBIDC, 1,009 number of food processing units are in the pipeline.

Agri-export zones: Six agri-exports zones (AEZ) of West Bengal are mentioned in Table 5.12. The AEZs, though operational, are in a nascent stage with potential to increase exports from the region.

Agro food parks: Agro food parks are being developed in the State with the intention of providing support to small and medium entrepreneurs by assisting them (financially) in setting up capital intensive facilities like cold storages, warehouses, quality control labs, effluent treatment plants etc. The following food parks (Table 5.13) are present in the State.

Taxation policy of the State Government: The Central Government levies direct taxes such as personal income tax, corporate tax and wealth tax, as well as indirect tax such as customs duty, excise duty, central sales tax and service tax. The State Governments are empowered to levy state sales tax and various other local taxes.

VAT: The levy and collection of VAT is governed by the West Bengal VAT Act, 2003. There are different slabs viz. 0 per cent, 1 per cent, 5 per cent 14.5 per cent, 35 per cent of VAT which is levied on different commodities. Schedule of VAT rates are depicted in Table 5.14:

Tax on entry of goods: This tax in West Bengal is governed by West Bengal Tax on Entry of Goods into Local Areas Act, 2012. The Act levies 1 per cent entry tax on some goods specified in the Act.

Electricity duty: Electricity duty is also levied by the State Government with slabs decided depending on nature and industry of usage.

Potential areas for investment

Based on raw material availability in the State and adjoining areas, the following (Table 5.15) processable activities hold potential in the State. The list is indicative and may not be treated as exhaustive.

TABLE 5.12 Agri-export zones of West Bengal

Crop	Agri Export Zones
Pineapple	Jalpaiguri, Siliguri, Coochbehar, Uttar Dinajpur
Mango	Malda, Murshidabad
Litchi	Malda, Murshidabad, Nadia, North 24- Parganas
Vegetables	North 24 Parganas, Nadia, South 24 parganas, Howrah
Potato	Hooghly, Burdwan, Howrah, Purba Medinipur
Flowers	Purba Medinipur, Siliguri, Jalpaiguri, Nadia

Source: Adhunik Uddyan Bijnan Prajukti (2016), faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya

TABLE 5.13 Agro food parks of West Bengal

Name of the Food Park	Location	No. of units set up/to be set up	Project Cost (Million Rs.)	Status	Items
Maldah	Maldah	25	160.8	Complete	Fruits and vegetable processing
Sudharas	Sankrail, Haora	11	189.3	Complete	Potato chips, Kurkure, Ice cream, Biscuits, Ware House for Agro products, Packaging items for storage of food prod
Haldia	Haldia, Purba Medinipur.	40	188.0	Under Implementation	Under implementation
Siliguri	Siliguri	20	142.1	Nearing Complete	Biscuits, F&VP
Kandua	Kandua, Haora	5	165.7	Complete	Biscuit, Cake, Dal, Kurkure, Pkg. of oil, Ware house
Sultanpur	Sultanpur, South 24 Parganas	40	80.1	Complete	Preservation and Marketing of fish
Kakdwip	Kakdwip, South 24 Parganas	80	92.4	Complete	Preservation and Marketing of fish
Chakgaria	Chakgaria, South 24 Parganas	10	80.1	Complete	Preservation and Marketing of prawn

Source: Adhunik Uddyan Bijnan Prajukti (2016), faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya

TABLE 5.14 Value added tax for different agro products

VAT rate in %	Items
0	Fresh milk, Curd, Lussi, butter milk, separated milk, Paneer, Bread except pizza bread, Fresh vegetables & fruits, Meat, fish & Prawn (except cured or frozen),
5	Snack food, Processed and preserved vegetables and fruits, Processed meat, poultry & fish products, skimmed milk powder, vegetable oil

Source: Dept. of Commercial Taxes, Government of WB (2012)

TABLE 5.15 Potential areas for investment in industries for processed products

Crop	:	Processed products that may be derived
Rice	:	Milled rice, bran oil, powder, poha, puffed rice, noodles, etc.
Potato	:	Chips, flakes, powder, fries, starch etc.
Cauliflower, Cabbage, Okra, Carrot, Brinjal	:	Fresh cut, frozen and assorted products
Tomato	:	Puree, Juice, concentrate, ketchup, sauce etc.
Guava	:	Juice, concentrate, fruit drinks, frozen halves, candies, Jam, Jelly
Citrus Fruits (Aonla)	:	Juice, candy, powder
Pineapple	:	Juice, candy, pulp, concentrate, jam, jelly etc.
Mango	:	Pickle, Aam Papad, Chutney, Candy, dried mango powder, Jam, Jelly etc.
Raw Milk	:	Butter, crème, ghee, cottage cheese, flavoured milk, spreads, milk powder, ice-cream, curd, buttermilk
Fish	:	Fresh and frozen processed, Dry fish
Meat	:	Fresh and frozen processed

Source: Adhunik Uddyan Bijnan Prajukti (2016), faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya

Alarming issues

India inherited a stagnant agriculture at the time of its independence in 1947. Thus the first task of the National Government in the post independence session was to initiate the growth process in the agricultural sector. When we look back to review these growth processes of Indian agriculture during the last seven post independence decades, we find several success stories which have transformed the country from the image with "begging bowl" to not only "self-sufficient" one in food grains but also to be a leading exporter of some agricultural produces in the global market. In this laborious long journey, the country has added a number of gems to her crown by impressive revolutions in the agricultural sector - Green (from 51 to 253 million tonnes foodgrains), White (from 17 to 146.3 million tonnes milk), Blue (from 0.7 to 6.1 million tonnes fish) and Yellow (from 5.2 to 26.7 million tonnes oilseeds). The green revolution in mid sixties, steered by research based new technological development involving new materials, methods and ways of organizing farm inputs like seed of high yielding varieties, water, fertilizer, plant protection chemicals etc. and the Government policy transformed the agriculture dramatically. As a result, the output exhibited manifold increase in production and productivity.

Despite this magnificent progress during the last few decades we can not ignore the grim side of the story as well. The country as well as the State of West Bengal occupies dismally a low position in respect of yield levels in comparison to many other countries. Planners, agricultural scientists and agricultural economists are badly worried about the slow growth rate of agricultural production in the recent years. The population has been escalating at alarming rate, while the average growth rate of total food grain production is not at all satisfactory. So, there is no other option except to produce more and more. It is also a fact that in a country like India augmenting crop production by increasing the area under cultivation is almost next to impossible. It is more true with the state of West Bengal. The dismal situation regarding the low position in respect of yield levels is attributed to poor input use efficiency, degradation of resources like soil and water and deceleration of total factor productivity. There is, therefore, an urgent need for massive well planned action programme for enhancing input use efficiency and crop productivity to sustain the tempo of agricultural growth in both irrigated and rainfed areas of our state as a whole.

As a matter of fact the following issues must be brought into light for keeping the pace of agricultural growth of the State in future mitigating the evil impacts of its varied operations and modern technologies/tools on biodiversity, water, air, soil and socio-economy as a whole:

Apathy of peasants to farming - social issue

The aberrant weather, changed climatic condition with reference to rainfall pattern, temperature and humidity and havoc crop pest occurrence; increasing cost of inputs (seeds, fertilizers, pesticides etc.); reduction in holding size due to excessive fragmentation of land; absence of minimum support price (MSP) for most of the agricultural produces; inadequate market infrastructure and uncertain prices of agricultural produces, especially of highly perishable products; and above all resultant less return received from rice and many other agricultural crops, make the farmers' apathy in growing rice and in many a cases other crops also. The small farmers from the remote areas are often forced to accept distressed sell of their products of hard labour. Management of farm animals is also becoming more difficult due to high cost of feed and less rather rare availability of fodder *vis-à-vis* lack of remunerative marketing facilities. All these issues have created frustration in the mind of a large

section of the farming community making them to take decision for alternative remunerative profession like masonry, jewelry, hosiery or garment making works and agricultural labours, in other districts of the native state and cities of other states like Odhisa, Bihar, Jharkhand, Kerala, Andhra Pradesh etc. Practically, they are trying to come out from "high-tension agriculture" to "low tension" one. Landless classes are switching over from lease-in peasants to wage earning field labourers. At present, this type of change in occupation is very common in the stress tracts like Coastal and Red Lateritic zones. As a result of this, different districts of the entire State are facing an acute crisis of labourers during the prime period of cultivation (usually at the time of sowing/transplanting/harvest/post harvest operations like cleaning, grading, packaging and warehousing etc) of almost all the crops. Moreover, leasing the land to others by the landowner results in ill maintenance of land avoiding thinking of the sustainability and soil health issues as land is considered as nothing but a money earning machine to them.

Water issues

Water is the basic need for the sustenance of all living beings. It is obvious that nature is the key source of water and sweet water is the only permissible drinking water. About 97.5 per cent of the water available in the world is almost undrinkable and unsuitable for any purpose. 70 per cent of the drinkable water i.e. sweet water (2.5% of the total water) comes from glaciers and the rest amount remains as the groundwater. The source of this ground water is rapidly getting reduced owing to escalating demand for irrigation purpose, rapid industrialization and urbanization as well as indiscriminate use of water in all the domestic and nondomestic spheres. Statistics show that every half to two third of the world population will have to face the acute scarcity of water in the coming 20-25 years.

Overexploitation of ground water, cultivation of high water-requiring crops like rice in all the agricultural seasons (pre-kharif or summer, kharif or rainy and rabi or winter and boro exclusively for dry season), overdependence on groundwater, reluctance to water saving technologies are the key causes behind water crisis (quantity factor) and water quality (quality factor like arsenic, fluoride and heavy metal poisoning etc.).

At this moment about 280 crore people of almost all the continents of the world fall in the grip of this alarming water crisis for at least one month in a year. 120 crore people do not get uncontaminated good quality water. The main cause of death of the children below 5 years is water borne diseases and at any moment, 50 per cent of the beds in the hospitals around the world are occupied by the patients suffering from such type of diseases.

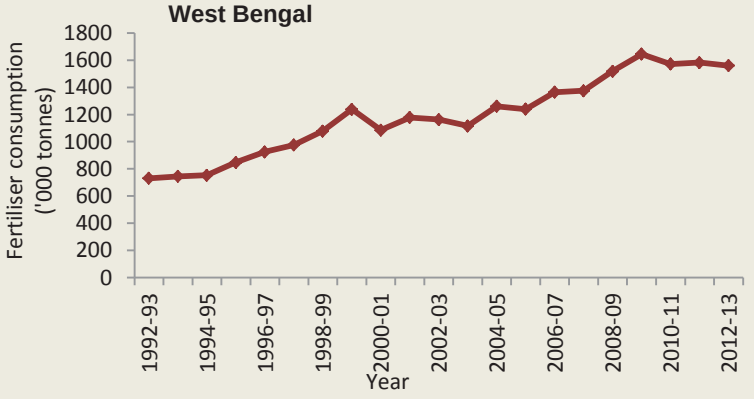
Eutrophication, the ecosystem's response to the addition of artificial or natural nutrients, mainly phosphates, through detergents, fertilizers or sewage to an aquatic system results in explosive growth of some aquatic plants and algae. It ultimately hampers the growth of the aquatic flora and fauna, resists penetration of solar radiation inside the water body and creates hypoxia.

Soil erosion issues

Land is the most vital basic natural resource. It is a dynamic and complex combination of geology, topography, hydrology, soil and flora as well as fauna and has impact on every sphere of human activity. Different sectors including agriculture, industries, infrastructure and power projects have demand for land. Intensive farming practices, accelerated soil and water erosion, erratic rainfall, increasing human population and livestock population also have contributed to unsustainable land use leading to degradation of this valuable

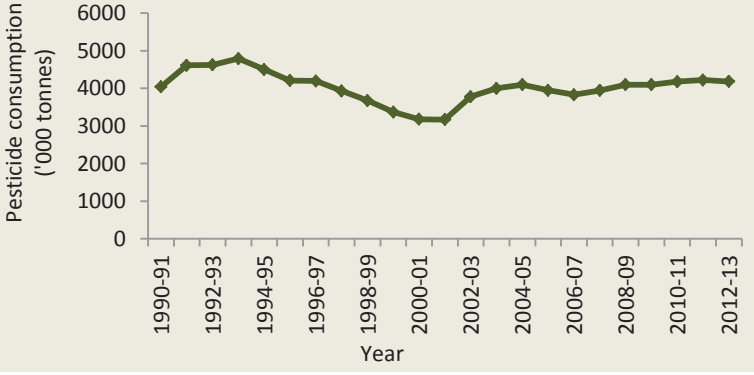
resource in West Bengal. Measures should be taken to check erosion through conserving soil by utilizing these lands through growing different medicinal and aromatic plants, bio-diesel crops and even grasses like vetiver and sabai. Promising results are found in checking river bank erosion through vetiver plantation. Both the grasses are highly remunerative and have shown their potentiality in employment generation and livelihood development aspects in the adjoining villages of the rivers. Agro-forestry is also an outstanding choice for these eroded areas.

FIGURE 5.13 Total fertilizer consumption of West Bengal



Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Department of Agriculture and cooperation, Ministry of Agriculture, Govt. of India.

FIGURE 5.14 Total pesticide consumption of West Bengal



Source: Agricultural Statistics at a glance- 2014. Directorate of Economics and Statistics (2014). Department of Agriculture and cooperation, Ministry of Agriculture, Govt. of India.

Chemical fertilizer and pesticide issues

Chemical pesticides and fertilizers played a significant role in the improvement of crop yields all over the world along with India as well as the state of West Bengal during the last five decades. Use of fertilizers along with pesticides, high fertilizer responsive dwarf crop varieties with high yield potential, providing and utilizing of surface *vis-à-vis* ground water resources, intensive cropping and versatile chemical pest management practices played the pivotal part in bringing green revolution of late sixties in India. The trend of fertilizer consumption of West Bengal during last twenty years is represented in the Figure 5.13.

Insect pests play a major role in crop damage and yield reduction. Jassid, white fly, thrips, boll worms, aphids, and mites are posing serious threat to several high value cash crops. About 70 insect pests are reported to attack paddy crop and cause 20-25 per cent losses on recurrent basis. Insects on many instances practically reduced the food availability by over 50 per cent. The pesticide consumption pattern of West Bengal during last twenty years has been depicted in Figure 5.14.

The main causes of environmental pollution due to indiscriminate use of pesticides and chemical fertilizers may be focused largely on:

- Farmers ignorance about fertilizers and pesticides application (method, time and quantity);
- Lack of awareness about integrated nutrient, water and pest (insect, disease, weed, rodents etc.) management;
- Improper storage and mishandling of such chemicals
- Improper disposal of empty containers
- Reluctance vis-à-vis lack of awareness amongst farm families and common people regarding pesticides pollution in their daily food and water.

So, the following measures should be kept in mind to mitigate the ill impacts on the below mentioned sectors.

Environment

- Harmful pesticides and chemical fertilizer create pollution in the environment if they are used in indiscriminate fashion. So, their judicious use reduces the pollution load;
- Careful use of pesticides and chemical fertilizers offers benefits to the soil-water-plant-animal-human being continuum.
- Integrated approach in pest management at the initial stage and in the long run switching over from chemical farming towards organic farming via integrated management systems should be advocated.

Farmers/ common people/ domestic animals/ birds etc.

- The farmers are directly affected by the ill effects of pesticides and different other chemicals during spraying or application to the field crops. Proper protection adopted during such spray/application may save them from the direct bad impacts of these chemicals;
- The farmers, common people, domestic animal, birds etc are indirectly affected by the bad effects of these chemicals through consuming polluted food products as well as water etc. Proper measures taken in the agricultural field by the farmers during application and necessary precautionary steps adopted during consumption of food materials etc. by the common mass and feeding the animals and birds may save the entire living mass by reducing the pollution load in the food chain.

Industries

There are number of eco-friendly chemical pesticides, specific graded fertilizers and good number of organic manures, bio-pesticides, bio-fertilizers etc. prevailing in the market. The industries may come forward to survey on these aspects, promote these agricultural inputs to the farmers and produce such inputs as per the demand of the entire agricultural system for its betterment.

Abiding by these mandates ultimately the national economy would be benefited through checking the degradation of soil, providing pure and safe water to the nation, reducing overall pollution load, protecting the bio-diversity, lesser import of agro-chemicals saving valuable foreign exchange and making the human resource of the country healthy.

Biodiversity/seed issues

Seed is considered as a fundamental input for successful agricultural production. The State has achieved a considerable progress in production and use of quality seeds. Seeds of different crops are multiplied in the Government farms, West Bengal State Seed Corporation Ltd, State Agricultural Universities, West Bengal Comprehensive Area Development Corporation, co-operatives and private agencies etc. West Bengal State Seed Certification Agency is mainly associated with the production of certified seed in the State. As per the report of the Department of Agriculture, Government of West Bengal, 2011-12 the State produced 1626.6 ton paddy, 49.98 ton wheat, 9.35 ton of jute, 61.35 ton of pulses, 78.32 ton oilseeds, 88.75 ton potato, 82.8 ton sugarcane, 19.5 ton dhaincha and 10.66 ton seeds of other crops. Seed village programme under Central Sector Scheme (CSS) is also in operation. Besides, production of hybrid seed paddy, maize as well as Varietal Replacement Programme (VRP) are also functioning in the state under RKVY scheme. Near about 7,000 seed villages are under execution for the production of quality seeds of paddy, pulses, oilseeds etc. Under CSS; more than 3,500 seed villages have already been completed under Green Revolution Programme. Seed bank project for

developing infrastructure on storage of seeds, data bank and information service related to seeds, quality control and management of seed bank are also in operation.

Biodiversity is the whole host of life forms within a particular ecosystem. It is often used for measuring the health of biological systems. Introduction of high yielding varieties in the intensified agricultural system has sharply diminished the area for traditional/indigenous varieties in the State resulting in the extinction of different local varieties/land races. The trade and marketing policy of the national and multinational seed agencies and a parallel proclivity/inclination of the farmers towards HYVs of different crops during green revolution as well as post green revolution eras are the key causes behind such phenomenon. Thus, at this phase, it is a crying need to protect and preserve all the land races/local varieties of paddy, pulses, brinjal, chilly, amarathus, tomato and different other vegetables; banana, mango and various other major and minor fruits having marvelous potentiality to survive in their respective stressed regions, combat with the versatile pest attack and acclimatize with the changed climatic conditions. Practically, they are the ores of special genes expressing their special features in distinct crop quality, taste, aroma and high nutritional value as well as in disease resistance, adaptation to poor soils, drought, water logging, cold temperatures etc. The indigenous technological knowledge (ITK) should also be addressed, validated and given priority particularly in the stress areas. The age old agricultural systems should also be offered priority - they should never be given up. The knowledge of the heritage agriculture should be intermingled with the modern ones for the sake of sustenance of the entire agrarian systems. Over dependence on a very few HYVs, far divergence from the traditional ones and simultaneous use of large amounts of chemical fertilizers and pesticides resulted in loss of varied biodiversity like fish, frogs, beneficial insects, birds, snakes and many other elements of the system.

In order to protect valuable germplasms of different crops from contamination by genetically modified (GM) crops and preempt possible adverse effects on health and nutrition of the people of West Bengal, any open field trails and commercial cultivation of genetically modified crops should completely be banned in the State. The mutually exclusive nature of ecologically sustainable farming with the synthetic chemical-dominated conventional agriculture would be further vitiated by the introduction of GM technology.

Agriculture and climate change issues

The earth's surface temperature has been slowly increasing for the last 15,000 years, since the last ice age. Global warming refers to the increase in temperature of the earth's surface. It is a natural process and without it the temperature would be –18ºC instead of the pleasant +15ºC as it is today. The Green House Gases (GHGs) influences the earth's temperature. Increase in GHGs in atmosphere makes the earth atmosphere warmer that adversely affects life processes. Global warming is the cause of climate change. Climate change is not a scientific debate but a real concern being a global issue having trans-boundary effects:

- Global mean temperatures already increased by 0.74ºC during last 100 years, likely to increase further by 1.8-6.4ºC by 2100 AD;
- Snow cover is projected to contract;
- Sea level rise to be 0.18 - 0.59 m;
- More natural disasters - frequent hot & cold extremes, heavy precipitations, flash flood, frequent drought, storms and cyclones etc. would be the common phenomenon;
- Eleven of the last twelve years (1995-2006) rank among the 12 warmest years.

Potential impact of climate change on agriculture are

- Cereal productivity to decrease by 10-40 per cent by 2100.
- Greater loss expected in rabi. Every 1°C increase in temperature reduces wheat production by 4-5 million tons. Loss only 1-2 million tons if farmers could plant in time.
- Reduced frequency of frost damage: less damage to potato, peas, mustard.
- Increased droughts and floods are likely to increase production variability.
- Shift in pest disease scenario.

There is a effect of climate change in pest dynamics. The driving factors are increase in temperature, increase in CO_2 concentration, increase in vapour pressure and natural disaster (drought, flood, cyclone etc.) and the resultant impacts may be hastened lifecycle of insect and pathogen, more generations in a season, minor pests becoming a major problem and migration and spread of insect and pathogens.

The total precipitation has a decreasing trend across all agro-climatic zones of the State, except for the hill region. The rainfall pattern shows that there is not much change in total rainfall - monsoon rain decreased and pre-monsoon rain increased in Alluvial Zone. Onset of monsoon is getting delayed and precipitation has become very erratic. Both monsoon and pre-monsoon rain increased in Hills, Terai and Coastal Zones and rain became more erratic in Red Laterite Zone. Erratic distribution of rainfall is leading to run-off loss, flash floods, increased frequency of drought and flood and loss to kharif seedbeds, summer vegetables, jute, betel vine, flowers, etc. very often.

Increase in winter temperatures causes adverse effect on rabi crop. Special attention is needed for wheat, potato, winter pulses, oil seeds and vegetables. Duration of high temperatures during summer is extending resulting reduced production of late sown boro paddy. Besides, high night temperature is also reducing the crop production in general.

Other aspects of climate change are increase in intensity of extreme events such as cyclonic storms – Coastal zone are major sufferer; increase in foggy and cloudy days in winter resulting increase in pest and disease; widespread damage of rabi crops (potato, mustard, vegetables); and decrease in carbon and moisture retention capacity of soil.

Combating disaster, flexibility in crop/variety, conserving resources like water, fertilizer and chemicals, diversifying enterprise (Integrated Farming System) like livestock rearing, fishery and agro-forestry are the ways to combat climatic stress.

TABLE 5.16 Concern for different agro-climatic zones

Zone	Concern	Effects
Hill Zone	Increased winter Temp High intensity of rain	Winter crops (wheat, potato) getting affected Citrus size decrease More land slide
Terai Zone	Increased rain intensity Increased winter span	High nutrient loss by leaching Favourable condition for wheat
Old alluvial Zone & New alluvial Zone	Decreased monsoon rain Increased temperature Foggy weather	Water stress to rice More disease pest
Red Lateritic Zone	Erratic rain High temperature	Increased water stress (drought) at different growth stages
Coastal Zone	More cyclonic storms Increased sea level High but erratic rainfall	More salinity problem Decreased water and nutrient use efficiency

Box 5.1 Some tips to combat climate change

Strategies	Outcomes
Options : Utilizing most profitable cropping window	
Staggered nursery, community nursery	To assure transplanting under erratic monsoon
Short duration crop	Avoid dry spell and high temperature spell
Crop diversification, variety diversification	Fight against disease pest, lessen risk
Using legume in crop rotation	Additional return with minimum input, benefit to soil
Relay/paira cropping	Using soil moisture and conserving carbon, saving time
Options : Nutrient management for crop & environment	
Adjusting application rates	Based on soil test report and crop need
Use slow-release fertilizer forms or nitrification inhibitors	Reduces nitrogen loss, increase fertilizer use efficiency
Timing of application	Application at critical stage
Placement of fertilizer	Placing the N more precisely into the soil to make it more accessible to crops roots
Options : Residue management for resource conservation	
Zero/minimum tillage	Save resource/energy, save time, protect beneficial microorganism
Residue incorporation	Restores soil carbon, maintains soil health
Avoiding burning of crop residue	Checks carbon emission, conserves moisture, protects beneficial microorganism
Options : Manage the Manure for protection of environment	
Covering the manure	Reduce N_2O emission and carbon loss
Composting the manure	Reduces GHG emission, conserves NPK
Separating solid from the slurry	Reduces methane emission

And the most important thing is a contingent planning for Natural disaster - Drought, Flood, Heat wave etc.

Need of new approach

New approach to combat climate change effects include community food security system and organic farming.

Community food security system

Community food security system involves gene banking, seed banking grain banking and water banking to achieve the UN Millennium Development Goal of eradicating hunger and poverty.

Organic farming:

Modern agriculture and horticulture with high yielding varieties, hybrids require heavy doses of synthetic chemicals such as fertilizers, insecticides, fungicides. However, the effect of indiscriminate use of fertilizer and pesticides without considering the future consequences started to show up and yields of crops have leveled off despite using higher doses of fertilizers. Resistance has developed among the pests against various pesticides. Environmental pollution is occurring at an alarming rate. With the increasing cost of cultivation in the conventional agricultural practices and no appreciable additional benefits in income, the farmers in general and small and marginal in particular are finding it extremely difficult to earn their livelihood and a large number of them are below the poverty line. The situation would further deteriorate with gradual fragmentation of holdings. In order to improve the socio-economic conditions of the farming community, soil health, productivity and production of crops at a lower cost in a sustainable farming system, it is considered essential to shift the production technology using organics. Organic farming is being mainly based on the utilization of local resources and is labour intensive, generates rural employment, avoids expensive inputs

like synthetic fertilizers and pesticides, improves soil fertility and sustains productivity and also requires less financial involvement. Apart from the superiority in nutritional value necessary for health care and prevention of various ailments through intake of organic food, organic agriculture has convincingly proved to be eco-friendly and prevents environment pollution and also increases tolerance to abiotic (drought, cold etc.) and biotic (pests and diseases) stresses ensuring crop production even under unfavourable environment.

Because of food safety, higher nutritive value, taste and better storage life organic products have higher price premium both in domestic and export markets. Developing countries have also started realizing the advantages of organic farming and the movement is gaining momentum but at a slow pace. Conversion from conventional to organic agriculture is not an easy task particularly in developing countries because of reduced initial income and food insecurity, lack of technical awareness, support price, marketing and the adverse push-sale attitude of the input dealers in particular. Since organic agriculture is a technology of utmost priority for small and marginal farmers of West Bengal to survive and flourish with sustainable farming system in crop production and animal husbandry, it needs to be introduced through the different extension methods at the farmers' level.

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Chapter 6

Forest and Wild Life

West Bengal has a recorded forest area of 11,879 sq km which constitutes 13.38 per cent of the State's geographical area. The forests occur mainly on the slopes of the Darjiling Himalayas, the Himalayan foothills, the lateritic tracts in the southern part of the State, and in the Sundarban delta region. The forests are rich in biodiversity and harbor a wide variety of plants and animals. They are also a source of timber, fuel wood and non-wood forest products. The Department of Forests, Government of West Bengal is responsible for the overall management of forests and wildlife in the State.

Of the total recorded forest area of the State, Reserved Forests constitute 59.38 per cent and Protected Forests 31.75 per cent. The remaining forest area is Unclassed State Forest. Reserved Forests are notified under the Indian Forest Act and enjoy a higher degree of protection (human activities are prohibited unless expressly permitted). Protected Forests are also notified under the Forest Acts but the restrictions are less stringent (human activities are permitted unless expressly prohibited). Unclassed Forests are forests which have not been included in reserved or protected forest categories. The district wise distribution of forest area is shown in the Table 6.1.

The forest cover of the State, as assessed by the West Bengal Forest Department, is 15.68 per cent of the State's geographical. The forest cover includes all lands which have a tree canopy density of 10 per cent and above and have a minimum area of one hectare.

The climatic conditions in the State extend from alpine in the Himalayas in the north to tropical climate in the southern coastal region. As a result, the State has diverse forest types. The forests fall under eight major forest types: (i) Tropical Semi-Evergreen forests, (ii) Tropical Moist Deciduous forests, (iii) Littoral and Swamp forests, (iv) Tropical Dry Deciduous forests, (v) Sub-tropical Broadleaved hill forests, (vi) Montane Wet Temperate forests, (vii) Himalayan Moist Temperate forests and (viii) Sub-alpine forests.

Source: Kalyan Rudra

TABLE 6.1 Area under forests (in sq km)

District	Reserved Forests	Protected Forests	Unclassed State Forests	Total Area
Darjiling	1115	-	89	1204
Jalpaiguri	1483	217	90	1790
Koch Bihar	-	42	15	57
Bankura	80	1311	91	1482
Purba and Paschim Medinipur	8	1166	535	1709
Barddhaman	3	192	82	277
Puruliya	112	729	35	876
Birbhum	8	54	97	159
Hugli	3	-	-	3
Nadia	5	3	5	13
Murshidabad	1	7	-	8
Maldah	8	5	7	20
Uttar and Dakshin Dinajpur	8	4	6	18
North 24 Parganas	43	-	-	43
South 24 Parganas	4177	42	1	4220
Haora	-	-	-	-
Kolkata	-	-	-	-
West Bengal	7054 (59.38%)	3772 (31.75%)	1053 (8.87%)	11879 (100%)
All India	423311	217245	127881	768437

Source: Annual Report 2014-15 of the Directorate of Forests, Government of West Bengal

TABLE 6.2 Forest types of West Bengal

Forest Type	Area (sq. km.)	Location	Major Species
Tropical Semi-Evergreen Forests	357.50	Jalpaiguri district	*Shorea robusta, Michaelia champaca, Terminalia myriocarpa, Ailanthus grandis, Phoebe spp.*
Tropical Moist Deciduous Forests	1376.19	Duars and Terai area of North Bengal	*Shorea robusta, Michelia champaca, Lagerstroemia parviflora, Terminalia belerica, Chukrasia velutina.*
Littoral and Swamp forests	2120.08	North 24 Parganas and South 24 Parganas districts	*Ceriops spp., Avicennia spp., Rhizophora candelaria etc.*
Tropical Dry Deciduous Forests	3575.70	Bankura, Puruliya, Medinipur, Birbhum, Barddhaman	*Shorea robusta, Anogeissus latifolia, Boswellia serrata, Terminalia belerica, T.tomentosa*
Subtropical Broadleaved hill forests	339.41	North Bengal hills (300 m-1650 m)	*Schima wallichi, Castanopsis indica, Phoebe attenuata, Castanopsis tribuloides*
Montane Wet Temperate forests	200.31	North Bengal hills (1650 m-3000 m)	*Quercus spp., Acer spp., Machilus spp., Michelia spp.*
Himalayan Moist Temperate forests	295.36	North Bengal hills (1500 m-1800 m)	*Michelia exels, Abies densa, Tsuga brunoniana, Rhododendron spp.,Arundinaria malinga, Machilus spp., Acer, Quercus etc.*
Sub-alpine forests	14.21	North Bengal hills (3000 m-3700 m)	*Tsuga brunoniana, Picea spp., Abies densa, Quercus spp., Juniperus spp., Rhododendron spp and Betula utili.*

Source: Annual Report 2014-15 of the Directorate of Forests, Government of West Bengal

Wildlife and biodiversity

The wide range of physical features and climate conditions in West Bengal has resulted in a diversity of forest ecosystems - it is the only the state in India to have both coastal and alpine ecosystems. The forests harbour and sustain varied flora and fauna, including many rare and endangered species. In spite of its small area (2.7% of the area of the country), the State has 53 per cent of bird species, 47 per cent of mammals, 32 per cent of reptiles and 21 per cent of angiosperms recorded in India. These include the Bengal Tiger, Asian Elephant, Bison, one-horned Rhinoceros, Himalayan Black Bear, Red Panda and many other endangered species of animals.

In order to conserve the unique biodiversity of the State, a network of protected areas has been created. The State has five national parks, fifteen sanctuaries, two tiger reserves, two elephant reserves, and one biosphere reserve. The total area under the protected area network is 4,064 sq km which amounts to 34 per cent of the total forest area and 4.54 per cent of the total geographical area of the State.

TABLE 6.3 Protected areas in West Bengal

National Parks

Sl. No.	Protected Area	Area (sq km)	District
1.	Singalila National Park	78.60	Darjiling
2.	Neora Valley National Park	88.00	Darjiling
3.	Buxa National Park	117.10	Jalpaiguri
4.	Gorumara National Park	79.45	Jalpaiguri
5.	Sundarban National Park	1330.10	South 24 Parganas
Total		**1693.25**	

Wildlife Sanctuaries

Sl. No.	Protected Area	Area (sq km)	District
1.	Jorepokhri Salamander Wildlife Sanctuary	0.04	Darjiling
2.	Senchal Wildlife Sanctuary	38.88	Darjiling
3.	Chapramari Wildlife Sanctuary	9.60	Jalpaiguri
4.	Mahananda Wildlife Sanctuary	158.04	Darjiling
5.	Jaldapara Wildlife Sanctuary	216.51	Jalpaiguri
6.	Raiganj Wildlife Sanctuary	1.30	North Dinajpur
7.	Bethuadahari Wildlife Sanctuary	0.6686	Nadia
8.	Ballavpur Wildlife Sanctuary	2.021	Birbhum
9.	Ramnabagan Wildlife Sanctuary	0.14	Barddhaman
10.	Bibhutibhusan Wildlife Sanctuary	0.64	North 24 Parganas
11.	Narendrapur Wildlife Sanctuary	0.10	South 24 Parganas
12.	Sajnakhali Wildlife Sanctuary	362.40	South 24 Parganas
13.	Halliday Island Wildlife Sanctuary	5.95	South 24 Parganas
14.	Lothian Island Wildlife Sanctuary	38.0	South 24 Parganas
15.	Buxa Wildlife Sanctuary	368.99	Jalpaiguri
Total		**1102.2096**	

TABLE 6.3 Protected areas in West Bengal

Tiger Reserves

Sl. No.	Protected Area	Area (sq km)	District
1.	Buxa Tiger Reserve (including WLS & NP)	760.87	Jalpaiguri
2.	Sundarban Tiger Reserve	2585.00	South 24 Parganas and parts of North 24 Parganas
Total		**3345.87**	

Biosphere Reserves

Sl. No.	Protected Area	Area (sq km)	District
1.	Sundarban Biosphere (including STR areas)	9630	South 24 Parganas and North 24 Parganas
Total		**9630**	

Elephant Reserves

Sl. No.	Protected Area	Area (sq km)	District
1.	Eastern Duars Elephant Reserve	977.51	Jalpaiguri
2.	Mayurjharna Elephant Reserve	414.00	Paschim Medinipur, Bankura and Puruliya
Total		**1391.51**	

Joint Forest Management

West Bengal is a pioneer among Indian states in adopting joint forest management, a system of forest management that involves local communities in forest protection and regeneration. Joint Forest Management had its genesis in the early 1970s at Arabari Forest Range in Paschim Medinipur district where forest officials motivated villagers to protect degraded forest patches in exchange for a share of non-timber forest produce. It was later extended to other forest areas of the State and Forest Protection Committees were formed in most forest fringe villages. Subsequently, the State Government took a decision to share 25 per cent of usufructs and net profit of the intermediate and final yields from the forests with villagers. Participatory management was extended to protected areas with the formation of Eco-development Committees in villages surrounding sanctuaries and National Parks. At present, there are 4,312 Forest Protection Committees and 107 Eco-development Committees in the State. The practice of joint forest management in the State has resulted in regeneration of degraded forests and economic benefits to the fringe population.

Sundarban
Source: Kalyan Rudra

Afforestation and conservation schemes

West Bengal is a heavily populated state with an average population density of 1,028 people per sq km, the second highest in India. The per capita forest and tree cover in West Bengal is 0.0115 ha which is much less than the national average of 0.075 ha. Because of the rapid increase of population and high population density, the forest resources of the State are under great anthropogenic pressure.

Forest and wildlife management in the State aims at conservation of forests and biodiversity while being responsive to the livelihood needs of forest dependent people. To this end, a number of afforestation and conservation schemes are being implemented in the State. The major thrust areas are:

- Afforestation on available forest and private/vested lands;
- Restoration and rejuvenation of degraded forests with the involvement of local population;
- Soil and water conservation;
- Conservation of ecologically fragile area;
- Habitat improvement in protected areas;
- Eco-development activities in and around protected areas;
- Socio-economic development of forest fringe population;
- Research on clonal propagation of tree-species including NTFP bearing trees;
- Raising people's awareness about conservation of wildlife and forests through creation of Nature Interpretation Centres, Ecotourism facilities and publicity campaigns.

Chapter 7

Biodiversity

Biodiversity is the diversity of life reflected at various levels from genes to ecosystems. Though, it is described most often at the level of species. It is the most important resource for mankind even today. Biodiversity has now drawn special attentions of experts and aware citizens for its decline at an unprecedented high rate during the last two centuries. On the other hand, it has gained newer values with the emergence of biotechnology industries that exploit genetic diversity lying in the diversity of species and varieties of organisms to produce new drugs and other important products for human welfare. And, last but not the least, is the emerging understanding of the role of biodiversity in the functioning of any ecosystems.

India is one of the top few megadiverse countries recognized to exist on earth. It is due to her high diversity of ecosystems, species richness and endemism, as well as, for the richness of traditional knowledge on herbal medicines etc., for the exclusive domestic biodiversity and their wild relatives. West Bengal though occupies only a small slice (2.7%) of India's total geographical area, it is blessed with quite a high share of its biodiversity of species and ecosystems. It is the only State in India that includes five distinct ecological zones, - the high and cold mountain areas with temperate vegetation that descend to the foothills with dense tropical forest covers in the north, the lowest intertidal zone covered with tropical mangroves in the south, the semi-arid undulating plateau in the west with the vast flood plains in the east. Out of the 16 forest types noted in India, 10 can be seen in the State (Research Circle, Dept of Forests, GoWB, 2010A). At the species level, this State is a major stakeholder of Indian flora and fauna, for example, it possesses 3,580 (21.33%) species of angiosperms and 1,831 (23%) species of vertebrates - the two of the most prominent groups of life (Ghosh, 1998, Sanyal *et al.*, 2012). West Bengal is also rich in traditional knowledge relating to the use of medicinal plants and indigenous varieties of crops and livestock which are the highly valued cultural components of a country's biodiversity.

Diversity of ecological zones

No other state in India is as rich as West Bengal in terms of possessing ecologically distinct zones. They are-

- High mountains of the Eastern Himalayas with altitudes reaching from 500 to 3,600 m above MSL in the Darjlling district.

State Wild Biodiversity Symbols

State Animal: Fishing Cat (*Prionailurus viverrinus*)
Source: Apurba Chakraborty

State Bird: White Throated Kingfisher (*Halcyon smyrnensis*)
Source: Santanu Kuveskar via wikimedia commons

State Tree: Chhatim or Saptaporny (*Alstonia scholaris*)
Source: West Bengal Biodiversity Board

State Flower: Shiuli or Shephali (*Nyctanthes arbortristis*)
Source: West Bengal Biodiversity Board

- Tropical forest clad foothills and adjacent plains lying mostly in the districts of Darjiling, Jalpaiguri and newly formed Alipurduar.
- Extensive flood plains along the river Bhagirathi and its tributaries from north and from west. This zone includes the districts of Koch Bihar, Uttar and Dakshin Dinajpur, Maldah, Murshidabad, Nadia, Hugli, Haora, Barddhaman and Birbhum and parts of Jalpaiguri, Alipurduar, South and North 24 Parganas.
- Dry undulating plateau in the western sides of the State covering districts of Puruliya, Bankura and Paschim Medinipur.
- Estuarine and coastal mangroves ecosystems in the South and North 24 Parganas and in the coasts of Purba Medinipur.

Another zone of intermediate nature between the lower alluvial plains and the dry, undulating plateau in the western side is recognized often as an agro-ecologically distinct zone. This one is referred to as Rarh in bengal. Physiographically, the region is actually upper alluvial plains.

Biogeographic affinities

The Directorate of Forests, GoWB, following Roger and Panwar (1998) includes the biodiversity of West Bengal in the following biogeographic provinces of India-

1. Central Himalayas (Darjiling district).
2. Chotonagpur Plains of the Deccan Peninsula (Puruliya and part of Bankura district)
3. Lower Gangetic Plains (Jalpaiguri, Alipurduar, Koch Bihar, North and South Puruliya, Maldah, Murshidabad, Nadia, Barddhaman, Birbhum, Purba and Paschim Medinipur, North 24 Parganas and parts of Bankura and South 24 Parganas)
4. Eastern Coast (part of South 24 Parganas).

Faunal diversity

The fauna of West Bengal include representative species from almost every Phylum of animals. Of the 96,373 animal species recorded in India (MoEF&CC, Govt. of India, 2014), the State shares 11,042 of them (Sanyal *et al.*, 2012). Along with this, of the 2577 species of Protists (mostly single celled protozoans) recorded in India, 1136 have been found in the State. The invertebrate fauna in the State is documented to be with 8,079 species of which 5,470 species are insects (Sanyal *et al.*, 2012). Most species rich group of the State fauna are of course, the arthropods (6,785 species) including the insects (5,407 species). The vertebrate fauna in the State is comprised of around 36.75 per cent of all known vertebrates in the country (Sanyal *et al.*, 2012) (Table 7.1). These are certainly lower estimates, as, new explorations in different parts of the State are yielding new species regularly, and many species are being reported for the first time from the State. Especially, most of the invertebrate groups in the State are expected to turn much richer with such explorations and new studies in lesser explored pockets of the State. For example, recent surveys of the intertidal fishes and macro invertebrate fauna along the north-eastern coasts of India including West Bengal, brought out many species so far unrecorded in India and also some species being completely new to science (for e.g. Prassana and Tudu, 2014, Tudu *et al.*, 2013).

TABLE 7.1 Species diversity in major groups of animals within the State (Sanyal *et al.*, 2012)

Major groups of Animals	No. of species in West Bengal
Porifera (sponges)	16
Platyhelminthes (flat worms)	248
Nemtodes (round worms)	306
Molluscs	274
Annelids (earthworms, leeches)	194
Insects	5407
Arachnids (include spiders)	1094
Crustaceans (prawns, crabs etc)	251
Echinoderms (starfish etc)	22
Pisces (fishes)	610
Amphibians	39
Reptiles	148
Birds	846
Mammals	188

Endemic species

It's difficult to find species of animals which are endemic to only just one state of India due to overlapping of eco-geographical regions between the states. Yet, West Bengal can claim some endemism in few groups. Especially, the mountain areas of the State in the north occupy a major chunk of one of the biodiversity hot spots on earth - the Eastern Himalayas, thus, sharing a good part of the flora and fauna endemic to the region. For examples, Paliwal (2013) enlisted 17 species of earthworms which are endemic to the district of Darjiling, thus, to West Bengal only. Ghosh (1988) claims 143 species out of a total of 516 from five selected families (of the orders Homoptera and Hemiptera) of insects recorded in the State as endemic ones. Walnut Kukri snake (*Oligodon juglandifer*) is reported from Darjiling hills only, its distribution is assumed to be restricted in the Darjiling district and adjacent hill areas. Jerdon's Tree frog (*Philatus jerdoni*) has been reported only from Darjiling. Most remarkably, a completely new species of frog was found a few years ago from Chilapata in North Bengal by a local school teacher and described as *Minervarya chilapata* by a team of national and international experts (Ohler *et al.*, 2009). Bengal or Marsh Mongoose (*Herpestes palustris*, Ghosh, 1965) was claimed as a distinct species and the only endemic mammal found in the State. Though, ITIS (Interagency Taxonomic Information System,

as on 24 Aug 2016) considers it as a subspecies of *H. javanicus*.

Some flagship groups of wild animals from the State

Most of the charismatic wildlife species that enrich India's biodiversity status are also found in this State. Many of these are considered endangered at different degrees and thus, given protections accordingly by the Wildlife (Protection) Act of India (1972, amended till 1993). Others, mostly smaller ones, are now gaining more attentions from specialists and wildlife lovers with the emerging understandings of their ecological roles and appreciations for their attractive appearances.

Tigers of Sundarbans are uniquely adapted to estuarine habitats
Source: Joydip Suchandra Kundu

A magnificent tusker in a North Bengal forest
Source: Arjan Basu Roy

Mammals

The State shelters a rich mammalian fauna of 188 species that include almost all charismatic bigger wildlife and many other interesting ones reflecting the richness and importance of the diversity of wild fauna in the State. Table 7.2 mentions about some of the interesting and important mammals of the State.

Birds

Bird life is extremely rich in West Bengal including many as regular visitors in winter or summer from other parts of the country or globe along with the permanent resident ones. A recent estimate suggests the bird species richness of the State around 861 (Sen, 2014). Even in village habitats at the heart of intensively cultivated flood plains one may see at least 130-180 species of birds over various seasons (Bhattacharyya, 2016). It is definitely much richer in forested areas, especially in the tracts of Sundarbans and Himalayas. Some of the birds of the State that bird lovers would like to watch with delight include Rufous necked Hornbill, Kalij Pheasants, Satyr Tragopan, Rusty bellied Shortwing, Rufous winged Lark or Bengal Lark, Asian Fairy-Bluebird, Jerdon's Baza, White bellied sea Eagle, Long legged Buzzard, Ruddy Kingfishers, Brown-winged Kingfisher, Lesser adjutant Stork and many more.

In a long term study concluded in 2000, Prakriti Samsad, a renowned Kolkata based nature study organization recorded 183 species of birds within the Sundarban Tiger Reserve. Beside richness of waders, birds of prey and all other kinds of birds, Sundarbans is the place where one can see nine species of kingfishers including the Brown winged kingfisher, a mangrove specialist. Prakriti Samsad also recorded 288 birds from the Lava-Lolegaon region

TABLE 7.2 Some important wild mammals in West Bengal

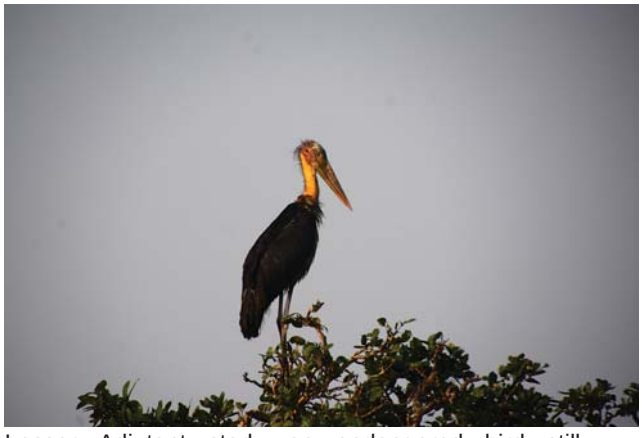
Name	**Status**: Global(IUCN), Indian(WPA)	Status in West Bengal
Bengal Tiger (*Panthera tigris tigris*)**:** The only population of unique mangrove adapted tigers in India is found in WB part of Sundarbans. Others in the North Bengal	Endangered, Schedule-I	Estimated to be around 135: Sundarbans-102, N.Bengal-Buxa-20 (claim based on WWF-WII data 2011-13, though figures are debated), may be another 10-15 in other N.B. forests
Great Indian One-Horned Rhinoceros: The western most surviving gene pool of this precious wildlife is found in the forests of North Bengal	Vulnerable, Schedule-I	Total-236 (Wildlife Wing, DoF, GoWB 2013-14) Gorumara-Chapramari-50 and Jaldapara NP- 186
Asian Elephants: The State possesses two spatially isolated gene pools of this largest land mammal of Asia.	Endangered Schedule-I	Total-647, N. Bengal-529, S, Bengal-118 (2010 stats by WLW)
Gaur or Indian Bison: This gorgeous wild bovine is considered a wild relative of Zebu- our domesticated cow	Vulnerable Schedule-I	Increasing populations in NB forests have reached around 2500. Biggest herds at Gorumara NP
Leopard: Once found in every forest tracks excepting mangroves, this agile predator is now restricted mostly in the forests of North Bengal foothills and plains	Near Threatened Schedule-I	Estimated to be 164 in North Bengal forests by wildlife wing of WBFD, presence of Black panthers –the melanic form of the leopard recorded from Buxa
Clouded Leopard: Very little about the life of this smallest of the big cats is known. The beautiful but highly elusive species used to be seen more as skins seized from the poachers. Now the WBFD has taken initiative to study the species	Vulnerable Schedule-I	Recorded from Buxa, needs further exploration to find out population status in the State, villagers in Gorkhey and Shrikhola adjacent to Singhalila N.P. reported sightings recently to wildlife trekkers
Himalayan Black Bear (*Ursus thibetanus*)**:** A huge and aggressive carnivore	Vulnerable Schedule-I	Observed in the Singhalila and other forests at higher ranges. Sloth bears are found in Dooars and sometimes in the forests of Puruliya
Red Panda (*Ailurus fulgens)***:** This cute looking furry arboreal animal is taxonomically unique being the only representative of family Ailuridae and not being closely related to the Giant Panda	Vulnerable Schedule-I	Observed quite regularly in upper Neora valley and other high altitude forests of Darjiling districts
Binturong (*Arctictis binturong*)**:** also known as Bear Cat because of some similarities to both. This nocturnal black civet like animal is difficult to spot	Vulnerable Schedule-I	Recently recorded officially in Buxa, but locals reporting it seeing in the forests of foothills for long. Thus, definitely a population exists in the region though the status is yet to be ascertained
Yellow-Throated Marten (*Martes flavigula*)**:** the largest of martens in the old world, a cute looking animal with brightly coloured furry body and long tail	Least Concern	It's quite commonly seen in the Himalayas and its foothills by the wildlife lovers
Leopard Cat (*Prionailurus bengalensis*)**:** A miniature leopard like cat. Interestingly, the highly valued pet cat variety called Bengal Cat is a breed between this species and a domestic one	Least Concern	Once commonly found in the forests of all regions in West Bengal even in village groves. Population has declined, especially in village areas. Recently quite regularly spotted in Sundarbans
Asian Golden Cat (*Catopuma temminckii*)**:** A heavily built medium sized wild cat	Near Threatened	Rarely seen, but its distribution includes the forests of Neora valley, Buxa, Mahananda WLS
Spotted Linsang (*Prionodon pardicolor*)**:** A small slender carnivore with body painted like a leopard and long tail banded like a lemur	Least Concern	A rare species claimed to be recently spotted in JP WLS
Marbled Cat (*Pardofelis marmorata*)**:** Size of a domestic cat but with beautifully marked furry body and longer tail. Arboreal in habit.	Nearly Threatened	Another beautiful small wild cat, quite elusive by nature, to be found in the foothill forests in Buxa and other areas in N.B.
Fishing Cat (*Prionailurus viverrinus)***:** A medium sized powerful cat, capable of killing goats and cattle calves, but prefer to hunt fishes and bigger rats	Endangered (IUCN)	The State mammal. Has been quite common in the forests, groves and reed beds in and around wetlands, even close to villages. Due to rapid reclamation of wetlands, its population has declined rapidly

TABLE 7.2 Some important wild mammals in West Bengal

Name	**Status**: Global(IUCN), Indian(WPA)	Status in West Bengal
Badgers: Different species like Ferret badgers, Honey Badger & Hog Badgers	Vulnerable Schedule I, II	Distributions of these badgers include WB. Ferret badgers are spotted in Gorumara NP
Himalayan Serow : A goat antelope	Near Threatened	Seen in Sighalila N.P.
East Himalayan Goral: Resemble goat, but it's a bovine (cow family)	Near Threatened	Seen in Latpanchor in Mahananda WLS and in Senchal WLS.
Pangolin (*Manis crassicaudata)***:** This scaly, unique looking mammal is delight to watch moving and hunting for termites and other insects	Endangered Schedule I	Originally all over the State except in Sundarbans and very high altitude (the Chinese pangolin *M. pentadactyla* is also found in Buxa).
Otters: Three species- Oriental small Clawed Otter, Common Otter, Smooth-coated Indian Otter are found in the State	Common Otter- Near threatened, other two Vulnerable	Otters were a common sight in the wetlands of Bengal even within villages. All three species have declined significantly, Small Clawed Otters recovering in Sundarbans.
Striped Hyena (*Hyaena hyaena*)**:** A true hyena, roam solitarily or in monogamous pair in search of prey and scavenging	Near Threatened, III	Not uncommon in the forested tracts of Puruliya, Bankura, Paschim Medinipur
Indian Wolf (*Canis lupus pallipes*)**:** Move in pack, hunt smaller mammals in the region	Least Concern Schedule I	Roam in the dry forested tracts in the south WB, pack move over a big range
Dhole or Asiatic Wild Dog (*Cuon alpines*)**:** Social, hunt and defend territory in a pack	Vulnerable Schedule II	A small population is recovering in the Dooars Forests
Hoary bellied Squirrel (*Callosciurus pygerythrus*): Beautiful brown squirrel	Least Concern	Common in Jaldapara and other forests in NB
Malayan Giant Squirrel (*Ratufa bicolour*)**:** The most gorgeous squirrel of India	Least Concern	Easily seen in most of the denser forests in Dooars and foothills
Hodgson's Giant Flying Squirrels (*Petaurista magnificus*)**:** Nocturnal by habit, starts gliding from tree top to lower groves (upto 100m) from dusk.	Least Concern	A good population could be seen in Singhalila NP and even around DarjIling Zoo
Jungle Cat (*Felis chaus*)**:** A bigger an arrogant looking version of the common domestic cat found in India	Lower Risk Schedule II	Once very common even in and around villages, their numbers are reducing very fast
Bengal fox (*Vulpes bengalensis*)**:** A cute, small furry harmless animal that thrive on rats, insects and vegetable diets	Lower Risk Schedule II	It has been a very common faunal element in Bengal villages along with the Jackals. Its populations have declined, though, still found in many villages
Himalayan Palm civet (*Pamuga larvata*)**:** A civet of Himalayan foothills	Least Concern	Quite common in the North Bengal forests of foothills and plains
Crab eating mongoose (*Herpestes urva*): A unique mongoose, eat crabs and can swim	Least Concern	Easy to find in Mahananda WLS and other forests of Dooars
Large Indian Civet (*Viverra zibetha*)**:** A nocturnal predator, much bigger in size than other than small civet or palm civet	Near Threatened, I	Once abundant even in village groves, has become quite rare in recent years
Porcupines: Two species-Indian Porcupine and Himalayan Crestless porcupine	Least Concern Schedule III	Common in the plains and lower altitude northern forested tracts of the State but found also in pockets in the districts of Haora, Hugli etc.
Irawadi Dolphin (*Orcella brevirostris*)**:** Smaller but close relative of Killer Whale	Vulnerable Schedule II	It is not uncommon in the estuarine waters of Sundarbans
Bottle nose Dolphin (*Tursiops* sp.)**:** Wide global distribution, highly intelligent	Least Concern Schedule II	Still can be seen on the sea mouth of Matla rivers
Gangetic Dolphin (*Platanista gangetica*): a blind, river dolphin with long snout	Endangered Schedule I	Once highly abundant in the courses of Hugli river, even along Kolkata, now quite rare

alone in Darjiling Himalaya (more added in last few years) during 2000-01. The freshwater wetlands in the State are also extremely rich in bird life. There are innumerable heronries (breeding colonies of usually mixed species of water birds) found all over the State. The heronry at Kulik in Uttar Dinajpur is the largest of all in the State, probably, in entire Asia.

In recent years, there are quite a few additions to the States' bird fauna like Fire Throat, Large Billed Reed Warbler and few others being observed for the first time in the State, thanks mostly to the efforts of amateur but expert bird watchers.



Lesser Adjutant stork, an endangered bird still commonly found in many areas of the State
Source: Arjan Basu Roy

Reptiles

Sanyal *et al.* (2012) from ZSI, reported 148 species of reptiles from West Bengal. These reptiles include 98 species of snakes, 2 species of crocodiles (Estuarine Crocodile and a small population of Gharial), 17 species of turtles and tortoise, 30 species of lizards including monitor lizards.

The snakes of the State include the giants, the non-venomous Indian Rock Python (*Python molurus*) and its bigger (around 13 ft, 30 kgs) close kin - the Burmese Python (*Python bivittatus*), as well as the smallest ones (3-5 inch) the blind worm snakes (*Typhlops sp.*) The gorgeous King Kobra, the longest poisonous snake (may reach up to 18 feet) in the world, is now restricted to the foothill forests of North Bengal and Sundarbans. Though, they are secretive in nature, watching one in these forests is not a very uncommon incident. The other two cobras – the Monocled Kobra and Spectacled Kobra are much more common and found in different colour variations. Vipers and Craits are two other groups of common venomous snakes. Attractive non-venomous ones include the Ornamental Flying Snake (*Chrysopelea ornate*, the 'Kalnagini' of Bengali mythology), Bronzebacks, Green Whip Snake and many others.

The King- a king kobra in Gorumara forest
Source: Arjan Basu Roy

A giant estuarine crocodile in Sundarbans creek
Source: Arjan Basu Roy)

Tokey Gecko, now in high demand for traditional medicines in South East Asia
Source: Arjan Basu Roy

The State has three of the four monitor lizard species found in India - the water monitor (*Varanus salvator*) being the largest of them (may reach 20 kgs), and the other two being the Bengal monitor and Yellow monitor. Of the smaller lizards, Tokay gecko (*Gekko gecko*, the 'Takkhak' in Bengali) a common lizard in the villages and forests of West Bengal has recently earned serious concern for sudden increase in the rate of their illegal capture and smuggling for alleged use in quack medicines in China and South-East Asia.

Amphibians

This fauna so far include around 45 species of frogs and toads. The list is certainly expected to be further enriched if more serious explorations for them are taken up. Interesting species include Asian painted frog (*Kaloula pulchra*), Indian balloon frog (*Uperodon globulosus*), Pied warty frog or Bird poop frog (*Theloderma asperum*), Jerdon's bull frog, etc. Several new records of frog species in the State have been made in recent years (Deuty *et al*., 2009). *Minervarya chilapata* is the species of frogs absolutely new to science, recorded from West Bengal in recent times (Ohler *et al*., 2009).

The most famous of amphibians from West Bengal of course, is the Himalayan Salamander or Newt (*Tylototriton verrucosus*), the only representative of the tailed amphibian order called Caudata in India. They are found in the aquatic bodies of Darjiling hills. The Jorpokhri Salamander Wildlife Sanctuary in Darjiling district has been created with the focus of conserving this schedule-I species. Hill people of Tibetan origins in the district worship and protect this newt (they call it - *Gorra*) as a sacred animal. As if to complete the representation of all amphibian orders in the State, *Ichthyophis sikkimensis* - a species of legless Gymnophiona live in the Darjiling hills.

Minervarya chilapata, a frog completely new to science was first spotted in Chilapata forest
Source: Shubhadip Paul

Fishes

High species diversity and rich aquatic resource base of fishes, crustaceans, mollusks are nurtured by the rich fabric of inland waters that include fast flowing rivers and streams in the Himalayan terrains, a rich network of river courses and stagnant water wetlands in the vast flood plains of Ganga-Brahmaputra (Bhattacharyya, 2012). Burman (2007) enlisted 239 species belonging to 147 genera, 49 families and15 orders of freshwater fishes. Some of these species are of course migratory ones entering from estuaries and marine waters into the freshwaters for breeding, etc. (e.g. the famous *Hilsa*). Added to this freshwater fauna is the richness of fishes in the lower

estuarine and coastal waters, the diversity of which are at par with the freshwater fauna.

West Bengal possesses 59 threatened and 42 near threatened freshwater fish species of India (Molur and Walker, 1998 and Menon, 1999, 2004). Moreover, it has been found that this State also contains 7 freshwater fish species endemic to India of which three species are threatened. North Bengal contributes a good share of the fish species richness of the State including several threatened, near threatened and endemic ones. (Burman, 2007)

This rich and diverse aquatic resource base includes also a diversity of prawns and shrimps, crabs and edible mollusks. They have been traditionally the major source of animal proteins and employments and economy as well for millions of inhabitants of the State. At present, this natural resource base appears to be over-exploited and in crisis for existence. The reasons for such decline include destructions of wetlands by land filling, pollutions, insufficient and whimsical rainfall along with changing hydrology affecting breeding and growths of the fishes. Added to that with serious impacts, is the increasing popularity of a commercial pisciculture model that involves mostly induced bred, exotic species of fishes and needs removal of all naturally breeding indigenous fishes from the culture ponds.

Butterflies

Butterflies are not only an important indicator group for assessing the biodiversity status of many ecosystems, they are nature lovers' delights. Growing number of wildlife tourists are now keen to watch and photograph them. They thus, now add value to the ecotourism industry. Many amateur but serious nature lover groups and individuals regularly watch butterflies. They explore the wilderness in various parts of the State for sighting and photographing rare and new species. Nature mates, one of such groups estimates the butterfly species richness of the State to be more than 500, with new records of species being added regularly in recent years. Some of the butterflies found in the State that attract special attentions from the nature lovers and wildlife photographers are- the famous Kaizer-i-Hind, Bhutan Glory, Golden Birdwing, Common Birdwing, Yellow Gorgon, White Tiger, Common Banded Peacock, Krishna Peacock, Constable, Common Map, Common Gem, Painted Jezebel, Purple Sapphire and many more.

Odonates

Like butterflies, Odonates (dragon flies and damselflies) are fast becoming nature lovers'

Common Gem, one of the rich and beautiful butterfly fauna
Source: Arjan Basu Roy

Common Banded Peacock- another winged beauty of the State's fauna
Source: Arjan Basu Roy

and wildlife photographers' beloved target. Ecologically speaking, this amphibious predator insect group is a very important component in the food chains of any ecosystems with freshwater aquatic elements. So far, a total of 227 species are recorded from the State. The figure is expected to be fattened more, given the new records regularly reported by young field researchers and serious amateur Odonate watchers.

Ants

Ants, one of the most important elements of tropical terrestrial ecosystems and indicator of its health, show highest diversity of species and genera in West Bengal among the states of India. So far, 382 of 828 species and 65 out of 100 genera of ants recorded from India have been found from West Bengal (Bharti *et al.*, 2016). Yet, many important forest zones in the State remain underexplored or unexplored, thus, the ant fauna remains to be enriched much more (Sheela, *pers comm.*, 2016).

Floral diversity

Based on the floristic studies by the Botanical Survey of India (BSI), it is revealed that the Angiosperm flora of West Bengal state harbours about 3,580 species under 1,333 genera in 200 families (Chakraverty *et al.*, 1999). Besides, the State supports 21 species of Gymnosperms, 416 species of Pteridophytes, 771 species of Bryophytes, 873 species of Algae, 539 species of Fungi and 329 species of Lichens (Table 7.3 and Figure 7.1). There are about 850 species of medicinal plants identified from the State by BSI and about 1600 species are used by various tribal communities of the State (Chakraverty *et al.*, 1999). These figures are being upgraded further by the BSI (ENVIS Centre on Floral Diversity, updated 29 Aug 2016) with regular additions in different groups of new species and new reports of occurrence of species obtained from further explorations and studies.

Rhododendron flowering in high altitude of eastern Himalayas
Source: Arjan Basu Roy

According to the BSI, natural vegetation of West Bengal can be classified into following 5 distinct phyto-ecololgical zones (Bhattacharyya, 1997) –

- Himalayan zone between 500 to 3800 m above msl in the district of Darjiling
- Sub-montane Terai region and the adjacent plain
- Vast alluvial plains on both side of Bhagirathi and its northern and western tributaries
- The Western dry flanks of Chotonagpur plateau
- Mangrove forests of Sundarbans

The State flora is specially enriched by the unique Himalayan elements. Nearly, 40 per cent of Himalayan flora is endemic of which majority are found in the biodiversity hot spot of the Eastern Himalayas (DoEn, GoWB, 1998) including mountainous parts of North Bengal. The rich diversity and uniqueness of the flora in this region attracted many botanists in the colonial periods to explore the area and write about them, most famous of them being J. D. Hooker, the great botanist friend of Charles Darwin.

The natural flora show distinct altitudinal succession from tropical vegetation of the foothills and lower hills to subtropical forests in the middle altitude and then to the temperate vegetations typical of higher

Eastern Himalayas including sub-alpine characters at the higher altitude above 3000m msl. This mountain flora is uniquely characterised by the abundance and high species richness of ferns, mosses and lichens along with the trees, herbs and shrubs. The famous plants of higher altitudes include several species of *Rhododendron*, *Magnolia campbellii* etc., many coniferous Gymnosperm like *Taxus* sp., *Pinus roxburghii*, *Tsuga brunoniana*, *Abeis pindrow*, *Larix griffithii* and the introduced species *Cryptomaria japonica*. (Bhattacharyya in Flora of WB, BSI, 1997).

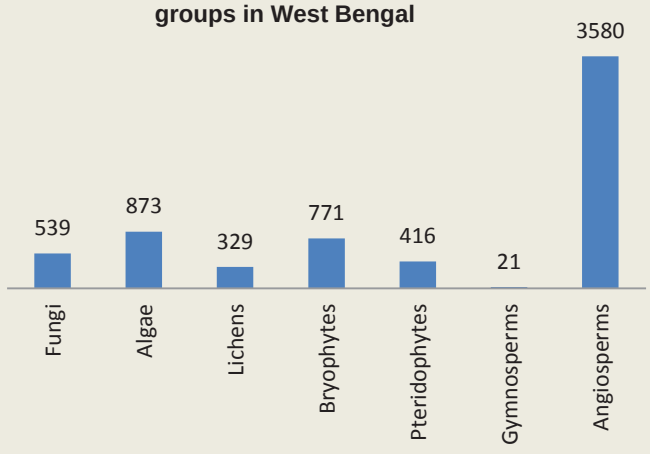
Flora of Terai and Dooars: According to Champion and Seth, 1968, the natural vegetations of Terai and Dooars plains include forest formations of Northern Tropical Wet Evergreen, Northern Sub-tropical Semi-evergreen and North Indian Moist Deciduous types. The prominent species being in these forests are – Sal (*Shorea robusta*), Nageswar (*Mesua ferrea*), Jaam (*Scizigium cumini*), Latore (*Artocarpus chaplasha*), Champ (*Michelia* spp.), Panisaj (*Terminalia myriocarpa*), Gokul (*Canarium* sp.), Sissoo (*Dalbergia sissoo*), Chikrassi (*Chukrasia tabularais*) etc. Big patches of swampy grasslands formed in the moribund course of rivers or on the mudflats in the Dooars plain, are the important habitats for the Rhinos and other wildlife in the region. A great amount of original forest covers in North Bengal of course are lost to the tea gardens and encroachment of human habitats since the colonial period.

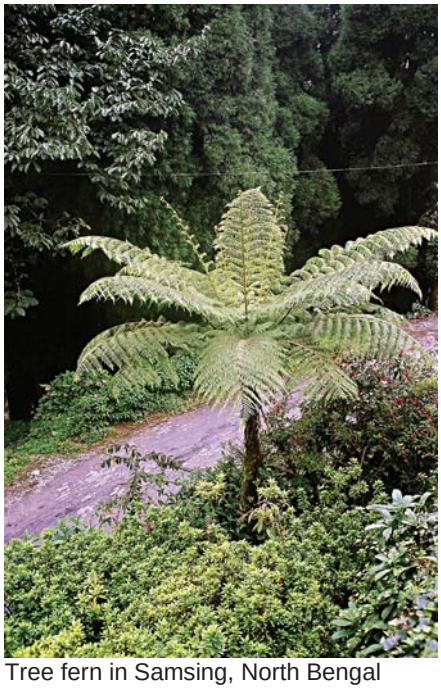
The natural flora in the drier tracts of Paschim Medinipur, Bankura and Puruliya, along with Rahr region in the districts of Birbhum and Barddhaman, are of Northern Tropical Dry Deciduous type forests (according to the classifications of Champion and Seth, 1968) with prominent tree species being Sal, Piasal (*Pterocarpus marsupium*), Kend (*Diospyros melanoxylon*), Mahul or Mohua (*Madhuca latifolia*), Bahera (*Termenalia bellerica*) , Kusum (*Schleichera oleosa*), Asan (*Termenalia tomentosa*), Dhaw (*Anogeissus latifolia*) and Palash (*Butea*

TABLE 7.3 Floral diversity of West Bengal
(in terms of number of Species recorded)
(from Chakraverty *et al.*, 1999)

	West Bengal	India
Fungi	539	14500
Algae	873	6500
Lichens	329	2051
Bryophytes	771	2850
Pteridophytes	416	1200
Gymonosperms	21	64
Angiosperms	3580	17500

FIGURE 7.1 Species richness of floral groups in West Bengal





Tree fern in Samsing, North Bengal
Source: Arjan Basu Roy

Golpata (*Nypa fruticans*), an estuarine palm
Source: Arjan Basu Roy

monosperma). Forest patches except in few parts in this region have been highly degraded and now contain mostly plantations of regenerated Sal from the coppices or monoculture plantations of *Acacia auriculoformis* or *Eucalyptus* sp.

Sundarbans is the largest single patch (including the contiguous part lying in Bangladesh) of estuarine mangrove forests remaining in Asia and it carries highest diversity of plants found in any mangrove community. Along with 35 truly mangrove species, another 28 are found which are considered mangrove associates and 7 more species that are called mangrove obligates (DoEn, WB, 1998). The true mangroves of Sundarbans include famous trees like Sundari (*Heretiera fomes*), Bain (*Avicennia* spp.), Goran (*Ceriops* spp.), Goria (*Kandelia kandel*) etc. and palms like Golpata (*Nypa fruticans*) and Hental (*Phoenix paludosa*). There are of course many other non-halophytic plants grow in the different microhabitats created in the estuarine expanses of Sundarbans.

Medicinal plant diversity

West Bengal has a strong tradition of using herbal medicines by Ayurvedic and other folk medicine practitioners. Much of their medicinal ingredients depend on locally available plants and other organisms. Though, availability and abundance of many medicinal plants are more in forested tracts, even the usual flora in and around a village anywhere in West Bengal harbour many plants that villagers use regularly to treat common ailments according to their traditional knowledge. With the emergence of a fast growing and huge commercial market of herbal medicines, uncontrolled and increasing volume of collections has led to the decline in availability of many medicinal plant species. On the other hand, many species traditionally used in folk medicines remain yet to be scientifically evaluated or even properly documented. Novel genes in such medicinal species if found any, have unbelievably high commercial potentials in the global biotechnology industries. Experts think that this biodiversity resource base could turn out to be the major support in boosting up the economy of a megadiverse country like India. The documentations and legal registration of various medicinal plant usages are required to shield against biopiracy, ensure conservations and for developing entrepreneurships based on sustainable use and justified benefit sharing with the local people. These are now prioritized as a state policy in India under the Biodiversity Act of India, 2002.

As per the assessment of demand and supply of medicinal plants in India published by FRLHT (the well known Bangalore based organization working for revitalization of traditional health systems in different parts of the country) and National Medicinal Plants Boards (NMPB) in 2008, out of 960 traded medicinal plant species 178 species are consumed in volumes exceeding 100 MT per year, with their consolidated consumption accounting for about 80 per cent of the total industrial demand of all medicinal botanicals in the country. FRLHT provides a checklist of 2,800 medicinal plants of West Bengal, while enlisting 5,662 medicinal plants for entire India

(http://envis.frlht.org/checklist/WestBengal.pdf). NMPB under the Ministry of Ayush, GoI, recognized 31 medicinal plants gardens in West Bengal (http://www.nmpb.nic.in/, 2004-05 data).

The West Bengal State Medicinal Plants Board was set up in the year 2004 and is now functioning under the control of the NMPB. To cope up with the demands of reliable planting materials (seedling /sapling/cutting etc.) of medicinal plants throughout the State, it has set up a 2 acres nursery at the State Pharmacopoeial Laboratory & Pharmacy for Indian Medicines, Kalyani, Nadia. They are now able to propagate and sale seedlings/cutting etc. of about 34 important medicinal plants species in large quantities.

Under a UNDP project (UNDP-CCF-II, Project No. 13047) coordinated by FRLHT, the State Forest Department undertook execution of

(a) Rapid Threat Assessment (RTA)
(b) Establishment of Medicinal Plants Conservation Area (MPCA).

Accordingly, seven MPCAs were selected across the length and breadth of the State forests spreading over a total of 1,560 ha. Of these three viz. North Sevoke, Sursuti and North Rajabhatkhawa are in North Bengal Plains (Dooars & Terai area), two viz. Dhotrey and Tonglu in Darjiling hills and two viz. Bonnie camp in Sundarbans and Garpanchakot in Puruliya, are in South Bengal. The third component of the project, promoting Home Herbal Garden was handed over to an NGO (Tagore Society for Rural Development). There are certainly many other efforts towards documentation and conservation of medicinal plants in the State like the ones by Narendrapur Ramakrishna Mission Ashram and various NGOs.

There are also many other plants which are documented being in demands both traditionally and in commercial markets as source of aromatic substances, decorative elements and for crafting mats, baskets etc.

Wild Chirata (*Swertia chirata*) - a highly valued medicinal herb
Source: Arjan Basu Roy

Aristolochia griffithii, a herb of high conservation value for its medicinal properties and being host plants for many important butterflies
Source: Arjan Basu Roy

Microbial diversity

Microbes including bacteria certainly remain the least explored groups yet. What microbiologists have so far identified is a miniscule part of the rich and unique microbial diversity expected to be present in an ecologically diverse state like West Bengal. Scientists all over the world are desperately searching for microbes that might carry unique genes to be used in

pest controls, pollutants cleansing, medical purposes and many other human welfares (and allegedly for biological warfares too). Apart from the human welfare dimension, the major interest behind the huge investments in biotechnology industries that are happening now for finding out such genes from microbes is of course, the enormous commerce potentials of them.

Sanyal *et al.* (2012) mentioned only 85 bacteria in the State flora, which is a ridiculously low figure. This may be due to unavailability of a common inventory of bacterial species documented in the State. Also, the explorations for microbes in the diverse ecosystems of the State have been far from being sufficient, if not, insignificant.

In recent years, there are emerging efforts in using latest molecular sequencing techniques and metagenomics to find out useful microbial communities from various ecosystems in West Bengal. For example, an IISER-Kolkata group reports presence of arsenic oxidizing bacterial genera like *Acidovorax*, *Hydrogenophaga*, *Albidiferax*, *Bosea*, and *Polymorphum*, from the ground aquifers of arsenic affected areas of Nadia district (Ghosh *et al.*, 2014). Another group from the University of Calcutta, in a study of samples from various depths of soil in the mangroves of Sundarbans, reports 2,746 species of bacteria belonged to 33 different phyla revealing the dominance of Proteobacteria, Firmicutes, Chloroflexi, Bacteroidetes, Acidobacteria, Nitrospirae and Actinobacteria respectively (Basak *et al.*, 2015). On the other hand, researchers from the Jadavpur University used microbial culture techniques to isolate several strains of bacteria from the soils of Sukhna forests in North Bengal that showed various enzyme activities like amylase, cellulase, pectinase and protease (Chopra, 2014). Several other research teams are now busy in such bio-prospecting for useful bacteria and bacterial communities in different high stress environments, for example, the sewage disposal sites in the East Kolkata Wetlands (EKW). Efforts are also there to find out microbes capable of producing nano particles of gold, silver etc. using the latest nanotechnology for the medical and other industrial usages.

Domesticated biodiversity: Indigenous stocks

Wild biodiversity are products of natural selection and other natural evolutionary forces. Domesticated biodiversity is the purposeful modifications of it by humans through artificial selection, i.e. selective breeding. People have been creating new varieties of crops and livestock with many desirable characters since the discovery of domestication and cultivation some 8-10 thousand years ago. These human created biodiversity are now an important subset of the total biodiversity resources on earth for the human race. The genes for various desirable characters (e.g. adaptations to stressful local conditions like drought, flood, high salinity, traits like disease resistance, special qualities like aromatic produces, etc.) that are carried by these artificially selected varieties are most valuable genetic resources for creating further new modern varieties of crops and livestock. With the availability of ever-improving genetic engineering techniques, these genetic resources are now considered precious commercial resource base of a nation.

Specialists have also acknowledged the key role of such folk crop varieties or landraces in sustainable agriculture, and called for the conservation of the germplasms of these crops along with the traditional knowledge associated with them. The 1992 Earth Summit in Brazil took special note of the rapid disappearance of a multitude of folk crop varieties all over the globe. The Agenda 21 called for establishing in situ conservation of crop genetic resources in farmers' fields, and local ex situ conservation in farm communities, for the development of sustainable agriculture (UNCED 1993).

With the green revolution for achieving a big jump in farm productivities, high yielding varieties (HYVs) were promoted since early eighties at the costs of folk varieties of rice and other crops. But, the introduced HYVs are highly depended on increasing inputs of synthetic chemicals as fertilizers and for pest and disease controls over the years. As a result, the spreads of HYVs cultivation have been responsible for pollutions of soils and waters and alleged for killing the scores of natural biodiversity associated with the traditional crop fields including the soil microbes and the organisms like earthworms that are responsible for natural soil fertility. And, these harmful chemicals, most of them being least bio-degradable, are biomagnified through the food chains to affect the entire biodiversity of the crop fields and surrounding ecosystems, ultimately causing many types of serious health hazards to humans. This is while the productivity of HYVs started dropping after a decade of golden harvests despite increasing inputs.

But, the most important crisis HYVs have created is the loss of most of indigenous or folk varieties of crops from the repositories of our farmers. Being discouraged from cultivating locally adaptive folk varieties for lesser productivity and encouraged to adopt HYVs, most of the farmers destroyed the seeds of the traditional varieties which they for generations had kept sowing, preserving, exchanging for free with their neighbours according to their needs. With them, lost is a big chunk of the unique man-made biodiversity and associated traditional knowledge. Those varieties very likely, had genes for surviving against droughts, floods and other environmental stresses, to win over diseases and pest attacks and for many other qualities much superior to the present HYVs. We lost them forever. Some of the crops that traditionally West Bengal has been rich in diversity are discussed below.

Rice

West Bengal is an important part of the south-east region that is considered as the Vavilov Centre of origin (the geographical location on earth where a crop or a livestock was domesticated) of rice (*Oryza sativa*). Expectedly, the diversity of indigenously evolved unique cultivars of rice and its wild relatives available in the State had been quite high. Older literature, for example, Hunter (1857) noted specifically the richness of folk varieties cultivated and presence of wild and semi-wild varieties of rice growing in different districts of erstwhile Bengal province. One of the wild varieties, *Oryza croacta*, ('dhani ghas' in bengali) still grow abundantly on the intertidal mudflats in Sundarbans. Recent surveys at village levels by the present author indicate a luxury of choice existed for a farmer to cultivate varieties of rice each year from his own stock of 20-30 indigenous cultivar seeds, according to their flavours, tastes and other qualities, even thirty years ago.

According to Dr. Debal Deb, a well known activist working for *in situ* conservation of folk varieties of rice in Eastern India, West Bengal had nearly 4200 folk varieties under cultivation prior to the

Kalonunia, a unique indigenous rice variety still cultivated in some areas of the State
Source: WBBB

Green Revolution (Paul, 2012). The State Rice Research Station, Chunchura had recorded in the 1970s about 5556 rice varieties of which about 3500 varieties were sent to International Rice Research Institute (IRRI) of the Philippines during the period from 1975 to 1983 (Guevarra 2000 in Deb, 2005). Incidentally, most of the HYVs are created at IRRI, and many of the special genes that are incorporated in the HYVs were obtained from the folk varieties from India including West Bengal (Gadgil and Rao, 1998).

Dr. Deb with his colleagues started their works in Bankura in 1997 on collection, characterization and *in situ* conservation of folk rice varieties through local farmers' participations. They maintain more than 750 folk rice varieties. This is the largest non-governmental seed exchange bank in Eastern India. Among the State run initiatives, Agricultural Training Centre, Fulia, Nadia in its Biodiversity Conservation Farm is maintaining (207 varieties) and distributing folk rice varieties among farmers. The Rice Research Station of Chuchura, Hugli, also maintains several folk rice varieties. These apart, many individuals and civil societies are also sincerely engaged now with in situ conservation of folk rice varieties in order to ensure future food security (Paul, 2012).

All these efforts face strong obstacles from the short term appeals of HYVs and long term negative impacts made already by HYVs on farm soils and environment (e.g. soils over loaded with chemical fertilizers, increasing resistance by pests and diseases, vanishing of friendly fauna like earthworms, predators and parasites of pests due to rampant use of chemical pesticides etc.). Also, farmers are strategically misguided by the dealers and advertisements of multinational corporate that sell those farm chemicals leading to overuse or misuse of them. The agricultural policies of the states so far lack in strategies to counter that.

With the recent urge for introducing genetically manipulated crop seeds, patented and marketed by northern multinational corporations, farmers' options and capabilities are likely to become further restricted in terms of crop variety selection and farm management decisions. Many experts are anxious that new Indian laws like Plant Varieties Protection Act (2004), the Patent Ordinance (2004), and the Seed Bill (2004) would rather help the vested interests of transnational seed companies by abolishing farmers' rights to save, cultivate and exchange their seeds and the farmer's autonomy altogether (Deb, 2005).

Mango

More than 150 varieties of mangoes are found in West Bengal. Some of the commercially well known varieties of Mango from the State are Fazli, Gulabkhas, Himasagar, Kishenbhog, Langra and Bombey Green. Kishenbhog is indigenous to West Bengal. Golapkhas and Himsagar are also considered Bengal's pride mango. Maldah, Murshidabad are two districts most famous for producing many of these mango varieties at commercial scale. There are also 5-6 other commercial varieties of mango produced by hybridization between indigenous varieties that are now widely cultivated in the State. There have been of course, many locally cultivated or semi-wild varieties of mango found in other parts of the State which are well known for their tastes and flavour but they usually do not reach beyond the local markets. Like the folk varieties of other crops, they too are quickly vanishing.

Tea

Tea grown in the specific tea gardens at the slopes of Darjiling hills are known as Darjiling tea which has earned the fame and an elite status in the world for its unique delicate flavor and taste. Strangely enough, the clones of the same tea plants grown elsewhere, even at the foothills of the district, fail to yield the same quality. It's the complex of climatic and edaphic factors

of the original localities that are suspected for such peculiarity. Due to its unique appeal, Darjiling tea has been in high demand in the national and international market. Tea produced from other localities in other states of India and in other countries, used to be labelled as Darjiling tea to sneak into this elite market. To protect it from such spurious products in the market the Darjiling tea has been assigned a GI (Geographical Indication) tag in 2004-05 through the Indian Patent Office. It is actually the first Indian product to receive a GI tag. Thus, teas grown or manufactured anywhere else now cannot be called Darjiling tea. Indian Tea Board has certified only 78 gardens in the district as producer of actual Darjiling tea. The other tea varieties cultivated in numerous gardens dotted along the foothills and adjacent plain between the river Mechi in the West and river Sankosh in the east are classified with the Assam tea by characters, though, they do have some subtle uniqueness in taste and flavour.

Other vegetables

The fertile alluvial soil of the riverine plains of the State has been famous for high production of many species of other crops including vegetables and pulses. Traditionally, many of these vegetables and pulses cultivated in various parts of the State include many indigenous local varieties with distinct unique qualities. Many cultivated vegetables also have their wild relatives found to grow in the same localities.

Livestocks

The most famous of the indigenous breed of livestock is the Bengal Goat. Though small in size, its prolific breeding capacity, adaptability to thrive in tropical humid weather without much care, the good taste of its (of the buck) meat and highly quality of its skin, made it famous even beyond the boundary of Bengal since the colonial time or even before. Alfred Wallace, the famous naturalist and collaborator of Darwin's theory of natural selection, once met a local king in a small island kingdom of Borneo during his expeditions to the Indonesian Archipelago in (1855) and asked his highness's permission and helps to do field works inside the jungles within his jurisdiction. The king agreed happily but on condition that Wallace would present him along with few other trivial things `goat from Bengal'!

The other indigenous variety of livestock that the State can be proud of is the Garol sheep, now reared only in Sundarbans' villages. The breed was known to be taken to Australia to incorporate its gene for prolific breeding capacity to famous Australian Marino and then to many other varieties all over the world. The other two distinct local stocks are Chotonagpuri and Bonpala. The former are found in the dry western districts and the latter in the humid forested tracts of Dooars and adjoining river plains. The Siri breed of cattle is adapted to the severe cold and rain of Darjiling district. A small population of Yak (*Poephagus grunniens*), the cattle adapted to the extreme cold and low-oxygen environment of high altitude have been found in some parts of this district. An

Garole sheep, a unique indigenous variety registered from the State
Source: Rudra Roy Choudhury

indigenous variety of domesticated pig, called Ghoongroo pig with distinct quality of breeding and adaptation to the tropical climate has been identified in the eastern sub-Himalayan region of the State. Aseel, a majestic indigenous breed of fowl are found in the tribal dominated areas of South West Bengal. Traditionally the breed is reared for meat and tribal- sport of cock-fighting. The other indigenous breed, the Haringhata Black fowl is highly regarded for backyard rearing, disease resistance capacity and as good egg layer. Apart from them, West Bengal has many other breeds and varieties of livestock that need proper characterization. (Directorate of Animal Resources & Animal Health, GoWB)

Decline in the biodiversity of the State

The decline of populations and local extinctions of many species is a global phenomenon that worries the scientists, experts and aware citizens all over the world. This part of the goal is no exceptions to it. During the colonial regime, indiscriminate hunting by royalties and British officers of large mammals, crocodiles for trophies and game birds along with destructions of wild habitats led to the serious decline of the populations of many of species and complete wiping out of many others from the State. This elite practice continued even after the independence though at a slower rate till the enactment of the Indian Wildlife (Protection) Act in 1972. While charismatic wild big vertebrates, for e.g. tiger, elephants, gaur, rhinos, deer, and crocodiles etc. – the erstwhile trophy species got special attentions for protections in the initial phase, others remained mostly neglected. With the emergence of the concept of biodiversity and increasing awareness on the role of all biological organisms in maintaining an ecosystem, conservation scientists started drawing attentions of wildlife managers towards all biodiversity and ecosystems as a whole. Despite some improvements, the activities with new biodiversity approach are far from being sufficient. For example, other than few groups like birds which are well studied regularly mostly by amateur but sincere naturalists, the status of most groups of organisms especially, the smaller ones including invertebrates still could not be ascertained.

On the other side, documentations of species diversity in most of the groups barring a few prominent ones like mammals, birds and reptiles remain significantly incomplete. With the surge in numbers of the nature lovers exploring different corners of the State, easy digital photography and wide network of social media, new species in a few groups like birds, frogs, butterflies, odonates are now recorded which were not recorded before from the State. This is of course beside the professional efforts by the scientists in ZSI and other institutes. Unfortunately, the efforts are far from being enough to fill the gaps left in the biodiversity documentations of the State. And, who knows, how many species in different groups have reached near extinction or gone extinct from the State even before being documented. Of course, this is a general picture with variations in the magnitude across the states in India and elsewhere.

Local extinctions and threatened species

Unfortunately, the State has lost several important wild mammals like Javan Rhinos (*Rhinoceros sandaicus*) and Sumatran Rhinos (*Dicerorhinus sumatrensis*), Wild Buffalo (*Bubalus bubalis*), Nilgai (*Boselaphus tragocamelus*), Barasinga or Swamp Deer (*Cervus duvauceli*), Musk Deer (*Moschus moschiferus*), Snow leopard (*Uncia uncia*), Indian Pilot Whale (*Globicephala macrorhyncus*), Black Finless Porpoise (*Neophocaena phocaenoides*). Among birds, most prominent losses are of Greater Adjutant stork, Monal Pheasants, Mountain

Quail, Pink-headed duck. Birders are yet to document Masked Finfoot, the elusive water bird of mangroves in our part of Sundarbans. Four species of vultures, once very common in West Bengal, now globally threatened. Only, a few small populations of White Rumped Vulture thrive in different parts of the State. Bengal Florican which had the last good population in the grasslands of Jaldapara Wild Life Sanctuary, are feared to be extinct now. Marsh Crocodiles and Gharials which were quite abundant in the riverine tracts of the State were thought to be extinct from the State. Though, in very recent years a small population of Gharial has been documented from the course of Bhagirathi.

The State now provides shelter to several species of mammals, birds, reptiles and few other groups which have been declared threatened globally by IUCN and are included in the Schedules of Indian WPA according to their local population trends and vulnerability to poaching for illegal trades as per the CITES.

There are 37 rare and threatened taxa of plants in the State (Chakraverty *et al.*, 1999) and another 19 taxa described from West Bengal, which are not collected after type collections, thus, their status in the State being unknown (Sanjappa & al., 2012).

Habitat degradations, habitat loss, conversions

Globally, habitat loss is considered the single most important factor responsible for decline in biodiversity. The greatest loss of wild habitats in the State took place during the colonial regime when the British administration started reclaiming huge tracts of mangroves in Sundarbans to settle agricultural populations there. Similar ways, in North Bengal the virgin forest covers in the plains, foothills and also in the higher slopes of Darjiling were cleared for tea gardens. Sal dominated natural mixed forest of south West Bengal were felled for supplying railway sleepers and then converted to monoculture of Sal in large scale. Added to these habitat destructions was the indiscriminate hunting of game animals by local and British elites that led to some conspicuous extinction events in the State like Sumatran and Javan Rhinos, Water Buffaloes.

Encroachments of human settlements to forest patches continued, though not in that large scale any more, due to increasing populations, refugee influx etc. The rate of large scale destructions started slowing down significantly only since late 1970s, with the establishments of sanctuaries, national parks and other wildlife reserves to bring more and more forest areas under protections. But, it is yet to stop completely. Illegal felling of timber trees, especially from lesser protected patches are a regular phenomenon. Poaching of Rhinos for horns and of Elephants for tusks are reported almost each year. Insufficient vigilance due to lack of sufficient ground staff of the forest department, lack of coordination between the forest department, police and army often fail to resist or catch the culprits who are connected to and supported by a criminal nexus with international connections. Conservationists are worried as some important forest patches in North Bengal are on the way to leave space to developmental projects. Encroachments and forest degradations are also taking place due to the problems relating to the socio-economic crisis in tea gardens. The wetlands all over the State, especially in the urbanized localities are fast vanishing along with its biodiversity to real estate projects despite legal restrictions and protests from civic societies.

Spread of HYV cultivations is definitely one of the major causes of destructions of wild biodiversity including birds, fishes and scores of invertebrate species. Toxic chemicals used for controlling pests and diseases of the crops in HYV cultivations also kill indiscriminately natural pollinators, predators and parasites of the pests. Significant decline in the populations of

Overharvesting is a major problem for wild Hilsa populations
Source: Arjan Basu Roy

many natural pollinators of crops affecting the crop productions - are complained by the farmers from many localities of the State where pesticides are used heavily. Pesticide pollutants are affecting aquatic habitats and its biodiversity in entire West Bengal. Low lying paddy fields in connection with network of wetlands are traditional breeding grounds for most of the fishes and many other wild aquatic species. The increasing toxic chemicals poured in the paddy fields in the flood plains and wash offs from there is alleged to be a major reason for the serious decline in the diversity and natural productivity of freshwater fishes in the region. Wash offs from tea gardens carrying remnants of toxic pesticides pollute the streams and rivers in the hills of North Bengal. Mass scale deaths of fishes and other aquatic organisms in the streams and rivers of the Dooars are often reported.

Losing wetlands in large scale due to land filling by real estates and few other developmental projects, is the most serious concern for the fishes and other aquatic biodiversity in the State. Also, the changing hydrology is to be equally blamed for the present dismal picture of aquatic biodiversity in the State. Reducing flow of waters through the Bhagirathi despite intervention at Farakka is a serious concern for the life based on the river system down streams. Indiscriminately erected dams on the flows of other rivers and channels restrict natural flooding of wetlands, filling of wetlands etc. Along with the weak and/or whimsical monsoon in recent decades, they are affecting the freshwater aquatic biodiversity of the State seriously. Same things happen in the Sundarbans - one of the major fish producing areas in the State. The unplanned constructions of embankments for reclamations that reduce the natural spill over areas for the tide waters, seriously affect breeding and growth of many estuarine fishes, prawns and crabs. With the lowering productivity and increasing demands for fish resources, overharvesting is inevitable and that's happening now. The best indicator of such habitat loss and degradations is the *Hilsa*, the quintessential fish of Bengal. Once, *Hilsa*, the most adorable item in any Bengali kitchen, used to be purchased from market if the fish was above a kilogram and it was readily available. Now it is rare to find a *Hilsa* of that size in the Bhagirathi or its tributaries.

The other factor which is affecting seriously the freshwater biodiversity in the plains of West Bengal, is the widespread practice of intensive aquaculture of a few selective commercial species, most of them being exotic. In this culture process, a pond is cleaned and maintained with artificial food inputs. Any naturally occurring populations of indigenous species of fishes, crustaceans, mollusks and other invertebrates along with natural hydrophytes are not allowed to exist there in the process.

Invasive species

Invasive alien species (IAS) are those who invade into a new region or ecosystems where they were never found before naturally. They are considered as serious threats to indigenous biodiversity across the globe by the CBD. They also often impose

enormous costs on agriculture, forestry, fisheries, and other human enterprises, as well as on human health. Though, many non-indigenous species of crops and live stocks have been adopted in all countries with success to add up to the welfare of the people, they are usually the domesticated ones. The problems are usually with the wild varieties of IAS which are often found to aggressively outcompete many local species in absence of any efficient local predators.

There are many IAS recognized now as serious threats to India's biodiversity including that of West Bengal. For example - water hyacinths. This aquatic plant is one of the most prominent invasive alien species that pose enormous problems for the freshwater bodies in the entire flood plains of West Bengal, as they do the same elsewhere in India (in fact, all over the tropics). They aggressively grow to cover water surfaces, outcompete local hydrophytes, chock the water flows, change the water quality so that many natural species of aquatic animals including fishes could not survive. Lantana camara, an IAS from the new world has encroached heavily the shrub layers of the forests, hedges and bushes around agricultural fields, replacing the natural shrubs. While the indigenous flora suffers losses, wild and domestic herbivores suffer from food crisis as its leaves or fruits are inedible to most. Mikania micrantha, a creeper allegedly introduced in West Bengal in the early 20th century to cover airstrips during World War II is now considered a notorious IAS. It grows at unbelievable speed to cover up the swampy grasslands and forest floors to deprive the wild grazers from food species in the forests of North Bengal.

Many freshwater exotic fishes were brought in for boosting up productivity in pisciculture in the State are turning out to be IAS threatening the rich indigenous fish diversity and various wetland ecosystems. These include various exotic carps like Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmichthys molitrix*), Common carp (*Cyprinus carpio*) who are better competitors over our indigenous carps like Catla (*Catla catla*), Mrigel (*Cirrhinus mrigala*), and Raikhoira or Taitkani (*C. reba*). There are rapidly growing exotic fishes like Sutchi catfish (*Pangasious sutchi*), North African Catfish (*Clarius gariepinus*), and Rupchanda (*Colossoma* sp., this is originally a South American species, a cousin of piranha, but not a piranha) whose seeds are alleged to be illegally smuggled from Bangladesh. They are now cultured at commercial scale in the ponds of two 24 Parganas and fast spreading into other districts. The African catfish (locally known as 'hybrid Magur') is an inveterate carnivore, aggressive competitor and reported to grow upto 60 kgs! The negative impacts of them on our indigenous fish fauna are easily predictable. All these alien species are invading into natural water bodies of the State including the riverine tracts and trying to establish as natural populations at the cost of indigenous species in those habitats. Then, there are the prolific breeding, ever-adapting, omnivorous invaders - Tilapia (*Tilapia mossambicus* and *T. nilotica*) who have already invaded into most of our natural water bodies. Bhakta *et al.* (2007) reported significant presence of eight of the above exotic species in the river Churni which flows through the district of Nadia into the river Bhagirathi. There are also

Rupchanda - An invasive giant from Amazon in our waters - Red Pacu (*Colosomma* sp.)
Source: Santi De

frequent reports obtained in media about catches of exotic aquaria species from natural water bodies.

There may be a biodiversity disaster under incubation due to these IAS, as, the history of IAS in many other countries give such an indication.

West Bengal Biodiversity Board: Activities, laws and acts, PBR

The West Bengal Biodiversity Board (WBBB) was established in 2004 in compliance with the Biodiversity Act, 2002, as a statutory body under the Department of Environment, Government of West Bengal. The WBBB functions towards ensuring proper implementation of the Biological Diversity Act, 2002 in the State. The West Bengal Biodiversity Rules, 2005 were formed With effect from 27th January, 2006 in exercise of the power conferred by section 63 of Indian Biological Diversity Act, 2002. It confers legal purview to restrictions on usage of biological resources of the State by Indian citizens. As such, `an application fee in the prescribed form for access to the West Bengal Biodiversity Board has been made mandatory for Indian citizens seeking to use any biological resources occurring in the State or knowledge associated thereto, for purposes of commercial utilization or bio-survey and bio-utilization.' The Biological Diversity Act envisages a three tier system for implementing the same with National Biodiversity Authority at the apex with its headquarters located in Chennai, each state with its individual State Biodiversity Board and each local body with a Biodiversity Management Committee (BMC). (http://wbbb.gov.in)

For the local level management of biodiversity, the WBBB facilitates formation BMC at the Block or Panchyat Samity level in rural areas, Municipality and Corporation level in urban areas. A BMC becomes a statutory body linked to the local government i.e. the Block level Panchayet Samity. As on April, 2016, 195 BMCs have been formed in different local bodies of all districts in the State including one at the Bidhan Nagar Municipal Corporation.

One of the major assignments of any State Biodiversity Board under the above Act and laws is to document the occurrence of local wild and cultivated diversity including medicinal plants along with all traditional knowledge associated with them in the form of a register called People's Biodiversity Register (PBR). The PBR is an official document which is to ensure local people's rights and possession over the local biodiversity resources and related knowledge. Besides, it documents the availability and population status of a species of wild plants, animals and local folk varieties of crops or livestock. A PBR is prepared usually at Gram Panchayet level by a BMC involving a team of local experts and organizers to survey and interact with people from all strata of society in the villages. So far, WBBB has succeeded in preparation of more than 100 PBRs in different regions of West Bengal. These PBRs are expected to help in assessing the status of different species and varieties, be the source of information for commercial entrepreneurships based on sustainable use of local biodiversity and/or traditional knowledge, and of course, to safeguard the ownership of local people over the bio-resources and traditional knowledge against biopiracy and ensuring justified benefit sharing.

The WBBB also recognizes and support the traditional culture of common people in conserving wild biodiversity including many smaller wildlife species living in and around the village habitats outside the State protected areas for wildlife (Chatterjee *et al.*, 2014). One of these efforts is to document and conserve traditional sacred groves in different parts of the State. The WBBB is also engaged in awareness building and supporting initiatives to document and conserve local biodiversity. One of the remarkable efforts by the Board in this

connection is the publication of a series of illustrated pocket book field guides for kids and non-technical persons to easily identify groups of wild plants and animals around their localities. Another successful endeavour of WBBB is implementation of the most unique element of the Biodiversity Act, 2002 i.e. the mechanism of the Access and Benefit Sharing (ABS) through signing of Agreement with the commercial users of bioresources in the State.

Conservations of wildlife and wild habitats

The Wildlife Wing of the West Bengal Forest Department (WBFD) is the official custodian for protecting the wild species and their habitats from decline and decimation. The State at present possesses 15 wildlife sanctuaries and 6 national parks scattered all over the State representing almost all kinds of forest types and wild habitats. The first tiger reserve in the country was established in Sundarbans. It is to conserve the gene pool of unique mangrove adapted tigers along with other wildlife and estuarine mangrove biodiversity (sharing with Bangladesh of course). Later, the Sundarban Biosphere Reserve was declared including all remaining and reclaimed areas of Sundarbans. Buxa Tiger Reserve is the second one in West Bengal which was created to preserve the northern gene pool of tigers in the State. Though, at present, presence of tigers there is a hotly debated topic in the circle of conservationists. On the other hand, Mahananda Wild Life Sanctuary, Jaldapara Wild Life Sanctuary along with some other parts on the foothills appear to have a small but thriving population of tigers. Leopard, still are found in every forests of North Bengal except in very high altitude areas, though their population has declined in most parts.

Jaldapara National Park, Gorumara National Park along with the adjacent Chapramari Wild Life Sanctuary, are the last abode of Great Indian One-horned Rhinos in the State where they are doing fairly well along with Gaurs and other wildlife. Elephants in North Bengal have definitely increased in numbers over last few years. While the State Forest Department can definitely claim credits for this, low density of large predators like tiger which are supposed to keep a check on growth of these big herbivores might be a significant factor.

An area of 414.06 sq km covering the forested tracts in the districts of Bankura, Puruliya and Paschim Medinipur has been declared as the Mayurjharna Elephant Reserve that would contiguous with the elephant reserves in adjacent Singbhum (Jharkhand) and Mayurbhanj (Odisha). To extend the area of Tiger Reserve in Sundarban, a new sanctuary has been notified in parts of South 24 Parganas having enough mangroves and regular tiger movement in it.

The wildlife wing is now trying also to extend its conservation efforts beyond charismatic mega vertebrates and supporting conservations of smaller but important wildlife, for example butterflies and their host plants.

The State Forest Department has to spend every year a huge budget for chasing back straying animals especially elephants, and for paying compensation to local people for loss of life, properties or injuries. Tranquilising operations are taken up regularly for managing the straying animals or treatment of sick ones. Several rescue centres are maintained for rearing and treating rescued infants, injured or old animals all over the State. The Crocodile Project at Bhagabatpur in Sundarbans rear endangered salt water crocodiles from eggs and release hatchlings in the different parts of the national park. Similarly, the captive breeding and release of endangered river terrapin *Batagur baska* are also done from here. An effort to breed endangered species of vultures has been initiated at

Rajabhatkhawa in Buxa, but its success is yet to be assessed.

Taking actions against illegal poaching, seizing smuggled wildlife and wildlife products and ensuing legal battles to punish the offenders remain as major tasks of the wildlife wing of the State Forest Department. In comparison to many other states, this State seems to be performing somewhat better in wildlife protections, though, far from being at sufficient level. Lack of man-power and other resources especially, at the field levels, stand as major obstacles before a much better performance.

Research: The WBFD assign research projects time to time to specialised Institutes and University departments to augment its information base required for better management, but it is far from being, sufficient. Especially more survey based studies are required to document the present status of different endangered and indicator groups of wild biodiversity and wild habitats.

People's participations: For conserving forests and wild biodiversity, the WBFD now promotes local people's participations seriously. The Joint Forest Management (JFM) system initiated in this State is now a model for the entire country and beyond. Forest Protection Committees (FPC) are formed with local people as joint stakeholders to share the responsibilities of protecting the forests and revenue earned from it. Similarly, Eco Development Committees (EDC) are formed and functioning in the Wild Life Sanctuaries and National Park areas where FPC could not be allowed to function for legal reasons. Apart from these, the wildlife squads created all over the State to rescue wild animals, chasing the straying animals back into forests. These squads remain extremely busy in north and south Bengal mostly to chase away crop depredating elephants from villages to forests. They need local people to form and act as chasing groups, popularly called *Hula* party with crackers and fire torches working under the guidance local wildlife squad.

There are a few NGOs and many individuals in the State sincerely involved in supporting conservation activities. They help in biodiversity documentations and also serve as watchdogs for spotting misdeeds and violations relating to the conservation of biodiversity. If, such civil society component becomes stronger and more sincere, cumulatively, the conservation efforts for wild biodiversity in the State will be stronger too.

Man-wildlife conflict

One of the major problems in conserving biodiversity is the conflict of interests between conservator agencies and local people living close to protected areas like National Parks and Wild Life Sanctuaries. The most acute being the conflicts between them and big wildlife like elephants, tigers, leopards and gaur that stray from forests into neighbouring human habitats in search of easy foods and other reasons.

Especially for the elephants, the loss of the natural habitats including their traditional movement routes through forest corridors between fragmented forest patches have become a serious management problem for the State Forest Department in recent decades. This is due to increasing incidents of man-elephant conflicts resulting in deaths, injuries and loss of properties in the forest-fringe localities, thus, antagonising local people against wildlife. Elephants are also getting harmed or even killed sometimes in retaliations. Worst in recent years for North Bengal elephants has come out in the form of a railway tract through the Dooars forests that has been converted to broad-gauge regular train traffics from a scantily used narrow-gauge one. It cuts across many traditional regular routes of elephant movements along the north-south axis. Elephants are dying regularly in collision with the engines of fast moving trains. Despite requests for driving with

specified precautions from the WBFD to the concerned Railway departments including high level meetings, situation seems to be not improving.

Elephants in south West Bengal appear to be the biggest and permanent headache for the State Forest Department and of course, the local people. A few vagabond groups of elephants, known as Dalma elephants in reference to their erstwhile permanent residence, move all around in South West Bengal surviving mostly on crop fields for foods and any plantations or natural patch of forests nearby for rests. Local wildlife squads and the *hula* parties (groups of local volunteers trained to chase elephants) in this region remain busy throughout the year in chasing elephants from one place to other. Worryingly this population is growing fast. Success of the WBFD against poaching has become curse in disguise as country's law prohibits culling as a measure for conservation.

In fact, the increasing populations of Rhino and Gaur within the restricted sizes of available habitats for them in North Bengal appear to be a serious concern. Especially, recent data (WLW, WBFD, Annual Report, 2014-15) in comparison to a previous study (Bhattacharyya, 1994, WWF-ER) show that straying incidents of Gaurs have increased significantly. Destructions of scrub forests in and around tea gardens are leading to regular leopard depredations inside the labour settlements of the tea garden and adjoining localities.

Tiger straying into the forest-fringe villages of Sundarbans has been a perennial problem since the reclamation of mangroves for human settlements. Conflicts often resulted in the deaths of tiger in retaliations of lost cattle or rarely, a human life. The problems seem to be somewhat better managed now by the tiger reserve management of the WBFD by encircling the village facing fringes of the jungle with strong nets to prevent tigers moving out. The continuous efforts of awareness building among the local people by NGOs and of course, emerging employment opportunities with the increasing ecotourism in the region are also important factors in such conflict resolutions. Incidents of tiger attacks on people going inside the forests for fishing and honey/wood collections are still quite common. The department has recently increased the compensations for those who die or get seriously injured while entering with legal permissions within the specified areas of the mangroves. Also, efforts are made continuously to provide them with alternative incomes. But, it is far from being fully resolved.

The other dimension of man-wildlife conflicts has been relating to the local human population being denied entry into their traditional foraging habitats because of legal restrictions once those areas are declared as sanctuaries, national parks and other protected areas. Thus, these people are denied access to their traditional bio-resource base for collecting firewood, fodder and other biomass for mere living. Such conflicts had serious socio-economic and political consequences which are now attempted to be resolved by JFM model where people are allowed to gather firewood etc. for subsistence and get a share of revenue earned from timber and other produce, if possible. With the declining populations of wild animals are mostly due to large scale habitat degradations and erstwhile, elite hunting practices, worrying wildlife lovers and watchdogs now protest strongly against any hunting by tribals for traditional source of meats and/or rituals, often leading to the harassment and some legal measures against the hunters. Such conflict also antagonizes the tribals against State's wildlife conservation efforts who are hardly made aware of the laws and offered alternatives to their traditions.

Biodiversity markets

Biodiversity has been and still now, is the major natural resource base for people to

subsist on in a biomass based civilization like India (Gadgil, 1992). Now, it is turning out also to be the most potential resource base for developing enterprises of great commercial potentials in a megadiversity country like India. Biodiversity of West Bengal definitely has high potentials to be used commercially as well as sustainably for solving the acute problems of unemployment and boosting up socio-economic growth in the State. It can be achieved through involvement of local stakeholders. Deriving regular economic benefits from the biodiversity resource bases are the best motivation for people to participate in the conservation of local biodiversity and commercial enterprise, if any, developed based on them.

For example, while traditional medicine based industries are flourishing fast all over the globe, encouraging the local people to conserve and/or cultivate wild medicinal species and feed the market demand would ensure economic benefits to them along with conservation and sustainable use of such resource. The genetic diversity found in medicinal plants and the traditional knowledge associated with them both is the most important resource for the strongly emerging biotechnology based global pharmaceutical markets. Same is true for the diversity of genes available in the locally adapted varieties of land races of crops and indigenous livestock, as well as, of genes from the microbes and other organisms with uniquely useful properties.

Mat weaver, many traditional crafts thrive on local biodiversity resources
Source: WBBB

Scared of toxic components being in foods and pollutions in ecosystems due to indiscriminate use of synthetic chemicals, a good section of aware citizens are moving towards organically grown foods. Hence, a good market of it has emerged which is growing fast. Thus, if supported and organized well, the organic cultivations of indigenous varieties (which are usually appreciated for their better tastes, flavours and other qualities and they grow well only in organic environments) can at a time contribute to the economy, check environmental pollutions and conserve the precious domesticated genetic diversity for further improvements through biotechnology. Also, products like flavoured jaggery traditionally made from the juices obtained by tapping palm trees like 'Taal' i.e. Toddy palm (*Borassus flavillifer*) and 'Kejur' i.e. Indian date palm (*Phoenix sylvesris*) which grow naturally all over the plains in the State, have high potentials to reach wider markets if, promoted. Of course, same is also true for the quintessentially bengali 'Nolen Goor', an exquisitely flavoured liquid molasses made from the date palm juice only during winter and the variety of traditional sweet items made with it. There are many natural products obtained from forests and wetlands in all parts of the State that are traditionally used to craft many articles of storage, decoration novelties, mats etc. The available traditional skills for such crafts are highly commendable and often exclusive. Thus, they could be supported further to reach wider and better markets. Lac (a product from an insect that grow on some specific host tree species) is still produced in large quantities in the forested tracks of PuruliYa, Bankura and Paschim Medinipur. It has a wide market because it is used as dye and resin in various industries. Being organic and proven safe even for foods and

cosmetics, lac would certainly be in higher demands in the coming days to replace unsafe synthetic pigments. Wild silks called 'Tasar' are obtained from the forested tracts of south West Bengal, while other two wild varieties of silks called 'Eri' and 'Muga' are produced in North Bengal. The domesticated silk moth *Bombyx mori* is cultivated in all districts in lesser or greater amount except in Haora and Hugli. All these varieties of silks are used by traditional expert handloom artisans in Murshidabad and Bishnupur to produce exclusive Sari and other garments which are famous and have good markets.

Ecotourism is based on the natural biodiversity of a locality and now the major source of income and employment in many countries of the world. In fact, ecotourism is considered as an important industry which can grow sustainably and without polluting the environment, if managed well. West Bengal with such a mosaic of beautiful landscapes and high diversity of charismatic wildlife animals along with many lesser known but highly attractive animals and plants, certainly have a very high potentials to attract tourists from all around the nation and globe. No other state in India would be able to provide in a few days' package, the views of snow capped peaks of Himalaya through Alpine or Sub Alpine forests, the exhilarating thrill to watch the rare Great One Horned Rhino with herds of Gaurs, Elephants, Deer in the forests of Dooars, the glittering expanse of freshwaters in the networks of rivers and wetlands entrapped in the ocean of brightly green paddy fields in the Gangetic plains, a boating cruise over the mighty river like Bhagirathi, the undulating landscape inferno with the mass blooming of Butea trees in the drier tracts of south west districts and the unique feeling while moving through the puzzling web of channels and creeks in the world's greatest estuarine mangroves on a boat anxiously looking to spot the unique Bengal Tiger. A lot of efforts to satisfy the increasing demands of ecotourism are now put in by the West Bengal Tourism Department, West Bengal Forest Development Corporation, District administrations. They often do that in collaborations with local people and of course, hundreds of private enterprises. The most significant development is the home stay arrangements by local people that have been now growing well in beautiful spots of the Darjiling Himalayas, Forested foothills and plains of Dooars and elsewhere. If, it could be controlled well to minimize disturbance on original habitats and wildlife, pollutions and social mal behaviours by a section of tourists, ecotourism could grow as the most significant sustainable industry of West Bengal.

Aquarium fishes: Most of the species of fishes native to the State are also recognized as aquarium species and are in good demand by the aquarists especially from the developed countries. Captive and selective breeding of the wild ones to suit the aquarists' demands and to avoid overharvesting of natural populations could emerge as a sustainable industry with high socio-economic potentials. Unfortunately, natural populations of these fishes are now harvested from all kinds of ecosystems - from hill streams to estuaries of the State by a few enterprising individuals or private agencies and exported. The whole exercise is highly unsustainable and illegal according to the biodiversity act and laws. The WBBB or WBFD have hardly any control over them. Immediate steps must be taken to check it and to organize it in sustainable and legal ways.

District-wise biodiversity

Darjiling

The district brings international glory to the State being an important part of one of the most important biodiversity hotspots on earth - the Eastern Himalayas and thus,

sharing a globally recognized unique diversity of fauna, flora and of course, for its beautiful landscapes. Quite justifiably, a major area and best preserved parts of these landscapes and along with their biodiversity are protected in two national parks - Singhalila and Neora Valley National Parks, and four wildlife sanctuaries - Senchal Wild Life Sanctuary, Jorphokri Salamander Wild Life Sanctuary and the Mahananda Wild Life Sanctuary (major portion). The district landscapes show a steep altitudinal variation starting from around 100 m and reaching 3,630 m above mean sea level at Sandakfu. It includes steep climbs, deep gorges, narrow and deep valleys with innumerable hill stream and few lakes. Gradual changes in the characters of forests along this gradient and their further variations in the slopes, valleys or gorges at the same altitude have bemused botanists and nature lovers from early colonial times to the present. James Gamble (in 1875), the revered colonial botanist described beautifully about these forests –

'deep valleys filled with strange vegetable forms, serpent like lianas, trees of monstrous size and shape, perhaps clothed with fairly blossoms of epiphytic orchids or the delicate tracery of pendant ferns, mount thence upwinding paths through dark forests whose only colour is that of the mossy hangings of the gigantic stems or the occasional flower of the scented Magnolia to the regions of winter snow where the masses of Rhododendron cover with their gorgeous tincts the slopes of the upper hill and twist in every conceivable shape their wonderfully coloured limbs'.

Even today, a trek to Tonglo and Sandakfu, won't deprive any nature lover from such feelings. Added attractions would be the innumerable birds and butterflies in wide ranges of colours and forms, and the gorgeous view of the Kanchenjanga (the third highest peak in the world) from Faloot. One may have sightings of coveted and endangered wildlife like Red Panda, Clouded Leopard, Himalayan Black Bear and among birds - Kalij pheasants. The forests and wild biodiversity of high altitude Eastern Himalayas are arguably best preserved in this part, given the recent large scale destructions of its contiguous eastern parts in Nepal. The unique and rich resource base of medicinal plants available in these forests and folk knowledge associated with them are also worth mentioning.

The Padmaja Naidu Zoo in Darjiling town houses various high altitude and rare species of animals including Snow Leopard, Clouded Leopard, Red Panda, Tibetan wolf, Himalayan Salamander and many rare birds. It's well known captive breeding centre for the highly endangered Snow Leopard.

Jalpaiguri

A district which used to span from the border of the Darjiling district up to the Assam border along the river Sankosh in the west, now, share its eastern parts to the newly formed district of Alipurduar. It still possesses a good representation of wildlife rich terai and foothills' tropical forests in mosaic with swampy grasslands. These include the famous rhino habitats in Gorumara National Park, Chapramari Wild Life Sanctuary and a chunk of the eastern portion of the Mahananda Wild Life Sanctuary. Other significant forest patches in Baikunthapur and Apalchand are also important habitats for wildlife including elephants, Gaurs etc., and of course, birds and butterflies. Rhinos from Gorumara migrate into Apalchand forests time to time. The extensive water body within the Baikunthapur forests in Gajaldoba created by the Teesta Barrage is an important site for sighting thousands of migratory birds from Ladakh and Central Asia.

The beautiful landscape of the district is mostly a mosaic of forests, silvery flows of rivers including the mighty Teesta and many smaller ones, green tree - savanna like expanse of tea gardens and small

settlements hidden under the shades of evergreen fruit trees like Jack fruit, Mango and Jamun. Added to it is the treat to the eyes when a range of snow clad peaks of the Eastern Himalayas including the great Kanchenjanga comes out above the skyline of green forested lower hills.

Alipurduar

The newly created district from the eastern part of erstwhile Jalpaiguri, includes most of its forested areas under two national parks and the Buxa Tiger Reserve. The Jaldapara National Park now harbours the largest density of Great One Horned Rhinos in India ensuring almost sure sightings by the visitors. Elephants and Gaurs are also enough abundant along with scores of important species of birds. Sightings of rare Pygmy Hog and Bengal Florican are claimed but highly debated.

Chilapata, a dense patch of forest teeming with wildlife lies in between Jaldapara and Buxa. The forests of Buxa including the National Park and the tiger reserve apart from charismatic wildlife and rich birdlife appears to be a goldmine of the insect diversity. It's the butterfly watcher's paradise. Several new species of spiders have been reported recently (Roychoudhury *et al.*, 2014). Many other new species in various groups of smaller fauna including the important group like ants are expected to be discovered, if, serious explorations are taken up in the region. For example, Dr. Sheela, an ant specialist from ZSI, found several species of ants just by a small search around Raja Bhatkhawa tourist complex which include the first ever record of genus *Philidris* from India and the record of three other rare species, *Lophomyrmex kali*, *Lophomyrmex bedoti* and *Diacammas calpratum* (Sheela, *pers. comm.*)

Koch Bihar

Once dotted with dense patches of forests harbouring big wildlife including tigers, the district is now without any significant patch of forest. *Rasik Bill*, a big freshwater wetland with rich aquatic fauna and flora serve as residence for many water birds. Many migratory birds also visit the Bill in winter. Also, a network of seasonal rivulets and stagnant swampy water bodies (locally called `chhora') are all around in the district that shelter a rich diversity of indigenous freshwater fishes and other elements of inland aquatic biodiversity. Weaving a special type of mat called 'sheetal pati' in Bengal from the stem sheath of a wetland plant called `pati gaach' (*Schumannianthus dichotomus*) cultivated in the local lowlands is a major small industry of the district. This mat is in high demand in the market for its exclusive qualities and durability. Other fashionable and novel products are also produced from the same materials by the same artisans.

Uttar Dinajpur

The Raiganj Wild Life Sanctuary at Kulik in this district, better known as Kulik bird sanctuary is claimed to be the largest heronry in Asia. The habitat is basically a patch of small forests with wetland areas including the river Kulik where on average 70-80 thousand birds including Asian Open Bill Stork, various herons, egrets and cormorants come to breed during the months of May and December. Such a huge population of breeding waterbirds, especially of the Asian Open Bill Stork has earned a special international status for Kulik. This sanctuary is home to some 160 more species of birds that are resident or winter migrants, smaller mammals and reptiles including monitor lizards.

The district has also earned a special status for agro-biodiversity of land races of rice. Most famous of them is *Tulaipanji* - the rice which might outcompete the famous Basmati once cultivated traditionally with only organic inputs.

Dakshin Dinajpur

This district shares many biodiversity characters of its northern neighbour including cultivation of *Tulaipanji* in pockets. The abundance of big stagnant wetlands (*dighi*) in the fabric of small rivers harbour many species of smaller aquatic fauna including a remarkable richness of fishes. The fish locally called *Chapilla* is rated high for its taste.

Maldah

Maldah is famous for its mango productions including the famous varieties like Fazli, Kishenbhog. Ripe mango extracts sundried to look like leather, called 'Amsatto', are home based small industry and in highly demand in the market for its exclusive tastes and flavours. The migratory bird populations in the huge lake of the Farakka dam and the Nayabadh wetland complex attract each year bird lovers and ornithologists from Kolkata and other parts of the country. A local variety of mung bean, called *Sona moog*, with an unparallel quality and fragrance is cultivated in a small pocket of the district called Bhutnir Char, but found nowhere else in the country.

Murshidabad

A land of Nawabi history embedded in a complex tangle of big rivers - the Bhagirathi, the Padma and the smaller one - the Jalangi and innumerable number of huge, big and medium sized wetlands called Bill. Usually these are oxbow lakes created from meandering courses of river Bhagirathi. Many of them still have at least seasonal connections with the river channels, and many others have been cut off from it. As a result, this mosaic of wetlands has the unparallel species richness and abundance of freshwater fishes and other wetland biodiversity including mollusks and birds. For example, Ahiran Bill is one such wetland which is rich in resident and migratory birds. The deep water rice varieties which were once common in the low lying areas of Bengal are still traceable in this region.

Nadia

The district still has a few small patches of forests worth mentioning. The best known to nature tourists is the Bethuadahari Wild Life Sanctuary - home of smaller wildlife and many species of birds. The sanctuary is also an asylum for rescued wildlife like spotted deer, gharial, rock python and different species of turtles and geckoes. Other forest patches in the district are protected to shelter natural populations of many smaller mammals like Bengal fox, civets, jungle cat, birds, reptiles, frogs and butterflies etc.

Barddhaman

The eastern part of the district is typical flood plains of Bhagirathi with abundance of wetlands. Purbasthali wetland complex is a remarkable one. It is basically an oxbow lake with several small islets within it created by the meandering course of the Bhagirathi. The lake still has connection with the river channel, though that being increasingly silted. This wetland complex is one of the best sites now in the Gangetic plains for watching a rich diversity of residential and migratory birds. It is quite rich also in native species of hydrophytes and supports a diverse fauna of freshwater fishes, mollusks, crustaceans and odonates. Most importantly, a small breeding population of Gharial which was thought to be extinct in the State for at least half a century was recently identified close to this wetland complex by an NGO group. With support from the WBBB, they are now trying to make the local fishermen aware and mobilize local administrations for conserving the population of this extremely threatened species.

Previously, large water bodies of both Durgapur and Mython barrage have been

winter home of a good number of many migratory water birds. Unfortunately, Durgapur barrage stays abandoned by them in recent years. There is also a small protected patch of Sal forests in the district - the Rambagan Wild Life Sanctuary, which provides shelter to smaller wildlife and birds. The district is also known for the high productivity and traditional diversity of rice crop.

Hugli

Agricultural diversity especially, that of rice is traditionally the most important biodiversity component of the district. It occupies the western bank of the river Bhagirathi, now called Hugli and possesses the originally beautiful riverscape with the richness of riverine biodiversity including fishes. Though, the district has no more any significant patch of forests, wild scrubs and bushes in and around villages, on the dried beds and banks of the rivers Mundeshwari and Damodar provide shelter to many smaller mammals like jackal, hare, jungle cat, civets and variety of snakes. There are few swampy wetlands within the district which are home of many wetland birds and animals. Previously, the vast swamp in Dankuni area was a rich haven for water birds and other wetland animals. Unfortunately, much of it has been reclaimed already.

Haora

This district shares the western bank of the river Hugli. But, the most prominent biodiversity feature of the district is the abundance of swampy wetlands, much of which form extensive reed beds. The latter is a very good wildlife habitat for many species of birds to roost and nest. It's also a preferred habitat for the State animal - the Fishing cat. Big predatory fishes like Gojal (*Channa maurilius*) which are killed selectively by pisciculturists from their culture ponds along with many other species unwanted by commercial pisciculture, find asylum in these wetlands. A big tank at Santragachi remains the only spot close to urban centre of Haora where each year 4-5 thousands migratory ducks make their winter home. It includes species like rare Fulvous Whistling-duck, Swinhoe's Snipe, Ferruginous Pochard, Comb Duck and the more common Gadwall, Garganey, Northern Pintail, Northern Shovelers and others. The wetland though being surrounded by dense human settlements, birds are least bothered by the human presence including the crowd of bird lovers from Haora and Kolkata gathering to watch them. This is mostly due to the efforts of local people to protect them with the support of the Forest Department, a few NGOs and of course, of the Railway department to whom the area belongs to. This birding spot is used every year by a well known NGO - Prakriti Samsad and some others to teach the students and general citizens to identify the bird species and to make them aware about their conservations. It is now named as the Satragachi Bird Sanctuary, though its sanctuary status is yet to be fully official. The famous and historical Botanical Garden at Shibpur is significant in its presence in the scenario of the State's biodiversity because of its richness of native collections along with exotic ones and being an ideal urban sanctuary for birds, smaller mammals, snakes and smaller groups.

South 24 Parganas

The greater parts of Indian Sundarbans lie in this district. It includes the southern part of the Sundarban Tiger Reserve (STR) and the National Park, the entire Sajnekhali Wild Life Sanctuary, Halliday Wild Life Sanctuary and newly created West Sundarban Sanctuary. The wild biodiversity includes the variety of uniquely adapted mangrove plants, tiger, crocodile, spotted deer, wild pig, water monitors along with a rich birdlife. The mangrove laden estuaries are

rich and safe haven for hundreds of fish and crustacean species, most of them having high commercial values. Flowering of mangrove plants attract wild honeybees (mostly, *Apis dorsata*) who build thousands of big honey filled combs during the flowering season. The intertidal mudflats are sites to watch for interesting activities of variety of crabs, mollusks and strange looking amphibious fishes called mud skippers.

Sundarbans are inhabited not only by mangroves and wildlife, several million people live in thousands of villages built in reclaimed intertidal lands by erecting high mud embankments to protect inflows of saline tidal water. Though, agriculture inside the villages has been the main stay for subsistence, a good majority of villagers traditionally had livelihoods that depend on the wild biodiversity resources like fishes, honey, medicinal plants and woody biomass from the mangrove areas. Still, a good number of them follow the same. Huge amounts (nearly, 400 tonne in 2013-14) of wild honey are collected by specialized honey-gatherers (called *Mouli*) every year from the mangroves. The activities of fishing, gathering honey, cutting timber, etc. inside the tiger habitats are highly risky, thanks to Sundarban tigers' infamous knack of considering humans as prey.

The entire original intertidal zone of Sundarbans including all wild habitats and villages are declared in 1989 as the Sundarban Biosphere Reserve (SBR) as part of the global Man and Biosphere (MAB) network with the aim to keep a harmony between the man and natural environment. Uniqueness of Sundarbans (including the Bangladesh part) has earned for it the 'World Heritage Site' status from UNESCO.

North 24 Parganas

South-eastern parts of this district include the north-eastern zone of the STR. The wild biodiversity found in this zone are more or less similar to that of southern zone. Though being lesser saline than other parts some difference like more occurrences of Sundari and Nypa palm along the eastern side is notable. The other protected area in the district is the Bibhuti Bhusan Wilfe Life Sanctuary at Parmadan – a small patch of forests with the river Ichamoti gently flowing through its border. The wildlife includes a rich variety of birds, frogs, butterflies, odonates and spiders.

The district is dotted with quite a few large stagnant wetlands (called 'bills') which have been rich in diversity of native fishes and other aquatic fauna including resident and migratory populations of wetland birds.

Purba Medinipur

Most parts of the district are low-lying flood plains trapped in the intricate network of big and small river courses which converge to meet the exposed estuarine coastline in the south-east. Thus, the district is rich in aquatic fauna having freshwater, estuarine and coastal characters including the fishes, edible crustaceans and mollusks. The swamps and marshes yield plant products like Shola (pith of *Aeschynomene aspera*), and Madurkathi (*Cyperus segetinus*) - a sedge used for making mats which the district is famous for.

The coast line of the district is famous for beach tourism. The sand dunes protected with various sand binders like Goat-foot creepers (*Ipomia* sp.) and *Casurina* plantations along with the wide open silvery beaches crawled by thousands of red ghost crabs (*Ocypod* sp.) looking like a moving red carpet and small backwater pools throbbing with life due to the amusing activities of a variety of fiddler crabs (*Uca* spp.) and mudskippers, are biologically and aesthetically a unique habitat for the State. Much of it though, is affected by mal-tourism practices which need to be controlled to restore the original biodiversity of this coastal habitat.

Paschim Medinipur

The gently undulating lateritic landscape of the district except in the small patch of riverine flood plains of the river Subarnarekha in the south of the district, was originally densely covered with deciduous forests of Sal, Piasal, Kusum, Mahua, Karanja and other trees, teeming with all kinds of wildlife including tiger, leopard, sloth bear (O'Malley, 1911). This forested landscape spreads over the districts of Bankura, Puruliya and western parts of Birbhum and Barddhaman and is actually the eastward extension of the Chotonagpur plateau. The forested lands had been originally inhabited and traditionally used for living by tribals like Santhal, Sabar. They were taken over by the Britishers, partly declared as reserve forests and partly handed over to the zaminders (hence referred to as Jungle Mahal i.e. Forest Estates). Felling for the timbers at large scale and promoting coppicing of Sal instead of natural regenerations of mixed species forests resulted in continuous degradation and shrinkage of the original forest covers of the district (and, adjoining similar landscape). Large scale clearing of the forests happened in a very short span of time when zamindars were stripped of their ownerships by an Act of 1953 by the Indian Government after independence. With natural forest covers gone, the wild biodiversity harboured there suffered significantly. Yet, whatever wilderness survived and then little restored following the introduction of the JFM, support now wildlife of mammals like Wolf, Hyena, Wild Pig, Porcupines, Pangolins, Civets and Jungle Cat, many varieties of snakes, lizards and monitors and of course, a rich life of birds. Of course, the herds of infamous Dalma elephants move around in the region on regular basis. District contributes a good part of the Mayurjharna Sanctuary for them. These forests now mostly managed by FPCs, yield variety of forest produces like Sal leaves (for making plates etc.), seeds of Sal, Mahua and Karanja used for extracting oils, many medicinal products, materials for fabricating articles like baskets, mats, brooms contributing significantly to the livelihood of forest-fringe people. Non-destructive collections of fire woods are allowed for self consumption, though illegal sales of it do take place in local towns. Plantations managed by FPCs are felled in cycles and FPC member families get 25 per cent from the sale proceeds.

Bankura

Most of the original patches of mixed forests are gone. Highly degraded relics of original forests exist here and there. Patches of *Butea* scrubs with lonely canopy of Mahua or Karanja are now dotting over the eroded, undulating meadows with plantations of coppicing Sal, Acacia and Eucalyptus taking over original forest patches all over the districts. Most of the forests are now managed under FPCs. Apart from the straying herds of 'Dalma' elephants, no big animals are found anymore, fauna resemble that of Paschim Medinipur and PuruliYa including small packs of wolf and stripped hyena roaming. Considerable forest covers still survive in the Jaipur forests near Bishnupur. Apart from the dominating Sal, few other tree species like Mahua, Piasal, Kusum, are found with dense growth at the shrubs and herb layers. A herd of captive bred spotted deer released there, seem to be flourishing now. District is of course still rich with the traditional knowledge of tribals and many medicinal products are collected by them along with other forest produces. Many indigenous rice varieties have been documented from the district quite a few of which remain in practice yet.

Puruliya

The undulating landscapes of the Chotonagpur plateau extend into this district and are dotted with small hill ranges and isolated hillocks along with their dry

deciduous scrub-forest covers. Now degraded and wiped out from most of the parts, yet significant forest covers remain in patches in places like Ayodha Hills, Panchet hills. Wildlife originally found, are all gone except wild pig, porcupine, wolf, hyena, hare, etc. and the elephants. Birdlife and diversity of reptiles including snakes and lizards are quite rich. Fishes in the dams and river courses once diverse and abundant, are now in decline. Lac culture is a prominent livelihood activity in parts of this district. Forest patches are maintained mostly by FPCs under JFM. Forest produces other than timbers and firewoods include lots of medicinal plant products. A medicinal plant garden representing the diversity of south West Bengal has been established at Garpanchokot by the Forest Department.

Birbhum

The district especially in the western parts (the Rarh), is lateritic and has closer resemblance with the adjacent western districts in flora. The original forest covers of mixed deciduous forests are all gone, existing patches are mostly plantations of Sal, Eucalyptus and Acacia. Near Bolpur, the Ballavpur Wild Life Sanctuary shelters herds of Spotted Deer, Blackbuck and water birds in the wetland inside it. Many species of migratory water birds in large numbers visit every year the water bodies at Tilpara and Bakreswar barrage.

Kolkata

Born in the lap of mangroves, the city of Kolkata once shared the wild biodiversity of Sundarbans including the tigers. Since then, Kolkata grew fast by removing and modifying the original habitats. Yet, the present day Kolkata is one of the biodiversity rich cities of India, thanks to the abundance of wetlands and greeneries in and around the city. While the wide stretches of the river Hugli run along its entire western boundary, expanses of shallow wetlands linked to the river Bidyadhari make its east. This complex of wetlands is referred to as the EKW which has earned the status of a Ramsar Site for its richness of biodiversity including that of resident and migratory water birds and for the unique functioning of the ecosystem with the involvement of local people producing vegetables and fishes by innovative farming methods. The greeneries maintained in a rich number of parks and gardens inside the city support a rich fauna. A small patch of forests (originally an orchard) at the southern boundary of the city has been declared as a the Chintamoni Kar Wild Life Sanctuary for its richness of birds, butterfly and other fauna. In fact, spotted here a butterfly – the Malayan Green Banded Peacock (*Papilio palinurus*) is considered as the first ever record of the species in India and a frog - Annandale's tree frog (*Chirixalus simus*) is the first ever record for the State. In last few years, a huge natural area along with several water bodies in the new satellite town of Rajarhat has been developed into an ecological park including bird watching sites, a dedicated butterfly conservation area along with a netted dome to watch live butterflies from close. Kolkata's biodiversity is quite well documented and monitored thanks to an active army of serious amateur bird watchers and nature lovers along with few professionals. Unfortunately, land filling by the real estate nexus is now a serious threat to the EKW and other smaller wetlands in the city. Concretization of banks of the wetlands inside the city is also affecting their rich aquatic fauna and flora and natural ecosystem functioning. The city has also lost a lot of green covers along some roads due to ongoing extension and developmental projects which need to be restored as soon as possible.

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Chapter 8

Water Resource

Fresh water is under stress due to its limited supply and increasing demand all over the world. Stresses arising from the growing demand for irrigation, rapid urbanisation, industrialisation, generation of power and rampant pollution of both surface and ground water need to be addressed with informed interdisciplinary approach. Fresh water is not available in plenty everywhere all the time. The rainfall in India and West Bengal is spatially uneven and temporally skewed. The geographical scenario in West Bengal is changing due to expansion of agricultural land, shrinking forest cover, uninterrupted growth of population, sporadic and unplanned growth of urban centre and emergence of some industrial complexes.

The water management planning in West Bengal has changed appreciably during the post-independence period. The dam-canal network of the Damodar Valley Corporation, Mayurakshee project, Kanshabati project and the Teesta project did not work to the level of expectation. There was a wide gap between irrigation potential created and the area actually irrigated. The water hardly reached tail-end of the command areas. The farmers relied more on groundwater for irrigation and consequently the groundwater level in many districts of West Bengal has been depleting. This is largely due to indiscriminate exploitation of groundwater to ensure irrigation for Bodo or dry variety paddy cultivation. The State Water Investigation Department (SWID) in its report (2011) has described the groundwater scenario in 296 blocks of West Bengal. The SWID has monitored fluctuation of groundwater level during the period 2002-11. It is reported that pre-monsoon (observed in the month of April) groundwater level has gone down in 259 blocks and rate of decline in 136 blocks was found to the tune of more than 20 cm/year. On the average, groundwater level in the monitored blocks was declining at the rate of 25.5 cm/year. The lowering of the groundwater level has far reaching impacts, including reduced base flow causing desiccation of rivers in the lean months.

A critical look at water management in West Bengal reveals four major areas of concern. These are:

- The demand of water for irrigation has been given top priority but there is a gap between irrigation potential created and the area actually irrigated.
- Attempts were made to intercept flowing water and distribute through dam-canal network in four river

valley projects. The storage capacities of the reservoirs were found inadequate to meet the growing demand for irrigation. Transmission and distribution losses complicated the situation further.

- The volume of water in groundwater pool was often thought to be unlimited. Over exploitation caused lowering of groundwater level as well as gradual contamination with arsenic or fluoride.
- The rivers were used as the outlet of urban and industrial wastewater, and the environmental costs of polluting the surface and ground water were not paid proper heed.

The demand of water will increase in accordance with the growth of population. The population of West Bengal has grown from 26.30 million in 1951 to 91.28 million in 2011. The major sectors of water usage are agriculture, industry, power generation and domestic water supply. While domestic water demand is expected to grow in line with the population growth, demand in other sectors may rise more sharply due to GDP growth (which has been consistently faster than the population growth) and induction of water-intensive technologies. The greatest challenge will be meeting the growing demand with limited supply.

West Bengal is fortunate to have abundant precipitation. In addition to the water resource, generated from the rainfall, West Bengal receives a substantial trans-boundary flow through the rivers entering from the neighbouring states. The assessment of availability of water and its demand in different sectors are important issues of planning. The Expert Committee on Irrigation (1987) made a comprehensive assessment of both surface and ground water in 25 river basins of West Bengal and the database generated in that report has so far been cited by many water-managers. However, the geographical scenario of West Bengal has changed drastically since the Expert Committee submitted its report and we need to assess our water resources afresh. It is important to note that the administrative boundary of West Bengal, which is largely the colonial legacy, was drawn without any regards to the holistic eco-hydrology of the area and as such district-wise assessment of water resources is an important issue (Rudra, 2009). Moreover, the said Committee did not take into account the trans-boundary water, which enters the State from upstream region, nor did it estimate the quantum of evapotranspiration and infiltration. However, the report of the Expert Committee is the first baseline work towards sustainable water management. The Committee estimated the surface water resource of West Bengal as 13.29 million hectare metre (mham.) and only 40 per cent of that was said to be utilisable. On the other hand, utilisable ground water was estimated to be 1.46 mham (Table 8.1).

TABLE 8.1 Earlier estimate of water resource in West Bengal (in million hectare metre)

Surface and Ground water	Availability	Utilisable
Surface water	13.29	5.31
Ground water	1.46	1.46
Total	14.75	6.77

Source: State Irrigation Department, 1987

Water resource in West Bengal

West Bengal covers an area of 88,752 km^2 and the average annual precipitation is 1,795 mm. The precipitation varies widely across the districts. While Jalpaiguri district receives 3,899 mm of annual rainfall, Puruliya in South Bengal receives 1,329 mm rainfall. It is observed that 77 per cent of the annual precipitation is received during four monsoon months and only 23 per cent occurs during remaining eight months. Table 8.2 describes the precipitation in different districts of West Bengal.

The surface water generated from precipitation is not totally available for human use. About 22 per cent of the

precipitation infiltrates through the soil and recharges the ground water and 33 per cent goes back to atmosphere through evapotranspiration. It is important to note that farm land contributes a substantial part to the total evapotranspiration. The precipitation within the geographical territory of West Bengal generates 159.27 billion cubic metre (bcm) of water annually. The surface water available in West Bengal amounts to 77.06 bcm when infiltration and evaporation are excluded. The replenishable groundwater resources amount to 31.72 bcm per year. A small part of the infiltrated water eventually resurfaces as natural discharge and this amount may be regarded as overlap between surface water and groundwater resources. After adjusting for this overlap, the total internal water resource of West Bengal comes to 105.82 bcm per year. Since West Bengal is located at the tail-end of the Ganga basin, it offers outlet to a huge trans-boundary flow. If this flow is considered and added, the total annual water resource amounts to 694.30 bcm. The Ganga alone brings 525 bcm of water, but this is a channelized flow and has restricted use. While low-lying tracts of the State experience brunt of the flood during the late monsoon, the Rarh Bengal (Paschim Medinipur, Bankura, Puruliya, western part of Barddhaman and Birbhum) suffers from

About 22 per cent of. precipitation infiltrates through the soil and recharges the ground water and 33 per cent goes back to atmosphere through evapotranspiration

TABLE 8.2 Annual precipitation in West Bengal

Districts	Area (km^2)	Population in million (2011)	Annual precipitation (mm)	Volume of precipitation		
				Total (bcm)	Monsoon (%)	Non- Monsoon (%)
Darjiling	3149	1.85	3141	9.89	80.1	19.9
Jalpaiguri	3402	2.38	3899	13.27	78.6	21.4
Alipurduar	2825	1.49	3899	11.01	78.6	21.4
Koch Bihar	3387	2.82	3302	11.18	77.2	22.8
Uttar Dinajpur	3140	3.01	1567	4.92	79.9	20.1
Dakshin Dinajpur	2219	1.68	1711	3.80	75.9	24.1
Maldah	3733	3.99	1491	5.56	78.1	21.9
Murshidabad	5324	7.10	1402	7.46	75.9	24.1
Birbhum	4545	3.50	1387	6.30	77.9	22.1
Barddhaman	7024	7.72	1349	9.47	77.0	23.0
Nadia	3927	5.17	1309	5.14	72.4	27.6
North 24 Parganas	4094	10.01	1613	6.60	73.5	26.5
Hugli	3149	5.52	1471	4.63	73.2	26.8
Bankura	6882	3.60	1360	9.36	78.3	21.7
Puruliya	6259	2.93	1329	8.32	80.8	19.2
Purba Medinipur	4795.2	5.10	1621	7.77	74.0	26.0
Paschim Medinipur	9285.8	5.91	1535	14.25	75.0	25.0
Haora	1467	4.85	1621	2.38	74.4	25.6
South 24 Parganas	9960	8.16	1771	17.64	75.0	25.0
Kolkata	185	4.50	1686	0.31	74.5	25.5
West Bengal	88752	91.29	1795	159.26	76.8	23.2

Source: Calculations from the model described in Rudra (2012), adapted to latest precipitation data (1901-2010) from IMD

water-short condition in lean months (March to May). It is observed that about 45 per cent of the internal water resource of the State is available in North Bengal and the South Bengal is endowed with the remaining 55 per cent. Table 8.3 describes the water resource in the districts of West Bengal.

The estimated total water resource, reported in Table 8.3, is also referred to as the utilizable water. The utilizable water is popularly defined as the part of the total water resource which can be stored in dams and reservoirs or abstracted from ground water pool. It is also thought that this water can be put for beneficial use of mankind. In India, the utilizable water is officially assessed as 1,123 km^3 or 28 per cent of total water; of which 690 km^3 can be harnessed from surface and 433 km^3 from replenishable ground water source. India has not yet achieved the stage of maximum possible storage. The storage of 690 km^3 is possible only if additional reservoirs are built to the required extent. It is further said that the quantity of utilizable water can be enhanced to the tune of 200 km^3 through inter-basin transfer of water.

Notably every drop of rain water is a part of the hydrological cycle or part of the ecological life support system. The human society intercepts or abstracts a portion of this flow for its survival. Ecosystem services are, however, no less important for our survival. The Indian farmers have inherited the culture of utilizing the rain drops falling on the agricultural land. In Bengal, overflow

TABLE 8.3 Estimated water resource of West Bengal (bcm)

Districts	Surface Water			Ground Water (Annual)	Total (internal)	*Total annual water
	Monsoon	Non-monsoon	Annual			
Darjiling	6.90	1.08	7.98	0.51	8.44	26.26
Jalpaiguri	8.28	1.82	10.10	1.54	11.49	33.07
Alipurduar	6.92	1.42	8.34	1.28	9.49	21.89
Koch Bihar	5.85	1.36	7.21	2.45	9.41	60.85
Uttar Dinajpur	1.51	0.04	1.55	1.74	3.14	13.74
Dakshin Dinajpur	1.41	0.33	1.75	0.83	2.47	13.07
Maldah	1.94	0.12	2.06	1.61	3.52	547.15
Murshidabad	1.69	0.04	1.73	2.45	3.95	560.12
Birbhum	1.95	0.06	2.00	1.60	3.46	10.40
Barddhaman	2.36	-0.16	2.20	3.41	5.30	70.93
Nadia	0.56	-0.11	0.45	2.24	2.46	54.87
North 24 Parganas	2.15	0.73	2.89	1.58	4.31	59.18
Hugli	1.01	0.34	1.35	1.59	2.78	75.64
Bankura	3.32	-0.27	3.05	2.10	4.95	21.40
Puruliya	3.17	0.68	3.86	0.73	4.50	16.36
Purba Medinipur	3.36	1.06	4.42	0.71	5.06	83.94
Paschim Medinipur	4.91	0.64	5.55	3.13	8.32	15.74
Haora	1.04	0.26	1.30	0.35	1.62	73.69
South 24 Parganas	7.74	1.29	9.02	1.87	10.89	85.11
Kolkata	0.21	0.04	0.25	0.00	0.25	70.21
West Bengal	66.28	10.77	77.06	31.72	105.81	694.30

Source: Calculations from the model described in Rudra (2012), adapted to latest precipitation data from IMD. Groundwater data are obtained from the Central Ground Water Board.

*Total water resource means surface + ground – overlap + trans-boundary water.

irrigation has been an age old tradition. The farmers learnt the art of sustainable use of water and silt that spilled over the land during the flood (Willcocks, 1930). So the phrase 'utilizable water', has a wider connotation beyond the engineering understanding which justifies the same as the volume that is intercepted in reservoirs or abstracted from ground water pool.

Since 1948 some dams/reservoirs were built across the rivers of West Bengal. The Damodar Valley Corporation was conceived as the first multi-purpose river valley project of the country. Notably the four reservoirs of DVC (Tilaiya, Konar, Mython, Panchet) and that of Massanjore store water draining from Jharkhand and have lost their capacity substantially due to sedimentation. Table 8.4 describes storage capacity of 34 reservoirs which serve the West Bengal. The Farakka barrage can store 8.7 million cubic metre water to induce 1,132 cumec water into the Bhagirathi-Hugli river. This project has a dedicated purpose of resuscitating the navigational status of the Kolkata-Haldia ports. The Teesta Barrage pond at Gajoldoba had initial storage capacity of one million cubic metre. The project was expected to irrigate 0.34 million hectare under the first sub-stage but the irrigation potential created till 2013-14 is only 37 per cent of the ultimate irrigation potential in first sub-stage.

The storage of the monsoon water and transfer of the same to the non-monsoon season has been age-old culture of Bengal. There exist more than two million water bodies in West Bengal. Many of them go dry during lean months. The Government of West Bengal adopted an extensive programme of rain water harvesting through resuscitation of derelict ponds and excavation of new ones where land is available. This programme is described as *Jol dhoro-Jol bhoro*. The target of the Government in 2011 was to resuscitate 50,000 derelict ponds during the period 2011-2016. The official records claim that 110,000 such projects have been executed till June 2014 (Rudra, 2015).

TABLE 8.4 Effective storage capacity (mcm) of the DVC and other reservoirs

Reservoir	Effective storage	Reservoir	Effective storage
Tilaiya	335.83	Lipaniya	2.74
Konar	284.34	Sali	2.34
Mython	804.00	Totko	6.50
Panchet	504.00	Taragonia	1.37
Massanjore	549.13	Kariwar	0.31
Mukutmanipur	900.40	Dimu	0.68
Hinglo	14.15	Khoirabera	5.20
Nachan	0.87	Moutorjor	1.69
Baro Mandira	1.22	Beko	2.72
Maliajor	3.42	Turga	1.70
Paraga	1.58	Barabhum	5.18
Rupai	1.56	Ramchandrapur	2.99
Dangra	1.42	Bandhu	2.19
Saharajor	7.41	Futiyari	1.85
Golamarjor	1.71	Hanumata	5.02
Kumari	4.32	Patloi	4.21
Bakreswar	2.3	Farakka	8.7

Source: http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Dams_in_West_Bengal and unpublished records of State Irrigation Department

The mode of water use has drastically changed in West Bengal with the expansion of high yielding agricultural programme since early 1970s. It was the beginning of a new era of increasing dependence on ground water. The traditional rain-fed agriculture was substituted by a new water-intensive agriculture and that was sustained by exploiting ground water. The age-old surface water irrigation practices were gradually abandoned. There are wide gaps between irrigation potential created and the area actually irrigated by large dam-canal networks of DVC and other projects. There is considerable transmission-distribution loss in all major irrigation projects. It was

Mode of water use has drastically changed in West Bengal with the expansion of high yielding agricultural programme since early 1970s

observed that longer the distance between reservoir and irrigation command area, more the infiltration-evaporation loss. In order to deal with the shortage of water for modern farming, local farmers increasingly depended on minor irrigation. In the absence of any regulation to curb the exploitation of ground water, the piezometric level was depleted exceeding threshold limit in many parts of the West Bengal. The lowering of the groundwater level was accompanied by contamination with arsenic and fluoride.

The decentralised storage of water in ponds and wetland is extremely important for rural economy. Bengal had the traditional culture of storing water in pond and dighis. This culture was gradually decayed since 1970s when people relied more on groundwater. The groundwater was safe for drinking and saved people of rural Bengal from water-borne diseases. However, use of groundwater for agriculture led to overexploitation.

Table 8.5 describes rain water storage capacity of wetlands, ponds and reservoirs in different districts of West Bengal. This further includes the flow of water from one district to other through canal. The data show that the storage capacity of small structures is higher than those of dams, even after years of emphasis on the latter.

TABLE 8.5 Utilizable stored water in districts (in million cubic metre)

Districts	Ponds/ wetlands	Reservoir	Total storage capacity
Darjiling	0.912	0	0.912
Jalpaiguri	10	1	11
Aliprduar	6	0	6
Koch Bihar	63	Nil	63
Uttar Dinajpur	132	Nil	132
Dakshin Dinajpur	93	Nil	93
Maldah	156	87	243
Murshidabad	287	Nil	287
Birbhum	404	199	603
Barddhaman	434	430	864
Nadia	126	Nil	126
North 24 Parganas	232	Nil	232
Hugli	248	212	460
Bankura	334	500	834
Puruliya	963	43	1006
Purba Medinipur	165	Nil	165
Paschim Medinipur	320	Nil	320
Haora	78	Nil	78
South 24 Parganas	244	Nil	244
Kolkata	No data	Nil	No data
West Bengal	4296	1472	5768

Source: Sengupta, Goswami, Rudra, 2014 (updated)

Water resource in the rivers

West Bengal is proverbially land of rivers and often described as *nadimatrik* (land nourished by rivers). The rivers of West Bengal can be subdivided into four major groups and those are:

(a) South flowing rivers of North Bengal;
(b) Tributaries to the Bhagirathi-Hugli river;
(c) The Ganga and its distributaries; and
(d) Tidal creeks of the Sundarban.

All these rivers except the Ganga and the Teesta are either rain fed or tidally active. Notably the base flow from the groundwater pool contributes substantial water into the rivers during the lean months. But over-exploitation of the groundwater to ensure irrigation for the Rabi crops and Bodo paddy has reduced base flow since 1970s and consequently many perennial rivers now go dry in the non-monsoon months. This has caused cessation of ecological services of these rivers.

There is hardly any information in the public domain regarding the flow of the rivers of northern and eastern India. The discharge data are generally treated as classified information. Though the Central Water Commission have gauge stations and records flow of rivers at some important locations, the data base of the trans-boundary rivers and their tributaries are kept secret and made available only for the official use. In the absence of real-time data, the only option is to estimate the flow in rivers through mathematical modelling.

The mean monthly flows of 19 major rivers are estimated by taking into the rainfall in the basin, infiltration and evapotranspiration. The flow of rivers in four selective months is given in Table 8.6.

Water: per capita availability

The demand of water for a human being is not only restricted to his or her domestic demand. The water-footprint of a person is much larger than normally understood. It is estimated that 1,300 m^3 of water is required to produce food for a person at desired nutritional level (Rockstorm and Falkenmark, 2005). The ecological services demand more water. A human being needs 1,700 m^3 of water/year to satisfy all kinds of requirement. When the annual per capita availability of water is less than 1,000 m^3, the area is supposed to be suffering from "water-scarcity". When availability is between 1,000-1,700 m^3, the area is considered as "water stressed". The per capita availability of water in West Bengal was 4,023 m^3 in 1951 and it declined to 1,159 m^3 in 2011 (Table 8.7). In 2011 conditions, seven districts were found water-stressed as per capita water availability was less than 1,700 m^3. Six districts were found to suffer from water-scarcity. Absolute scarcity was found in four districts where availability was below 500 m^3/year/capita. In West Bengal, average availability of water in 2011 indicates that it is "water-stressed". The index was computed on the basis of the surface and ground water available within West Bengal and population total as per census. The trans-boundary water that comes from the adjoining states is not taken into account.

TABLE 8.6 Estimated flow of some important rivers of West Bengal

River	Location	Flow in different month (cumec)			
		February	May	August	November
Torsa	Balarampur	57.2	831.1	1534.5	94.4
Jaldhaka	Gitaldaha	14.0	575.8	996.9	5.7
Teesta	Haldibari	299.2	1008.9	1591.9	347.8
Mahananda	Godagarighat	206.9	901.1	1689.6	7.8
Bansloi	Jangipur	16.9	35.9	132.3	1.0
Pagla	Jangipur	4.9	14.5	45.4	0.4
Mayurakshee	Kalyanpur	68.1	182.7	646.0	5.5
Ajoy	Katwa	40.2	72.6	415.7	3.8
Jalangi	Mayapur	95.0	125.4	90.2	2.8
Churni	Chakdah	81.1	97.3	47.9	2.5
Damodar	Uluberia	66.3	103.4	1749.1	6.9
Dwarkeswar	Arambag	39.2	80.3	335.8	2.8
Silai	Khanakul	23.0	67.8	259.2	2.4
Kansai	Trimohoni	77.1	166.5	663.6	5.3
Bhagirathi	Chakdah	1568.7	1808.6	4466.4	1158.5
Padma	Jalangi	4484.2	5007.6	40458.6	4297.6

Source: Calculations from the model described in Rudra (2012), adapted to latest precipitation data from IMD. Groundwater data are obtained from the Central Ground Water Board. This calculation is based on official data of upstream flow of Ganga at Farakka, which could not be verified

TABLE 8.7 Declining per capita water availability (in cubic metre)

District(s)	1951	1971	1991	2011
Darjiling	18355	10791	6490	4568
Jalpaiguri	22881	11985	7590	4824
Alipurduar				6362
Koch Bihar	14064	6653	4333	3337
Uttar Dinajpur	5744	2839	1657	1045
Dakshin Dinajpur		3279	2006	1472
Maldah	3758	2185	1336	883
Murshidabad	2303	1344	833	556
Birbhum	3244	1949	1354	988
Barddhaman	2418	1353	876	687
Nadia	2154	1105	640	477
Hugli	1732	968	638	504
Bankura	3753	2438	1765	1377
Puruliya	3851	2809	2024	1537
Purba Medinipur	3984	2429	1315	992
Paschim Medinipur			1855	1408
Haora	1003	669	433	333
North 24 Parganas	3409	1799	592	431
South 24 Parganas			1906	1335
Kolkata	93	80	57	56
West Bengal	4023	2388	1554	1159

Source: Rudra (2015)

Demand of water in different sectors

The supply of drinking and domestic water has always been priority for the Government. The Government of West Bengal has target of supplying 70 litres of water per capita per day in rural areas under its "Vision-2020 Plan". It was possible to provide arsenic free drinking water to a rural population of about 15 million till March 2015 (http://www.wbphed.gov.in). The drinking and domestic water supply together accounts for less than 3 per cent of the total annual demand.

It is revealed from Table 8.8 that agriculture is largest consumer of water and that is about 56 per cent of the total annual consumption of water in all sectors together. Still this appears to be much less if we compare the same with country's annual water demand in agricultural sector which amounts to 85 per cent. In West Bengal, demand of irrigation goes up during lean months when dry variety paddy is cultivated and the evaporation in drought prone districts exceeds rainfall. An increasing trend of irrigation demand since late nineties was observed but a subsequent levelling off, perhaps due to shortage of water and/or drop in profitability in agriculture was also noted (Rudra, 2009). In future, market demands for greater productivity may increase the pressure for multi-cropping, and consequently increase the demand for water for irrigation. The industry and energy sectors together consume 29 per cent of annual water demand. The water use in hydro-power generation is generally treated as non-consumptive demand but ecological cost of such production system cannot be denied. Even the low dam hydropower project interrupts longitudinal connectivity and creates dry stretches in the river. This leads to loss of biodiversity and change in physical properties of flowing water. The thermal power projects which earlier discharged ash-laden water are now under strict surveillance of the Central Pollution Control Board (CPCB) and the West Bengal Pollution Control Board (WBPCB) and gradually leading towards total recycling of wastewater and zero liquid discharge.

TABLE 8.8 Demand of water in different sectors (mcm)

Sector	2011	Demand (in %)
Drinking	0.274	<1
Domestic	2271	1.52
Agriculture	84607	56.45
Industry	24938*	16.64
Energy	17352*	11.58
Forest/Ecosystem	20704	13.81
Total	**149872.274**	

Source: Computed from records of WBPCB (April 2016)

Pollution load in the rivers

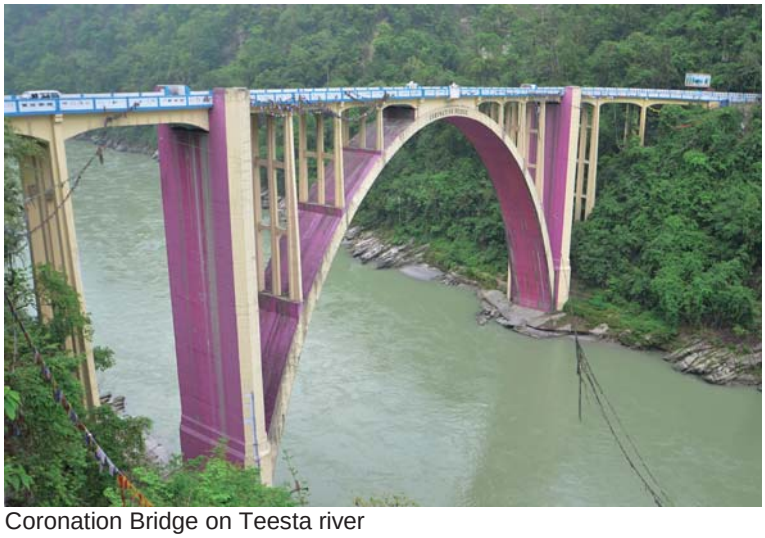
West Bengal is drained by an intricate network of rivers which nourishes the life and economy since the dawn of civilization. But many rivers have lost their pristine water quality due to mixing of urban and industrial wastewater. Regular monitoring reveals that rivers are hardly fit for bathing as per standard fixed by the Government of India.

Water quality of any river means the physical, chemical, biological and aesthetic properties of water which determine its fitness for use and its ability to maintain the health and integrity of aquatic ecosystems. The pollutants remain in dissolved or suspended condition. The West Bengal Pollution Control Board in collaboration with the Central Pollution Control Board, under the National Water Monitoring Programme (NWMP), conducts regular monitoring of water quality of all major rivers of the State for assessing the nature and extent of pollution control needed in different rivers, evaluating the effectiveness of pollution control measures already in existence and also to assess the fitness of water for different usages.

The Ganga-Bhagirathi system

The Ganga is obviously the most significant river of the State. It enters the State of West Bengal dashing the Rajmahal hill of Jharkhand and flows about 80 km upto Farakka where a mighty barrage tames the river. The barrage was dedicated to the Nation in 1975 to resuscitate the navigational status of the port of Kolkata by inducing 40,000 cusec of water into the Bhagirathi-Hugli river. The Ganga approximately delineates Indo-Bangladesh border between Farakka and Jalangi.

The Bhagirathi takes off from the Ganga at a village called Mithipur (Murshidabad district), about 2 km north of Jangipur or about 40 km to the southeast of Farakka barrage. It flows southward for about 500 km and ultimately discharges into the Bay of Bengal at Gangasagar. The 280 km stretch of river below Nabadwip is tidal. This tidal reach of the river is known as Hugli. The Jalangi and Churni are two offshoots of Ganga-Padma and exceptionally flow southwest to join Bhagirathi at Mayapur and Payeradanga respectively. These two rivers drain an area of about 6,408 km^2 from Murshidabad and Nadia. Both Jalangi and Mathabhanga-Churni are now beheaded from their feeder and do not get any upstream water supply during lean months. The Mathabhanga is bifurcated into two channels namely Churni and Ichhamati at Majhdia (Nadia). While Churni flows west, the Ichhamati flows south towards Sundarban. The Bhagirathi-Hugli river receives seven tributaries from the west and these are Bansloi, Pagla, Mayurakshee, Ajoy, Damodar, Rupnarayan and Kansai. These rivers together drain an area of about 66,000 km^2.



Coronation Bridge on Teesta river
Source: Kalyan Rudra

The levels of dissolved oxygen at all the eleven stations both during pre-monsoon and post monsoon season are always above the minimum standard indicating that the river water is fit for survival of aquatic life. The BOD level has been found above the permissible limit (3.0 mg/l) at Baharampore, Palta and Garden Reach both during pre-monsoon and post-monsoon

TABLE 8.9 Water quality of the Bhagirathi-Hugli river

Stations	DO (mg/l)		BOD (mg/l)		TCC (MPN/100ml)		FCC (MPN/100ml)	
	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015
Baharampore	7.2	7.3	5.5	6.2	110000	110000	80000	80000
Nabadwip	7.1	6.5	1.25	3.0	110000	110000	70000	80000
Tribeni	7.1	6.0	1.88	4.3	140000	110000	70000	80000
Palta	6.0	5.7	3.58	4.65	220000	110000	140000	80000
Serampore	6.5	5.6	2.68	1.15	140000	80000	110000	70000
Dakshineswar	6.3	5.1	5.0	2.85	500000	400000	80000	250000
Haora-Shivpur	5.4	4.9	2.1	5.5	80000	280000	22000	140000
Garden Reach	5.3	5.4	3.1	3.4	170000	240000	110000	130000
Uluberia	5.0	3.7	1.45	2.7	30000	13000	11000	8000
Diamond Harbour	6.6	5.2	1.2	4.2	22000	70000	11000	30000
Patikhali	7.1	6.0	1.4	2.45	5000	30000	2300	13000

Source: WBPCB (2015)

TABLE 8.10 East bank and west bank canals polluting the Bhagirathi-Hugli river

Sampling Point	Flow (MLD)	BOD Load (tons/day)
East bank canals		
Circlar Canal	320.3	7.06
Tolly Nallah	380.2	26.99
Dhankheti Khal	65.2	15.13
Akhra Food Ghar	83.4	2.00
Kharda Khal	63	2.33
Nimtala Khal	20.7	1.55
Kashipur Khal	16.1	6.31
Mistry Ghat, Barrackpore	22.7	3.63
Cossipore Ferry Ghat	19.8	1.27
Chitpur Ghat	15	0.96
Baranagar Khal	10.3	0.99
Diamond Club Khal	0.96	2.01
Total	**1017.66**	**70.23**
West bank canals		
Hastings Ghat, Rishra	42	3.57
Nazirganj Nallah	326	5.22
Chatra Khal, Serampore	28.4	1.45
Bagh Khal, Rishra	18.4	1.03
Telkal Ghat	21.9	3.03
Ramkrishna Mullickghat Road	12.2	1.09
Foreshore Road Martin Burn	17.6	2.48
Kuthighat Belur Math	5.76	0.95
Total	**472.26**	**18.82**

Source: WBPCB

seasons. The bacterial count shows that the river water is highly contaminated by enteric bacteria. Hence the river water may not be directly used for recreational purposes and drinking purposes without proper disinfection. The level of micro-pollutants (trace metals, pesticides etc.) were found to be well within the limit in river Bhagirathi-Hugli.

North Bengal rivers

The North Bengal covering an area of about 21,763 km^2 is drained by four major rivers and their numerous tributaries. The major rivers are Mahananda, Teesta, Jaldhaka and Raidak-Torsa. Mahananda drains to the Ganga, while the other three rivers drain into the Brahmaputra. The rivers have sources in the Himalayas beyond the northern border of West Bengal and they flow southward across Indo-Bangladesh border either into the Ganga or Brahmaputra. The Himalayan rivers debouch on the plains of North Bengal at approximately 300 m contour and the river-valleys become wide. All rivers deposit substantial sediment load in this stretch due to declining slope and flood is an inevitable menace almost every year.

The WBPCB monitors water quality of four rivers of North Bengal. These are Mahananda, Teesta, Kaljani and Karola. The Mahananda has low water levels during summer and winter and goes almost dry in March-April. The river Teesta originates from a glacial lake of North Sikkim at an elevation of 8,550 m. After traversing a length of about 414 km in India and Bangladesh, the Teesta meets the Brahmaputra or Jamuna at Rangpur in Bangladesh. The river Karola is a rain fed river and a tributary of the River Teesta. The Karola river runs almost parallel to the river Teesta for about 45 km and meets Teesta at Jalpaiguri town. The Kaljani is a tributary of the Raidak-Torsa and is also a rain fed river. The analysis of water quality of four major North Bengal rivers is given in Table 8.11:

The DO level in all the four rivers are well above the minimum acceptable level and the BOD level is within the maximum tolerance limit. The waters of these rivers, in terms of bacteriological parameters, are unfit for human consumption. The anthropogenic activities in both sides of these rivers create the major sources of pollution. However, these rivers support a healthy aquatic life in all seasons.

South Bengal rivers

Since these rivers are exclusively rainfed, many of them go dry during lean months. The western plateau is the upper catchment of all major tributaries to Bhagirathi and the areas are regionally covered with lateritic and red soil. Geomorphologically, the catchments have three segments. The upper part is the area of erosion with an adjoining area of sediment transfer and finally the lowermost area of deposition. All major rivers have formed para-deltas before their outfalls into the Bhagirathi and the plains lying to the west of it (i.e. Bhagirathi) is a series of coalescing deltas.

The catchment areas of these rivers have been extensively deforested due to expansion of agricultural land and growth of human settlements. The increasing sediment load has been the major cause of decay of rivers, which are now choked with sand and silt. The combined catchment areas of these tributaries are about 66,000 km^2 and about 30 per cent of that area lies in Jharkhand.

The WBPCB monitors water quality of almost all the major rivers of the South Bengal and those are Damodar, Barakar, Dwarka, Mayurakshi, Dwarkeswar, Kansai, Rupnarayan, Silabati, Churni, Jalangi, Mathabhanga and Vidyadhari. The monitoring results are narrated in Table 8.12.

The dissolved oxygen level in the rivers except Churni, Mathabhanga and Vidyadhari is above the tolerance limit (4.0 mg/l) in all stations. Since the Mathabhanga-Churni remain disconnected from its feeder (Padma) during lean months and receives untreated waste from the Sugar Mills of Bangladesh, the DO in the water remains below the tolerance limit and occasionally

TABLE 8.11 Water quality of the North Bengal rivers

North Bengal Rivers	Stations	DO (mg/l)		BOD (mg/l)		TCC (MPN/100ml)		FCC (MPN/100ml)	
		Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015
Mahananda	Siliguri	8.2	6.3	1.5	3.5	8000	14000	2600	3000
	Ramghat	6.4	6.0	3.5	4.8	14000	220000	5000	110000
Teesta	Siliguri	7.0	8.5	1.2	2.6	3000	7000	1100	3000
Kaljani	Alipurdwar	7.2	7.0	2.1	1.0	7000	14000	3400	3000
Karola	Jalpaiguri	7.8	6.5	1.8	1.8	9000	14000	2700	5000

Source: WBPCB (2015)

TABLE 8.12 Water quality of the South Bengal rivers

South Bengal rivers	Station	DO (mg/l.)		BOD (mg/l.)		TCC (MPN/100ml.)		FCC (MPN/100ml.)	
		Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015	Apr. 2015	Oct. 2015
Damodar	Dishergarh Village	8.7	8.0	1.4	4.8	3000	90000	1700	50000
	Dhenna Village	8.3	7.2	1.9	2.8	3000	22000	2300	17000
	Narainpur	7.6	6.9	2.6	1.4	1400	5000	1400	3000
	Mujher Mana	5.2	6.2	3.4	5.5	35000	2700	28000	2200
	Burdwan Town	7.5	10.8	1.6	6.2	1700	13000	1300	3400
Barakar	Asansol Water Intake Point	8.3	8.3	2.1	1.1	8000	3400	5000	3300
Dwarka	Upstream of Tarapith	4.2	7.8	3.7	3.9	2200	17000	2200	14000
	Downstream of Tarapith	6.0	7.7	5.4	3.6	1100	3400	800	3400
Mayurakshi	Suri Town	6.7	7.1	2.5	3.8	400	3400	400	3300
Dwarkeswar	Bankura	7.4	10.0	2.1	1.0	NIL	3400	NIL	2600
Kansai	Midnapore	9.9	7.7	2.7	2.25	13000	17000	5000	8000
Silabati	Ghatal	5.1	6.7	1.4	2.65	2200	7000	1300	2600
Churni	Majhadia	1.3	2.6	13.5	7.4	1100000	80000	700000	70000
	Santipur Town	3.5	2.1	5.9	8.57	140000	110000	90000	80000
Mathabhanga	Gobindapur	1.5	1.9	14.3	6.8	1700000	110000	1100000	80000
Jalangi	Krishna Nagar	8.7	2.4	2.5	3.86	110000	80000	70000	70000
Rupnarayan	Kolaghat	6.3	5.6	2.1	1.95	13000	28000	5000	14000
	Geonkhali	6.8	6.0	0.75	2.25	2600	160000	1700	30000
Vidyadhari	Haroa	1.2	1.8	11.75	8.12	80000	110000	30000	50000
	Malancha	4.6	1.5	1.2	10.75	50000	50000	23000	30000

Source: WBPCB (2015)

goes down to nil. However, DO level has been found above the tolerance at the confluence with the Bhagirathi. As the river Vidyadhari is highly polluted due to mixing of sewage discharges of North 24 Parganas, the DO level remains much less than the minimum permissible limit during most of the months.

Slightly high BOD level in the Dwarkeswar river is due to high discharge of effluents from hotels and restaurants near Tarapith. The water quality in terms of bacteriological parameters (TCC and FCC) was found to be unsafe for human consumption without any proper treatment. Extremely high level of bacteria was found in the rivers of Churni, Mathabhanga and Jalangi. This is mostly due to surface runoff and domestic waste disposal. The TCC values of river Mayurakshi in April, when river goes almost dry, remain within the national standard. Analysis of water samples for the micro-pollutants (trace metals, pesticides etc.) of all the rivers shows that the level of micro-pollutants always remain well within the limit.

Changing rainfall pattern

Rainfall pattern in West Bengal has changed appreciably over the twentieth century. It is observed from analysis of the rainfall data during the period 1901-2010 that rainfall in the month of June has been declining and that in that in September has been increasing. There is also a tendency of unusually concentrated rainfall which leads

to more runoff and less infiltration. The main findings of the analysis are noted below:

- June precipitation has declined from 1901 to 2010 at the rate of about 1 mm per year in North Bengal.
- In South Bengal June rainfall has declined by about 48 mm and September rainfall has increased about 33 mm.
- Model based predictions for future:
  - Delayed onset of monsoon,
  - Marginal decline in monsoon rainfall.
- Our crop-calendar needs to be adjusted.

Concluding remark

West Bengal, being located at the tail-end of the Ganga basin, is a hydrologically subsidised State, which receives huge volume of transboundary water. But the supply of this water is so skewed that West Bengal bears the brunt of flood during monsoon and faces water-short condition during the lean months. In absence of any regulation regarding equitable sharing of the transboundary water, the withdrawal of water from the rivers by upper riparian states during the lean months has been increasing at an uninterrupted pace leaving meagre share for West Bengal. The National Water Policy (2012) proclaimed *"There is a need for comprehensive legislation for optimum development of inter- State rivers and river valleys to facilitate inter-State coordination ensuring scientific planning of land and water resources taking basin/sub-basin as unit with unified perspectives of water in all its forms (including precipitation, soil moisture, ground and surface water) and ensuring holistic and balanced development of both the catchment and the command areas. Such legislation needs, inter alia, to deal with and enable establishment of basin authorities, comprising party States, with appropriate powers to plan, manage and regulate utilization of water resource in the basins".* This issue should be addressed afresh at the national level. The growth of population and increasing demand of water are intertwined. The increasing population leads to more stress on all natural resources. A plan for revival of our traditional water conservation system would be economically viable and environmentally sustainable. A paradigm shift from present supply side management needs to be relooked and alternate cropping pattern may reduce the demand. The amount of water required to produce 15 quintals of bodo rice can be utilized to produce 36 quintals of wheat and 20 quintals of pulses. The judicious and productive use of scarce irrigation water is important. The National Water Policy (2012) rightly said - "Planning, development and management of water resources need to be governed by common integrated perspective considering local, regional, State and national context, having an environmentally sound basis, keeping in view the human, social and economic needs". A water policy for West Bengal needs to be formulated on top priority.

Increasing population leads to more stress on all natural resources. A plan for revival of our traditional water conservation system would be economically viable and environmentally sustainable.

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Chapter 9

Groundwater

The state of West Bengal covers an area of about 88,752 sq km bounded by latitude 20°31' and 27°14'N and longitude 85°51' and 89°53'E consisting of 20 districts and 341 blocks. The entire area falls under three major river basins – (i) Brahmaputra Basin – part of Darjiling, Jalpaiguri and Koch Bihar districts, (ii) Ganga Basin – part of Darjiling, Jalpaiguri and all the remaining districts, and (iii) Subarnarekha basin – parts of Puruliya, Purba and Paschim Medinipur. The average rainfall in the State is 1,750 mm. In the Himalayan region the average rainfall ranges from 2,500-6,000 mm. In the southern part, the average rainfall ranges from 1,125 to 1,900 mm. The major part of the State is covered by unconsolidated sediments of Quaternary period and the hard rocks comprise only about one-fourth of the total geographical area (Figure 9.1).

The dynamic groundwater resources of the State has been assessed jointly by the CGWB and State Ground Water Department under the supervision of the State Level Committee for 269 administrative blocks, out of the 341 blocks, based on 'stage of groundwater development' and 'long term pre-monsoon and post-monsoon water level trend' as per GEC-97 method. The 72 blocks which have not been assessed are either hilly having slope more than 20 per cent (13 blocks in Darjiling and Jalpaiguri districts) or are in coastal areas where groundwater occurs in confined condition (29 blocks in South 24 Parganas, 5 blocks in North 24 Parganas, 9 blocks in Haora and 16 blocks in Purba Medinipur district) and cannot be assessed by GEC-97 method.

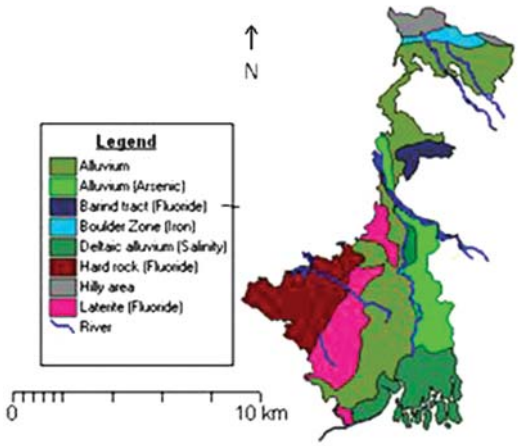

FIGURE 9.1 **Hydrogeology and water quality of West Bengal's groundwater**

The base year of computation of the resources is 2008-09. The dynamic groundwater resource is also known as Annual Replenishable Groundwater Resource since it is replenished/recharged every year.

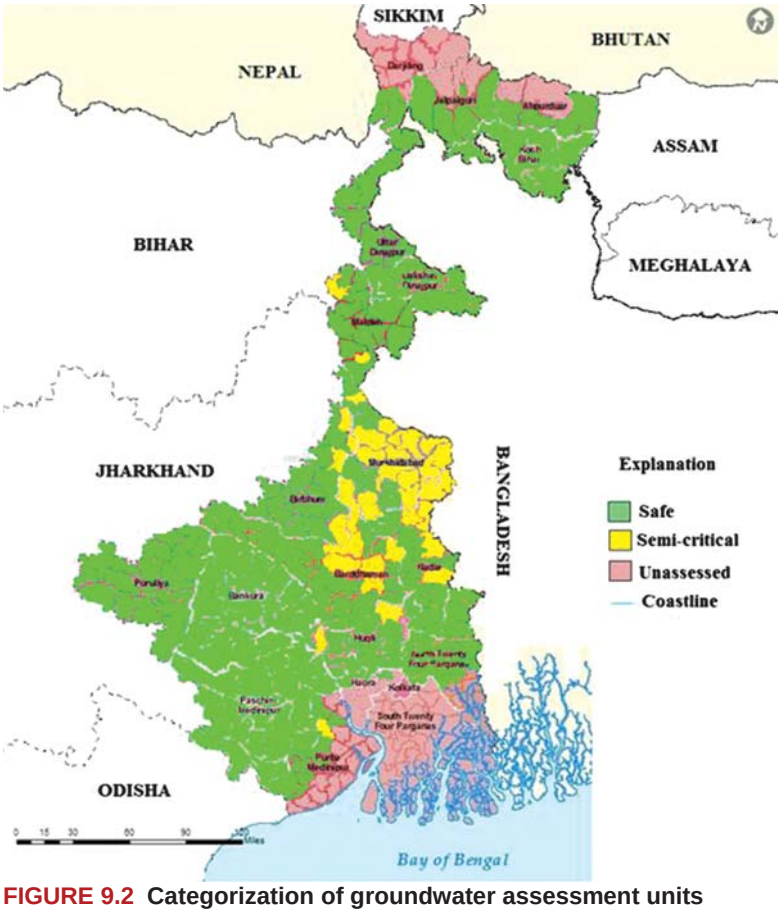

FIGURE 9.2 **Categorization of groundwater assessment units**

The Annual Replenishable Groundwater Resource for West Bengal has been assessed as 30.5 billion cubic meter (bcm). The major source of groundwater recharge is the monsoon rainfall. About 60 per cent of the Annual Replenishable Resource i.e. 18.2 bcm are contributed by monsoon rainfall recharge. The overall contribution of rainfall to country's Annual Replenishable Groundwater Resource is 77 per cent and the share of other sources viz. canal seepage, return flow from irrigation, recharge from tanks, ponds, and water conservation structures taken together is 23 per cent. District-wise groundwater resource of West Bengal as on March, 2009 is given in Table 9.1. South-west monsoon being the most prevalent contributor of rainfall in the country, about 67 per cent of State's annual groundwater recharge takes place during the Kharif period of cultivation. Keeping 2.92 bcm for natural discharge, the net annual groundwater availability for the State is 27.58 bcm. The gross draft for all uses is 10.91 bcm. Therefore, leaving about 1.02 bcm of groundwater for domestic and industrial use to 2025, the net groundwater availability for future irrigation use is 16.75 bcm. The stage of groundwater development for West Bengal as a whole is 39.54 per cent (Table 9.1).

Out of 269 administrative blocks, 38 blocks are categorised as 'Semi-critical' and the rest are 'Safe' (Table 9.2). Categorisation of blocks does not take into account the quality of groundwater. Hence there may be several 'safe' blocks where the groundwater contains high concentration of arsenic, fluoride etc. and hence may not be safe for drinking.

District-wise groundwater scenario

Darjiling district

A major portion of the Darjiling district is characterized by very rugged topography. The northern part comprises part of the Eastern Himalayan range. It is underlain by crystalline rocks and consolidated sedimentary rocks of the Gondwana and Siwaliks. South of the Siwalik range lies a piedmont deposit known as the 'Bhabar' which transgresses southwards into the 'Terai' belt. The 'Terai' further south merges into the alluvial plain. The 'Bhabar' is characterized by the occurrence of thick, laterally extensive area of sediments comprising boulders, cobbles, pebbles mixed with sand and clay. Clay lenses are also present within these assorted sediments. The 'Terai' is also composed of a mixture of cobbles, boulders, pebbles and sands of varying grades.

Presence of these coarse sediments from surface down to a depth of 65 m in the northern parts facilitates direct recharge to the aquifers from precipitation. Groundwater generally occurs under

TABLE 9.1 **Groundwater resources availability, utilisation and stage of development of West Bengal (as on 2009)**

Name of District	Annual replenishable groundwater reso (bcm)					Natural discharge during non-monsoon	Net Annual Ground-water availability (bcm)	Existing Gross Ground-water draft for irrigation (bcm)	Existing Gross Ground-water draft for domestic (bcm)	Existing Gross Ground-water draft for industrial (bcm)	Existing Gross Ground-water draft for all uses (bcm)	Provision for domestic, and industrial requirement supply to 2025 (bcm)	Net ground-water availability for future irrigation develop-pment (bcm)	Stage of groundwater development (%)
	Monsoon season		Non-monsoon season		Total									
	Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
Maldah	0.96	0.05	0.25	0.18	1.44	0.13	1.31	0.49	0.04	0.02	0.55	0.08	0.74	41.71
Nadia	1.12	0.18	0.42	0.49	2.21	0.22	1.99	1.68	0.04	0.02	1.74	0.08	0.35	87.43
Koch Bihar	1.58	0.04	0.61	0.10	2.34	0.23	2.10	0.38	0.03	0.01	0.42	0.05	1.68	19.75
North 24 Parganas	0.95	0.08	0.27	0.23	1.52	0.15	1.37	0.77	0.04	0.02	0.83	0.08	0.51	60.77
Dakshin Dinajpur	0.69	0.05	0.19	0.15	1.09	0.11	0.98	0.42	0.01	0.01	0.44	0.03	0.54	44.28
Uttar Dinajpur	1.18	0.07	0.32	0.20	1.77	0.15	1.62	0.71	0.03	0.01	0.75	0.06	0.85	46.24
Bankura	1.07	0.30	0.28	0.50	2.16	0.20	1.95	0.54	0.03	0.02	0.59	0.06	1.35	30.10
Puruliya	0.53	0.11	0.13	0.06	0.83	0.08	0.75	0.01	0.03	0.01	0.05	0.05	0.68	7.08
Jalpaiguri	1.99	0.02	0.60	0.04	2.64	0.26	2.37	0.07	0.02	0.01	0.10	0.05	2.26	4.42
Barddhaman	1.72	0.37	0.50	0.78	3.37	0.31	3.06	1.45	0.05	0.02	1.52	0.08	1.55	49.67
Murshidabad	1.34	0.19	0.41	0.46	2.40	0.22	2.18	1.63	0.06	0.03	1.72	0.11	0.61	78.87
Birbhum	0.71	0.25	0.19	0.47	1.62	0.15	1.47	0.30	0.03	0.02	0.35	0.06	1.11	23.65
Haora	0.19	0.03	0.06	0.09	0.37	0.04	0.33	0.05	0.01	0.00	0.06	0.02	0.27	18.59
Darjiling	0.39	0.01	0.11	0.02	0.52	0.05	0.47	0.01	0.01	0.00	0.02	0.01	0.45	3.98
Hugli	0.88	0.18	0.25	0.36	1.67	0.17	1.50	0.49	0.04	0.02	0.55	0.07	0.94	36.37
Purba Medinipur	0.55	0.02	0.15	0.08	0.80	0.08	0.72	0.19	0.02	0.01	0.22	0.04	0.49	30.43
Paschim Medinipur	2.31	0.22	0.70	0.52	3.75	0.36	3.39	0.93	0.05	0.03	1.01	0.10	2.37	29.66
State Total	**18.16**	**2.17**	**5.44**	**4.73**	**30.50**	**2.91**	**27.56**	**10.12**	**0.54**	**0.26**	**10.92**	**1.03**	**16.75**	**39.54**

Source: CGWB and SWID, 2011

TABLE 9.2: Categorization of the Blocks of West Bengal

Name of District	No. of Assess-ment Block	No. and Categorization of Assessment Block			
		Safe	Semi-critical	Critical	Over-exploited
MaldaH	15	13	2	0	0
Nadia	17	11	6	0	0
Koch Bihar	12	12	0	0	0
North 24 Parganas	17	17	0	0	0
Dakshin Dinajpur	8	8	0	0	0
Uttar Dinajpur	9	9	0	0	0
Bankura	22	22	0	0	0
Puruliya	20	20	0	0	0
Jalpaiguri	8	8	0	0	0
Barddhaman	31	25	6	0	0
Murshidabad	26	9	17	0	0
Birbhum	19	15	4	0	0
Haora	5	5		0	0
Darjiling	4	4		0	0
Hugli	18	16	2	0	0
Purba Medinipur	9	8	1	0	0
Paschim Medinipur	29	29	0	0	0
Total	**269**	**231**	**38**	**0**	**0**

Source: CGWB and SWID, 2011

unconfined condition with a hydraulic gradient from north to south. Groundwater occurs at a deeper level in the 'Bhabar' compared to that of the 'Terai' and fluctuation of the water table is also less in the 'Terai'. In deeper aquifers, groundwater occurs under confined condition. Near Naxalbari, yield of tubewells is about 120 m^3/hr. In Siliguri within a depth span of 150 m the yield of wells ranges from 60-114 m^3/hr. Groundwater potentiality in the district gradually improves towards south, especially south of Siliguri. The transmissivity of the aquifer in and around Siliguri ranges between 100-472 m^2/day and hydraulic conductivity ranges between 1.41-10.00 m/day.

Jalpaiguri district

Jalpaiguri district has a rugged topography. The extreme northern part of the district is underlain by crystalline metamorphics of the Himalayan range. It is followed southwards by a wide zone of piedmont deposits called the 'Bhabar' and the 'Terai', which in turn merge with the southern alluvial plains. The piedmont zone consists of unconsolidated assorted material ranging in size from gravels, pebbles and cobbles. These materials were brought down by the torrential hill streams like Raidak, Torsa and Teesta emanating from the Himalayas. In the subsurface very coarse material, mainly boulders occur down to an average depth of 65 m. Below this, granular zone consisting of gravel, pebbles and boulders are encountered with thin lenses of clay. Deep and shallow tubewells can be constructed. Deep tubewells within the depth span of 130 m below ground level (bgl) are capable of yielding water up to 250 m^3/hr. The hydraulic conductivity and transmissivity ranges between 13-84 m/day and 795-3,800 m^2/day respectively.

Koch Bihar district

Koch Bihar district is underlain by a thick fluviatile deposit of Quaternary age consisting of a thick succession of boulders, pebbles, fine to coarse sand with varying proportion of clay down to a depth of 290 m bgl. Presence of granular sediments has facilitated direct infiltration of rainwater into the groundwater body and hence groundwater occurs in an unconfined condition. The hydraulic conductivity and transmissivity varies between 21-340 m/day and 957-14,000 m^2/day. The average yield of the tubewells in this district is 150 m^3/hr.

Uttar and Dakshin Dinajpur districts

The two districts are underlain by fluviatile sediments composed of sand, silt, clay and gravels increasing in thickness from north to

south. In the south-western part of Dakshin Dinajpur district 'Barind' is exposed. Siwaliks underlie the alluvium, which in turn are underlain by the Archaean metamorphics. Groundwater occurs under unconfined condition in a single aquifer of coarse to medium sand and gravel of more than 100 m thickness in Uttar Dinajpur district. The yield of the tubewells is >150 m^3/hr. In the Dakshin Dinajpur district, groundwater occurs under semi-confined to confined condition in the fine to medium sand aquifers interlayered by thin clay beds. The cumulative thickness of the aquifer in this district is 50–70 m. The yield of the aquifer in the Recent Alluvium is moderate to large varying between 50-150 m^3/hr and at places even higher. In the Older Alluvium the yield is moderate to large (50–150 m^3/hr). The transmissivity of the aquifer in general ranges between 379-2,047 m^2/day for both the districts.

Maldah district

Maldah district is located in the Garo-Rajmahal Gap, separating the deltaic West Bengal in the south and is underlain by Quaternary alluvial deposits of two different ages. The Older Alluvium lies to the east of river Mahananda forming the 'Barind' upland tract. A small pocket of Barind is also observed on the western bank of the river Mahananda in and around English Bazar Municipality. The Recent Alluvium lies to the west of the River Mahananda. Sub-surface lithological data reveals that the thickness of the silt and clay layer at the upper part of the lithologic column ranges 3-15 m in the Recent Alluvium area and the thickness of this layer gradually increases towards the Older Alluvium area. The upper silt and clay layer is underlain by fine sand of 10-20 m thick, which in turn is again underlain by medium to coarse sand of various thicknesses. Generally, groundwater in the district occurs under unconfined condition. Several promising saturated granular zones are present in the depth span of 17-178 m bgl. The potentiality of the groundwater in the Older Alluvium is very low. The discharge of the tubewells ranges between 10-47 m^3/hr. In the Recent Alluvium the discharge of the tubewells ranges between 180-200 m^3/hr. Transmissivity of the aquifers varies between 758-2,969 m^2/day.

Birbhum district

In Birbhum district the rock types that are exposed from west to east are hard crystalline rocks of Archaen age, Gondwana deposits of Permo-carboniferous to middle Jurassic age, Rajmahal Trap of Jurassic to Cretaceous age, Laterite and Older Alluvium of Pleistocene age and Recent to sub-recent Alluvium deposits. In the crystalline rocks, groundwater occurs under unconfined condition in weathered residuum and in semi-confined condition in fractures within a depth of 100 m bgl. The yield of dug wells in weathered residuum is around 5 m^3/hr whereas in the fractures tapped by bore wells it is <20 m^3/hr. In the Gondwana rocks, groundwater occurs in the fractured rocks under semi-confined condition to confined condition within 100 m bgl with tubewells yielding 10-22 m^3/hr of water. In the Rajmahal Trap, water bearing fractures are encountered at depths >75 m bgl and yield of wells varies between 15-20 m^3/hr. In the Laterite and Older Alluvium, groundwater occurs under unconfined to semi-confined condition having limited yield of 5-15 m^3/hr and is abstracted mainly by dug wells. A deep confined aquifer of Tertiary age exists at a depth range of 100-400 m bgl having yield prospect of 80 m^3/hr. In the Recent Alluvium deposits groundwater occurs under unconfined to semi-confined condition with yield prospects up to 150 m^3/hr.

Murshidabad district

The district is underlain by a sequence of Quaternary alluvium. The area lying to the

west of the River Bhagirathi is mainly covered by Older Alluvium deposited by Ajoy-Mayurakshi-Damodar river system. These deposits are characterized by yellowish brown sand, silt and clay. Groundwater occurs both under unconfined and confined conditions. In the north-western part of the district, Pleistocene deposits represented by laterite, lithomerge and clay occur above the level of recent flood plains. The area to the east of the river Bhagirathi is mainly covered by Recent Alluvium. Two major sand bearing horizons occur down to a depth of 100 m from the ground surface. The upper horizon occurs from 12-45 m bgl and is composed of fine sand. The lower horizon from 45 to 75 m from the ground surface is composed of medium to coarse sand. This is a potential zone and tubewells tapping these granular zones yield about 225 m^3/hr for 3-7 m drawdown. Groundwater in the eastern part of the district occurs in a thick zone of saturation under unconfined condition. Generally this zone extends down to 157 m bgl. It is one of the most potential areas for groundwater development. The aquifer materials are generally gravel and sands of varying texture. The transmissivity of the aquifer in Murshidabad district varies from 2,459-6,264 m^2/day. Tubewells are capable of yielding 200 m^3/hr of water. The depth of tubewells in Older Alluvium is about 200 m. In Recent Alluvium generally these are constructed within 120 m depth.

Nadia district

This district is underlain by a thick pile of unconsolidated sediments of Quaternary age. The area is more or less flat often broken by numerous river cut-offs which from local depressions. The subsurface sediments are composed of sands of various textures with occasional gravels up to a depth of 180 m. Groundwater occurs in these sediments under unconfined condition. The transmissivity of the aquifer varies from 3,497-13,951 m^2/day. The tubewells constructed within 150 m depth are capable of yielding about 200 m^3/hr of water.

Bankura and Puruliya districts

Groundwater in Puruliya district and in the western part of Bankura district occurs under unconfined condition in the weathered residuum and in semi-confined condition in the fractures, fissures and joints of the Achaean crystalline rocks. There are three sets of joints in the bed rock. These joints strike NE-SW, E-W and N-S with steep dips. The opening of the joints is ≥1 mm and acts as conduit for groundwater circulation. In Puruliya district, two more or less parallel shear zones occur in the district with roughly E-W trend. The more prominent one occurs in the southern part of the district and the other less prominent one in the northern part of the district. The weathered residuum is within 15 m bgl and is developed by dug wells having limited yield of 5 m^3/hr. In Puruliya district, the average yield of dug wells in granite gneiss and mica schist is 4.80 m^3/hr and 0.92 m^3/hr respectively. The fractures within a depth of 100 m bgl is developed by bore wells or dug cum bore wells with a discharge of 20 m^3/hr. Large diameter dug well pumping tests in the Hanumata, Nangasai and Sanka sub-basins of Puruliya district reveals that the transmissivity of the unconfined aquifer ranges between 2-12 m^2/day. In Bankura district, large diameter dug well pumping tests also reveal that the aquifer in the Archaean crystalline rocks is of low potentiality with transmissivity varying between 7-34 m^2/day.

The central part of Bankura district is covered by laterite and Older Alluvium of Pliestocene age. Here laterite, lithomerge and sands of various grades are usually intercepted down to depths of 20-25 m below land surface. Around Bishnupur, tubewells fitted with hand pumps have been constructed down to a depth of 60-70 m

bgl. They tap 6-9 m thickness of saturated, coarse to medium sand. Westwards around Bheduasol, the depths of tubewells are within 15 m bgl below within granite gneiss. Groundwater occurs under unconfined to semi-confined condition having limited yield of 5-15 m^3/hr. There is a deep confined aquifer of Tertiary age at a depth range of 100-400 m bgl having yield of 80 m^3/hr.

The eastern part of Bankura district is covered by alluvium consisting of a succession of coarse to fine sand, silt and clay. The depth of alluvium generally increases towards the east from 80 m near Govindapur to 435 m near Rupatganj. Aquifers are fairly thick, regionally extensive and confined in nature with yield of up to 150 m^3/hr. Artesian condition is found to exist in certain parts along the Rivers Dwarkeswar, Jaipanda and Chanpa. The aquifer characteristics improve from west to east and southeast. Transmissivity of the aquifer in the eastern part of the district varies between 273-806 m^2/day.

The Lower Gondwana rocks of Raniganj Coalfield extend to the northern extremity of the two districts. The rocks are mainly coarse feldspathic sandstones with interbedded grey shales containing plant fossils. A few coal seams are also found within this formation. The average yield of sandstone formation is 16 m^3/hr.

Barddhaman district

Hydrogeologically Barddhaman district can be divided into three units. They are (i) Lower Gondwana terrain of the Raniganj Coalfield in the west in Asansol–Baraboni area, (ii) Central Tertiary and Older Alluvium zone in Durgapur area, and (iii) Recent Alluvial plain in the east.

In the Lower Gondwana terrain, groundwater occurs in the zone of weathered residuum and in joints, cracks and fissures of sandstones and shales. Transmissivity of the sandstone aquifers ranges between 50-200 m^2/day. In the Tertiary rocks, groundwater mainly occurs under unconfined condition in the weathered residuum and in fractured and fissured zones. The Tertiary rocks are poor repositories of groundwater. Within these Tertiary rocks, there are small alluvial pockets capable of yielding moderate supplies of water. The alluvial fill gradually increases towards east and northeast of Durgapur. The yield of tubewells in these Older Alluvial formations east of Durgapur is on an average 90 m^3/hr for about 6 m of drawdown.

The alluvial tract in the flood plains of Ajoy-Damodar-Mayurakshi-Hugli river system is the most important from the point of groundwater development. This alluvial tract, east of Panagarh-Illambazar road, has on an average a minimum thickness of unconsolidated sediments of about 210 m. It progressively increases towards east and northeast. Towards west and northwest, the thickness dwindles as the rocks of the Tertiary-Gondwana–Archaean systems are approached. The alluvium comprises alternating coarse to fine sands, silt, and clay with occasional gravels and pebbles. These granular materials within the alluvium are good repositories of groundwater and are extensively tapped by means of heavy-duty tubewells. Groundwater in the shallow aquifers occurs under unconfined condition and under confined condition in the deeper aquifers. The transmissivity of the aquifer is of the order of 750 m^2/day. The yield of tubewells varies between 20-300 m^3/hr.

The alluvial tract in the flood plains of Ajoy-Damodar-Mayurakshi-Hugli river system is the most important from the point of groundwater development

Hugli district

The district is underlain by alluvial sediments of Quaternary age consisting of a succession of clay, silt, sand of various textures and occasional gravel. The sediments are mostly clayey in the western and southern parts and sandy in the

northern part. The area to the north of Tarakeswar-Singur road is mainly underlain by sand of varying texture from land surface down to a depth of 154 m with minor clay partings. The most striking feature of the sub-surface geology of the district is the occurrence of a thick clay bed below 170 m. This has been found to continue even beyond the depth of 457 m.

Groundwater occurs under unconfined as well as under confined condition. The entire district is considered the most promising belt for large-scale groundwater development. Shallow tubewells tap the aquifer in the depth range of 45-80 m bgl comprising medium to coarse sands. Heavy duty tubewells are capable to yield about 250 m^3/hr. Pumping tests carried at two places in the eastern part of the district at Tribeni and Sahaganj indicate that the hydraulic conductivity and transmissivity of the confined aquifer ranges between 92-214 m/day and 4,128-5,409 m^2/day respectively.

The entire Hugli district is considered the most promising belt for large-scale groundwater development

Haora district

The district is underlain by a thick pile of alluvial sediments of Quaternary age consisting mainly of clay, silt, sands of various grades and occasional gravels. In Uluberia–Bauria–Kona tract confined aquifers generally occur up to the depth of 300 m below which thick bluish clay occurs up to a depth of 450 m. The upper confining clay bed which is 30–70 m thick, occur just below the land surface and shows a tendency to increase in thickness towards east. In about 300 sq km area in parts of Jagatballavpur and Udainaryanpur blocks, a fairly thick granular zone occurs right from the surface. Salinity in groundwater especially in the shallow zone is pronounced in Uluberia and Panchla and in few places in Jagatballavpur. Fresh groundwater occurs in the depth range of 50-224 m except in Shyampur block where fresh groundwater has been encountered at depth ranging 198–269 m. Pumping tests carried out at various locations of the district reveals that the transmissivity of the confined aquifer varies between 446-1,872 m^2/day and the discharge of the tubewells on an average is 200 m^3/hr.

Kolkata

Groundwater in Kolkata city occurs in a confined condition. An aquiclude represented by clay and silty clay with an average thickness of 40 m occurs at the upper part of the sedimentary sequence. This aquiclude is underlain by coarse clastics of 300 m thickness consisting of sands mixed with gravel. These coarse clastics form the aquifer material. Below these coarse clastics, there is again a clay bed whose thickness is over 300 m. Because of the presence of clay beds at the top and bottom, the groundwater in the Kolkata's aquifer occur under confined condition. Pumping tests carried out at six locations in Kolkata reveal that the potentiality of the aquifer to transmit water decreases from north to south. In the extreme northern portion of the city at Sinthi, the transmissivity is 7,774 m^2/day whereas it is 1,560 m^2/day in the extreme south at Bansdroni. Groundwater resource of the city is being developed on a large scale since the late fifties. As a result of this development, there has been a noticeable change in the groundwater flow pattern (Figure 9.3). The change over from an open N-S natural groundwater flow pattern of the fifties to the present closed system is clearly a result of uncontrolled human activities involving overdraft of groundwater in this area. The average daily overdraft relative to a recharge of 218.5 million litres of groundwater is estimated at 73.5 million litres. Due to this over withdrawal, the theoretical land subsidence in Kolkata ranges between 7-14 mm/year. In and around East Kolkata Wetlands the theoretical land subsidence ranges between

1.12-43.8 mm/year with a mean of 13.53 mm/year. Though clearly visible evidence has not yet been recorded in the city, continuous over-pumping of the aquifer may spell danger in the near future.

Groundwater modelling indicates that the hydrology of the region is particularly sensitive to pumping because of the low natural hydraulic gradients that result from the relatively flat fluvial-deltaic morphology. The general south-easterly groundwater flow driven by the regional water table topography in the unperturbed pre-pumping system changed significantly when extensive pumping began in Kolkata forming local depressions in the hydraulic head pattern. Under simulated natural pre-pumping flow conditions, groundwater at a depth of 100 m in Kolkata city was recharged from distant locations in the northwest, where the groundwater is arsenic-free, whereas at present, the recharge areas have migrated towards the pumping centres, where groundwater at places is arsenic polluted.

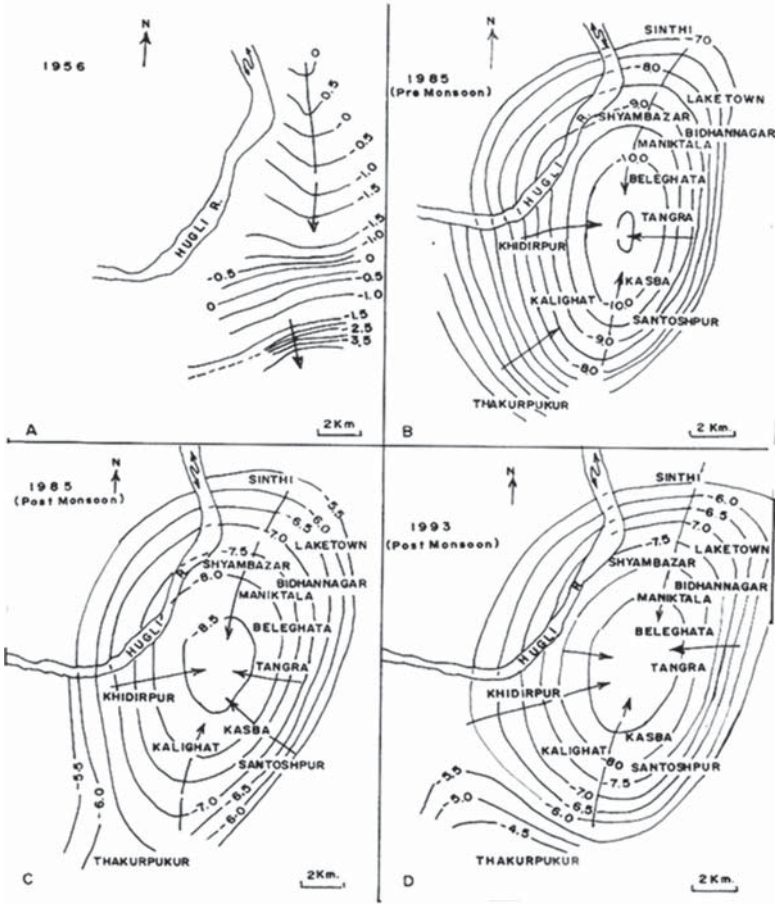

FIGURE 9.3 Changing groundwater flow system of Kolkata
(arrows indicate groundwater flow direction)

Paschim and Purba Medinipur districts

The geohydrological set up of Paschim Medinipur is quite similar to Bankura district. Eastwards the lateritic highland merges with the deltaic plain of the Ganga in the Purba Medinipur district. Rivers Rupnarayan and Subarnarekha constitute the eastern plain of the Purba Medinipur district and this plain extends right up to the Bay of Bengal.

Paschim Medinipur district is characterized by an undulating terrain covered by hard rocks in the north-western part, lateritic upland and Older Alluvium in the eastern and south-eastern parts. Exploratory boreholes in the eastern part of this district indicate that within the depth of 300 m the Pleistocene Older Alluvium is underlain by Upper Tertiary rocks. These comprise clay, sand and siltstones with streaks of lignite. The thickness of the Tertiary sediments increases towards east in Purba Medinipur district. Groundwater occurs under unconfined condition in the crystalline rocks in Paschim Medinipur district. In the older sedimentary sequence the deeper aquifers occur under confined condition being overlain by a 20–40 m thick clay bed. Artesian condition has been observed in the low lying areas of the Silai and Kaleghai basins. The principal water bearing zones consisting of coarse sediments occur at a depth range of 21–149 m. The yield of heavy duty tubewell tapping confined aquifer is 90-136 m^3/hr of groundwater for a drawdown of 6-10 m. Aquifers occurring in the northern part of the district have the low potentialities as indicated by transmissivity value of 43 m^2/day. The aquifers occurring in the eastern part have high transmissivity ranging 1,760-4,106 m^2/day, while in the northern part the value varies between 108-698 m^2/day. In the

central part the transmissivity of the aquifers is on an average 400 m^2/day.

In Purba Medinipur district around Tamluk, Contai and Digha a number of aquifers have been encountered. The aquifer consists mostly of medium to coarse sand. Fresh aquifers occur within the depth span of 120-300 m sandwiched between saline aquifers. The upper saline-water bearing aquifers are separated generally from the underlying fresh water group of aquifers by a 20 m thick impermeable clay layer. In Tamluk town, a number of 15 cm diameter tubewells with 15-22 m screens has been sunk in the depth span of 131-174 m bgl. The yield of theses tubewells ranges between 30-110 m^3/hr. In Digha the aquifers within the depth of 8-100 m have been found to be saline but aquifers below the depth of 100 m contain fresh water. The water in granular zones above 8 m is again fresh. In Contai, salinity hazard in the upper aquifers have been recorded only in Khajuri block in the depth range of 61-137 m bgl. At Panskura, fresh aquifers are encountered in the depth range of 122-183 m bgl above which saline groundwater occurs. The aquifer materials are coarse to fine sand with intervening clay lenses. Yield of tubewells tapping these aquifers is 200 m^3/hr for about 6 m of drawdown. In the Panskura–Debra area, the aquifer material of the deeper fresh water aquifer crops up to the surface and hence the aquifer becomes unconfined in nature. At Mahisadal, fresh water aquifers are encountered at a depth range of 113-171 m bgl. The aquifer materials are mainly fine to coarse sand with intervening clay lenses. Discharge of tubewells is about 170 m^3/hr for a drawdown of about 5 m.

The Haldia Municipality Area (HMA) falls under the Development Authority forms a part of the coastal plain blocks of Purba Medinipur district. In this area, fresh aquifers generally occur in the depth range of 120-220 m bgl. Here saline groundwater body overlies the fresh groundwater. Studies have indicated a steep fall in piezometric surface to the tune of 5-7 m during 1970–2000 due to over-development of groundwater resources for industrial and community uses in Haldia and adjacent industrial area. As a result, ingress of saline water into fresh water aquifers had occurred because of the close proximity of the area to the Bay of Bengal. Central Ground Water Authority had therefore notified "Haldia Industrial Complex", Haldia, District-Medinipur, West Bengal as 'Notified Area' for regulation of groundwater abstraction vide public notice 8/2000 published in August 2000 under section (v) of the sub–section 2 of section 3 of the Environment (Protection) Act, 1986.

North 24 Parganas district

The district is bounded by the River Hugli in the west and the River Ichhamati in the east. The area is flat with land surface rising hardly 3-4 m above the mean sea level. Numerous low-lying depressions in the form of marshes, cut off lakes, etc. are abundant. The entire district is covered by Quaternary sediments consisting of clay, silt, sand, gravel and occasional 'kankar' down to great depths. In the northern part of the district these sediments are encountered at least down to a depth of 250 m bgl. Around Salt Lake and Rajarhat, a thick horizon of coarse sand and gravel is encountered in the depth range of 67–168 m. In the northern part around Habra-Gobardanga-Swarupnagar area where the top clay is either very thin or has pinched out, groundwater occurs under unconfined condition in the depth range of 3–74 m bgl. In Barasat–Deganga-Basirhat, groundwater occurs in the depth range of 28–65 m bgl with a conspicuous clay capping and hence the aquifer is under confined condition. The aquifer, which is unconfined in nature up to Kanchrapara, becomes confined in the area south of Kanchrapara and occurs under a thick blanket of impermeable sticky clay ranging in thickness 15-60 m. The transmissivity of the aquifer varies between 5,227-8,139 m^2/day.

South 24 Parganas district

South 24 Parganas is a vast low lying alluvial plain drained by a network of rivers, tidal channels and creeks which are often interconnected. Groundwater occurs in a confined condition as the water bearing formations are overlain by a thick blanket of clay aquiclude below the land surface. The thickness of this aquiclude varies between 15-75 m. A thick multi-aquifer system comprising sands of various thicknesses alternating with thin clay layers exists below the upper clay bed down to a depth of 400 m bgl. In Sundarbans, aquifers yielding potable water exist in the depth span of 195-275 m and appear to be fairly persistent in aerial extension between the eastern bank of the River Hugli and western bank of the River Matla. They are probably in continuation with those occurring below Sagar and Kolkata. The aquifers in the area are fairly productive. In Kakdweep-Tangrabichi area, the yield varies between 136-150 m^3/hr with a drawdown of 1.5-15 m. The transmissivity of aquifer below Kakdweep is around 1,232 m^2/day.

A study of the hydrological features clearly indicates that the surface water system does not have any hydraulic continuity with the deeper fresh groundwater system to a significant level in the entire lower deltaic region. However, the top clay bed sometimes contains red silt or fine sand beds. In some localities, the groundwater from these beds is extracted through dugwells and wells fitted with hand pumps for very limited domestic purpose. The water table of these zones seems to be either in equilibrium or in effluent relation with the river system. Considering the range of tidal fluctuation and the very low level of land in respect of the river water level, it is possible that in some areas south of Diamond Harbour and Canning, temporary influent nature may develop during the high tide period. During the high tide if the river water level comes above the water table the river water starts to penetrate the formations. The overall permeability of the formations in the shallow level is very low due to its predominantly clayey nature and so the extent of penetration is very limited. During low tide in such areas the micro-flow system along the river will be reversed and the groundwater will start to flow towards the river. So the ultimate limit of penetration of the river water to the over bank formations, if any, will be restricted within a very short distance say 200-500 m. Thus the non-biodegradable pollutant from the river Hugli should not be polluting the shallow level groundwater system to any appreciable extent. In any case, the groundwater is not being used in any domestic, industrial, irrigational purposes in this region. As already pointed out, the water of the deep groundwater reservoir is hydraulically disconnected from the river and has its sources in the upland region and there is no possibility of estuarine Hugli water contaminating these deep reservoirs of groundwater.

Groundwater abstraction for irrigation
Source: Kalyan Rudra

Water of the deep groundwater reservoir is hydraulically disconnected from the River Hugli and has its sources in the upland region and there is no possibility of estuarine Hugli water contaminating these deep reservoirs of groundwater

The mode of occurrence of groundwater in the Sagar Island is almost similar to that of groundwater occurring in the coastal tracts of the district of South 24 Parganas. The island has some complex geohydrological problems and peculiar hydrochemical situation prevailing within it, as it is entirely surrounded by brackish to saline estuarine water. A ubiquitous blanket of highly plastic, sticky clay, which locally grades into silty clay and clayey silt, underlies the ground surface of the island. The thickness of this layer varies between 4-25 m and being impervious, effectively prevents any local recharge of groundwater. Below this clay blanket, a huge succession of unconsolidated sediments of fluvio-tidal and marine origin continues up to depth of at least 600 m bgl. The sediments comprise light grey to yellowish grey, sticky, plastic clay; yellowish grey to deep grey coloured silt; yellowish grey, deep grey and white coloured medium to fine grained sands; and occasional beds of angular to sub-rounded gravels. Within these thick sediments there are 8-10 aquifers, varying in thickness 9-30 m and occurring within a range of 12 m to nearly 400 m bgl. These aquifers can be classified into two distinct groups on the basis of water quality. The shallower group of aquifers occurs within 180 m bgl are generally restricted to a depth range of 55-165 m bgl and yield mostly brackish groundwater unfit for human use. On the other hand, the deeper group of aquifers occurs beyond 180 m bgl and generally restricted to a depth range of approximately 265-375 m bgl are the potential sources of fresh water. The upper group of brackish water bearing aquifers and the lower group of fresh water bearing aquifers are separated from each other by a thick and persistent layer of impervious clay horizon, which occurs within 180-200 m bgl and has an approximate thickness of around 30 m. The groundwater in the deeper aquifers is under confined condition and is tapped by small diameter tubewells fitted with handpump.

Groundwater level and fluctuation

The water level data measured during various times of the year in 2013-14 in more than one thousand wells throughout West Bengal (Table 9.3) indicate that during summer, the water level of majority of the wells lie at a depth of 5–20 m. During August and November, the water level

TABLE 9.3 Depth to water level and distribution of percentage of wells in West Bengal

Period	No. of wells analysed	Depth to water levels (m bgl)		Number of wells showing depth to water level (m bgl) in the range of					
				0-2	2-5	5-10	10-20	20-40	>40
		Min.	Max.	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Pre-monsoon 2013	1120	0.33	31.43	29 (2.59)	295 (26.34)	461 (41.16)	286 (25.54)	49 (4.38)	0 (0)
August 2013	1014	0.00	25.65	287 (28.30)	393 (38.76)	194 (19.13)	124 (12.23)	16 (1.58)	0 (0)
November 2013	1030	0.00	22.60	284 (27.57)	426 (41.36)	225 (21.84)	89 (8.64)	6 (0.58)	0 (0)
January 2014	1012	0.11	26.93	88 (8.70)	487 (48.12)	281 (27.77)	139 (13.74)	17 (1.68)	0 (0)

Source: CGWB, 2014

TABLE 9.4 **Annual fluctuation and percentage distribution for different ranges for water level in West Bengal**

Period	No. of wells analysed	Range in m				Rise (m)			Fall (m)			Rise	Fall	Wells showing no changes
		Rise		Fall		0-2	2-4	>4	0-2	2-4	>4			
		Min.	Max.	Min.	Max.	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Pre-monsoon 2013 to Pre-monsoon 2012	630	0.03	8.52	0.01	9.65	181 (28.78)	32 (5.09)	9 (1.43)	337 (53.58)	49 (7.79)	21 (3.34)	222 (32.59)	407 (64.7)	0 (0)
Aug. 2013 to Aug. 2012	738	0.01	13.84	0.01	12.99	298 (40)	62 (9)	76 (10)	238 (32)	42 (6)	15 (2)	436 (59)	295 (40)	7 (1)
Nov. 2013 to Nov. 2012	765	0.01	14.13	0.01	11.70	432 (56.47)	120 (15.69)	62 (8.10)	125 (16.34)	15 (1.96)	11 (1.44)	614 (80)	151 (20)	0 (0)
Jan.2013 to Jan. 2014	766	0.01	10.82	0.01	20.75	430 (56.14)	86 (11.23)	30 (3.92)	178 (23.24)	17 (2.22)	21 (2.74)	546 (71)	216 (28)	4 (1)
Pre-monsoon 2013 to Aug. 2013	921	0.01	22.04	0.04	11.57	255 (28.00)	343 (37.00)	27.2 (30.00)	37 (4.00)	7 (1)	6 (1)	870 (95)	50 (5)	1 (0)
Pre-monsoon 2013 to Nov. 2013	917	0.01	21.09	0.01	10.31	209 (23.00)	336 (37.00)	340 (37.0)	26 (3)	2 (0)	4 (0)	885 (97)	32 (3.0)	0 (0)
Pre-monsoon 2013 to Jan. 2014	903	0.01	15.85	0.01	12.25	357 (40)	284 (31.0)	175 (19)	65 (7)	7 (1)	13 (1)	816 (90.00)	85 (9.00)	2 (0)

Source: CGWB, 2014

TABLE 9.5 **Decadal water level fluctuation and percentage distribution for different ranges for water level in West Bengal**

Period	No. of wells analysed	Range in m				Rise (m)			Fall (m)			Rise	Fall	Wells showing no changes
		Rise		Fall		0-2	2-4	>4	0-2	2-4	>4			
		Min.	Max.	Min.	Max.	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Mean [Pre-monsoon (2003-12)] and Pre-monsoon 2013	755	0.01	6.55	0.01	13.87	216 (28.61)	43 (5.70)	9 (1.19)	356 (47.15)	91 (12.05)	40 (5.30)	268 (35.50)	487 (64.50)	0 (0)
Mean [Aug. (2003-12)] and Aug. 2013	791	0.01	13.42	0	20.67	309 (39.1)	43 (5.4)	44 (5.6)	284 (35.9)	78 (9.9)	31 (3.9)	396 (50)	393 (50)	2 (0)
Mean [Nov. (2003-12)] and Nov. 2013	809	0.01	13.8	0.01	11.7	432 (53.40)	76 (9.4)	25 (3.1)	208 (25.7)	44 (5.4)	24 (3.0)	533 (66)	276 (34)	0 (0)
Mean [Jan. (2004-13)] and Jan. 2014	822	0.01	9.44	0.01	20.75	429 (52.2)	64 (7.8)	13 (1.6)	236 (28.7)	45 (5.5)	34 (4.1)	506 (62)	315 (38)	1 (0)

Source: CGWB, 2014

TABLE 9.6 District wise average rainfall and water level data of assessed Blocks

District	Average Rainfall (mm)	Average Pre-monsoon water level (m bgl)			Average Post-monsoon water level (m bgl)			Average Fluctuation (m)		
		Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Maldah	1453	3.99	17.54	7.36	2.07	12.54	4.62	1.20	5.55	3.05
Nadia	1474	4.38	6.90	5.33	2.23	3.93	2.86	1.87	2.97	2.47
Koch Bihar	3608	3.12	4.27	3.91	2.41	3.63	2.85	0.55	1.50	1.06
North 24 Parganas	1523	3.77	8.56	5.39	1.61	6.13	2.99	-0.25	4.06	2.40
Dakhin Dinajpur	1690	6.00	12.15	8.39	1.87	4.73	3.74	2.24	8.09	4.59
Uttar Dinajpur	2087	3.19	5.63	4.38	1.74	3.29	2.56	0.77	3.40	1.83
Bankura	1422	3.70	12.14	6.58	2.54	5.89	3.40	1.01	8.05	3.24
Puruliya	1276	5.41	11.39	6.94	2.61	4.55	3.24	1.78	6.84	3.69
Jalpaiguri	3319	3.41	4.85	3.98	1.90	3.93	3.12	0.04	1.76	0.86
Barddhaman	1496	2.89	16.57	8.83	0.00	12.95	5.54	-1.0	15.00	3.28
Murshidabad	1417	4.18	16.93	8.27	1.53	15.12	4.94	0.20	6.02	2.95
Birbhum	1289	4.12	14.57	8.52	2.08	9.98	5.21	0.83	5.26	3.30
Haora	1625	8.77	12.83	10.39	5.38	6.94	5.96	3.04	5.89	4.42
Darjiling	2829	4.32	4.52	4.42	2.45	2.53	2.49	1.87	1.99	1.93
Hugli	1523	7.17	17.13	12.48	4.68	9.31	6.58	1.96	8.72	5.90
Purba Medinipur	1629	11.90	15.06	13.27	4.23	8.68	6.83	4.49	7.67	6.43
Paschim Medinipur	1560	1.83	15.07	9.30	2.84	6.39	4.72	-2.80	9.57	4.59

Source: CGWB and SWID, 2011

shallows up and lies at a depth range of <5 m. In January 2014, the majority of the water level again falls and rests at a depth range of 2-10 m.

A comparison of depth to water level of 2013 with 2012 reveals that in general there is a fall in the water table in the pre-monsoon period in about 65 per cent of the analysed wells, the maximum being in the range of 0-2 m, in the monsoon the water table recovers in 59 per cent wells and in January and November, majority of the wells show rise in the water table (Table 9.4). In 2013, the rise in water table is observed in 95 per cent of the wells with the onset of monsoon the maximum being in the range of 2-4 m and continues in November (97%) and January (90%). This indicates that the unconfined aquifers in West Bengal are sufficiently recharged to cope with over-extraction in the hot summer months.

A comparison of depth to water level of pre-monsoon 2013 with decadal mean pre-monsoon (2002-2012) reveals that in general, there is decline in the water level in West Bengal in the range of 0-2 m in >64 per cent wells (Table 9.5). Similar comparison for August reveals that the decline in the water level is observed in 50 per cent of the wells. On the other hand, decadal level comparison of the water for November and January reveals that there is a rise in the water level in 66 per cent and 62 per cent wells.

Based on the data collected during 2008 from Hydrograph Network Stations of West Bengal established by the State Water Investigation Directorate (SWID), Government of West Bengal and CGWB, Ministry of Water Resources, Government of India the district wise average pre-monsoon water level, post-monsoon water level and water level fluctuation is presented in Table 9.6.

Groundwater quality

West Bengal have a diverse geological formations starting from oldest Archaean crystalline to Recent Riverine Alluvium. Therefore, the State contains groundwater of variable character under natural conditions. Over the greater part of the State the groundwater is of excellent quality and suitable for drinking, agricultural or industrial purposes. But there are areas especially in the coastal tracts where the groundwater is brackish to saline. In some areas copious quantity of groundwater occurs, they are rich with excessive fluoride, arsenic, iron, manganese and other heavy metals. Again due to large-scale groundwater utilization in recent years for agricultural purpose, contamination of groundwater has taken place in localized pockets. Industrial effluents have also been found responsible for contamination of chromium and other heavy metals.

Arsenic

Arsenic (As) is a natural constituent of the earth's crust and is the 20th most abundant element. The average concentration of arsenic in the continental crust is 1-2 mg/kg. Arsenic in drinking water is a current menacing problem of West Bengal. Thousands of people are suffering from an incurable disease of arsenic contamination and more thousands may be affected with this disease in the near future. With the onset of Green Revolution in this part of the country during the sixties and outbreak of epidemics of cholera, millions of tubewells were sunk to tap the plentiful and apparently clean water in the sands and silt of the Ganga flood plain to provide for drinking and irrigation purposes. This was a bad mistake made unknowingly. Arsenic pollution of groundwater in some parts of West Bengal was first reported in 1978. During 1980s a sizeable population of these areas was suspected to be suffering from arsenic related diseases. The first diagnosis of arsenicosis was made in 1984 in a village in North 24 Parganas district. The arsenic affected areas lie on a NNE-SSW tract of approximately 470 km extending from Maldah in the north to South 24 Parganas in the south. Along this linear tract arsenic-contaminated groundwater has been found almost to the east of the Bhagirathi-Hugli river system. Arsenic at concentration above 50 µg/l in tube well waters has been reported by PHED

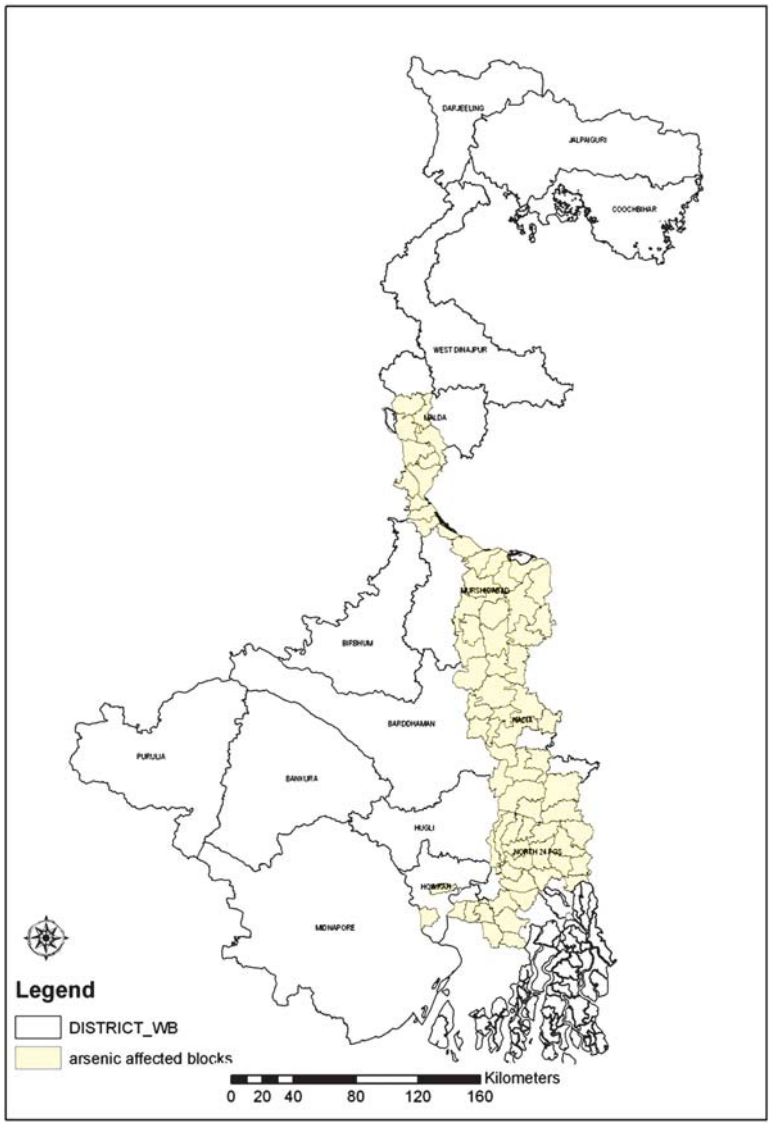

FIGURE 9.4 Arsenic affected Blocks of West Bengal
Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

(www.wbphed.gov.in/main/index.php/water-quality/background-wq), accessed on 9th March 2016) in parts of 83 blocks, 11 municipalities and 18 non-municipal urban areas of 8 districts of West Bengal. The 8 districts are Maldah (7 blocks), Murshidabad (21 blocks), Nadia (17 blocks and 3 municipalities), Barddhaman (5 blocks), Hugli (2 blocks), Haora (2 blocks and 1 municipality), North 24 Parganas (21 blocks and 7 municipalities) and South 24 Parganas (8 blocks). Arsenic has also been reported from some locations in Kolkata city mostly along the course of the river Adi Ganga and in an isolated pocket in Behala region. An important noticeable feature is that arsenic-contaminated groundwater occurs in pockets and tube wells within a distance of 10-50 m may pump out water with or without arsenic. Another important feature is that arsenic contaminated areas are located in the Upper Deltaic Plain of Delta Proper at approximate depths of 12–15 m, 35–46 m and 70-150 m below ground level. A preponderance of the arsenic contamination has been found within 35–46 m aquifer. However, in some areas both deep and shallow aquifers are also affected.

During 1980s, a sizeable population of these areas was suspected to be suffering from arsenic related diseases. At present the total population at risk in the eight districts is about 16.7 million out of a total population of 45.6 million in these districts, affecting few of them dermatologically. In addition to the rural sector, about 12 million people (out of a total urban population of 22.5 million) are also at risk. Thus, the total risk population of the State is about 28.7 million out of a total State population of 80.2 million.

Total population at risk in the eight districts is about 16.7 million

Recently it has been elucidated that the late Pleistocene impermeable clay palaeosols termed Last Glacial Maximum Palaeosol (LGMP) influence groundwater flow and As-pollution in shallow aquifers across the Bengal Basin. The presence of the LGMP defines palaeo-interfluvial areas; the LGMP being absent from palaeo-channel areas. Groundwater in palaeo-channels is polluted by arsenic, whilst that beneath palaeo-interfluvial areas is not. Palaeo-interfluvial aquifers are unpolluted because they are protected by the LGMP from downward migration of arsenic, and from downward migration of organic matter that drives As-pollution via reductive-dissolution of As-bearing iron oxyhydroxides. Horizontal groundwater flow carries arsenic from palaeo-channels towards palaeo-interfluvial aquifers, in which sorption of arsenic minimizes the risk of pollution.

Studies have shown that arsenic occurs naturally in the sediments of the Bengal Delta and is released into the groundwater by complex natural and possibly human-induced chemical mechanisms. Several mechanisms have been proposed over the last decade. Oxidative dissolution of arsenic-bearing sulfide minerals caused by lowering of the water table or recharge of water high in dissolved oxygen or by introduction of oxygen by mixing in pumping wells has the potential to release arsenic into solution. Alternatively, competitive ion exchange with phosphate from fertilizer has been proposed to release arsenic. Though these and other mechanisms may operate locally, the primary mode of arsenic mobilization throughout most of the Bengal Delta is weathering of sulphide minerals and transportation of arsenic with the fluvial sediments from the Himalayas and the likely release of arsenic sorbed to iron oxyhydroxide during reduction of iron under anoxic aquifer conditions. The iron reduction is microbially mediated and driven by degradation of organic carbon, though the carbon source and the location of reduction are incompletely known and likely variable throughout the delta. Potential sources of the organic carbon include buried peat, young organic matter transported from the surface, plant-derived organic matter leaking

from aquitards that overly, or are intercalated in, the aquifers and waste-water. Arsenic release may occur at depth within the aquifer or near the surface, with subsequent transport to measurement depths.

Fluoride

Fluorine is the lightest member of halogen group of elements and most electronegative of all elements. In solution it forms fluoride (F^-). Fluoride forms strong solute complexes with many cations. Concentration of fluoride in the continental crust is 611 mg/kg. Various rock types contain fluoride at different levels: basalt, 360 µg/g; granites, 810 µg/g; limestone, 220 µg/g; sandstone, 180 µg/g; shale, 800 µg/g; oceanic sediments, 730 µg/g; and soils, 285 µg/g. Fluoride is an essential constituent in minerals such as fluorite, apatite, cryolite and topaz. Minerals like biotite, muscovite and hornblende may contain considerable per cent of fluoride.

High fluoride content in groundwater of West Bengal was first reported in 1997 around Nasipur village in Nalhati–I block of Birbhum district. Here the fluoride concentration has been reported to be as high as 10-16 mg/l causing deformity in bones, fluorosis, dental caries, etc. The contaminated water was reported from tubewells tapping groundwater from basaltic rocks at around 90 m depth. Concentration of fluoride above 1.0 mg/l has been reported from Koch Bihar (1.40 mg/l, max), Jalpaiguri (2.20 mg/l, max), Darjiling (2.02 mg/l, max), Uttar Dinajpur (2.50 mg/l, max), Dakshin Dinajpur (5.18 mg/l, max), Maldah (8.0 mg/l, max), Hugli (6.28 mg/l, max), Purba Medinipur (1.16 mg/l, max), Paschim Medinipur (4.42 mg/l, max), Bankura (1.90 mg/l, max), Puruliya (7.87 mg/l, max), Barddhaman (4.03 mg/l, max), Birbhum (17.48 mg/l, max), South 24 Parganas (1.80 mg/l, max).

The population exposed to fluoride contamination is about 6.34 million people

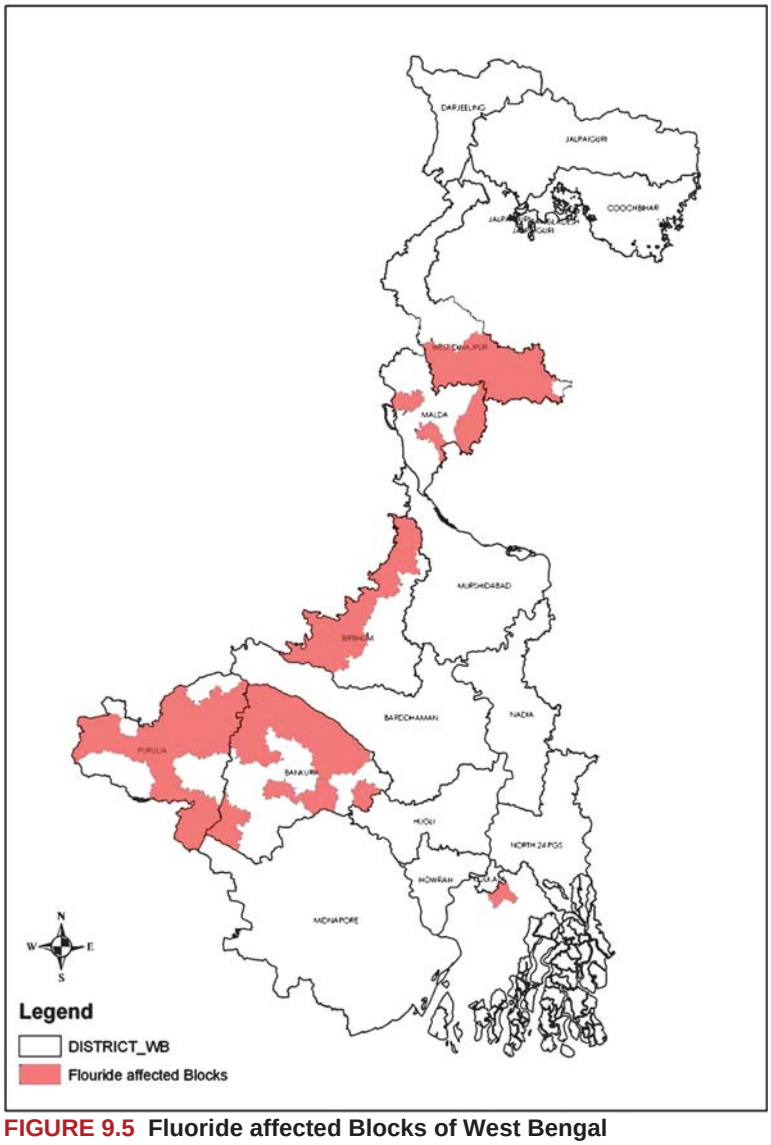

FIGURE 9.5 Fluoride affected Blocks of West Bengal

Source: Water Resource and Its Quality in West Bengal, West Bengal Pollution Control Board, 2009

spreading over 1,073 villages of 131 blocks and 1 municipality of which about 4 million people are at risk residing in 643 villages of 63 blocks. Hydrogeologically the areas underlain by basalt, granite and older alluvium have possibilities of high fluoride in groundwater.

In hard rock areas, Precambrian metamorphic rocks are rich in apatite, fluorite, biotite and hornblende which are the probable sources of fluoride in

groundwater. The inter-trappeans and ash-beds within basalts contribute fluoride. Fluoride mineralization is favoured by presence of structurally weak planes like shear/fracture zones, joints and contacts of host rock and vein quartz. Rocks subject to high degree of geological deformation give rise to network of deep interconnected fractures/joints. Presence of fractured and jointed zones up to deeper level favour mobilization of fluoride from shallow aquifer to deep aquifer.

In the Older Alluvium, fluoride is contributed by minerals such as biotite, hornblende and caliche nodules. The presence of fluoride bearing minerals in the host rock, chemical processes (like decomposition, dissociation and dissolution) and rock-water interaction are considered to be the main causes of fluoride in groundwater. Sharp recession of water saturated zones (as a result of over-pumping of groundwater) provide room for long contact time and thus favour differential leaching of fluoride into the groundwater. The occurrence of fluoride in groundwater also depends upon climatic condition, hydraulic characteristics of aquifer which govern the contact time of circulation at shallow and deep levels within the enclosing rocks/minerals and the presence of other ions in the natural water such as bicarbonate and calcium ions, as well as pH and Eh condition of the water.

Nitrate

The nitrate content of groundwater has been found within 45 mg/l in most of the areas in West Bengal. But nitrate pollution in West Bengal is increasing rapidly. Nitrate concentration >45 mg/l has been observed in water samples from Bankura (5 blocks) and Barddhaman (2 blocks) districts. Nitrate may affect nervous system, vasodilator cardiovascular system and may cause stomach cancer and also methemoglobinemia in infants.

Iron

Iron content in groundwater in major part of West Bengal is less than 0.3 mg/l. However, in some isolated pockets of Medinipur, Haora, Kolkata, Hugli, Bankura and Maldah iron content is higher than 1 mg/l. In parts of Kolkata, Haora, Hugli and Maldah the concentration is more than 2 mg/l. In the Himalayan foothills in the districts of Darjiling, and Jalpaiguri groundwater in the near surface aquifer contents high iron with concentration above 3 mg/l. It has also been observed that places where arsenic concentration is high, iron concentration is also very high and at places in the eight districts where high arsenic is observed the concentration of iron exceeds 10 mg/l.

Chloride

In 57 blocks (Purba Medinipur-15 blocks, South 24 Parganas-29 blocks, North 24 Parganas-5 blocks and Haora-8 blocks) in the coastal tract of West Bengal, groundwater in the upper aquifer (Subarnarekha basin 8-100 m, in Haldia area in Kasai basin 40–115 m, in South 24 Parganas and Haora districts 20–150 m depth range) is high in chloride. In these depth ranges specific conductance is also high and is above 1,500 micromhos/cm at 25^0C. Conductivity in the coastal part of West Bengal increases towards south-east direction. In the north-western part the value 5,000 micromhos/cm and in the south-eastern part the value becomes 20,000 micromhos/cm. However, aquifers occurring in the depth span of 115-300 m in Digha, 125-300 m in Haldia, and 170-350 m in South 24 Parganas district are relatively fresher and chloride content of groundwater is within permissible limit. A high concentration of chloride in groundwater in the upper aquifers is probably related to sub-marine and estuarine environment in which the sediments were deposited as also

owing to seawater intrusion due to proximity to the sea and tidal influence.

Heavy metals

Heavy metals such as lead (>0.01 mg/l) have been reported in the groundwater of Maldah, Murshidabad, Nadia, North 24 Parganas, South 24 Praganas and Kolkata; cadmium (>0.003 mg/l) in North 24 Parganas and South 24 Parganas; chromium (>0.05 mg/l) in North 24 Parganas and Murshidabad; manganese, copper, chromium and cadmium above their respective acceptable limit of the Indian Drinking Specification (BIS 10500) in the groundwater of English Bazar block of Maldah district and cadmium, chromium, copper, nickel in Kolkata and Haora cities.

Bacteriological pollution

Another important type of groundwater pollution, which is generally overlooked, is bacteriological pollution. Groundwater under unconfined condition, especially in the rural areas, is open to large-scale bacteriological contamination due to absence of human excreta disposal facilities. Contaminated water may harbour several bacteria and viruses capable of causing water-borne diseases such as typhoid fever, dysentery, cholera, diarrhoea and hepatitis.

Analytical results of groundwater samples for bacteriological quality are meagre. Analysis reveals that shallow groundwater collected from dugwells in Puruliya district is bacteriologically contaminated. In 5 blocks of Puruliya district viz. Banduan, Arsa, Baghmundi, Jhalda–I, and Jhalda–II groundwater is 100 per cent bacteriologically safe. In the remaining 15 blocks, the number of unsafe samples varies between 10-58 per cent. Few deep groundwater samples collected from Kolkata and Haora cities are also bacteriologically contaminated.

Groundwater development and management

Unplanned development of groundwater has resulted in over-exploitation and deterioration of water quality in some areas of West Bengal. The management options available are (i) augmenting ground water availability through artificial recharge, and (ii) ground water regulation through administrative and legal measures.

Augmenting groundwater reservoirs requires construction of artificial recharge structures. Structures are to be scientifically designed depending on geology, hydrogeology, availability of surface run off, topography, etc. The rate of evaporation is very high at places and ranges from about 50 to more than 300 cm/year. Thus, proper care is to be exercised if the harvesting structure is to store water on the surface.

Historically, under the Easement Act of 1882, groundwater is considered an easement connected to land. Ownership of groundwater thus falls to the land owner who is free to extract and use it as he/she deems fit. Private individual investing his own resource can construct wells of any design installing pumps of any capacity. When the Easement Act was promulgated, the popular and prevalent means of groundwater withdrawal were through dug wells. With the advent of electrically powered pumps the demand for groundwater has increased manifold. Exclusive rights over water have resulted in not only exploitation of needy farmers but also that of the groundwater resources.

As a result, for legal and administrative measures for regulation of groundwater development the Central Ground Water Board has been constituted as Central Ground Water Authority in January 1997 under the Environment (Protection) Act 1986.

Activities of the Authority include monitoring of groundwater contamination, registration of agencies involved in construction of wells, registration of

persons/agencies engaged in sale and supply of mineral water, clearance to ground water based projects, conducting mass awareness programmes and training in rain water harvesting. Central Ground Water Authority has notified 11 areas for groundwater regulation and also notified 32 areas for registration of groundwater abstraction structures in India.

To control and regulate the development of groundwater Ministry of Water Resources circulated a Model Bill to the states in 1970, which was again re-circulated in 1992 and 1996. Ministry of Water Resources had redrafted the model bill and circulated to states again in 2005. Andhra Pradesh, Goa, Tamil Nadu, Kerala, West Bengal, Gujarat, Maharashtra, Karnataka and UT of Lakshadweep and Pondicherry have enacted the legislation.

In urban areas to restore the rapidly falling groundwater level building byelaws have been amended and rainwater harvesting has been made mandatory. State Governments of West Bengal, Gujarat, Maharashtra, Tamil Nadu, Nagaland, Delhi, Karnataka, Kerala, Madhya Pradesh and Union Territory of Daman and Diu have made provision of roof top rainwater harvesting structure in buildings mandatory.

In West Bengal areas having problems in groundwater development can be categorized as (i) areas having decline in long-term groundwater level e.g. Haldia Industrial Complex Area and Kolkata Municipal Corporation Area, (ii) areas affected by arsenic contamination, (iii) areas affected by fluoride contamination, (iv) areas having saline/brackish groundwater bodies, and (v) areas having high iron content in groundwater.

For protection and preservation of the groundwater resource of West Bengal the 'The West Bengal Ground Water Resources (Management, Control and Regulation) Act, 2005' has been passed in the Thirteenth Legislative Assembly on 19th July, 2005. As per the provision in the Act three authorities have been formed at the State, district and corporation levels to manage the groundwater resources of West Bengal. If any person contravenes or fails to comply with any of the provisions of the Act or the rules to be made or obstructs the State Level Authority or the District Level Authority or the Corporation Level Authority, or any person authorized by the State Level authority, he shall be punishable for the first offence with fine which may extend to five thousand rupees, and for second or subsequent offence with fine which may extend to ten thousand rupees.

Management strategies in 'Safe' and 'Semi-critical' areas

In 'Safe' blocks in Darjiling, Jalpaiguri and Koch Bihar and in hard rock terrain of Puruliya, western parts of Bankura, Barddhaman, Birbhum and Paschim Medinipur, there is good scope for large-scale groundwater development. In 'Semi-critical' blocks in Bankura, Barddhaman, Birbhum, Hugli, Maldah, Murshidabad and Nadia, groundwater development may be done with caution. Monitoring of water level should be done regularly to understand the trend of water level.

Management strategies in Arsenic affected areas

Substantial mitigation of As pollution present in groundwater from shallow palaeo-channel aquifers could be achieved by simply drilling wells a little deeper, so that they tap the palaeo-interfluvial aquifer. Wells fitted with handpump may be constructed at any depth below the Last Glacial Maximum Palaeosol in a palaeo-interfluvial setting. These wells may deliver As-free water for hundreds of years. In deep aquifer below palaeo-channel setting wells with hand pumps may be constructed at depths of at least 200 m bgl to provide safe drinking water for the foreseeable future. Caution is warranted regarding the development of any new motor-fitted wells in the deep aquifer below palaeo-interfluvial or palaeo-channel

aquifers for both irrigation and drinking purposes. A programme of regular water-level and water quality monitoring of selected drinking water wells should be undertaken that would both characterize the state of water quality in the aquifer and serve as an early-warning system for the impending arrival of contaminants in water supply wells.

Other options for arsenic mitigation are (i) large scale piped water supply for the rural communities by drawing water from the rivers and treating them for removal of pathogenic microbes, (ii) conservation and upgradation of traditional surface water sources like ponds, dud wells etc. in villages which are free from As but grossly contaminated with pathogenic microbes, and (iii) removing As from the groundwater by using technologies like adsorption (activated alumina/iron oxide), co-precipitation (oxidation, coagulation and filtration) or ion exchange. These technologies could be applied in community plants attached to hand pump tube wells or large diameter motor fitted tubewells.

The Arsenic Task Force constituted by the Government of West Bengal recommended that priority to be given for community piped water supply schemes based on surface water sources with necessary treatments. Where this is logistically and financially not feasible, groundwater based piped water supply schemes with necessary arsenic removal treatment should be undertaken. Rainwater harvesting should be taken up to support the above schemes. The Task Force also recommended that all arsenic affected villages should be supplied with safe water from the piped-water supply schemes with at least on standpost in the affected habitations. The mitigation measures taken so far in West Bengal by PHED, Government of West Bengal are shown in Table 9.7. As a part of IEC programme, interactive sessions are organised at the district and state levels under PHED-UNICEF joint plan of action. For water quality surveillance, twenty

TABLE 9.7 Different schemes for Arsenic mitigation in West Bengal as on 31.3.2014

	Measure/Scheme	Number	Rural Population Covered (Lakh)
Short Term			
1.	New handpump fitted tubewells at deeper aquifer	8037	20.09
2.	Sanitary protected ring wells	166	0.41
	Total of Short term		**20.50**
Medium Term			
3.	Arsenic Treatment Unit with existing handpump fitted tubewells	2396	5.99
4.	Arsenic Removal Plant for existing groundwater based Piped water supply Schemes (PWSS)	12	1.90
5.	New big diameter deeper aquifer tubewells for existing PWSS	8	1.20
6.	New Groundwater based PWSS	250	43.64
7.	Nadia Murshidabad ground water based PWSS	1	1.12
8.	Groundwater based PWSS(Old Sub-Mission)	4	0.57
9.	Ground water based PWSS(W.Q. Sub-mission)	171	14.30
	Total of Medium term		**68.72**
Long Term			
10.	Surface water scheme for Malda	1	8.90
11.	Surface water scheme for South 24 Parganas	1	16.28
12.	Surface Water Scheme for North 24 Parganas	1	4.65
13.	Surface Water Scheme for Mahyampur	1	0.41
14.	Surface Water Scheme for Balupur	1	0.47
15.	Surface Water Scheme for Gour & Mahadipur(Aug)	1	0.10
16.	Surface Water Scheme for Beldanga	1	0.35
17.	Surface Water Scheme for Nadia (Northern Sector)	1	7.54
18.	Surface Water Scheme for Purbasthali-II	1	1.41
19.	Surface Water Scheme for Murshidabad (Central Sector)	1 (Part)	2.45
20.	Surface Water Scheme for Raghunathganj-I	1 (Part)	1.31
21.	Surface Water Scheme Haringhata	1 (Part)	1.60
	Total of Long term		**45.20**
	Total rural population covered		**134.42**

Source: http/www.wbphed.gov.in

NGO run rural laboratories have been set up under JPOA programme for arsenic mitigation in addition to twenty one district level and project based PHED laboratories. A GIS based mapping project for arsenic affected areas have also been undertaken by the PHED and West Bengal Council of Science and Technology, Government of West Bengal, supported by UNICEF.

Management strategies in Fluoride affected areas

The best solution to the fluoride problem is to avoid locating wells in high fluoride aquifers. The fluoride concentration often fluctuates within the same catchment and change of well site is one of the options. In the absence of alternative source of drinking water, the deflouridation techniques may be practiced for safe drinking water. Some of the common defluoridation techniques are (i) Nalgonda Technology (use of lime and alum), (ii) Prasanti Technology (use of activated alumina) (iii) Reverse Osmosis, and (iv) Ion Exchange (use of resin). Technologically these techniques are quite successful but sustained use of these treatment techniques in rural areas has not been achieved. Various artificial recharge techniques may also be applied to improve the quality of water by dilution. Integrated fluoride management with nutrition intervention with participatory approach by the beneficiaries probably may offer better solutions.

Management strategies in coastal areas

In the coastal areas while developing groundwater from deep aquifers proper precautions has to be taken to prevent inward migration of salt water–fresh water interface. In the absence of detailed study the exact nature of this interface is not known. In some coastal areas heavy withdrawal of groundwater has led to the decrease in the seaward flow of groundwater causing sea water to enter and penetrate inland into the concerned aquifer. Such seawater incursion has caused tremendous damage to the local groundwater supply system. The chances of salt-water incursion can be lessened to some extent by locating the well further inland instead of near the coast. Since the deep aquifers have a gentle southerly dip and the groundwater recharge is mainly from the north, it would be better if in the future large scale groundwater development is concentrated in the up dip parts of the aquifers.

In the Sundarban area, the seawater incursion into the confined aquifers at depths greater than 200 m is been hindered by the presence of a thick aquiclude overlying the aquifer and by the pressure of the fresh groundwater in the confined aquifer. The following points are to be considered during construction of heavy-duty tubewells in and around Sundarban Biosphere Reserve:

- Electrical logging of the borehole especially resistivity, gama ray and self potential logging should be done to determine the thickness and depth of potential aquifers and to get an idea about the chemical quality of the formation water.
- Mostly the aquifers are made of fine sand (0.2 to 0.06 mm). To avoid sand rushing proper slot size should be selected after grain size analysis of the aquifer material. Generally, 1 mm slot size is suitable for this type of aquifer. Housing pipe should be extended down to the depth of 40 m. A minimum thickness of 35 m of granular zone may be tapped to have discharge of 100-150 m^3/hr.
- The size of gravel should be properly selected after grain size analysis of the aquifers. The gravel should be hard, chemically inert, mostly siliceous material and thoroughly cleaned.
- Where fresh water aquifers are overlain by brackish water effective cement sealing above the top of the fresh water aquifer should be done. Above the

- sealed portion annular space between the casing and the wall of the well should be filled up with clay.
- Suitable corrosive resistance material such as stainless steel, PVC and fiberglass for strainers should be used for better life of the tubewell.

In case of large scale groundwater development from the confined aquifers steps should be taken to monitor piezometric surface and quality of groundwater. The brackish water aquifer system, which overlies the fresh water aquifer system, should be monitored to identify any change in the groundwater regime of the brackish water aquifer system consequent to development of underlying fresh water aquifers if leaky condition exists.

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Chapter 10

Wetlands

Wetland ecosystem of West Bengal comprising of fresh water temporary or permanent large and small fish ponds and aquaculture systems, salt marshes, swamps and mangroves, shallow lakes, fresh, brackish and salt water lagoons, vast expanse of sewage fed water bodies, potholes as well as the littoral zones of lakes, riparian habitats in the river valleys, hill streams, and vast flood plains of large rivers as well as their deltas and many other tributaries.

According to a report of the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India (1990), Indian wetlands covers 4.1 million ha (excluding paddy field and mangroves) of which 1.5 million ha are natural and 2.6 million ha man made. Area of natural wetland encompasses about 291,963 ha while manmade wetland covers 52,564 ha and obviously vast portion of wetlands in this State is still not computed. Different types of wetlands and water bodies in India with their natures and utilisations are depicted in Table 10.1.

In West Bengal, there are about 54 natural and nine man made wetlands which are more than 100 ha (Biswas and Trisal, 1993) and in addition to these there are numerous small water bodies including ponds, puddles, potholes, natural depressions and other types of water bodies.

Major identified functions of wetlands ecosystem associated with aquatic vegetation are

- Ground water discharge, recharge and stream flow maintenance;
- Flood mitigation and desynchronization;
- Shoreline stabilization and reduction of erosion;
- Sediment trapping, nutrient retention;
- Removal, food chain support;
- Biodiversity functions, *i.e.*, supporting plant, animal and microbial diversity habitat with special references to fish and other wild life habitat;
- Active recreation and passive recreation and age-old cultural heritage values;
- Traditional wetland practices and subsistence livelihood support.

Most of the wetlands adjacent to the river system act as buffer by virtue of the biofiltering properties of the microphytes as well as macrophytes present in these wetlands. Biological, chemical and physical processes in wetlands are often able to immobilize and transform a wide range of environmental contaminants including the drastic load of faecal coliforms and nutrients, which, in excess, would cause

TABLE 10.1 Area of wetlands in India

Types and nature of utilisation	Area
Area under paddy cultivation	40.9 million ha
Total area for Pisciculture	3.6 million ha
(a) Fresh water fish culture	1.6 million ha
(b) Brackish water fish culture	2.0 million ha
Area under capture fisheries	2.9 million ha
Mangroves	0.4 million ha
Estuaries	3.9 million ha
Back waters	3.5 million ha
Rivers including main tributaries (km)	28,000 km
Canals and irrigation channels	1,13,000 km
Total Area of Wetlands (excluding rivers)	58.2 million ha

Source: Anonymous, 1990

severe eutrophication and pollution. Heavy metals, pesticides and industrial wastes, for instance, can be bound to soil and sediment particles and there by rendered more or less inert. Regular deposition of nutrient rich-silt combined to the success of agriculture along large rivers. Sediment is also vital for maintaining aquatic fertility and physical stability of flood plains and deltas. The wetlands act as filters for certain kinds of waste and soluble contaminants. The process is important for controlling supplies of water for human consumption and also in maintaining the flow of ground water which may support other wetlands at the point of discharge. Discharge of wetland stored ground water may be important in sustaining the agricultural production of surrounding land. The task of valuing an ecosystem involves both the valuation of the components and the identification of the synergism they generate. These wetlands and water bodies are extremely significant for their carbon sequestration values and thus are naturally important for global temperature amelioration.

According to physiography and hydrology, wetlands of West Bengal can be divided into four regions: (a) Wetlands of the Gangetic alluvial plains; (b) Coastal wetlands; (c) Wetlands of the semi-arid regions, *i.e*, Rarh region; and (d) Sub-Himalayan wetlands.

Gangetic alluvial plains

These are mainly confined to alluvial plains of lower Gangetic delta of West Bengal ranging between $21^0$39' N to $22^0$32' N latitude to $88^0$03' to $88^0$20' E longitude. These parts include a spectacular range of variation of aquatic flora and fauna. Based on water quality, wetlands and water bodies of this region can be divided into oligotrophic, mesotrophic, eutrophic, brackish and saline water types. There is a sharp variation of plant and animal communities in these diverse type of water bodies as well as species richness and association.

Water bodies present in these regions are both of perennial and temporary types. The temporary wetlands can be termed as cyclical wetlands in respect of hydrology. These water bodies are locally called ponds, beels, baors char, dighi, bheri, sarobar, bandh, haor, sayar, nayanjali etc. Part of the irrigation canals and numerous potholes sometimes cannot be ignored from their diversity context. However most of the ponds and beel fisheries in Gangetic West Bengal are extensively managed for fish farming and are thus not good domain for adequate aquatic flora and fauna. Wetlands of the alluvial plains are the domain of maximum representative wetland families in West Bengal.

The Gangetic alluvial plains include trans-boundary wetlands like 'Bhutnir Char', 'Bhatia Beel' in the district of Maldah, 'Balli Beel' in the North 24 Parganas, temporary cyclical wetlands like 'Borti Beel', 'Nangla Beel' of North 24 Parganas. Changing direction of Ganges from its usual course has resulted in several horse-shoe shaped oxbow lakes like 'Chaltia Beel', 'Chander Beel', 'Bishnupur Adi Ganga', 'Dhopghati', 'Bhandardah Beel', 'Bhabta Beel' (Hariharpur), 'Kaldanga Ghat' (Islampur) and 'Ahiran Beel' in the district of Murshidabad and 'Bhomra

Beel', 'Chand Beel', 'Kulia Beel' in Nadia district, east and west 'Panishala' wetlands, 'Sagardighi', 'Rasik Beel' are among the permanent wetlands (cut-off meander type) in district of Koch Bihar. Wetlands around Dankuni and Mrigala (district Hugli) are diverse in their floral and faunal composition.

Coastal wetlands

Coastal Wetlands of West Bengal constitutes lower parts of the Bengal basin in the western fringes covering about 27 per cent coast line (Purba Medinipur) and about 73 per cent coast line on the central and eastern part (South 24 Parganas and North 24 Parganas) are mostly saline (polyhaline to eurohaline) in nature. Active deltas in the coastal regions form the world's largest mangrove region - The Sundarbans ecosystem – having wide spectrum of biological diversity, which is aesthetically, ecologically and economically important in the national and international level as well as this is important for its age-old traditional and cultural values and it is now the World Heritage site declared by the UNESCO. 'Gobaria Beel' near the Sundarban mangrove forest is also a productive tidal wetland. In addition to this Dadanpatrabar-Alampur coastal tidal wetland complex in the Purba Medinipur district, a combination of sand dune, mud flat and creek within the CRZ-I, is significant from its biodiversity values.

Wetlands and water bodies of the Rarh region

Geographically the Rarh region can be divided into Rarh plain and Rarh plateau (consisting of rolling upland). Most of the water bodies in this region are of man-made perennial reservoir type. All these water bodies are rain fed (annual average rainfall is about 1,300 mm) and remain saturated during monsoon to winter months, however, get dried in summer. Water bodies distributed in these regions mainly consist of ancient as well as perennial reservoirs standing on old alluvial or laterite alkaline soil with occasional coarse sand or gravels located at about 50-100 m above mean sea level. Several perennial water bodies in this region are the host of several primitive plant families with rare representatives (*Caldesia oligococca, Butomopsis latifolia, Spiranthes australis* etc.) and threatened and also a few endemic species.

Bill fishery in Murshidabad after receding of water table: Fish cum paddy cultivation is a natural practice
Source: Ghosh S. K.

Wetlands and water bodies of the Northern Bengal

Geographically the North Bengal can broadly be divided into Terai and Duars and water bodies of the Terai and the Duars are distinctly different from their hydrology and physiography. Water bodies of the Duars region include hilly streams (locally called 'Jhora'), rivers and few perennial and seasonal lakes and reservoirs mainly distributed in the Darjiling district. The Terai region comprising of marshes, backwater wetlands and man-made ponds, ditches, lake, dighi etc. distributed in Jalpaiguri, Koch Bihar, Uttar Dinajpur and Dakshin Dinajpur. Sukhiapokhri, Jorpokhri and several other ditches of Darjiling district are the only habitat in India for the Himalayan Newt

or Salamander. More than 75 macrophytic species have been described from this region like *Hydrolithrum wallichi*, *Rotala densiflora*, *Rotala rotandafolia*, Hydrocotyle sibthorpioides *Marsilea quadrifolia* (in upper altitude), *Aponogeton natans*, *Blyxa octandra* and others (Dutta *et.al.*, 2003). Water cress or *Nasturtium officinale* (above 3,000 ft from the msl) is an interesting species cultivated by the locals in the water courses of upper altitude having significant medicinal properties. Macrophyte based wastewater treatment bed has been setup in the national lake of Mirik in 2006-07 for better conservation of water quality and biological diversity of the lake (Ghosh, S. K., 2014).

Precautionary classification of wetlands for facilitating protection

It is true that all the wetlands and water bodies of this State cannot be conserved, however, we have to set a strategy for conservation of wetlands at least, which have rationale. One such classification of wetlands for prioritisation of conservation issues for the Indian subcontinent is mentioned here (Ghosh, D., 1997). The most practicable initiative will be to introduce the precautionary classification of wetlands that divides wetlands into three separate schedules as under:

Schedule I: Wetlands that are outstanding or highly significant will have to be conserved with or without minor modification/upgradation for their critical importance to the community.

Schedule II: Wetlands, which require transformation of the existing water regime for a different set of wetland functions and uses for the community to enhance the sustainability and efficiency of the resource base.

Schedule III: Wetlands, which may be filled up to allow more pressing development needs for the general wellbeing of the community. Schedule III Wetlands will again be divided into two groups.

Schedule IIIA: Wetlands that will be filled up elsewhere and will be replenished.

Schedule IIIB: Wetlands that will be filled up and for which no replenishment is possible.

In West Bengal, specific legal protection for conservation of wetlands of pisciculture importance already exists, what is lacking is, the environmental consciousness of a specific group of people by any means who are becoming the real actors of degradation of nature.

District wise distribution of wetlands

A compilation of district wise distribution of wetlands in West Bengal has been prepared by the IESWM, Department of Environment, GoWB from the satellite imagery data. In this treatment water bodies less than 2.25 ha has been ignored but considering the huge number of such water bodies steps should be taken for their necessary conservation (Table 10.2).

Spatial distribution of wetlands varies from one district to another, both in numbers as well as in area. Among the natural wetlands seasonal waterlogged type of wetland (WSL) type in Medinipur, cut-off meander (COM) in Koch Bihar, marsh and swamp in Dinajpur and oxbow types lakes (OL) in Nadia are significant in case of inland man-made wetlands (IMMW). Maximum number of reservoirs is observed in Bankura, tanks in Puruliya, man-made water logged (MMWL) in Birbhum, abandoned quarries (AQ) in Barddhaman and ash ponds/cooling ponds in Murshidabad and Medinipur districts.

In terms of spatial distribution of different types inland wetlands in the districts of West Bengal, WSL class is most abundant, occupying an area of 20,956.49 ha in Maldah district. Lakes/ponds in Murshidabad occupy 8,069 ha and swamps in Dinajpur cover 5,477.68 ha. Another important type of wetlands, viz. COM/OL occupy 6,543.14 ha in Murshidabad district.

In case of IMMW, reservoirs in Puruliya are spread over 15,012.82 ha, tanks in Barddhaman are extended over 1,789.37 ha. Ash pond/cooling ponds occupy an area of 667.03 ha in Murshidabad district, AQ in Barddhaman district covers an area of 415.07 ha and IMMWs in Birbhum occupy 215.65 ha. Coastal wetlands mostly fall in South 24 Parganas and Medinipur districts. Among this, mangroves of the Indian part occupy 175,322.55 ha and aquaculture ponds extend up to 4,148,156 ha. A study indicates about 7,056 wetlands (≥ 2.25 ha) in West Bengal are covering approximately 504,306.56 ha (Bhattacharya *et al* 2001). Research team of IESWM has done intensive survey in Barddhaman, Birbhum, Nadia and 8 selected wetlands in West Bengal.

Bill fisheries estimated to be 46,000 ha (Jhingran, 1989) representing 22 per cent of the total fresh water area excluding river and tributaries. There are 116 Beel fisheries in five districts, viz., Hugli, Nadia, Murshidabad, North 24 Parganas and Birbhum significant for fish and macrophytes (Table 10.3).

Increasing population pressure, massive expansion of real estate business, rapid urbanization and fencing in wetlands by the name of industrialization, results in encroachment of vast expanse of wetlands for so called development, overlooking environmental imbalance, have led to social and ecological disorders.

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TABLE 10.2 District-wise distribution of wetlands (≥2.25 ha) in different districts of West Bengal

District	Geographical area (sq km)	Area (ha)
Darjlling	3149	271.79
Jalpaiguri	6627	1089.99
Koch Bihar	3387	4930.51
Dinajpur (undivided)	5350	10699.37
Maldah	3733	29416.95
Murshidabad	5324	22076.89
Birbhum	4545	1727.1
Barddhaman	7024	6412.34
Bankura	6882	6913.60
Puruliya	6259	I6804.89
Medinipur (undivided)	14081	20807.22
Hugli	3149	1631.19
Nadia	3927	21874
Kolkata	185.39	87.32
24 Parganas (undivided)	14054	367258.24
Haora	1467	1925.65

Source: Bhattacharya *et.al.* 2001, Vass, 1989 & Statistical Abstract of West Bengal

TABLE 10.3 Distribution of Beel fisheries in five districts of West Bengal

Characteristics	District				
	Hugli	Nadia	Murshidabad	North 24 Parganas	Birbhum
Number of Beel fishery	6	43	43	23	1
Range of effective area (ha)	3-75	2-130	7-210	12-600	100
Depth distribution (m)	2.5-3.5	2.5-7.0	3-5	3.5-8	2.5
Drainage pattern	ND	D/ND	ND	ND	D
Connected river	Farraka, Ganga	Ganga, Ichhamati, Bhagirathi and Jalangi	Ganga and canals	Ichhamati	Mayurakshi
Total area (ha)	174	15982	13161	1742	100

Adapted from Vass, 1989 D: Drainage ND: Non Drainage

Health of the wetland ecosystem

In West Bengal, majority wetlands are exploited for organized pisciculture practice, which results in time scale change of physicochemical parameters. Here for the urgent need of the society, it is hardly possible to find out wetland without pisciculture practice. Nutrient addition for better food supplement is the practice, where natural food chain or energy flow is altered by socioeconomic pressure.

A good fish pond or ecosystem means a transparent water table with submerged flora in controlled condition, plenty of food, solar radiation and oxygen and also a clear substratum, which enables the spawning and laying eggs for the fish species. The bottom should be a good domain for aquatic worms and other bottom dwellers to be consumed by the fishes. These are the prerequisites for a healthy aquatic ecosystem. There should be scattered floating leaf and floating stem species and free floating species only at the margin to provide shade and halt for the epizootic fauna as well as provide support for shoreline stabilization. All this is possible with traditional ecological eyes which can see long term benefit for the fishes. Unfortunately ecology has to surrender to the grasp of unit productivity of the system.

Coastal brackish water fisheries: coexistence of aquatic plants increase biodiversity without hampering productivity in 24-Parganas South.
Source: S. K. Ghosh

The traditional fishermen community of the East Kolkata Wetlands consider colour, odour and taste for the management of their ecosystem, which is unique in the world. Likely in Bhaluka wetland (Nadia), the fisherman community accept aquatic plants in their water bodies which provide better ecosystem functions with sound productivity (Ghosh, 2005).

Habitat requirement for the growth and development of plants and animals in wetlands is one of the important parameters for management of wetlands. Inter-relationships between various factors of an ecosystem are complex. In West Bengal, for better health and management of the wetlands, water quality parameters must be taken into consideration for reaching restoration of critical species in the system. Plants starting from algae to angiosperm plays pivot role in the management of hydrology and water-quality of the wetlands. In addition to these, advance knowledge of ecosystem management may help in stopping deterioration of water quality.

Conversion of fresh water wetlands to waste water wetlands or fresh water wetlands to brackish water wetlands for commercial production of fish or shrimp results in deterioration of ecosystem health in the Gangetic Bengal.

Massive destruction of submerged plant species in the Rabindra Sarobar lake (National Lake) during the last two decades has altered the ambient water quality of the lake which leads to fish-death due to change in water quality in recent times.

Water is essential for all ecosystems and all activities of human beings. Water makes up nearly 90 per cent of all living cells of the body. Out of 1.4 million cubic kilometers of water in the earth about 97.5 per cent is sea and brackish water and nearly 75 per cent of the remaining 2.5 per cent is locked up in icecaps and glaciers. Thus only a fraction of a percentage point

of the total water on earth remains available for human utilization. Unfortunately today, 1.2 billion people do not have access to adequate supply of safe water and 2.2 billion people do not have adequate sanitation. Water-borne disease causes millions of preventable deaths especially among children in developing countries. World Water Council predicts, by 2025 as many as 52 countries with more than three billion people will be water stressed. At present per capita water supply around the globe is about one-third lower than 25 years ago. The Council also alarmed that the expected growth of population over the next 30 years can extend to at least 8 billion, which means the water demand to be more than 650 per cent. Agriculture is the largest (about 70%) consumer of water in the world (World Water Council – Six years Progress: 1994-2000). Rapid population growth in the developing countries will enhance the demand of water in next 25 years particularly for domestic, municipal and industrial use as well as for treatments of waste.

West Bengal occupies 2.7 per cent of India's land area and accommodates 7.5 per cent of its population. According to a study by the South Asia Research Society, Kolkata, the actual pressure of population upon West Bengal may indeed be higher than what is estimated from Census data, which are seldom complete. According to census data (2011), West Bengal population is more than 91.28 million. The most populous district of West Bengal is North 24 Parganas (10,009,781). North and South 24 Parganas, Maldah, Uttar and Dakshin Dinajpur districts are significant for transboundary wetlands. Infiltration from neighbouring Bangladesh to these districts results in an additional anthropogenic pressure, which has direct impacts on the wetlands of these districts. At least 2-3 per cent population of these districts is otherwise dependent for their subsistence livelihood support from wetlands based resources.

Hydrology and trophic structure of aquatic ecosystems are governed by the interactions of plant, animal and microbial communities of wetlands. Aquatic animals are completely dependent for their survival on aquatic plants. Even diversity of avifauna and also the mollusks and amphibians are directly correlated with the aquatic plants. Wetlands and human interdependence is well addressed. Algae, alone covers 40 per cent of the known biodiversity in wetlands aquatic plant, are important source of dissolved oxygen, food source for water fowl and herbivorous fishes as well as nesting and roosting ground for birds, amphibians, reptiles and aquatic mammals.

Diversity of macrophytes in aquatic and wetland habitat of West Bengal

Wetlands are significant for their hydrophytic vegetation (Cook, 1996). Aquatic plants play a significant role in the maintenance of the health of the wetlands of West Bengal covering a meagre of 8.5 per cent of the wetland areas (considering water bodies >100 ha) of India provide shelter for more than 60 per cent diversity of aquatic and wetland flora (Ghosh, 2005).

Diversity of wetland plants of West Bengal is richest in India represented by more than 380 species belonging to 176 genera and 81 families. In general, wetlands of the alluvial plain of the lower Ganga deltas are richest in macrophytic plant diversity in aquatic habitat due to variations in physicochemical parameters of water and bottom sediments. Highly saline coastal wetlands are vegetated with mangroves and sea-grasses. Wetlands of the sub-Himalayan and semi-arid regions are also distinguished for their physiography, hydrology and floristic composition. Perennial water reservoirs in the semi-arid regions are rich sources of floristic diversity.

Aquatic and wetland pteridophytes

A least 8 genera and 26 species of aquatic and wetland pteridophytes distributed in 7 families in the Indian wetlands. The wetlands of West Bengal represent 6 genera and 8 species belong to 6 families which is 75 per cent of the reported aquatic and wetland pteridophytes of India and about 8.6 per cent of the world at the genus level. However, the species level diversity of aquatic and wetland pteridophytes of West Bengal is about 31 per cent of India and little more than 2 per cent of the world known population (Table 10.4). *Salvinia molesta* mostly occupies the water bodies receiving saline flush or nutrient loads from the catchment. But this species is not abundantly distributed in wetlands of other parts of India or neighbouring states of West Bengal. There is no gymnosperm representative in the wetlands of West Bengal.

Freshwater angiosperms

Freshwater strictly aquatic angiosperm of the world is represented by more than 141 genera and 1,023 species of which the Indian subcontinent supports 54 genera and 122 species. Wetland habitat of West Bengal represents 26 genera and 43 species.

Strictly aquatic and wetland monocot representatives

The Indian subcontinent supports 12 families, 30 genera and 75 species of strictly aquatic monocot (Table 10.5). The wetlands of West Bengal support 32 species belonging to 19 genera and 10 families. The Indian wetlands represent nearly 40 per cent of the world strictly aquatic families. Hydrocharitaceae and Lemnaceae are among the dominant families.

Strictly aquatic and wetland dicot representatives

The Indian subcontinent supports 9 families, 24 genera and 47 species of strictly aquatic. In the wetland habitat of West Bengal, there are 8 families, 8 genera and 12 species (Table 10.6). This is about 33 per cent at genus level and about 25 per cent at species level diversity of the strictly aquatic plants of India. The entire Nymphaeaceae family is now under threat as the rhizomes of the members of Nymphaeaceae family are randomly harvested for alternative vegetables and medicines in rural Bengal. There is no representative of the family Podostemaceae in West Bengal (Table 10.6).

TABLE 10.4 Wetland pteridophytes of West Bengal with respect to their representatives in India and world

Family	Genera					Species				
	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India
Azollaceae	1	1	1	100.00	100.00	6	1	1	16.66	100.00
Isoetaceae	1	1	1	100.00	100.00	130	11	1	0.77	9.09
Marsileaceae	3	1	1	33.33	100.00	72	7	1	1.38	14.28
Polypodiaceae	1	1	1	100.00	100.00	60	1	1	0.625	100.00
Pteridaceae (=Parkeriaceae)	2	2	2	100.00	100.00	7	3	2	28.57	66.66
Salviniaceae	1	1	1	100.00	100.00	10	2	2	20.00	100.00
Total	**9**	**7**	**7**	**77.77**	**100.00**	**285**	**25**	**8**	**2.80**	**32.00**

Source: Ghosh, 2005

TABLE 10.5 Strictly aquatic monocot representatives of West Bengal with respect to their counterpart in India and world

Family	Genera					Species				
	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India
Alismataceae	11	5	3	27.27	60.00	100	7	5	20.00	71.40
Aponogetonaceae	1	1	1	100.00	100.00	45	10	3	6.66	30.00
Hydrocharitaceae	17	8	5	29.40	62.50	100	13	5	20.00	38.50
Lemnaceae	4	4	3	75.00	75.00	35	15	5	14.30	33.30
Limnocharitaceae	3	2	1	33.33	50.00	12	2	1	8.33	50.00
Najadaceae	1	1	1	100.00	100.00	50	10	3	6.00	30.00
Pontederiaceae	8	2	2	25.00	100.00	32	3	3	9.37	100.00
Potamogetonaceae	3	1	1	33.33	100.00	108	6	4	3.70	66.66
Ruppiaceae	1	1	1	100.00	100.00	7	1	1	14.30	100.00
Typhaceae	1	1	1	100.00	100.00	11	2	2	18.20	100.00
Total	**50**	**26**	**19**	**38.00**	**73.07**	**500**	**69**	**32**	**6.40**	**46.37**

Source: Ghosh, 2005

TABLE 10.6 Strictly aquatic dicot representatives of West Bengal with respect to their counterpart in India and world

Family	Genera					Species				
	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India	World wide (no.)	India (no.)	West Bengal (no.)	% of World	% of India
Cabombaceae	2	2	1	50.00	50.00	5	2	1	20.00	50.00
Ceratophyllaceae	1	1	1	100.00	100.00	4	2	1	25.00	50.00
Elatinaceae	2	2	1	50.00	50.00	36	5	2	5.55	40.00
Menganthaceae	5	1	1	20.00	100.00	39	8	2	5.13	25.00
Nelumbonaceae	1	1	1	100.00	100.00	2	1	1	50.00	100.00
Nymphaeaceae	6	5	1	16.66	20.00	65	7	2	3.07	28.57
Sphenocleaceae	1	1	1	100.00	100.00	1	1	1	100.00	100.00
Trapaceae	1	1	1	100.00	100.00	3	2	2	66.66	100.00
Total	**19**	**14**	**8**	**11.40**	**33.33**	**155**	**28**	**12**	**2.67**	**25.53**

Source: Ghosh, 2005

Overlapping families in the wetland habitat

In West Bengal, there are about 273 species and 103 genera distributed in 39 families (Table 10.7) have representative in both the wetland and terrestrial habitat, *i.e.* overlapping family. Orchidaceae in the Indian subcontinent is represented by two genera, viz., *Spiranthes australis* and *Zeuxine strateumatica* and both the two species have been reported from the wetlands of West Bengal. Among the overlapping families, Cyperaceae is dominant, having 72 species and 13 genera, followed by Poaceae having 45 species and 24 genera and Scrophulariaceae having 27 species and 6 genera.

Due to habitat alteration and change in physico-chemical parameters of water bodies, species like *Aldrovanda vesiculosa* have either been shifted or become extinct from the wetland habitat of West Bengal. Several species like *Solanum glaucum* restricted in salt-water ditches in the

TABLE 10.7 Flowering plant families having representatives in wetland habitat of West Bengal with respect to their counterparts in India

Name of the Families	Genera			Species		
	India (No.)	West Bengal (No.)	% of India	India (No.)	West Bengal (No.)	% of India
Acanthaceae	3	1	33.33	9	3	33.33
Amaranthaceae	2	2	100.00	4	4	100.00
Amaryllidaceae	1	1	100.00	1	1	100.00
Apiaceae	3	3	100.00	3	3	100.00
Araceae	6	5	83.33	37	9	24.32
Asclepiadaceae	1	1	100.00	1	1	100.00
Asteraceae	9	7	77.80	18	9	50.00
Balsaminaceae	1	1	100.00	1	1	100.00
Boraginaceae	3	2	66.66	7	3	42.85
Brassicaceae	1	1	100.00	1	1	100.00
Burmanniaceae	1	1	100.00	5	2	40.00
Campanulaceae	1	1	100.00	3	2	66.66
Cannaceae	1	1	100.00	1	1	100.00
Caryophyllaceae	1	1	100.00	1	1	100.00
Commelinaceae	4	3	75.00	12	10	83.30
Convolvulaceae	3	1	33.33	5	2	40.00
Cyperaceae	26	13	50.00	171	72	42.10
Droseraceae	2	1	50.00	4	3	75.00
Elatinaceae	2	1	50.00	5	2	40.00
Eriocaulaceae	1	1	100.00	39	8	20.50
Fabaceae	4	4	100.00	12	9	75.00
Gentianaceae	1	1	100.00	2	1	50.00
Haloragaceae	1	1	100.00	5	2	40.00
Hydrophyllaceae	1	1	100.00	2	1	50.00
Lamiaceae	1	1	100.00	4	1	25.00
Lentibulariaceae	1	1	100.00	27	15	55.50
Lythraceae	3	3	100.00	38	11	28.90
Onagraceae	1	1	100.00	6	4	66.66
Orchidaceae	2	2	100.00	2	2	100.00
Poaceae	42	24	57.14	75	45	60.00
Polygonaceae	1	1	100.00	7	5	71.40
Ranunculaceae	1	1	100.00	1	1	100.00
Rubiaceae	2	2	100.00	3	3	100.00
Scrophulariaceae	14	6	42.85	66	27	40.90
Solanaceae	1	1	100.00	1	1	100.00
Sphenocleaceae	1	1	100.00	1	1	100.00
Trapaceae	1	1	100.00	2	2	100.00
Verbenaceae	2	2	100.00	2	2	100.00
Xyridaceae	5	1	20.00	7	2	28.57
Total	**157**	**103**	**65.6**	**591**	**273**	**45.85**

Source: Ghosh, 2002, Ghosh, 2005

coastal West Bengal. *Alternanthera philoxeroides* is an exotic weed that invades open water interface of the wetlands extensively next to *Eichhornia crassipes* in plains. *Canna* sp. belonging to the monotypic family Cannaceae is found in both the wetland and terrestrial conditions in the tropics. *Sagittaria montevidensis* ssp. *montevidensis*, *Rumex dentatus*, *Eichhornia crassipes*, *Cyperus exaltatus* and grasses like *Panicum* sp., *Paspalidium punctatum* are common in sewage fed water bodies.

Coastal wetlands and diversity of saltwater angiosperms

In the Indian subcontinent, salt-water angiosperms are mostly dominated in the mangrove ecosystems. The total mangrove area of India is about 6,560 sq km (Anonymous, 1992) of which the mangrove area of the Indian Sundarbans covers about 4,267 sq km. Distribution of different mangrove categories is depicted in the Table 10.8.

Mangroves of the Indian Sundarbans, comprising of 79 floral species, (Table 10.9) are distributed into 41 families and 54 genera and among this, 35 species are true mangrove types (Naskar & Guha Bakshi *et. al.*, 1999). The herbaceous plants of the Sundarban mangrove and mangrove-reclaimed areas are represented by 30 species belonging to 25 genera and 13 families (Ghosh *et. al*, 1990). A new mangrove associate species *Acanthus albus* has been included recently by H. S. Debnath, B. K. Singh and P. Giri (TNN, Dec 06, 2013).

The Sundarbans mangrove ecosystem is also a unique corridor for the vertebrate fauna. The forests and water bodies of the Sundarbans provide dwelling places, habitats, breeding sites and roosting ground for a wide range of vertebrate species encompassing about 250 species of fishes, 8 species of amphibians, 57 species of reptiles, 161 species of birds and 40 species of mammals many of which are

TABLE 10.8 Distribution of salt-water angiosperms in the Indian Sundarbans

Distinctive groups	Family	Genus	Species
Major Mangrove elements	5	8	18
Minor mangrove elements	10	11	15
Mangrove associates	26	35	46
Total	**41**	**54**	**79**

TABLE 10.9 List of true mangroves in the Indian Sundarbans with their family and local names

Family	Name of the species	Local names
Acanthaceae	*Acanthus ilicifolius*	*Haraguja, Sea Holly*
Acanthaceae	*Acanthus volubilis*	*Lata haraguja*
Myrsinaceae	*Aegiceras corniculatum*	*Khalsi*
Aegialitidaceae	*Aegialitis rotundifolia*	*Satari, Tora*
Meliaceae	*Amoora cucullata*	*Amur*
Avicenniaceae	*Avicennia alba*	*Kala baen*
Avicenniaceae	*Avicennia marina*	*Peara baen*
Avicenniaceae	*Avicennia officinalis*	*Sada baen*
Tiliaceae	*Brownlowia tersa*	*Lata, Bola Sundari*
Rhizophoraceae	*Bruguiera cylindrica*	*Sona champa, Thushia*
Rhizophoraceae	*Bruguiera gymnorrhiza*	*Kankra, Natinga*
Rhizophoraceae	*Bruguiera parviflora*	*Champa, Kankra Bokul*
Rhizophoraceae	*Bruguiera sexangula*	*Banduri, Kankra*
Rhizophoraceae	*Ceriops decandra*	*Goran*
Rhizophoraceae	*Ceriops tagal*	*Mat Goran*
Fabaceae	*Cynometra ramiflora*	*Shingara*
Fabaceae	*Derris trifoliata*	*Kalilata*
Fabaceae	*Derris umbellatum*	*Panilata*
Euphorbiaceae	*Excoecaria agallocha*	*Genwa, Blinding tree*
Euphorbiaceae	*Excoecaria bicolor*	*Genwa*
Sterculiaceae	*Heritiera fomes*	*Sundari*
Sterculiaceae	*Heritiera littoralis*	*Sundari*
Malvaceae	*Hibiscus tortuosus*	*Paras*
Rhizophoraceae	*Kandelia candel*	*Goria*
Combretaceae	*Lumnitzera racemosa*	*Kripa*
Arecaceae	*Nypa fruticans*	*Golpata, water coconut*
Arecaceae	*Phoenix paludosa*	*Hital, sea date palm*
Rhizophoraceae	*Rhizophora apiculata*	*Garjan*
Rhizophoraceae	*Rhizophora mucronata*	*Garjan*
Sonneratiaceae	*Sonneratia apetala*	*Keora*
Sonneratiaceae	*Sonneratia caseolaris*	*Keora*
Tamaricaceae	*Tamarix dioica*	*Nona Jhau*
Tamaricaceae	*Tamarix gallica*	*Nona Jhau*
Meliaceae	*Xylocarpus granatum*	*Dhundul, Pohar*
Meliaceae	*Xylocarpus mekongensis*	*Pitamari*

Source: Compiled from Naskar and Guha Bakshi, 1987; Mangroves of the Sundarbans, Volume 1: India, by A. B. Chaudhuri and A. Choudhury, IUCN, 1994.

Aldrovanda vesiculosa: An insectivorous extinct plant species of fresh water wetlands of West Bengal. Possible reasons for extinction may be eutrophication in water bodies and habitat modification
Source: Ghosh S. K.
Courtesy: Herbarium section, Indian Botanic Garden, Haora

endangered in other parts of the world (Chaudhury & Choudhuri, 1994). Nearly half a million poor coastal people depend for their livelihood support on the resource of Sundarban mangrove forest.

Significance of the mangrove vegetation

Mangroves vegetation of the Sundarbans of both the Indian territory and Bangladesh provide tangible and intangible benefits to the stakeholders. This unique ecosystem regulates the economy of certain areas in the coastal part of the globe for its manifold benefits to coastal population. Summary of the diverse benefits derived from the mangrove ecosystem is highlighted below:

- Golpata (*Nypa fruticans*) palms can provide many useful products to local people living near the mangrove areas. The most important commercial product of *Nypa* is sugar produced from its sap. The sap can also be used for vinegar and alcohol production. The dried leaves of this palm are used for thatching roofs of houses of people living in this area. In Bangladesh golpata is extensively marketed in Khulna district for making roofs of earthen huts.
- The mangrove vegetations are economically very significant for their products like timber, firewood, honey, wax, alcohol, tannins and even medicines.
- Certain mangrove species are highly efficient in detecting or assessing the change of ambient environment. Bioaccumulation of heavy metals by certain mangrove species, specially, Kalo Baen (*Avicennia alba*) and Keora (*Sonneratia apetala*) can act as bio-purifier or bio-filter. The concentration of heavy metal pollutants in different parts of mangrove plants may be useful for water quality monitoring programme in the Sundarbans (Guha Bakshi *et al*., 199).
- The precious wood of sundari (*Heritiera fomes*) serves as a valuable source for timber wood and has a good export value that may support the rural economy.
- Capture fisheries, honey, forest wood, rearing of prawns are few of the significant means of livelihood support in the Sundarban area of India. The annual total yield of fish and prawn from the Sundarbans area is about 20,285.2-39,999.7 ton, which represent about 91.6–95.5 per cent of the fish and prawn catch from the entire Hugli-Matla estuarine system (Sinha, 1998). In addition, several thousand rural women folks in the Sundarbans survive on collection of molluscs from the Matla riverbed in Canning (South 24 Parganas).

Exotic wetland weeds

Exotic weeds mostly of South American origin now occupy the major portion of the open water interface of the unmanaged water bodies in the wetlands of West Bengal. *Eichhornia crassipes* and *Alternanthera philo*xeroides, *Sagittaria montevidensis* ssp. *montevidensis* occupies the water edges of wastewater canals in lower Bengal, whereas, *Sagittaria sagittifolia* is common in the nutrient enriched wetlands of North Bengal. Free floating aquatic weeds like *Salvinia molesta* and *S. cucullata* are also common in the brackish water and nutrient rich water bodies.

Threatened plant species in the wetlands of West Bengal

Several species are becoming rare in their earlier native area due to habitat modification, alteration in the physico-chemical parameters of water and the bottom sediments due to anthropogenic pressures (Table 10.10).

East Kolkata Wetlands: Ramsar site of West Bengal

The only Ramsar site of the State, The East Kolkata Wetlands (earlier the salt water lakes at the eastern fringes of Kolkata) is one of the 17 case study sites designated by the Ramsar Bureau for understanding the wise use of wetlands. The East Kolkata Wetlands (22º25'-22º40' N Latitude and 88º20'-88º35' E Longitude) is popular for its waste recycling properties. The halophytic vegetation of the earlier Sundarbans during early 1930s largely dominated the East Kolkata cluster of wetlands. Later on, a gradual change has taken place that resulted in change of water quality from polyhaline condition to almost fresh water (Ghosh and Sen, 1996) with a change in the profile of flora and fauna of the region. During 1945, the total area of the wetlands of the eastern part of Kolkata was about 8,097 ha out of which about 4,684 ha has been converted for fish farming with city sewage. Lack of regulatory control on these wetlands and expansion of Kolkata city towards its eastern fringes led to gradual encroachment. This resulted in shrinking of these wetlands and the present area of the conservation boundary is about 3,905 ha. These clusters of sewage-fed water bodies presently consist of 286 bheries. The existing system not only minimises the nutrient load of wastewater discharged from the Kolkata Metropolitan city, but also provides three folds of benefits (viz., fish, vegetables and paddy) to the population of the city like Kolkata and its suburbs (Ghosh, D., 1983, 1991, 1993, 1994, 1995, 1996 and Ghosh and Furedy, 1984, Ghosh and Mitra, 1997, Ghosh and Ghosh, 2003b).

The unique East Kolkata wetlands: A tutorial ecosystem for traditional practices
Source: S. K. Ghosh

Significance of study of aquatic vegetation for management purpose

Aquatic and wetland vegetation in almost all the parts of the globe is considered as weed and during the last few decades several attempts have been made to identify the active components of the aquatic weeds those provide livelihood support. It needs no further mention that quite a good number of aquatic and wetland plants provide food and fodder, but their overgrowth in the culturable aquatic ecosystem, particularly those utilised for pisciculture, cause serious problems. In water bodies, where fish culture is regularly practiced, conglomeration of aquatic weeds, particularly of submerged and of floating growth forms, cause direct problems for growth and development of fish population. Although there are lot of herbicides like 2,4 D amine salt, Dalapon, Maleic Hydrazide, Diquat, Dichlobenil, etc. in the market for controlling weeds in the fish

TABLE 10.10 Some significant threatened plants in fresh water wetlands of West Bengal

Plant	Threat
Aldrovanda vesiculosa	This plant was last collected during 1957 from Tripura (Deb, 1975). Now probably *Aldrovanda* is extinct from West Bengal due to habitat alteration and change in water quality parameters.
Caldesia oligococca	Distribution became restricted due to alteration of physico-chemical parameter of the habitat and also due to anthropogenic pressures.
Caldesia parnassifolia	Same as *C. oligococca*
Drosera burmannii	Over- grazing and anthropogenic pressures.
Drosera indica	Over- grazing and anthropogenic pressures.
Euryale ferox	No natural population has been recorded from Bengal except in Maldah, where it is cultivated for commercial purpose
Isoetes coromandelina	Habitat modification and overconsumption by pigs in its place of origin.
Najas marina	Change in physico-chemical parameters of the habitat and anthropogenic pressures.
Spiranthes australis	Very poorly explored taxa, and its rarity might be due to reproductive failure or unfavourable habitat
Utricularia striatula	Intra-specific and inter-specific competition, grazing and habitat modification.

Source: Ghosh, 2005

ponds but none of these are efficient to control all the plant species at recommended levels without disturbing other living communities. Extensive use of these herbicides has resulted in development of a wide range of susceptible aquatic plants and these aquatic plants sometimes develop phenotypic alterations.

In addition to these, extensive use of herbicides has also been accounted for loss in diversity of wilderness fish species. Biological control of aquatic weeds has been recommended in India by the introduction of herbivorous grazer fishes like *Ctenopharyngodon idella*, several fresh water snails, exotic natural enemies like *Neochetina bruchi*, *Neochetina eichhorniae* and *Orthogalumna terebrantis* for the control of *Eichhornia crassipes*. (Nagarkatti & Jayanth, 1984; Jayanth & Nagarkatti, 1987a; Jayanth & Nagarkatti, 1987c).

Wetlands for commercial significance

Commercially significant wetlands in India can be broadly divided into conventional and non-conventional types. Paddy and jute fields are commonly treated as conventional types and such types of wetlands are not included in this. Apart from 170 Indian wetland sites studied by WWF-India (WWF-India, 1993) including two Ramsar Sites and 16 lakes, rest of the fresh water wetlands are mostly utilized for either aquaculture or are somehow managed for Traditional Commercial Practices (TCP).

Fresh water aquaculture and estuarine fisheries

Nearly 0.2 million ha fresh water wetlands are distributed in West Bengal, Assam, valley districts of Manipur, Northern Bihar, foothills of Arunachal Pradesh, Meghalayas and Eastern Uttar Pradesh. Average fish yield in fresh water fisheries is estimated about 100-200 kg/ha/yr but these wetlands are capable of producing even up to 5-10 ton/ha/yr if managed properly (Jhingram 1989). Estuarine fisheries of the Sundarban delta of the Indian territory include nearly 1,392 saline water area having 3-260 ha size covering approximately an area of 43,000 ha. Estuarine wetlands of the Sundarban yield about 36,167.5 ton/year commercial fish (Sinha, 1998).

Traditional commercial practices in wetlands of West Bengal

Traditional commercial practice or TCP (other than paddy and jute cultivation and fish farming) in the wetlands of West Bengal is an indigenous culture of not less than

300 years. Unproductive wetlands were the natural harbour of reeds, cattails and other emergent hydrophytes having reasonable market value. Rural people in different parts of the State, particularly South and North 24 Parganas, Hugli, Haora and Medinipur were responsible for commercialisation of major wetland products obtained from plant resources like *Typha elephantina* and *Typha domingensis* (Hogla), *Aeschynomene aspera* (*Shola*), *Cyperus pangorei* and *Cyperus corymbosus* (Madurkathi), *Trapa natans* var. *bispinosa* (Paniphal), *Euryale ferox* (Makhana) etc. The entire information relating to TCPs in the wetlands of West Bengal is vast but incomplete. In West Bengal, at least 2-3 per cent of the rural population are otherwise dependent on the nonconventional wetland resources for their livelihood support at least up to subsistence level. (Satpathy, 1964 Hazra *et. al.*, 1996; Ghosh, 1998, Ghosh, 2005, Ghosh and Santra, 1995, Ghosh and Santra, 1997, Ghosh, S. K., 1998a, Ghosh, S. K., 1998b, Ghosh, S. K., 1999, Ghosh & Ghosh, 2003a, Ghosh, 2005). Traditional commercial practices of wetland plants in West Bengal can be broadly divided into 'major practices' and 'minor practices'.

Major commercial practices

Mat cultivation

Commercial mat is obtained from two species of sedges, viz., *Cyperus pangorei* and *Cyperus corymbosus*. Inferior quality of mat is also prepared from several members of the family Cyperaceae like *Cyperus malaccensis*, *Cyperus iria*, *Cyperus exaltatus* etc. A coarse quality mat is also obtained from *Typha elephantina* and *Typha domingensis* in several parts of the tropics. Commercial cultivation of mat plants is reported in two districts of West Bengal, namely Medinipur and North 24 Parganas. During the study period, nearly 95 per cent of the Integrated Rural Development Programme (IRDP) loan for the district was

Traditional Commercial Practices with mat plant (*Cyperus Pangorei*) in Paschim Medinipur
Source: S. K. Ghosh

provided for mat cultivation in Sabang Block. More than 12,000 families benefited from this practice.

Hogla (cattails) cultivation

Cultivation and management of cattails, locally called *hogla* pati (*Typha elephantina* and *Typha domingensis*) is more than a century old practice particularly found in the wetlands of lower Bengal. It is surprising that even today records of *hogla* cultivation at the village/block level remain inadequate. More than 20,000 rural people of the districts of South and North 24 Parganas, Haora, Hugli and Medinipur are engaged in mat cultivation, management and marketing of products obtained from *hogla*. More than 3,000 ha wetland area is now exploited for hogla cultivation practice in West Bengal. *Typha* swamp also exhibits biodiversity of associated flora and fauna. *Typha* is a significant species for ecological restoration of wetlands. This species is also important for its economic rehabilitation at least at the subsistence level (Ghosh, 2005).

Harvesting of *hogla* leaves for thatching of mats. More than 20,000 people in the State depend on this practice for their subsistence livelihood support
Source: S. K. Ghosh

Shola (hat plant) cultivation

'Shola' is obtained from the soft stem pith of *Aeschynomene aspera* and *Aeschynomene indica*. Commercial shola pith used for art works is obtained from *A. aspera*. Cultivation of *A. aspera* is restricted to mostly North 24 Parganas in West Bengal. Recently local farmers of Maheshpur of South 24 Parganas district have taken initiatives to reclaim wetlands for *shola* cultivation. More than 20,000 people of Maheshpur (Mathurapur P. S. of South 24 Parganas) were dependent on *shola* art in the State and presently more than one lakh people of West Bengal are otherwise dependent on different phases of *shola* arts. Less remunerative boro paddy cultivation is also practiced somewhere in these wetlands when water level recedes. About 150-200 families (mostly migrated from Bangladesh) are the major harvester of *shola* plants in Swarupnagar area adjoining to the transboundary wetlands of Balli Beel (Ghosh, 2005).

Temporary shelters thatched of *Typha elephantina* (*hogla*) leaves in the Sagar Mela ground. More than 10,000 such shelters are prepared with *hogla* leaves each year in the Sagar Mela ground
Source: S. K. Ghosh

Makhana (fox nut) cultivation

Makhana is commercially cultivated in more than 900 ha wetland area in West Bengal and about 5,000 people are somehow dependent on makhana cultivation practice in the district of Maldah (Ghosh, 2002a). Makhana is very recently cultivated in the Railway trackside wetlands or nayanjali near New Jalpaiguri station of the district Jalpaiguri. Makhana seeds harvested from this region is hopefully remunerable and presently the productivity of raw makhana seed is 2,000-3,500 kg per ha per year (Ghosh, 2000) in Harishchandrapur area. Food value of *makhana* is depicted in Table 10.11.

TABLE 10.11 Analysis of proximate components of makhana seed ample collected from Maldah

Parameters studied	*Makhana* Seed (Edible Part) (Wt. %)	*Makhana* Product (Wt. %)
Moisture	27.83-35.11	10.30-14.24
Ash (Minerals)	0.39-0.31	0.57-0.51
Fat	0.21-0.17	13.91-13.51
Protein	13.71-11.11	11.32-10.36
Crude Fibre	0.28-0.22	0.47-0.41
Carbohydrate	57.58-53.08	63.43-62.97

Source: Ghosh, 2002a

Minor commercial practices in wetlands: Cultivation of paniphal and supplementary vegetables

Vast expanse of wetland and water bodies of West Bengal are significant for cultivation of water chestnut locally called *'Paniphal'* or *'Singhara phal'* (*Trapa natans* var. *bispinosa*), lotus (*Nelumbo nucifera*) and supplementary vegetables.

Harvesting and selling of supplementary vegetables from wetlands is a common practice in rural Bengal for subsistence livelihood support. Leafy twigs, petioles and rhizomes of several aquatic herbs are traditionally consumed by many communities in Bengal of which *Ipomoea aquatica* or kalmi is most prominent one. Kalmi is cultivated in the city fringes of Kolkata and Dhamua, Canning and other areas of South 24 Parganas in lower Bengal. In addition, other aquatic herbs like kachu (*Colocasia esculenta*), hincha (*Enhydra fluctuans*), sushni (*Marsilea minuta*), alligator's weed locally called jalsakhi or ban-hincha (*Alternanthera philoxeroides*) and shaluk, *i.e..*, water lilies (*Nymphaea nouchali* and *Nymphaea pubescens*) are significant for their market potential. Several other aquatic herbs like thankuni (*Centella asiatica* and *Hydrocotyle sibthorpioides*), kulekhara (*Hygrophila schulli*) and bramhi (*Bacopa monnieri*) and shimraiya (*Nasturtium officinale*) are also consumed as supplementary vegetables for their medicinal value.

In addition to this, a wetland fern (*Diplazium esculentum* (Retz.) Sw. ex Schard.) locally called dhenki-shak is also sold in the metropolitan market as supplementary vegetable. Dhenki shak has a very good market in Assam particularly in Guahati and Maligaon markets. The plant is also sold in city markets as secondary supplementary vegetables. Among these, cultivation practices of Kalmi shak (*Ipomoea aquatica*) in less remunerable wetlands is popular in the State. Quite a good number of people are also dependent on wetlands for cultivation of aquatic medicinal herbs and aquarium plants in the local markets. Nearly 1 per cent of the State rural population is otherwise dependent on minor wetland practices for their subsistence livelihood support (Ghosh, 2010, Ghosh, 2011, Ghosh, 2012).

The rural people also face occupational hazards from these practices due to lack of health awareness.

TABLE 10.12 Summarized statement of traditional practices in wetlands studied in eight districts of West Bengal during 1997-2000

Districts	Wetlands under traditional practices (ha)	Dependent population	Population supported by TCP (%)
South 24 Parganas	530.17	178600	3.10
Kolkata	27	50000	1.10
Haora	369	20000	1.08
Hugli	127.4	10175	0.23
Nadia	753	45443	5.20
Bankura	700	12000	0.50
Puruliya	100	10000	0.45
Medinipur (undivided)	4798	252011	4.40

Source: Ghosh, 2002

Problems relating to wetland biodiversity

Unsatisfactory socio-economic status in the Indian subcontinent leads to overuse of natural resources of wetlands. Intensive search for alternative food resource from the wetlands for sustenance have forced an alarming level of modification of physicochemical parameters in the natural wetland habitat in the Indian subcontinent. This disturbance of natural wetland habitat, eutrophication, frequent change in the settlement pattern, mono-culture practice (like fisheries) for maximum profit earning and economic instability along with basic

Drosera indica - insect eating plant in the wetlands now became endangered due to habitat modification. Researchers have identified the scope of cancer treatment with active component obtained from *Drosera indica*
Source: S. K. Ghosh

ignorance are the major driving forces for a mediocre diversity of wetland and aquatic macrophytes in the Indian subcontinent. In the National Biodiversity Strategic Action Plan, 2002 following threats were identified.

- Population explosion leads to encroachment of wetlands for other land uses.
- Weed infestation in wetlands has resulted in shrinkage due to excessive evapotranspiration.
- Sedimentation in wetlands.
- Unmanaged pisciculture practices with adequate nutrient addition in many parts of West Bengal has resulted in change in water quality and decline of species diversity in wetlands.
- Fertilisers and pesticides from agricultural runoff have resulted in decline of species diversities particularly in cases of wilderness fishes like *Ambassys chanda*, *Khalisa khalisha* etc.
- Export of germplasm of few aesthetically and medicinally important aquatic and wetland plants is also identified as threats towards dwindling biodiversity.
- Conversion of fresh water wetlands into brackish water fisheries (locally called nona bhery) in many parts of mangrove reclaimed areas of the Sundarbans has resulted in shifting of several species.
- Traditional process of prawn fingerling collection in the coastal wetlands has been reported to have direct bearings towards decreasing fish population in West Bengal.
- Monoculture practice and over use of several economically significant taxa has resulted in loss in diversity in wetlands.

Identification of gaps

- Lack of proper information and scientific database at district level.
- Significance of wetlands as a resource has not been incorporated in the district level planning processes except some attention towards fisheries.
- Absence of law enforcement body for protecting wetlands.
- Lack of field based research on wetland biodiversity at university level.
- Lack of knowledge on biodiversity and human intervention.
- Lack of adequate knowledge towards bearings of river pollution on the decreasing diversity of flora and fauna in riverine wetlands.

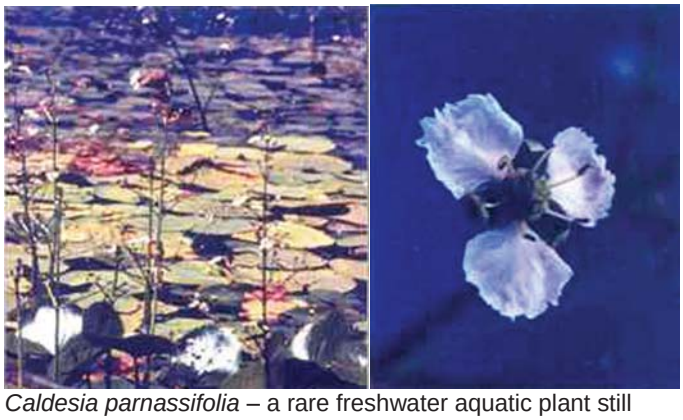
Strategy for future wetland management

- A State level wetland management policy should be framed with adequate participation of the stake holders and the policy makers. The recommendations adopted for wetland conservation should be taken into practice with the involvement of the rural community prioritizing the knowledge of traditional practices.
- Detailed mapping of water bodies of West Bengal by using GIS technique.

- Compilation of a district level scientific inventory of freshwater aquatic and wetland plants of West Bengal.
- Compilation of a district level scientific inventory of aquatic and wetland animals of West Bengal.
- Preparation of district-level seed bank and herbaria of aquatic and wetland plants including scanned images of aquatic and wetland plants.
- Identification of impacts of pesticides on the wilderness ichthyofaunal diversity.
- Studies of flora and fauna of the river stretches of West Bengal.
- A directory of traditional practices in wetlands should be prepared for conservation of diversity of traditional practices including the cultural heritages involved with these practices.
- Encouraging a wider study of tutorial ecosystems like East Calcutta Wetlands and possible replication with local modifications. Expansion of developmental works should be stopped immediately for conservational of this unique ecosystem for man and wetlands.
- Identification of major and minor threats in conservation of wetlands and identification of threats of generic and species level for biodiversity of aquatic and wetland flora & fauna.
- Studies on the scope of introduction of wetland ecology and their role in sustaining man and environment in the curriculum of school, college and varsity level.

Action Plan

- Preparation of a corrected and widely accepted list of water bodies in West Bengal following GIS.
  (Suggested actors: Government, scientists, NGOs)
  (Timeframe: 5 years)
- Preparation of a district level map of water bodies by GIS technique
  (Suggested actors: Government, scientists)
  (Timeframe: 3 years)



Caldesia parnassifolia – a rare freshwater aquatic plant still found in the wetlands of West Bengal

- In-situ conservation of rare and endangered plant and animal species in at least one selected water-body for each district.
  (Suggested actors: Government, scientists, other interested resource persons)
  (Timeframe: 3 years)
- Identification of water-bodies up to 0.16 ha. This will increase the number of wetlands reported and help in their mapping and conservation
  (Suggested actors: Government, NGOs)
  (Timeframe: immediate)
- Time scale compilation of aquatic and wetland plants, including both the vascular and non-vascular hydrophytes.
  (Suggested actors: Government, scientists, any other bona fide resource person)
  (Timeframe: 5 years)
- Compilation of phytoplankton and zooplankton diversity in freshwater wetlands.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Determination of ecotonal habitat and their biotic resources.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Time scale compilation of aquatic and wetland fauna.
  (Suggested actors: Government, scientists, NGOs, any other reputable resource person)
  (Timeframe: at an interval of 10 years)

- Preparation of herbaria/museum with scanned images for documentation.
  (Suggested actors: Government, scientists, NGOs)
  (Timeframe: 5 years)
- Preparation of an inventory of important wetlands having avifaunal importance.
  (Suggested actors: Government, scientists)
  (Timeframe: 3 years)
- Identification of invasive species in the aquatic ecosystem for better management.
  (Suggested actors: Government, scientists)
  (Timeframe: 2 years)
- Preparation of an inventory of river flora and fauna of West Bengal.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Preparation of inventory of the exotic and poisonous plants in aquatic ecosystem.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Survey of the status of freshwater otters in wetlands.
  (Suggested actors: Government, scientists)
  (Timeframe: 2 years)
- Studies on the impact of pollution on the diversity of river flora and fauna
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years, Time series studies needed)
- Inventorying wetland plants exploited for traditional practices.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Identify and conserve amphibian diversity of the State through wider protected area network.
  (Suggested actors: State Biodiversity Board, scientists, other resource persons)
  (Timeframe: 5 years)
- Reintroduce species (like *Aldrovanda vesiculosa*) those are reported earlier in the locality.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Promote conservation of salamander habitat in the State.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Preparation of an inventory of wilderness fish in different districts of West Bengal.
  (Suggested actors: Government, scientists)
  (Timeframe: 3 years)
- Time scale computation of the loss in species diversity in wetlands following pesticide application.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Identification of communities involved in traditional practices and study their role in conservation of biodiversity.
  (Suggested actors: Government, scientists)
  (Timeframe: 5 years)
- Threat identification in aquatic ecosystem and ecotones.
  (Suggested actors: Government, NGOs)
  (Timeframe: 3 years)
- Promote biodiversity festival more and more in the concerned areas involving stake holders and students of school, colleges and varsities for awareness and conservation purpose.
  (Suggested actors: State Biodiversity Board and specific communities surviving on wetland resources)
  (Timeframe: 5 years)

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Chapter 11

Mineral Resource

The exponentially growing vast human population in West Bengal and the rate of economic growth have resulted in widespread and intensive extraction of geological resources for consumption which remain un-replenished over time. There are two salient aspects that seem to be playing the dominant role for preponderance of pollution in the Bengal basin including Kolkata:

- Chemistry and nature of the rocks and sediments (geochemical entities).
- Ecological deficit and exhaustion of geological and ecological assets, resorting to solutions due to which (human interventions) the demand shift from one ecosystem to another.

It has been found everywhere in the perspectives of mining and geology of West Bengal that if one system becomes more dependent upon another system for its survival than the latter can accommodate, the whole system may collapse. The exponentially growing vast human population in Bengal basin, much higher than the carrying capacity, has indulged in widespread and intensive extraction of geological resources for its consumption which are principally non-renewable. The panorama is continuing for the last few decades. The steady growth of human system is reconciled by excessive borrowing from the natural geological system. This usually results in a systems collapse also collaborated by the Earth Report (2002).

There are few primary reasons for environmental pressure:

- Excessive greed in the richer echelon of the society - more a matter of how much, how many and what they consume.
- Exponential growth of population more prominent in particular section of the poorer people.
- For most of the people, ignorance is bliss and they prefer that way.
- People are highly indifferent to and callous about environment and prefer to neglect any civic problem (particularly those concerning environment) or avoid it.

West Bengal mineral scenario

West Bengal is one of the easternmost states of India that covers an area of 88,752 sq km, dominantly (75% of the total area) underlain by soft rocks. The rock formations vary in age from Pre-Cambrian to Tertiary with major land mass covered by Quaternary formation. The ferruginous laterites and lateritic soil cover derived from weathering of hard rocks are considered to be

Box 11.1 Mineral reserve in West Bengal

Coal	:	Barddhaman, Bankura, Birbhum, Puruliya and Darjiling districts
Apatite	:	Puruliya and Bankura districts
China Clay	:	Birbhum, Bankura and Barddhaman districts
Fire Clay	:	Bankura, Birbhum, Barddhaman and Puruliya districts
Dolomite	:	Jalpaiguri and Puruliya districts
Feldspar	:	Puruliya and Bankura districts
Quartz	:	Bankura and Puruliya districts
Iron Ore	:	Paschim Medinipur, Puruliya and Bankura districts
Granite	:	Puruliya and Bankura districts
Lead	:	Darjiling district
Zinc	:	Darjiling district
Silica Sand	:	Puruliya and Bankura districts
Tungsten	:	Bankura district
Vermiculite	:	Paschim Medinipur district
Manganese Ore	:	Paschim Medinipur district
Sillimanite	:	Paschim Medinipur and Puruliya districts
Barytes	:	Predominantly in Puruliya, Bankura and Birbhum districts
Copper	:	Predominantly in Puruliya, Bankura and Birbhum districts
Gold	:	Predominantly in Puruliya, Bankura and Birbhum districts
Kyanite	:	Predominantly in Puruliya, Bankura and Birbhum districts
Pyrite	:	Predominantly in Puruliya, Bankura and Birbhum districts
Titanium	:	Predominantly in Puruliya, Bankura and Birbhum districts
Blackstone	:	Predominantly in Puruliya, Bankura and Birbhum districts

younger in age than Tertiary, and form the base of the Quaternary formation. Mineral reserve in West Bengal is shown in Box 11.1.

There are good possibilities of obtaining mineral oil and natural gas in the areas near the Bay of Bengal, in Purba Medinipur, Sundarbans, South 24 Parganas and North Bengal plains. Research is undergoing for finding natural gas in various places. The estimated production of certain important minerals of West Bengal is given in Table 11.1.

TABLE 11.1 Production of some important minerals of West Bengal

Minerals	Unit	Yearly production			
		2009-10	2010-11	2011-12	2012-13
Coal	'000 tonnes	23133	21659	24230	26467
Natural Gas	million cubic meter	38	41	84	107
Apatite	tonnes	2110	1261	136	-
Feldspar	tonnes	3050	2702	5031	13560
Fire Clay	tonnes	46179	36868	82423	93733
Kaolin (China Clay)	tonnes	99439	89845	92148	95607
Quartz Sand	tonnes	15823	16906	16084	30258
Silica Sand	tonnes	-	55000	51130	71772
Sulphur (Recovered as by-product from oil refinery)	tonnes	15511	25292	31749	36382

Source: State Statistical Hand Book, 2014 and Indian Minerals Year Book, 2013 of Indian Bureau of Mines

Environmental impacts of mining of geological resources

West Bengal is one of the most gifted states in the country in terms of natural resources. The West Bengal's Mining Policy, which was announced in June, 2002, reflects the State Government's vision for development of minerals and mining based industries in the State. The major mining activities relate to sands and gravels, silica sands, china clay, fire clay, other clays, tungsten, lead-zinc, dolomite, apatite and coal. Coal constitutes 99 per cent of the minerals extracted in West Bengal.

River bed sand mining
Source: WBPCB

Sand and gravel mining

The extraction of sand and gravels from rivers, streams, flood plains and water channels conflict with the functionalities of the river ecosystem. Some of the disturbances are from mining methods and others are from the machinery used. Social pressures like population growth in West Bengal cause further environmental impacts of these aggregate mining. Excessive in-stream sand and gravel mining causes degradation of rivers; poses threats to bridges, river banks and nearby structures. An earthquake of Richter scale above 6.0 may cause severe damage if excessive in-stream sand mining continues.

Sand mining also affects the adjoining geo-systems and their uses that local people make of the river. There occurs continuous depletion of river beds, as removal of sand exposes impervious clay horizons underlying the sand. Increasing occurrences of floods can happen therein. Widening of river courses due to sand mining increases the possibility of flooding, as there is no smooth flow of the water. This can ultimately lead to collapsing of river beds and banks. As streams and rivers widen and deepen, there is contamination and shortage of sand aquifer water due to formation of ponds. Bed degradation is caused by pit excavation and bar skimming. Bed degradation occurs through head cutting and hungry water effects represent greater risk to aquatic resources.

Sand mining accelerates the pace of ecological degradation, leaching of heavy metals, organic enrichment and silting by sand particles. It is estimated that 2.5 times of negative environmental impacts occurs due to sand and gravel mining. Removal of river sands leads to deepening and widening of rivers. Artificial rivulets are formed, as resources are extracted uncontrollably, leading to medico-geological problems.

Pit sands and gravels extracted from open areas create uncovered deep pits causing accidents to children and livestock of crowded villages. Erosion of soil and environmental degradation occurs due to continuous mining around mines.

Mines dispose wastes on open areas and river beds causing land pollution. Gangue and overburdens are disposed onto streams and open lands. Dust and noise pollution from trucks ferrying sands and gravels are causes of concern for people around, as trucks move at late nights disturbing sleeps.

Degradation of land, deforestation and loss of vegetation are serious and create negative impacts of sand gravel mining. They destruct river bank hinterland, infrastructure, flora and fauna where extraction is done approaching river beds. For example, on way from Dunlop to Dakshineswar, sand mining is rampant on Ganges river tracts posing threats to local environment. Environmental management plan needs to be prepared with close monitoring programmes, and it will vary with the nature and specificity of the areas.

Silica sand mining

Mining of silica sands causes deforestation and change in the region's topography turning them into wastelands. Vegetation loss promotes erosion, land degradation and loss in biodiversity. Increasing truck haulage, blasting at the sites and increase in Suspended Particulate Matter reduces the air quality of the region. In the refining process of silica sand, large quantities of water are used for washing. Due to large extraction of groundwater for such purpose, the groundwater table may go down. Due to surface run-off, accumulation of sand, silt and clay in natural channels take place causing disruption to natural drainage system of the area. Silicosis is widely prevalent amongst the workers of stone crushing units of Birbhum district. The bad carcinogenic effects are revealed after long time.

Silicosis is widely prevalent amongst the workers of stone crushing units of Birbhum district.

Kaolin (China Clay) mining

Kaolin, also known as china clay, is natural clay formed by chemical weathering of aluminium silicate minerals like felspars. It is relatively pure clay predominantly consisting of kaolinite [$Al_2 Si_2 O_5(OH)_4$], associated with other clay minerals like dickite, halloysite, nacrite and anauxite. Kaolin is commercially valued for its whiteness and fine particle size which distinguish it from other clays, such as, ball clay and fireclay. Other physical characteristics that influence commercial utility include brightness, glossiness, abrasiveness and viscosity. It often contains small amounts of impurities in the form of rock fragments, hydrous oxides and colloidal materials.

Kaolin is produced and consumed in crude and processed forms. The major use of crude china clay is in cement and of processed china clay in ceramic industry. The clay is formed in-situ in West Bengal. It is soft and easily extracted with no blasting required.

There is tremendous scope for future mining of china clay in West Bengal. Mining of china clay takes its toll on land (geomorphology), soil cover, forest cover, surface and groundwater. It causes landscape damage leading to temporary water accumulation during rains creating health hazards. Beside mining areas, there lie reserve and other forests in West Bengal where continued mining may lead to sufficient large scale depletion of biodiversity and wild life. All these areas that come under mining leases may gradually turn into ecological hotspots if proper safeguards are not adopted. The leasehold lands for china clay mining raises concern of geogenic lead poisoning as well.

Fire Clay mining

Clay extraction from natural habitats has consequential effects on natural environment. The effluents resulting from clay mining can be enormous such as air and water pollution, soil erosion, geo-environmental disasters, loss of biodiversity and economic wealth. Clay mining poses major pollution sources to water bodies. Eroded and drained materials could fill the cement pores and water bodies. Thus, vital

water bodies could be lost particularly in dry areas. Very sound planning is, therefore, required during mining. Run-off after heavy rainfall often increases the sediment load of water bodies. The disturbed organic materials that end up in nearby streams or other aquatic ecosystems represent the key challenge of many mines.

Fireclay beneficiation creates carbon dioxide emission that comes through firings at brick kilns. It is also recommended that fireclay manufacturing plants should be close to fireclay mines ensuring minimum transport of mined out products.

Clay mining

Clay mining may modify stream morphology by disrupting channels, diverting stream flow and changing the slope and bank stability of stream channels. These disturbances can reduce water quality. Increased sediment load can smother benthic organisms in streams and oceans, eliminating food sources for predators and decreasing the available habitats for fish to migrate and spawn. The rivers of South 24 Parganas namely Vidyadhari and Matla exhibit such disastrous scenarios. High sediment load can also decrease the depth of streams resulting in greater risk of flooding during times of high stream flow (that may or may not essentially be floods).

Clay mining activities change the colour of water bodies since silts and nanominerals results in removal of vegetation. In case of material harvesting from deep pits, water accumulation can cause diseases like malaria. Vast agricultural farmlands can thus be destroyed. Clay mining should not be done in dried-up areas since its cementing actions choke wells and water flows.

Tungsten mining

The mining of Wolframite $(Fe,Mn)WO_4$, an ore of tungsten, has negative impacts on the environment. It is done by opencast mining. Tungsten is used in industrial and military operations. Tungsten triggers changes in soil microbial communities, resulting in their deaths and increase in fungal biomass. It leads to death of red worms of humus and plants. Soil acidification occurs due to dissolution into deeper layers of soil. Soluble tungsten concentration can be as low as 5-10 mg/l. It can cause a decrease in biomass production by 8 per cent which is probably due to production of stress proteins. Plants and worms take up tungsten ions from soil in significant amounts, while an enrichment of tungsten in plant rhizosphere is observed. These results provide an indication that tungsten compounds may get introduced into food chain leading to probabilities of high damage to living systems.

Base metal (Lead-Zinc) mining

Mining operations involving sulphide minerals (such as Lead-Zinc in Gorubathan of Darjiling district) generally result in excavation of rocks from the subsurface anoxic conditions onto the surface oxic environment. This transformation results in generation of acids and leaching of metals, that are then transported into the neighbouring soil, surface and ground water systems. In the process, metal-rich particulates are also supplied to streams and rivers, with latent deleterious reactions sometimes occurring decades to centuries later.

The presence and release of toxic natural nanoparticles from heavy metal mining complexes and their associated processing plants (active and/or abandoned) through release of acid/alkaline/metal mine drainage water has important implications for the environment.

In older mining operations, it is a common practice still to dump the waste rocks (still containing sulphides), as well as the smelter wastes, directly into or near the river and stream channels and/or on any convenient (for dumping) surface location in the mining-metallurgical complex. Moreover,

the emissions from the smelters affect the plants, soils and water bodies after they are vented off to the atmosphere. The affected natural elements are generally observed in line with the flow direction of gases. Floods and channel aggregation transport these wastes further downstream and deposit them on floodplains. On the floodplains, sulphides are oxidized in place and are transformed via microbial and inorganic reactions to oxic phases such as sulphates, oxides, hydroxides and oxyhydroxides. When the floodplain is eroded by channel migration, these new compounds and residual sulphides can then again be eroded into the river and transported further in downstream direction. Therefore, over the passage of time, the wastes move through a mosaic of complex redox and pH environments that have profound effects on both the solid and solute phases. These changes ultimately control the bioavailability, and hence, the toxicity of the metals to aquatic organisms, insects, and potentially to mammals, including human beings.

The nanominerals being stable have a greater potential for distribution. Whether the heavy toxic metals are converted to nano forms during transport or during dispersal, agglomeration, deposition and interaction with other constituents in different environmental niche' have not been confirmed. But that they preferably attach themselves to hydrated oxides of iron, more particularly nanoferrihydrites and vernadites (Fe and Mn hydrates) are observed. It is also known that along with these ferrihydrites and vernadites, the heavy toxic nanograins are transported miles in a riverine system. Nanoparticles are so reactive that they also tend to bond with each other and create new pollution. Whether the toxic nanometals can travel by themselves or they have to have the hydrated nanominerals as carriers for transport is not known for certain. In other words, whether these heavy nanometal particles remain free or become fixed, remains to be scientifically confirmed.

> Over the years, there has been an uncontrolled discharge of solid, liquid and gaseous wastes from dolomite mines and their processing units. As a result, the nearby vegetation and croplands show severe symptoms of dolomite poisoning.

The mineral nanoparticles in the soil system (where long exposure in-situ defines the mode of occurrence), the ferrihydrites, reflect an interesting feature. The aging phenomenon appears to catch up with the above iron nanooxyhydrates. One may thus find hematite or goethite instead of ferrihydrates – a product of Fe-oxyhydrate transformation through aging. In these circumstances, the sun ray has an additive effect.

The ubiquitous role of nanoparticles in causing environmental pollution must be assessed for finding out the possibilities of utilizing these nanites in monitoring and provenance analysis of multi-faceted pollution in metal mining ecosystem(s).

Dolomite mining

The dolomite mines of Indo-Bhutan border that stretches from the 'Buxa' region of North Bengal to 'Phuntsholing' area of Bhutan form a part of the Buxa Series of rocks of West Bengal. These rocks belong to very high-grade metamorphic types. They are suitable for manufacture of refractory bricks for blast furnace lining; their powder is used for land modification in agriculture, and also in tea gardens as soil conditioner. Cement industry also has a great demand for these dolomites.

However, the dolomite mines of Indo-Bhutan border are contributing to a lot of environmental pollution in the vicinity. Although most of these mines are operational in the Bhutan region, their adverse effects are being felt across the border in the Indian territory. Over the years, there has been an uncontrolled discharge of solid, liquid and gaseous wastes from these mines and their processing units. Blasting of dolomite leads to fracture and collapse of country rocks.

As a result, the nearby vegetation and croplands show severe symptoms of dolomite poisoning. Tea and sal plantation are the worst affected sectors of this region due to such toxicity. The tea estates of Lankapara, Hatipota and Jayanti are reported to be badly hit by dolomite toxicity.

Reports have revealed that dolomite leachate is a potential growth inhibitor – a phenomenon called dolomite poisoning. Different concentrations of this leachate have shown toxic and inhibitory effects on physiology and growth processes of certain plant species, such as seed germination, seedling establishment, seedling survival, speed of germination, length of root and shoot system, and on secondary growth pattern. Chemically, the dolomite slurry is characterized by high salinity, hardness, and presence of elements such as Ca^{2+}, Na^{+}, CO_3^{2-}, HCO_3^{-}, etc. This slurry exerts stickling effects on growth and development of selected plant species and alters their interaction with ambient environment. It is, therefore, important to study the germination and seedling growth pattern of these plantations and suggest measures for mitigation on case-to-case basis. The effects of marble slurry on germination and seedling growth of Vigna radiata has been appreciable. The study shows that the percentage of seed germination and seedling establishment is dose dependent, irrespective of crops. The adverse effects are manifested through a chain-reaction on the natural ecosystem; some important ones are listed below:

- Choking of river beds due to debris accumulation resulting in sharp meanders, frequent changes in water-flow path and recurrence of flash floods in the stream and river channels of the catchment basin.
- Sharp rise in pH which becomes detrimental for the acid loving plants, especially tea, and hampers their production (The North Bengal region is famous for tea plantation all over the world).
- Loss of productivity due to blockage of stomata of tea leaves in the tea tracts that lie adjacent to the dolomite quarries, their downstream processing factories, and the ancillary cement industries.
- Affects the potability of both surface- and subsurface- water as well as soil quality in the command area by sharp rise in salt content.
- Affects the elephant migration routes and corridors of other wild animals due to unplanned blasting of dolomites followed by the load of falling debris, and mass-scale deforestation that takes place thereto.

Apatite mining

West Bengal Mineral Development and Trading Corporation (WBMD&TC) operates the apatite mine in Puruliya district of West Bengal from several decades. They produce three grades of apatite: (i) High grade above 30 per cent P_2O_5, (ii) Average grade of about 20 per cent P_2O_5 and (iii) Low grade of 12 per cent P_2O_5. The average grade is directly marketed as fertilizer for application in tea garden, etc. The medium or average grade apatite is mined from areas around the main ore body and contains substantial amount of ferruginous materials besides other gangue minerals. The low grade ore is dumped separately and occasionally blended with high grade of ore to prepare the average grade for direct marketing. Thus every bit of apatite from the mines is used, except the top soil.

The apatite deposits of Beldih, Puruliya district, West Bengal, occurs along the east-west trending Beldih-Kutni shear zone or northern shear zone (North Singhbhum Shear Zone) belonging to Precambrian Singhbhum Group of Satpura Orogeny. The polymetamorphic sequence of the area consists of phyllites, mica-schists, ortho-quartzites, amphibolites, granites, gneisses, calc-silicates and migmatites. The apatite ore occurs as apatite-quartz-magnetite vein

within the chlorite-phyllite. The ore body is a composite lens separated by phyllite partings. The mineralization is controlled by lithology and structure. The comprehensive mineralogical study reveals that the apatite is mixed fluor-hydroxyl-apatite in composition having fluorapatite in structure. The main impurities that are associated with the apatite mineral are quartz, chert, magnetite, hematite (martitised), goethite and ilmenite. The ore body contains considerable proportion of some trace and Rare Earth Elements (REE).

During beneficiation of apatite, the typical problem arises out of iron removal, as presence of iron hinders value addition in terms of phosphate for downstream operation. Phospho-gypsum, phosphoric acid and phosphate fertilizers are some of the important byproducts of apatite. Phospho-gypsum is used widely in cement manufacture. Phospho-gypsum is formed as a by-product during manufacturing of phosphoric acid. It contains about 1 per cent P_2O_5, 1 per cent F and 10-30 times more radon, none of which is desirable. Environment Protection Agency (EPA) of USA stipulated in 1989 that phospho-gypsum is unsuitable for sale as common gypsum. Production of each tonne of P_2O_5 yields about five tonnes phospho-gypsum. EPA has prescribed stringent measures for storage, transport and disposal of phospho-gypsum.

The use of phosphate fertilizer also falls under scrutiny. Much attention has been paid to its role in stimulating the growth of algae and other organisms in surface water, the process known as eutrophication. This phenomenon is deleterious because it causes de-oxygenation of lakes and shallow, isolated arms of water bodies. Fertilizer phosphate does not leach readily from soil.

One of the best ways to remove this phosphate is through the addition of lime which causes precipitation of apatite. However, this procedure, being relatively costly, has not been applied widely. Instead, the use of phosphate in detergents has been discouraged.

Due to long spell of apatite mining in and around the Beldih of Puruliya, fluoride pollution has taken place in the groundwater, and instances of fluorosis are on the rise. The rural population is the worst affected sector, because of the absence of centralized water treatment system in these areas. Outbreak of media reports on this issue has become a matter of grave concern for the Government in view of the strategic location of Puruliya, its poor socio-economic status and the tribal dominated demography.

Microscopic studies of drill cuttings have revealed fluoride bearing minerals, viz. apatite and fluorite. Two other fluoride bearing minerals like biotite mica and hornblende are also noted that might have also added fluoride into the groundwater. Fluoride from the hydrothermal fluids usually gets adsorbed into the sheet structure of these silicate minerals and stays there until the conditions are congenial for the leaching to take place. Abnormal level of fluoride is also observed within the pegmatite veins. Fluoride mineralization has been found to have been favoured by the presence of structurally weak planes like shear/fracture zones, joints and contacts of host rock and vein quartz. Incidentally, all these conditions are prevalent in the present project area.

The mineralization of apatite has taken place along two prominent linear zones – one located in the north Puruliya region and referred in geological literature as the 'North Puruliya Shear Zone' (covering the areas of Jhalda-Jaipur-Raghunathpur) and the other located in the south Puruliya region and geologically referred to as the 'South Puruliya Shear Zone' (covering the areas of Balarampur-Beldih-Barabhum).

A wide array of physico-chemical factors operating under different hydrogeological regimes is responsible for fluoride enrichment to take place from the fluoride bearing host (country) rock into the saturated zone of groundwater. The dominant hydrochemical facies of

subsurface water in these fluoride affected provinces of Puruliya is Na-K-Ca-Mg-HCO_3 type which has favoured continued leaching from the fluoride rich host rock under alkaline pH condition of the circulating water.

Although 'rock-water interaction' seems to play the major role behind the enrichment process, fast recession of water table (due to excessive groundwater withdrawal) and long spells of drought (as fallout of climate change) have triggered the gradual leaching of fluoride into the circulating water. Prevalence of physical and chemical weathering under arid to semi-arid conditions in high alkaline groundwater zones further favours quick dissolution of fluoride into the circulating water.

The villagers who thrive on this non-potable fluoride rich water bear the brunt of the deadly disease called 'fluorosis' and are clearly witnessed to suffer from yellow cracked teeth, joint pains, crippled limbs and quick aging.

Coal mining

The extraction of coal has always resulted in varying degrees of environmental resource degradation and social impacts, including displacements and migration of people within and outside the leasehold lands. Unregulated mining of coal has the potential to release harmful substances into the soil, air and water. In the Raniganj Coal Field, presence of toxic phenol, heavy metals and fluoride in mine sump water is a regular feature. Emission of Coal Bed Methane (CBM) from the rock cleats and coal fire are recurrent phenomena – possible contributors of global warming. The opencast mining leads to formation of heaps of overburdens that changes the original geomorphology and geohydrologic regimes. Underground mining, on the other hand, releases harmful elements into air, water and soil. Further, blasting removes ecologically valuable top soil, containing seed banks, making it difficult for vegetation

Open cast coal mining
Source: Coal India Limited

to recover. Deforestation due to mining leads to disintegration of biomass, loss of biodiversity and contribute to soil erosion. Occupational health hazards and ergonomic distress are of vital importance for workers of coal industry and coal-based ancillary industries.

The processing and beneficiation of coal in coal washeries, coal crushing units, coal transportation corridors, coal-fired thermal power plants, fly and bottom ash and coal ash ponds, and stowing activities produce a slew of pollution to the ambient environment that affects the human and biotic health of the ecosystem. The effects of damage in coal mining areas may continue to manifest for years even after the mine is shut down.

Geo-environmental impact analysis from systems perspectives

Any geological and mining phenomena have a long lead time for exhibiting their adverse environmental impacts. The trees that are now being felled as a result of urban growth and the smog created due to emergence of SPM will have their devastations on

human health (lung diseases) after a time gap. Mining activities result in a series of inter-related problems both in the core and buffer zones of the quarry sites.

Mining definitely creates strong adverse environmental impacts that are manifested through chain-reactions on the natural ecosystem. Proper environmental assessment followed by sound environmental management practices are, therefore, required to be undertaken to find out the levels and extent of the effects of mining-induced toxicity in different regimes of the ecological system. This would only help to arrive at a holistic solution from techno-economic and scientific perspectives.

The detailed environmental surveys must be conducted on a zone of 5 km radius from the pollution/work activity centres (core mining/smelting areas). The impact of the chemistry of the elements, observed in the sediments, soil, and in the water resources, including the flood plain and the river-bed of the river(s) adjacent to the mines, must be examined and correlated with the specificities as a total system. However, for West Bengal, not much data are still available from the mining occurrences; hence nothing is known till date to entail the role of mining impacted particles.

It is also required to develop an optimal land use plan for the mining affected provinces. This would prevent expansion and migration of mining-induced wastelands that get fast affected adjacent to mines. Necessary measures must be suggested to overcome the adverse impacts on the local biodiversity as well.

As regards to the choking of river and stream courses by debris, suggestive measures must include controlling the size of the debris, as far as practicable, so that the river currents can carry them over a long distance and placer concentration could be avoided on the river beds.

Further, it is necessary to adopt sound geomorphology-based mining practices and good reclamation plan at the mine sites to ensure that blasted debris are prevented from falling into the stream courses. The preferred remedial measures include:

- Rebuilding of soil structure;
- Restoration of soil pH;
- Increase in soil fertility;
- Re-establishing of nutrient cycles;
- Top soil management as well as control of influence of soil erosion on reclaiming lands.

In fine, to work out a holistic solution or problem solving exercise in mining and geo-environmental analysis, the general approach around is to break apart the geological problems in order to make complex tasks easier to deal with. But this creates a bigger problem – the ability to see the consequences of the actions for solution is lost and the sense of connection to the larger whole (i.e. the logistic environment) is damaged beyond repair. All the parts of the whole and their relationships to one another become incomprehensible; hence the problem in its entity cannot be solved. Landfills, for example, generally imply that wastes are dumped without any multimedia analysis into the land directly. The area does not contain any human habitation. It is known that some treatment technologies, while solving one pollution problem, create others. Most contaminants, especially toxics, present problems in more than one medium. Since nature does not recognize jurisdictional compartments, these same contaminants are often transferred across media. For example, air pollution control devices or mining wastewater treatment plants prevents wastes from going into the air and water but the toxic ash and sludge that these systems produce can themselves become hazardous wastes. Thus, the landfill site contaminants pose diverse threats in respect of groundwater, drinking water, soil, surface water, air impacts, flora impacts, human and animal life impacts. In USA, because of these threats of the landfills, CERCLA (The Comprehensive Environmental Response, Compensation and Liability Act) was enacted

in 1980 and the Superfund programme was initiated. It goes without further elaboration that threats are generated because the Earth is a systems entity with inter-connected and inter-dependent components which cannot be ignored.

A well-knit communication strategy must be developed for awareness sensitization and motivation of the local villagers and to generate Knowledge-Attitude-Practice (KAP) of adopting safe environmental practices amongst the stakeholders. The final judgement is of course left to the decision of the environmental planners, policy makers, scientists and engineers to provide reprieve and respite to mining environments from subtle ingress and influx of bizarre and deadly pollution phenomena.

Corporate Social Responsibility (CSR) in geological and mining systems

The mainstreaming of environment into the ambit of mining developments has never been made worldwide. As a result, the adverse environmental impacts of geological explorations and mining activities could seldom be gauged instantaneously, owing to long lead time of their natural manifestations. The countries in which the greatest impacts of geological exploration and mining have been felt are the most industrialized ones. Actually, mining itself has been crucial to the development of the industrialized nations. Not only do its mining problems and pollution create concern, citizens of the industrialized nations enjoy living with the luxury of free time and options necessary to be able to devote themselves to such environmental concern. But in poorer communities, the struggle of everyday survival far outweighs aesthetic concern for the environment.

Abraham Maslow's concept of a 'hierarchy of needs' can be applied in explaining the difficulties of establishing the environmental movement in poor countries. However, the exponential increase in population in the said communities and countries is a serious add-on problem. The questions sometime do arise in this context whether a sense of ethics can be instilled into the minds of the poorer section of the human world.

On the basis of five levels of need in the hierarchy of needs for every human being, the Corporate Social Responsibility (CSR) concept in poor countries may be accommodated. The five levels of need in the hierarchy from the bottom to top are:

Survival (physiological needs): food, shelter, health

Security (safety needs): protection from danger and threat

Belonging (social needs): friendship, acceptance and love

Self-esteem (ego needs): self-respect, recognition, status

Self-actualization (fulfillment needs): creativity, realization of individual potentialities.

Lower levels must be at least partially satisfied before the poor individuals can give attention to higher levels and then they may be able to commit himself to geo-environmental needs. A prior imperative is, however, education. The corporate sectors in the context of social responsibility may work out the modes of action on the basis of Maslow's 'hierarchy of needs' as applicable site-wise. The corporate sector will have to make a detailed status report on the basis of evaluation of group of the people concerned.

In poor countries like India, if the exponential growth of population is not controlled, concern for environmental ethics may become redundant in the said scenario. CSR will tend to become only a theoretical proposition and unrealistic in the context.

Moreover, the impoverished community's survival needs for the food and shelter supersede any idealistic desire they may have to preserve the environment. For example, when a coal mining company turns

to 'strip mining' – a process that essentially rips the mountains to shreds and contaminates the groundwater with heavy metals released – can the poor miners (daily labourers) be expected to jeopardize the welfare of their entire families by protesting because the methods of the employer are environmentally negligent. Their survival needs for food and shelter supersede everything.

Abuse of this natural hierarchy as discussed above has been defined as environmental racism and is epitomized by the disproportionately large number of landfills, chemical plants, mineral beneficiation/metallurgical plants and toxic dumps in the region where the poorer communities stay in the poorer countries. India's political and industrial rich are in the same manner indulging in environmental racism. Environmental ethics in this connection can allay fear concerning ecological integrity and responsibility.

In the traditional ethical theories, established hierarchies of duties, rights, virtues and desired consequences exist so that situations where no single course of action satisfies all of the maxims can still be resolved. Debate continues over where the environment falls in this hierarchy.

Chapter 12

Industrial Pollution Management

The resource-rich state of West Bengal was the industrial hub of the country both during the British regime as well as the immediate post-independence era. West Bengal is well endowed in terms of natural resources, which includes variety of minerals, myriads of agricultural and horticultural products, floricultural items, rich resources for pisciculture and aquaculture and an attractive market for livestock. The State has also been blessed with climatic conditions suitable for agriculture, horticulture and fisheries. Cottage industries dominated the industrial landscape of Bengal upto the middle of the nineteenth century. The muslin of Dacca (now in Bangladesh) made Bengal's weavers earn accolades throughout the world for their fineness of texture and quality.

West Bengal had rich deposits of coal, rock-phosphate, granite, manganese, silica, fire clay, road metal, quartz, apatite, dolomite, feldspar, limestone etc. After the first coal mine was opened in Raniganj in 1820, coal mining became a major activity in the area, the output amounting to approximately 36,000 tons a year. The development of coal mining provided a stimulus to the development of various industrial activities. Kolkata was linked with mineral-rich Raniganj by railway line in 1853 when Lord Dalhousie was the Governor-General of India. This facilitated the flow of Raniganj coal into Kolkata and soon industries began to grow rapidly. Towards the middle of the 19th century, Kolkata appeared in the industrial map of the world. Gradually cotton mill, paper mill, glass, chemical and various other industries were established in and around Kolkata. This resulted in a heavy concentration of industrial activities like jute mills and presses, cotton ginning, bailing and weaving mills, textile mills, silk weaving mills, iron and steel foundries, paper and paperboard mills, glass, rubber, paper tissues, motor car manufacturers and ordinance factories in Kolkata, North 24 Parganas and South 24 Parganas, Hugli and Haora. The first jute mill of India was established in 1854 at Rishra near Serampur, 12 miles north of Kolkata by George Acland of the Borneo Company.

The first pig iron factory of India was established at Kulti in the Raniganj coalfield in 1874. The tea industry also was established in the Darjiling and Jalpaiguri districts. The early part of twentieth century saw the expansion of various industrial activities in the State. The first steel mill in Bengal was established at Burnpur and gradually various engineering and ancillary industries were started in the Asansol

and Kolkata areas. As early as 1946, the Industrial Survey Committee studied the possibilities of the development of new industries in the State. The Committee found scope for expansion of sugar, paper, cotton textiles, silk, engineering, machine tools and leather industries and recommended development of several small industries like handloom, cotton, jute-weaving. cutlery, handmade paper, coir, brass and bell-metal ware. However, the partition of the country in August 1947 adversely affected the industrial life of the State. The jute industry, the most important earner of foreign exchange resources for India was the hardest hit.

The establishment of the Damodar Valley Corporation (DVC) in 1947 and a number of projects in the public sector helped industrialisation of the area. The construction of a barrage on the Damodar by the DVC opened a new era of economic development in the area. Canals taken out from near the barrage supplied water for agriculture and industries in the Durgapur area. The DVC also set up a thermal power station and a power supply grid which was the source of power in the area initially. This area is very near to the coal mines of West Bengal and Bihar. Availability of power and raw materials, easy access to the port of Kolkata and the market helped the growth of large, medium and small industries in the area.

Subsequent to the establishment of the locomotive industry at Chittaranjan, the cable factory at Rupnarayanpur and small scale Industries in different parts of the coal mining area, the Kulti Burnpur industrial complex developed fast. Located on the northern banks of the Damodar, Durgapur developed into a major industrial complex. The main line of the Eastern Railway from Haora to Mughalsarai passes through Durgapur, which is only 98 miles by rail from Kolkata. The Grand Trunk Road passes parallel to the main line of the Eastern Railway. From the British era to the post-independence period, West Bengal progressed steadily in the industrial map of the country due to the following driving forces.

- Suitable geographic location
- Rich mineral resources
- Connectivity and accessibility
- Availability of power
- Availability of water
- Availability of skilled and technical manpower

Industrial development in the State

Building on the legacies of the yesteryears, today West Bengal is India's 6th largest economy of the country and has recorded a gross state domestic product (GSDP) of US$ 132.86 billion in 2014-15. The State's GSDP expanded at a compound annual growth rate (CAGR) of 11.06 per cent from 2004-05 to 2014-15 (Source: http://www.ibef.org/states/west-bengal). The State's strategic position in the eastern region makes it a natural gateway to the east. It is well connected by land, air and sea routes to major global cities including the thriving South-East Asian region. The State also offers excellent connectivity to the rest of India in terms of railways, roadways, ports and airports and is hence highly suitable for industrial growth and development. West Bengal’s total length of roads is over 92,000 km with some 50,000 km of surfaced length of which over 5,400 km are National and State Highways.

The State Government proposed an investment of US$ 8.2 billion for the budget 2015-16. It allocated US$ 99.67 million for constructing Asia Highway 2, which will connect Nepal border (Kakarbhita) to Bangladesh border (Banglabandha). A number of road development projects have been taken up under public-private partnerships (PPP). The Barasat-Krishnanagar section, Palsit-Dankuni road project and Panagarh-Palsit road project are some of the PPP projects being taken up in the State. Under the Backward Regions Grant

Fund Programme (BRGF), 171 projects for widening and strengthening of 2,087 km of roads, and 18 new bridges are anticipated to be operational soon. (Source: http://www.ibef.org/states/west-bengal).

The State has 2 modern ports at Kolkata and Haldia respectively. In addition, a 3000 acre Port-cum-special Economic Zone is shortly coming up in Kulpi. Another 23.4 million tonnes/annum capacity port facility is coming up at Haldia Dock II in Salukhkhali and Rupnarayanchak with an area spanning 160 acres. Further, the entire stretch of inland waterways on the river Ganges between Haldia and Allahabad has been declared as a National Waterway (NW1). The 560 km Haldia-Farakka stretch of NW1 in West Bengal is being developed as a part of multi-modal system for cargo tariff from Nepal, Bhutan, North Bengal and North Eastern States. Kolkata is well connected to the rest of India and all other prime locations of the world by the Netaji Subhas Chandra Bose International Airport. There is another airport at Bagdogra, which links Siliguri with the important destinations within the country. The Kazi Nazrul Islam International Airport (the country's first private sector Aerotropolis) built over 650 acres at a cost of Rs. 600 crore is also another domestic airport (planned as an international airport) located at Andal in West Bengal. This airport's hinterland comprises the towns of Bardhaman, Bankura, Bishnupur, Puruliya, Suri, Bolpur/Shantiniketan, Rampurhat in South Bengal and Dhanbad & Bokaro in Jharkhand and it especially serves the industrial cities of Asansol and Durgapur. In terms of manpower, West Bengal has an abundant pool of talented and skilled workforce that can cater to the requirements of the traditional industries as well as the needs of the new and emerging opportunities in areas such as Information Technology (IT) and IT enabled services (ITeS), Biotech and Non-conventional energy. The ambitious accessibility and connectivity plans of the Government will go a long way in the industrial development of the State.

The State has promoted foreign direct investment, which mostly came in the software and electronics fields; West Bengal is one of the fastest growing states in the IT sector housing over 500 IT and ITeS companies of which around 200 companies are engaged in export from Kolkata while approximately 300 more companies are engaged in domestic businesses. Kolkata is becoming a major hub for the IT industry. More than 120,000 professionals were employed directly in both export and domestic sectors and secondary employment was estimated to be at least five times more. The Government's aggressive IT literacy programme in the schools and colleges of the State in collaboration with some of the top software and IT training organizations has largely helped the growth of this sector in West Bengal.

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Apart from manufacturing and engineering industries, agriculture is the chief occupation in the state. West Bengal is the largest producer of rice in India and the second largest tea-producing State in India. Rice production for the State totalled 15.4 million tonnes in the year 2015. During 2014-15, the State produced 329.3 million kg of tea, accounting for 27.8 per cent of India's total tea production. The State is also home to the globally acclaimed Darjiling tea variety. Kolkata is also the prime centre for India's jute industry. During 2014-15, West Bengal accounted for 79.6 per cent of India's total jute production. In the food and agro processing sector, West Bengal is one of the three front-running states in India. Agriculture contributes 30 per cent to the state domestic product while employing 57 per cent of the workforce. Fruits, vegetables and cereals grow in abundance in agrarian West Bengal.

The State holds 1st position in fish production, 2nd position in production of potato, vegetables and fruits and 4th position in total food grains production. Agro and food processing industries form a very important part of the State's economy. The State Government is setting up a number of policies and plans to focus on the selected areas like vegetables, fruits, fisheries, rice, poultry, dairy and floriculture.

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Gem and jewellery is another thriving industry of the State and West Bengal has had a rich and continuing tradition of craftsmanship for handmade gold jewellery. Jewellery from this region is famous throughout the world for its intricate designs and quality of workmanship. The State Government has taken a number of initiatives including setting up Manikanchan, the exclusive gems and jewellery SEZ at Salt Lake, Kolkata.

Real estate is also a booming industry in the state of West Bengal. The State has certain basic advantages in the housing sector: high urban population growth, changing lifestyle and awareness levels, relatively low cost of land, availability of construction workers at economic rates, need for integrated complexes offering all facilities – city within a city, good rail, road and air links and improvements in the State's transport system.

One of the foremost industries of the State is tourism. The State is endowed with all the diversities of nature – from the arid Chhotanagpur plateau region in the west, forests in the north and south, mountains in the north, sea beaches in the south and rivers crisscrossing the length and breadth of the State; more specifically, the snow-capped peaks of the Himalayas, Darjiling – referred by many as the Queen of Hill Stations, the Darjiling-Himalayan Railway declared as a World Heritage Site, the vast tea estates of the Dooars, the famed Royal Bengal Tiger of the Sundarbans, the mangroves, innumerable historical landmarks of India's and Bengal's glorious history are all wonders for the prospective tourists. Such varied panorama offers the discerning traveller a very wide choice and caters to the requirements of varied and diverse travel segments and consequently, tourism is a very flourishing industry in the State.

West Bengal has been a pioneer in power development over the years. NASSCOM-Gartner ranks West Bengal's power infrastructure as the best in the country offering one of the lowest power tariffs in India. As of January 2016, West Bengal had a total installed power generation capacity of 10,063.84 megawatt (MW). In 2014-15, a 250 MW thermal power unit was commissioned in Durgapur and a 210 MW of Bandel Thermal Power Station was renovated. The 3rd and 4th units of Sagardighi Thermal Power Plant, of 500 MW have also been made operational. In 2014-15, construction of a 293 MW hydropower plant in Darjiling district was approved which is expected to be operational soon. (Source: India Brand Equity Foundation). Haldia Energy Limited – a 2x300 MW power plant was commissioned in Purba Medinipur district in the year 2015. In the new area of clean energy, West Bengal has a large reserve of coal bed methane gas. Two private companies are already producing coal bed methane in West Bengal – Great Eastern Energy and ESSAR are running many wells. The State can also boast of superior communication infrastructure as it is the first Indian state to adopt mobile telephony with optical fibre based information super highway.

The growth of the petrochemical sector has been very impressive in the State both in terms of units set up and investment volume. The main reason for the growth of this industry is due to upstream and downstream industry linkages by the oil refining and petrochemical units set up in the State. Petroleum industries have gained increasing importance and a number of

petroleum and downstream industries have come up in the State.

West Bengal is also one of the country's leading states for export of finished leather goods and accounts for almost 25 per cent of the country's leather exports. There are about 538 manufacturing industries in the State producing leather goods. A state-of-the-art integrated leather complex has been set up on the eastern fringes of Kolkata by the State Government with the objective to relocate the existing old tanneries from the heart of the city as well as to create provisions for setting up new tanneries along with ancillary units related to leather goods manufacturing. The Complex has a capacity to process 1000 kg/day of raw hides and skins using 35 MLD (million litres/day) of water.

The State is focussed on development of industrial growth centres, clusters and sector-specific industrial parks and Intelligent Parks for the IT and ITeS companies. The West Bengal Industrial Development Corporation Ltd. (WBIDC) was formed in 1967 as a premier agency of the State to catalyze investment and help industrial development in the State. The State has a Single Window Facility called the 'State Investment Facilitation Centre' (SIFC).

Fortunately, West Bengal also has a prosperous hinterland of some extremely mineral-rich states like Jharkhand, Bihar and Odisha producing coal, iron ore, manganese, bauxite, chromite, dolomite, graphite, kainite, copper, gold, silver, mica, gypsum in enormous quantities which is an added benefit for the industries of West Bengal.

It gradually became evident that industrial development of West Bengal is essential in our pursuit of economic growth, employment generation and betterment of the quality of life. It is however, needless to say that industrial development often comes hand in hand with environmental degradation, stress on natural resources and ultimately affects the quality of life. Hence, it is extremely crucial to adopt proper precautionary measures for environmental preservation and protection.

A state-of-the-art integrated leather complex has been set up on the eastern fringes of Kolkata by the State Government. The Complex has a capacity to process 1000 kg/day of raw hides and skins using 35 MLD (million litres/day) of water

For the purpose of effective surveillance and monitoring, the West Bengal Pollution Control Board (WBPCB) under the Department of Environment, Government of West Bengal classified the industrial units into five different categories: 'Red', 'Orange',

Box 12.1 Geographical and geological advantages of the state of West Bengal

- West Bengal is the third largest state in India in term of mineral production, accounting for about one-fifth of total mineral production. Coal accounts for 99 per cent of extracted minerals.
- The Raniganj coal belt alone accounts for more than 30,147 million tons of best quality coal.
- An alternative source of natural gas, Coal Bed Methane reserves in West Bengal is estimated as 1.64 million cubic feet.
- Rock Phosphate deposits are found in Beldih, Chirugora and Kutni regions of Purulia district.
- The deposits of granite are found to abound the districts of Puruliya, Bankura and Birbhum.
- Kaolinite with medium to low plasticity and firing index is used as fireclay, which is found in the regions of Birbhum, Barddhaman, Puruliya, Bankura and Medinipur districts.
- West Bengal is well endowed with thick and extensive deposits of basaltic trap rocks in Birbhum district, which are used for preparing road metals.
- Good quality quartz is available at Mirmi in Puruliya district.

Source: http://wbidc.com/images/pdf/CHAPTER3.pdf "Advantage West Bengal"

TABLE 12.1 List of industries registered with the WBPCB

Category	Small	Medium	Large	Total
Green	11416	114	97	11627
Orange	19991	406	378	20775
Red*	7279	476	862	8617
Total	38686	996	1337	41019

Source: WBPCB EMIS
* Excluding Health Care Facilities numbering 6607

'Green', 'White' and 'Exempted'. Such classification is also in sync with the Central Pollution Control Board (CPCB) directions for harmonization of industrial classification across the country. The 74 types of Red category units have maximum pollution potential, the 93 types of Orange category units have moderate pollution potential and the 67 types of Green category units have the least pollution potential. Some industries which have negligible pollution potential have been identified and marked as 'White' (37 types) and 'Exempted' category (51 types) and such activities do not require any prior permission for setting up and operation within the State.

Table 12.1 shows the number and size-based classification of industries registered with the WBPCB in West Bengal. Figure 12.1 and Figure 12.2 show the number of industries registered with the WBPCB indicating both the category-wise distribution as well as the scale-wise distribution. The Table 12.2 and Figure 12.3 show the district-wise distribution of factories in West Bengal registered with the Chief Inspector of Factories, West Bengal. The general profile of industries in West Bengal for the large and medium scale are thermal power plants, oil refinery, petrochemicals, integrated iron and steel, sponge iron, paper and pulp, fertilizer, textile, paints, bulk drug, distillery etc. The profile of small scale industries are rolling mill, foundry, ferro alloy, secondary lead smelting, galvanizing, dyeing bleaching, rubber, ceramic, tanneries, plastic product manufacturing, printing etc.

Table 12.3 shows the district-wise profile of industries scattered within the State and Table 12.4 shows the district-wise number of industries registered with the WBPCB. Figures 12.4, 12.5 and 12.6 show the sector-wise distribution of large and medium scale Red category, Orange category and Green category industries in West Bengal respectively.

FIGURE 12.1 Scale-wise distribution of industries registered with the WBPCB

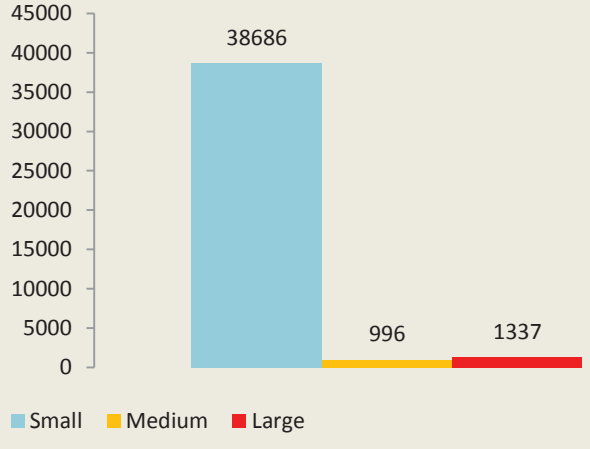


FIGURE 12.2 Category-wise distribution of industries registered with WBPCB

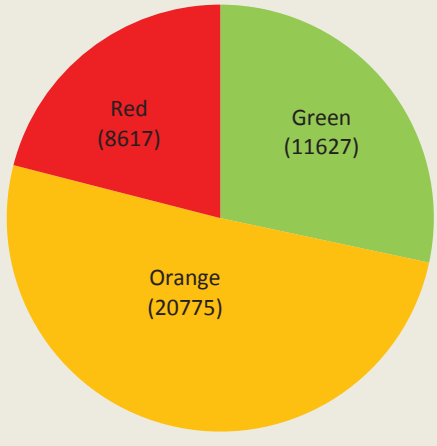


TABLE 12.2 Districts wise distribution of registered factories in West Bengal

District	Number
Koch Bihar	46
Maldah	75
Murshidabad	79
Puruliya	109
Uttar & Dakshin Dinajpur	110
Birbhum	181
Nadia	234
Bankura	255
Darjiling	313
Purba & Paschim Medinipur	393
Jalpaiguri	540
Hugli	780
Kolkata	1055
Barddhaman	1201
Haora	3257
North & South 24 Parganas	7381
Total	**16009**

Source: Chief Inspector of Factories, West Bengal; Statistical Abstract 2013, Bureau of Applied Economics and Statistics, Government of West Bengal

Note: Number of factories exclude 25 Defence Factories

FIGURE 12.3 Districts wise distribution of registered factories in West Bengal

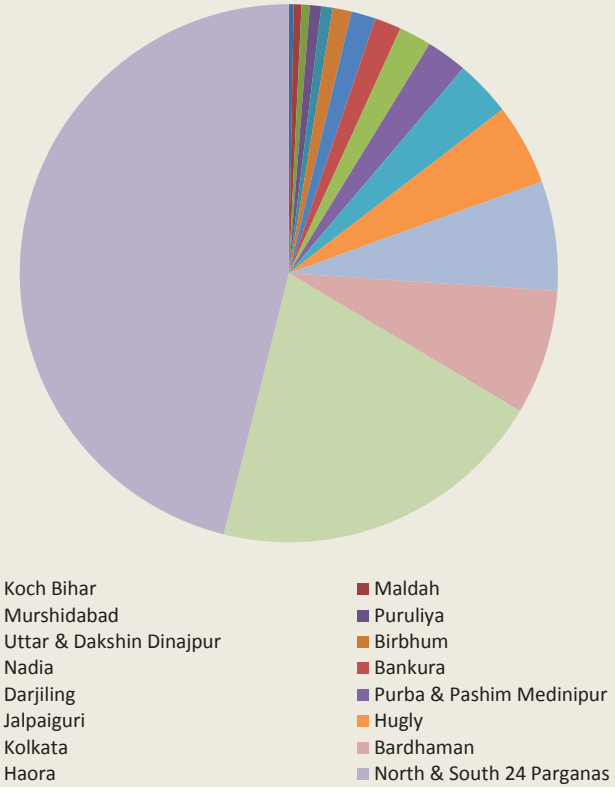


TABLE 12.3 District wise profile of industries

District	Key industries
Bankura	Food and Food-Processing Industries, Textile Product, Ply-wood Industry and Veneer Mills, Paper Industry, Particle Board etc.
Barddhaman	Iron & steel industries, Fertilizers Industries, Mining Industries, Equipment Manufacturing, Cement Industry, Rice and Oil seed Mills etc.
Koch Bihar	Fertilizer Industries, Jute Twine and Weaving Industry, Electrical Casting Industry, Mustard Oil Mill and Fruit processing etc.
Darjiling	Tea industries and Tourism Industry
Hugli	Rice Mills, Rubber Factories, Chemical Factories etc
Haora	Foundry, Re-Rolling Mills, Basic Metal & Metal Products, Electrical & Electronic, transport Equipment & Spares, Rubber Moulded Goods. Manufacturing industry etc.
Nadia	Food and Fruit Processing, Jute Diversified, Pipes & Tubes, Electronic and computer peripherals etc.
North 24 Parganas	Printing, Book Binding, Cement Manufacturing, Oil Seed Milling, General Electrical Works etc.
Uttar Dinajpur	Agriculture and Allied Industries, Food Products, Hosiery and Garments, Chemical Industry, Engineering and Fabrication etc.
Puruliya	Sponge Iron Industry and Non-Metallic Mineral Product Industry etc.
South 24 Parganas	Cement Industry, Agro-Industry, Chemical Industry, Equipment Manufacturing Industry, FMCG Industry etc.
Dakshin Dinajpur	Agro Food-Based Industry, Mineral and Forest-Based Industry, Chemical Based Industry, Handicrafts, Engineering, Automobiles Servicing etc.

TABLE 12.4 District-wise number of industries registered with the WBPCB

District	Red	Orange	Green	Health Care Establishment	Total
Alipurduar	1	8	6	15	30
Bankura	400	473	224	216	1313
Birbhum	512	484	447	362	1805
Barddhaman	1203	2135	1025	817	5180
Koch Bihar	48	146	73	148	415
Darjiling	93	457	438	179	1167
Uttar Dinajpur	68	341	176	174	759
Dakshin Dinajpur	50	231	54	132	467
Hugli	749	2170	1021	958	4898
Haora	1859	4006	987	482	7334
Jalpaiguri	262	554	234	222	1272
Kolkata	1749	3736	5248	1097	11830
Maldah	130	794	248	198	1370
Purba Medinipur	249	1014	589	582	2434
Paschim Medinipur	249	1014	277	659	2199
Murshidabad	127	447	296	638	1508
Nadia	208	492	378	407	1485
North 24 Parganas	1110	3339	1733	1033	7215
Puruliya	416	184	97	158	855
South 24 Parganas	1540	3089	1809	1006	7444
Total	**11023**	**25114**	**15360**	**9483**	**60980**

Source: WBPCB EMIS

FIGURE 12.4 Sector wise distribution of large & medium scale Red category industries in West Bengal

Source: WBPCB Study on "Status of Industrial Pollution Control in Large and Medium Scale Industries of West Bengal" through IISWBM in October 2010

Ministry of Environment, Forests and Climate Change (MoEF&CC), GoI issued a notification on January 16, 1991 to ensure compliance of environmental standards in polluting industries and formulated 15 point programme for priority action. Accordingly, the CPCB selected 17 categories of highly polluting industries throughout the country for priority surveillance. Figure 12.7 and 12.8 shows the 17 category of industries identified by the MoEF&CC and their district wise distribution in the State.

The CPCB had identified "Grossly Polluting Industries" (GPI) as those industries that discharge effluents into a water course and (a) handle hazardous substances, or (b) whose untreated effluent has biological oxygen demand (BOD) load of 100 kg per day or more, or (c) a combination of (a) and (b). In 1993-94, the CPCB initiated identification of industries along the

FIGURE 12.5 Sector-wise distribution of large & medium scale Orange category industries in West Bengal

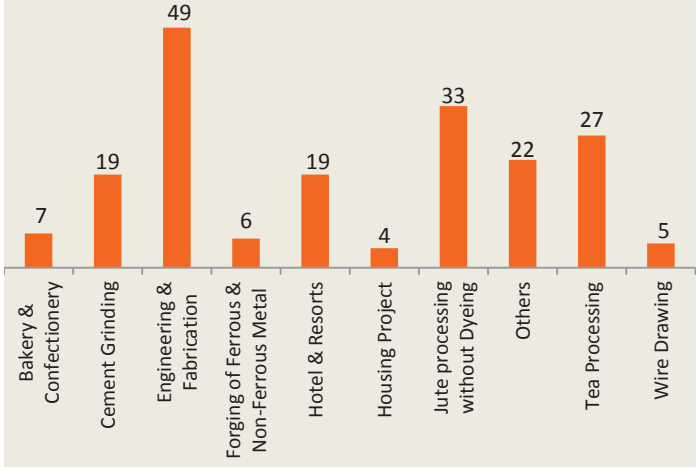
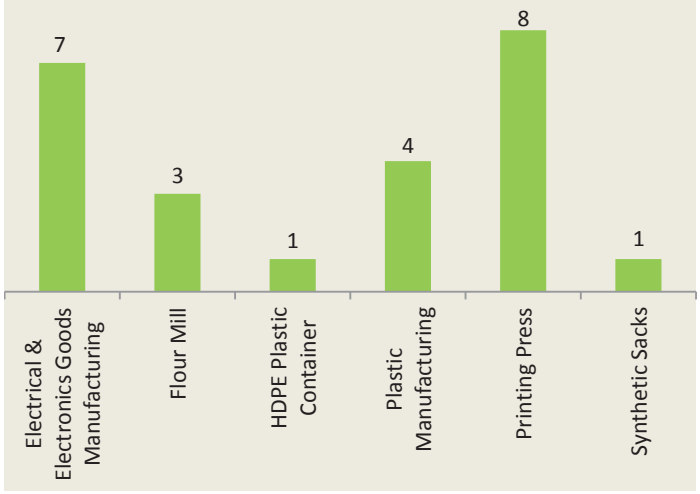
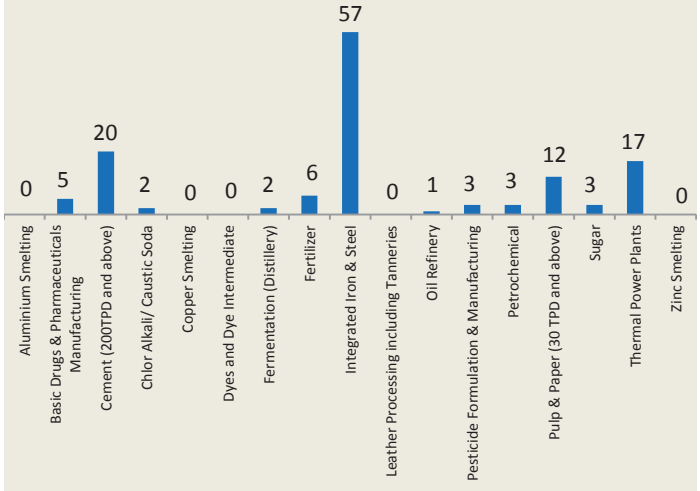


FIGURE 12.6 Sector-wise distribution of large & medium scale Green category industries in West Bengal



Source: WBPCB Study on "Status of Industrial Pollution Control in Large and Medium Scale Industries of West Bengal" through IISWBM in October 2010

FIGURE 12.7 17 category industries in West Bengal



Source: WBPCB

FIGURE 12.8 District wise distribution of 17 category industries in West Bengal

Source: WBPCB

rivers to control industrial discharges into rivers. In July 1997, the National River Conservation Authority (NRCA) directed the industries located on the bank of water-bodies to install requisite effluent treatment systems. Subsequently, action was initiated for inventorization of GPIs and ensuring compliance. Currently there are 43 identified GPIs in the Ganga River Basin area of West Bengal. These industries are under strict surveillance. A district-wise distribution of these industries is indicated in Figure 12.9:

In recent times in connection with a matter before the Hon'ble National Green Tribunal (NGT), GPI was re-defined as industries discharging effluents into a water course and by the CPCB as Seriously Polluting Industries (SPI) and the CPCB has classified 33 sectors of industries as SPI sectors as indicated in Table 12.5. There are currently 547 SPIs in the state of West Bengal and these are under surveillance of the Board.

FIGURE 12.9 District wise GPIs

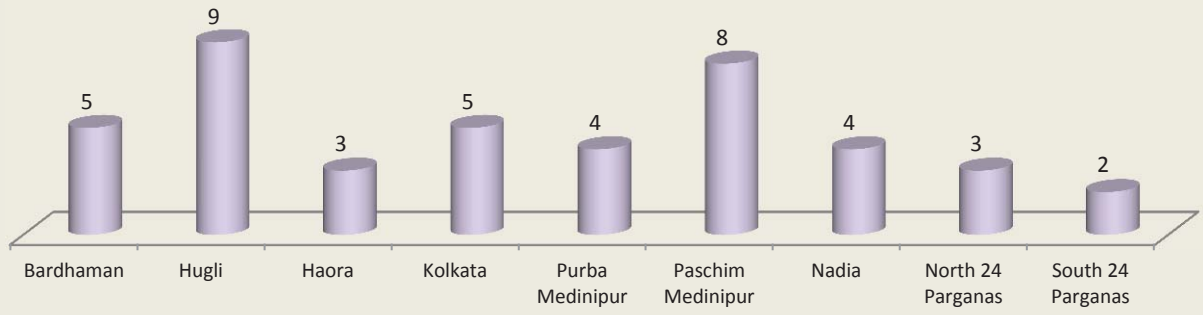


TABLE 12.5 Sector-wise list of SPI
(Approved by the Principal Committee constituted by NGT vide original application no.196 of 2014 & ors. dated 17.11.2014)

	Sector
1	Distillery including Fermentation industry
2	Sugar
3	Tannery
4	Pulp and Paper (Paper manufacturing with or without pulping)
5	Slaughter Houses and meat processing industries.
6	Dyes and Dye-Intermediates
7	Yarn/ textile processing involving bleaching, dyeing, printing and scouring etc.
8	Thermal Power Plants
9	Milk Processing and Dairy Plants
10	Pesticides (Technical) (excluding formulation)
11	Pharmaceuticals (excluding formulation)
12	Petrochemicals (Manufacture of and not merely use of as raw material)
13	Aluminium Smelter
14	Chlor Alkali
15	Organic Chemicals manufacturing
16	Synthetic fibers including rayon, tyre cord, polyester filament yarn
17	Industry or process involving metal surface treatment or process such as pickling/ electroplating/ phosphating/ anodizing/ galvanizing etc.
18	Manufacturing of Paints, Varnishes, Pigments and intermediate (excluding blending/ mixing)
19	Automobiles Manufacturing (Integrated facilities)
20	Coal Washeries
21	Copper Smelter
22	Oil Refinery (Mineral Oil or Petrol Refineries)
23	Heavy engineering including Ship Building (with investment on Plant & Machineries more than 10 crores)
24	Hydrocyanic acid and its derivatives
25	Manufacturing of Lubricating oils, greases of petroleum based products
26	Coke making, liquefaction, coal tar distillation or fuel gas making
27	Zinc Smelter
28	Chlorine, fluorine, bromine, iodine and their compounds
29	Chlorates, perchlorates and peroxides
30	Basic Chemicals and electro chemicals and its derivatives including manufacture of acids
31	Food & Beverages (Alcoholic and non-alcoholic)
32	Photographic films and its chemicals
33	Industrial carbon including electrodes and graphite blocks, activated carbon, carbon black

Industrial pollution: Impact and response

Development and industrialization should both be sustainable in nature and the industries should understand their obligation to mother earth. With the gradual rise in the number of industries in the State, the pollution that comes hand-in-hand needs to be controlled. The state of West Bengal has in the process of industrialization seen and encountered deterioration of environment in many occasions. Environmental challenges were faced in various areas for *eg.* coal mining, foundries, tanneries, power plants, sponge iron, galvanising, dyeing and bleaching, ceramics industry etc. For instance, while coal mining contributed significantly towards the economic development of the State and nation, it also put tremendous pressure on local flora and fauna in the Pachami and other areas in the coal belt of the State. The effect of mining on ground water level, silting of surrounding water bodies and land are also of great concern as it adversely affects the entire eco-system. Huge quantities of waste materials are produced during mining and in absence of proper waste disposal the surrounding land, water and air is greatly affected in turn deteriorating the quality of life of the people in the vicinity.

Similarly the century-old tanneries located right within the heart of the city of Kolkata were a big environmental challenge since they had no or insignificant

treatment systems for their highly polluted effluents which were discharged into the open drains and sewers of Kolkata. The streets of Tangra, Tospia and Tiljala were filled with the characteristic stench of raw and semi-treated leather for decades. Historically, the skylines were dotted with smoke-belching chimneys of foundries in Howrah, rubber, ceramics and dyeing, bleaching industries in Kolkata, sponge iron and ferro-alloy industries in Bankura, Birbhum, Puruliya and Barddhaman.

In the light of such prevailing circumstances it was extremely crucial to bring all industries under a regulatory regime and ensure that the industries complied with the regulatory norms for prevention and control of pollution. As per the provisions of the Water (Prevention and Control of Pollution) Act, 1974 and the Air (Prevention and Control of Pollution) Act, 1981, all industries, which are likely to discharge sewerage or trade effluent into the environment or likely to emit any air pollution into the atmosphere, are required to obtain consent from the WBPCB. The WBPCB issues two types of consents.

Consent to Establish: to be obtained before establishment of any new industry and before expansion or modification of existing industrial process (*Some activities attracting provisions of the EIA (Notification) 2006 dt.14/09/2006 as amended require Environmental Clearance prior to obtaining Consent to Establish*).

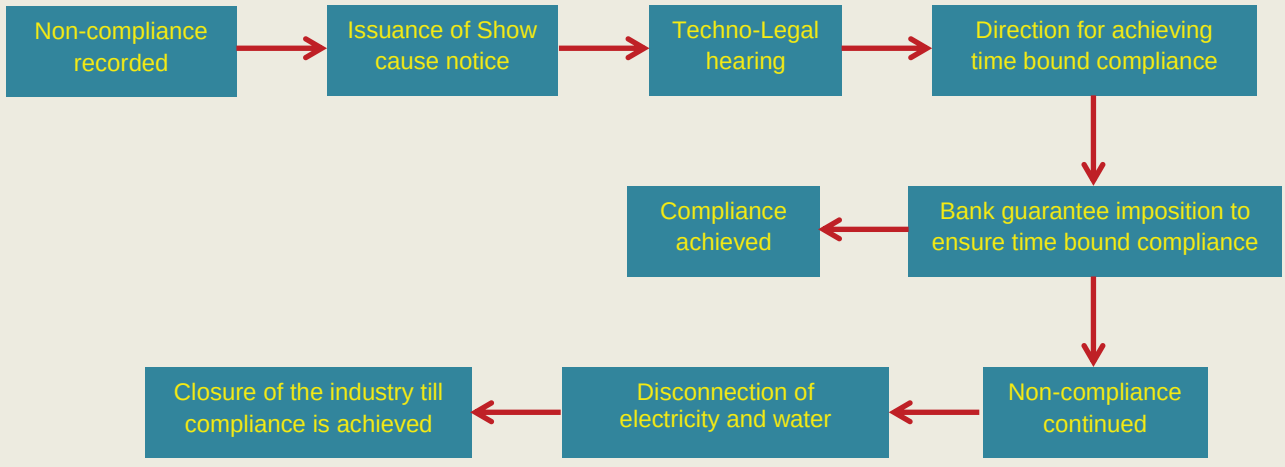
Consent to Operate: to be obtained for running any industry and to be renewed periodically.

Certain types of industries which attract provisions of the EIA (Environmental Impact Assessment) notification (vide S.O. 1533 on September 14, 2006) are required to obtain Environmental Clearance. The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India has re-engineered the EIA notification (vide S.O. 1533 on September 14, 2006) by superseding the earlier notification vide S.O. 60(E) dated January 27, 1994. As per the new notification, the activities requiring EIA clearance have been grouped as A or B, depending on its potential impacts on human health and natural and man-made resources to be processed for environmental clearance by the Environmental Impact Assessment Authority of the Government of India and the Government of West Bengal respectively.

The ways of controlling pollution are diverse. Direct control of pollutants *eg.* reduction of lead content in motor spirit, controlling mercury pollution from caustic soda industries, improved house-keeping for controlling discharge of heavy metals, like chromium and nickel, in electroplating industries etc. Secondly controlling polluted areas or stretches necessitates an integrated approach towards environmental management through control at source, which in turn involves concerted efforts in evolving time-targeted action plans, and their implementation through various agencies. The third approach directed at polluting sources involves securing compliance with the effluent and emission standards prescribed in respect of the polluting industries. The State started prioritizing surveillance on the special categories of industries like the 17 categories, grossly polluting types etc. Of late many of these identified 17 category industries have been directed to ensure online monitoring systems for effluent and emissions and are under regular surveillance of the WBPCB.

All industries of the State are required to go through a comprehensive consent mechanism prior to establishment as well as prior to operation following the transparent "Industrial Siting Policy" prevalent in the State. Once the industries are established and are operational, they are subject to priority surveillance and monitoring of their environmental performance. All non-compliant industries are subjected to regulatory action as indicated in Figure 12.10.

FIGURE 12.10 Regulatory action against industrial non-compliance



Apart from the legislative and regulatory role, the Government has tried to respond to the problems on a promotional note as well. The consent administration for small-scale industries were simplified and decentralised through General Managers of numerous District Industries Centre, District Land and Land Reforms Offices and multiple Regional Offices of the WBPCB. Various Government organisations work in close association with NGOs, academic institutions, chambers of commerce and industry associations for the betterment and support of industries within the State.

One example of a major promotional role played by the State Government was when WBPCB provided financial assistance for change of fuel in small boilers and ceramic kilns within the KMC area under the WBPCB-India-Canada Environment Facility (ICEF) bilateral project. This project helped over 250 rubber, plywood, dyeing, bleaching, and ceramics industries to change the boiler fuel from coal to oil or gas. The project, titled "Pollution Prevention and Waste Minimization of Small Scale Industrial Units in the Kolkata Metropolis Area", was aimed at reduction of particulate emission from a large number of small scale industries operating in the heart of the congested city of Kolkata for several years. These industries were set up mostly after the independence in the thinly populated parts of the city when there was no concern for environment and no legislation for controlling the same. The emission from these industries could not be contained through regulatory mechanism alone as these industries were mostly small scale and unorganized and were operating from small premises without available space for commissioning pollution control equipment and also lacking technical expertise to operate such equipment. The problem could be solved only by a mandatory order from the WBPCB under the Environment (Protection) Rules, 1986 mandating the industries to use cleaner fuel (oil/gas) in place of coal complemented by a financial package for such changeover through change in heating equipment under the ICEF project financing such change over.

WBPCB-ICEF project reduced particulate emission by 95•98% and greenhouse gas emission by about 32,000 tonnes per annum

This project was successful not only in reducing particulate emission by 95·98 per cent (about 13.72 TPD), but also beneficial from the climate change point of view by

reducing greenhouse emission in the form of carbon dioxide by about 32,000 TPA as the oil fired equipment is much more energy efficient in comparison to old energy-inefficient coal fired small boilers and ceramic kilns. The WBPCB provided equal share of funds as ICEF, New Delhi and the industries were reimbursed 50 per cent of the cost of phasing out of coal fired equipment and installing new oil fired ones. This is possibly a unique example of a regulatory authority going beyond its regulatory role and acting as a promotional agent for ensuring sustainable operation of old traditional industries within city limit maintaining environmental discipline, rather than shifting them away from the city.

Another major response of the State has been towards management of classified wastes like hazardous and bio-medical wastes generated from various industries and health care establishments respectively. 939 industries have been identified in West Bengal that generate about 0.2 million tonnes of hazardous wastes per year. As storage, treatment and disposal of hazardous wastes is cost intensive, all industries in the State have opted for the services of Common Hazardous Waste Treatment, Storage & Disposal Facility (CHWTSDF). West Bengal has one CHWTSDF at Haldia operated by M/s. West Bengal Waste Management Limited, a joint venture company formed by the Haldia Development Authority and M/s. Ramky Enviro Engineers Ltd. The facility has been in operation since 2006. In addition to treatment and disposal of hazardous wastes generated in West Bengal, the CHWTSDF also receives incinerable hazardous wastes from the neighbouring state of Sikkim as per agreement signed by the WBPCB with the Sikkim State Pollution Control Board. The State also regulates bio-medical wastes as per the provisions of the Bio-medical Wastes (Management and Handling) Rules, 1998 and their amendments and the WBPCB is the Prescribed Authority for enforcement of these rules in West Bengal. All health care establishments (excepting clinics, dispensaries, pathological laboratories, blood banks providing treatment/service to less than 1,000 patients per month) generating and handling bio-medical wastes are required to obtain authorisation from the WBPCB and submit annual returns on bio-medical waste generation and disposal to the WBPCB every year. All bio-medical waste generators are required to segregate the wastes at source and either treat such wastes on their own or dispose it through some authorized Common Bio-medical Waste Treatment Facility (CBMWTF). As installation and operation of individual treatment facilities entail high costs, most health care establishments opted for the service of CBMWTFs. Six privately owned CBMWTFs are currently operating in the State.

Another significant response of the State was through the effort taken towards environmental upgradation of critically polluted areas in West Bengal on the basis of the Critical Environmental Pollution Index (CEPI). On 13.01.2010, the MoEF&CC had imposed a moratorium in the critically polluted areas (CPA) namely Haldia, Haora and Asansol on setting up of new industries and also expansion of existing industries requiring environmental clearance as per the EIA notification dated 14.09.2006 and its amendments. Keeping in mind the environmental load bearing capacity of sensitive areas like Haldia, Haora and Asansol, which have many major industries, elaborate short and long term action plans were taken since 2010 involving the major industries and concerned local bodies. These areas and industries were rigorously monitored as per CPCB guidelines through a third party on a yearly basis. Reassessment of the CEPI score during 2013 revealed that continuous efforts taken for implementation of pollution abatement action plans for up-gradation of environmental quality in these CPAs show decreasing trend in CEPI score for all three CPAs as compared to CEPI score during 2010 as shown in Table 12.6.

TABLE 12.6 Critically Polluted Area Scores in 2010 and 2013

Critically Polluted Area	CEPI score (during 2010)	CEPI score (during 2013)
Asansol	70.20	56.01
Haldia	75.43	61.58
Haora	74.84	61.11

Source: CPCB, MoEF&CC

TABLE 12.7 Fly ash generation and utilization in 2014-15 in India and West Bengal

Head	West Bengal	India
No. of Thermal Power Station	17	145
Installed Capacity (MW)	12468.00	138915.80
Fly Ash Generation (Million tonne)	19.0883	184.1435
Fly Ash Utilization (Million tonne)	14.7969	102.5433
Percentage Utilization	77.52	55.69

Source: Report on Fly Ash Generation at Coal/Lignite based Thermal Power Stations and its Utilization in the Country for the year 201415, Central Electricity Authority, New Delhi, October, 2015

Another major achievement of the State is in the area of ash management. Ash (both fly ash and bottom ash) generated by coal/lignite based thermal power plants require huge amount of scarce land for ash ponds/dykes for storage and pollute surface and ground water, air and also adversely impact agriculture and health. Ash management remains an issue in spite of persistent effort by the authorities to insist on 100 per cent ash utilization on the basis of the notification issued with time-bound schedules by the MoEF&CC in 2009. In this State in the recent past a number of conferences, seminars, technical workshops, awareness programs etc. were organized for promotion of ash utilization under the project titled "Capacity Building for Efficient Utilization of Thermal Power Plant Ash in the State of West Bengal" in association with Fly Ash Unit, Department of Science and Technology, Government of India. It is interesting to note that the percentage of fly-ash utilization during 2014-15 in the country was is 55.69 per cent while West Bengal achieved 77.52 per cent utilization as shown in Table 12.7. During 2014-15, 34 thermal power stations across the country achieved 100 per cent or more fly ash utilization level of which West Bengal has 8 stations (Table 12.8). Out of 35 thermal power stations during 2014-15 achieving fly ash utilization level in the range of less than 100 per cent to 75 per cent, West Bengal has 3 stations (Table 12.8).

TABLE 12.8 Thermal power stations with Fly ash utilization of 100 per cent or more during the year 2014-15

Sl. No.	Thermal Power Station (Power Utility)	Installed Capacity (MW)	Fly ash Generation (Million tonne)	Fly ash Utilization (Million tonne)	% Utilization
Thermal power stations with Fly ash utilization of 100 per cent or more during the year 2014-15					
1.	Budge Budge Generating Station (CESC Ltd.)	750.00	1.3770	1.3770	100.00
2.	Southern Generating Station (CESC Ltd.)	135.00	0.2720	0.2720	100.00
3.	Titagarh Generating Station (CESC Ltd.)	240.00	0.4220	0.4220	100.00
4.	New Cossipore Generating Station (CESC Ltd.)	160.00	0.0216	0.0216	100.00
5.	Mejia Thermal Power Station (DVC)	2340.00	3.8250	4.5249	118.30
6.	Dishergarh Power Station (DPSCL)	12.00	0.0312	0.0312	100.00
7.	Bandel Thermal Power Station (WBPDCL)	450.00	0.3269	0.5611	171.64
8.	Haldia Energy Ltd.	600.00	0.0700	0.0700	100.00
Thermal power stations with Fly ash utilization < 100% and ≥ 75% during the year 2014-15					
1.	Durgapur Thermal Power Station (DVC)	350.00	0.5120	0.4599	89.81
2.	Durgapur Projects Ltd.	891.00	0.4560	0.4036	88.50
3.	Kolaghat Thermal Power Station (WBPDCL)	1260.00	2.4845	2.2362	90.01

Source : Report on Fly Ash Generation at Coal/Lignite based Thermal Power Stations and its Utilization in the Country for the year 2014-15, Central Electricity Authority, New Delhi, October, 2015

Over the years, ash has been utilised in various areas like cement and concrete, mine filling and stowing, bricks, blocks and tiles manufacturing, reclamation of low lying area, ash dyke raising, construction of roads, embankments, flyovers, agricultural sector, hydro power sector and other miscellaneous activities.

In order to prevent and control industrial pollution, national level standards are developed and notified by the Central Government from time to time. Industry specific standards are available for all major types of industries and for all other types, general standards are applicable. To achieve the standards specified, polluting units are required to install air pollution control system (APCS) to arrest air pollutants and Effluent Treatment Plant (ETP) for treating liquid effluent before discharge into the environment.

In West Bengal, the waste water generated from 43 GPIs is about 200 MLD and this waste water is discharged into the river Ganga or its tributaries. These units have all installed pollution control systems and are rigorously monitored by the WBPCB. Realizing the need for continuous monitoring of quality of emissions/discharges from industries, all highly polluting industries had been directed to install online effluent quality and emission monitoring systems to help track the discharges of pollutants from these units and thereby strengthen the monitoring and compliance through self-regulatory mechanism. Out of the 43 GPIs, 39 have already installed such online monitoring systems and online data are being transferred to the WBPCB's server.

Besides this, 54 major drains connecting/discharging to river Ganga have been identified by the WBPCB carrying municipal sewage and industrial effluent. The WBPCB has already started quarterly monitoring of these drains from January 2017.

Installation of pollution control equipment by individual units is not always a feasible option due to lack of finance, space, technical knowhow, operating expertise, etc. This is especially true for small and medium enterprises. Therefore various approaches have been adopted by industries to ensure compliance with the standards. The most common adopted measure is the installation of Common facilities like Common Effluent Treatment Plants (CETP). As described earlier, instead of installing air pollution control systems, a change in fuel or raw material can also reduce the emission of polluting substances. In Kolkata, the change in fuel from coal to oil in small scale boilers led to substantial improvement in the air quality. Some units have adopted zero liquid discharge whereby liquid effluent discharge from the units to the environment has been stopped and the effluent has been taken into use after adequate treatment. This has also led to resource conservation. Another option is the shifting of polluting industries to sparsely populated areas or to industrial areas or complexes. However, shifting is not an easy option in a developing economy and therefore it is seldom practiced. A successful example of reduction in pollution by shifting of operations is the Calcutta Leather Complex.

Box 12.2 Success story: Calcutta Leather Complex in Bantala

The Calcutta Leather Complex in Bantala was developed by the State Government to facilitate the shifting of all tanneries operating in Tangra, Topsia and Tiljala in Kolkata in compliance of the order of the Hon'ble Supreme Court. The Complex, developed over 1,100 acres, started operation in 2005. It now has 326 tanneries (245 shifted from Kolkata and 81 new). The total wastewater generation is estimated to be 19.91 MLD and this is treated in a Common Effluent Treatment Plant (CETP) of capacity 20 MLD (4 modules each of capacity 5 MLD). The Government has taken the initiative to add two more modules each of capacity 5 MLD to ensure treatment of effluent to be generated by upcoming tanneries in the Complex. The CETP in the Calcutta Leather Complex is an example of how small and medium industries can benefit from such common facilities.

Box 12.3 Success story: Common Hazardous Waste Treatment Storage and Disposal Facility in Haldia

Another example of a successfully operating common facility is the Common Hazardous Waste Treatment Storage and Disposal Facility (CHWTSDF) in Haldia. The facility has been developed by a private operator in partnership with the Haldia Development Authority in PPP mode. It is in operation since 2006 and is the first such facility developed in the eastern region. It is an integrated facility having both incineration and secured landfilling facilities. This has been accepted by the industries as a viable alternative compared to development and operation of individual onsite hazardous waste treatment and disposal facilities and all hazardous waste generating industries in the State are availing the services of this common facility. The facility has a capacity of 1,20,000 TPA for landfilling, 60,000 TPA of waste stabilization capacity and 10,800 TPA of incineration capacity. As per Annual Report submitted the CHWTSDF, the quantity of hazardous waste collected and treated in the year 2015-16 is as follows:

Wastes	From other generators (MT)	In-house generation (MT)	Total quantity of waste (MT)
Waste collected and disposed through Direct Landfilling	11157.965	679.770	11837.735
Waste collected and disposed through Stabilisation followed by Landfilling	30511.946	168.270	30680.216
Waste collected and disposed through CHW Incinerator	6073.296	2.960	6076.256
Total Waste collected and disposed in CHWTSDF	47743.207	851.000	48594.207

Conclusion

Industrialization has historically been accompanied by increasing pollution and depletion of natural resources. Paradoxically, in the modern world, without technology and innovation, industrialization will not happen and without industrialization, economic growth and development will be stalled. Development also entails rise in use of inputs, materials and fossil fuels, which generate environmental pollution and degradation, especially in low income communities. Hence it is imperative and of utmost necessity to build a resilient infrastructure, foster innovation and promote inclusive and viable industrialization. All the stakeholders including the Government, local authorities, industrial managers as well as technical cooperation and collaborating agencies need to come together at this juncture to help the organised industries of today to meet the burgeoning demands within the confines of constraints and pressures by harnessing resource efficiencies to the maximum. This can be achieved only with effective integration of the economic, social and environmental aspects of development and by reconciling all dimensions of sustainability.

The State realizes the urgency of providing the necessary stimulus measures for its industries and service sectors to induce an inclusive economic growth in the state. Hence, the State has formulated an Industrial and Investment Policy in the year 2013. The vision statement of the Policy is- "*to fuel the state's industrial and economic growth with a multi-pronged strategy with emphasis on MSMEs and large investments, public private partnerships, infrastructure development, skill formation and employment generation by nurturing an industrial climate of hope, resilience and innovation.*"

The State Government proposes to achieve the objectives set out in the vision and mission of the policy by the following proposed strategic interventions:

1. Creation of quality infrastructure in the industrial clusters in the State including power, communication, rail and road connectivity. Creation of 'State Manufacturing Zones' in line with National Industrial Manufacturing Zones (NIMZ) and promotion of industrial corridors to capitalize the locally available resources and strengths like availability of natural resources, ports, road network and rail linkages for accelerating growth of manufacturing sector.
2. Facilitation of directed mega investments into the sectors offering huge

employment opportunities and having multiplier effect on the development of micro, small and medium enterprises in the form of forward and backward linkages

3. Adoption of coordinated approach to the development of all sectors of economy through creation and consolidation of sufficient land bank by the developing agencies, including the development authorities, corporations and IDCs to meet current and future requirements of the entrepreneurs.
4. Single Window Clearance: The State Government has implemented the single window clearance whereby "Service Delivery" will be completely electronic with following key targets to achieve efficiency and complete transparency:
   (a) Online application/file tracking features and electronically guided work flow for application movement on the eBiz portal.
   (b) Time bound clearances at each level.
   (c) Online decentralization of domain expertise, clearance requirements and departmental.
   (d) Know-how on the eBiz portal.
   (e) Apex Committee for the assessment and decision based on clear policy framework for decision making, as already done in land allotment policy 2012, for one of the key Investment and Industrial Policy of West Bengal components. Fixed annual timetable of monthly meetings of Apex Committee to expedite the decision making.
   (f) Departmental Nodal Officers in the rank of Joint Secretary and above for information, guidance and issue resolution, if any.
5. Create convergence of schemes for the growth of MSMEs and provide financial, technological and other supports to smaller enterprises of women, youth, minorities and first generation entrepreneurs.
6. Leverage the existing strengths of potential sectors in the State such as food processing and agro, textiles, gems and jewellery, cement, paper, steel, petrochemicals and downstream, leather, tourism, gems and jewellery, energy and ICT etc. with linkages to the available resources such as manpower, agricultural and horticultural output, mineral deposits, marine, natural gas and coal etc.
7. Encouraging private sector participation in infrastructure projects under Public Private Partnership (PPP) especially in industrial infrastructure, power, communication, roads and bridges, ports, airports, tourism and hospitality, health and education sectors.

The State intends to eliminate systemic bottlenecks in the process of industrialization and has kept "Ease of Doing Business (EoDB)" as one of the key components of this policy. The State has undertaken Phase-I initiatives based on the simplified tax regime and e-governance in financial matters. In the Phase-II, the Government will be extending the EoDB to other aspects of business cycle, beginning from setting a business, to a "Single Window Service Delivery System" and covering the incentive tracking and delivery. The first attempt in this direction has been to reduce the 99 pages of documentation to start a business to a 7 page document. This will be further simplified by bringing the various departments and their services, related to setting up a business, into a single electronic window. West Bengal stands 11th among Indian states in rankings based on ease of doing business and reforms implementation, according to a study by the World Bank and KPMG. Some components of EoDB include:

1. Shilpa Sathi (e-enabled business portal).
2. Time bound, process driven and ICT enabled systems: All the applications received for industrial projects would be sent to the line departments for their clearances. All enquiries and the

necessary approvals or rejections, stating grounds for such rejection, shall be completed within 30 days by the various Departments. The nodal Department i.e. the Commerce and Industries Department will solicit the missing documents, clearances etc. in another 15 days, from various Departments and declare the outcome of the application.

3. e-Tendering and e-Procurement.
4. Optimum incentives to the investors.
5. Minimizing the time and space of file movement, reducing the red tape.
6. Ready land bank information in public domain.
7. Bringing the best talent and knowledge in the private sector in planning and implementation through Transaction Advisory Services from empanelled firms.
8. Transparency in the allotment and sharing of public resources.

The components of EoDB are intended to provide efficient, convenient, transparent and integrated electronic services to the applicants. All the departments including the WBPCB have adopted this EoDB. The WBPCB has adopted and implemented the Online Consent Management with effect from 01.06.2015. Under the Online Consent Management, all applicants (project proponent/entrepreneur/local body etc.) are required to file applications for consent and authorization (Consent for Establishment, Consent for Operation, Hazardous Waste Authorization, Bio-medical Waste Authorization, Municipal Solid Waste Authorization etc.) through the WBPCB's Environment Management Information System. Other primary features of the EoDB are as follows:

1. Decentralization of consent management.
2. Helpdesks at all offices of WBPCB for providing guidance to industries.
3. Simplification of documents accompanying Consent for Establishment and Consent for Operation applications.
4. Time-bound pollution clearances by reducing application processing time.
5. 49 non-polluting Green industries exempted from consent requirement by WBPCB.
6. Standard operating procedure for approval and inspection process introduced.
7. Extended validity period of CFE and CFO introduced.
8. Requirement of pollution control certificates as prerequisites for providing electricity connection has been withdrawn.
9. Auto-renewal of CFE for further period of time required for setting up the industry based on self-certification.
10. Auto-Renewal of Consent for Operation for units having no change in activity, capacity, investment etc. for further period of time based on self-certification.
11. Introduction of online payment system in addition to the existing mode of payment through challan.
12. Introduction of Third Party verification towards environmental compliance of medium risk (Orange) industries.

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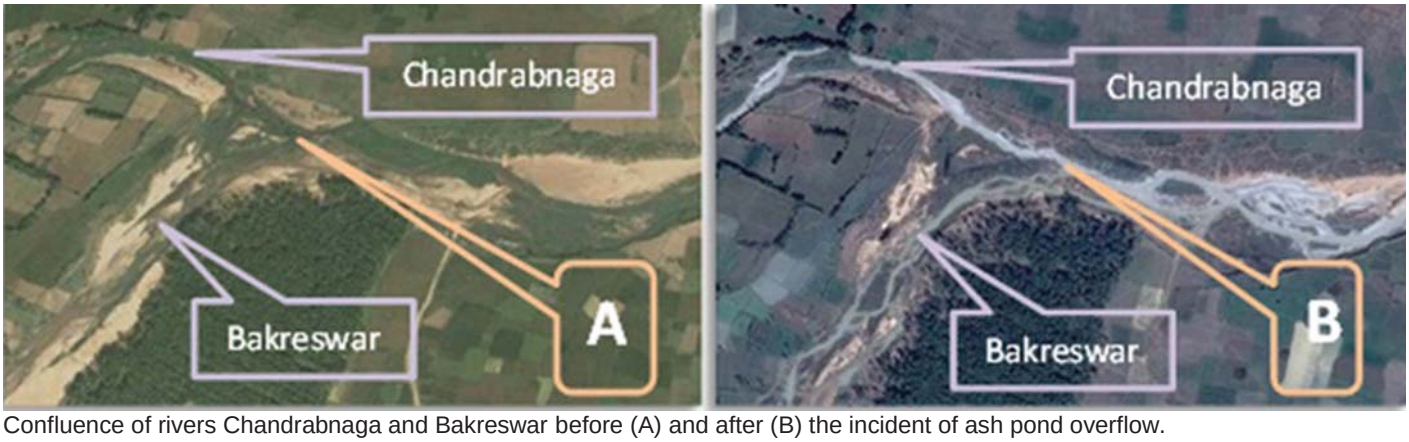
An environmental disaster that killed a river and the story of it's restoration

The Bakreswar and the Chandrabhaga are two important tributaries within Mayurakshi basin. Chandrabhaga is a left-bank tributary of Bakreswar and these two rivers join each other at Parbatipur about 11 km. downstream of Bakreswar Thermal Power Plant ash-pond. The combined river flows further east to join with Kopai and takes the name Kunye which ultimately discharges into the Bhagirathi through *Hizol bill* near Kandi. The two outlets draining from the *Hizol bill* are Uttarasan and Babla.

Bakreswar Thermal Power Plant (BKTPP) was installed during late 1980s and underwent huge expansion in respect of its' capacity since then. Although situated in comparatively water-short region of the state, the huge water requirement was decided to be met from surface water accumulated in the reservoir constructed baffling the river Bakreswar. Both the Bakreswar and Chandrabhaga are exclusively rain-fed and remained perennial by the base flow from ground-water pool during lean months. Since a reservoir was commissioned across Bakreswar river in June 2000, a considerable length of river downstream of the dam has gone dry causing not only desiccation of the river but also cease of ecological services. The reservoir covers an area of 9.42 km^2, with water-storage capacity of 27 million m^3 and a catchment area of 109.42 km^2 with land use patterns of forestry and villages. The BKTPP requires 90,000 m^3 of water/day and this is supplied from Tilpara barrage through a pipe line. The reservoir plays a supplementary role and supplies water to the plant during 2-3 lean months when supply from the Tilpara is interrupted due to maintenance or any other reason.

The catastrophe in nutshell

- Power generation capacity of the BKTPP initially in year 2000 was 630 MW followed by an expansion to 1,050 MW in year 2008. This was done without any expansion of ash pond. This forced the BKTPP authority to dump the ash in to the only ash pond
- The BKTPP authority got coal with more than 40 per cent ash content.
- Huge ash-pond overflow contaminated the Chandrabhaga river.



Confluence of rivers Chandrabnaga and Bakreswar before (A) and after (B) the incident of ash pond overflow.
Source: WBPCB

- The Total Suspended Solid (TSS) of the river went over 25 times that of the discharge standard for the ash pond overflow.
- Ash pond was fully filled up from June to November of 2014.
- Ash accumulation rate was 2500 m^3 per day
- Total ash accumulation during 10/07/2014 to 20/11/2014 (110 days) – 275,000 m^3.
- Ash evacuated during 10/07/2014 to 20/11/2014 (110 days) – 27,992 m^3.
- Ash pond overflowed during 10/07/2014 to 20/11/2014 (110 days) –247,000 m^3 to Chandrabhaga river.

To a conservative estimate, to the tune of 200,000 m^3 was dumped by the incident of ash pond overflow and was to be removed from the river bed to set the river to come back to normalcy again.

Intervention of the Honourable National Green Tribunal

The event of ash-pond over flow happened during September-November 2014 and the two rivers, Chandrabhaga primarily and Bakreswar after it's confluence with Chandrabhaga received huge amounts of ash dumping on their beds. The Hon'ble National Green Tribunal stepped in and following their order(s) the massive and historical river clean up activity started.

- No further discharge from the ash pond should reach the river Chandrabhaga and Zero Liquid Discharge (ZLD) should be implemented with immediate effect.
- The BKTPP should construct and commission the new ash-pond immediately.
- De-silting of the stretch of the river Chandrabhaga, be done on war footing, manually and not deploying any mechanical dredger and should be completed before the monsoon of 2015.
- Disposal of removable materials may be done to abandoned mine(s) or supplied to brick fields, highway authority and organizations legally permitted to use such ash.
- Livelihood support must be provided to the local people. One tube well for drinking water was to be established and one pond of area around 10 cottah was to be dug up in each village surrounding the affected river stretch.

Confluence of two rivers at Parbatipur
Source: WBPCB

Removal of ash deposition from the river bed

Deposition of huge quantity of ash on the riverbed changed the hydro-geomorphic character of the river. It was found during inspection from the point of ash discharge to the point of confluence of river Chandrabhaga and river Bakreswar, the depths of the deposited ash layer to vary from a depth of 1,200 cm to 46 cm on an average. In their attempt in cleaning up the mess, the BKTPP authority deployed heavy earth moving instruments to remove the ash from the river bed. This created a deeper channel down the mid-stream for the water flow, dumping the ash-sand mixture on both sides of this channel on the riverbed itself. Dumping of this ash-sand mixture on the sides of the water channel changed the ecology of the entire stretch of the river during which the action was performed. This is true not only for the region through

TABLE 12.9 Total Suspended Solids (TSS) in ash pond discharge/bypass

Date	TSS (mg/l)	TSS Standard (mg/l)
During the incident		
Jun-2014	1722	100
Jul-2014	14	100
Aug-2014	176	100
Sep-2014	2978	100
Oct-2014	2538	100
Nov-2014	2816	100
Present day situation		
Sep -2016	20	100
Oct-2016	14	100
Nov-2016	16	100
Dec-2016	16	100
Jan-2017	32	100
Feb-2017	32	100

which the water flows, but for the regions on the bank as well, which is why no sign of aquatic life could be identified for the stretch travelled during the inspection. Subsequently, the ash deposit were removed manually and that helped rejuvenate the river.

Deterioration of water quality

Water quality of the river Chandrabhaga has drastically improved and the locals are freely using the water for all sorts of purposes excepting direct drinking. It appears that after one more monsoonseason the quality of water in Chandrabhaga will turn out to be as before. The Table 12.9, regarding the discharge of the ash pond during the incident and recent times is a clear indicator that the river water quality is free from the phenomenal threat.

Restoration of loss of biodiversity

Biodiversity, the index "last to reappear after restoration" for the health of the water body, has been found to be in place. Mother the Nature has been seen to take up the issue of restoration of the river biodiversity which could be visibly confirmed through appearance of algae and other aquatic plants including various fish species moving merrily in the river water. All these are clear evidence of the restoring biodiversity of the river system.

Re-appearing blue-green algae found in Chandrabhaga during February 2016
Source: WBPCB

Re-appearing small fishes found in Chandrabhaga during February 2016
Source: WBPCB

Livelihood support

With interventions by the BKTPP and the District authority to support the livelihood issues of the river side villagers, the condition improved much. Of the principal uses of the water resource, direct drinking of the river water may take some more time to be established. To substantiate, sufficient arrangements has been made in form of tube wells dug in close proximities of the habitations on both sides of the river Chandrabhaga. All other livelihood issues like bathing, cloth washing etc. including drinking by the domesticated animals have been restored.

Concluding remarks

The incident narrated here is a clear example of the "Developmental Spree" of now-a-days endeavour of re-shaping the world with little or no consideration to what may come if checks and balances are not weighed in the balance of appropriate consideration. It is to be reckoned that the pathway for development is complex and one-size-fits-all type of solution does not, to be precise, 'cannot' confront the severe complexity. Out of the myriad of global environmental narratives some general principal has to arise. What is required for the 'sustainability', has to be done. That the "Cost to be paid by the nature" is suicidal, need not any proof and is to be discarded outright. To do any less would be a dereliction of our social responsibility. That technology rules, and shall continue to do so is accepted by everybody, but, it is the opinion of all wise men that where there are and when there are alternatives and choices, democratic political processes should be at the centre of decision making – not the technology.

People using Chandrabhaga river after restoration
Source: WBPCB

Cattles drinking water from Chandrabhaga river after restoration
Source: WBPCB

Chapter 13

Air Quality

"*Air pollution has been a problem since the days of ancient Rome*" according to Joseph Stromberg (Smithsonian Magazine, February 2013). In fact, the history of anthropogenic air pollution dates back further - about 19,000 to 20,000 years before ("Early Pottery at 20,000 Years Ago in Xianrendong Cave, China". Science 336 (6089): 1696–1700. June 29, 2012). This evidence has been obtained from the Xianren Cave and the potteries found therein made some 20,000 years ago. These objects clearly bear the signature of the amount of fire that was required to bake the soil to get the texture seen on the objects. Fairly systematic accounts of ancient day events of air pollution are found in the works of Célia Sapart of Utrecht University and her colleagues (C. J. Sapart, G. Monteil, M. Prokopiou, R. S. W. van de Wal, J. O. Kaplan, P. Sperlich, K. M. Krumhardt, C. van der Veen, S. Houweling, M. C. Krol, T. Blunier, T. Sowers, P. Martinerie, E. Witrant, D. Dahl-Jensen, & T. Röckmann; Natural and anthropogenic variations in methane sources during the past two millennia. Nature 490, 85–88, 04 October 2012). They recorded the chemical signature of methane in ice samples spanning 2,100 years and correlated the accumulation of this gas with changes in human population and land use, such as the decline of the Roman empire and the Han dynasty, and the population expansion during the medieval period.

The Xianren Cave

Pottery in Xianren Cave made some 20,000 years ago

Urban air started getting polluted during the early days of the industrial revolution in Europe and the United States as the age of coal, dusts and smoke had started. The Great Smog of Britain (December 1952, number of deaths greater than 10,000) established the ill effects of air pollution. Invisible threats like photochemical smog, acid rain, ozone layer depletion and climate change issues followed the extreme high growth in the use of coal and oil for industry and transportation just after the second world war (S. Mosley, Environmental History of Air Pollution and Protection, in Encyclopaedia of Life Support System, 2010). Opinion started getting strengthened in favour of effective legislation for control of air pollutants and putting sustainability at the heart of decision making. Governments across the globe underpinned the very foundation of combat responses to air pollution.

Global climate change is the most significant environmental issue of present times and is predominantly due to air pollution. Governments, businesses, households and individuals are striving round the world to act to contain air pollution. West Bengal saw early industrialization during the mid-eighteenth century and is now facing an acute air pollution problem around the urban and industrial areas. General awareness of citizens is the only insurance for conserving the environment for future generations in ways that protect our economic well-being, social systems and cultural wealth. Air quality data presented in this article are all collected and collated by the West Bengal Pollution Control Board and is publicly available at the "Air Quality" button on the website www.wbpcb.gov.in.

Understanding air quality

Air does not understand any boundary. Even then air quality is defined on the basis of the sovereign political boundary of a nation state. Air pollutants are those that exist in air in excess of the concentration that existed in the pristine air. Usually the emissions from the activities of organized living on earth, or, the activities of "civilization" are referred to as air pollutants. Like every other country, India also have a definition of ambient air, *i.e.*, the air an average Indian is allowed to breath day in and day out.

The Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India notified the National Ambient Air Quality Standards (NAAQS) [GSR 826(E) dated 16 November 2009] through stipulation of maximum permissible limit of 12 ambient air quality parameters. These parameters are: Particulate Matter (size less than 10 μm) (PM10), Particulate Matter (size less than 2.5 μm) (PM2.5), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Ozone (O_3), Carbon Monoxide (CO), Ammonia (NH_3), Benzene (C_6H_6), Benzo(a)Pyrene (BaP), Lead (Pb), Arsenic (As) and Nickel (Ni). (Table 13.1)

Systematic estimation of the air quality in West Bengal started in the year 1998. In its current phase, the WBPCB monitors the air quality parameters in 12 districts during the period October 2012-December 2016. The present report covers air quality data (2012-2016) and gives an account of the annual concentrations of air pollutants of the districts covered. As for the rest of the districts, for the first time, one full year-round determination of air quality has been performed in 2016, hence, the January to December, 2016 variations are reported for parameters of immediate interest.

This report covers air quality data of places where air sampling was performed. Apart from the Kolkata, the air quality monitoring stations in rest of the districts have been positioned in urban conglomerates or industrial hubs. Therefore, reporting about the air quality of a district obviously does not speak about the entire district but, rather, the urban areas including industry centers. For example, the air quality of district Darjiling is monitored

TABLE 13.1 National Ambient Air Quality Standard 2009

The Gazette of India; Extraordinary
Registration No. 33004/99; New Delhi, Monday, November 16, 2009

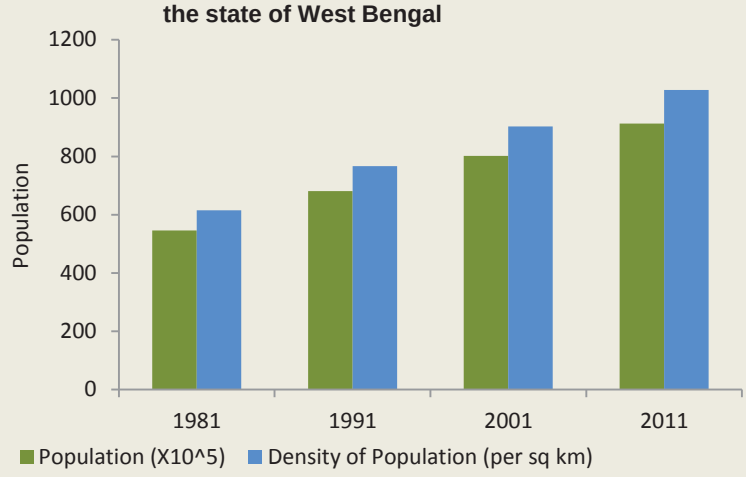
SI	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (Notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	• Improved West & Geek • Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	• Modified Jacob • Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (size less than 10 µm) or PM_{10}, µg/m^3	Annual*	60	60	• Gravimetric • TOEM • Beta Attenuation
		24 Hours**	100	100	
4	Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$, µg/m^3	Annual*	40	40	• Gravimetric • TOEM • Beta Attenuation
		24 Hours**	60	60	
5	Ozone (O_3), µg/m^3	8 Hours**	100	100	• UV Photometric • Chemiluminescence • Chemical Method
		1 Hours**	180	180	
6	Lead (Pb), µg/m^3	Annual*	0.5	0.5	• AAS/ICP; EPM 2000 or equivalent
		24 Hours**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m^3	8 Hours**	02	02	• NDIR Spectroscopy
		1 Hours**	04	04	
8	Ammonia (NH_3), µg/m^3	Annual*	100	100	• Chemiluminescence • Indophenol Blue Method
		24 Hours**	400	400	
9	Benzene (C_6H_6), µg/m^3	Annual*	05	05	• GC based continuous analyzer • Adsorption and GC ATD
10	Benz(α)Pyrene (BaP) – Particulate Phase Only, ng/m^3	Annual*	01	01	• Solvent extraction followed by HPLC / GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	• AAS/ICP; EPM 2000 or equivalent
12	Nickel (Ni), ng/m^3	Annual*	20	20	• AAS/ICP; EPM 2000 or equivalent

* Annual arithmatic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

* 24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year, 2% of the time, they may exceed the limit but not on two consecutive days of monitoring.

[F. No. Q-15017/43/2007-CPW]
-Sd-
RAJNEESH DUBE, Jt. Secy.

FIGURE 13.1 Extremely fast growth of population in the state of West Bengal



at stations in Siliguri and Darjiling cities. Therefore, the rest of the area of Darjiling obviously cannot be ascribed to the air quality presented in this report. To make it meaningful, the number and percentage of people covered by the urban/industrial setups in the districts are referred.

Driving forces for adverse impact on air quality

A guarantee for food and shelter notwithstanding, at the individual level, the driving force extends through ever increasing demands for mobility, entertainment and culture. In a macroscopic context, the growth of population establishes the driving force that creates pressure on the air quality. The density of population in West Bengal has increased rapidly in the last three decades as shown in Figure 13.1.

Population, transport, energy use, industry, landfills and waste disposal are the primary sources that contribute to the driving force in air quality. They contribute to the overall process of augmentation of household consumption structured according to the economic sectors (*e.g.* agriculture, energy, industry, transport, households).

The main component of the driving force is expressed by the 'consumption by households'[1] Our lifestyle choices, the goods and services we consume, how these area are produced and disposed off, all affect the extent and manner of our impact on the environment. The purchasing of goods and services for our sustenance is an approximate measure of the pressure households place on the environment through consumption. Thus, household consumption can be a useful indicator of the impact our lifestyles have on the environment. Purchasing patterns finally reflect on the consumption which is influenced by a range of factors such as population size, income, the availability and affordability for goods and services, economic trends, and consumer preferences.

In West Bengal the retail sector is a major sector that has high consumption potential. It is an indicator of the pressure this driving force has on environment. "*The best that Kolkata can offer to retailers is the attractive household expenditure and an illustrious high-street variety retailing. It has a fairly high concentration of SEC A (Annual Income more than INR 300,000) and SEC B (Annual Income more than INR 500,000) households whose propensity to consume is usually higher than others. However, rents in prime areas are not affordable and the retail stock is also low, both of which make penetration of the retailers difficult*" comments a market report ("India's Retail Luxury Quotient-Exploring the Luxury Clusters of India" of Jones Lang LaSalle.in September 2013).

The driving force for air quality therefore may be ascribed to the following indicators

[1] "Consumption by Households" is used here to represent the fact of the time that creates the "Driving Force" which is utmost necessary to represent the STATE OF THE SYSTEM, required to present the State of Environment report. Discourses like 'relative contributions of households from different economic strata' is not considered apposite in the current contest, which can be taken up vis-à-vis the analysis on 'finiteness of nature' at appropriate forum.

- Household consumption;
- Vehicle kilometer travelled;
- Energy generation and consumption;
- Waste generation, treatment and disposal;

Pressures

Human society, under the driving forces, move to create pressure on the environment as it eventually leads to human activities, i.e., activities in meeting human need – be it legitimate or exaggerated. Such human activities are referred to as 'pressures' on the environment, which result from production or consumption processes. The pressure can be subdivided into several groups:

- Over-utilization or excessive use of environmental resources;
- Land use change (including loss of prime land for waste disposal);
- Emissions from human activities (construction, industry, transportation etc.);
- Scarcity of pure air which is healthy to inhale;

Pressure on the environment changes the state of the environment itself and this publication is an attempt to capture the status of air quality of the state of West Bengal under such Driving force – Pressure scenario.

State of air quality: West Bengal at a glance

West Bengal has good air quality in most places for most of the time. Nevertheless, emissions from industrial sources and road traffic affect air quality in the districts. Around 32 per cent of the state population live in these locations. Both large and small urban settlements are affected by poor air quality.

Small and inhalable air particulates are the causes of worsening air quality which is worst during high winter time. These particulates are known as PM10 and PM2.5 particulates, because they are smaller than 10 and 2.5 microns in dimensions (as they migrate through air) respectively. The twin cities Kolkata and Haora, home to about one-third of the State population (31.87%, 29,303,002 of 91,276,115) experience high PM10 & PM2.5 particulate levels for about 5.5 months every year spanning the winter. Most of the other district headquarters of the State also have particulate concentrations higher than the national standard during the winter months.

The entire state, throughout the year, hardly ever experience non-compliant air quality for any of the air pollutants other than the Particulate Matters. NO_2, the gaseous air pollutant sourced from high temperature industrial burning processes and automobile exhaust emissions, occasionally miss the standard during winter months in the city area.

The air pollution monitoring network is being expanded and upgraded to ensure continuous monitoring where air pollutant levels are of concern. An account of such levels of air pollutants of concern are provided below that shows that the Particulate Matter (PM) is of practical concern for the entire State, with special reference to the cities and district towns. NO_2 in its' count, although scored non-compliance (NC) for 1 per cent of days in all the three years computed over the entire State, this can be attributed to the contribution of the twin city Kolkata and Haora to the pan-state averaged air quality as is obvious from the data presented for the districts separately.

West Bengal		
Total Population	Population affected by air quality	% population affected by air quality
91276115	29,093,002	31.87

Table 13.2 summarizes the status of air quality in respect of four traditional parameters which are affected by almost all air quality events. The remaining eight parameters, viz., Ozone (O_3), Carbon Monoxide (CO), Ammonia (NH_3), Benzene (C_6H_6), Benzo(a)Pyrene (BaP), Lead (Pb), Arsenic (As) and Nickel (Ni) are presented in Table 13.3. None of these eight parameters showed deviation from the standard values during these three years excepting for an hour for CO in Kolkata which corresponded with the night of Kalipuja in 2015. Thus, the air quality of the State conforms to the acceptable levels for these parameters. However, in view of the augmentation of air quality events in the state, monitoring of these parameters are being made more intense by deploying continuously operated air quality monitoring systems.

Table 13.4 summarizes the non-compliance cases for the eight parameters other than the particulates, NO_2 and SO_2. The data was obtained from monitoring stations in Kolkata, Barddhaman and North 24 Parganas during 2013, 2014 and 2015. It is seen that non-compliances for these 8 parameters did not happen in these 3 years

TABLE 13.2 Air quality in respect of four traditional parameters in West Bengal and yearly days of non-compliance

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan -dard	% Days of NC	Value	Stan-dard	% Days of NC	Value	Stan-dard	% Days of NC	Value	Stan-dard	% Days of NC
2013	104	60	42	67	40	42	7	50	0	36	40	1
2014	110	60	49	65	40	47	7	50	0	40	40	1
2015	109	60	50	69	40	61	8	50	0	42	40	1

NC: Non-compliance

TABLE 13.3 Status of air quality in respect of eight parameters in West Bengal

Air quality parameter	Kolkata			Barddhaman			North 24 Parganas		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
O_3 (Max) (μg/m^3)	89.50	120.50	103.00	106.13	110.52	80.87	107.70	111.54	87.93
O_3 (Avg) (μg/m^3)	36.29	46.77	47.59	36.61	54.78	47.18	40.80	55.68	44.67
O_3 (Min) (μg/m^3)	7.00	9.50	13.50	8.85	10.00	18.64	9.35	10.00	18.25
NH_3 (Max) (μg/m^3)	62.17	33.33	62.17	33.94	35.92	37.64	33.45	37.20	34.88
NH_3 (Avg) (μg/m^3)	16.30	14.05	17.98	20.67	26.17	22.61	20.85	26.31	22.37
NH_3 (Min) (μg/m^3)	5.00	5.00	5.00	8.12	9.60	16.13	5.00	13.64	17.17
CO (Max) (mg/m^3)	3.90	3.50	4.90	1.54	1.31	1.26	1.74	1.30	1.23
CO (Avg) (mg/m^3)	0.90	0.08	0.08	0.68	0.64	0.61	0.68	0.63	0.64
CO (Min) (mg/m^3)	0.02	0.02	0.02	0.26	0.34	0.32	0.25	0.33	0.32
Pb (Max) (μg/m^3)	1.33	0.63	2.63	0.76	0.81	0.26	0.91	0.59	0.28
Pb (Avg) (μg/m^3)	0.21	0.17	0.17	0.21	0.15	0.14	0.19	0.16	0.15
Pb (Min) (μg/m^3)	0.03	0.02	0.02	0.09	0.03	0.07	0.08	0.03	0.09
Ni (ng/m^3)	6.22	7.23	7.43	7.41	8.76	11.74	7.39	9.54	12.63
As (ng/m^3)	3.02	2.34	2.74	1.84	2.07	2.31	1.61	2.10	2.62
C_6H_6 (μg/m^3)	0.84	0.84	0.77	1.12	1.35	1.51	1.08	1.32	1.64
B(a)P (ng/m^3)	0.19	0.44	0.36	0.35	0.55	0.34	0.22	0.49	0.39

Standards: O_3=180 μg/m^3 (hourly), NH_3=100 μg/m^3 (annually), CO=4.0 mg/m^3 (hourly), Pb=1.0 μg/m^3 (daily), Ni=20.0 ng/m^3 (annually), As=6.0 ng/m^3 (annually), C_6H_6=5.0 ng/m^3 (hourly), B(a)P=1.0 ng/m^3 (annually),

except for CO, that too for only 7 defined hours in Kolkata district only.

Non-compliance cases were further analyzed as shown in Table 13.5. Non-compliance for CO during 2013, 2014 and 2015 occurred during Kalipuja and Dweepavali nights. So this is clearly correlated with the specific events of fireworks.

Particulate air pollution is thus the exclusive pollutant which is problematic for the entire state. Figure 13.2 presents the pan state scenario in respect of the PM10 and PM2.5 pollutants. For the entire period from 2006 to the present, air quality has been non-compliant in respect of PM10. The same is reflected for PM2.5 after its introduction in November 2009 in the national standard following which monitoring started during the end of 2012. 2012 was the year when transition of air quality monitoring from 4 parameters to 12 parameters including PM2.5 took place.

District-wise air quality status is presented in the following section covering 19 districts. As the Alipurduar district has been created very recently dividing the earlier Jalpaiguri district into two, the air quality of Alipurduar has not been presented separately. Monitoring of air quality of Alipurduar district has been initiated very recently in the year 2016, after its' creation. The district wise status of air quality, 2016 trends are reflected for the indicator air quality parameters, namely, PM10, PM2.5, NO_2 and SO_2, the first three being such air pollutants in which some of the city areas are non-compliant in the State. Air quality scenario of the districts are presented in tabular form from Table 13.6-13.17, followed by graphical presentations (Figure 13.3-13.21) of the annual behaviour of the indicator pollutants during year 2016 and the estimated population exposed to such air quality in those districts.

TABLE 13.4 Non-compliance events in West Bengal for eight air quality parameters mentioned in Table 13.2

Parameters	2013	2014	2015
O_3 (Hourly)	NIL	NIL	NIL
NH_3 (Daily)	NIL	NIL	NIL
CO (Hourly)	NIL	NIL	7 days in Kolkata
Pb (Min)	NIL	NIL	NIL
Ni (Annually)	NIL	NIL	NIL
As (Annually)	NIL	NIL	NIL
C_6H_6 (Annually)	NIL	NIL	NIL
B(a)P (Annually)	NIL	NIL	NIL

TABLE 13.5 Non-compliance days for CO in Kolkata

Hour	Event	Date
2200 to 2300 on	Kalipuja Night	10/11/2015
2300 to 2400 on	Kalipuja Night	10/11/2015
2000 to 2100 on	Dweepavali Night	11/11/2015
2100 to 2200 on	Dweepavali Night	11/11/2015
2200 to 2300 on	Dweepavali Night	11/11/2015
2300 to 2400 on	Dweepavali Night	11/11/2015
0000 to 0100 on	Dweepavali Morning	12/11/2015

FIGURE 13.2 PM10 and PM2.5 yearly profile during 2006 to 2016 in West Bengal

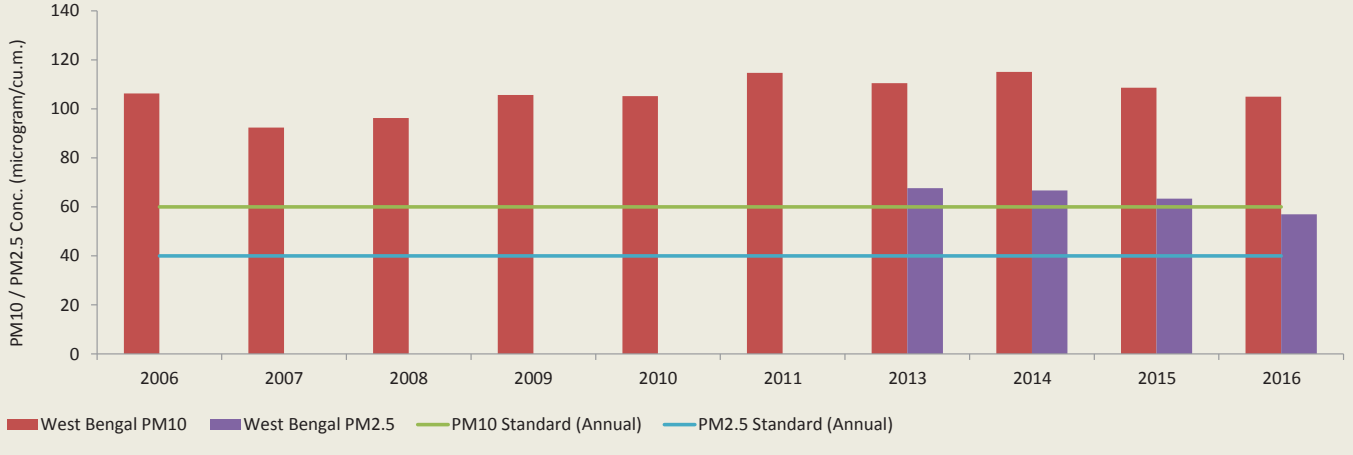


TABLE 13.6 **Air quality in respect of four traditional parameters in Bankura district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	85	60	35	Not Done	40	Not Done	7	50	0	40	40	0
2014	69	60	13	Not Done	40	Not Done	8	50	0	54	40	0
2015	99	60	43	Not Done	40	Not Done	8	50	0	55	40	0

TABLE 13.7 **Air quality in respect of four traditional parameters in Barddhaman district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	109	60	48	66	40	51	8	50	0	44	40	0
2014	112	60	57	60	40	43	9	50	0	56	40	0
2015	103	60	50	67	40	60	8	50	0	55	40	0

TABLE 13.8 **Air quality in respect of four traditional parameters in Darjiling district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	86	60	27	Not Done	40	Not Done	6	50	0	26	40	0
2014	119	60	51	Not Done	40	Not Done	6	50	0	23	40	0
2015	88	60	25	Not Done	40	Not Done	3	50	0	18	40	0

TABLE 13.9 **Air quality in respect of four traditional parameters in Purba Medinipur district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	106	60	44	Not Done	40	Not Done	8	50	0	34	40	0
2014	136	60	69	Not Done	40	Not Done	11	50	0	38	40	0
2015	153	60	96	Not Done	40	Not Done	19	50	0	50	40	0

TABLE 13.10 **Air quality in respect of four traditional parameters in Hugli district and yearly days of non-compliance**

Year	PM10 (µg/m^3)			PM2.5 (µg/m^3)			SO_2 (µg/m^3)			NO_2 (µg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	116	60	50	Not Done	40	Not Done	7	50	0	32	40	0
2014	122	60	58	Not Done	40	Not Done	9	50	0	33	40	0
2015	143	60	78	Not Done	40	Not Done	15	50	0	43	40	1

TABLE 13.11 **Air quality in respect of four traditional parameters in Haora district and yearly days of non-compliance**

Year	PM10 (µg/m^3)			PM2.5 (µg/m^3)			SO_2 (µg/m^3)			NO_2 (µg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	114	60	45	73	40	34	7	50	0	32	40	0
2014	109	60	61	67	40	52	9	50	0	35	40	0
2015	124	60	79	73	40	72	15	50	0	43	40	1

TABLE 13.12 **Air quality in respect of four traditional parameters in Jalpaiguri district and yearly days of non-compliance**

Year	PM10 (µg/m^3)			PM2.5 (µg/m^3)			SO_2 (µg/m^3)			NO_2 (µg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	86	60	28	Not Done	40	Not Done	5	50	0	26	40	0
2014	105	60	47	Not Done	40	Not Done	6	50	0	23	40	0
2015	87	60	26	Not Done	40	Not Done	3	50	0	17	40	0

TABLE 13.13 **Air quality in respect of four traditional parameters in Kolkata district and yearly days of non-compliance**

Year	PM10 (µg/m^3)			PM2.5 (µg/m^3)			SO_2 (µg/m^3)			NO_2 (µg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	124	60	46	69	40	41	8	50	0	43	40	6
2014	131	60	50	71	40	47	6	50	0	47	40	10
2015	114	60	41	61	40	38	4	50	0	45	40	4

TABLE 13.14 **Air quality in respect of four traditional parameters in Maldah district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	103	60	50	Not Done	40	Not Done	6	50	0	27	40	0
2014	110	60	48	Not Done	40	Not Done	5	50	0	23	40	0
2015	81	60	13	Not Done	40	Not Done	3	50	0	16	40	0

TABLE 13.15 **Air quality in respect of four traditional parameters in Nadia district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	101	60	41	Not Done	40	Not Done	6	50	0	36	40	0
2014	100	60	40	Not Done	40	Not Done	4	50	0	38	40	0
2015	87	60	29	Not Done	40	Not Done	3	50	0	36	40	0

TABLE 13.16 **Air quality in respect of four traditional parameters in North 24 Parganas district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	96	60	41	60	40	42	8	50	0	42	40	0
2014	102	60	52	63	40	46	9	50	0	55	40	1
2015	115	60	63	76	40	75	9	50	0	59	40	0

TABLE 13.17 **Air quality in respect of four traditional parameters in South 24 Parganas district and yearly days of non-compliance**

Year	PM10 (μg/m^3)			PM2.5 (μg/m^3)			SO_2 (μg/m^3)			NO_2 (μg/m^3)		
	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC	Value	Stan-dard	% days of NC
2013	104	60	41	Not Done	40	Not Done	6	50	0	39	40	0
2014	101	60	46	Not Done	40	Not Done	4	50	0	39	40	0
2015	90	60	34	Not Done	40	Not Done	3	50	0	36	40	0

District: Bankura

Total Population	3596674
Population affected by air quality	299773
% population affected by air quality	8.33

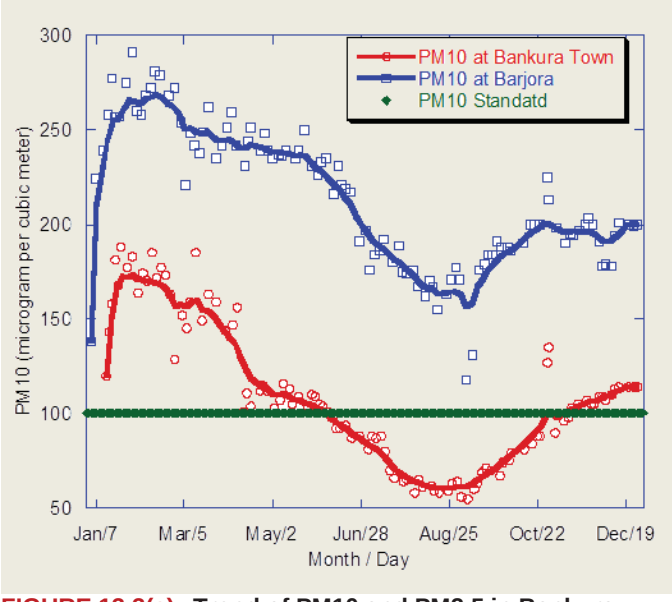


FIGURE 13.3(a) **Trend of PM10 and PM2.5 in Bankura during 2016**

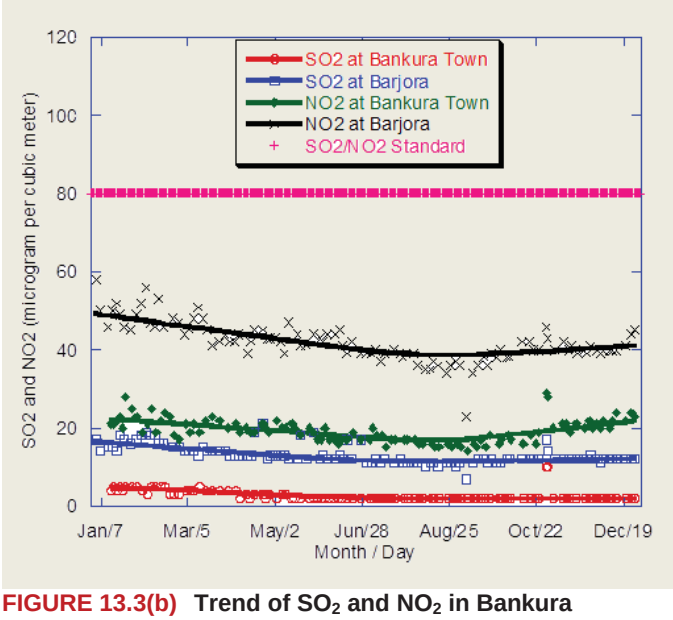


FIGURE 13.3(b) **Trend of SO_2 and NO_2 in Bankura during 2016**

District: Barddhaman

Total Population	7717563
Population affected by air quality	3078299
% population affected by air quality	39.89

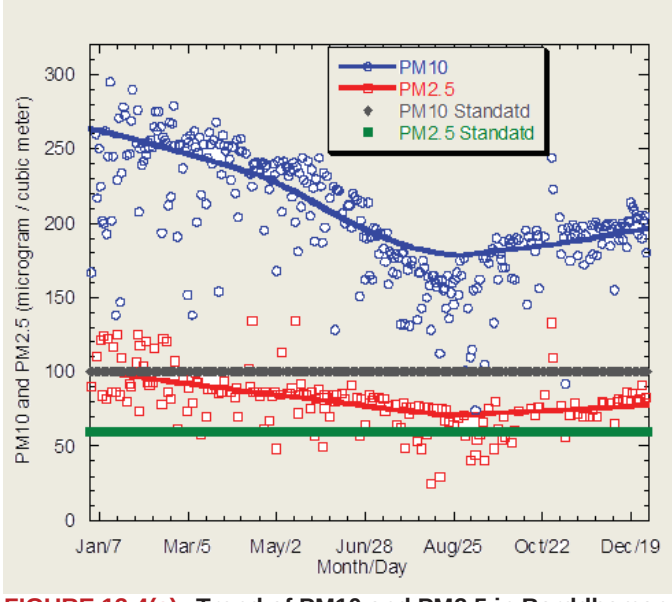


FIGURE 13.4(a) **Trend of PM10 and PM2.5 in Barddhaman during 2016**

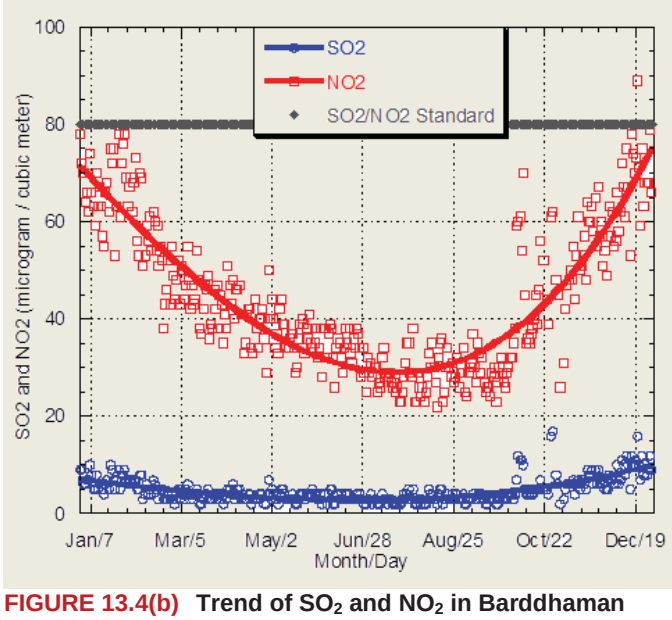


FIGURE 13.4(b) **Trend of SO_2 and NO_2 in Barddhaman during 2016**

District: Birbhum

Total Population	3502404
Population affected by air quality	449448
% population affected by air quality	12.83

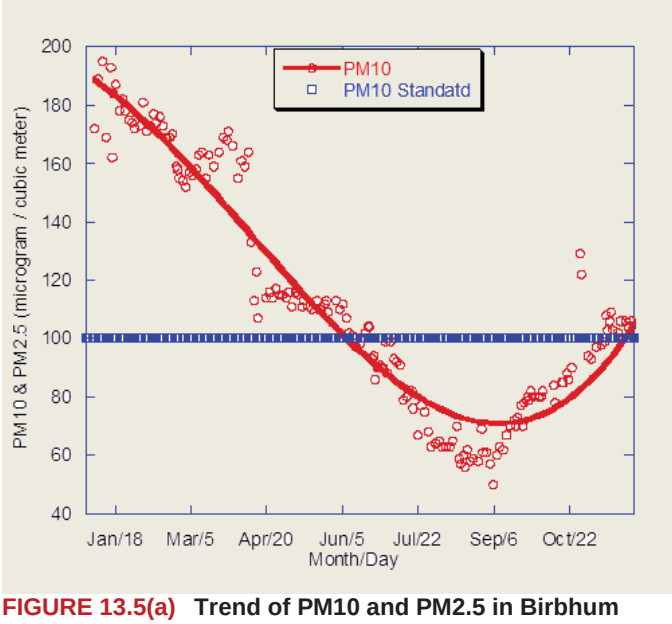


FIGURE 13.5(a) **Trend of PM10 and PM2.5 in Birbhum during 2016**

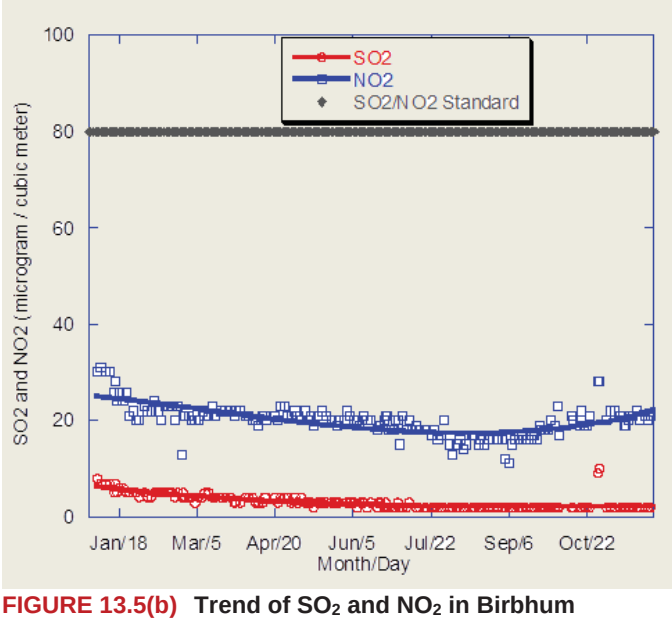


FIGURE 13.5(b) **Trend of SO_2 and NO_2 in Birbhum during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: Dakshin Dinajpur

Total Population	1676276
Population affected by air quality	236295
% population affected by air quality	14.1

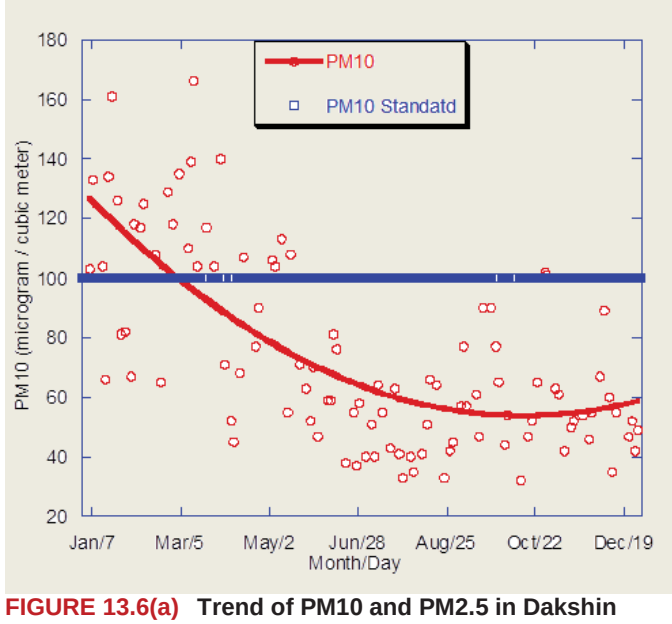


FIGURE 13.6(a) **Trend of PM10 and PM2.5 in Dakshin Dinajpur during 2016**

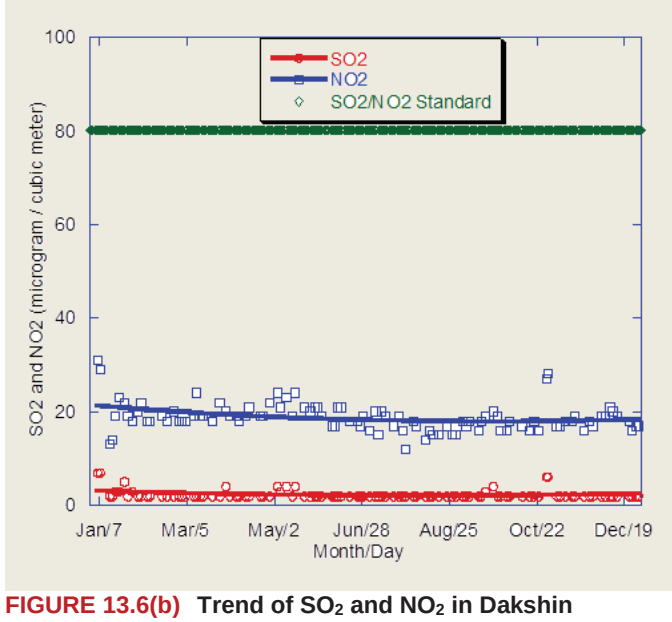


FIGURE 13.6(b) **Trend of SO_2 and NO_2 in Dakshin Dinajpur during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: Darjiling

Total Population	1846823
Population affected by air quality	727963
% population affected by air quality	39.42

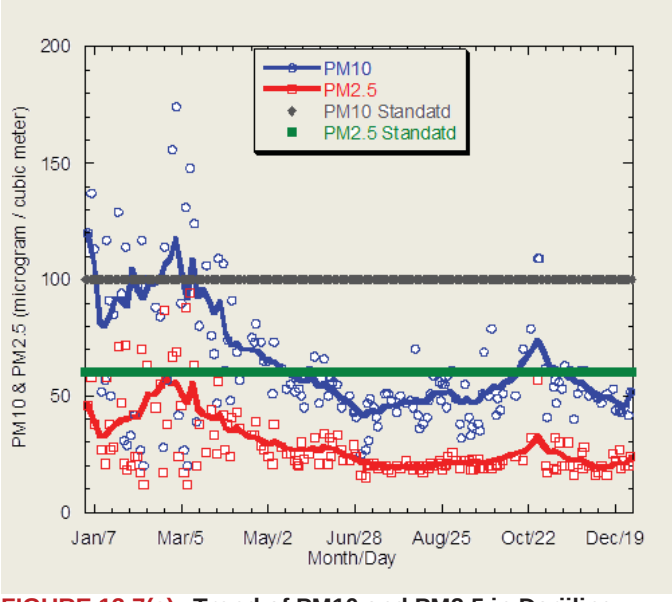


FIGURE 13.7(a) **Trend of PM10 and PM2.5 in Darjiling during 2016**

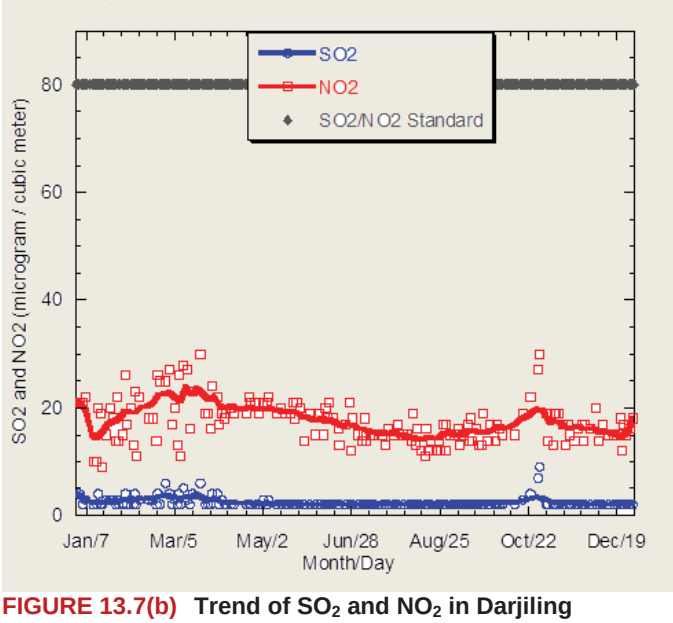


FIGURE 13.7(b) **Trend of SO_2 and NO_2 in Darjiling during 2016**

District: Haora

Total Population	4850029
Population affected by air quality	3074144
% population affected by air quality	63.38

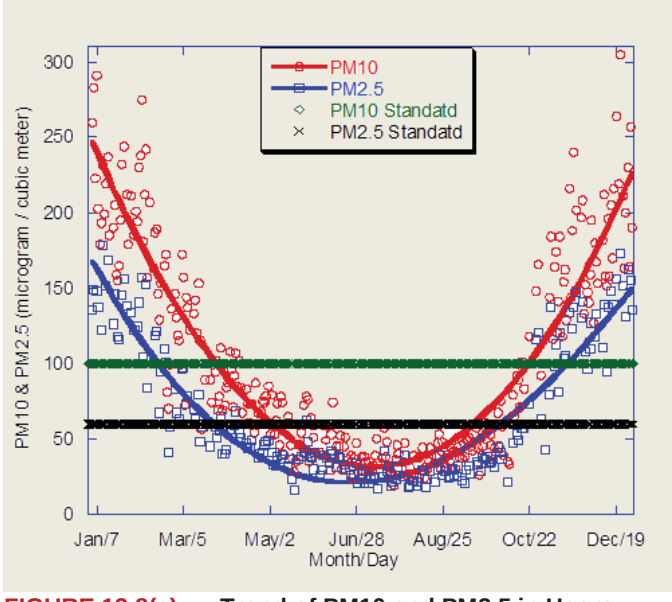


FIGURE 13.8(a) **Trend of PM10 and PM2.5 in Haora during 2016**

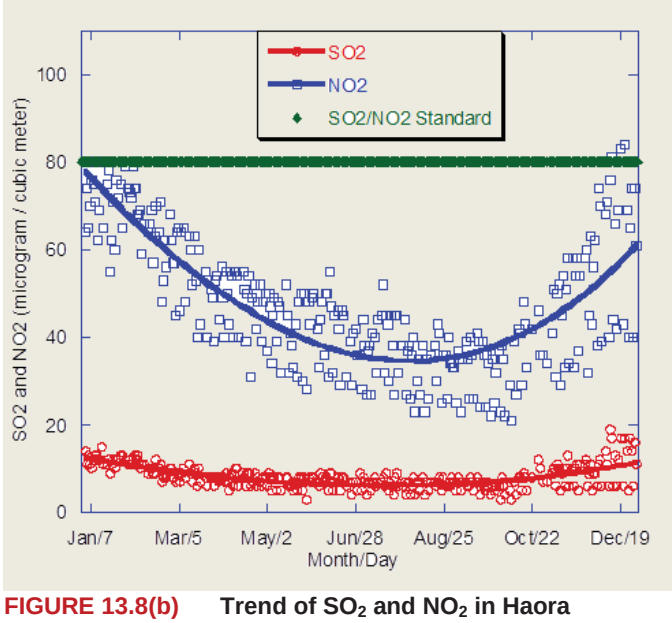


FIGURE 13.8(b) **Trend of SO_2 and NO_2 in Haora during 2016**

District: Hugli

Total Population	5519145
Population affected by air quality	2128499
% population affected by air quality	38.57

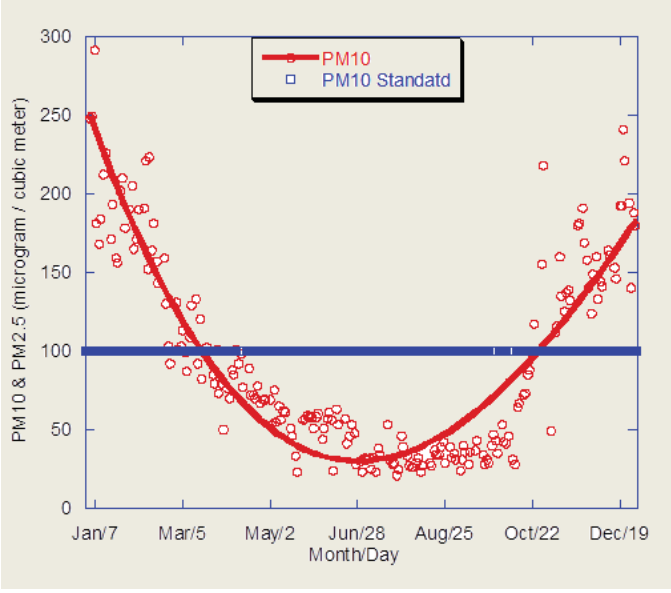


FIGURE 13.9(a) **Trend of PM10 and PM2.5 in Hugli during 2016**

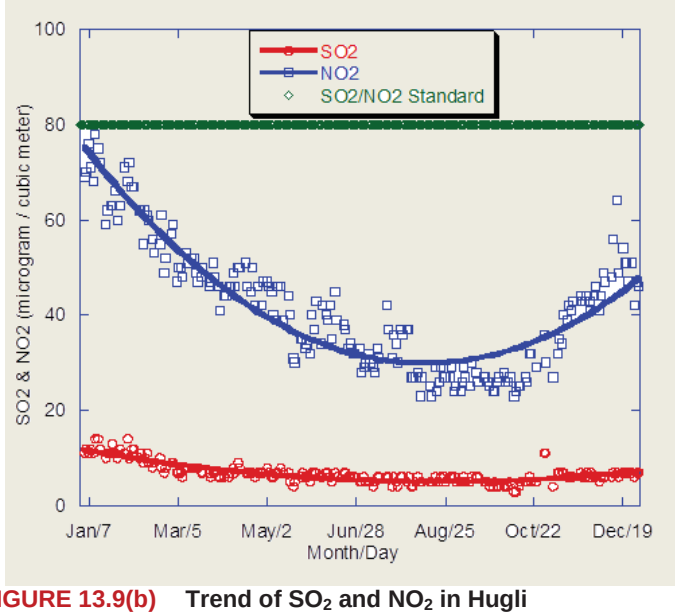


FIGURE 13.9(b) **Trend of SO_2 and NO_2 in Hugli during 2016**

District: Jalpaiguri

Total Population	2381750
Population affected by air quality	652103
% population affected by air quality	27.38

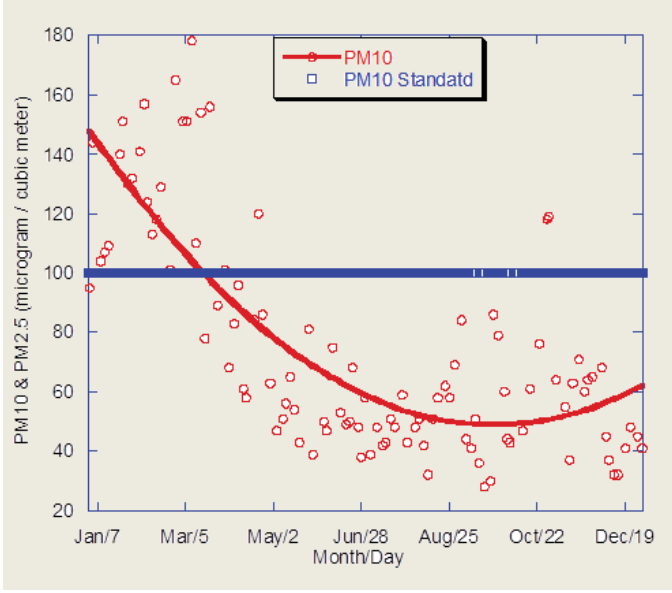


FIGURE 13.10(a) **Trend of PM10 and PM2.5 in Jalpaiguri during 2016**

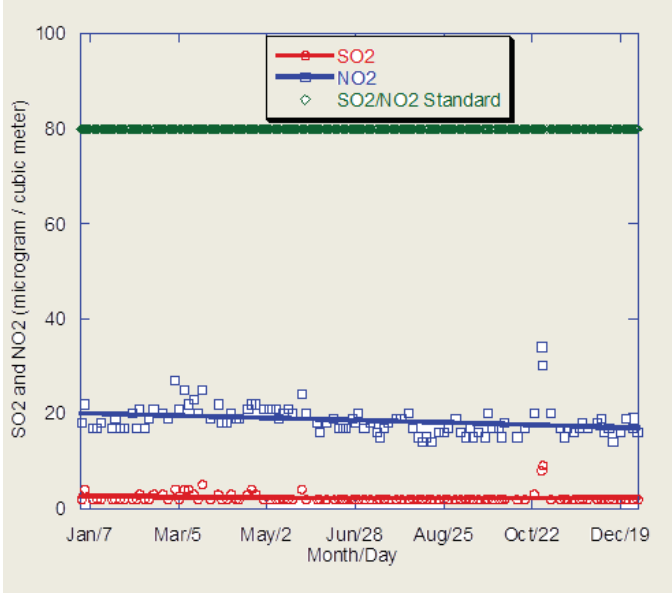


FIGURE 13.10(b) **Trend of SO_2 and NO_2 in Jalpaiguri during 2016**

District: Koch Bihar

Total Population	2819086
Population affected by air quality	289434
% population affected by air quality	10.27

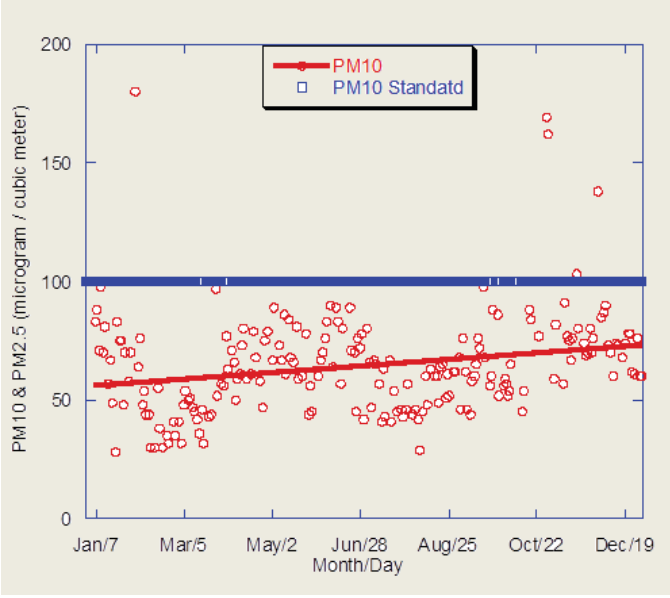


FIGURE 13.11(a) **Trend of PM10 and PM2.5 in Koch Bihar during 2016**

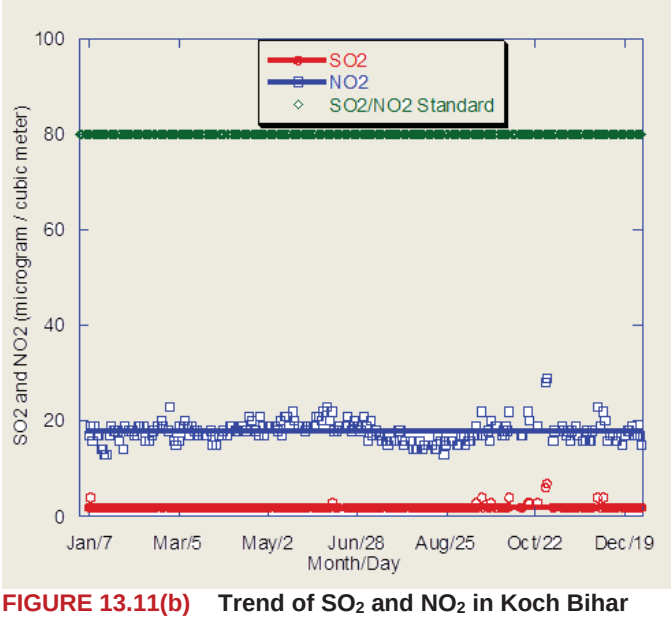


FIGURE 13.11(b) **Trend of SO_2 and NO_2 in Koch Bihar during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: Kolkata

Total Population	4496694
Population affected by air quality	4496694
% population affected by air quality	100

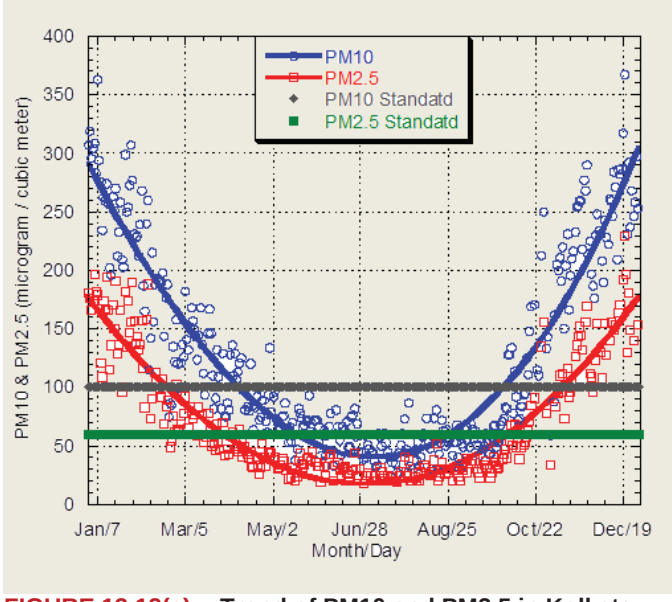


FIGURE 13.12(a) **Trend of PM10 and PM2.5 in Kolkata during 2016**

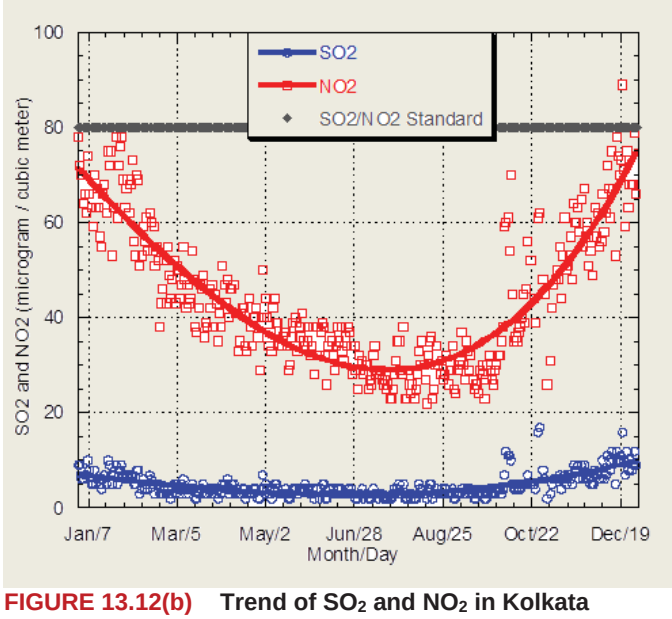


FIGURE 13.12(b) **Trend of SO_2 and NO_2 in Kolkata during 2016**

District: Maldah

Total Population	3988845
Population affected by air quality	541660
% population affected by air quality	13.58

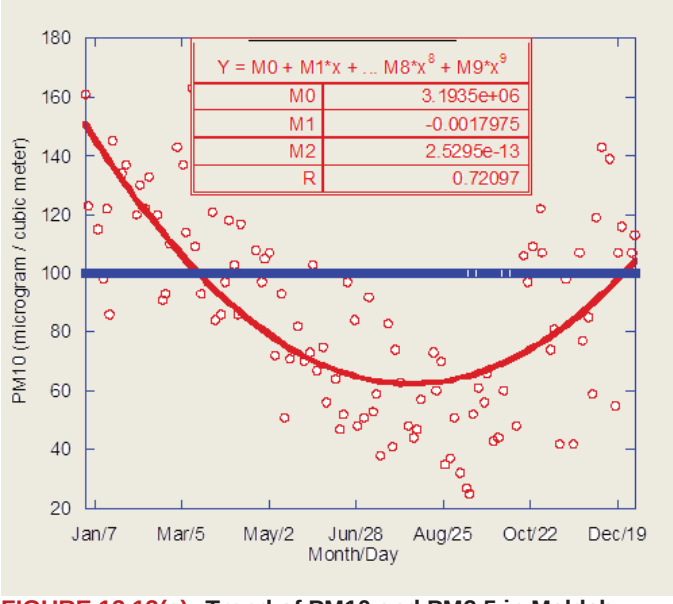


FIGURE 13.13(a) **Trend of PM10 and PM2.5 in Maldah during 2016**

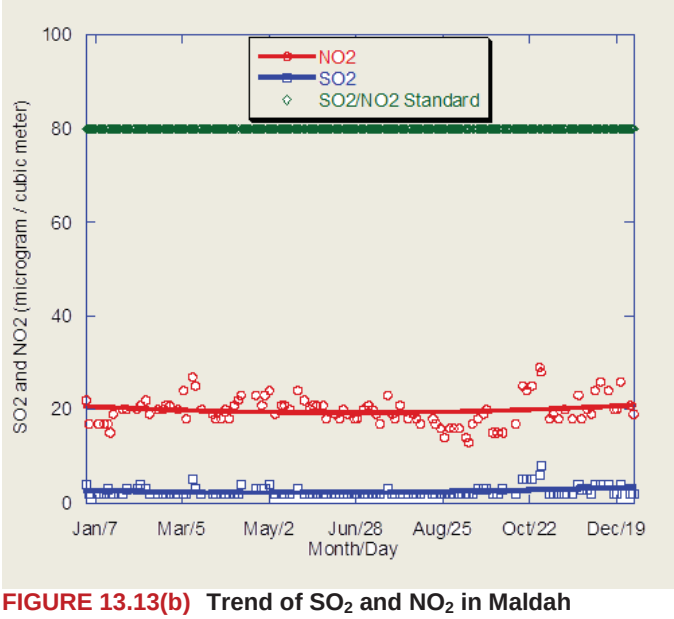


FIGURE 13.13(b) **Trend of SO_2 and NO_2 in Maldah during 2016**

District: Murshidabad

Total Population	7103807
Population affected by air quality	1400692
% population affected by air quality	19.72

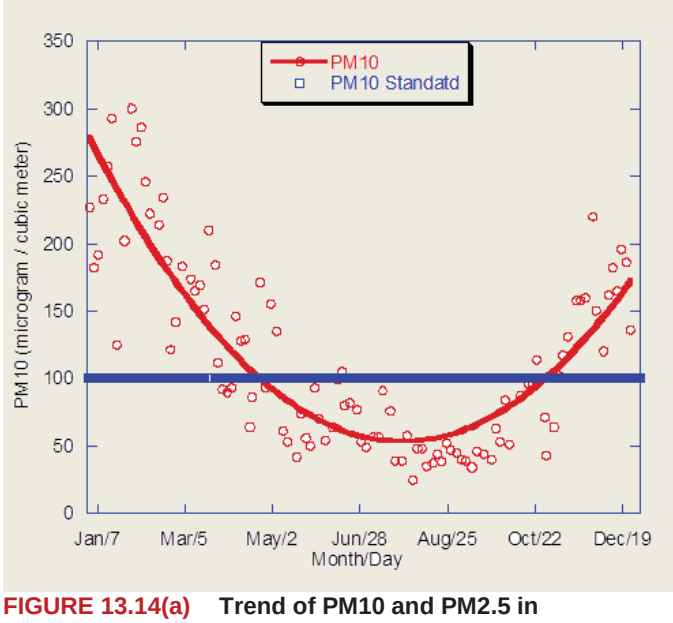


FIGURE 13.14(a) **Trend of PM10 and PM2.5 in Murshidabad during 2016**

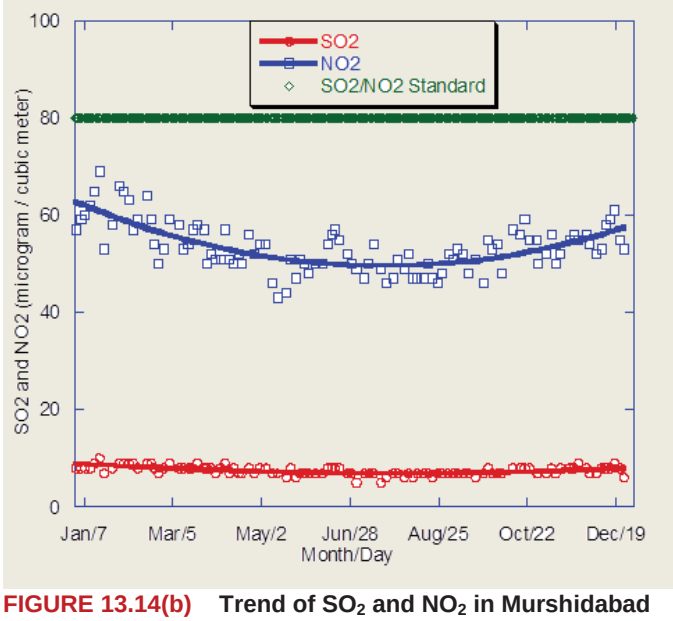


FIGURE 13.14(b) **Trend of SO_2 and NO_2 in Murshidabad during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: Nadia

Total Population	5167600
Population affected by air quality	1438873
% population affected by air quality	27.84

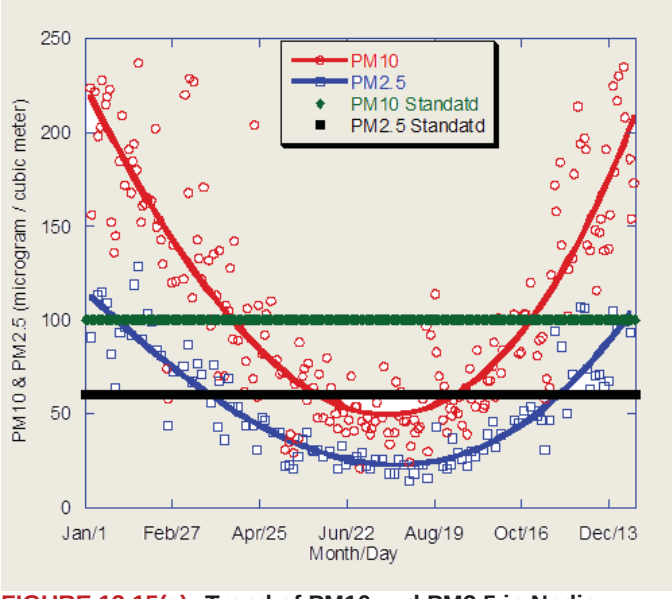


FIGURE 13.15(a) **Trend of PM10 and PM2.5 in Nadia during 2016**

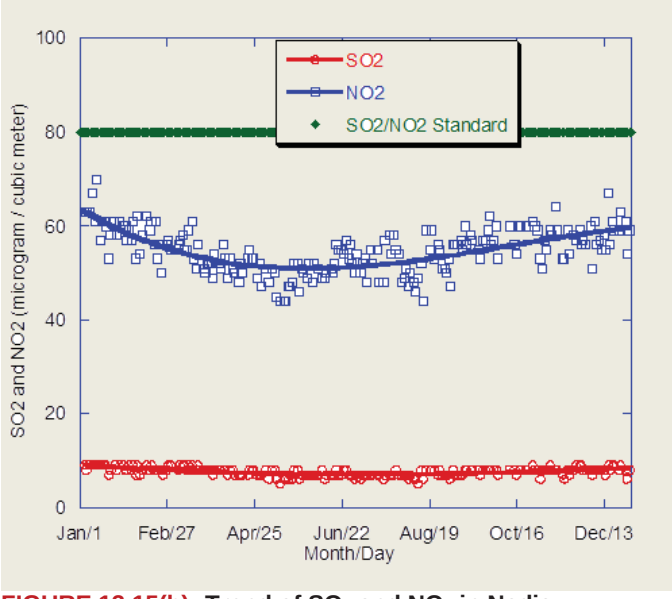


FIGURE 13.15(b) **Trend of SO_2 and NO_2 in Nadia during 2016**

District: North 24 Paraganas

Total Population	10009781
Population affected by air quality	5732162
% population affected by air quality	57.27

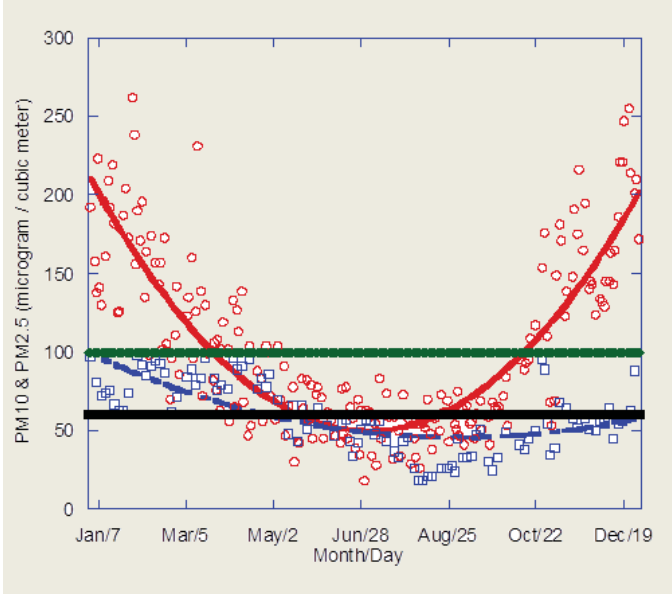


FIGURE 13.16(a) **Trend of PM10 and PM2.5 in North 24 Parganas during 2016**

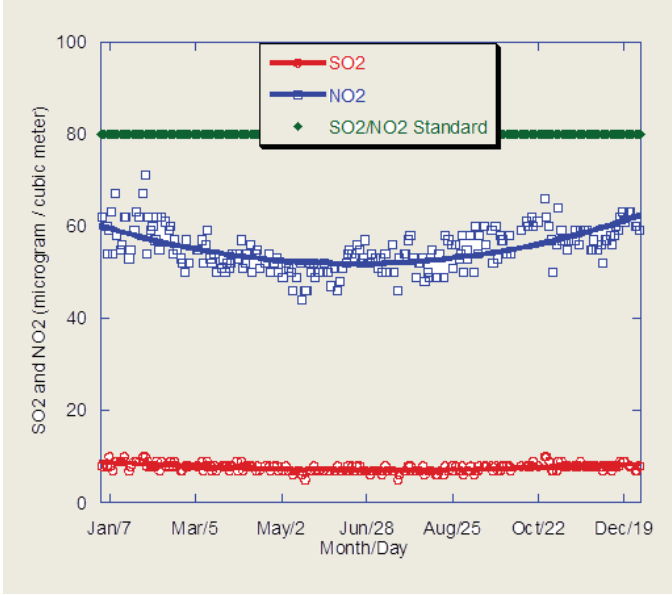


FIGURE 13.16(b) **Trend of SO_2 and NO_2 in North 24 Parganas during 2016**

District: Paschim Medinipur

Total Population	5913457
Population affected by air quality	722686
% population affected by air quality	12.22

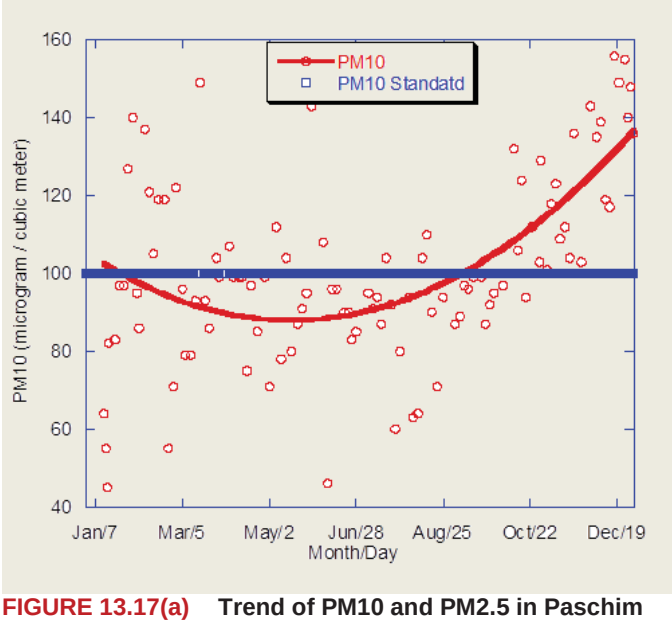


FIGURE 13.17(a) **Trend of PM10 and PM2.5 in Paschim Medinipur during 2016**

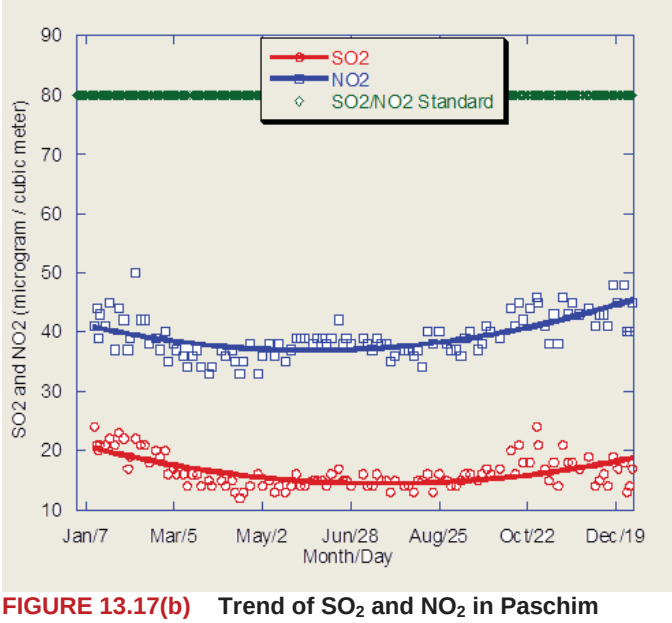


FIGURE 13.17(b) **Trend of SO_2 and NO_2 in Paschim Medinipur during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: Purba Medinipur

Total Population	5095875
Population affected by air quality	592714
% population affected by air quality	11.63

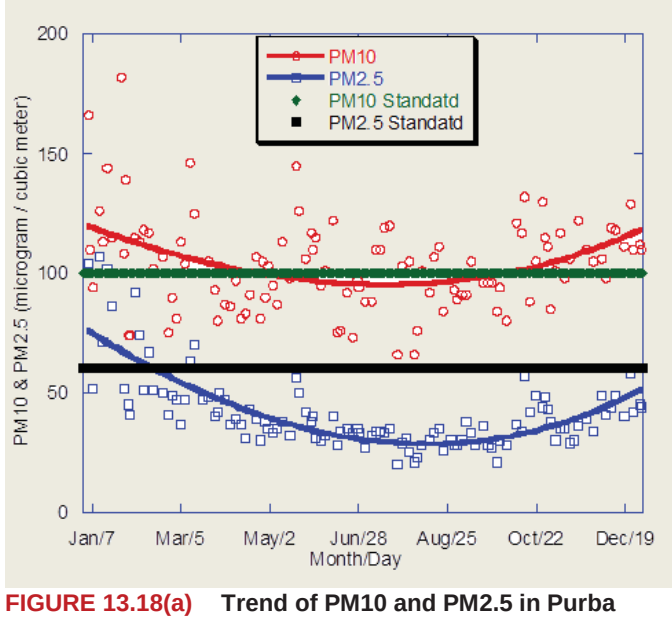


FIGURE 13.18(a) **Trend of PM10 and PM2.5 in Purba Medinipur during 2016**

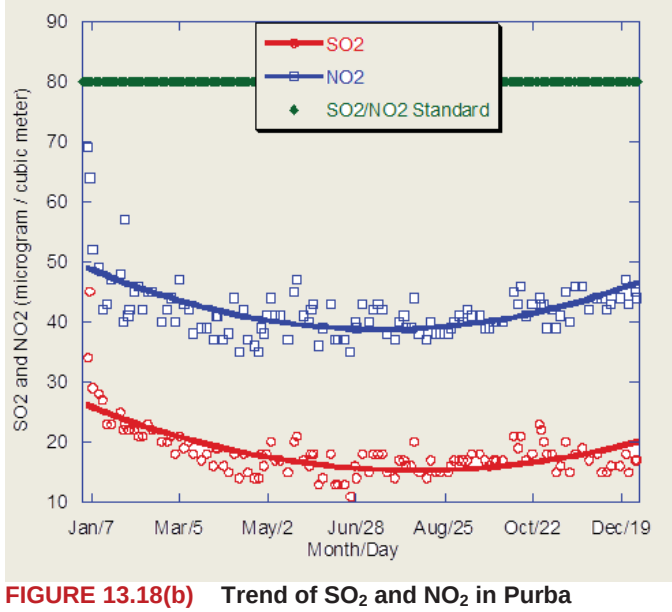


FIGURE 13.18(b) **Trend of SO_2 and NO_2 in Purba Medinipur during 2016**

District: Puruliya

Total Population	2930115
Population affected by air quality	373314
% population affected by air quality	12.74

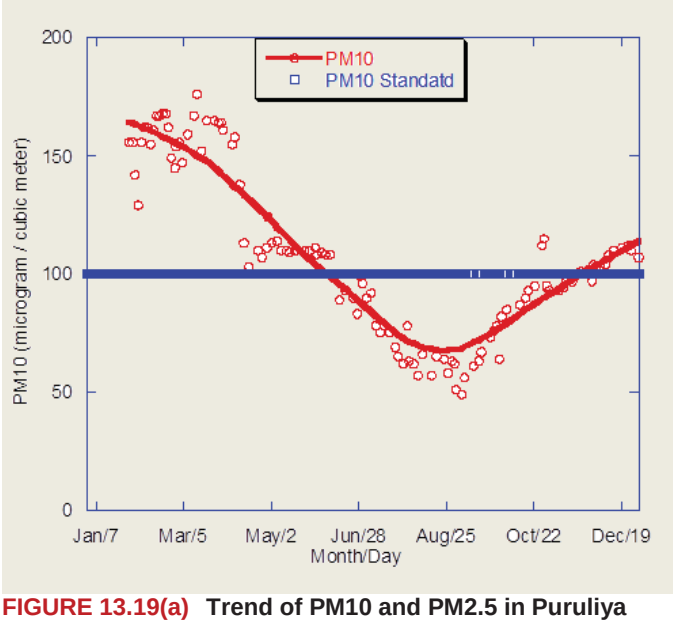


FIGURE 13.19(a) **Trend of PM10 and PM2.5 in Puruliya during 2016**

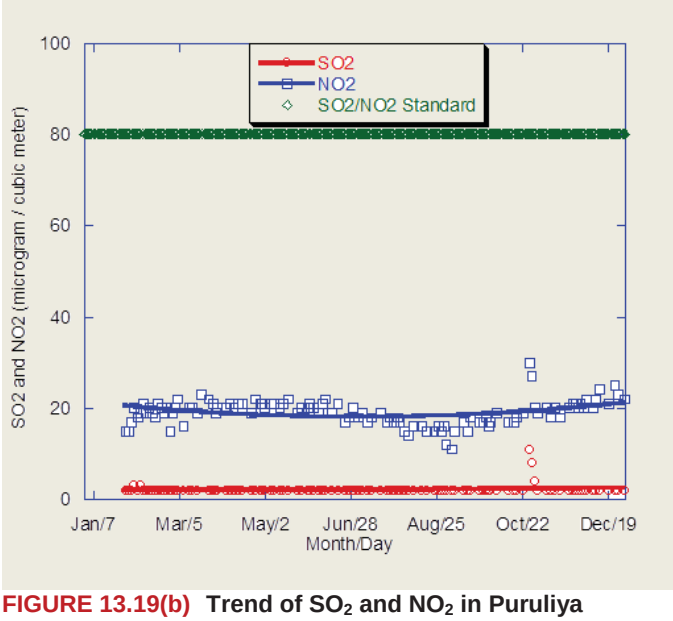


FIGURE 13.19(b) **Trend of SO_2 and NO_2 in Puruliya during 2016**

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

District: South 24 Paraganas

Total Population	8161961
Population affected by air quality	2087773
% population affected by air quality	25.58

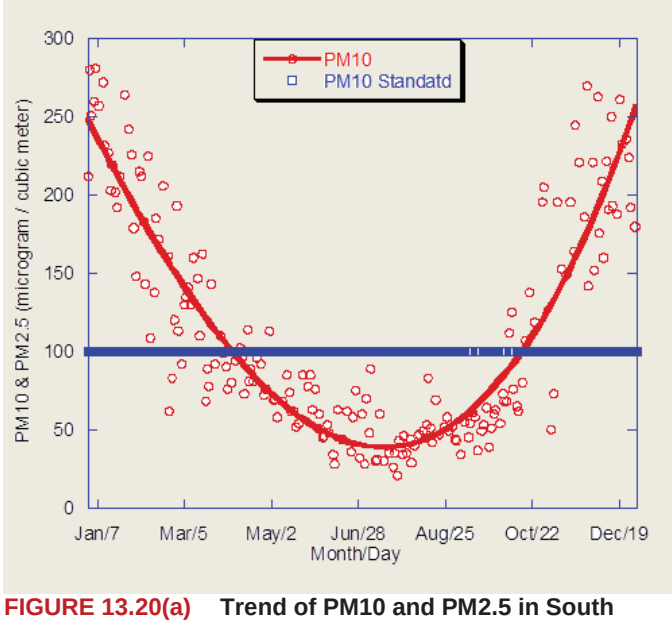


FIGURE 13.20(a) **Trend of PM10 and PM2.5 in South 24 Parganas during 2016**

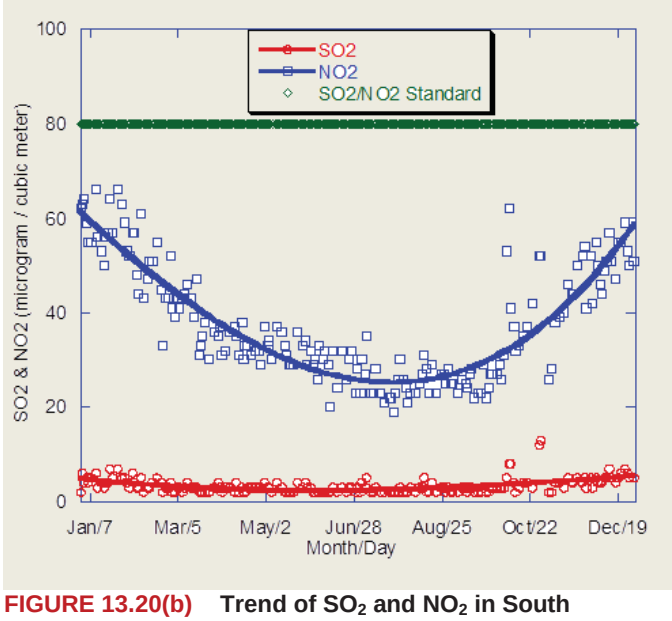


FIGURE 13.20(b) **Trend of SO_2 and NO_2 in South 24 Parganas during 2016**

District: Uttar Dinajpur

Total Population	3007134
Population affected by air quality	362228
% population affected by air quality	12.05

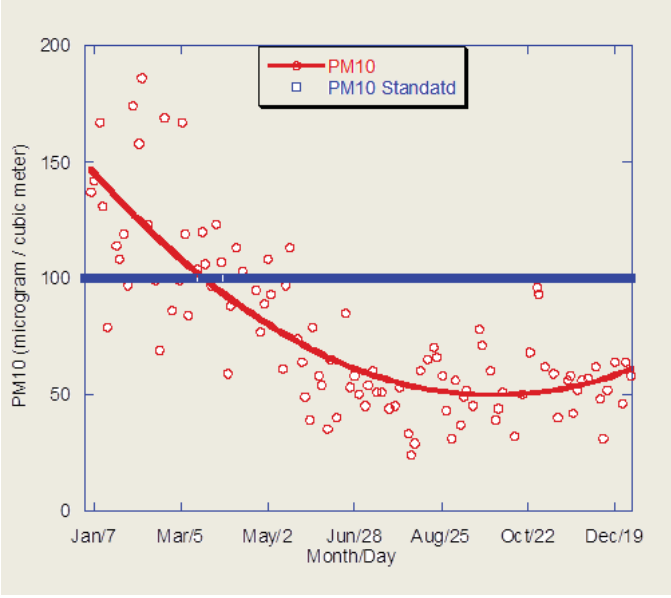


FIGURE 13.21(a) Trend of PM10 and PM2.5 in Uttar Dinajpur during 2016

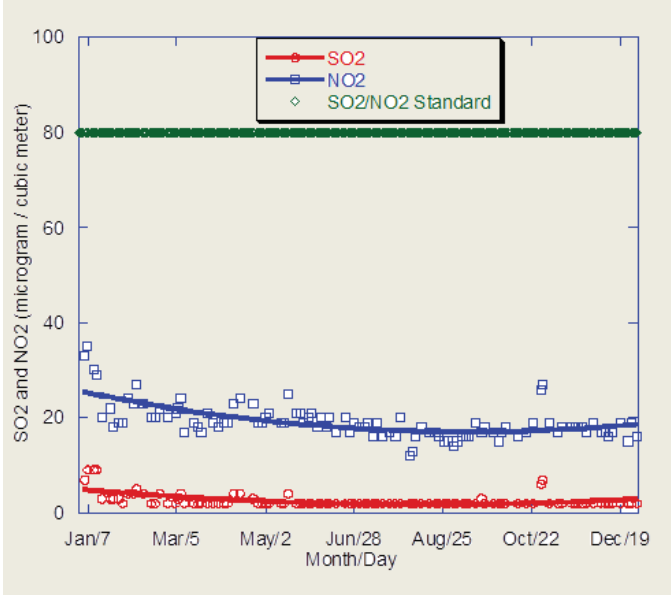


FIGURE 13.21(b) Trend of SO_2 and NO_2 in Uttar Dinajpur during 2016

Note: Air quality monitoring in this district was initiated from January 2016, and thus, no data before that is available.

Impacts

The pressure brings about changes in the physical, chemical and biological states of the environment which determine the quality of the ecosystem's goods and services for human welfare. This environmental impact is bound to have "economic" impacts on the functioning of the ecosystems and their abilities to support humanity. Obviously human health is the best indicator of such impacts.

Box 13.1 World Health Organization Fact Sheet (September 2016)

World Health Organization, in its Fact Sheet of September 2016 on Ambient (outdoor) air quality and health circulated the following to the world:

- Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.
- The lower the levels of air pollution, the better the cardiovascular and respiratory health of the population will be, both long- and short-term.
- In 2014, 92 per cent of the world population was living in places where the WHO air quality guideline levels were not met.
- Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3 million premature deaths worldwide in 2012.
- Some 88 per cent of those premature deaths occurred in low and middle income countries, and the greatest number in the WHO Western Pacific and South-East Asia regions.
- In addition to outdoor air pollution, indoor smoke is a serious health risk for some 3 billion people who cook and heat their homes with biomass fuels and coal.

Box 13.2 International Agency for Research on Cancer press release (October 2013)

On 17th October, 2013, the specialized cancer agency of the World Health Organization, the International Agency for Research on Cancer (IARC), through a press release announced that it has classified outdoor air pollution as a Group-1 carcinogenic agent to humans.

- After thoroughly reviewing the latest available scientific literature, the world's leading experts convened by the IARC Monographs Programme concluded that there is sufficient evidence that exposure to outdoor air pollution causes lung cancer (Group 1). They also noted a positive association with an increased risk of bladder cancer.
- Particulate matter, a major component of outdoor air pollution, was evaluated separately and was also classified as a Group-1 carcinogen to humans. The IARC evaluation showed an increasing risk of lung cancer with increasing levels of exposure to particulate matter and air pollution. Although the composition of air pollution and levels of exposure can vary dramatically between locations, the conclusions of the Working Group apply to all regions of the world.
- "The air we breathe has become polluted with a mixture of cancer-causing substances," says Dr Kurt Straif, Head of the IARC Monographs Section. "We now know that outdoor air pollution is not only a major risk to health in general, but also a leading environmental cause of cancer deaths."

Box 13.3 Cancer Therapy Vol 8 , 56-70, 2011

Imran Ali, Waseem A. Wani and Kishwar Saleem in Cancer Therapy Vol 8 , 56-70, in 2011 mentions the following.

- It was observed that lung cancer was rare in the beginning of the last century (Parkin DM, Muir CS, Whelan SL (2002) Cancer Incidence in Five Continents, IARC Scientific Publications, Lyon, 7, 155) but later on it was diagnosed in various patients. Banker et. al. (Banker DD (1955) J Post Grad Med 1, 108. (Cited in Nagrath SP, Hazra DK, Lahiri B, Kishore B, Kumar R) reported about 9210 consecutive autopsies of lung cancer patients in 1970, which were 14.4% of all cancer types. But, nowadays, it has become almost epidemic resulting in greater number of deaths than those caused by colorectal, breast and prostate cancers. The data collected by the National Cancer Registry Program of the Indian Council of Medical Research; from six different parts of the country including both rural and urban areas; showed varying degrees of incidence in different areas (ICMR, 1988-89). The most common forms of malignancies in males during 1989 in Bombay, Delhi, and Bhopal were cancers of trachea, bronchi and lungs, all related to the cause of Air Pollution.

Response

The policies and practices that can seriously affect the undesired impact and/or can affect any part of the chain between driving forces and impacts may be termed as the response of the society subject to the challenge. As an example, the policy of the Government of West Bengal during early years of the last decade of changing the fuels of the industries in Kolkata from solid (coal) to liquid (diesel or furnace oil) produced tangible positive impact on the air quality of Kolkata.

All air pollutants, those that figure in the NAAQS-2009, have defined effects on human health and environment. The relative abundances (concentrations) of these pollutants differ depending on the air shed, i.e., designated areas with similar climate, weather, meteorology and topology which affect the interchange and diffusion of pollutants in the atmosphere and also areas which share common interest or face similar development programs, prospects or problems. Monitoring data collected over the years show that the cities, viz., Kolkata, Haora, Durgapur, Haldia and Siliguri including the urban conglomerates are predominantly affected by the particulate pollution and to some extent by oxides of nitrogen. Although all the air quality parameters are monitored in cities of Kolkata, Haora, North 24 Paraganas and Durgapur, the monitoring stations are not with sufficient density that could reflect the status of the city statistically. The present report covers these air quality parameters only.

In urban West Bengal, relative abundances of the particulate quality parameters and NO_2 are most reckonable, with SO_2 as the specific indicator of solid fuel burning which is still the principal fuel for industry in our

state. PM10, the respirable fraction of the suspended air particulates, and PM2.5, the tiniest particulates in air that goes deep into the human lung with every inhalation are having the most pronounced impact on human health in present day urban conglomerates, and WHO has identified these two air pollutants as the most vulnerable ones. NO_2 is the product of high temperature burning of fossil fuel and solar radiation while SO_2 is the direct imprint of sulfur in coal/oil. Both these gases are precursors of acid rain and needs close monitoring round the year. These four air pollutants are the most dangerous and indicative ones for city areas, especially Kolkata, which is showing marked increase in respect of fossil fuel burning because of fast changing lifestyle and use of more vehicles and other fuel-burning intensive gadgets and appliances.

The WBPCB has been on the job of analyzing the monitored air quality data since long, responding mainly to legislative queries, judiciary requirements and administrative purposes. To respond to the impacts as delineated in this report, (as the air quality is impacted most by the most dangerous air pollutants, i.e., PM10 and PM2.5..), the following recommendations are found commensurate to complete the DPSIR (Driving force – Pressure – Status – Impacts – Response) cycle for the present report.

Augmentation of air monitoring network

(a) The WBPCB has already extended the functional air monitoring network with effect from 01.01.2016 for all the district towns deploying semi-automatic machineries. Further augmentation through installation of 5 additional continuous air monitoring stations near Science City and Ballygunge Phanri in Kolkata and Sector-V in Bidhannagar and at Ramakrishna Mission Vivekananda University, Belur and Padmapukur Water Works in Haora and Siliguri town has been initiated.

(b) The WBPCB should make arrangements for continuous monitoring of PM2.5 at the existing automatic air monitoring stations at Victoria Memorial and Rabindra Bharati University and also at the additional 6 recommended stations as mentioned above. Therefore, PM2.5 which was monitored in 2 stations only in Kolkata, should be monitored in 9 stations and in case of Haora, PM2.5 should be monitored at 4 stations in place of 1 station.

(c) Since sources like road dust, construction activities, burning of municipal wastes and industrial wastes (including plastics), operation of DG sets and industrial emissions etc. are also contributing to the deterioration of air quality of these twin cities, the WBPCB has initiated activities for a source apportionment study to collect and generate data on contribution of various sources of pollution at important areas in Kolkata and Haora in order to formulate strategy to combat air pollution. This study is to be conducted by a national level agency, which has the expertise and experience in conducting such studies. Long-term pan-state air quality management plan may be evolved on the basis of the results of source apportionment study to be carried out by WBPCB.

Traffic management

(a) Phasing out/scrapping of commercial vehicles that are more than 15 years old.

(b) Traffic re-engineering to remove congestion from densely populated/most frequented road stretches.

(c) Traffic signals may be replaced with circular round about for removal of congestion from densely populated/most frequented road stretches.

(d) Underpasses may be constructed in major crossings where large scale cross over of pedestrian takes place.

(e) Strict enforcement of possession of valid PUC Certificate in all the vehicles plying within city area and imposition of penalty for non-compliance of the same.
(f) Operationalization of e-rickshaws and e-carts as the mode of transport for last mile connectivity.
(g) Strict enforcement of 'No Parking' rules and compounding of offences committed.
(h) Construction of multi-layered or underground car parking space.
(i) Prohibit illegal car repairing garages from coming up on streets and thorough fares.
(j) Reducing the time at traffic signals to compare with the International Standard of 90 seconds (Max).
(k) All ULBs (urban local bodies), KMC and HMC in particular, should insist on either underground or multitier parking arrangement within the premises while sanctioning building plans for large housings, malls etc.
(l) Construction of pavements for all city streets to increase space for smooth traffic movement.
(m) Provision of cycling and walk ways throughout the two cities.
(n) Number and operational aspects of the AETCs need to be relooked by the State Transport Department for enhancement/betterment.
(o) AETCs should be connected to a centralized server for better monitoring and enforcement.

Other recommendations

(a) Strict implementation of non-use of road/street spaces for purpose of private business (shops/godowns/ vegetable-selling etc.) or vehicle parking.
(b) Open burning of coal and wood in municipal areas should be stopped.
(c) Strict implementation of direction issued by Department of Environment, Govt. of West Bengal vide no. EN/3170/T-IV-7/001/2009 dated 10 December 2009 by the concerned municipal authorities (KMC and HMC) and all concerned Government Departments for controlling air pollution.
(d) Complete banning of open burning of solid waste anywhere in the State.
(e) Plantation of new leafy saplings in the available space in different parts of the city areas to mitigate the level of air pollution.
(f) Sprinkling of water daily at important traffic junctions during the peak winter months (October to February) by the ULBs to mitigate suspension of particulate matters in the air.

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World Health Organization, in its Fact Sheet of September 2016 on "Ambient (outdoor) Air Quality and Health", available at "http://www.who.int/mediacentre/factsheets/fs313/en/"

The press bulletin of the specialized cancer agency of the World Health Organization, the International Agency for Research on Cancer (IARC), available at "https://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf"

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Chapter 14

Climate Change

Climate change is now being recognized as an urgent and potentially irreversible threat for the mankind and the planet earth. Adaptation to impending climate change impacts and mitigation of the major causes of the climate change are being envisaged as priority area by world leaders, scientists, policy makers. On 12th December, 2015 one ninety five (195) countries of the world signed an international agreement at Paris to combat climate change and to contain the rise of average global surface temperature within 2^0C. This agreement is expected to speed up low carbon economy, sustainable growth and is expected to re-orient many existing policies and business guidelines. Such changes in course of action at international level shall produce long term impacts on global economy. India being a signatory to this agreement shall have to take appropriate actions and every state is also required to initiate its own adaptation and mitigation programme. It is now, therefore, essential to have a look at the present status of climate change and its related fields in state of West Bengal for deciding the next course of action. It is also essential to revisit the common definitions of climate, climate change, climate normal, climate variability and the basics of the climate science at the very beginning of this chapter.

Climate, climate normal, climate change and climate variability

Climate is long term statistic of weather. Climate normals are usually three decade averages of weather parameters like temperature, precipitation and humidity. Climate change is deviation from expected weather or climate normals.

Climate varies with time due to interplay of natural forces. This climate variability was a slow mechanism earlier, which used to be observed over a very long period. The speed of changes in surrounding habitats caused by such alterations of climate was so slow that the rest of the world could internalise its impacts through evolutionary processes. In recent times the climate is changing at a rate faster than usual, across the globe. The world finds it quite difficult to match the pace of changing climate and to adapt to a new climate regime for survival. Threat of mass extinction is looming large, unless appropriate adaptation measures are not initiated to cope up with accelerating climate stress.

The climate variability is outcome of natural forces like Milankovitch cycle and geological cycles etc., but the recent faster pace of climate change cannot be explained by the natural forces only. The typical pattern of observed climate change like increase of average global surface temperature can appropriately be simulated by standard climate models only when natural forces are coupled with global anthropogenic forces (Figure 14.1) [1].

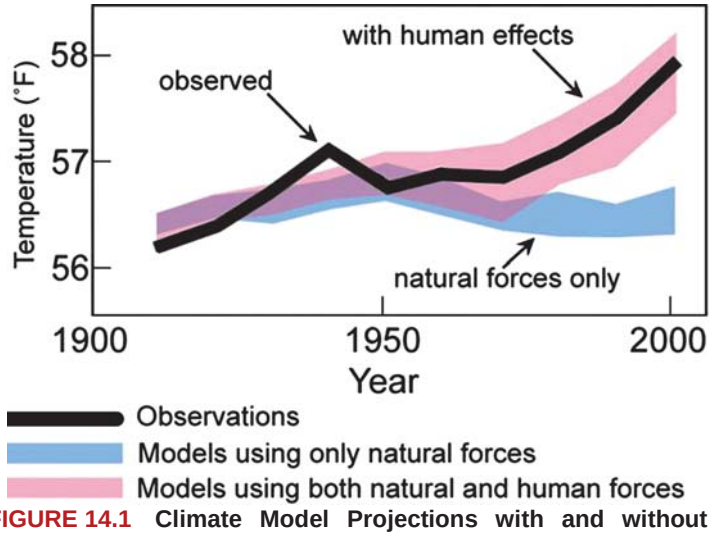


FIGURE 14.1 **Climate Model Projections with and without human forces *vis-a-vis* observations on increase of Global Surface temperature with time [1]**

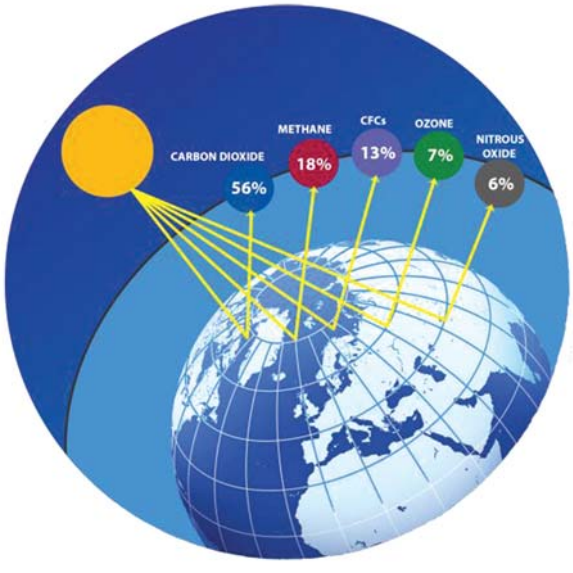


FIGURE 14.2 **Percentage of total energy trapped by different GHGs [2]**

The human actions like fossil fuel burning or deforestation cause increase of GHG concentration in the atmosphere. Increasing GHGs entrap more energy in earth's atmosphere, which interferes with earth's energy balance. The climate change phenomenon like global warming sets off. Changes of land use pattern, emission of black soot aerosols are other human forces, which in aggregate have resulted in rising trend of global average surface temperature over past one hundred to one hundred and fifty years.

In other words, human activities are the major drivers of recent climate change. The climate change is a global phenomenon. The amount of GHG spewed from one particular location in the earth does not act as an isolated energy blanket over that geographical location only. Instead, overall atmospheric CO_2 concentration is increased, which in turn prevents the outgoing long wave radiation to leave the atmosphere. Energy content in earth's atmosphere, which governs the entire climate dynamics, thus increases. Earth's energy balance is disturbed and perturbations begin in climate system. Percentages of energy entrapped by different GHGs are shown in Figure 14.2 [2].

Fossil fuels burning by mankind shoot up from the very beginning of industrial revolution in 1750. Consequently, GHG concentration started increasing. It is estimated that 1980$\pm$410 Giga tonne of GHG was emitted due to anthropogenic activities during 1750-2010 [3]. GHG concentrations increased in the atmosphere. As each GHG has its own residence time, the contribution by each GHG in terms of global warming differs from others. Table 14.1 [4-7] provides an idea about degree of increase in GHG concentration in atmosphere. The cumulative concentration of GHG emitted by different countries since 1850 is provided in Figure 14.3 [8].

It is quite evident from the Figure 14.3 that historical contribution of India since 1850 is only 3 per cent leaving aside the contributions made by any single state like

West Bengal. Unfortunately, this meagre contribution does not leave India free from the threats posed by the rapidly changing climatic conditions. In 2008, the National Action Plan on Climate Change (NAPCC) [9] was released by Prime Minister's Office, Government of India to combat climate change at national level. Each state has prepared the State Action Plan on Climate Change [10] to cope up with climate stress in tune with NAPCC at state level. Both reports are available in public domain. The science behind the means by which the drivers causes climate change is available in various reports in public domain.

TABLE 14.1 Degree of increase in GHG concentration (in ppm) in atmosphere

GHGs	1750 [4]	2015	GWP for 100 year time scale
Carbon Dioxide	278	401[5]	1
Methane	700	1800 [6]	24
Nitrous Oxide	270	328 [7]	298

Note: Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide over a given period of time.

The other GHGs with high GWP like CFCs and Halons are not provided in the table because these chemicals were not produced by humans in 1750.

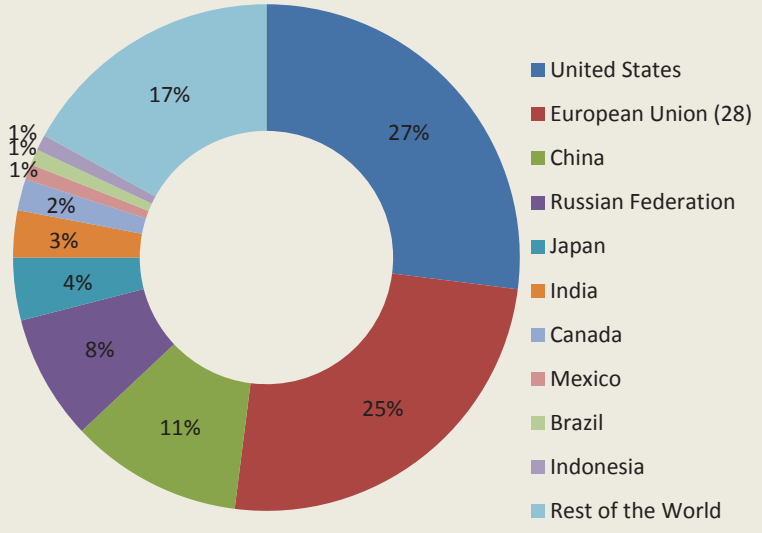
Status of drivers of climate change in West Bengal

Principal drivers of climate change are envisaged as (a) Population, urbanization, concretization; (b) Emission from transport sector; (c) Emission from energy generation and use; (d) Industrial emission; (e) Emission from agricultural fields; (f) Emission from domestic sector; (g) Change in forest type and less carbon sequestration.

Population, urbanization, concretization

Global population is increasing (Figure 14.4) [11]. Ensuring quality of life for everyone in a 7+ billion population planet is a big challenge for the world leaders. Increasing productivity per unit area of land to cater the need of a growing population is one the of frontier research for industrial, commercial and agricultural sectors. More energy and food is required for more people and these activities often enhance the GHG emissions resulting in to global warming. At present containing average global temperature rise without compromising the principle of equity is a burning question in global politics. At state level, West Bengal also has to deal with very high population density and its related developmental challenges.

FIGURE 14.3 Historical contribution of different countries in terms of GHG emission [8]



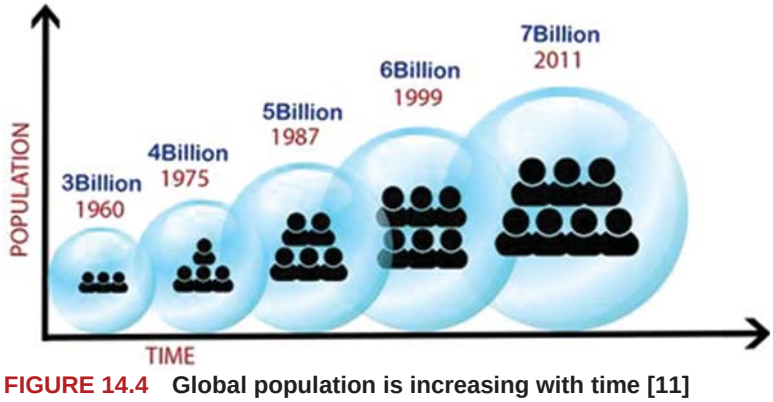


FIGURE 14.4 Global population is increasing with time [11]

The population density of West Bengal is 1,028 person per sq km [12] in comparison to average population density of 368 persons per sq km for India [13], 145 persons per sq km for China and 35 persons per sq km for USA [14]. USA and China are two other major GHG emitters of the world. The demand for agricultural yield, accommodation, daily consumables per unit area of land parcel is significantly higher on the available 88,752 sq km area of West Bengal. Sheer pressure to cater the need of this growing population often overrides environmental concern or any other land use guidelines prevailing in the State. Uncontrolled irreversible changes in land use pattern enhance the global warming by increasing the concretization, heat reflectivity and less carbon sequestration (Figures 14.5 and 14.6). More and more number of people migrate to cities and towns in search of livelihood and in the process cities and towns expand its built up area encroaching upon the green pastures, water bodies and wetlands which were earlier acting as carbon sinks. The district wise trend of urbanization in the State is provided in Table 14.2 [15]. Significant district wise variability in increase in urbanization is apparent from the Table 14.2. The district of Maldah, South 24 Parganas, Murshidabad, Jalpaiguri and Birbhum had faster rate of urbanization between 2001-2011, while Kolkata, Haora, North 24 Parganas, Hugli, Barddhaman, Darjiling are districts with more than 30 percent urbanization. Darjiling and Sundarban in South 24 Parganas are two most vulnerable spots in context of climate change. Unplanned growth of urbanization in these two particular districts may increase the vulnerabilities of these two districts manifold.

TABLE 14.2 Percentage wise urbanaization in different districts in state of West Bengal [15]

Districts	1991	2001	2011	Decadal increase
Maldah	7.07	7.32	13.58	86
South 24 Parganas	13.30	15.73	25.58	63
Murshidabad	10.43	12.49	19.72	58
Jalpaiguri	16.36	17.84	27.38	53
Birbhum	8.98	8.57	12.83	50
Nadia	22.63	21.27	27.84	31
Puruliya	9.44	10.07	12.74	27
Haora	49.58	50.36	63.38	26
Darjiling	30.47	32.34	39.42	22
Hugli	31.19	33.47	38.57	15
Bankura	8.29	7.37	8.33	13
Koch Bihar	7.81	9.10	10.27	13
Barddhaman	35.09	36.94	39.89	8
Dakshin Dinajpur	13.35	13.10	14.10	8
North 24 Parganas	51.23	54.30	57.27	5
Kolkata	100.00	100.00	100.00	0
Uttar Dinajpur	13.34	12.06	12.05	0
Purba Medinipur			11.63	NA
Paschim Medinipur			12.22	NA
West Bengal	27.48	27.97	31.87	14

The urbanization also causes more transport activities within the urban area as well as inward and outward movements. Burning of fossil fuel from the transport sector directly contributes to the increase of GHG emission. A cursory view of transport sector is provided in next section.

Emission from transport sector

Most of the vehicles are driven by fossil fuels and are constant sources of air pollution and GHG emissions. A likely GHG emission assuming typical kilometre run, fuel use etc. from the transport sector in West Bengal can be 61 Gg/year of CO_2 (1 Gg=10^9 gram). The GHG emissions from these vehicles can be estimated with additional details about the nature of fuels used, age of vehicles, mileage, average distance travelled by each types of vehicle etc. Figure 14.7 [16] provides a cursory view of district wise motorised traffic plying in West Bengal in 2011. Table 14.3 [17] provides an idea about number of passengers served by different State Transport Authorities. Similar estimate from private sector is required to estimate per capita emission from transport sector.

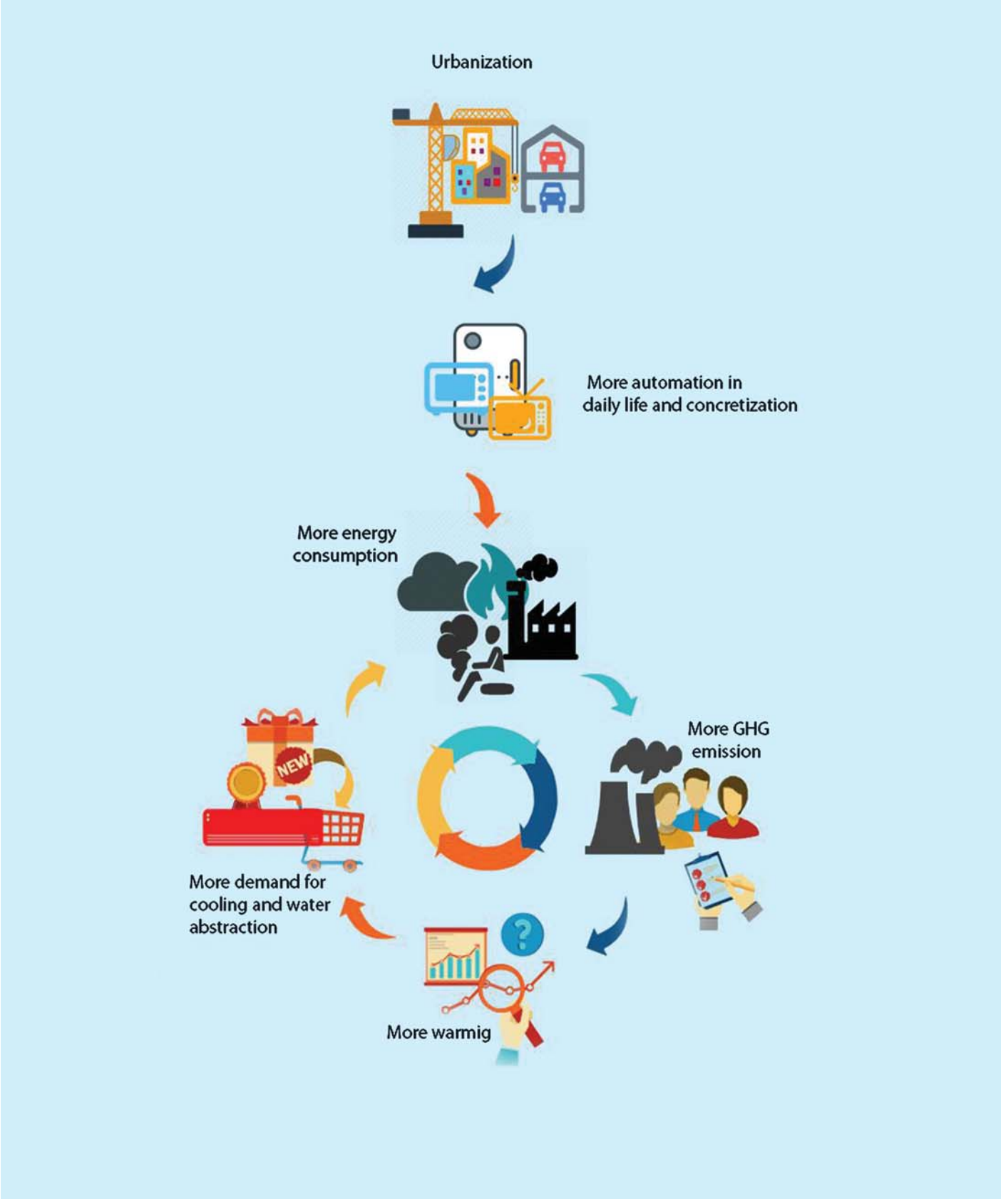


FIGURE 14.5 **Initiation of positive feedback due to urbanization in Business As Usual mode**

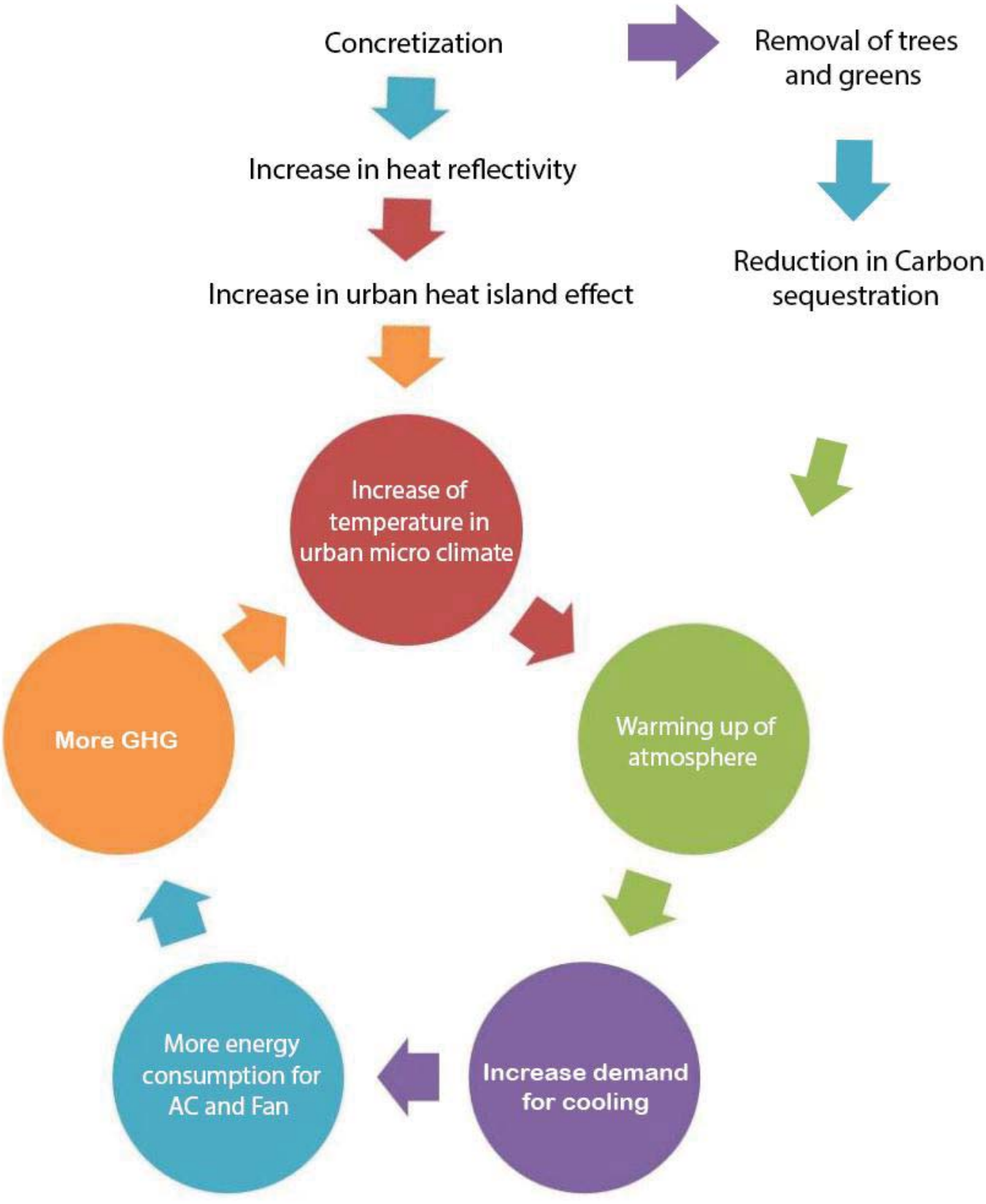


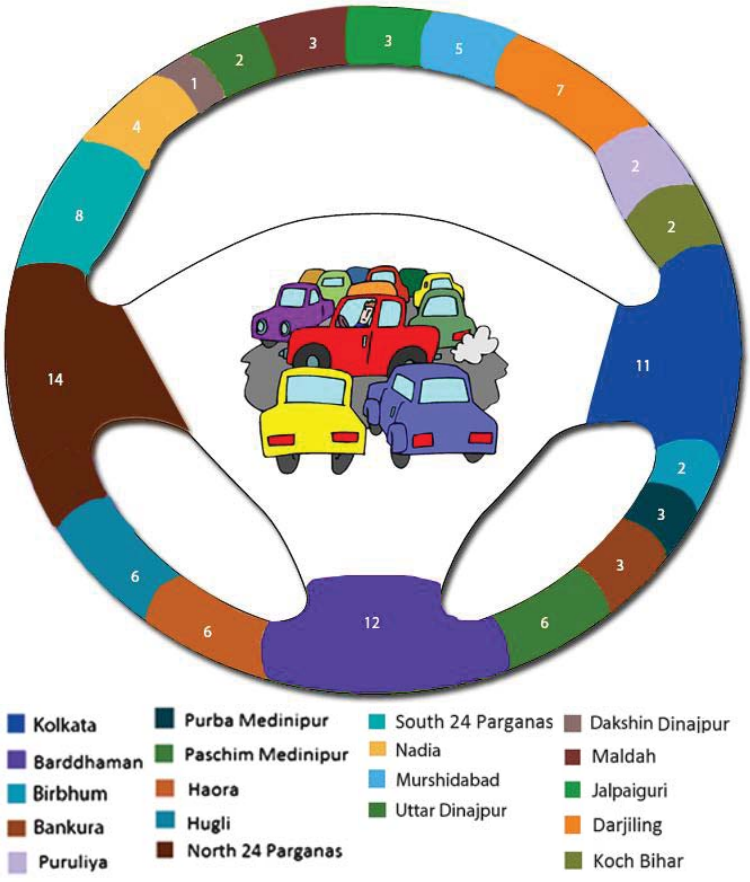
FIGURE 14.6 **Initiation of positive feedback due to concretization**

It is no denying fact that speed, mobility, safety and comfort for the passengers are to be ensured by the State transport as well as private transport authorities but time has come to also have a check on quality of fuel, energy efficiency and mileage of the vehicles. Improved mileage and other low carbon alternatives can enhance mobility without increasing GHG to the atmosphere viz. e-rickshaw.

Energy generation and use

Human development and energy consumption is found to be strongly correlated all over the world (Figure 14.8) [18]. The Human Development Report 2004, West Bengal shows the HDI (Human Development Index) was 0.61 in 2004 [19] for the state of West Bengal and thus can be used for making an idea about per unit electricity consumption. Energy is consumed for generation and operation of most of the basic amenities and products enjoyed by the citizens of any country today. India as a country is still in lower segment of per capita energy consumption. The first BUR (Biennial Update Report) to UNFCCC on climate change estimates India's per capita GHG emission in 2010 was 1.65 ton CO_2 equivalent only [20]. The power generation figures for West Bengal are provided in Table 14.4 [21]. The installed capacity has increased 4.4 times 1980-81 to 2011-12. The actual generation has increased 7.66 times during same period. This indicates that GHG emission from power sector has increased in last three decades but efficiency of power generation has also improved.

The power generation capacity of West Bengal was 9,110.03 MW in financial year 2011-2012 (Derated capacity, excluding NTPC) [22] and power generation was 47,690 MKWH [23] for the same financial year. The power generation in West Bengal is heavily skewed with coal based thermal power generation (Figure 14.9 and 14.10). Table 14.5 shows use of solar power in individual or micro scale operations [24].



Source: Statistical Abstracts of West Bengal, 2013

FIGURE 14.7 District wise percentages of registered motor vehicles in West Bengal (as on 31st March, 2012) [16]

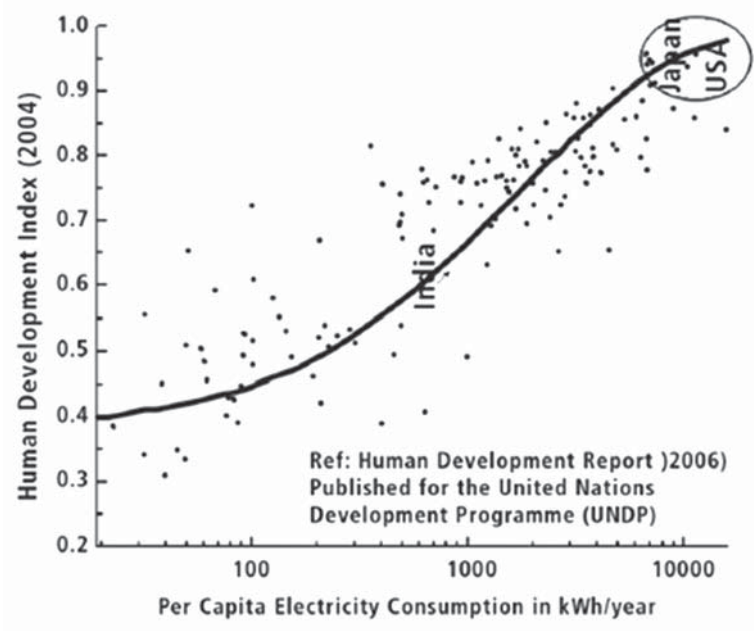


FIGURE 14.8 Human Development Index vs. per capita electricity energy consumption [18]

TABLE 14.3 Transport service provided by state transport authorities [17]

Calcutta State Transport Corporation	
Average number of vehicles put on road per day	424
(a) City	338
(b) Long distance	86
Total passengers served (in lakh)	115.705
North Bengal State Transport Corporation	
Average number of buses put on road per day	479
(a) Within the State	469
(b) Inter State	10
Total passengers served during the year (in lakh)	588.98
South Bengal State Transport Corporation	
Fleet strength as on 31st March (number)	484
Average number of buses put on road per day	349
Total passengers served during the year (in lakh)	1024.75
Calcutta Tramways Company Limited	
Tram Services	
Number of tram cars	269
Average number of vehicles put on road per day	105
Total length run (in '000 kms)	2607
Total passenger served (in lakh)	485
Bus Services (started from Nov. 1992)	
Fleet strength as on 31st March (number)	340
Average number of buses put on road per day	235
Total passenger served during the year (in lakh)	514
West Bengal Surface Transport Corporation Limited	
Bus Services	
Fleet strength as on 31st March (number)	152
Average number of buses put on road per day	90
Total passengers served during the year (in lakh)	65.48
Launch Services	
Fleet strength as on 31st March (number)	41
Average number of launch vehicles put on river per day	17
Total passengers served during the year ('000)	8141

TABLE 14.4 Power generation pattern [21]

Year	Total installed capacity (MW)	Derated capacity (MW)	Energy generated (MKWH)
1980-81	2081.01	1945.16	6260.65
1990-91	3271.06	3244	10304.19
2000-01	5769.07	5607.7	22446.91
2007-08	7052.72	6909.92	35884.57
2008-09	8241.83	7441.83	38626.33
2009-10	8711.83	8366.82	41684.13
2010-11	8441.83	8126.82	44432.94
2011-12	9173.23	9110.03	47960.65

Twenty three (23) small hydro power projects with 98.40 MW capacities has been set up and work of 17 additional small hydro power projects with 84.25 MW capacities are under progress [25]. One estimate of Government of India indicates that there is a potential of setting up 203 small hydropower projects with power generation capacity of 396.11 MW. However, the impacts on the hydrology of the small hydro power are to be fully analysed before exploiting the fullest possible potential. The source wise renewable energy generation potential of West Bengal is provided in (Table 14.6) [26].

FIGURE 14.9 Installed steam generation capacities in MW

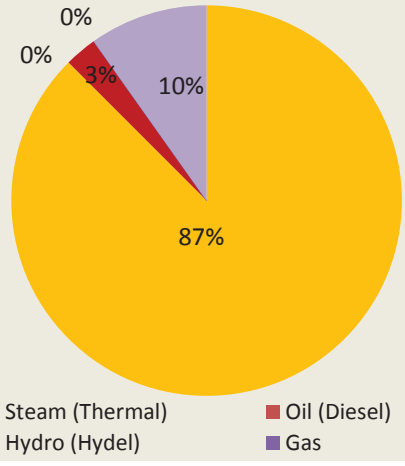
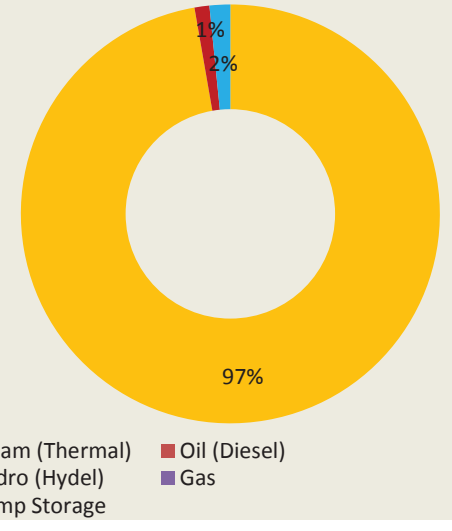


FIGURE 14.10 Percentage wise power generation in 2011-12



The GHG emission from power sector in West Bengal was estimated to be in the range of 29,400–39,200 Gg of CO_2 and 105-140 Gg CO in 2010 [27]. Introduction of renewable energy sources is expected to bring down the GHG emission from the State. In 2011-12 financial year, 18,790.59 MKWH, power was sold to the customers within the State by WBSEDCL (West Bengal State Electricity Distribution Corporation Limited), which is about half of total power sold to ultimate customers. The nature of change in power consumption in different sector over three decades is provided in Figure 14.11 [28]. Domestic, agriculture and commercial sectors show rise in electricity consumption.

Industrial emission

Thermal power generation, integrated iron and steel industries, ferro-alloy, cement grinding plants, tanneries, engineering and fabrication units and foundries are most common types of industries in West Bengal. Different estimates have been provided by different groups of researchers. A detailed review of each work with thorough comparative analysis is required to obtain a final estimate.

Emission from agricultural fields

The emission from agricultural fields of India is higher than global average. Globally 13.5 per cent of country's total emission is from agriculture whereas Indian agricultural field contributes to 19 per cent of total emission. Methane and nitrous oxide are the two major GHGs emitted from agriculture. The main sources of methane are activities of methanogens – a small group of methane producing microbes in soil saturated with water in a paddy field, food digestion by rumens in anaerobic conditions, wet lands etc. Application of fertiliser and manure, cultivation are major source of nitrous oxide. Contribution of different agricultural activities to GHG emission from this sector is provided in Figure 14.12 [33]. Emission from Indian agriculture was estimated to be 2,903 Gg (Gg = 10^9 gram or thousand ton) for methane and 79.91 Gg for nitrous oxide in 1994-95. In the same financial year, the Global Warming

TABLE 14.5 Use of solar power based products in West Bengal [24]

Lanterns	Home Lights	Street Lights	Pumps Stands alone	Power plant	Grid connected*
17662	140034	8726	48	889	1150

TABLE 14.6 Source wise potential of the renewable energy generation in West Bengal (as on 31.03.2012) [26]

Renewable energy source	MW
Wind Power	22
Small Hydro	396
Biomass	396
Power Co-generation and Bagasse fired	0
Waste to Energy	148
Potential in MW	962
Distribution (%)	0.65

FIGURE 14.11 Trends of energy consumption in different sectors in past three decades [28]

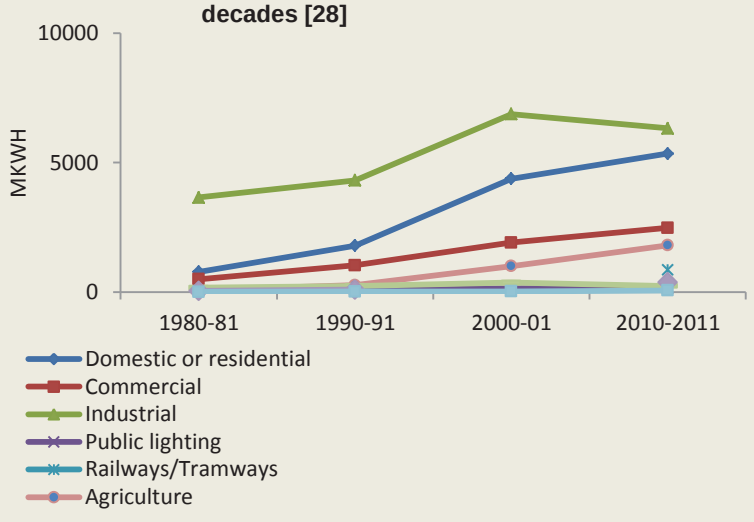


FIGURE 14.12 **GHG emissions from different agricultural activities [33]**

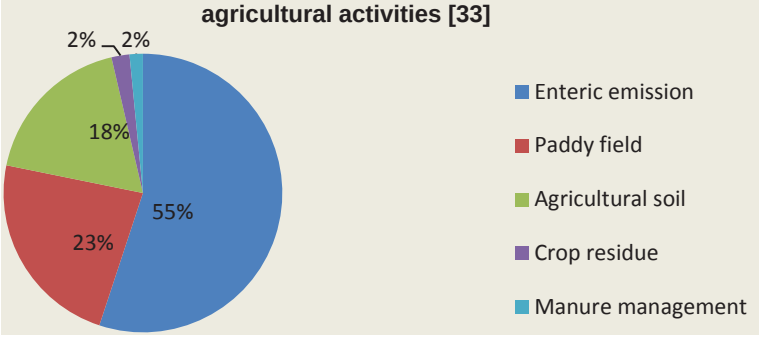
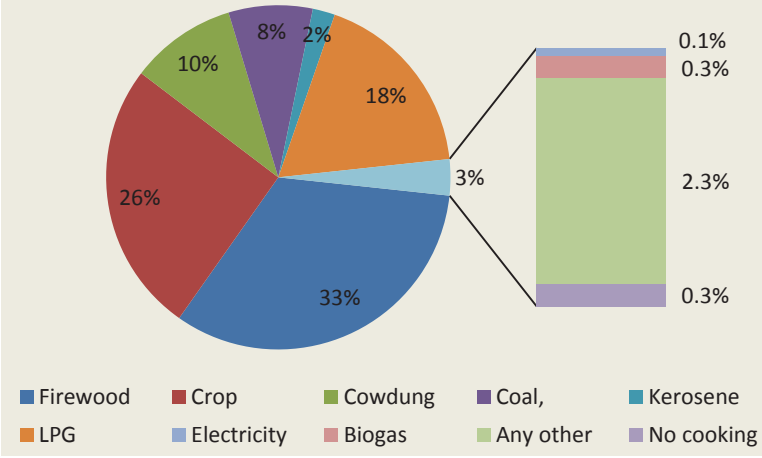


FIGURE 14.13 **Percentage distribution of households by types of fuel used other than electricity [35]**



Potential (GWP) was estimated to be 85,729 $GgCO_2$ from agricultural sector [29]. The similar data for West Bengal is 447.7 Gg of Methane, 3.38 Gg of Nitrous Oxide and 10,448 $GgCO_2$of GWP [30].

It is to be kept in mind that the food grain yield has increased from 1.19 t/ha to 1.74 t/ha [31]. In 2004, the emission from West Bengal is shown as 7,000-10,500 Gg of CO_2, 306-408 Gg of CO and 940-1,410 Gg of methane in 2004 [32]. District wise distribution in Table 14.7 of agricultural land provides an idea about the share of GHG emission from each district.

Emission from domestic sector

The major source of domestic emission is cooking fuel and lighting other than electricity. The types of fuel used for cooking in West Bengal are provided in Figure 14.13. On an average only 1.1 per cent of households are using solar energy for lighting. District wise distribution of households with electricity is provided in the Table 14.8.

TABLE 14.7 **District wise agricultural land in state of West Bengal (as on 2011-12, area in ha) [34] and forest land [37]**

State/District	Reporting Area	Cultivable Area	Area not available for cultivation excluding forest	Forest
West Bengal	**8684113**	**5700848**	**1809596**	**1173669**
Barddhaman	698762	465029	212568	21165
Birbhum	451118	335089	100176	15853
Bankura	687998	389162	158440	148930
Purba Midnapore	396594	293011	102684	899
Paschim Midnapore	928581	598399	158247	171935
Haora	138676	88559	50117	-
Hugli	313379	216069	96780	530
North 24 Parganas	386524	262127	124397	-
South 24 Parganas	948710	378378	144032	426300
Nadia	390655	300951	88488	1216
Murshidabad	532499	399105	132623	771
Uttar Dinajpur	312466	280662	31224	580
DakshinDinajpur	221909	194910	26067	932
Maldah	370862	293908	75275	1679
Jalpaiguri	622700	349858	93842	179000
Darjiling	325469	159699	41195	124575
Koch Bihar	331565	264936	62373	4256
Puruliya	625646	439530	111068	75048

TABLE 14.8 Percentagewise distribution of the households with electricity [36]

District	Households with electricity	Households with electricity as main source of lighting	Households with solar energy as main source of lighting	Households with no lighting
Bankura	84.8	44.2	0.7	0.5
Barddhaman	89.2	61.6	1	0.7
Birbhum	93.3	41.1	0.7	0.6
Koch Bihar	86.4	27.6	0.7	0.2
Dakshin Dinajpur	85.5	42.4	0.9	0.5
Darjiling	95.8	77.7	0.9	1
Purba Medinipur	92.6	48.3	1.1	0.3
Hugli	92	76	1	0.7
Haora	96.9	77.4	1.3	0.7
Jalpaiguri	83	44.4	0.7	0.4
Kolkata	98.8	96.2	1.6	0.2
Maldah	89	35.5	0.9	0.6
Murshidabad	86.5	34.6	0.7	0.5
Nadia	88.3	50.6	0.7	0.5
North 24 Parganas	92	70.4	1.3	0.5
Puruliya	82	33.4	0.9	0.4
South 24 Parganas	84.2	47.3	3.3	0.4
Uttar Dinajpur	84.3	33.3	0.6	0.2
Paschim Medinipur	89.6	52.6	1.1	0.4
Average	**89.1**	**52.4**	**1.1**	**0.5**

Change in forest type and less carbon sequestration

Unlike the other drivers, the forest areas acts as carbon sink and sequester carbon and reduces the CO_2 concentration in the air. A strong seasonality is exhibited in CO_2 concentration level each year as significant amount of carbon is assimilated by photosynthesis during summer. The recorded forest area is 11,736 sq km [37], with 59 per cent of reserved forest, 32 per cent of protected forest, 9 per cent of unprotected forest [38]. District wise data is provided in Table 14.7 [34]. The degrees of carbons sequestration greatly vary with types of plants. As for example C3 plants are far more efficient than C4 plants as the photosynthetic pathway of C3 plant is not saturated with carbon at present CO_2 level. An estimate in 2012 shows that 1,753 Gg carbon is stored at West Bengal Forest while India as a whole stores 98,829.9 Gg of carbon [39].

Pressure

The most studied outcome of increasing GHG emission is the rising CO_2 concentration in the atmosphere. In 2015, NASA conducted a study on the distribution of CO_2 over different continents (Figure 14.14) [40]. The distribution of CO_2 in atmosphere is governed by the global circulation of climate forces like wind and oceanic currents. India is a tropical country and air over India is towered with CO_2 level of 400+ ppm. Similar studies on methane and N_2O shall provide a more complete picture. However, the level of accumulation of so much GHG in the atmosphere is a cause of concern.

Scientific studies suggest that increase of CO_2 over more than 400 ppm is bound to bring untoward changes in climate like sea level rise, acidification of oceans, coral bleaching and many more. In fact, climate changes are also taking place as level of

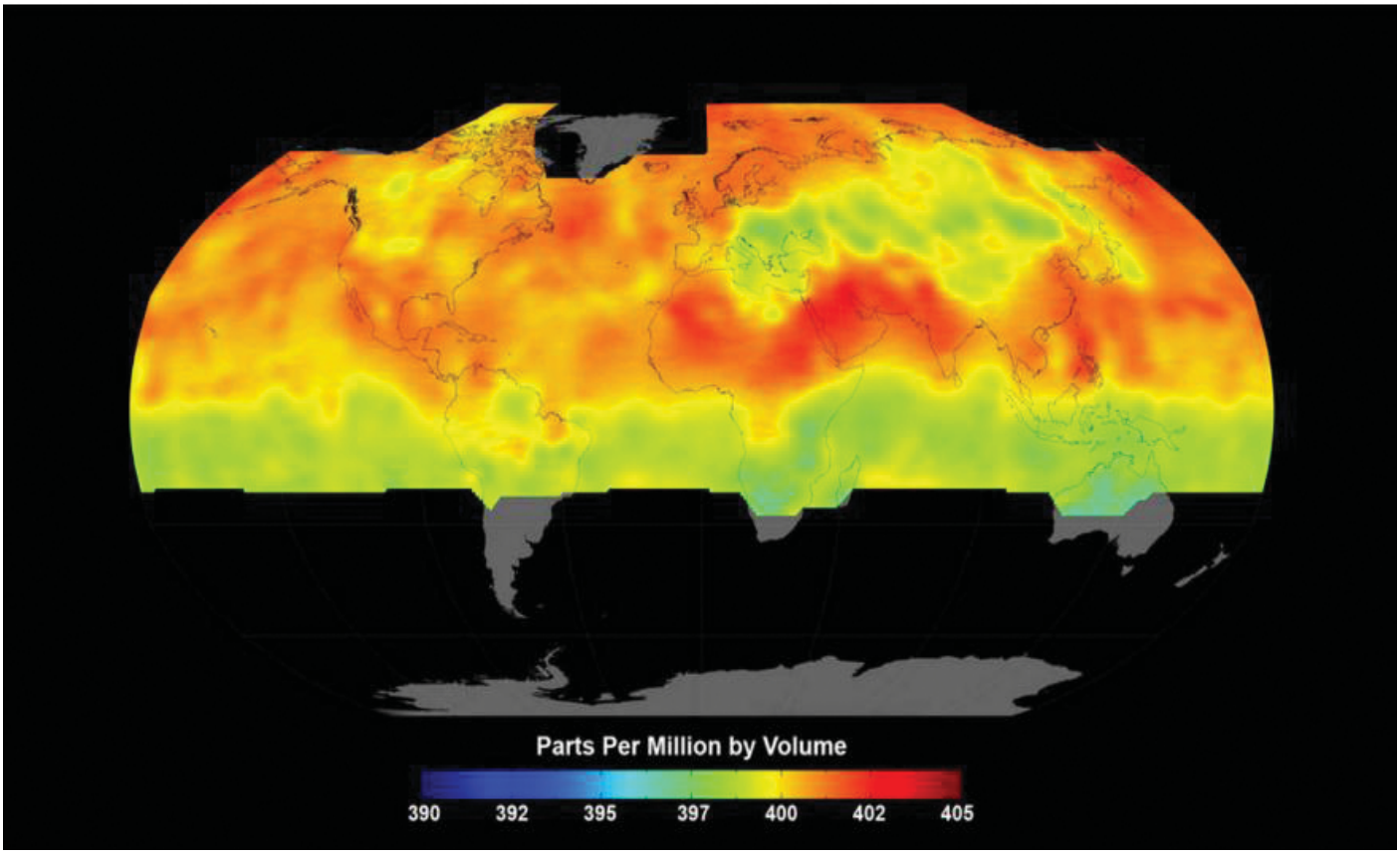


FIGURE 14.14 Distribution of CO_2 concentration over different countries [40]
Global average carbon dioxide concentrations as seen by NASA's Orbiting Carbon Observatory-2 mission, June 1-15, 2015. OCO-2 measures carbon dioxide from the top of earth's atmosphere to its surface. Higher carbon dioxide concentrations are in red, with lower concentrations in yellows and greens" [40].
Source: NASA/JPL-Caltec,

CO_2 is rising. Already observed trend of changes of different climate parameters like temperature, rainfall etc. is discussed in following section.

Status of observed climate and climate projections

The SAPCC, WB states: *"At India level, the annual mean temperature of the country for the period 1901-2009, as a whole has risen by 0.56°C (IMD, 2010) and by 2050s the temperature is projected to rise by 2-4°C (NATCOM, 2004). Further, the MoEF, GOI report focusing on four climate sensitive regions of India (INCCA, 2010), projects that even by 2030's the annual mean surface air temperature may rise by 1.7°C-2.0°C with respect to current climate base line (1960-1990)" [41].*

Climate in West Bengal

The climate of the State is tropical and humid except in the northern hilly region which is close to the Himalayas. The temperature in the mainland normally varies between 24°C-40°C during summer and 7°C-26°C during the winter. The average rainfall in the State is about 1,750 mm with considerable variation among the districts ranging between 1,234 mm in Birbhum to 4,136 mm in Jalpaiguri [42]. The observed changes in climate are provided in next paragraphs.

Temperature rise

Usually climate is thirty years' average of weather. In SAPCC, a data analysis has been conducted for a time period of 37 years to observe the changes with respect to available 100 years IMD data for most of the weather stations in West Bengal. It was reported that maximum temperature observed in a day is decreasing while minimum observed temperature is rising i.e. diurnal difference is decreasing. West Bengal is divided in to six agro-climatic zones namely hill zone, terai zone, old Alluvial and new Alluvial zones, laterite zone and saline coastal zone (Figure 14.15) [43]. The districts covered under each zone are provided in Table 14.9 [44]. The change in temperature is provided for the six zones in Table 14.10 [45]. Reduction in diurnal difference usually has impacts on physiological cycles of plant, animal and humans.

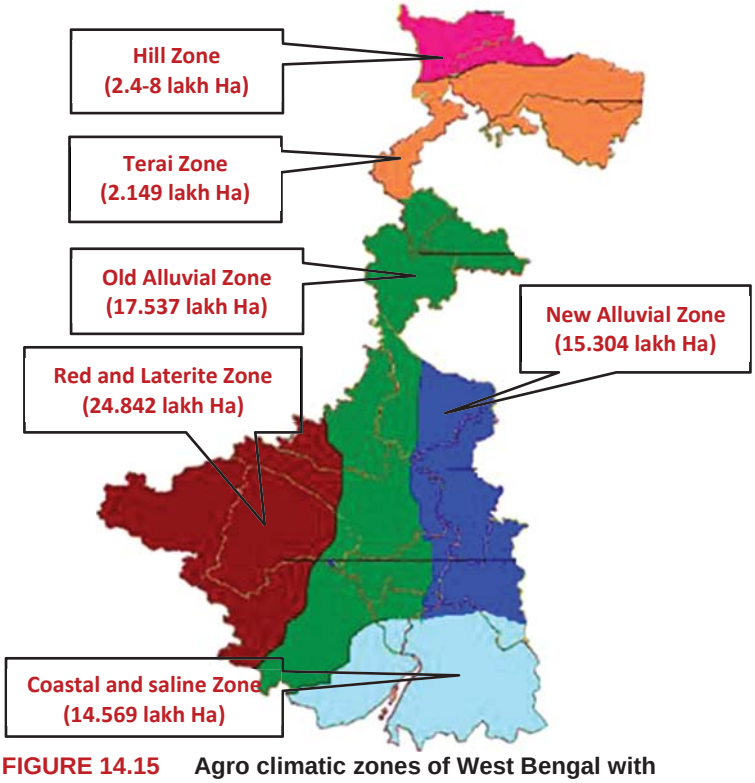


FIGURE 14.15 **Agro climatic zones of West Bengal with cultivable area**

TABLE 14.9 **Districts covered under each zone**

Agro climatic zones	District	Description with GSM weather station [44]
Hill region	Hilly areas of Darjiling district	Terraced, brown forest, shallow, highly acidic (pH 4 to 6), moderately fertile soil. Temperature range: 8.9-14.9°C Annual rainfall: 3,550 mm ***Darjiling***
Terai Zone	Remaining area of Darjiling district, Koch Bihar and Jalpaiguri	Sandy to Sandy loam soil.Temperature range: 12.8-32.3 °C. Annual rainfall: 2,000-3,500 mm ***Koch Bihar, Jalpaiguri***
Old Alluvial Zone	Uttar Dinajpur, Dakshin Dinajpur and Maldah	Old alluvial zone Mostly flat, Loam, deep, mostly neutral soil. Temperature range: 15.1-35.3 °C. Annual rainfall: 1,600–1,800 mm. ***Maldah, Balurghat***
New Alluvial Zone	Murshidabad, Nadia, North 24 Parganas, Haora, Hugli and Barddhaman	Flat to rolling, Light to heavy, acidic to neutral (pH 5.7) soil. Temperature range: 15.6-35°C. Annual rainfall: 1,200–1,700 mm ***Kalyani, Krishnanagar***
Red Laterite zone	Birbhum, Bankura, Puruliya, Paschim Medinipur	Undulating, coarse textured, susceptible to erosion, acidic soil. Temperature range: 14.8 to 37 °C. Annual rainfall: 1,100–1,300 mm ***Bankura, Puruliya***
Saline Coastal region	Purba Medinipur, Hugli, South 24 Parganas, Kolkata	Alluvial, fine textured, saline soil. Temperature range: 16-34 °C. Annual rainfall: 1,500–1,700 mm ***Diamond Harbour, Canning***

TABLE 14.10 **Change in of diurnal difference of temperature in six agro-climatic zone**

Change in zones	Hill zone	Terai zone	Old alluvial	New alluvial zones	Laterite zone	Saline coastal zone
Maximum temperature	-0.25^{o}C	-0.25^{o}C	-0.25^{o}C	-0.5^{o}C	-0.5^{o}C	-0.5^{o}C
Minimum temperature	+1.5^{0}C	+1.5^{0}C	+1.5^{0}C	+1^{0}C	+0.5^{o}C	+1^{0}C
Net reduction in diurnal difference	1.75^{0}C	1.75^{0}C	1.75^{0}C	1.5^{0}C	1^{0}C	1.5^{0}C

TABLE 14.11 Change in rainfall in six agro-climatic zone

Agro climatic zones	District	Precipitation and likely changes
Hill region	Hilly areas of Darjiling district	Average annual rainfall ranging from 1700-2500 millimetres [48]. Rainfall is increasing.
Terai Zone	Remaining area of Darjiling district, Koch Bihar and Jalpaiguri	Annual rainfall: 2,000-3,500 mm [46].
Old Alluvial Zone	Uttar Dinajpur, Dakshin Dinajpur and Maldah	Higher Rainfall is observed in mid October [49]
New Alluvial Zone	Murshidabad, Nadia, North 24 Parganas, Hugli and Barddhaman	Higher Rainfall is observed in mid October [50]
Red Laterite zone	Birbhum, Bankura, Puruliya, Paschim Medinipur	According to observations (2000-2009), this region is also experiencing lower rain fall than expected in the non-monsoon months [51]
Saline Coastal region	Purba Medinipur, Hugli, South 24 Parganas, Kolkata	There is however, a distinct decrease in rainfall in the non monsoon periods, with no change indicated for the eastern part of Puruliya during Oct-Nov period [52]

Rainfall

A periodic shift in monsoon has been observed. There are two hubs in West Bengal, namely, North Bengal and South Bengal divided by river Ganga that receive distinctly different quantity of rainfall. The rainfall intensity in North Bengal extending from Darjiling in the north to Maldah district in the south varies between 25.51 mm/day to greater than 44.51 mm/day. In the southern region, the rain fall intensity varies between 25.51 mm/day to less than 21.51 mm/day [47]. Subtle changes have been noticed in rainfall in different agro climatic zones (Table 14.11) [48-52].

Cyclones

The SAPCC, WB states: *"Long term observations between 1900-2008 show an increasing trend in the frequency of tropical cyclonic storms (88-117 kmph) as well as formation of severe cyclonic storms (118-167 kmph) in the Bay of Bengal during the period 1900-2008). Further, storm surges form when heavy winds produced by tropical cyclones generate the disturbances in the ocean. As these surges propagate into the shallow regions, they amplify and produce large variations of sea level at the coast. The height of the storm surge depends on wind speed, the shape of the coastline, and variations in the water depth along the coastline. Height also depends on phase of the tide. If a surge occurs during high tide, the storm surge will be higher than if it occurs during low tide. Category 5 tropical cyclones can produce storm surges in excess of 6 m (20 feet). Because the storm surge occurs ahead of the eye of the storm, the surge will reach coastal areas long before the cyclone makes landfall"* [53].

Mean sea level rise

The average sea level rise has been 1.3 mm per year along the Indian coast [54]. However, tide gauge observations at the Diamond Harbor port, Sagar and Digha for 1960-2015 period at the rate of five year interval suggest no conclusion should be drawn about extent of sea level rise before further research and analysis of tidal fluctuation in this particular region.

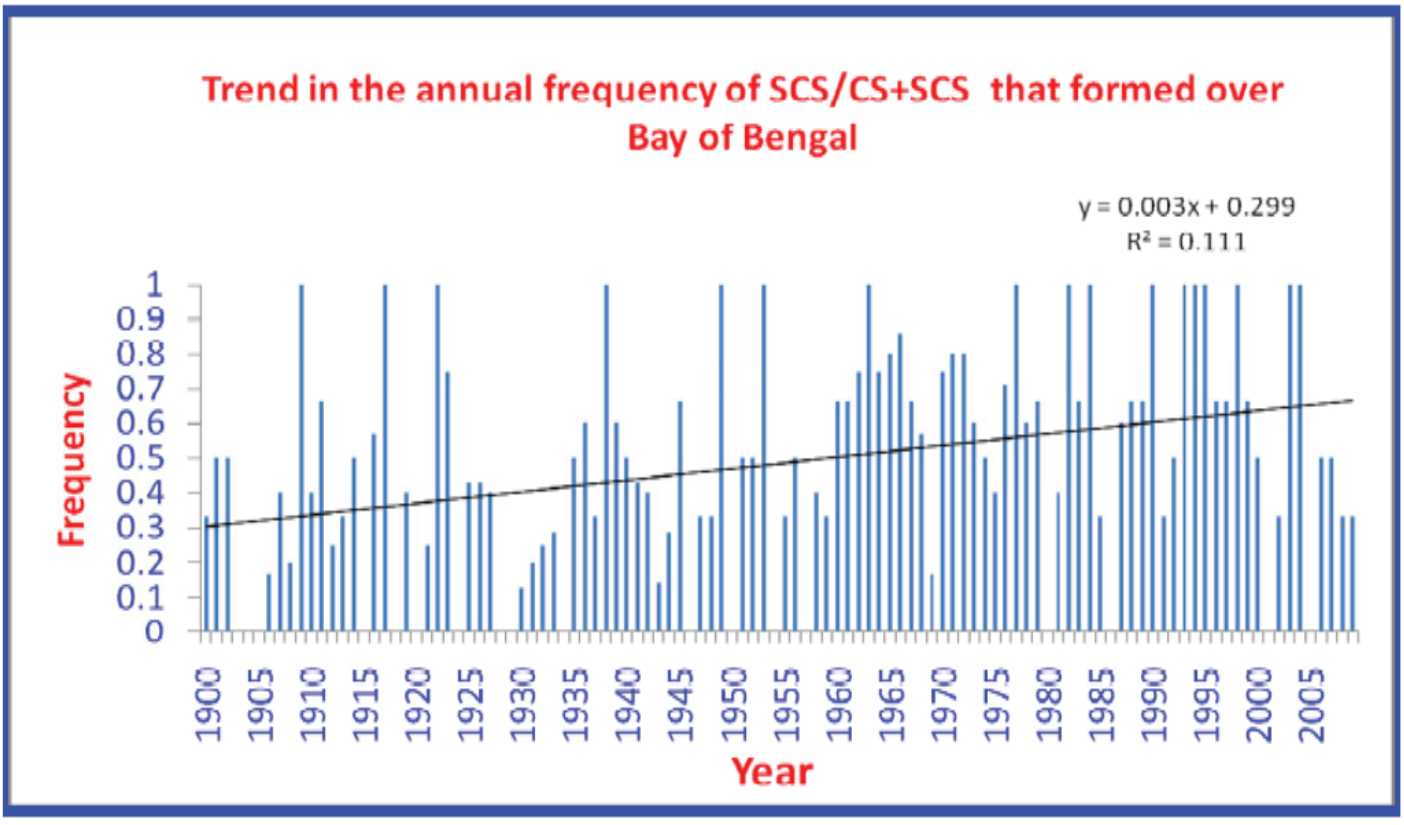


FIGURE 14.16 **Increasing trends of severed cyclonic storm over the region of Bay of Bengal [55]**
Source: IMD, 2010, reprinted from SPACC (WB)

Impacts

The impacts of the increase of GHG concentration coupled with other non climate factor may be classified into two types:

- Primary Impacts and
- Secondary Impacts

The primary impacts are the changes on weather parameters whereas the secondary impacts are the changes caused by the primary impacts with or without impacts by non-climate factors. Both types of impacts are discussed briefly.

Estimation of primary impacts by climate projections [54]

It is stated in the SAPCC, WB (2010) that climate projections for 2050s and 2100 have been derived from PRECIS (Providing Regional Climate for Impact Studies). PRECIS is a Hadley Centre portable regional climate model, developed to run on a computer with a grid resolution of 0.44°x0.44°. PRECIS simulation datasets were provided by the Indian Institute of Tropical Meteorology, Pune. The climate change scenarios were driven by the GHG emission scenarios-IPCC A1B, which assumes a future world of very rapid economic growth, a global population that peaks in mid-century and declines thereafter, and assumes rapid introduction of new and more efficient technologies.

Rainfall

The projections made by PRECIS about rain fall are provided in Figure 14.17 [57] upper pane, which suggest that rainfall shall decrease in January and February in almost all the zones except Sundarban. The monsoon rain fall is likely to remain same for throughout the State.

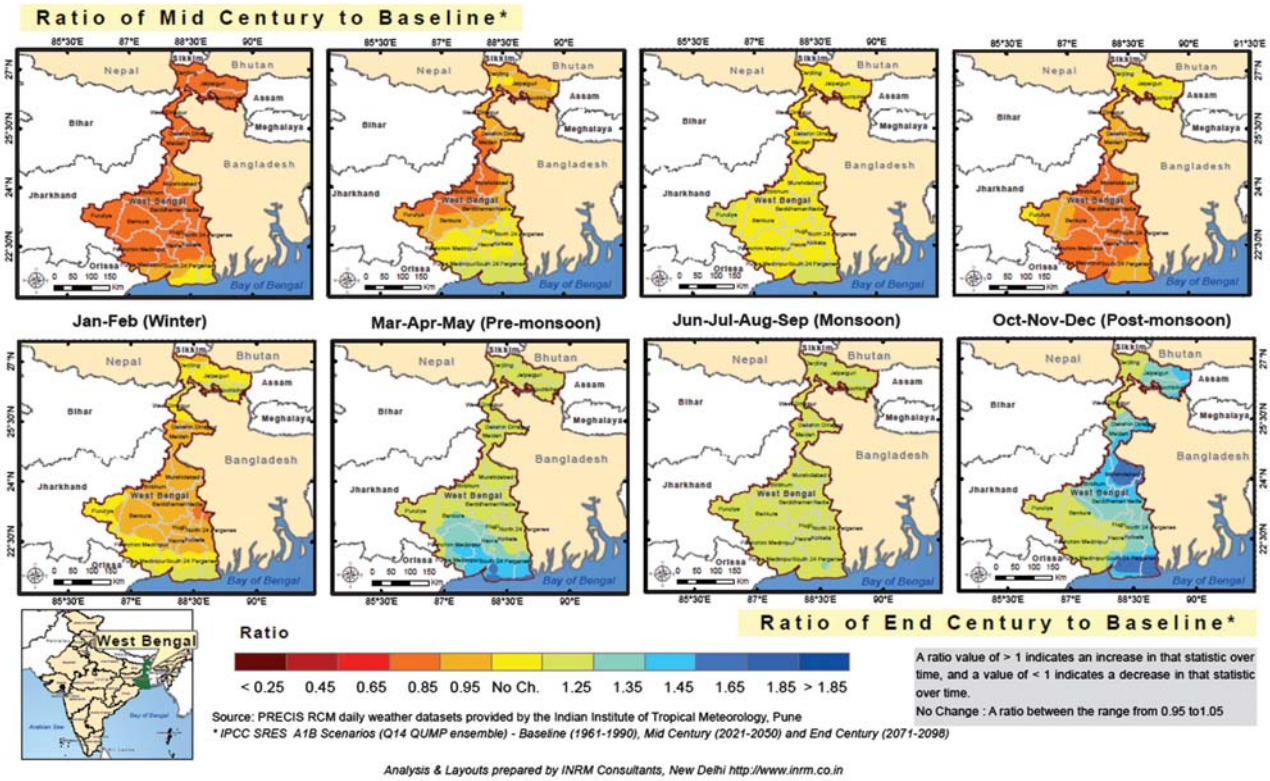


FIGURE 14.17 **Projected changes in average rainfall during winter, pre-monsoon, monsoon and post monsoon season in West Bengal 2050s (upper pane) and in 2100 (lower pane) [57]**

Source: Reprint from SAPCC, WB

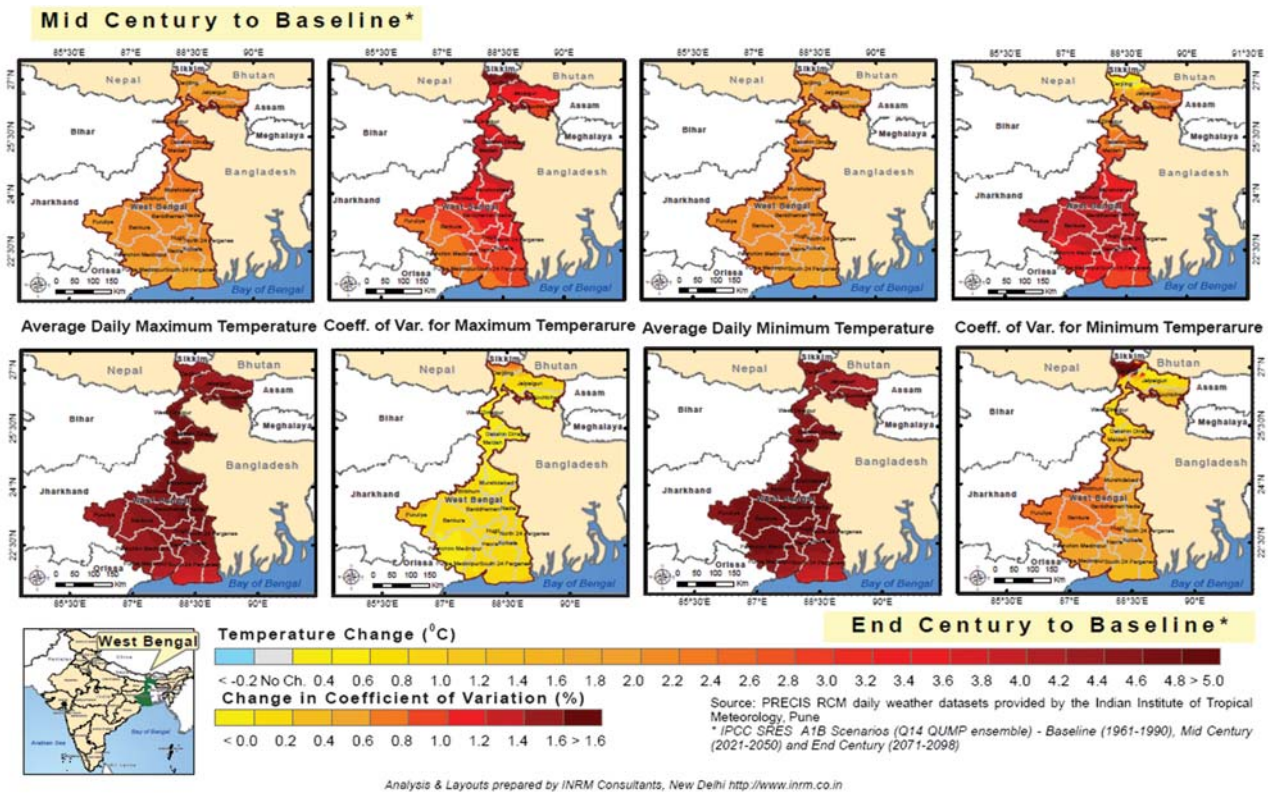


FIGURE 14.18 **Projected changes in temperature in 2050s (upper pane) and in 2100 (lower pane) [59]**

Source: Reprint from SAPCC, WB

Another climate model CMIP5 has been accepted by scientific community around 2010-11. The national level downscaling of GCM by Chaturvedi *et. al.* (2012) using CMIP5 shows that the post monsoon rain (October, November, December) shall increase [58]. However, the degree of increase shall vary spatially.

In 2100, however, significant increase in precipitation is projected in winters in the terai, hill and the new alluvial zone, with the lower zones receiving a slightly more rainfall with respect to base line.

Temperature

The SAPCC, WB, 2012 also shows that temperature in 2050s as per SRES Scenario (Please see Box 14.2). The average daily maximum and minimum temperatures are both projected to rise by 2.2°C in 2050s.The daily maximum and minimum temperatures are likely to rise by 3.6^{0}C to 5^{0}C with respect to the base line i.e. 1960-1990" (Figure 14.18) by 2100 [59].

This observation on temperature is also corroborated by the study, in which district wise downscaling of temperature (with a grid resolution of 0.25°x 0.25°) is being done by Indian Institute Technology, Bombay (IITB). As per the reports available till when this article is in press the maximum temperature as well as minimum temperature is like to increase for state of West Bengal. In the on-going study by IITB 5 GCMs (Global Circulation Models) (CNRM-CM5, GFDL-ESM-2M, MIROC5, CanESM2 and MPI-ESM-LR) are being used in the analysis and the results shown here are based on their ensemble mean. Likely increase in temperature is shown in Table 14.12 and Figure 14.19 [60].

TABLE 14.12 Anomaly of temperature spatial average [60]

Future scenario	Likely changes during 2011-2040 is projected on basis of trend analysis for the period 1961-1990		Likely changes during 2041-2070 is projected on basis of trend analysis for the period 1961-1990		Likely changes during 2071-2100 is projected on basis of trend analysis for the period 1961-1990	
	ts (max)	ts (min)	ts (max)	ts (min)	ts (max)	ts (min)
RCP 2.6	0.892	1.036	1.149	1.451	1.2372	1.454
RCP 4.5	1.066	1.166	1.701	1.852	1.934	2.225
RCP 8.5	1.238	1.338	2.087	2.576	3.044	4.02

RCP: Radiative Concentration Pathways (RCP) [61]

Box 14.1 [61] Radiative Concentration Pathways [56]

In IPCC 5th Report AR5, four RCPs are selected and defined by their total radiative forcing (cumulative measure of human emissions of GHGs from all sources expressed in Watts per square meter) pathway and level by 2100. In other words, these four RCPs supercede the SRES scenarios and are based on GHG concentration trajectories which may lead to increase in energy per square meter. The RCPs were chosen to represent a broad range of climate outcomes, based on a literature review, and are neither forecasts nor policy recommendations.

RCPs	Description
RCP 8.5	Rising radiative forcing pathway leading to 8.5 W/m2 in 2100
RCP6	Stabilization without overshoot pathway to 6 W/m2 at stabilization after 2100
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m2 at stabilization after 2100
RCP2.6	Peak in radiative forcing at ~ 3 W/m2 before 2100 and decline

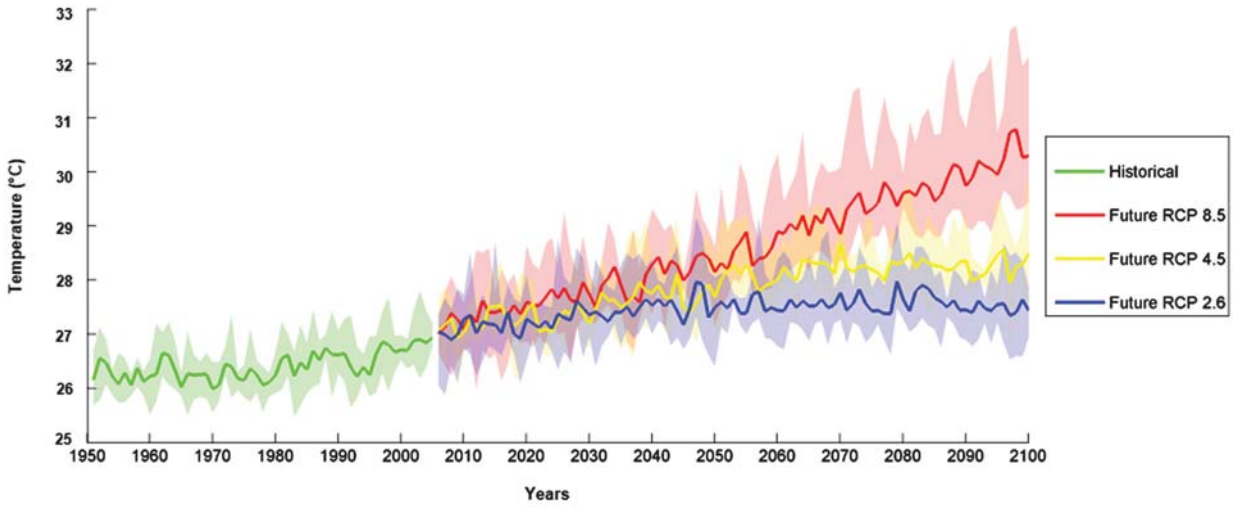


FIGURE 14.19 **Likely changes in average temperature of West Bengal under RCPs [60]**

Box 14.2 SRES scenario [62]

In 1996, the IPCC began the development of a new set of emission scenarios. The approved new set of scenarios is described in the IPCC Special Report on Emission Scenarios (SRES). Four different narrative storylines were developed to describe consistently the relationships between the forces driving emissions and their evolution and to add context for the scenario quantification. The four scenarios are provided below:

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological changes in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Evaporation

Evaporation is not projected to change even with changes in temperature ranges in model estimates.

Cyclones and Storm surges

The increasing trend of cyclones shall continue. However, a draft report by TERI suggests that more cyclones shall form in the month of September and October.

Extreme weather events

TERI study projects that warm nights are to increase for A2, A1b and B2 scenario. Heat Wave Duration Index (HWDI) is going to increase in central part of West Bengal.

Impacts due to climate change

These types of changes in climatic parameters are going to impact the hydrology, agriculture, forest and biodiversity, Himalayan ecosystem, urban and rural infrastructures, human health, coastal ecosystem in many ways. It is not possible to provide detail description of the problems faced in each sector within this limited space. The detail is already available in SAPCC, WB. Some of the priority issues are discussed in following paragraphs.

Hydrological regime of the entire region gets affected due to change in rain fall pattern

A SWAT model analysis suggest that the blue water flow (water yield obtained from rainfall plus deep aquifer recharge) in most of the districts in West Bengal is decreasing from the range of 5,000-1,000 mm/hr to 800- 1,000 mm/hr by mid-century. The blue water flow is not projected to change for Darjiling, Koch Bihar and two 24 Parganas due to climatic reasons.

Green water flow (rate of evapotranspiration) is increasing. Green water storage is decreasing for south western part of West Bengal to 76-100 mm per year by mid-century [63].

All this may affect the minimum ecological flow of a riverine system and cause harm to the aquatic species and the water reserve of the State as a whole. Non-availability of adequate water in time may jeopardise the industrial operation and daily life of the citizens.

Plant and animal physiologies are going to be affected due to change in availability of water and change in temperature.

Agricultural productivity, productivity of live stock, fish production are going to be affected if appropriate actions are not initiated on time. A recent study by Banerjee *et. al.* 2016, [64] show, wet season rice (*Oryzasativa*) may reduce by 20.0 per cent and 27.8 per cent in 2025 and 2050 and mustard production may reduce by 25.0 per cent and 32.7 per cent in 2025 and 2050.

Forest and biodiversity is also expected to be affected due to species migration, early pollination and other disturbances.

Coastal ecosystems including Sundarban and Himalayan ecosystems are identified as vulnerable areas. Sundarban faces the threats of salinity intrusion, storm surges, sea level rise, loss of sweet water ponds, cyclones and loss of livelihood. Himalayan ecosystem is considered as a fragile ecosystem and is more susceptible to climate stress. It is the habitat of various endemic species. The rich and diverse biodiversity of Himalayan region faces serious threats due

- to flash floods in it's steep terrain;
- to change in habitable range of temperature;
- to upward movements of invasive species as region becomes warmer;

Vulnerability of human habitats enhances with increase in flood, shortage of regular water supply, increasing cyclones and extreme weather conditions and other similar factors.

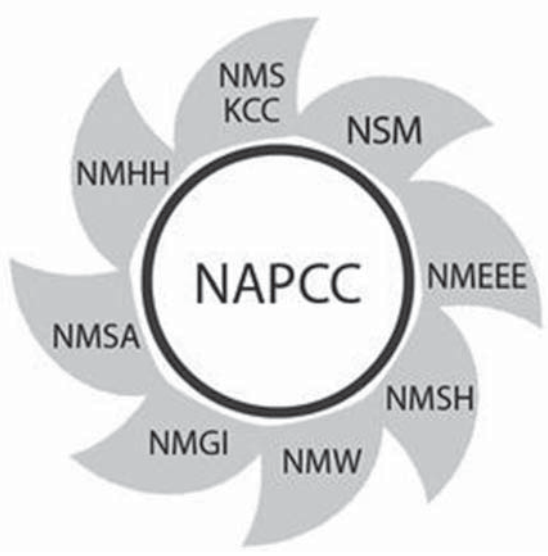
Human health is affected in a hotter and less humid climate. Heat strokes

become more common. In a warmer climate many vector borne diseases spread due to extension of transmission window. Frequent infection may lead to increase morbidity and mortality.

Morbidity, loss of productivities, loss of ecological goods and services, loss of habitats affect the livelihoods and overall wellbeing of the region and leads to socio-economical problems. Actions are to be initiated to improve the resilience of people to adapt to climate change. Mitigation of GHG emissions are also being initiated by improving the energy efficiency and opting for low carbon technologies.

Responses to climate threats (up to March 2017)

Action has been initiated at State level. As mentioned above, the State level action plan has been prepared under the guidance of the Chief Secretary, Government of West Bengal. Action programmes have been enlisted in different sectors. Eight national missions (Figure 14.20) have been set up by the Government of India under different nodal ministries at central level as per NAPCC, 2008.



NMKCC : National Mission on Knowledge for Climate Change
NMHH : National Mission on Human Health
NMSA : National Mission on Sustainable Agriculture
NMGI : National Mission on Green India
NMW : National Mission on Water
NMSHE : National Mission on Sustaining Himalayan Ecosystem
NMEEE : National Mission on Enhanced Energy Efficiency
NSM : National Solar Mission

FIGURE 14.20 Eight missions set up as per NAPCC, 2008

The adaptation programmes are expected to have well defined linkages with the National Missions and State Action Plan on Climate Change (Figure 14.21)

The Department of Environment, Government of West Bengal is acting as the nodal department for climate change related activities. Climate Change Cell has been set up at the Department of Environment, GoWB for co-ordination among various departments and facilitation of adaptation programmes. Climate Cells have also been set up at Department of Science and Technology for State level work under National Mission for Sustaining Himalayan Ecosystem (NMSHE) and at Water and Irrigation Department for State level National Water Mission (NMW). In parlance of climate change, the response actions are broadly classified in two following categories:

- Adaptation to impending climate change;
- Mitigation of GHG emissions;

In state of West Bengal adaptation as well as mitigation measures are being planned/executed.

Understanding the vulnerable areas is precondition for preparation of an effective climate resilient developmental plan. Three such initiatives have been spear headed by the Department of Environment, Government of West Bengal.

- Vulnerability studies have been carried out for Kolkata city in context of storm and inundation.
- A study has been taken up for the coastal districts of West Bengal.
- One more vulnerability study for Himalayan region has been started by Department of Science and Technology

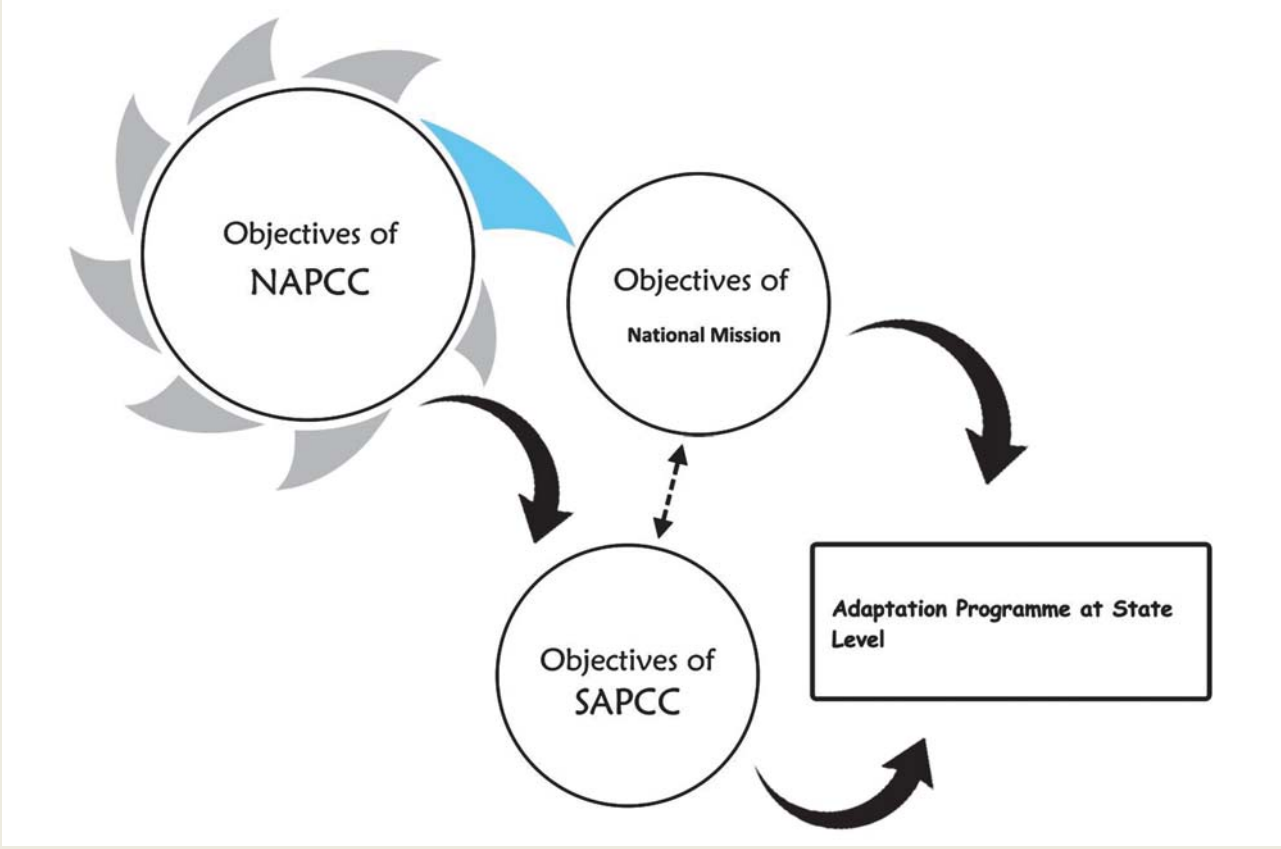


FIGURE 14.21 **Linkages among NAPCC, SAPCC, WB, National Mission and State Level Adaptation Programme**

in partnership with the Department of Environment and Administrative Training Institute.

Mapping vulnerable fisher folk settlements through remote sensing and GIS technology is under preparation by Fisheries department.

Work has been initiated to introduce solar energy, water conservation and other related fields as part of adaptation and mitigation measure.

Low carbon path, energy and water conservation

West Bengal has set up a 900 MW pumped storage project at Baghmundi, Puruliya. Proposal of similar 1,000 MW solar photovoltaic power plant is also being considered. A 10 MW solar project on bank of Teesta Canal Fall stage II H.E has been completed in Uttar Dinajpur district. A 500 KW canal top solar photo voltaic plant has also been installed in Rajarhat. Rooftop solar photo voltaic power panels of 5kWp have been installed in off grid mode in 100 schools. Similar installations of 2 kWp have been done in 10 other schools. Solar panels in grid connected mode of capacity 10 kWp have been installed in 120 schools and of capacity 5 kWp has been installed in 70 schools. This project is being expanded as 500 more schools are being brought under 10 kWp roof top solar power projects. The Department of Power and Non-conventional Energy Sources, institutions like West Bengal Pollution Control Board, WBSEDCL, and WBGEDCL are working in this sector.

Installation of solar panels under 'Aloshree' Programmee

The State Government has introduced 'Aloshree' programme. It is decided that grid connected solar roof top photo voltaic system shall be installed in government buildings. All departments have been involved in this programme.

Installation of grid connected pole top solar street lighting

Urban local bodies (ULBs) like Kolkata Municipal Corporation (KMC) are implementing roof top solar projects. Kolkata Municipal Corporation has installed pole top solar lightings in select areas for grid connected carbon neutral lighting.

Remote village electrification by solar power

Different villages in Sagar and Gosaba block and in few remote blocks in Puruliya have been/are being provided with solar home lighting and solar street lighting systems.

Water conservation measures

Climate change threatens the existence of natural water reserves. The sustainability of economic growth and development of a state depends on availability of water resources. Water is a key input to economic growth sectors and contributes to gross domestic product (GDP). To sustain jobs, employment, economic growth and social stability, leaders of today and tomorrow are to make investment decisions that promote water security. A State Action Plan on Climate Change for Water Sector is under preparation under the stewardship of Irrigation and waterways Department, GoWB. Efforts are being taken by State Environment Impact Assessment Authority (SEIAA, WB) for introduction of water conservation practices like dual plumbing, rainwater harvesting and water recycling in large projects. Few projects have already been taken up by the departments working in water sector. Intensive work has started for river rejuvenation in three rivers in laterite zone. A massive spring shed rejuvenation programme has been taken up in hilly region by Panchayat and Rural Development Department. 600 (six hundred) springs are to be covered in 2016-2017. An ICZMP (Integrated Coastal Zone Management Plan) project is also being executed in coastal zone of West Bengal under the Department of Environment, GoWB. An updated water sector specific action plan is under consideration.

Rain water harvesting

Mass scale Rainwater Harvesting at Darjiling as an adaptation measure

Rain water harvesting (RWH) is a well recognized measure for water conservation. Roof top RWH is usually installed in standalone buildings as demonstration projects. Considering the projections about rainfall in Darjiling and the acute shortage of potable water, a project has been taken up to provide water to the poorer section of Darjiling people under National Adaptation Fund Climate Change (NAFCC) scheme. While the Department of Environment has spearheaded the project concept, the field execution is under progress by Municipal Engineering Directorate. Better access to water would lead to improve community health and improve the resilience of the vulnerable section of citizen. This type of mass scale rain water harvesting for converting a climate risk of extended monsoon to a climate gain is first of its kind in India and is expected to be replicated in different parts of the country.

Other rainwater harvesting projects at different districts

The WBPCB and Institute of Environmental Science and Wetland Management (IESWM)

are also implementing Rain water harvesting (RWH) scheme in various schools and colleges. The Department of Environment, GoWB has funded project for setting up 18 district RWH demonstration centre in each of 18 districts of West Bengal. The IESWM has already set up 12 RWH district demonstration centre in 12 districts. Work is in progress for the remaining six districts. Since 2011-12, the IESWM has also set up:

- Roof top RWH system at Learning Centre, State Bank of India at Salt Lake;
- Roof top RWH based water supply schemes for Schedule Tribe Girls Hostel of Saltora Netaji Centenary College, Saltora, Bankura;
- Roof top RWH system for Hostel of Mahishadal Girls' College, Mahishadal, Purba Medinipur;
- Roof top RWH system for the Students of Krishnabati Primary School, Krishnabati, Hugli;
- Roof top RWH system for the Students of Gopalpur High School, Gopalpur, Mahishadal, Purba Medinipur.

Setting up waste to energy plant

Work has started for setting up of a 5 MT waste to energy plant at Barasat Municipality. Few other municipalities are also exploring the scope of setting up common waste to energy plant.

Enhancing energy efficiency

State Environment Impact Assessment Authority, West Bengal (SEIAA, WB) is imposing conditions for installation of roof top solar panels so that at least 1 per cent of total energy demand of the project is met from solar power by every project.

SEIAA, WB is also imposing conditions to environmental clearance projects for improving energy efficiency like use of LEDs and double glazing windows and water conservation practices like dual plumbing and water recycling. The urban local body like NDITA (Naba Diganta Industrial Township Authority) are pursuing the developers to install solar panels.

Plantation and afforestation

- Massive plantation programme has been taken up in dry regions of West Bengal like Asansol, Puruliya, Bankura, Paschim Midnapur.
- Large scale plantation programmes are also being carried out at Sundarban and other coastal districts.

Project for implementation of demonstration projects

The Department of Environment has played key role in ensuring the successful completion of following demonstration projects:

(a) Livelihood diversification through Integrated Production Systems at different locations of Maldah, Murshidabad district, jointly by Development Research Communication and Service Centre (DRCSC). This project was supported and facilitated by GIZ and MoEF&CC under CCARI (Climate Change Adaptation in Rural India). The Department of Environment, GOWB was the state partner for this project. In fact, the success of this demonstration project catapulated to awarding of first project under Adaptation Fund to any Indian agency. US$ 2.5 million (approximately Rs. 15 Crore) Adaptation Fund has been awarded to The DRCSC for the project on "Enhancing Adaptive Capacity and Increasing Resilience of Small & Marginal Farmers of Puruliya and Bankura Districts, West Bengal".

(b) Salt tolerant species and preparing for disasters at Mousuni Island, Sundarban by WBUA&FS (West Bengal University of Animal and Fishery Science) and WWF, India.

Building climate change information management system (CCIMS), information dissemination, awareness generation

Independent research works are being taken up by different academic institutes to study

various aspects of climate change. Information is also made available at public domain. A consolidation of database shall help the citizens, government departments and other concerned agencies to access and use the information as and when required. Downscaling of GCM (Global Circulation Model) data to regional level and district level is the need of the day. The Department of Environment, GoWB is working in this direction.

Concluding remark

Population is growing and demands for better living condition and livelihood options are also escalating. Climate Change is inducing more uncertainty in our daily lives as well as in long term development plans. Conservation of water resources, aggressive forestation and minimisation of the adverse impact of climate change on agriculture needs to be done. Food security of the citizens cannot be compromised. Climate proof development plans are to be prepared so that the pace of development can be sustained even in an adverse climate. Four major aspects of this battle against climate change are :

- understanding and assessing the degree and intensity of climate change impacts at district level or block level for appropriate intervention and field level execution of projects;
- enhancing the capacity of the people to adapt to a unforeseen hostile climatic condition;
- building resilience so that the state rises against all odds even when climate change hits hard;
- reduction of GHG emission wherever possible;

The state of West Bengal is forging ahead for development with due consideration for improving climate resilience and integration of adaptation measures. Mainstreaming of climate change perspectives in state level plans are needed for building climate resilient West Bengal.

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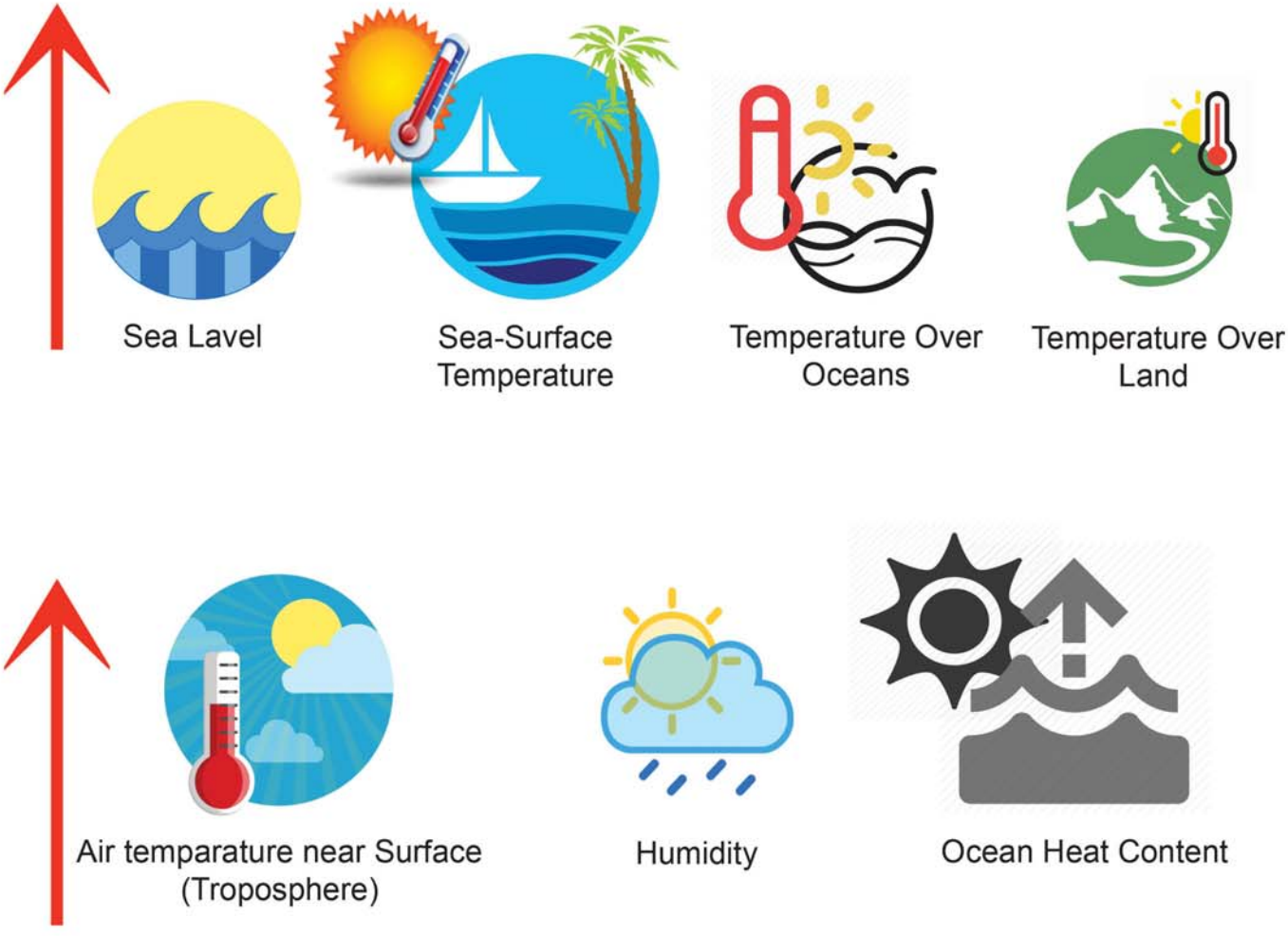
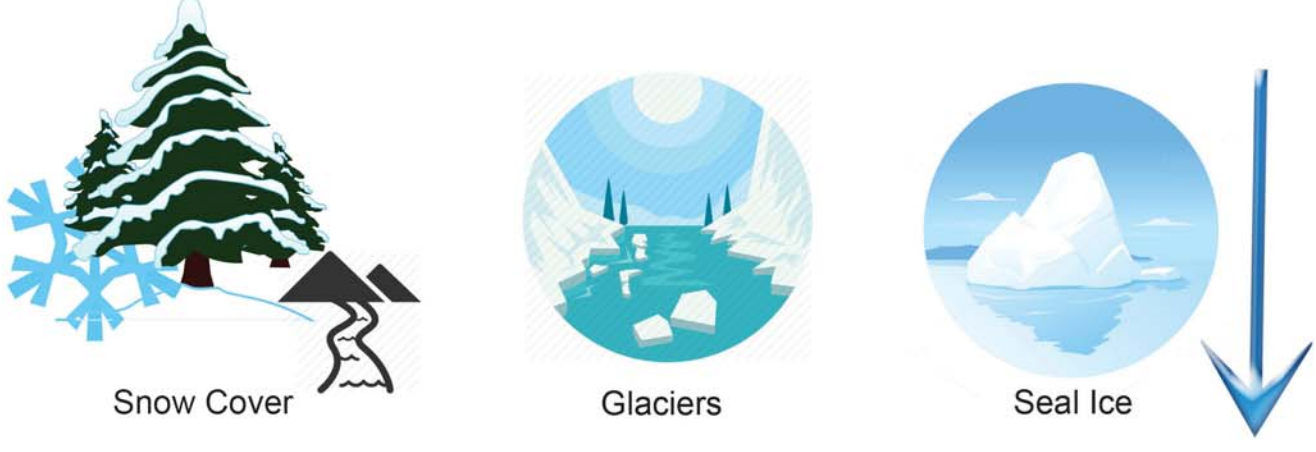
Increasing Climate Change Indicators



Decreasing Climate Change Indicators



Chapter 15

Solid Waste Management

Solid waste generation is associated with different activities at different places and accordingly the composition as well as characteristic of waste may depend on very many factors at the source of generation and types of activities. Urban Local Bodies (ULB) (Corporation/Municipality) provide services for solid waste management (SWM) in respective cities and towns. The ULBs possess infrastructures for rendering the services of SWM though in many cities and towns such services need immediate improvement including infrastructural development. In rural areas of the state of West Bengal where around 70 per cent population reside, neither infrastructures nor services exist for SWM. In the villages conservancy services since not available, the solid waste generated there remain scattered within the villages. However, recently schemes for solid and liquid waste management have been initiated in Gram Panchayat under Nirmal Bangla Mission/Swacch Bharat Mission program.

Solid waste management is a part of public health and sanitation and according to the Indian Constitution falls within the purview of the State List. Since this activity is non-exclusive, non-rivaled and essential, the responsibility for providing the service lies within the public domain. The activity being of a local nature is entrusted to the ULBs for the cities and towns. The ULBs undertake the task with their own staff, equipment and funds. In a few cases, part of the said work is contracted out to private agencies. In rural areas, Gram Panchayats have to undertake the task of managing solid waste and accordingly capacity needs to be built up through institutional development with the involvement of local communities.

The objective of solid waste management is to collect waste at the source of generation, recovery of recyclable materials for recycling, conversion of organic waste to produce compost or bio-gas and secured disposal of remaining waste. Such management system must be sustainable with the basic goal of safeguarding public health and environment from any adverse impact.

Solid waste consists of organic and inorganic waste materials produced by household, commercial and institutional establishments that have no economic value to the owner. It is heterogeneous waste and usually the solid waste is collected as mixed waste by the municipal conservancy workers. Uncontrolled open dumping of solid waste may cause adverse impact to the environment resulting in ground and surface water pollution, soil

contamination, air pollution, odor nuisance etc. The adverse environmental impact may cause deleterious effect on man, animal and other living beings.

Municipal solid waste generation depends on very many factors, *e.g.* socio-economic condition, population density, culture and tradition, habit and practice, climate etc. Quantity of waste generation is increasing due to improvement in socio-economic condition of the people, technological advancement, consumerism, advancement in goods packaging etc. Uncontrolled use and disposal of plastic carry bags is aggravating the problem in managing the municipal solid waste.

The collection and disposal of municipal solid waste is one of the pressing problems of city life which has assumed great importance in recent past. With the growing urbanization as a result of economic growth and industrialization, the problems of managing solid waste are becoming acute and call for immediate and concerted action. Generation of huge quantum of municipal solid waste, if not managed rationally, may cause degradation of environmental quality resulting in adverse impact on the quality of life of the people. To establish sustainable solid waste management system for a city or town, policy framework needs to be adopted to make it smart and healthy.

Situation analysis

In West Bengal, urban areas are comprised of 7 Municipal Corporations, 119 Municipalities and 1 Notified Industrial Township. As per Census 2011, urban and rural population in the State was 29,093,002 and 62,183,113 respectively. The ULBs provide conservancy services to the citizens but such services are varying in nature with deficiencies as well as constraints. In recent years the ULBs are exerting more efforts with manpower, equipment and machineries and fund. However, in general, the solid waste management systems in ULBs need improvement in a planned manner with renewed resources and efforts.

Quantity of solid waste generation

In West Bengal, municipal solid waste generation ranges between 0.3-0.6 kg/cap./day. Considering weighted average as 0.435 kg/cap./day, the quantity of municipal solid waste generation is around 12,600 MT/day. Kolkata city generates around 3,500 MT/day sold waste. In class I town, solid waste generation is 0.4 kg/cap/day. Kolkata and Haora generates 0.6 kg/cap/day solid waste. In other small towns waste generation is around 0.3 kg/cap/day. The average density of mixed solid is 500 kg/m^3. The waste is voluminous in nature and occupies considerable space. But the waste is compactable and it may be practiced as and when necessary.

Physical characteristics of municipal solid waste

The municipal solid waste is heterogeneous in nature comprising of organic, inorganic–recyclables and inorganic–non-recyclable materials. The general characteristics of municipal solid waste may be as shown in Table 15.1 depending on very many factors:

The quantitative analysis of municipal molid waste of five towns, e.g. Bidhannagar, Titagarh, Chandannagar, Kharagpur and Raniganj is presented in Table 15.2. The

TABLE 15.1 General characteristics of municipal solid waste

Characteristics	Range (%)
Organic	40-55
Ash/earth (inert/inorganic)	15-25
Paper / cardboard /duplex board, plastic /PVC/HDPE, rags/cotton/sanitary napkins, glass, ceramic, rubber, earthenware, wood, hay/straw/thermocol, leaves, metals, others (not specified)	25-30

TABLE 15.2 Physical characteristics of urban solid waste in West Bengal

Components of solid waste samples	Name of the municipal towns					Average (%)
	Bidhannagar	Titagarh	Chandannagar	Kharagpur	Raniganj	
	Composition in percentage					
Garbage (organic putrescible)	68.93	37.02	40.99	35.87	35.80	44.00
Ash/earth (inert/inorganic)	3.50	40.72	21.50	26.96	27.80	24.21
Paper/cardboard/box/duplex board	4.96	3.40	9.16	5.91	5.96	5.90
Plastic/PVC/HDPE	7.61	2.70	6.70	10.29	4.98	6.50
Rags/cotton/textile	0.75	1.10	1.76	2.13	0.44	1.24
Rubber	0.02	-	0.09	--	1.26	0.46
Leather	-	0.22	--	--	6.49	0.03
Wood	--	--	0.15	--	0.16	0.01
Earthenware	3.80	5.30	3.12	6.76	--	4.85
Ceramics	--	0.11	0.11	--	2.13	0.01
Glass	2.60	0.68	0.87	0.36	7.16	2.40
Hay/straw /thermocol	0.10	0.02	0.10	0.23	0.18	0.13
Leaves	0.27	2.50	12.50	2.97	1.48	4.00
Metals	0.36	0.09	0.30	0.21	--	0.25
Others (Coconut shell brickbat, pencil battery etc.)	7.10	6.15	2.65	8.31	6.16	6.07

Source: WBPCB & SWRE/JU)

quantitative analysis of solid waste revealed that 48 per cent waste was comprised of biodegradable in nature. Around 24 per cent of solid waste consisted of ash/earth/silt (inert matter) and rest 28 per cent wastes were found to be the mixture of several components *i.e.* paper, plastic, rags, cotton, leather, rubber, glass, earthenware metal etc. Around 50 per cent of the miscellaneous wastes (28%) were found to be recyclables. The waste analysis result also indicated that the organic part of solid waste ranged between 35.8-68.93 per cent.

Chemical characteristics of municipal solid waste

Chemical analysis of solid waste is important in selecting treatment and disposal option and also designing the waste management system. In general following chemical characteristics may be found in municipal solid waste at the source of generation.

Moisture content : 50-70%
NPK : 1.5-2%
Calorific value : 800-1200 kcal/kg

Qualitative chemical analysis of municipal solid waste of five municipal towns (Bidhannagar, Titagarh, Chandannagar, Kharagpur and Raniganj) is presented in Table 15.3. The chemical analysis result (dry weight basis) indicated presence of nitrogen, phosphorus and potassium in mixed municipal solid waste as 7,321.52 mg/kg, 3,514.35 mg/kg and 8,780.05 mg/kg respectively. The total organic carbon ranged between 5-21 per cent with average as 11.19 per cent. The C/N ratio of solid waste ranged between 10.98-20.74 per cent and average value as 15.28 per cent. In this context it can be mentioned that for facilitating composting, the C/N ratio may be 15-30 and accordingly the organic part of municipal solid waste may be converted to compost. The average calorific value of municipal solid waste was found to be 1,432 kcal/kg which showed slightly higher

TABLE 15.3 Chemical analysis of solid waste samples collected from municipal towns of West Bengal

Parameters	Concentration/value					Average value
	Bidhannagar	Titagarh	Chandannagar	Kharagpur	Raniganj	
Moisture content (%)	70.40	28.35	54.15	25.32	52.55	46.15
Loss on ignition at 900C (%)	61.60	18.13	40.87	20.60	29.73	34.20
Total Nitrogen (as N) (mg/kg)	14457.60	4552.25	8539.00	3301.75	5757.00	7321.52
Total Phosphorus (as P) (mg/kg)	5042.00	3887.00	3132.50	2070.00	3440.25	3514.35
Potassium (as K) (mg/kg)	17708.00	7139.25	10202.50	3746.25	5104.25	8780.05
Total organic carbon (%)	21.00	5.00	14.80	6.85	8.32	11.19
Calorific value Kcal /kg	2531.00	914.25	1836.25	1004.75	872.25	1431.78
C/N ratio	14.52	10.98	17.33	20.74	14.45	15.28

Source: WBPCB & SWRE/JU)

than the calorific value of solid waste in India ranging 800-1,200 kcal/kg. The higher trend in calorific value of municipal solid waste may be due to increasing packaging waste generating from purchase of consumer goods.

Components of solid waste management

The following are the components of solid waste management

- Source segregation and on-site storage;
- Collection;
- Intermediate storage/transfer station;
- Transportation;
- Recycling;
- Treatment;
- Disposal;

Storage

Storage of solid waste at source is the first essential step of SWM. Every household, shop and establishment, institution generates solid waste which should normally be stored at the source of generation till these are collected for treatment and disposal. On-site storage is of primary importance because of public health concerns and aesthetic consideration. Unsightly makeshift containers and even open ground storage – both of which are undesirable are often seen at many residential and commercial areas. Proper storage of solid waste is essential for containerized waste collection system.

Segregation

The term segregation indicates separation and storage of individual constituents of waste materials. Segregation aims at minimizing the waste and ensuring reduction in landfill space for final disposal, recycling of waste and resource recovery. As per Solid Waste Management Rules 2016, solid wastes are to be segregated for organic and inorganic waste. The following are the objectives of segregation of municipal solid waste:

- To separately store recyclable materials for reuse/recycling.
- To ensure that wastes which can be processed for recovery of material and energy (through composting, bio-digestion or any other suitable technology) do not get mixed with undesirable elements;
- To separately store household hazardous waste material/biomedical waste, if generated for safely disposal through appropriate process.

In municipal towns of West Bengal solid waste mostly is not segregated as organic and/inorganic waste. Though it has been planned for source segregation of solid

waste but it is yet to be implemented mostly. In the preparation of Gram Panchayat level scheme for solid and liquid waste management (Swachh Bharat Mission–Nirmal Bangla Program) emphasis has been given for segregation of solid waste at the household level and accordingly separate coloured containers are to be kept for the storage of organic and inorganic solid waste. At present around 15 per cent of municipal solid waste is salvaged by rag pickers or scavengers and they earn their livelihood by selling the salvaged items. The waste segregation (only recyclable inorganic waste) takes place at the following locations:

- At the source/household level;
- At the road side vats and community bins;
- At transfer stations;
- At waste processing site;
- At the landfill site;

Considerable quantum of recyclable solid waste materials segregated at the source of generation (old newspaper, old books and notes, thick plastic, glass, empty containers, empty cosmetic bottles, old clothes etc.) are sold to the 'kabariwalas' or roadside vendors.

Collection

Collection of solid waste is one of the essential steps of solid waste management. Collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed on the streets, drains, water bodies etc. Normally ULBs provide daily waste collection services through containerized pedal tricycles or handcarts from all households and other establishments. Such practice is known as house to house waste collection system. Today, in many municipal towns house to house collection of solid waste can be seen either fully or partially. Solid waste collection from ward community bins, private housing societies, multi storied buildings, commercial complexes, institutions is also practiced in many municipal towns in West Bengal. In many municipal towns Ward Committees play vital role in organizing the primary collection system including routing and scheduling of collection and also maintaining co-ordination with the citizens.

Transportation

The functional element of transfer and transportation involves:

(i) Transfer of waste from the primary collection vehicle (pedal tri-cycle or handcart) to the larger transport vehicle.

(ii) Subsequent transport of the wastes to the processing centre or disposal site.

In many municipal towns motorized vehicles with detachable containers are used for secondary transportation of solid waste. Trucks or lorries with fixed container are also used for carriage of solid waste. Tractor-trailers are also used for secondary transportation of municipal solid waste. The secondary transportation vehicles are also engaged for carriage of municipal solid waste from road side vats.

In Kolkata, compactor fitted vehicles have been pressed into service for carriage of bulk solid waste as well as to abolish open vats from the city, Such type of vehicles with increased frequency of road sweepings have made the city more clean. Use of compactor fitted vehicles has been extended in a few municipal towns in Kolkata Metropolitan Area (KMA).

Recycling

Material recycling can occur through sorting of waste into different streams at the source or at a centralized facility. Sorting at source is more appropriate and economical than sorting at a centralized facility. Certain waste items (newspaper, thick plastic, containers, metals etc.) are segregated at household level and are sold to the roadside vendors or 'kabariwalas'. Around 15 per cent of municipal solid wastes are salvaged by rag pickers or scavengers from

Rag pickers collecting waste materials for livelihood
Source: WBPCB

road side vats, disposal sites etc. These rag pickers and scavengers are not organized labourers and they do not work under any institutions or non–governmental organization. They salvage recyclable materials from municipal solid waste for their livelihood but face occupational health hazard as well as social insecurity.

In none of the ULBs in West Bengal salvaging of recycling materials has been institutionalized. Organized recycling is not practiced and as a result the present system of salvaging and recycling causes health hazards and environmental pollution.

Treatment

Solid waste can be processed as well as treated through various processes to produce utilizable products, e.g. compost, bio-gas, electricity etc. In West Bengal, a few ULBs have adopted different processes to convert organic waste to compost. Both vermi-composting and windrow composting are practiced in selected municipal towns. However, performance of composting units needs improvement. ULBs are also experiencing problem of marketing of compost. Utilization of municipal solid waste for biogas or electricity generation is yet to be started in the municipal towns. However, many ULBs are exploring possibilities to utilize municipal solid waste for generating bio-gas, electricity, refuse derived fuels etc. In one ULB (Barasat Municipality) experimental unit (5 MT/day) is in the process of installation for generating electricity from organic solid waste.

Disposal

One of the facets of solid waste management is the disposal of waste. Today, the disposal of waste by land filling or uncontrolled open dumping is the ultimate fate of all solid waste. In all the municipal towns uncontrolled open dumping is practiced. Though in some municipal towns sanitary land filling facilities were developed but these facilities are not being properly used by the ULBs.

Uncontrolled open dumping of solid waste practiced by the ULBs are causing ground water pollution, surface water pollution, air pollution, fly nuisance etc. Many ULBs are facing scarcity of land for disposal of solid waste and that has caused serious threat to the environment. This is a serious issue for many ULBs in Kolkata Metropolitan Area and accordingly serious attention needs to be extended by the departments of Urban Development, Municipal Affairs and Environment to solve the problem immediately. The concept of shared/regional disposal of municipal solid waste is being considered in Kolkata Metropolitan Area and accordingly each of the shared disposal sites would take care of secured disposal of solid waste generating from municipal clusters (4-7 municipal towns).

Quantum of disposal of municipal solid waste by secured land-filling can be minimized by installing composting facilities (vermi-composting/windrow composting) and organized segregation/sorting/recycling system. The quantum for secured land-filling could be reduced to between 30-35 per cent of generated municipal solid waste resulting in considerable reduction in land requirement for disposal of solid waste.

Solid waste management in West Bengal

Cities/towns

There are total 127 ULBs in West Bengal. The classifications of these ULBs and number of cities/towns in each class is shown in Table 15.4.

TABLE 15.4 Classification of cities/towns in West Bengal

Types of town as per population range	Number
Class I Towns (more than 100000 population)	58*
Class II Towns (50000 ≤ 100000)	28
Class III Towns (20000 ≤ 50000)	32
Class IV Towns (10000 ≤ 20000)	8
Class V Towns (5000 ≤ 10000)	1
Class VI Towns (≤ 5000)	0
Total	**127**

*Including two metro cities Kolkata & Haora

Solid Waste Management Rules 2016 and authorization

The Solid Waste Management Rules 2016 applies to every local authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid waste. Every local authority shall, within the territorial area of the municipality, be responsible for the implementation of the provisions of these rules, and for any infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid waste. The Solid Waste Management Rules 2016 have superceded the Municipal Solid Waste (Management and Handling) Rules 2000. The above mentioned provision is the same in both the Rules. However, in the new Rules, in addition to the ULBs, the village panchayats of census towns and urban agglomerations have also been made responsible for SWM.

In the above context, as per provision of the Municipal Solid Waste (Management and Handling) Rules 2000, all municipal authorities had to obtain 'Authorization' from the West Bengal Pollution Control Board for managing municipal solid waste following compliance criteria laid down in the said Rules. The current status of compliance of the ULBs with respect to authorization is furnished in Table 15.5.

TABLE 15.5 Current status of compliance of the ULBs with respect to authorization

Status	KMA	Non KMA	Total	Remark
Total ULBs	42	85	127	--
ULBs applied with Detailed Project Report	39	48	87	--
ULBs applied without Detailed Project Report	1	23	24	--
Total ULBs applied	40	71	111	--
ULBs yet to apply	2	14	16	--
Authorization granted	33	39	72	--
Authorization applied but not granted	5	8	13	--
Authorization revoked	1	0	1	Bidhannagar

Source: WBPCB

MSW generation status

In urban centres of West Bengal, solid waste generation is around 12,600 MT/day. As per ULBs annual reports about 85 per cent municipal solid waste is collected daily and as a result huge quantum of solid waste remain accumulated at various places in the towns. The solid waste generation ranges 0.3-0.6 kg/cap/day in cities and towns in West Bengal. Kolkata and Haora cities generate 0.6 kg/cap/day while generation of solid waste in class I towns is 0.4 kg/cap/day and rest of the towns is 0.3 kg/cap/day.

Status of development of MSW facility

So far 72 ULBs (KMA-33, Non–KMA-39) have obtained authorization from West Bengal Pollution Control Board after submission of Detailed Project Report (DPR) for development of municipal solid waste treatment and disposal facilities. Rest of the 55 ULBs are yet to obtain authorization from WBPCB. The status of development of MSW facilities of 72 ULBs is presented in Table 15.6.

TABLE 15.6 Status of development of MSW facility in 72 ULBs (as on 31.03.2016)

Sl. No.	District	Name of ULB obtained Authorization	Location	Status of development of MSW facility
1.	North 24 Parganas	Ashoknagar–Kalyangarh Municipality	Non KMA	Yet to be developed
2.	North 24 Parganas	Baranagar Municipality	KMA	Sanitary Land Fill (SLF) developed jointly with Dum Dum and South Dum Dum Municipality but filled up with mixed waste
3.	North 24 Parganas	Barasat Municipality	KMA	Yet to be developed
4.	North 24 Parganas	Barrackpore Municipality	KMA	SLF and Vermi-compost plant have been developed, operation yet to be started
5.	North 24 Parganas	Basirhat Municipality	Non KMA	Yet to be developed
6	North 24 Parganas	Bhatpara Municipality	KMA	Yet to be developed
7.	North 24 Parganas	Dum Dum Municipality	KMA	SLF has been developed jointly with Baranagar and South Dum Dum Municipality but filled up with mixed waste
8.	North 24 Parganas	Garulia Municipality	KMA	SLF and Vermi-compost plant developed jointly with North Barrackpore Municipality but compost plant has stopped operating and landfill is being used for mixed waste dumping
9.	North 24 Parganas	Gobardanga Municipality	Non KMA	Yet to be developed
10.	North 24 Parganas	Habra Municipality	Non KMA	Yet to be developed
11	North 24 Parganas	Halisahar Municipality	KMA	Yet to be developed
12	North 24 Parganas	Kamarhati Municipality	KMA	SLF and Vermi-compost plant developed. Compost plant is sparingly used and land fill site is used for mixed waste dumping
13	North 24 Parganas	Kanchrapara Municipality	KMA	Yet to be developed
14	North 24 Parganas	Madhyamgram Municipality	KMA	Yet to be developed

Sl. No.	District	Name of ULB obtained Authorization	Location	Status of development of MSW facility
15	North 24 Parganas	New Barrackpore Municipality	KMA	SLF and Vermi-compost plant developed jointly with North Dum Dum Municipality as model facility founded by CPCB and KMDA. Presently this is in dilapidated condition
16	North 24 Parganas	North Barrackpore Municipality	KMA	SLF and Vermi-compost plant developed jointly with Garulia Municipality but now compost plant has stopped operating and landfill is being used for mixed waste dumping
17	North 24 Parganas	North Dum Dum Municipality	KMA	SLF and Vermi-compost plant developed jointly with New Barrackpore Municipality as model facility founded by CPCB and KMDA. Presently this is in dilapidated condition because of public resentment
18	North 24 Parganas	Panihati Municipality	KMA	SLF and compost plant developed but are presently in dilapidated condition
19	North 24 Parganas	South Dum Dum Municipality	KMA	SLF has been developed jointly with Dum Dum and Baranagar Municipalities but is now filled up with mixed waste
20.	North 24 Parganas	Taki Municipality	Non KMA	Yet to be developed
21	South 24 Parganas	Budge Budge Municipality	KMA	SLF and Vermi compost plant have been developed, but not taken into use
22	South 24 Parganas	Maheshtala Municipality	KMA	SLF and compost plant are in dilapidated condition
23	South 24 Parganas	Rajpur –Sonarpur Municipality	KMA	Yet to be developed
24	Bankura	Bankura Municipality	Non KMA	Yet to be developed
25	Barddhaman	Asansol Municipal Corporation	Non KMA	SLF developed under JNNURM project jointly with 4 other ULBs under Asansol Durgapur Development Authority. SLF was being operated by a private operator but currently the operations are suspended.
26	Barddhaman	Barddhaman Municipality	Non KMA	Yet to be developed
27	Barddhaman	Durgapur Municipal Corporation	Non KMA	SLF developed under JNNURM jointly with 4 nos. of other ULBs under ADDA. Compost plant installed. Operations of both SLF and compost plant have been discontinued / suspended
28	Barddhaman	Kalna Municipality	Non KMA	Yet to be developed
29	Barddhaman	Raniganj Municipality	Non KMA	SLF developed under JNNURM jointly with 4 other ULBs under ADDA. Compost plant installed. Operations of both SLF and compost plant have been suspended
30	Birbhum	Rampurhat Municipality	Non KMA	Yet to be developed
31	Koch Bihar	Koch Bihar Municipality	Non KMA	Yet to be developed
32	Koch Bihar	Haldibari Municipality	Non KMA	Yet to be developed
33	Koch Bihar	Mekhligang Municipality	Non KMA	Yet to be developed
34	Koch Bihar	Tufangang Municipality	Non KMA	Yet to be developed
35	Darjiling	Darjiling Municipality	Non KMA	Yet to be developed

Sl. No.	District	Name of ULB obtained Authorization	Location	Status of development of MSW facility
36	Darjiling	Kalimpong Municipality	Non KMA	Yet to be developed
37	Darjiling	Kurseong Municipality	Non KMA	Yet to be developed
38	Darjiling	Mirik Municipality	Non KMA	Yet to be developed
39	Darjiling	Siliguri Municipal Corporation	Non KMA	Yet to be developed
40	Hugli	Arambagh Municipality	Non KMA	Yet to be developed
41	Hugli	Baidyabati Municipality	KMA	Common regional landfill facility shared with 5 other ULBs developed and also vermi-compost plant developed under JICA project. Both facilities are in operation.
42	Hugli	Bansberia Municipality	KMA	SLF and Vermi compost plant developed but not taken into operation.
43	Hugli	Bhadreswar Municipality	KMA	SLF and Vermi- compost plant developed and in operation but are in poor condition.
44	Hugli	Champdani Municipality	KMA	Common regional landfill facility shared with other ULBs developed. Vermi- compost plant is under construction.
45	Hugli	Chandannagar Municipal Corporation	KMA	SLF and Vermi-compost plant developed and in operation but are in poor condition.
46	Hugli	Hooghly-Chinsurah Municipality	KMA	SLF and Vermi compost plant developed but not used. Now covered with mixed waste.
47	Hugli	Konnagar Municipality	KMA	Common regional landfill facility shared with Baidyabati, Serampore, Champdani, Uttarpara-Kotrung and Rishra Municipality Developed. Vermi-compost plant is under construction.
48	Hugli	Rishra Municipality	KMA	Common regional landfill facility shared with other ULBs developed. Vermi Compost Plant is under construction.
49	Hugli	Serampore Municipality	KMA	Common regional landfill facility shared with other ULBs developed. Vermi-compost plant is under construction
50	Hugli	Tarakeswar Municipality	Non KMA	Yet to be developed
51	Hugli	Uttarpara-Kotrang Municipality	KMA	Common regional landfill facility shared with ULBs developed. Vermi-compost plant is under construction.
52	Haora	Bally Municipality	KMA	SLF and Vermi Compost Plant developed and is in operation but is in extremely poor condition.
53	Haora	Howrah Municipal Corporation	KMA	Yet to be developed
54	Jalpaiguri	Alipurduar Municipality	Non KMA	Yet to be developed
55	Jalpaiguri	Jalpaiguri Municipality	Non KMA	Yet to be developed
56	Jalpaiguri	Mal Municipality	Non KMA	Yet to be developed
57	Kolkata	Kolkata Municipal Corporation	KMA	Compost plant is operated by a private operator, engaged by ULB. SLF is yet to be developed.
58	Maldah	English Bazar Municipality	Non KMA	Yet to be developed

Sl. No.	District	Name of ULB obtained Authorization	Location	Status of development of MSW facility
59	Maldah	Old Maldah Municipality	Non KMA	Yet to be developed
60	Purba Medinipur	Haldia Municipality	Non KMA	SLF and Vermi Compost plant developed and being operated by a private operator engaged by the ULB.
61	Purba Medinipur	Panskura Municipality	Non KMA	Yet to be developed
62	Murshidabad	Berhampore Municipality	Non KMA	Yet to be developed
63	Nadia	Chakdaha Municipality	Non KMA	Yet to be developed
64	Nadia	Gayeshpur Municipality	KMA	Yet to be developed
65	Nadia	Kalyani Municipality	KMA	Yet to be developed
66	Nadia	Nabadwip Municipality	Non KMA	Yet to be developed
67	Nadia	Ranaghat Municipality	Non-KMA	Yet to be developed
68	Nadia	Santipur Municipality	Non KMA	Yet to be developed
69	Uttar Dinajpur	Kaliaganj Municipality	Non KMA	Yet to be developed
70	Uttar Dinajpur	Raiganj Municipality	Non KMA	Yet to be developed
71	Dakshin Dinajpur	Balurghat Municipality	Non KMA	Yet to be developed
72	Dakshin Dinajpur	Gangarampur Municipality	Non KMA	Yet to be developed

Source: WBPCB

Box 15.1 Compliance to Schedule II of MSW Rules, 2000

- Good practices in cities/towns: All municipal authorities have taken some initiatives but none have achieved full compliance.
- House to house collection: All municipalities have taken some initiatives but results are insignificant.
- Segregation: All municipal authorities have taken some initiatives but none have achieved significant results.
- Storage: All municipal authorities have taken some initiatives but none have achieved full compliance.
- Covered transportation: All municipal authorities have taken some initiatives but none have achieved full compliance.
- Compost/vermi compost plant: Vermi-compost/compost plants were installed and started operation in 14 municipal towns but except 4 towns other municipal towns have stopped operation.
- Waste to energy: In Barasat municipal town waste to energy plant (5 MT/day) has been proposed to generate electricity (1,200-1,500 KW). It is under the process of installation.
- Sanitary Land Filling: In 18 municipal towns sanitary land filling facility has been developed but mostly mixed wastes are being dumped in the landfill site. One common regional landfill facility (for six municipalities) is presently operational.

Critical review of solid waste management in cities/towns

A study conducted by WBPCB through School of Water Resource Engineering (SWRE), Jadavpur University indicated increasing generation of solid waste with the increase in population density in the municipal towns. The increase in population density in a city or town normally results in lesser vacant areas. The residents in densely populated areas will have no other alternative but to keep all solid wastes in the household or community containers. So, chances of waste thrown in vacant spaces will get reduced considerably in densely populated areas. Further in densely populated towns the socio-economic conditions are comparatively better and accordingly generation of solid waste is comparatively higher.

It has been observed in municipal towns that collection of solid waste is less than the generation of solid waste. As a result some amount of solid wastes remain accumulated at various places in the towns. Analysis of information collected from 50 ULBs in West Bengal indicated that average collection of solid waste is about 85 per cent of waste generation. Maximum solid waste accumulation was noticed in Kaliaganj Municipality whereas minimum accumulation was found in Bidhannagar Municipality.

Solid waste compactors
Source: WBPCB

One of the facets of SWM is primary collection of waste. House to house collection, community bin collection and road side vat collection systems are prevailing in the municipal towns. In 72 per cent municipal town, the house to house collection system has been initiated fully or partly. Collection of solid wastes from community bins and road side vats are practiced in 54 per cent and 52 per cent municipal towns respectively. In many municipal towns both are practiced.

Primary transportation involves transportation of municipal solid waste collected from different household sources or community bins to primary transfer station. Mostly hand carts and pedal tricycles are used for primary transportation. Pedal tri-cycles are used in 92 per cent municipal towns whereas hand carts are used in 66 per cent municipal towns. 58 per cent municipalities are using both pedal tri-cycles and hand carts for primary collection of solid wastes.

Transportation of wastes from transfer stations/storage depot at regular interval is essential to ensure that no community bins/containers get overfilled and wastes do not litter streets. Hygienic condition can be maintained in cities and towns only if regular clearances of waste from transfer stations/storage bins are ensured.

In Kolkata, compactor attached waste transport vehicles have been pressed into service. Such compactor attached vehicles are kept at the location of open vats (now covered) and accordingly open-vats have been abolished in many locations of the city. It is expected that more number of such vehicles will be introduced to make Kolkata city cleaner.

But in many municipal towns traditional trucks/tractor–trailers are used for transportation of waste. Most of the vehicles for secondary transportation are found to be uncovered and as a result good quantum of wastes get spilled over while moving along the road causing pollution and acute discomfort to the pedestrian.

Again many vehicles are manually loaded causing serious disadvantage and occupational health hazard to the conservancy workers. Often loading heights of vehicles are higher than the standard height which results in uneconomical transportation due to higher loading time. Rational transportation system needs to be achieved through economical combination of vehicle capacity, crew size and trips per day. But most of the ULBs are not addressing the said economical combination of men and machine in secondary transportation of solid waste. In this context, it must be mentioned that around 70 per cent funds of SWM are utilized in secondary transportation of solid waste.

The final functional element in the SWM system is treatment and disposal. Uncontrolled open dumping of solid waste is practiced in majority of the municipal towns. In KMA, sanitary land-filling facilities have been provided by KMDA; but the same are not being properly utilized. In some municipal towns within KMA, vermi-composting units have been installed but in most of such municipal towns the vermi-composting units are not functioning satisfactorily. It is expected, that composting as well as sanitary land-filling for 6 municipal towns (Uttarpara, Rishra, Konnagar, Serampore, Champdani and Baidyabati) may function satisfactorily. The project is being implemented with JICA loan (14,100 lakhs) and State fund (2,900 lakh).

There are environmental risks from uncontrolled open dumping of solid waste. Leachate from solid waste may cause ground water and surface water pollution. Air pollution is also very common around the waste dump site. Complaints of odour nuisance from solid waste dump sites indicate insanitary condition of disposal site.

Successful compost plants functioning with business mode are yet to be developed. Inter-sectoral coordination to promote use of organic manure produced from municipal solid waste is absent. The issue of subsidy for organic compost production needs to be addressed by the concerned authorities. Environmental cost must be considered for ecologically balanced approach adopted in compost manufacturing from organic waste.

Social up-liftment of scavengers and rag-pickers is the critical issue and accordingly such issue needs to be addressed to achieve sustainable SWM. Organized recycling is practiced by none of the ULBs. But organized recycling must be a component of SWM and as such it should be introduced by involving existing rag-pickers and scavengers.

Environmental health impact

There are potential risks to environment and health from improper handling of solid wastes. Conservancy workers of municipalities, rag-pickers and scavengers are exposed to risks due to contact with the wastes. They are the victims of occupational health hazards and often suffer from different types of diseases. For the general public, the main risk to health is indirect and arises from the breeding of disease vectors, primarily flies and rats.

The most obvious environmental damage caused by municipal solid wastes is aesthetic, the ugliness of street litters and degradation of the urban environment and beauty of the city. Uncontrolled dumping of municipal solid waste may cause groundwater, surface water and air pollution. Open burning of solid waste may result in generation of toxic gasses.

Epidemiological studies have shown that a high percentage of workers who handle refuse and of individuals who live near disposal sites are infected with gastro intestinal parasites, worms and related organisms. Vector insects and rodents grown due to insanitary waste dumping can transmit various pathogenic agents causing very many diseases.

Organic fraction of solid waste, if not properly collected and further processed,

may cause serious adverse impact upon public health and environmental quality. Impact on environmental quality takes the form of foul odours, unsightliness, soil, water and air pollution. Thus, organic part of solid waste needs to be segregated at the source of generation and should be processed for converting to compost or could be utilized to generate biogas or electricity.

In many places waste recovery is an important unorganized livelihood for rag pickers and scavengers. They live and work under extensive health risks, which are largely un-documented, and suffer severe exploitation and deprivation. Possible health hazards include raised level of infant mortality, hand and leg injuries, intestinal and respiratory infections, eye infection, tuberculosis, lower back pain, malnutrition, skin disorder and exposure to hazardous wastes. At least 15 per cent of municipal solid waste is inorganic–recyclables. These can be segregated in a controlled manner by engaging the scavengers and rag-pickers. Earning from the sale of recyclable materials can be utilized for SWM as well as for social upliftment of the rag-pickers and scavengers.

National environmental indicator(s)

Solid Waste Management Rules 2016 apply to every local authority and village panchayats of census towns and urban agglomerations responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes. The Rule has set compliance criteria for different parameters of management of municipal solid wastes, such as, collection, segregating, storage, transportation, processing and disposal of municipal solid wastes. The Rule also provides criteria for land-fill site selection as well as specification for land-filling.

Monitoring of ground water quality shall be done during pre-landfill operations, filling and also during operational and post-operational period at such locations preferably to cover one up-gradient and two down-gradient monitoring wells. Ground water in and around landfill site shall not be used for drinking purposes or otherwise, unless it meets specified standards for that particular use. The ground water qualities shall conform to limits in Table 15.7 for monitoring purpose:

TABLE 15.7 Ground water quality standards in and around landfill site

Sl. No.	Parameters	IS 10500:2012, Edition 2.2 (2003-09) Desirable limit
1.	Arsenic	0.01 mg/l
2.	Cadmium	0.01 mg/l
3.	Chromium (as Cr^{6+})	0.05 mg/l
4.	Copper	0.05 mg/l
5.	Cyanide	0.05 mg/l
6.	Lead	0.05 mg/l
7.	Mercury	0.001 mg/l
8.	Nitrate as NO_3	45 mg/l
9.	pH	6.5-7.5
10.	Iron	0.3 mg/l
11.	Total hardness (as $CaCO_3$)	300.0 mg/l
12.	Chloride	250 mg/l
13.	Dissolved solids	500 mg/l
14.	Phenolic compounds (as C_6H_5OH)	0.001 mg/l
15.	Zinc	5 mg/l
16.	Sulphate (as SO_4)	200 mg/l

Source: Solid Waste Management Rules 2016

Ambient air quality at the landfill site and at the vicinity shall be monitored regularly and shall meet the standards prescribed by the CPCB for industrial areas. The concentration of methane gas shall not exceed 25 per cent of the LEL. In order to ensure safe application of compost, the standards mentioned in Table 15.8 for production of compost may be ensured. The standards for disposal of treated leachates are shown in Table 15.9.

TABLE 15.8 Specifications for compost quality

Parameters	Organic Compost	Phosphate rich organic manure
Arsenic (mg/Kg)	10.0	10.0
Cadmium (mg/Kg)	5.0	5.0
Chromium (mg/Kg)	50.0	50.0
Copper (mg/Kg)	300.00	300.00
Lead (mg/Kg)	100.00	100.00
Mercury (mg/Kg)	0.15	0.15
Nickel (mg/Kg)	50.0	50.0
Zinc (mg/Kg)	1000.00	1000.00
C/N ratio	<20	Less than 20:1
pH	6.5-7.5	(1:5 solution) maximum 6.7
Moisture, per cent by weight, maximum	15.0-25.0	25.0
Bulk density (g/cm^3)	<1.0	Less than 1.6
Total Organic Carbon, per cent by weight, minimum	12.0	7.9
Total Nitrogen (as N), per cent by weight, minimum	0.8	0.4
Total Phosphate (as P_2O_5) per cent by weight, minimum	0.4	10.4
Total Potassium (as K_2O), per cent by weight, minimum	0.4	--
Colour	Dark brown to black	--
Odour	Absence of foul Odor	--
Particle size	Minimum 90% material should pass through 4.0 mm IS sieve	Minimum 90% material should pass through 4.0 mm IS sieve
Conductivity (as dsm-1), not more than	4.0	8.2

Source: Solid Waste Management Rules 2016

TABLE 15.9 Standards for disposal of treated leachates

Parameters	Standard (mode of disposal)		
	Inland surface water	Public sewer	Land disposal
Suspended solids, mg/l, max	100	600	200
Dissolved solid (inorganic) mg/l, max	2100	2100	2100
pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
Ammoniacal Nitrogen (as N), mg/l, max	50	50	--
Total Kjeldahl Nitrogen (as N), mg/l, max.	100	--	--
Bio-chemical Oxygen Demand (3 days 27^{0}C) max, mg/l	30	350	100
Chemical Oxygen Demand, mg/l max.	250	--	--
Arsenic (as As) mg/l, max	0.2	0.2	0.2
Mercury (as Hg) mg/l, max	0.01	0.01	--
Lead (as Pb), mg/l, max	0.1	1.0	--
Cadmium (as Cd), mg/l, max	2.0	1.0	--
Total chromium (as Cr) , mg/l, max	2.0	2.0	--
Copper (as Cu), mg/l, max	3.0	3.0	--
Zinc (as Zn) , mg/l max	5.0	15.0	--
Nickel (as Ni), mg/l, max	3.0	3.0	--
Cyanide (as CN) , mg/l. max	0.2	2.0	0.2
Chloride (as Cl), mg/l, max	1000	1000	600
Fluoride (as F) , mg/l, max	2.0	1.5	--
Phenolic compounds (as C_6H_5OH) mg/l, max	1.0	5.0	--

Source: Solid Waste Management Rules 2016

Current pressure and trends

Solid waste management is always a challenge to the civic authorities. Municipal solid waste is heterogeneous mixture of organic and inorganic materials parts of which are recyclables. Tackling of solid waste includes practices followed by the waste generators at source and handling as well as managing the same by the civic authorities. The responsibilities no doubt, are equal or fifty-fifty. But unfortunately appropriate responsibilities are mostly not shared by the citizens and municipal authorities. Heap of solid waste can be seen accumulated at different places in the cities/towns. Solid wastes are thrown on the drains resulting in obstruction of waste water flow, water logging as well as risks of mosquito breeding. Quantity of solid waste generation is increasing due to increasing use of packaging materials and consumerism. Use of plastic carry bag is increasing even today in spite of campaign against use of thin plastic carry bags. It has caused detrimental effect on drainage system, water bodies and soil. Burning of plastic waste has also affected health and environment.

Municipal solid waste mostly is not segregated at the source of generation. If the wastes are not segregated as organic and inorganic, it would be difficult to adopt rational solid waste management system. As municipal solid waste are collected as mixed waste, so those are disposed on land in uncontrolled manner without adopting engineered land filling operation. Uncontrolled open dumping of solid waste results in environmental degradation and adverse impact on public health. Uncontrolled disposal of mixed wastes causes anaerobic decomposition resulting in methane and carbon dioxide generation.

Lands for disposal of solid waste are getting exhausted for many municipalities, as a result the ULBs are facing stiff challenges in managing solid waste. In some ULBs within KMA, lands for disposal of solid waste do not exist and as such, those ULBs are disposing solid waste outside municipal boundary.

Rag pickers and scavengers are engaged in picking up of recyclable inorganic for their livelihood by selling those for recycling. Those people are unorganized and work under distressed condition. Many small unauthorised recycling units are operating in unorganised manner.

Solid waste management system requires sufficient fund for meeting capital as well as operation and maintenance expenditure. Capital expenditure is required for purchase of machineries, equipment, transport vehicles, containers, land and construction of infrastructures. Vehicles and containers require quick replacement and as a result, on an average fund for capital expenditures will be required at every sixth or seventh year. Recurring expenditure on SWM is required for man power, fuel, maintenance of vehicles and equipment, Information-Education-Communication (IEC) campaign etc. Naturally fund is a constraint to all ULBs. Again, fund is generally not generated through selling of compost and recyclable inorganic materials. Mostly people do not contribute money for the conservancy services. But if the ULBs impose user fee under the Solid Waste Management Rules 2016, it will certainly help the ULBs to achieve sustainable SWM program.

Thus, serious attention is needed from ULBs, Urban Development Department and Environment Department for adoption and operation of rational solid waste management system to meet the current pressure and rising trend of solid waste generation.

Way forward

Solid waste management is a state subject as per the Constitution of India, and it is the primary responsibility of the State Government to ensure that appropriate SWM practices are introduced in all cities and

towns in the State. Though SWM is a state subject, it is basically a municipal function and as such ULBs are directly responsible for performing this important activity. The 74th amendment of the Constitution also envisages the ULBs to shoulder this responsibility.

Conservancy services within SWM have been poorly performed by most of the ULBs resulting in problems of public health, sanitation and environmental degradation. The situation is becoming more and more critical due to rapid pace of urbanization. The SWM system in most of the ULBs is found to be far from satisfactory due to lack of financial resources, institutional weakness, improper choice of technology, lack of public participation, non-involvement of private sectors etc. Therefore, there is a need for handling this problem in concerted as well as holistic manner and adopt strategies to tackle all aspects of waste management scientifically involving private agencies and/or NGOs wherever necessary and possible. A policy framework is, therefore, necessary for the state of West Bengal to guide and support ULBs in the State for managing the solid waste scientifically and cost effectively.

Enforced demand results from all motivations coming from external reasons, such as rules and regulations. Demand from enforcement will not exist if citizens/communities are allowed to adopt behaviours and practices independently. Enforcement is particularly necessary in cases of environmental protection including the protection of natural resources and human safety. Environmental ethics and environmental discipline are considered to be most important in formulating the enforcement for creating the demand amongst the community.

The demand for waste management services is growing as are the costs for waste management. At the same time there is growth in the emerging markets for recycled goods. There is also an increasing trend among the farmers to use organic compost in the agriculture field. But a subsidy on the account of environmental cost for the use of organic compost needs to be considered as a policy by the concerned authority for implementation.

Recovering energy from waste is an attractive option in terms of treating waste (environmental benefits) and increasing access to energy (social benefits), but the systems currently have low returns on investment and therefore financially unattractive. Even technologically the waste to energy scheme may not be viable because of very low calorific value of waste (1,000-1,200 kcal/kg). But enhancement of calorific value of municipal waste by addition of auxiliary waste with higher calorific value may be suitable for waste to energy conversion scheme and thus may be financially attractive. This option may help the city managers in future because of requirement of reduced quantum of land for disposal of remaining solid waste. The following issues need to be addressed during policy formulations:

- Effective public participation in segregation of solid waste at source (organic and inorganic).
- Management of solid waste should be according to the category of the waste *e.g.* organic, inorganic recyclable and inorganic non-recyclable.
- Door to door collection of solid waste from all sources (Residential houses, commercial establishments, markets, institutions etc.) through primary collection system.
- Public participation in primary collection of waste.
- Primary collection of waste including sweeping of streets on daily basis irrespective of Sundays and public holidays.
- Introduction of primary transfer stations (ward basis).
- Avoid double or multiple handling of solid waste. Solid waste should not touch the ground except at treatment and disposal sites.

- Containerized waste collection system must be ensured.
- Avoid mixing of different categories of waste.
- Compactor fitted vehicle can be introduced, if feasible, for compaction of particular category of waste.
- Transportation vehicle with detachable container may be used for secondary transportation.
- Transportation of waste on day to day basis in closed body vehicles.
- Processing of waste for generating compost, power and other useful products.
- Conversion of organic waste to compost would be appropriate to achieve ecologically balanced approach of nutrient recycling. Business mode could be developed to achieve it.
- Emphasis is to be given on recycling of inorganic recyclable in an organized manner.
- Rag-pickers and scavengers may be inducted in material sorting and recycling process for their social-uplift.
- Disposal of non-recyclable inorganic waste in environmentally acceptable manner through secured engineered land filling system.
- Institutional strengthening and capacity building in ULBs.
- Municipal clubs can be formed in managing solid waste with shared responsibility.
- Improving financial health through revenue earning.
- Human resource development and training.
- Encouraging private sector participation in waste management.
- Awareness and motivation campaign for peoples' participations.
- Involvement of Ward committees is SWM program.
- Development of appropriate IEC material.
- Welfare of the staff engaged in SWM services.
- Creation of public grievances redressal mechanism. Provision of enforcement of laws and rules.

One of the important aspects of SWM is environmental ethics and discipline. While all efforts may be made to build awareness among the community for public participation in SWM services in the urban areas, a mechanism for enforcement should be simultaneously created to discipline the citizens who do not adhere to the directions of the ULBs. Those who litter the streets or create unhygienic conditions, in spite of the facilities provided by the ULBs, may be punished through levy or fines, administrative charges etc.

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Chapter 16

Bio-medical Waste Management

The Government of India notified the Bio-Medical Waste (Management and Handling) Rules, 1998 on 20th July, 1998 under the Environment (Protection) Act 1986, to provide a regulatory framework for management of bio-medical waste generated in the country for the very first time. The implementation of the rules in the vast network of health care units (HCUs) in the country proved to be a mammoth task and the success was very limited. To implement the rules more effectively and to improve the collection, segregation, processing, treatment and disposal of bio-medical wastes (BMW) in an environmentally sound manner and thereby reduce the bio- medical waste generation and its impact on the environment, the Central Government reviewed the existing said rules and notified the Bio-medical Waste Management Rules, 2016 on 28th March 2016 in supersession of the previous rules notified in 1998.

As per the Bio-medical Waste Management Rules, 2016, "bio-medical waste means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps, including the categories mentioned in Schedule I appended to these rules". Bio-medical waste (BMW) consists of solids, liquids, sharps, and laboratory wastes that are potentially infectious or dangerous.

WBPCB, as the prescribed authority under the Bio-Medical Waste (Management and Handling) Rules, 1998, took up the task of preparation of a detailed inventory and status report on BMW management in West Bengal in 2010, in collaboration with a Kolkata based NGO, Society for Direct Initiative for Social and Health Action (DISHA). Some of the pertinent information in that report is worth noting before proceeding to discuss the present status.

Nearly 80–85 per cent of the wastes generated by health-care activities comprise of general wastes. The remaining approximately 15-20 per cent of waste is considered hazardous that may be infectious or toxic. When there is no source segregation of hazardous and non-hazardous waste and all the wastes are mixed together, the entire health-care waste turns infectious and hazardous. This increases the volume of waste and it becomes difficult to manage the huge volume. Also, it has been estimated that about 45 per cent of the BMW as a whole is made of recyclable materials.

Although not listed as a BMW in the rules, mercury waste generation from healthcare units is a matter of concern. In the study, it was estimated that at least 32 kg. of mercury waste was generated only from broken thermometers in bedded HCUs in the State. The process of phase-out of mercury bearing instruments has already been initiated in the State.

As in 1998 Rules, the WBPCB is the designated 'Prescribed Authority' for enforcement of the Bio-medical Wastes Management Rules, 2016. The responsibilities of the Board include granting of authorization to bio-medical waste generating units which are mostly health care units and Common Bio-medical Waste Treatment Facilities, maintaining an inventory of BMW generation and treatment in the State and preparing an annual report on the same.

The 1998 Rules were applicable only to health care units with beds and to those non-bedded health care units providing service to more than one thousand patients per month. The ambit of the Rules have now been widened and the Bio-medical Waste Management Rules, 2016 apply to *"all persons who generate, collect, receive, store, transport, treat, dispose, or handle bio-medical waste in any form including hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks, ayush hospitals, clinical establishments, research or educational institutions, health camps, medical or surgical camps, vaccination camps, blood donation camps, first aid rooms of schools, forensic laboratories and research labs"*.

Bio-medical Wastes
Source: WBPCB

The Rules have laid down specific treatment and disposal options for the different types of BMWs, according to their nature and potential hazard, to prevent environmental pollution due to inappropriate waste disposal. As per the provisions of the Rules, all health care units are required to segregate bio-medical wastes at source depending on the mode of final treatment as per the colour coding specified in the Rules. The colour coding specified in the new Rules are similar to the previous Rules but the system has been simplified and wastes have been regrouped as per the colours. Therefore now, there are four major groups of bio-medical wastes, denoted by four colours, based on the final treatment options. Segregated wastes are required to be stored in separate colour coded bags/containers and sharps are to be stored in puncture proof containers. Mutilation and shredding of waste has been prescribed to prevent chances of reuse.

As installation and operation of bio-medical waste treatment facilities by individual health care units is not ordinarily a viable option, only a few units have their own on-site bio-medical waste treatment facilities. There is only one unit having an incinerator, two units having microwave and four units having autoclaves as shown below:

- National Institute of Cholera and Enteric Diseases, Kolkata – incinerator
- Medical College and Hospital, Kolkata – microwave
- Malda District Hospital – autoclave
- Medinipur Medical College and Hospital – microwave
- Barasat District Hospital – autoclave
- Murshidabad District Hospital – autoclave
- Vivekananda Mission Netra Niramoy Niketan, Haldia - autoclave

All other health care units in the State, both Govt. and private, depend on the services provided by six privately owned Common Bio-medical Waste Treatment Facilities (CBWTFs). The health care units have all ensured treatment of bio-medical wastes by joining one of the following six Common BMW Treatment Facilities (CBWTFs) operating in the State:

- Greentech Environ Management Pvt. Ltd., Amratala Dhamua Road, PO-Chakparan Kantakhali, PS-Mograhat, South 24 Parganas, PIN-743 503
- Greenzen Bio Pvt. Ltd., Binnaguri, Fulbari, Bhaktinagar, Jalpaiguri
- Medicare Environmental Management Pvt. Ltd., 'F' Road, Belgachia, Haora, PIN-711 105
- Medicare Environmental Management Pvt. Ltd., KIGC, Phase III, Kalyani, Nadia
- Medicare Environmental Management Pvt. Ltd., Mangalpur, Raniganj, Barddhaman
- West Bengal Waste Management Pvt. Ltd., Sutahata, Haldia, Purba Medinipur

These common facilities pick up segregated BMWs from their member units and transfer the same for treatment to their respective facilities. All the facilities have incinerators for burning the high calorific value wastes and autoclaves for disinfection of the other wastes. The incinerators are all provided with air pollution control devices. The facilities have shredders for shredding of the autoclaved wastes to prevent reuse.

It must be noted here that even the units having on-site bio-medical waste treatment facilities like autoclaves or microwaves, have to depend on the Common Bio-medical Waste Treatment Facilities for the disposal of their incinerable waste.

The overall status of compliance of healthcare units as on December 2015 is shown in Table 17.1 (as per Annual Report submitted by WBPCB to the Central Pollution Control Board).

The Board regularly monitors the health care units to check the BMW segregation, storage and treatment arrangements. Joint inspection of health care units is also conducted along with officials of the Health and Family Welfare Department, Govt. of West Bengal. Defaulting units are called for hearing to explain the lapses observed during inspection and are usually given an opportunity to achieve compliance.

TABLE 16.1 Status of compliance of healthcare units (as on December 2015)

No. of bedded health care units that have applied for Consent to Operate and BMW Authorization	3334
No. of non-bedded health care units that have applied for Consent to Operate	3545
No. of non-bedded health care units applied for authorization	439*
Quantity of BMW treated and disposed	23555.6 kg/day

* Only units providing service to more than 1,000 patients per month were required to obtain authorization as per Bio-medical Waste (Management & Handling) Rules, 1998

After many years of consistent effort by the Board, the general awareness of the healthcare personnel with respect to bio-medical waste management has improved and BMW management in the health care units has also started showing signs of improvement. However, in spite of all measures taken by the Board for effective implementation of the Rules, the progress has not been significant. Mixing of bio-medical waste with general waste is a common phenomenon observed in most healthcare units except in some of the prominent private healthcare units. Also inappropriate waste segregation is causing operational problems in the Common Bio-medical Waste Treatment Facilities.

The Board has limited options when it comes to taking action against habitual defaulters. Imposing closure orders on health care units is neither desirable nor easy considering the nature of services

provided by them, more so, in the case of Government units. Therefore the fact remains that a large number of health care units (HCUs) continue to violate the provisions of the Rules.

In view of the poor compliance, the West Bengal Pollution Control Board has taken several initiatives to make the health care units aware of the Bio-medical waste Management Rules, 2016 and their duties as specified in the Rules. After notification of the Rules, the Board has conducted several meetings and regional level workshops throughout the State as listed below:

Date	Location
27.12.2016	Durgapur
25.01.2017	Chinsurah
31.01.2017	Asansol
09.02.2017	Siliguri
22.02.2017	Malda
01.03.2017	Haldia

The District Magistrates of all districts have been provided financial assistance to organize awareness workshops for health care units in their districts. Some such workshops have already been conducted. The district health authorities are being involved in all workshops and copies of the Rules are also being distributed.

Further, for raising the general awareness about bio-medical waste, several hoardings have been installed by the Board throughout the State with the help of local authorities and awareness messages have been broadcast for one month over three FM channels.

Through such consistent efforts, it is expected that the overall compliance of health care units with respect to the Bio-medical Waste Management Rules, 2016 will improve and the environmental pollution due to improper disposal of bio-medical waste will reduce substantially.

References

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Bio-Medical Waste (Management and Handling) Rules, 2016

Bio-Medical Waste Inventory and Status of Management in west Bengal, 2010, WBPCB and Society for Direct Initiative for Social and Health Action (DISHA)

Chapter 17

E-waste Management

Electrical and electronic appliances or gadgets become e-wastes when they are at the end of their useful lives. E-waste is chemically and physically distinct from other forms of waste like municipal or industrial waste; it contains both valuable and hazardous materials that require special handling and recycling methods to prevent environmental pollution/contamination and detrimental effects on human health.

Composition of e-waste is very diverse and differs in products across different categories. From the users point of view, e-waste may be divided into three categories – large household appliances, IT and telecom and consumer equipment. Refrigerators and washing machines represent large household appliances, personal computers, mobile phones and laptops are IT and telecom equipment whereas televisions represent consumer product. All the three categories of e-wastes contain more than thousand different hazardous and non-hazardous substances. There are 26 common components such as metals, motor/compressor, plastics, batteries, plastics with brominated flame retardants, electric cables and radioactive substances. Iron and steel constitutes about 50 per cent of the e-waste followed by plastics (21%), non-ferrous metals (13%) and other constituents.

The major challanges associated with e-waste management are its ever increasing quantum, and its scientific and environment-friendly disposal. Though a proper recycling policy and methodology can recover the valuable metals from e-waste, industrialized countries are somehow avoiding recycling and they have a tendency of exporting the same to the developing countries where labour cost is less and laws are less stringent. The major requirements and considerations for developing sound e-waste management system are:

- Special logistic requirements for collecting the e-waste from the source of its generation and transporting to the site of disposal and/or treatment, recycling, recovery, reuse.
- E-waste contains many hazardous substances which are extremely dangerous to human health and environment, and therefore disposal requires special treatment to minimize impacts in environment.
- E-waste is a rich source of metals such as gold, silver and copper, which can be recovered and recycled/reused into the production cycle.

Environmental and health issues of handling e-waste are adding to the problem especially in the developing countries. E-wastes are broken down not only for recycling but also for recoverable materials like plastic, metals, glasses and noble metals. Mechanical separation is the first step of recycling e-waste. In developing countries, this is generally done manually. Child labourers are often used and no proper safety norms are followed. In this process, residual waste particles, as small as of microscopic size, can be generated and can enter into the surrounding soil, water and air. Compaction to decrease the volume of waste leads to breakdown of e-waste and hence becomes more vulnerable to pollute the environment. Even a small amount of e-waste entering the residual waste introduces relatively high amount of heavy metals and halogenated substances. Such harmful substances leach into the surrounding soil, water and air during waste treatment or when they are dumped into landfills. Sooner or later, they would adversely affect human health and ecology. Such recycling activities sometimes lead to deterioration of local drinking water. It was found that a river near a Chinese 'recycling village' had lead-levels that were 2400 times higher than that specified in WHO guidelines.

People handling e-wastes are directly affected through respiration, through skin contact and through the mucous membrane of mouth and digestive system. People of developing countries are the worst-affected since people engaged in recycling and processing e-waste are mostly in the unorganized sector and are unaware of the associated health effects.

In most cases these problems arise out of improper handling, recycling and disposal methods. The hazardous or toxic components of e-wastes with their occurrences and adverse effects are given in Table 17.1 and 17.2.

TABLE 17.1 Pollutants and their occurrence in waste electrical and electronic equipment

Pollutant		Occurrence
Arsenic	:	Semiconductors, diodes, microwaves, LEDs (Light-emitting diodes), solar cells
Barium	:	Electron tubes, filler for plastic and rubber, lubricant additives
Brominated Flame-proofing agent	:	Casing, circuit boards (plastic), cables and PVC cables
Cadmium	:	Batteries, pigments, solder, alloys, circuit boards, computer batteries, monitor cathode ray tubes (CRTs)
Chrome	:	Dyes/pigments, switches, solar
Cobalt	:	Insulators
Copper	:	Conducted in cables, copper ribbons, coils, circuitry, pigments
Lead	:	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC (polyvinyl chloride) stabilizers, lasers, LEDs, thermoelectric elements, circuit boards
Liquid crystal	:	Displays
Lithium	:	Mobile telephones, photographic equipment, video equipment (batteries)
Mercury	:	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs
Nickel	:	Alloys, batteries, relays, semiconductors, pigments
PCBs	:	Transformers, capacitors, softening agents for paint, glue, plastic
Selenium	:	Photoelectric cells, pigments, photocopiers, fax machines
Silver	:	Capacitors, switches (contacts), batteries, resistors
Zinc	:	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances

Source: E-waste in India, Research Unit (LARRDIS) Rajyasabha Secretariat, New Delhi 2011

TABLE 17.2 Metal constituents in e-waste and their hazards

Pollutant	Occurrence
Lead	: A neurotoxin that affects the kidneys and the reproductive system. High qualities can be fatal. It affects mental development in children. Mechanical breaking of CRTs (cathode ray tubes) and removing solder from microchips release lead as powder and fumes.
Plastics	: Found in circuit boards, cabinets and cables, they contains carcinogens, BFRs or brominated flame retardants give out carcinogenic brominated dioxins and furans. Dioxins can harm reproductive and immune systems. Burning PVC, a component of plastics, also produces dioxins. BFR can leach into landfills. Even the dust on computer cabinets contains BFR.
Chromium	: Used to protect metal housings and plates in a computer from corrosion. Inhaling hexavalent chromium or chromium 6 can damage liver and kidneys and cause bronchial maladies including asthmatic bronchitis and lung cancer.
Mercury	: Affects the central nervous system, kidneys and immune system. It impairs foetus growth and harms infants through mother's milk. It is released while breaking and burning of circuit boards and switches. Mercury in water bodies can form methylated mercury through microbial activity. Methylated mercury is toxic and can enter the human chain through aquatic.
Beryllium	: Found in switch boards and printed circuit boards. It is carcinogenic and causes lung diseases.
Cadmium	: A carcinogen. Long-term exposure causes Itai-itai disease, which causes severe pain in the joints and spine. It affects the kidneys and softens bones. Cadmium is released into the environmenet as powder while crushing and milling of plastics, CRTs and circuit boards. Cadmium may be released with dust, entering surface water and groundwater.
Acid	: Sulphuric and hydrochloric acids are used to separate metals from circuit boards. Fumes contain chlorine and sulphur dioxide, which cause respiratory problems. They are corrosive to the eye and skin.

Source: E-waste in India, Research Unit (LARRDIS) Rajyasabha Secretariat, New Delhi 2011

Brett H. Robinson in 2009, reviewed the environmental contamination associated with the recycling of e-waste. The 'chemical cocktail' leached from e-waste is toxic to living beings. Incineration of e-waste increases the mobility and bioavailability of toxic heavy metals that is normally immobilized in the plastic matrix.

The aim of the present chapter is to make the reader aware about the present status of e-waste and to compile the available data on e-waste, especially in West Bengal, so that its management can be facilitated. The e-waste management status in West Bengal has eventually been corroborated with the same of India as well as with the international scenario.

Pressure and impact

For effective management, it is necessary to quantify and characterize electronic waste stream, to identify the major generators and to assess the risks involved. Difficulty in inventory management is one of the barriers for safe e-waste management. The global production of e-waste is a strong function of growth in economy and development of new technologies. In 2006, the world's production of e-waste was estimated as 20-50 million tonnes per year representing 1-3 per cent of the global municipal waste production of 1,636 million tonnes per year. In rich countries, e-waste may constitute up to 8 per cent by volume of municipal waste.

Total e-waste generated in India in the year 2010 was estimated to be more than 15 million tonnes. According to a study of IRGSSA in 2005, the state-wise break-up of generation of e-waste was available and in that study, the contribution of West Bengal was indicated as 10,059.4 tonnes per year. With the growth of information and communication technology in and around Kolkata in recent years, generation of e-waste has also increased by many orders of magnitude. Through a study conducted by the Indian Chamber of Commerce (ICC), it was estimated that e-waste generation in the Kolkata Metropolitan area was 25,999

Workers dismantling e-waste
Source: WBPCB

metric tonnes in 2010. Only seven types of equipment had been considered in the survey - desktop computers, laptops, printers, televisions, DVDs and mobile phones.

E-waste management

International conventions

As the cost of waste disposal sky-rocketed in the developed countries, toxic traders searching for cheaper solutions started shipping hazardous wastes to developing countries. Once on the shore, these wastes were dumped indiscriminately, spilled accidentally or managed improperly causing severe health problems to humankind and pollution to land, water and air. This cross border transport of hazardous wastes came into public attention during 1980s. To combat this malpractice, Basel Convention was negotiated under the auspices of United Nations Environment Programme (UNEP) in late 80s. It was adopted in 1989 and entered into force in 1992. Annexure I, VIII and IX of the convention list those wastes that are classified as 'hazardous' whereas Annexure II identifies wastes requiring special consideration.

As mentioned earlier, Basel Convention defined e-waste in its Annexure-VIII and heavy metals including mercury were considered as the hazardous materials discharged from e-waste.

The Basel Convention on the control of trans-boundary movements of hazardous wastes and their disposal is the most comprehensive global environmental treaty on wastes. It has 170 member countries (parties) and aims to protect human health and environment against the adverse effects resulting from the generation, management, trans-boundary movements and disposal of hazardous wastes.

Basel Ban (1995) called for prohibiting exports of hazardous wastes for any purpose from countries listed in the newly proposed Annexure VII to the convention. The ban amendment has not yet entered into force as it has to be ratified by 3/4th of the parties who accepted it. As of now, it is only moral binding. USA has ratified neither the original convention, nor the Basel Ban amendment.

In course of time after formation of Basel Convention, it was perceived by some of the members that the interests of less privileged nations of Africa and Asia are not protected by Basel Convention. Consequently, two more conventions came into force. One is Bamako Convention (1991) and the other is Rotterdam Convention (1998). In Bamako Convention, ban of the import into Africa and the control of trans-boundary movement of hazardous wastes were adopted by 12 nations of the organization of African Unity. It was more stringent compared to the Basel Ban and came into force in 1999. Rotterdam Convention (1998, came into force in 2004) was basically on the Prior Informed Consent (PIC) for certain chemicals and pesticides. 73 signatories and 117 parties were there. It is a multilateral treaty to promote shared responsibilities between exporting and importing countries in protecting human health and environment from the harmful effects of the hazardous chemicals. A key goal is to provide

technical assistance to developing countries for implementing the provisions of the convention. The Rotterdam Convention highlights transparency and environmentally sound management of chemicals. Among 40 chemical substances covered under the convention, mercury compounds, PBB (Polybrominated biphenyls) and PCB (Polychlorinated biphenyls) are found in e-wastes.

Though all these conventions are generally about hazardous wastes or chemicals, it eventually includes e-wastes and the movement of e-wastes are governed by these conventions as and when applicable.

Laws and regulations in India

The e-waste (Management & Handling) Rules, 2011 were notified in May 2011 and became effective from May 1, 2012. These rules were notified with primary objective to channelize the e-waste generated in the country for environmentally sound recycling which is largely controlled by the un-organized sector who are adopting crude practices that results in higher pollution and less recovery, thereby causing wastages of precious resources and damage to environment.

The e-waste rules placed main responsibility of e-waste management on the producers of the electrical and electronic equipment by introducing the concept of "Extended Producer Responsibility" (EPR). These rules applied to every producer, consumer or bulk consumer, collection centre, dismantler and recycler of e-waste involved in the manufacture, sale, purchase and processing of electrical and electronic equipment or components as specified in schedule–I. The regulatory agencies involved are SPCBs/PCCs and CPCB. The rules also called for the reduction in the use of hazardous substances in electrical and electronic equipment. Every producer of equipment listed in schedule-I of the rule was made responsible for ensuring that the products covered do not contain lead, mercury, cadmium, hexavalent chromium, poly-brominated biphenyls or poly-brominated di-phenyl ethers above a specified threshold.

In India, Department of Electronics and Information Technology, Govt. of India provides support for the e-waste (Management and Handling) Rules 2011, including restrictions of handling hazardous materials which is dealt by the Ministry of Environment, Forests and Climate Change (MoEF&CC), Govt. of India.

Very recently E-waste Management Rules 2016 have come into force. As per this amendment, most of the responsibilities of managing e-waste are on the producers. The responsibility of the State Government includes providing plan of implementation of environmentally sound management of e-waste through proper co-ordination with the departments of labour, industry and MoEF&CC.

Guidelines and current practices for treatment and disposal of e-waste

According to the guidelines of the MoEF&CC, the environmentally sound technologies for e-waste treatment involve complex treatment rationale driven basically by the material flow. The guidelines for treatment are divided into several steps.

Assessment of hazard potential of e-waste

- Identify the e-waste category;
- Identify the e-waste composition or determine it;
- Identify whether a particular component or the entire e-waste is hazardous;

Recycling, reuse and recovery

- Dismantling;
- Segregation of ferrous, non-ferrous metals and plastic;
- Refurbishment and reuse;
- Recycling/recovery of valuable materials;
- Treatment and disposal of dangerous materials and waste;

Treatment and disposal options

- Land filling;
- Incineration;

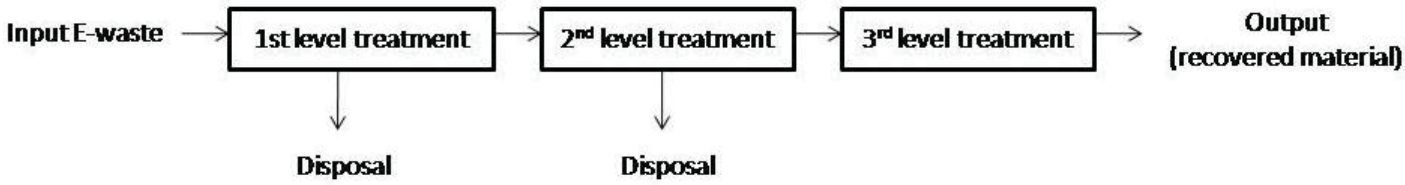

FIGURE 17.1 **Flow diagram for e-waste treatment**

Environmentally sound treatment technologies can be divided into different levels as follows (Figure 16.1):

1st level treatment

Inputs are e-wastes like TV, refrigerator, PC etc. There are three unit operations at first level of e-waste treatment: (a) Decontamination: removal of gases/liquids; (b) Dismantling – manual/mechanized breaking; and (c) Segregation. All these processes are dry and output from this level are (a) segregated hazardous wastes like CFC, Hg-switches, batteries and capacitors; (b) decontaminated e-wastes consisting of segregated non-hazardous e-wastes like plastic, CRT, PCB and cables.

2nd level treatment

In the second level treatment, inputs are decontaminated e-wastes consisting of segregated non-hazardous e-wastes like plastic, CRT etc. Three major unit-operations are involved in the second level – hammering, shredding and special treatment processes comprising of (a) CRT treatment consisting of separation of funnels and screen glass; (b) electromagnetic separation; (c) eddy current separation (d) density separation using water.

e-waste
Source: WBPCB

3rd level treatment

The third level treatment is carried out to recover the ferrous and non-ferrous metals, plastic and other items of economical value. Recycling of plastics may be by chemical, mechanical or thermal processes. Thermosets are shredded and reused because they cannot be remelted but thermoplastics can be remelted and formed into new products.

In chemical recycling process waste plastics are used as raw materials for petrochemical process or as reductant in a metal smelter. In mechanical recycling process, shredding and identification process is used to make new plastic product. In thermal recycling process, plastics are used as alternative fuel.

For metal recovery, lead is recovered from e-waste by reduction in blast furnace/reverbaratory furnace. Copper is also recovered by reduction with iron in blast furnaces. For recovery of precious metals, anode-slime from copper electrolytic process is used.

For non-CRT e-waste, the e-waste treatment facility in India uses the following technologies: (a) Dismantling; (b) Hammering/pulverization; (c) Shredding; (d) Density separation by water. The CRT treatment technologies used in India has following steps: (a) Neck-glass cut; (b) Acid (HNO_3) cleaning of tube; (c) Separation of

funnel and panel; (d) Acid cleaning of funnel and panel; (e)Recovery of funnel and panel glass.

Nevertheless all of the above processes have associated environmental issues.

State initiatives

Among the 25,999 MT e-waste generated in Kolkata Municipal area in 2010, 9,290 MT was available for recycling while only 2,022 MT was actually recycled. The total waste quantum for the study area was predicted to grow to 144,823 MT in 2019-20.

As per the list of Registered Recyclers with WBPCB (2016) there are two e-waste dismantlers in West Bengal - M/s. J. S. Pigments Pvt. Ltd. in Hugli and M/s. Lubrina Recycling in South 24 Paraganas. Bulk of the e-wastes generated in the State are sent to other states for recycling.

As an initiative for promoting e-waste recycling, a NGO has placed bins for collection of e-waste in important locations and renowned institutions for maximum visibility and to inspire people to dispose e-wastes in a responsible manner. The locations of the bins are at Paribesh Bhavan, Indian Museum, National Library, Birla Industrial and Technological Museum, University of Calcutta (College Street, Ballygunge and Rajabazar Science College campuses), Victoria House of CESC Ltd., Indian Institute of Social Welfare and Business Management, Samriddhi Bhavan, Tata Centre, Science City and ITC-Sonar Hotel.

Conclusion

Electronic waste or e-waste poses serious environmental and health hazards. Its constituents include plastics, ferrous, non ferrous and precious metals. For environmentally sound management of e-wastes, directives for Central and State Pollution Control Boards are applicable along with national and international laws. Currently most of the recycling in the country is done in the small scale sector with limited resources and technical expertise. This capacity of the recycling industry is required to be enhanced. Although the rules are based on the Principle of Extended Producer Responsibility (EPR), the activity of the producers is not at all visible. The Government is required to ensure that the producers establish a sound system of take back/ buy back of their end-of-life products and their channelization to organized e-waste recycling units. Also more public awareness should be created so that the public can hand over their e-wastes to the producers or their authorised agencies/ dealers instead of selling to local vendors.

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Chapter 18

Environment and Public Health

Civilization empowered man to exploit nature spelling degradation and pollution of environment and that's what we have been used to call development; the by-products of development has cast a shadow on the future of quality of air, soil and water of the world. An imminent future looms large on us when air fails to sustain breathing, food grown on soil becomes heavily contaminated with chemical poisons and water no longer remains the essence of life. The abnormal condition spells an onslaught on bio-systems, forcing its departure towards pathological condition of various diseases. Along with other parts of the world, India and our State and cities are also fast sliding into these ominous environmental conditions, with an effect on the health of their population.

The historic link between human health and environment manifest in the evolution of Public Health concerns. Public health is distinct from individual health; Public health is for communities, countries, regions and even continents. Epidemic, endemic and pandemic situations may prevail under specific circumstances. Epidemiological surveys and studies are necessary and helpful in understanding and addressing the situations.

Today, concerns for public health are integrated with concerns for sustenance, co-inhabiting with all living things - flora and fauna - in an ecosystem endowed with specific physical, chemical and biological attributes. That way, public health is strongly related with ecosystem health. But under the prevailing circumstances in India and within the country's legislative framework, we can, at best, address partly the status of some of the public health concerns *vis-a-vis* the environmental conditions in terms of the parameters and levels of pollution of air, water and soil. And thus, pollution connections are to be outlined here within an overview of environment and public health.

Public health is obviously linked with food and beverages - natural and processed - often with contaminants and adulterants in them and their levels, with clothing and dwelling habits in a given physical environment, with social and cultural habits and practices. But they are beyond the scope of the present discussion.

Contamination and pollution of air, water and to some extent, soil as monitored in terms of air pollution, water pollution, solid wastes, hazardous wastes etc. and the measures

undertaken to control them may be discussed for any assessment of status of environment impacting on public health.

Mass infections and infestations of hosts (humans, animals and plants) with agents (primarily microorganisms, but occasionally toxic or hazardous pollutants/contaminants) may precipitate in epidemic, endemic or pandemic pathological conditions. Keeping in view the vastness of the topic we may concentrate only on major diseases/pathological conditions strongly linked to environment.

Air and sound pollution and health

Air, especially in cities and towns, are polluted with toxic fumes and suspended particles of varying degree. Air pollutants adversely affect human health especially respiratory system of the city dwellers. WHO estimates that some 80 per cent of outdoor air pollution-related premature deaths are due to ischaemic heart disease and strokes, while 14 per cent of deaths are due to chronic obstructive pulmonary disease or acute lower respiratory infections; and 6 per cent of deaths are due to lung cancer.[1] A retrospective data analysis regarding rising incidence of asthma in children in Bangalore conducted by Dr. Paramesh showed that the prevalence was 26.7 per cent in 2004, a big leap from 9 per cent in 1979. Further analysis of data revealed that 19.34 per cent children from schools of heavy traffic area are affected as opposed to 11.5 per cent of low traffic area, indicating that air pollution drives our children towards chronic respiratory illness[2]. Menace of air pollution is also evident in rising trend of acute respiratory infection (ARI) by the report in India's National Health Profile, 2015[3], which states that there were nearly 3.5 million case reports of ARI in 2014, an increment of 140,000 from 2013 and 30 per cent jump since 2010.

In a study[4] conducted by CPCB, reduction of lung function in 43.5 per cent school children of Delhi was assessed, compared with 25.7 per cent in control group.

Chitta Ranjan Cancer Research Institute's (Kolkata) researchers have studied[5] the health impacts of air pollution on city dwellers and children and observed chronic exposure to urban pollution affects lung function, increases the risk of CVD and lung cancer, alters immunity, increased damage of DNA and chromosomes and increases the prevalence of depression and neuro-behavioural symptoms; the changes were positively associated with PM2.5 and PM10 in ambient air.

In a survey[6] of public health due to air pollution levels in the city targeting the group that included traffic police, garage mechanics, public transport-drivers, salesmen, hawkers and shopkeepers, higher respiratory disorders, cardio-vascular diseases and lung impairments.

The impact of sound of higher intensities (decibels) on human hearing is scientifically established. Quite some time back (in 1980s) extensive surveys were undertaken by WBPCB in Kolkata city and its suburbs particularly during the festive seasons.

In West Bengal, the decibel limit of firecrackers is 90 dBA against the National limit of 120 dBA. The matter was dealt with by the Hon'ble NGT (Eastern Region) and WBPCB argued strongly in favour of maintaining the lower limit in the State which received the approval of Hon'ble NGT (Eastern Region).

Water pollution and health

Water pollution related diseases and ailments having high impact in the State are

- Water borne infectious diseases
- Arsenic contamination of drinking water
- Fluoride contamination of drinking water

- Mercury (and other heavy metals like lead, chromium, cadmium, zinc, silver, copper etc.) poisoning of water
- Insecticides (and agrichemicals) in water.

Water borne infectious diseases

Water borne infectious diseases are due to faecal contamination of drinking water either at source or during transit. A glaring example in recent times, of diseases of epidemic scale is cholera epidemic in Haiti starting in October, 2010, continued up to 2015, taking a toll of about 9,000 people[7] and causing illness to 6 per cent Haitians[8]. Source of infection traced to faecal contamination of Artibonite River and its tributaries by human activities and destruction of outhouses of peacekeeping force by earthquake heading waste to flow in surface water channels.

West Bengal, part of the geographical region of the Ganges-Brahmaputra delta, the traditional home of cholera, witness time and again outbreak of cholera due to faecal contamination of piped drinking water and rural water bodies[9,10]. Apart from *V. cholerae*, the causative organism of cholera of epidemic scale, small outbreak and sporadic cases of diarrhoeal diseases and viral hepatitis are caused by many other bacteria, viruses and protozoa like *cryptosporidium*. The last named one, a coccidian parasite, usually excreted by cattle, contaminates the source of water. *Cryptosporidium* is resistant to all sorts of water treatment procedures, currently available and it is heat resistant.

Day-to-day management of much of water borne infectious diseases are vested in the local area authorities (Municipal Corporations, Municipalities and Panchayats) as per Sanitation Protocols but they do not adequately address ever-changing situation arising out of resistant strains of pathogenic organisms and vectors and are in need of augmentations from newer researches.

National Vector Borne Disease Control Programme (NVBDCP) is the central nodal agency for the prevention and control of vector borne diseases *i.e.* Malaria, Dengue, Lymphatic Filariasis, Kala-azar, Japanese Encephalitis and Chikungunya in India. It is one of the technical departments of Directorate General of Health Services, Government of India. State-wise information is available in the NVBDCP website.

Arsenic in drinking water

Chronic arsenic poisoning has emerged as a major health problem in West Bengal, Bihar, eastern Uttar Pradesh and Bangladesh[11]. Rampant lifting of underground water by shallow tube wells for agriculture and domestic purpose led to relative vacuum, which draws air from atmosphere, causing oxidation of natural arsenic in ground layers. Arsenic oxide being soluble, finds its way to ground water above the impervious layer. Consumption of this water for a long time, leads to chronic arsenic poisoning manifested clinically by pathological abnormalities referred to skin, lung, haemopoietic tissues, liver and enhanced rate of malignancy[12].

Half a century earlier, agrarian activities in Bengal was rain dependant or to a minor extent, surface water irrigated method. To make the success of green revolution, increasing lifting of ground water led to increased aeration of underground aquifer. Oxygen available in this may cause decomposition of arsenic rich pyrite (FeS_2) generating ferrous ions, which act as catalyst for further decomposition of pyrite and generation of arsenic oxide, a soluble compound.

Fluoride in drinking water

It has also been a matter of serious concern in many parts of India and also in the western districts of West Bengal. Regular monitoring of fluoride levels in drinking water extracted from underground is now practiced and information is available in the websites. The status of arsenic and fluoride

in drinking water drawn from underground aquifers in West Bengal and their management strategies has been already discussed in this report.

Mercury and other heavy metal poisoning

Poisonous substances generated by human activities may find their way into environment. This might lead to percolation of the substances to flora and fauna present there. Consequent health hazards may have disastrous impact. 'Minamata Disease' is an example of this kind of chemical poisoning. The marine products in Minamata Bay displayed high levels of mercury contamination (5.61 to 35.7 ppm). Consumption of these marine product caused poisoning of mercury amongst the population there with symptoms referred to central nervous system. Investigations revealed the source as mercury rich discharge from a chemical plant. High mercury content of sea water led to high mercury in cells of sea plants and consequently to marine fishes, consumed by people of the affected island[13].

In India and in West Bengal, there have been occasional incidences of mercury contamination of vital water sources close to specific industrial activities. But with the gradual discontinuation of mercury cells used in chlorine-alkali industries the menace has been largely contained. Still there are possibilities of such contamination not only of mercury but other heavy metals also, like lead, chromium, cadmium, zinc, silver, copper etc. from specific industrial and mining effluents, thermal power stations, household and industrial paints etc. They need attention but the provisions are poor at present.

Insecticides and other agrichemicals in water

Insecticide poisoning is enlarging into a major health problem due to its increasing use in agriculture. The worldwide deaths and chronic diseases are about 1 million/year[14]. Some years back, a news report from Andhra Pradesh[15] described use of soft drink by cotton cultivator as insecticide to raise the crop. This was less costly but stated to be more effective than use of chemical insecticide. The reason was traced to the presence of DDT in high quantity in ground water used for making that soft drink. In another study in Bangladesh, the concentration of DDT was found far above the cut off level in sea fishes in Coxbazar[16]. In fact, the DDT reached a very high concentration in agricultural products to cause health hazard, so its production is now restricted by Government policy.

Widely used organophosphorous compounds as insecticides *e.g.* Diazinon, Dimethoate, Parathion are associated with acute and chronic neuropathy, reproductive disorders due to blocking of progesterone receptors and generation of free radicals in high amount in liver and kidneys[17]. Animal experiment showed organophosphorous causes polyneuropathy, although there are rare reports of neuropathy in man by commercially available compounds. Still, case control studies reveal that chronic low level of organophosphorous pesticide exposure, can lead to central nervous system disorders like depression, anxiety disorders and cognitive defects, unrelated to psychiatric disorders[18]. According to WHO, it is estimated that there could be as many as 25 million agricultural workers in developing world suffering an episode of poisoning each year[19].

Apart from the insecticides, pesticides and herbicides, newer chemicals are being used in agriculture and construction works. Pollution potential of these increasingly added chemicals are little looked into which may be costly in future.

Hospital waste and infection

Hospital and health care establishments generate wastes demanding special

management procedures. They are referred to as Bio-medical Wastes and covered by the specific set of laid down rules. A separate chapter is provided for its discussion. It is not repeated here except commenting on its infection potential from the hospital environment to the larger community outside.

Data generated by an enterprising investigator[20] shows hospital environment in Kolkata is colonized by pathogenic bacteria, commonly isolated from nosocomial or hospital acquired infections. Thus, environmental samples show growth of *Staphylococcus aureus* (18–48%), *Pseudomonas* spp. (12–20%), *Escherichia coli* (24–42%), *Klebsiella* spp. (30–58%), *Acinetobacter* spp. (5–13%), *Enterobacter* spp. (4-21%), *Proteus* spp. (2–16%). It was further shown that neonatal deaths in teaching hospitals in Kolkata range from 28–39 per cent, reflecting the appalling situation of BMW management. Centre for Disease Control (CDC) recommends surveillance of neonatal septicemia, as a yard stick of hospital infection control efficacy. Hospital Associated Infection (HAI) in neonates has been the major contributor to neonatal septicemia.

Conclusion

This exercise can hardly be made comprehensive as most of the issues are essentially multi-sectoral demanding co-ordinated surveys and surveillances. As far as public health is concerned, the importance of intestinal nematode infection and anaemia in rural and underprivileged population cannot be overlooked, but the matter could not find a place here. The study[21] published about a decade earlier seems still relevant. Where to discuss about the 2008 bird flu (*avian influenza*) outbreak in West Bengal that, in fact, was a local expression of pandemic fall out of bird flu threatening not only India but the entire civilized world?

Much more remains to be identified and assessed. Extensive abuse of antibiotic medicinal preparations going increasingly into our environment remains unattended. Some of the most sensitive human organs/systems like the reproductive organs, the endocrine glands, the neural system etc. are getting regularly exposed to special toxins that are capable of altering their bio-functions in very minute doses. Above all, the national and state policies on public health remain areas of scrutiny and rejuvenation.

All our endeavours are presumably, for a better, cleaner and healthier environment, and that point is perhaps best driven home through an assessment of something akin to Ecosystem Health.

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Chapter 19

Urban Wastewater Management

Like it happened in the west following the industrial revolution in the early nineteenth century, the process of urbanization in India, especially after the independence, reveals a steady increase in the size of its urban population and number of urban centres. The level of urbanization gained speed since 1911 and a rapid rise was observed after 1950s. From a modest base of 25.8 million persons in 1901, the number of urban dwellers rose to 285 million in 2001 (28% of total population of the country). The proportion of population residing in urban areas in India further increased from 28 per cent in 2001 to 31.8 per cent in 2011. The number of towns in India increased from 5,161 in 2001 to 7,935 in 2011.

The projection for future is 850 million urban population in 2051 and in reference to our country, this growth is unregulated. Such unregulated growth of urbanization has led to an alarming deterioration in the quality of life in the urban centres in India. Indian cities suffer from infrastructure deficiencies, poor sanitation, water shortages and polluted natural watercourses. The aggregate impact of the distress is debilitating to manage daily lives and chores in this environment.

Gandhiji once commented, *'For India, Sanitation is more important than Independence'*. The issue is managing the urban wastewater. Urban wastewater is nothing but the spent water from a city or a town. Generally, 80–90 per cent of the water supply is discharged as wastewater or sewage. Due to rapid urbanization, there has been continuous migration of people from rural and semi-urban areas to cities and towns.

Inadequate treatment facilities for sewage have deteriorated the water quality of aquatic resources. Deterioration of the water quality results in health problems for the public at large. The rapidly increasing population and resultant wastewater generation may make all perennial aquatic resources unfit for their desired uses in the years to come, if wastewater generated in urban centres is not treated completely. The municipal wastewater treatment capacity developed till 2004 in India accounts for only about 27 per cent of wastewater generation in major urban centres (Class I and Class II cities).

As the water availability is going to reduce due to increase in population, the wastewater generation in any urban centre is going to be one of the major sources of alternative water supply after treatment for the downstream located urban centre. In view of such situation there is a need to attain 100 per cent wastewater treatment in each city with

more stringent standard. West Bengal ranks second amongst all states in India, after Maharashtra, in terms of discharge quantum of untreated wastewater.

In 2008, the Ministry of Urban Development, Govt of India published an ambitious report on urban sanitation entitled "National Urban Sanitation Policy" which enunciated salient features as below:

- Cities must be open defecation free.
- Must eliminate the manual scavenging system and provide adequate protective equipment for workers safety.
- Municipal sewage and storm water drainage must be properly managed.
- Recycle and reuse of treated sewage for non-potable use to be pursued.
- Solid waste collection and disposal must be done efficiently.
- Services to the poor and systems for sustainable results.
- Improved public health outcomes and environmental standards.

These, though highly desirable, were difficult to achieve within a given time frame, particularly the conventional sewerage with treatment is not only highly resource intensive with significant operation and maintenance cost, its wide spread adoption remains a distant dream. Naturally this had to be supplemented by on-site sanitation practices like septic tanks and various types of latrines e.g., the two pit pour flush latrines. Though many of the municipal towns in West Bengal have received "Nirmal Gram Purashkar" for doing away with dry latrines, there are many make-shift latrines in the slums of the city area.

TABLE 19.1 District-wise levels of urbanization in West Bengal in 2001 and 2011 and their respective growth

State/District	% of urban population to total population (2001)	% of urban population to total population (2011)	Difference/Growth
Darjiling	32.34	38.99	6.65
Jalpaiguri	17.48	27	9.16
Koch Bihar	9.1	10.25	1.15
Uttar Dinajpur	12.06	12.07	0.01
Dakshin Dinajpur	13.1	14.13	1.03
Maldah	7.32	13.8	6.48
Murshidabad	12.49	19.78	7.29
Birbhum	8.57	12.8	4.23
Barddhaman	36.94	39.87	2.93
Nadia	21.27	27.81	6.54
North 24 Parganas	54.3	57.03	2.73
Hugli	33.47	38.62	5.15
Bankura	7.37	8.36	0.99
Puruliya	10.07	12.75	2.68
Haora	50.36	63.3	12.94
Kolkata	100	100	0
South 24 Parganas	15.73	25.61	9.88
Paschim Medinipur	11.9	12.03	0.13
Purba Medinipur	8.29	11.56	3.36
West Bengal	27.97	31.89	3.92

Source : Census of India

Sanitary sewage

Sewage is defined as untreated municipal liquid. Generally, 80 per cent of the water supply is considered as wastewater or sewage. Sewage contains about 99.9 per cent of water while the remaining content may be organic or inorganic solid. Sewage denotes both black water and grey water at the house hold level, where black water refers to waste water generated in toilets and grey water refers to waste water generated in kitchen, bathroom and laundry.

Sewerage and sewage treatment

Sewage treatment technology

Sewage treatment technology may be generally classified as primary, secondary and tertiary. The general yardstick of evaluating the performance of sewage treatment plants is the degree of reduction of Biochemical Oxygen Demand, Suspended Solids and Coliforms bacterial load. The efficiency of a treatment plant depends not only on proper design and construction but also on good operation and maintenance. For treatment of domestic wastewater, normally secondary treatment followed by disinfection is done. Tertiary treatment is adopted when reuse of effluent for industrial purposes is contemplated.

Cost is the prime consideration in the selection of the treatment method. It includes capital cost, operation and maintenance costs, reinvestment cost, energy cost and land requirement.

Choice of treatment processes

Conventional systems

a) High Rate Trickling Filters
b) Activated Sludge Plants
c) Extended Aeration System
d) Waste Stabilization Pods
e) Aerated Lagoons
f) Oxidation Ditch

Recent developments

(a) Moving Bed Bio Film Reactor (MBBR)
(b) Sequencing Batch Reactor (SBR) / Cyclic Activated Sludge Process (C–Tech)
(c) Fluidized Aerobic Bed (FAB)
(d) Up-Flow Anaerobic Sludge Blanket Process (UASB)
(e) Membrane Bio Reactor (MBR)
(f) Constructed Wetlands (CW)
(g) In-situ Treatment using Bioremediation & Phytoremediation Techniques

Trends and technologies of sewerage and sewage treatment - Centralized vis-à-vis Decentralized sewage treatment system

While the conventional sewerage may be a comprehensive system for sewage collection and transport, it also remains as highly resource – intensive technology. Consequently, high capital cost and significant operation and maintenance cost of this system inhibits its widespread adoption in all sizes of urban areas.

The implementation of Centralized Wastewater Management System (CWMS) should not be considered as the only option available for collection, transportation and treatment of sewage. There are certain factors which govern the selection of options between CWMS and Decentralized Wastewater Management System (DWMS).

DWMS may be designed as the collection, treatment and disposal/reuse of sewage from individual houses, cluster of houses, isolated communities, industries or institutional facilities as well as from portion of existing communities at or near the point of generation of sewage. Decentralized systems maintain both the solids and liquid fraction, although the liquid portion and any residual solids can be transported to a centralized point for further treatment and reuse.

It has been emphasized that if the sewage from the urban and semi urban areas were reused for a variety of non-potable uses, the demand on the potable water supply could be reduced.

The choice of appropriate technology will also depend on several factors such as composition of sewage, availability of land, availability of funds and expertise. Different operation and maintenance options will have to be considered with respect to sustainable plant operation, the use of local resources, knowledge and manpower.

Existing sewerage and sewage treatment facilities

Before independence, sewerage systems were in operation in part of Kolkata, Titagarh, Bhatpara and Serampore. There after sewerage and sewage treatment facilities were introduced in Kalyani town in late 1950's. In late 1960's, under Salt Lake Township Project, sewerage and sewage treatment facilities were introduced in Bidhannagar town. In early 1970's, underground sewerage schemes were executed in part of Chandannagar, Bhatpara, Serampore and Haora. Sewerage and sewage treatment facilities are also in operation in New Town–Rajarhat township.

To save the river Ganga, an Action Plan called Ganga Action Plan (GAP) was taken up by Ministry of Environment and Forests, Govt of India in June 1985. This was the first river cleaning programme in India. Major sewerage and sewage treatment works were executed under Ganga Action Plan in West Bengal. The components under GAP (Phase-I and Phase-II) were as follows:

(i) Interception and diversion works to capture the raw sewage flowing into the river through open drains and divert them to sewage treatment plants for treatment.
(ii) Sewage treatment plants for treating the diverted sewage.
(iii) Low cost sanitation works to prevent open defecation on river bank.
(iv). Electric crematoria and improved wood based crematoria to conserve the use of wood and help in ensuring proper cremation of bodies brought to the burning ghats.
(v) River front development works such as improvement of bathing ghats, bank protection, viewer's gallery etc.
(vi) Other minor miscellaneous works like plantation of trees, public awareness programme etc.

Table 19.2 lists open drains/nullahs discharging untreated waste water into river Ganga in West Bengal.

Apart from the Ganga Action Plans, abatement of pollution to river Damodar: was also tried under which scheme, STPs were constructed in Durgapur and Asansol towns To combat the urban wastewater discharge to rivers Mahananda, Jorapani and Fulahar, two STPs of total capacity 52 MLD were constructed in Siliguri Town. In the district of Darjeeling, two STPs, of capacities respectively 12 KLD for Mirik and 25 KLD for Kurseang have been constructed. Moreover, the recently coming up large urban centres are also being tried to cover with appropriate STPs. In this attempt, Bidhannagar town has a STP of capacity 27.24 MLD and for the much talked about New Town–Rajarhat, three STP's of capacity 60 MLD, 32 MLD and 18 MLD respectively for Action Area I and Action Area II are in construction phase. In addition, under 'Namami Gange' programme, comprehensive Sewerage Integration Scheme with 100 per cent house connections are under execution in the towns: (i) Kalyani (ii) Gayeshpur (iii) Halisahar (iv) Bhatpara and (v) Budge Budge.

Existing scenario of off-site and on-site sanitation

Deficiencies observed – Off-site sanitation

Most of the Sewage Treatment Plants in West Bengal are either malfunctioning or not functioning. The reasons can be categorized in the following way:

TABLE 19.2 Open drains/nullahs discharging untreated waste water into river Ganga in West Bengal

Sl. No.	Location of Sampling Point	Flow (MLD)	BOD Load (Kg/Day)	Latitude			Longitude		
				D	M	S	D	M	S
Left (East) Bank									
1	Circular Canal	320.3	7045.5	22	35	37	88	21	6.7
2	Tolly Nala	380.2	26991.3	22	32	57	88	19	31
3	Dhankheti Khal near CESC Intake Point	65.2	15133.8	22	32	60	88	17	25
4	Akhra Food Ghar Adjacent to Hooghly River	83.4	2002.5	22	31	44	88	14	52
5	Khardah Municipal Drain connected to Hooghly River	63	2330.5	22	32	60	88	17	25
6	Debitala Pancha Khal, Ichapore	46	229.8	22	48	13	88	22	70
7	Khal near Nimtala Burning Ghat	20.7	1554.9	22	37	8.9	88	22	5.9
8	Munikhali Khal Adjacent to Arun Mistri Ghat – Chorial	19.4	54.21	22	31	26	88	14	52
9	Kashipur Khal Adjacent to Kamarhati Jute Mill	16.1	6309.8	22	40	31	88	21	55
10	In front of S P Bunglow, Mistri Ghat, Barrackpore	22.7	3628.8	22	46	11	88	20	25
11	Adjacent to Cossipore ferryghat & Gunshell factory	19.8	1269.04	22	35	56	88	21	22
12	Chitpur Ghat, Dilarjung Road	15	960	22	36	28	88	22	7
13	Majher Char Khal & Kalyani combined waste sewage near brick field with foam near sluice gate	16.5	363	22	58	27	88	24	36
14	Drain Opposite to Fort William, Judges Court Ghat	7.65	76	22	33	40	88	20	3
15	Garifa Rly. Stn., Patterson road adjacent to Ram Ghat	7.78	148.2	22	54	29	88	24	33
16	Garifa Rly, Stn. (North side) on Patterson Road (domestic)	9.68	475.3	22	54	33	88	24	32
17	Baranagar Khal Adjacent to Ratan Babu Ghat	10.3	990.7	22	37	48	88	21	33
18	Halisahar, adjacent to Prabhat Sangha play ground	1.07	236.1	22	55	41	88	24	39
19	Bagher Khal, adjacent to Hotel Dreamland	11.1	177	22	57	19	88	25	25
20	Drain between Pratapnagar and Rajbari	4.19	729.5	22	50	38	88	22	42
21	By the side of Alliance Jute Mill, Jagatdal Jetty	4.96	277.7	22	31	30	88	22	29
22	Gandhighat, South Gate – 1, Barrackpore	3.61	36.1	22	45	15	88	21	9.5
23	Balughat, Manirampur Pucca Drain	2.28	125.4	22	46	21	88	20	10
24	Bishalkshmi Ghat, adjacent to CESC Power House, Titagarh	4.01	256.7	22	44	1	88	21	48
25	Thanar Khal, adjacent to Thana & overhead tank of Naihati Municipality	5.29	201	22	53	36	88	24	42
26	Sasan Ghat, Naihati	2.92	32.08	24	27	37	88	4	17
27	Open pucca drain carrying waste for ward no. 9 & 10	1.2	140.4	24	28	8.4	88	4	10
28	Saidabad Kunja Bhata (Opposite to auto centre) ward no. 25	1.26	102.1	24	7	38	88	14	56
29	Shovabazar canal ner Sovabazar Launch ghat	0.42	28.97	22	36	48	88	22	7.3
30	Open pucca drain flowing adjacent to Diamond Club	0.96	2029.4	24	14	37	88	15	16
31	Open Kuccha drain carrying domestic waste for ward 16	0.66	32.3	24	14	34	88	15	25
32	Adjacent to boundary wall of Jangipur College and B D O Office	1.08	49.7	24	27	56	88	4	9.7
33	Shasan (burning) ghat, Bhairabpur, purbapara ward no 16	0.54	18.9	24	6	42	88	14	45
34	Radha Ghat (Old Ichagra Shashan ghat) Bhairabpur, Purbapara	0.48	61.9	24	6	27	88	14	46

TABLE 19.2 Open drains/nullahs discharging untreated waste water into river Ganga in West Bengal

Sl. No.	Location of Sampling Point	Flow (MLD)	BOD Load (Kg/Day)	Latitude			Longitude		
				D	M	S	D	M	S
Right (West) Bank									
1	Bhagirathi Lane, Mahesh, Serampore	41.5	327.625	22	44	37	88	21	21
2	Hastings Ghat Road, sdjacent to Hastings Jute Mill, Rishra, Hooghly	42	3569.18	22	43	27	88	21	20
3	Najerganj khal, North side of Shalimar Paint	326	5216.14	22	33	30	88	16	38
4	Singhi More Khal (Singhi mara Khal), Manikpur, Sankrail	26.1	67.95	22	32	33	88	13	54
5	Chatra Khal, Benia Para, Serampore	28.4	1445.85	22	45	32	88	20	30
6	Bagh Khal, Border of Rishra and Konnagar Municipality on G.T. Road	18.4	1030.575	22	42	51	88	21	20
7	Telkol Ghat	21.9	3028.49	22	34	35	88	20	24
8	Ramkrishna Mullick ghat Road	12.2	1087.4	22	34	23	88	20	13
9	130 Foreshore Road Martin Burn	17.6	2475.39	22	34	17	88	20	6.6
10	Shibpur Burning ghat	13.3	705.96	22	33	38	88	19	37
11	Jagannath Ghat Road, by the side of Bijoylakshmi Rolling Mill	17.3	448.71	22	36	40	88	21	21
12	Combined of Saraswati Khal and Rajgunge Khal, near Sankrail police station, near Pareshnath Hazra Ghat	2.77	16.62	22	33	32	88	13	57
13	Champdani Ferry Ghat, opp Nabal Gurage, Champdani, Poura bhavan Road PIN 712222	4.15	157.59	22	47	57	88	21	0.6
14	South side of Dawnagazi Ghat, Bally Municipality, Bally	1.31	36.59	22	38	34	88	21	30
15	Jagatnath Ghat, ward no 14, Lalababu Saha road, South side of Kathgola Ghat	9.33	133	22	37	42	88	21	32
16	101, Foreshore Road	6.24	167	22	33	44	88	19	37
17	Kuthighat South side of Belur Math	5.76	946	22	37	48	88	21	30
18	N.C. Pal Khal, Shankrail	3.87	266	22	34	1.2	88	14	52
19	Adjacent to Bazar para and Gari ghat (Ward No 18) Kuccha Drain	1.2	150	24	27	40	88	4	5
20	Shalimar Cold Deposit No 1, Naresh Kumar Ward	0.16	158	22	33	20	88	19	16

TABLE 19.3 List of Sewage Treatment Plants constructed under Ganga Action Plan (Phase–I and Phase-II) in West Bengal

Sl.	Name of the Town	Capacity of STP (MLD)
Within Kolkata Metropolitan Area (KMA)		
1	Kalyani	17.0
2	Halisahar	12.5
3	Naihati	18.03
4	Bhatpara	33.0
5	Garulia	7.90
6	North Barrackpore	15.25
7	Barrackpore	1.0
8	Titagarh	23.0
9	Khardah	3.0
10	Panihati	12.0
11	Baranagar – Kamarhati	40.0
12	Cossipore – Chitpore	45.0
Outside Kolkata Metropolitan Area (KMA)		
1	Nabadwip	4.0
2	Berhampore	4.0
3	Murshidabad	1.9

Sl.	Name of the Town	Capacity of STP (MLD)
Within Kolkata Metropolitan Area (KMA)		
13	Garden Reach	47.5
14	South Subarban (East)	30.0
15	Bansberia	8.0
16	Chandannagar	22.7
17	Bhadreswar	8.6
18	Baidyabati	6.0
19	Serampore	18.9
20	Konnagar	22.0
21	North Howrah and Bally	30.0
22	Howrah	45.0
23	Mahestala	4.0
24	Budge Budge	4.25
Outside Kolkata Metropolitan Area (KMA)		
4	Jiaganj - Azimganj	5.4
5	Katwa	2.3
6	Diamond Harbour	0.52

- Design waste water load is not reaching the STPs.
- Most of the intercepting structures are either damaged or non-existing.
- Major repair/renovation/replacement of electrical and mechanical equipment whose average life span is 15 years are not done due to paucity of operation and maintenance fund.
- House connections are not done.
- Most of the O&M agencies are not having proper technical personnel.
- Inadequate O&M fund.
- No revenue earning.
- Local bodies are not having requisite institutional, managerial and financial capabilities.

Programmes for sanitation working in West Bengal

In urban areas the following missions are in operation in sanitation sector:

Namami Gange Mission

In 2014, Government of India has renamed Ganga Action Plan as Namami Gange Mission. This is a centrally sponsored programme. Government of India is giving priority for the following major short term activities within the coming 3 years for rejuvenation of river Ganga. These are all pollution abatement measures.

(i) Rehabilitation and up–gradation of existing STPs along Ganga.
(ii) Ensuring 100 per cent sewerage infrastructure in identified towns along Ganga.
(iii) In situ sewage treatment in open drains.

Repair/renovation/replacement/up–gradation of sewerage and sewage treatment in all the towns along Ganga can be taken up under this programme.

Kolkata Environmental Improvement Investment Programme (KEIIP)

KEIIP is a multiagency endeavour to arrest environmental degradation and improve quality of life in Kolkata. Its work is mainly outer area of the city where the sewerage and drainage infrastructure is grossly inadequate. KEIIP's objectives are to reduce pollution by providing affordable access to basic urban services in slums, revamp and upgrade the sewerage and drainage system. The project had been taken up from April 2002 with the assistance from Asian Development Bank (ADB) and Department for International Development (DFID). The works necessary to overcome the deficiencies in sewerage and drainage within KMC area can be taken up under this programme.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT):

AMRUT is a centrally sponsored programme. The objectives of AMRUT are given below:

- Ensures basic infrastructure and sanitation;
- Focus on water supply and sewage;
- Promoting public transport;
- Improving urban governance through reform;
- Enabling walking, cycling, greenery and open spaces;
- Capacity building;

The cities/towns included under AMRUT Mission are mentioned in Table 19.4

Major repair/renovation/replacement works necessary for rehabilitation of the existing sewerage system of any of the above mentioned AMRUT towns can be taken up under this programme.

Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)

UIDSSMT is also a centrally sponsored programme which aims at improvement in urban infrastructure in small and medium towns. The main components of the scheme are as follows:

- Water supply (including desalination plants) and sanitation.
- Sewerage and solid waste management.

TABLE 19.4 Cities/towns included under AMRUT Mission

Sl No	Name of City / Town	Sl No	Name of City / Town
1	Kolkata (M.Corp.)	31	Chandannagar (M.Corp.)
2	Howrah (M.Corp.)	32	Uttarpara-Kotrung (M)
3	Durgapur (M.Corp.)	33	Krishnanagar (M)
4	Asansole (M.Corp.)	34	Barrackpore (M)
5	Siligiri (M.Corp.)	35	Shantipur (M)
6	Mahestala (M)	36	Balurghat (M)
7	Rajpur-Sonarpur (M)	37	Habra (M)
8	South Dum Dum (M)	38	Jamuria (M)
9	Rajarhat-Gopalpur (M)	39	Bankura (M)
10	Bhatpara (M)	40	North Barrackpore (M)
11	Panihati (M)	41	Ranigunj (M)
12	Kamarhati (M)	42	Nabadwip (M)
13	Bardhaman (M)	43	Basirhat (M)
14	Kulti (M)	44	Halisahar (M)
15	Bally (M)	45	Rishra (M)
16	Barasat (M)	46	Asokenagar Kalyangar (M)
17	North Dum Dum (M)	47	Baidyabati (M)
18	Baranagar (M)	48	Purulia (M)
19	Uluberia (M)	49	Kanchrapara (M)
20	Naihati (M)	50	Darjeeling (M)
21	Bidhan Nagar (M)	51	Titagarh (M)
22	Khragpur (M)	52	Dum Dum (M)
23	English Bazar (M)	53	Chapdani (M)
24	Haldia (M)	54	Bongaon (M)
25	Madhyamgram (M)	55	Khardaha (M)
26	Baharapur (M)	56	Jalpaiguri (M)
27	Raiganj (M)	57	Bansberia (M)
28	Serampore (M)	58	Bhadreswar (M)
29	Hugli-Chinsura (M)	59	Kalyani (M)
30	Medinipur (M)		

- Construction and improvement of drains/storm water drains.
- Construction/up-gradation of roads, high ways/expressways.
- Parking lots/spaces on roads, highways/expressways.
- Parking lots/spaces on public private partnership basis.
- Development of heritage areas.
- Prevention and rehabilitation of soil erosion/landslides in some special areas.
- Sewerage, drainage and sanitation improvement programme of small and medium towns not covered under AMRUT mission can be taken up under this programme.

Deficiencies observed under on-site sanitation

Except the areas served by sewerage and sewage treatment plants, all other areas are being served with mostly septic tanks and/or two pit pour flush latrines or dug well type latrines. Open air defecation has not yet been completely done away with.

In absence of water borne sewerage system, septic tank appears to be the only acceptable and affordable solution for storage and treatment of night soil. This could be designed for two to three years frequency of desludging though there are problems of disposal of both the sludge and the effluent having high BOD and pathogenic bacterial content. The effluent is very often disposed off to soak pit or leach pit. Problems are faced in water logged areas and also during monsoon when leaching efficiency decreases. It is the common practice to discharge high BOD effluent to drains and nullahs which find their way to water courses. It is very difficult for general public to assess the soak percolation rate and as such there is some sort of haziness and confusion about safe distance of source of drinking water from the pit with respect to depth of ground water table. The sludge is taken out, either manually or by gully pit emptier and disposed to trenching ground to dry up, by local authorities. The two pit latrines are also widely used. The effluent is soaked into surrounding soil and the sludge can be taken out after one year or so and safely utilized as manure in kitchen garden and the like. Safe distance of latrine/soak pit from drinking water sources should be two to three metre if ground water table is two metre below the bottom of the pit throughout the year. In case it is less than two metre, a safe distance of ten metre is necessary. For many households, the required land is not available to follow this.

The on-site sanitation is now widely covered under '*Swachh Bharat Mission*' (SBM) launched by Government of India.

The mission objectives are:

- Elimination of open defecation.
- Eradication of manual scavenging.
- Modern and scientific Municipal Solid Waste Management.
- To effect behavioral change regarding healthy sanitation practices.
- Generate awareness about sanitation and its linkage with public health.
- Capacity augmentation for ULB's.
- To create an enabling environment for private sector participation in Capex (Capital Expenditure) and Opex (Operation and Maintenance).

And the mission components are:

- Household toilets, including conversion of insanitary latrines into pour-flush latrine.
- Community toilets.
- Public toilets.
- Solid Waste Management.
- IEC & public awareness.
- Capacity Building and Administrative & Office Expenses (A&OE).

By Public Toilets, it is implied that these are to be provided for the floating population/general public in places such as markets, railway stations, tourist places, near office complexes, or other public areas where there are considerable of people passing by.

By Community Toilets, it is implied that a shared facility provided by and for a group of residents or an entire settlement. Community toilet blocks are used primarily in low – income and/or informal settlements/slums, where space and/or land are constraints in providing a household toilet. These are for a more or less fixed user group.

Mission coverage: All statutory towns are covered under this Mission.

Mission strategy

- City level sanitation plans;
- State sanitation concept;
- State sanitation strategy.

West Bengal Government has given this centrally sponsored programme a new name – '*Mission Nirmal Bangla*'. Nirmal Bangla is an offshoot of 'Swachh Bharat Mission', but conceived in a new avatar in West Bengal. 'Mission Nirmal Bangla' was launched by Government of West Bengal, in concurrence with the Swachh Bharat Mission, on 2nd October, 2014, when all existing sanitation projects were brought under this scheme.

In less than a year's time, West Bengal has reason to boast. On 30th April 2015, Nadia becomes the first Indian district to earn Open Defecation Free (ODF) status. The State can be made open defecation free under this programme.

Lessons learnt from the past

Given the realities of constraints of fund, land and managerial issues, off site sanitation with water borne sewerage system, though highly desirable, seems to be a difficult proposition. Laying of sewer network with house connections in narrow lanes of old cities and towns having high water table remain a serious concern. In absence of any user charges or development fees, local bodies find it very difficult to maintain the created assets and as a result, most of the treatment installations are either in shambles or in need of urgent repairs. The local bodies cannot retain skilled staff to maintain the assets to meet long term goals. The other notable points are:

- Sewerage and sewage treatment does not get priority because of the fact that the collected sewage terminates far away beyond the boundaries of the ULB and is a 'out of sight, out of mind' syndrome.
- Centralized STP's requiring long pumping main requires high energy cost.
- Operation and maintenance plans were not properly drawn up.
- Continuous and vigorous I&C Programme was not practiced.

Actions required

(i) A Master Plan for sanitation works within KMA and outside KMA should be prepared separately.

(ii) A Task Force comprising experienced technical personnel need be constituted immediately to find out the causes of malfunctioning/non–functioning of most of the existing sewerage facilities in West Bengal and also to find out the remedial measures to be undertaken.

(iii) A Broad Based Pragmatic Sanitation Policy need be finalized taking into account feasibility and sustainability concerns.

(iv) "No charge for infrastructure services" cannot be allowed to go on indefinitely. For making the system sustainable, user charges need be introduced.

(v) It is necessary to go for a rational 'Willingness to Pay' and 'Affordability to Pay' survey to feel the mind-set of the people for sustainability of the system. Such survey can provide guidance for a pragmatic pricing policy. In this connection it is to be mentioned that in early 1980's, Kolkata Metropolitan Water and Sanitation Authority (KMW&SA) used to charge Rs. 30/- per month per household for water supply in fringe areas within KMA. The rate of return was quite satisfactory and O&M cost was mostly met up with that fund. People Below Poverty Level (BPL) may be provided free services.

(vi) Decentralized Wastewater Management System (DWMS) may be adopted for collection, treatment and disposal/reuse of sewage from the community.

(vii) In situ treatment of wastewater drains/nullas using Bioremediation and Phytoremediation techniques should be introduced.

(viii) Third party inspection of the completed schemes should be initiated.

(ix) Operation and maintenance plan including yearly allocation of required fund and engagement of proper maintenance agency should be given priority.

(x) For operation and maintenance of Sewage Treatment Plants, Public Private Partnership (PPP) model may be introduced.

(xi) In smaller and medium towns, on site sanitation with septic tank and soak pit followed by chlorination with bleaching powder may be continued.

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Chapter 20

Environmental Regulation

India has had a philosophy of environment management dating back to the ancient Hindu period. Hindu culture had a great tradition of environmental conservation which taught to respect nature and to take cognizance of the fact that all forms of life, human, animal and plants are closely interlinked and that disturbance in one give rises to an imbalance in the other's. Moral injunctions acted as guidelines towards environmental preservation during the ancient period. Such injunctions were initially propagated by the religious scriptures, seers and later enforced by the rulers. Under the Mauriyan regime and Ashoka's rule, forest conservation and wildlife protection received the utmost attention. It was during this period that detailed and perceptive law provisions as contained in Kautalay's Arthashastra were followed and enforced.

Environmental protection concern received a setback in the medieval India as there had been a great deal of ecological loss due to frequent invasions and political instability. During the Mughal period, after returning of political stability, the environmental policy did not took a precise shape and the natural resource management remained by and large a neglected field.

During the British rule, the environmental concern took a new shape with the enactment of forest legislations and other legislations pertaining to pollution control and the first forest policy of 1894 whereby the State controlled forest administration initiated in India. The British period by far had not been a good period in the environmental history of India as it was during this period the natural resources were ruthlessly appropriated and exploited with a primary objective of earning revenue. The polity ignored the environment conservation.

Background of pollution control laws

Law is born out of social, economic and political causes. The first law for protecting nature was implemented in India during the British Rule. The year was 1905 and the whole of Bengal was caught up in the tide of the revolutionary movement following the partition of Bengal.

Amidst the storm, inconspicuous for the moment, was born in Calcutta, the Bengal Smoke Nuisance Act, with the purpose being mainly to preserve the dazzling whiteness of Victoria Memorial.

The British had come to our country to rule, not to serve. Hence in matters regarding the preservation of balance of nature in India, they had borne neither concern nor responsibility. Their thoughts remained limited within the borders of their own profits. Following the end of the British Rule, India plunged into a series of troubles – communal riots, the partition, external wars causing conflicts and disintegration, problems which glaringly and prominently stares us into the face even today. Hence India has not been able to pay proper attention to matters relating to environment. The Five Year Plans were implemented with a view to the economic development of the country. The Second Five Year Plan designed for industrial development paid no attention to the harmful consequences that nature would have to face with the growth of industry. Hence the plans remained unconcerned about protecting nature. This implies a lack of a sense of responsibility about protecting the environment and there was no awareness of the necessity of preserving it until the beginning of the seventies when a law for the protection of the environment was passed.

The United Nations Conference on the Human Environment, held at Stockholm, Sweden, in June 1972, was the first comprehensive international attempt to articulate the interrelationship between the quality of environment, a growing world population, and the world economic growth needed to sustain it. The conference recognized the need for specific national and international actions to ensure that economic growth is planned in full appreciation of the long term value of environmental protection and natural resources conservation.

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Since, 1974, number of Acts were enacted for the protection of environment and also there are other Acts which can be enforced for the protection of environment by the different enforcing authorities i.e. Police Authority, Local Authority, District Administration, Chief Inspector of Factories, Fisheries Department etc. The Department of Environment and the West Bengal Pollution Control Board are now the main enforcing authorities to protect the environment exercising its power under the provisions of Water (Prevention and Control of Pollution) Act, 1974, Air (Prevention and Control of Pollution) Act, 1981 and Environment (Protection) Act, 1986 and Rules made there under.

Constitutional aspect of environmental law

Environment protection has found a special mention in the Indian Constitution. In fact, the environment protection has been given a constitutional status in the Indian policy. The Constitution, being the fundamental law of the land, has a binding force on citizens, non-citizens as well as the State. The Fundamental Rights and the Directive Principles of State Policy underline our national commitment to protect and improve the environment. The Courts in India have also given a new interpretation to the constitutional provisions touching the environmental perspectives. In fact, the interpretation given to Article 21 of the Constitution, which is contained in the chapter on Fundamental Rights, has added new dimensions to the quality of life and the effect of environment relating thereto.

The Constitution of India, as originally enacted, did not contain any specific provision to deal with environmental pollution, though Article 47 made an indirect reference to improvement of public health as one of the primary duties of the states. This, in fact, envisages a pollution free environment for all the people. Some of the constitutional imperatives for control of environmental pollution are detailed below.

Distribution of Legislative powers

The Constitution provides for division of powers between the Union and the States. Part XIII of the Constitution contains provisions governing the legislative and administrative relations between the Union and the States. Within the framework laid down in the Constitution, the Parliament has been given the power to make laws for the entire nation whereas the State Legislatures have been given the powers to legislate for their respective states. Article 246 determines the distribution of powers between the Union and the States. The Parliament and the Legislature of any state have exclusive power to make laws with respect to any of the matters contained in List I (Union List) and List II (State List) in the VIIth Schedule of the Constitution respectively.

In addition to this, the Union and the States also enjoy concurrent powers to make laws on any subject enumerated in List III (Concurrent List) of the schedule. Besides, the Constitution also empowers the Parliament to enact laws in respect of matters contained in List II. Similarly, the Parliament has been vested with the residuary power to enact laws on matters not covered by the three lists. These provisions of the Constitution definitely enlarge not only the legislative ambit of the Parliament but also give a power to take administrative measures which are considered necessary for protecting human environment.

The Directive Principles of State Policy

Part-IV of the Indian Constitution lays down certain fundamental principles of state policy which the future government of the country will have to take into account while framing the laws for the governance of the country. Though the directives incorporated in Part IV of the Constitution are not enforceable in a court of law but the Indian Judiciary has made use of these directives in a number of cases and these have been read as complementary to the Fundamental Rights.

Article 253 and environmental legislation

Article 253 of the Constitution gives power to the Parliament to make laws implementing international obligation of the country as well as any decision taken at an international conference, association or other body. The provision reads, *"Notwithstanding anything in the foregoing provision of this Chapter, Parliament has power to make any law for the whole or any part of the territory of India for implementing any treaty, agreement or convention with any other country or countries or any decision made at any international conference, association or other body."* In view of the broad spectrum which could be addressed at the international convention, conference, treaties and agreements, Article 253 gives teeth to the Parliament to legislate on any of the matters enumerated in the State List.

Fundamental Rights vis-à-vis environment

Part III of the Constitution of India incorporates Fundamental Rights which have been made judicially enforceable. The Supreme Court of India has contributed significantly, especially during the 80's, in broadening the contents and contours of some of these basic rights. Here an attempt is being made to examine this perspective in the context of environmental protection.

The interpretation given by the Supreme Court in Maneka Gandhi's case has added new dimensions to the concept of personal liberty of an individual. It laid down that a law affecting life and liberty of a person has to stand the scrutiny of Articles 14 and 19 of the Constitution. In other words, if a law is enacted by a legislature which touches upon the life and liberty of a person and curtails it, then it is a

mandatory requirement that the procedure established by it for curtailing the liberty of a person must be reasonable, fair and just. It is this interpretation of Article 21, which the Court has extended further so as to include the right to a wholesome environment. In other words, environmental pollution which spoils the atmosphere and thereby affects the life and health of the person has been regarded as amounting to violation of Article 21 of the Constitution.

In this connection it will be worthwhile to refer to the decision of the Apex Court in Dehradun Query's Case. In this case, the Supreme Court entertained complaints from the Rural Litigation and Entitlement Kendra, Dehradun alleging that the operations of lime stone quarries in the Mussoorie-Dehradun region resulted in degradation of the environment affecting the fragile ecosystems in the area. In this case, the Supreme Court moving under Article 32, ordered the closure of some of these queries on the ground that these were upsetting the ecological balance. Though the judgement did not make a reference to Article 21, but involving jurisdiction by the Court under Article 32 presupposed the violation of right to life guaranteed under Article 21.

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In the case of Moulana Mufti Sayed Mohd. Noorur Rehman Barkati vs. State of West Bengal, while dismissing the writ petition, the Supreme Court held that nobody can exercise his right to practice, profess or propagate religion at the cost and in total deprivation of others right. It was held that 'Azan' is certainly an integral and essential part of the Muslim religion but use of micro-phone is certainly not an integral part of 'Azan' and it violates the fundamental right of the citizens under Article 19(1)(a) of the Constitution. The argument of the Environmental (Protection) Act, 1986, the Rules made thereunder and the Schedules thereof are ultra vires under Article 14 and 25, is wholly misconceived as the provisions had not resulted in any discrimination and citizens have a right to be protected against excessive sound under Article 19(1)(a) of the Constitution.

Constitutional remedies

A regulatory mechanism for the prevention of environmental degradation, through writ process is provided for in the Constitution. Under Articles 32 and 226 of the Constitution, the Supreme Court and the High Courts respectively, possess wide latitude to grant relief and prevent environmental damage by issuing directions, orders or writs.

Under Article 32, which itself is a fundamental right, any person whose fundamental right as conferred by Part III of the Constitution has been violated, can invoke the Supreme Court's jurisdiction to enforce his right. Whereas, the writ jurisdiction of the High Court under Article 226 may be invoked not only for the enforcement of a fundamental right but for any other purpose as well. For that matter, the Supreme Court's jurisdiction under Article 32 is more limited than the jurisdiction of the High Courts under Article 226. As now, the Supreme Court has accorded judicial recognition to the right to a wholesome environment as being implicit on Article 21, a litigant may accordingly assert his or her right to a wholesome environment against state, by a writ petition to either the Supreme Court or a High Court.

The Green Tribunal

The concept of environmental courts was initially and positively addressed in two minor judgements of the Supreme Court of India. In M. C. Mehta vs. Union of India, the Supreme Court observed that as

environmental cases frequently involve assessment of scientific data, it was desirable to set up environmental courts on regional basis with a legally qualified judge and two experts, to undertake relevant adjudication. Similarly, in Indian Council for Enviro-Legal Action vs. Union of India, the Supreme Court again floated the idea of establishment of environmental courts having both civil and criminal jurisdiction in order to deal with environmental issues in a speedy manner. Again, in the judgement of A. P. Pollution Control Board vs. Professor M. V. Nayudu, the Court referred to the need for established environmental courts. Such courts would have the benefit of expert advice from technically qualified environmental scientists, as part of the judicial process. It was suggested that the Law Commission of India should examine this matter in detail.

These judgements were a result of concern within the Supreme Court about complexity and uncertainty underpinned due to the scientific evidence presented to the Court. Such evidence generated tensions between fears expressed by claimants and the assurances given by the defendants. Scientists may refine, modify or discard variables or models as more information becomes available. However, agencies and Courts must make choices based on existing scientific knowledge. In addition, evidence generally presented in a scientific form may prove difficult to test or refute. Therefore, inadequacies in the record arising out of uncertainty or insufficient knowledge may not be properly acknowledged or considered.

Following the observations made by the Supreme Court of India and the principles laid down in the international conferences held at Stockholm and Rio de Janeiro, the Law Commission of India undertook an extensive study on the establishment of separate and specialized 'environmental courts'. The Commission is an active and influential participant in legal reform in India and it gave a detailed report on the subject of 'environmental courts'. The Law Commission recommended separate 'environmental courts' staffed exclusively by persons with judicial experience and supported by persons having scientific qualifications and experience in the environmental field. The proposed environmental courts were aimed at accessible, open and speedy justice.

The Commission came to the conclusion that in seeking a balanced decision in such cases, 'environmental courts' with scientific as well as legal inputs might be better placed to reach a proper and judicious determination. Such courts could have wider powers to make on the spot inspections and hear oral evidence from resident panels of environmental scientists.

The Law Commission in its 186th Report, has inter-alia recommended establishment of a separate 'Environment Courts' in each state, consisting of judicial and scientific experts in the field of environment for dealing with environmental disputes besides having appellate jurisdiction in respect of appeals under the various Pollution Control Laws. The Commission has also recommended for repeal of the National Environment Tribunal Act, 1995 and the National Environmental Appellate Authority Act, 1997.

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The National Green Tribunal Bill was introduced in Lok Sabha by the then Minister of Environment and Forests, Mr. Jairam Ramesh, on 31st July, 2009. The Chairman, Rajya Sabha in consultation with the Speaker, Lok Sabha in pursuance of Rule 270(b) of the Rules relating to the Department-related Parliamentary Standing Committees, the National Green Tribunal Bill, 2009 was referred to the Parliamentary Standing Committee on Science and Technology, Environment and Forests for its examination and report.

Based on the critique by members of the Parliament and recommendations of the

Parliamentary Standing Committee, the Central Government made seven amendments to the National Green Tribunal Bill, 2009. The amendments broadened the definition of 'persons aggrieved' to allow individuals to approach the Green Tribunal.

It also outlined the 'foundational principles' like Precautionary Principles, Polluter Pays Principle and Inter-generational Equity that would govern the Tribunal.

In keeping with the recommendation of the Parliamentary Standing Committee, the Act shall come into force in its entirety upon notification though the original Bill had given the Central Government the discretionary right for notifying different dates on which different provisions would come into effect.

The then Environment Minister, Mr. Jairam Ramesh informed that the Tribunal will have four benches across the country. It will follow a circuit approach to enable easy access for people. He also informed that *"Courts will go to the people. People won't have to come to the courts"*. The Parliamentary Standing Committee gave its report being the 203rd Report on the National Green Tribunal Bill, 2009 on 16th November, 2009 which was placed before both the Houses of the Parliament on 24th November, 2009. The Bill was passed by the Lok Sabha on 23rd April, 2010. The National Green Tribunal Act, 2010 received the assent of President of India on 2nd June, 2010, it formally came into existence as the National Green Tribunal Act, 2010.

The National Green Tribunal Act, 2010 came into force on 18th October, 2010

The National Green Tribunal Act, 2010 came into force on 18th October, 2010 on issuance of a notification by the Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India and the enactment of National Green Tribunal Act, 2010 led to repealing of the National Environment Tribunal Act, 1995 and the National Environment Appellate Authority Act, 1997. The MoEF&CC vide notification dated October 18, 2010 has also notified the establishment of National Green Tribunal. The Tribunal's dedicated jurisdiction is only in environmental matters and shall provide speedy environmental justice and help reduce the burden of litigation in the higher courts. Initially, the Tribunal was proposed to be set up at five places of sittings and will follow circuit procedure for making itself more accessible. The Principal Bench is functioning at New Delhi and the four zonal benches are at Bhopal, Pune, Kolkata and Chennai.

Judicial approach for protection of environment

Environmental litigation is of recent origin in India. During short span of time, the Indian judiciary not only has successfully undertaken a complex task of balancing the environmental and development concerns but in the process for its adjudication of cases, evolved new principles of the environmental jurisprudence. A few new trends have been set up by the judiciary which hitherto had not been seen in the legal system. Here an attempt is made to evaluate the role of the Courts with reference to certain specific situations in the context of environment protection.

Rural Litigation and Environment Kendra, Deradun Vs State of UP & Others, AIR 1985 SC 652

Supreme Court of India ordered closure of limestone queries. The question involve in this case was that the working of lime stone queries was polluting environment and disturbing ecological balance for which the people residing in the Moussouri Hills were suffering. This case was first of its kind in India on the issues relating to environment and ecological balance and the question raised for consideration are of grave importance and significance not only for the people residing in that area and also to the

welfare of the generality of the people of the country. Supreme Court reiterated that the task of environmental protection is not only that of the Government but is also every citizen's fundamental duty under Article 51A(g) of the Constitution.

M. C. Mehta Vs Union of India, AIR 1987 SC 965

The writ petition was filed praying for the closure and relocation of certain units of Sriram Foods on the grounds that such hazardous industries cannot be allowed to function in highly polluted areas. While this petition was pending, there were two instances of Oleum gas leakage. Supreme Court for first time laid down the rule of absolute liability in case of environment torts and the power of the Court to grant compensation in the case of Public Interest Litigation (PIL) under Article 32. Supreme Court held that *"Where an enterprise is engaged in a hazardous or inherently dangerous activity and harm results to anyone on account of any incident in the operation of such hazardous or inherently dangerous activity resulting in for example escape of toxic gas, the enterprise is strictly and absolutely liable to compensate all those who are affected by the accident and such liability is not subject to any exceptions which operate vis-à-vis the tortuous principle of strict liability under the rule in Rylands."*

M. C. Mehta Vs Union of India, AIR 1988 SC 1037

The writ petition was directed at the Kanpur Municipality's failure to prevent waste water from polluting the Ganga. The discharge of trade effluents passed through a primary treatment plant has been causing considerable damage to the life of the people who uses Ganga water and also to the aquatic life in the river.

The Supreme Court issued directions to the tanneries to set up effluent treatment plants within a period of six months. Each tannery is to make arrangement for the primary treatment of their effluent (before its discharge into the municipal sewer) and then discharge it into common treatment plant. The Court also directed the Central Government, Pollution Control Board and the District Magistrate to oversee the work.

The Court further observed that the closure of tanneries may bring unemployment, loss of revenue, but life, health and ecology have greater importance to the people. Just like an industry which cannot pay minimum wages to its workers cannot be allowed to exist, a tannery which cannot set up a primary treatment plant cannot be permitted to continue to be in existence.

Indian Council for Enviro-Legal Action Vs Union of India (1996) 3 SCC 212

The writ petition was filed against the Union of India, the Government of Rajasthan and the State Pollution Control Board to compel them to perform their statutory duties. The main issue under consideration was the pollution caused by chemical industries and the impending threat to people living in the vicinity. The Court held that –

(a) The authorities had not performed their duties under the law and therefore the Court had the authority intervene and give appropriate directions.

(b) The principle of 'absolute liability' is a binding principle and the Court can direct the industries to bear the costs of remedial measures under Article 32.

The 'Polluter Pays Principle' as interpreted by this Court means that the absolute liability for harm to the environment extends not only to compensate the victims of pollution but also the cost of restoring the environmental degradation. Remediation of the damaged environment

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is part of the process of 'sustainable development' and as such polluter is liable to pay the cost to the individual sufferers as well as the cost of reversing the damaged ecology.

Vellore Citizens' Welfare Forum Vs Union of India (1996), 5 SCC 647

The instant case is a Public Interest Litigation filed under Article 32 of the Constitution and was directed against the pollution caused by the discharge of untreated effluents by tanneries into agricultural lands, waterways etc. in the state of Tamil Nadu.

The Court held that - Keeping in mind the duty imposed on the State under Articles 21, 47, 48B, 51A(g) the State must adopt the principle of "Sustainable Development" as a balancing concept between industrialization and protecting the environment. *"Sustainable Development as defined in the Brundtland Report means Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs."*

The "Precautionary Principle" and the "Polluter Pays Principle" which are essential features of "sustainable development" are part of the environment law of the country. The principles are a part of customary international law and those rules of international law which are not contrary to municipal law shall be deemed to have been incorporated in the domestic law and shall be followed by the Courts as has been held by this Court in a plethora of cases.

The 'Precautionary Principle' – in the context of the municipal law - means environmental measures by the State Government and the statutory authorities must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious and irreversible damages, lack of scientific certainty should not be used as reason for postponing measures to prevent environmental degradation. The 'onus of proof' is on the actor or the developer/industrialist to show that his action is environmentally benign.

Municipal Council, Ratlam Vs Verdhichand, AIR 1980, SC 1622

The Supreme Court for the first time treated an environmental problem differently from an ordinary tort or public nuisance. The Court rejected the plea of financial difficulties of the Municipality in constructing public latrine and covering drains for redressing environmental pollution. It held budgetary constraints did not absolve a Municipality from performing its statutory obligation to provide sanitation facilities. Further, the Supreme Court interpreted Section 133 of the Criminal Procedure Code to impose a mandatory duty on a Magistrate to remove public nuisance whenever exists.

M. C. Mehta Vs Kamalnath (1997), 1 SCC 388

Facts of the case is that large area of the bank of river Beas, which is a part of protected forest, has been given on a lease purely for commercial purposes to the motel by the State Government. The area, being ecologically fragile and scenic beauty, should not have been permitted to be converted into private ownership and for commercial gains. In this case, Supreme Court ordered that

- The public trust doctrine is a part of the laws of the land.
- The prior approval granted by the Government of India, Ministry of Environment and Forests by letter dated 24.11.1993 and the lease deed dated 11.09.1999 in favour of the motel are quashed. The Himachal Pradesh Government shall take over the area and restore it to its original natural conditions.
- Public Trust Doctrine primarily rests on the principle that certain resources like air, water, sea and the forests have such

a great importance to the people as a whole that it would be wholly unjustified to make them a subject of private ownership. The doctrine enjoins upon the Government to protect the resources for the enjoyment of the general public rather than to permit their use of private ownership or commercial purpose.

M. C. Mehta (Taj Trapezium Matter) Vs Union of India (1997) 2 SCC 353

In this matter a Public Interest Litigation was filed under Article 32 to prevent the environmental pollution, which was causing the degradation of the Taj. The Court held that it is proved that the industries in the Taj Trapezium Zone using coke/coal are the main polluting industries and therefore these industries have to convert to natural gas or must stop functioning and relocate themselves as per the direction of the Court.

People United for Better Living in Calcutta Public Vs State of W.B. AIR 1993 Cal 215

The writ petition was filed for directions regarding the maintenance of the wetlands on the eastern fringe of Kolkata. The Court reiterated the principle of 'sustainable' development and held that

- While it is true that in a developing country there shall have to be developments, but the development shall have to be in closest possible harmony with the environment as otherwise there would be development but no environment. There should be a proper balance between the protection of environment and the development process and administrative actions ought to proceed in accordance therewith and not de hors the same.
- Wetlands being a bounty of nature do have a significant role to play in proper development of society whether economic or environmental. The State must prevent any encroachment on the wetlands and make all efforts to maintain their nature and character. The State was directed to restrain any reclamation of the wetlands and to maintain the nature and character of the wetlands in their present form.

Om Birangana Religious Society Vs State Cal LT 1996 (2) HC 474

This writ petition was filed for directions that the instant case the petitioner filed a writ application under Article 226 for directions that the right of the religious society to use microphones to play religious songs and propagate religion guaranteed under Article 25 cannot be restricted by the police and to direct the District Magistrate to accord necessary permission in this regard in terms of section 34 of the Police Act., 1963 (WB Amendment) which provides for the power of the police to regulate, prohibit, restrict the use of microphones etc. The Court held that

- Within the scope and ambit of the Art. 19(1)(a) of the Constitution is subject to the restriction imposed in Art. 19(2). The freedom of speech and expression guaranteed by Art. 19(1)(a) by necessary implication includes the right not to listen and/or to remain silent. It includes the right to leisure, sleep, right to read and speak with others and even the right to worship in his own way. Therefore the right to propagate one's religion cannot be allowed at the cost of deprivation of the rights of the others in the community guaranteed under Art. 19(1)(a).
- It cannot be said that the right to use loudspeakers is an integral part of the right guaranteed under Art. 25 to practice profess and propagate ones religion.
- Sound is a known source of pollution and by means of sound through loudspeakers other citizen cannot be made 'captive listeners' and made to hear something, which their body cannot bear.
- Police authorities / Administration have no absolute authority to grant permission

for using microphones. They must keep in mind the restriction that must be imposed in order to preserve fundamental rights guaranteed under Art. 9(1)(a).

The Court also gave directions that loudspeakers cannot be allowed to operate between 9 p.m. and 7 a.m. except when used by police, ambulances or fire brigades to carry out their duty. Loudspeakers used for religious communication must keep within the prescribed limits set down by the West Bengal Pollution Control Board.

The Court also gave directions that loudspeakers cannot be allowed to operate between 9 p.m. and 7 a.m. except when used by police, ambulances or fire brigades to carry out their duty

Burrabazar Fireworks Dealers Association Vs The Commissioner of Police, Calcutta, AIR 1998 Cal 121

The writ petition was filed by the Burrabazar Fireworks Dealers Association against the police notification (02-11-1996) pursuant to the order of the Pollution Control Board which prohibits the manufacture and sale or use of fireworks and crackers above 65dB in the ambient atmosphere under section 2(b) of the Environment (Protection) Act, 1986 and Rule 3 of Environment Protection Rules, 1986. The notification was challenged on the grounds that it is violative of Article 19(1)(g) which guarantee the right to freedom of trade and profession. The Court held that

- Art. 19(1)(g) does not guarantee the fundamental right to carry on any trade or business which creates pollution or which takes away the community's safety, health and peace. There is no inherent or fundamental right to manufacture, sell and deal with fireworks which will create sound beyond the permissible limits and which will generate pollution, which would endanger public health and order guaranteed under Art. 19(1)(g) and cannot be made 'captive listeners".
- The restriction on decibel level in the various areas of the city must be determined and notified by the PCB after giving due consideration to all relevant aspects and expert opinion.

W.P. No. 16280 of 1998 – Cutting of Trees

The Court drew attention of the State Government to the U. P. Protection of Trees in Rural and Hilly Areas Act, 1976 and expressed the desirability of having such type of legislation in West Bengal and asked the Government to take early steps accordingly. Ultimately Government of West Bengal got the West Bengal Trees (Protection and Conservation in Non-Forest Areas) Act, 2006 enacted with effect from 12.04.2006.

Badal Ch. Mondal Vs State of West Bengal & Others – W.P. 7255 (W) of 2000

In this matter, Hon'ble Court considered the expert repots. Direction was given that brick kilns which were situated at a distance of a least 1.6 km away in the east and west and 0.8 km away in the north and south of any orchard (because of wind direction) having chimneys at a height of more than 100 ft might be allowed to operate, but, if that were otherwise, they should be directed to establish their brick kilns outside the above mentioned distance or they must be asked to suspend their operation from February to May. Future consent also shall or shall not be given accordingly.

Before the National Green Tribunal, Principal Bench, New Delhi
Civil W.P. No. 3727 of 1985 along with other original applications

In connection with the Ganga pollution matters Hon'ble Tribunal is of the considered view that effective directions need to be passed in this case to prevent and control pollution of river Ganga, resulting from indiscriminate discharge of industrial effluent into the river. Accordingly,

Hon'ble Tribunal constituted three committees - Principal Committee, Implementation Committee and the State Level Committee to ensure proper implementation of the orders of the Tribunal. The Implementation Committee and the State Level Committee shall be responsible for implementation of the orders of this Tribunal. They shall report jointly or severely to the Principal Committee in regard to the various facts of compliance to the orders of this Tribunal and its progress from time to time. The Principal Committee shall be entitled to suggest policy decision and action plans that are required to be taken in the interest of environment. It shall have overall control over the State Level and the Implementation Committees. It shall be responsible for submitting monthly reports lo the Tribunal with complete data that is prepared and collected, during the intervening periods, during which orders are passed by the Tribunal from time to time. The Committees would ensure that proper criteria for identifying seriously water polluting industries is put on the website of the MoEF&CC, GoI, the respective states, CPCB and the concerned State Pollution Control Boards. Determination of this aspect need not be quantity-based but be quality based. This is for the reason that a smaller unit of the above industries/ units operating without consent and without having any ETP, may cause even much greater pollution than a bigger industry, which is operating with ETP and consent or a unit which is a 'no discharge unit' or 'zero discharge unit'.

The Tribunal also directed the Regulatory Authorities to issue guidelines in relation to the 'zero discharge unit'. A 'zero discharge unit' must essentially be a unit which does not discharge any amount of liquid effluents, not even treated effluents. It may be as a result of complete recycling of its effluents or evaporation or because of adoption of any other mechanical process, like incinerator etc.

Conclusion

The proper implementation of law depends on a disciplined administration, active judicial system and social consciousness. Mere enactment of laws does not suffice to serve their purpose. What is needed simultaneously is a mass consciousness regarding the necessity and use of law. Legally the 'Sati' system was abolished long ago. Yet even today widows are burnt alive on cremation pyres in the name of 'Sati ... Administration stands a silent witness. Rejoicing in the resurvival of Sati, its supporter distributes sweets amongst themselves. Similarly, laws passed for the protection of the environment will never be properly implemented until the masses become conscious of the necessity of protecting nature. However the responsibility of creating such a consciousness by national efforts and legal compulsion remains absolutely essential. In the present times quite a few important decisions have been taken by the Indian Judicial system. The highest seat of Judgement in India, the Supreme Court in deciding a case has stated that every man has the basic claim to a healthy, pollution-free environment in which he can live. In our country, correct implementation of laws for the prevention of pollution coupled with a social movement alone can give the next generation a pollution free society. The only other path points to an unknown, uncertain darkness which equals death in has monstrosity.

In summing up, brings us back to square one. The responsibility is ours, the power and means are in our hands, the world is ours and its all upto us either to face perils or to boldly assert survival for the human race.

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