

Water Allocations and Use in the Mahanadi River Basin

A Study of the Agricultural and Industrial Sectors

Craig Dsouza | Abraham Samuel | Sarita Bhagat and K.J. Joy



Forum for Policy Dialogue on Water Conflicts in India

Water Allocations and Use in the Mahanadi River Basin

A Study of the Agricultural and Industrial Sectors

Craig Dsouza | Abraham Samuel | Sarita Bhagat | K.J. Joy



July 2017

**Water Allocations and Use in the Mahanadi River Basin:
A Study of the Agricultural and Industrial Sectors**

Authors: Craig Dsouza, Abraham Samuel, Sarita Bhagat and K.J. Joy

© Forum for Policy Dialogue on Water Conflicts in India, Pune, Maharashtra, India

Supported by: Arghyam, Bengaluru, India

Layout: Rohinee, Mudra

Cover Photograph: Seema Ravandale

Cover Design and Printing: Mudra, 383 Narayan Peth, Pune.

Published by: Forum for Policy Dialogue on Water Conflicts in India, Pune
c/o Society for Promoting Participative Ecosystem Management (SOPPECOM)
16, Kale Park, Someshwarwadi Road,
Pashan, Pune 411 008
Maharashtra, INDIA
Tel: +91-20-20251168/ 2588 6542
Fax: +91-020-2588 6542
Email: waterconflictforum@gmail.com
URL: waterconflictforum.org ; conflicts.indiawaterportal.org

Copies are available at the above address

First published in July 2017

The contents of this publication may be used with due acknowledgement of the source. Any form of reproduction, storage in a retrieval system or transmission by any means requires a prior written permission from the publisher.

Citation: Dsouza, C., Samuel, A., Bhagat, S. and Joy, K.J. (2017). *Water Allocations and Use in the Mahanadi River Basin: A Study of the Agricultural and Industrial sectors*. Forum for Policy Dialogue on Water Conflicts in India, Pune

Contributory Price: Rs. 250/-

Contents

Acronyms	x
Glossary	xii
Foreword & Acknowledgement	xv
Executive Summary	xvii
Chapter 1: Introduction and Research Methodology	1
• Study Background	1
• Research Questions	2
• Methodology	3
The Process	4
Data Sources	7
Limitations and Guide to Interpreting Findings	9
• Report Roadmap	11
Chapter 2: Profile of the Mahanadi River Basin	12
• Agricultural Land Use	14
• Water Resources: Availability	17
• Water Resources: Development	20
• Agriculture	22
• Industry	23
• Water Conflicts in the Mahanadi River Basin	24
Chapter 3: Policy and Institutional Environment	26
• Odisha	26
Water Resource Planning	26
Legal Instruments and Rules	28
Institutions	30
Key Insights and Issues	32
• Chhattisgarh	34
Water Resource Planning	34
Legal Instruments and Rules	36
Institutions	37

Key Issues and Insights	38
Summing Up	40
Chapter 4: Case Study – Minimata Bango	41
• Context	41
• Process	43
• History and Project Specifications	44
• Status of Water Resources: The Minimata Bango Project	46
• Allocation of Water Resources	47
Agriculture	47
Industry and Urban	48
• Water Use	50
• In Conclusion	55
Chapter 5: Case Study – The Hirakud Project	56
• Context	56
• Process	57
• History and Project Specifications	58
• Status of Water Resources: The Hirakud Project	58
• Allocations of Water Resources	61
Agriculture	62
Industrial Water Allocations	62
• Water Use	64
Agricultural Water Use	64
Water for Hydro Power Production	66
• In Conclusion	67
Chapter 6: Agriculture and Its Water Use in the Mahanadi River Basin	70
• Seasonal Variations in Cropping	70
• Geographical Variations in Cropping	72
• Cropping Patterns	75
• Irrigation Coverage – Seasons and Crops	78
• Sources of Irrigation	82
• Estimated Water Allocations and Use	84
Chapter 7: Industries in the Mahanadi Basin	90
• Overview	90
• Estimating Water Allocations and Use	93

Chapter 8: Potential Avenues for Water Savings and Their Basin-wide Implications	97
• Agriculture	97
Rice Cultivation	97
• Industry	100
Thermal Power	100
Mining	104
Iron and Steel Plants	107
• Future Water Use Scenarios	108
Business-as-Usual (BAU) Method	108
Use of Water Saving Technologies	109
Use of Biomass-based Approach	110
Chapter 9: Way Forward	112
• Water Allocations and Distribution between Agriculture and Industry	112
• Policy and Legal Issues	113
• Institutions and Norms for Determining Water Allocation and Use	115
• Knowledge Gaps	116
• Water Resources Planning	116
• The Issue of Conflict Framing	117
Bibliography	119
Annexures	126

List of Figures

Figure 1	: Rivers of the Mahanadi Basin	31
Figure 2	: Trends in Land Use in the Mahanadi Basin (NRSC)	34
Figure 3	: Land Use Map of the Mahanadi Basin	35
Figure 4	: Three-year Running Average Monsoon Runoff at Tikarpara	38
Figure 5	: Three-year Running Average Non-monsoon Runoff at Tikarpara	38
Figure 6	: Live Storage Capacity in the Mahanadi Basin (MCM)	40
Figure 7	: Large Dams and Major Irrigation Projects in the Mahanadi Basin	41
Figure 8	: Various Institutions Responsible for Decision-Making, Planning and Allocation, Odisha	52
Figure 9	: Various Institutions Responsible for Decision Making, Planning and Allocation, Chhattisgarh	60
Figure 10	: Minimata Bango Project and Command Area	65
Figure 11	: Minimata Bango Project – Canal-wise Net Irrigable Area	69
Figure 12	: Minimata Bango Reservoir – Daily Reservoir Levels (in MCM)	75
Figure 13	: Map of Minimata Bango Command Area – Rabi Irrigation Coverage	79
Figure 14	: Hirakud Project and Command Area	82
Figure 15	: Hirakud Project – Historical Monsoon Rainfall	84
Figure 16	: Average Weekly Reservoir Levels in the Hirakud Reservoir (1983–2011)	85
Figure 17	: Hirakud – Area Irrigated and Water Released for Irrigation	90
Figure 18	: Hirakud – mm/Ha of Water Provided for Irrigation Season-wise	91
Figure 19	: Installed Capacity at Hirakud for Power Generation	91
Figure 20	: Hirakud – Annual Power Generated (Million Units) and Water Released (MCM)	92
Figure 21	: Hirakud – Seasonal Releases of Water for Power (MCM)	93
Figure 22	: Season and Gross Cropped Area – Chhattisgarh port of the Mahanadi Basin	97
Figure 23	: Season and Gross Cropped Area – Odisha port of the Mahanadi Basin	98
Figure 24	: Kharif Cropping (as percentage of Basin Cropped Area)	100
Figure 25	: Rabi Cropping (as percentage of Basin Cropped Area)	101
Figure 26	: Major Crop Groups in Chhattisgarh (Gross Cropped Area in Th Ha)	102
Figure 27	: Season-wise Crop Groups – Chhattisgarh part of Mahanadi Basin	103
Figure 28	: Major Crop Groups in Odisha (Gross Cropped Area in Th Ha)	104
Figure 29	: Season-wise Crop Groups – Odisha part of Mahanadi Basin	105

Figure 30 : Season-wise Irrigation in Mahanadi Basin - Chhattisgarh	106
Figure 31 : Kharif Irrigation (as percentage of Basin Area Irrigated) 2013-14	107
Figure 32 : Rabi Irrigation (as percentage of Basin Area Irrigated) 2013-14	107
Figure 33 : Season-wise Irrigation in Mahanadi Basin - Odisha	108
Figure 34 : Cumulative Water Allocations to Thermal Power Plants vs. Cumulative Thermal Power Capacity Installed in Chhattisgarh in the Mahanadi Basin	122
Figure 35 : Cumulative Water Allocations to Thermal Power Plants vs. Cumulative Thermal Power Capacity Installed in Odisha in the Mahanadi Basin	123
Figure 36 : Industries and Irrigation in the Mahanadi Basin	124
Figure 37 : Annual Primary Productivity vs. Annual Actual Evapotranspiration	142

List of Tables

Table 1 : List of Major Datasets Referred to	25
Table 2 : Characteristics of the Mahanadi Basin	31
Table 3 : Agricultural Land Use Statistics by the Ministry of Agriculture	33
Table 4 : Agricultural Land Use Statistics by the NRSC	34
Table 5 : Surface Water Availability and Storages in Major Peninsular River Basins	36
Table 6 : Yield at Different Dependability at Minimata Bango Dam and Hasdeo Barrage	70
Table 7 : Minimata Bango Project – Season-wise Planned Irrigation Water Allocations	71
Table 8 : Minimata Bango Project – Project Design	71
Table 9 : Minimata Bango Project – Industrial Water Allocations	73
Table 10 : Minimata Bango Project – Kharif and Rabi Irrigation (Target vs. Actual)	76
Table 11 : Hirakud Project – Historical 75% Dependable and Mean Runoff into the Reservoir	86
Table 12 : Hirakud – Water Allocations to Industries	88
Table 13 : Major Projects in the Mahanadi River Basin – Chhattisgarh	109
Table 14 : Major Projects in the Mahanadi River Basin – Odisha	110
Table 15 : Design Water Requirements for the Major Projects in the Mahanadi Basin	112
Table 16 : Changes in Area Irrigated and Source of Irrigation in the Mahanadi Basin	113
Table 17 : Estimated Surface Water Requirement for Irrigation, Season-wise, in the Mahanadi Basin - Chhattisgarh	114
Table 18 : Estimated Surface Water Requirement for Irrigation, Season-wise, in the Mahanadi Basin - Odisha	115
Table 19 : Chhattisgarh Economy – Statistics	118
Table 20 : Odisha Economy - Statistics	120
Table 21 : Comparison of the SRI with the Conventional Method of Growing Rice	127
Table 22 : Average Grain Yields in Conventional and SRI Methods	128
Table 23 : Summary of the Water Saving Practices (Thermal Power)	132
Table 24 : Summary of Mining Practices to Preserve Water Quality Near Mines	137

List of Annexures

Annexure 1: District-wise, Season-wise Area Sown, Chhattisgarh (2013-14)

Annexure 2: District-wise, Season-wise Area Sown, Odisha (2013-14)

Annexure 3: District-wise, Source-wise Gross Area Irrigated, Chhattisgarh (2013-14)

Annexure 4: District-wise, Source-wise Gross Area Irrigated, Odisha (2013-14)

Annexure 5: Year-wise and Season-wise Crop Groups in Chhattisgarh

Annexure 6: Year-wise and Season-wise Crop Groups in Odisha

Annexure 7: Proportion of Each District Lying in the Mahanadi Basin

Annexure 8: Norms for Water Use in Agriculture and Industry

Annexure 9: Stakeholders Consulted during the Course of this Research

Acronyms

AWD	Alternate Wetting and Drying
BALCO	Bharat Aluminum Company
BCM	Billion Cubic Meters
CCA	Cultivable Command Area
CEA	Central Electricity Authority
CG	Chhattisgarh
COC	Cycle of Concentration
CSE	Centre for Science and Environment
CSEB	Chhattisgarh State Electricity Board
CPCB	Central Pollution Control Board
CWINC	Central Water-Power Irrigation and Navigation Commission
CWC	Central Water Commission
DES	Directorate of Economics and Statistics
DoWR	Department of Water Resources
DPR	Detailed Project Report
EMP	Environment Management Plan
FOT	Farmer's Organisation and Turnover
FRL	Full Reservoir Level
GCA	Gross Command Area
GIA	Gross Irrigable Area
GoC	Government of Chhattisgarh
Gol	Government of India
GoO	Government of Odisha
GRP	Green Rating Project
GSDP	Gross State Domestic Product
GTOPO	Global Topological Elevation Model
IRRI	International Rice Research Institute
LBC	Left Bank Canal
LSC	Live Storage Capacity
LULC	Land Use Land Cover

MAF	Million Acre Feet
MCM	Million Cubic Meters
MoA	Ministry of Agriculture
MoWR	Ministry of Water Resources
MSL	Mean Sea Level
MT	Metric Tonne
MTPA	Metric Tonne Per Annum
MW	Mega Watt
MWh	Mega Watt-hours
NAS	Net Area Sown
NIA	Net Irrigable Area
NRLD	National Register for Large Dams
NRSC	National Remote Sensing Centre
NTPC	National Thermal Power Corporation Limited
O&M	Operation and Maintenance
OD	Odisha
OTC	Once Through Cooling System
OWPO	Orissa Water Planning Organisation
OWRCP	Orissa Water Resources Consolidation Project
QGIS	Quantum Geographic Information System
RBC	Right Bank Canal
RBO	River Basin Organisation
SAIL	Steel Authority of India
SECL	South Eastern Coalfields Limited
SRI	System Rice Intensification
SSC	Slow Speed Classifiers
SWRDP	State Water Resources Development Policy
UIP	Ultimate Irrigation Potential
UTCL	Ultra Tech Cement Limited
WAC	Water Allocation Committee
WAPCOS	Water and Power Consultancy Services Limited
WHIMS	Wet High Intensity Magnetic Separation
WRB	Water Resource Board
WRIS	Water Resources Information System
WUA	Water User Association

Glossary

Barrage

A water storage structure across a river that uses a gate mechanism to hold back water for the main purpose of diversion.

Biasi

The traditional method of rice cultivation in Chhattisgarh, which involves broadcasting of seeds directly over the ploughed soils in the field, unlike the transplanting method where seeds are first grown in a smaller field (nursery) and then transplanted by hand after a few weeks of growth.

Biomass

In this study, biomass is defined as the total dry mass of vegetative matter produced within an ecosystem.

Blow-down Water

The quantum of water that is removed from the cooling water loop in a thermal power plant to maintain a constant concentration of dissolved solids.

Canal Efficiency

The ratio of the amount of water delivered by the canal to a field to the amount of water released from a reservoir into the canal. Canal efficiency is a factor of the impermeability of the canal lining and the soils underneath the canal.

Catchment

The total area over which water falling in the form of precipitation will collect at a single point (most often, a reservoir system).

Command Area

The total area over which water stored in a reservoir is designed to deliver for irrigation.

Conveyance Efficiency

Synonymous to canal efficiency as defined above.

Cycles of Concentration

The ratio of dissolved solids in blow-down water to the dissolved solids in make-up water that replaces blow-down water. Higher cycles of concentration potentially indicate lower freshwater consumption.

Dead Storage Capacity

Water stored behind a reservoir that cannot be diverted towards other uses because its elevation is insufficient to flow downstream by gravity. Using water in the dead storage capacity is only possible if it is pumped out.

Dependability

Dependability is a term used to gauge the quantum of precipitation that is likely to fall at a given certainty. For instance, 1000 mm of rainfall at 75 per cent dependability indicates that based on historical rainfall records in 75 per cent of the years, the rainfall was equal to or greater than 1000 mm.

Evapotranspiration

The amount of water that moves from the soil to the atmosphere by either direct evaporation or through the body of a plant.

Field Application Efficiency

The ratio of the amount of water that is taken up by the plant to the amount of water available at the level of an individual field.

Gross Storage Capacity

The total amount of water stored within a reservoir including the usable live storage capacity plus the dead storage capacity.

Live Storage Capacity

The amount of water stored within a reservoir that requires no external energy and can simply flow under gravity towards its point of consumption.

Make-up Water

The freshwater added to the cooling loop of a thermal power plant to make up for blow-down water.

Overall Irrigation Efficiency

The ratio of water released from a reservoir to the amount of water taken up by crops within the command area. It is the result of canal efficiency multiplied by field application efficiency.

Reporting Area

A category in Land Use statistics equal to the total area counted within a district. This is often marginally less than the geographical area of the district.

Reverse Osmosis

A technology by which water is pumped under high pressure through a membrane material with tiny pores that remove impurities in water and only allow freshwater to pass through.

Runoff

In the context of the case studies in this report, 'runoff into the reservoir' is the amount of water that, after precipitation, finds its way into the reservoir, either flowing through streams or first infiltrating into the ground and then resurfacing as base flows.

Siltation Loss

The decrease in the storage capacity of a reservoir as a result of sediment which flows into the reservoir, carried by streams discharging into it.

Water Productivity

The amount of biomass produced per unit of water.

Water Rationalisation

In the context of the Hirakud case study, water rationalisation indicates the year-to-year revision in the allocation of water from a reservoir to specific industries based on existing storage of water in the reservoir.

Watershed

Synonymous to 'catchment' as defined in this glossary.

Foreword and Acknowledgement

Water conflicts manifest themselves in a myriad of forms, over all types of water sources (surface as well as groundwater) and for every need, from drinking water to domestic, agriculture and industrial use. The fact that economic development has failed to secure the basic domestic and livelihood water requirements of many and has, in many ways, threatened local sources of water across the country, is of grave concern. Engaging with these conflicts means understanding the drivers of conflict, whether they are climatic: for instance, scarcity of water in times of drought; economic: higher revenue oriented uses of water gaining precedence over its primary use or pollution rendering water sources unusable; social: differences between social groups revealing themselves overtly over water as a resource; or, political: governments declaring dubious projects seeking political mileage. Engaging also involves bringing together diverse stakeholders to a common platform for a discussion around these drivers and exploring means of alleviating conflicts. These means can be many, including legal, policy, institutional, management and technological changes.

The Forum has been in existence since 2004, and has completed two phases of its work. The first phase involved the understanding of water conflicts through the process of documentation. The major outcome of this phase was the compendium of case studies, 'Water Conflicts in India: A Million Revolts in the Making' (Joy, Gujja, Paranjape, Goud, & Vispute, 2008). The Forum has continued to document water conflicts in its subsequent phases with compendiums both with a geographical focus (conflicts in the Northeast, Odisha) and thematic focus (conflicts around floods, domestic water and sanitation). The focus of the second phase was also on resolving and preventing water conflicts, which saw efforts from the Forum to look at frameworks to resolve water conflicts and actively engage with live water conflicts in western Odisha and Kerala. With efforts to engage with active conflicts, the Forum had mixed experiences. While there was not enough traction in Odisha for dialogue to take place, in Kerala, the Forum's recommendations on a reservoir operation model were partially implemented by the state government.

Currently, the Forum is in its third phase and is working extensively to backstop conflicts (i.e. provide knowledge-based support relevant to upcoming water conflicts). It has taken up the Mahanadi river basin to study the key thematic issues such as environmental flows, agricultural and industrial water use, and groundwater. The present report talks about the allocation of water and use in the two largest sectors— agriculture and industry. The study is an attempt to understand the implication of these two sectors on the existing water resources and water planning, the rising water conflicts due to allocations and how these issues could be resolved in an equitable and sustainable manner. The Mahanadi

basin was chosen as an ideal basin for conducting this study, as Forum had developed a strong network in the basin in the previous phases and there is lot of potential for better and integrated management of the water resources. The agriculture-industry thematic research team, used a participatory research approach (the details of the methodology are explained in detail in the first chapter of this book), wherein it consulted diverse stakeholders, not only to collect information and data, but also to verify and understand the issues from diverse perspectives. All the primary and secondary data was collected in first two years of the project, with simultaneous analysis of the data and verification from the stakeholders.

This research would have been incomplete without key stakeholders from both the states and therefore, we extend our deepest gratitude for their timely inputs. These include many civil society groups: Paschim Odisha Krushak Sangathan (Western Odisha Farmer's Union) and Water Initiatives from Odisha, Chhattisgarh Bachao Andolan and SROUT, Korba from Chhattisgarh. Government officials in both states provided support to the research team— In Chhattisgarh, Superintendent. Engineer S.K. Awadhiya of the Water Resource Department, Chhattisgarh and especially Executive Engineer. R.K. Shivhare of the Minimata Bango Project at Machadoli and in Odisha, Sri. B.B. Dhal, Director of Water Services of the Department of Water Resources and Sri. R.K. Panda, Superintendent Engineer at the Hirakud Dam, Burla.

A peer review meeting was also conducted in February, 2017, where the entire report was shared with key people from the sector. We thank Mr. Dinesh Kumar, Dr. Lele, Mr. Pranab Choudhury, Mr. Bimal Pandia for their critical feedback and inputs.

We would also like to thank other thematic team members— Latha A., Shripad Dharmadhikary, Himanshu Kulkarni, Siddharth Patil, Neha Bhadbhade and the members from the Steering Committee of the Forum for their constant feedback. We would also like to thank Pratima Medhekar and Tanaji Nikam for their help in organizing stakeholder meetings at various levels.

We would like to acknowledge the financial support and encouragement provided by Arghyam Trust, Bengaluru. We thank Sugeeta Roy Choudhury for the copy-editing, Rohinee for the layout and Mudra Offset for the production of this report.

Pune
July 2017

Agriculture-Industrial Thematic Research Team

Executive Summary

Forum for Policy Dialogue on Water Conflicts in India conducted a three-year study in the Mahanadi basin to understand the inter-sectoral water allocations and decision-making processes, especially in the two large sectors — agriculture and industry. These two sectors were of major interest due to the large-scale expansion of thermal power, mining and iron and steel industries in the region and the rising conflicts for shift of water use from agriculture to industries. These industries tend to have a larger impact on the availability of local water resource and understanding their cumulative impact was thought to be important. The broader objectives of the study were to explore, a) increased industrial water use which is affecting agriculture, b) governance process that are shaping the water allocations and c) scope for saving water during irrigation and industrial processes.

With extensive secondary data analysis, literature review, stakeholder consultations and primary field work the Forum articulates the grassroot realities of water availability 'vs' water allocations. The report shares ideas for achieving equity and sustainability in' water allocations and the decision-making processes that lead up to them.

The Mahanadi Basin Profile

The Mahanadi Basin, which lies almost entirely within the states of Chhattisgarh and Odisha, drains an area of 141,589 km². The major tributaries of the Mahanadi are the Seonath, Hasdeo and Mand in Chhattisgarh and Ib, Tel and Ong in Odisha. Rice is by far the most important crop in the river basin. The two major water resource projects, which are studied in detail are the Minimata Bango in Chhattisgarh and Hirakud project in Odisha. About 5821 Th Ha (about 40%) of the area of the Mahanadi Basin is the annual Net Area Sown. Total cropped area has increased across the basin over the last two decades, largely due to increases in irrigation, while net area sown has fallen slightly across both states, more so in Odisha than Chhattisgarh. Fallow lands show no change in Chhattisgarh but a substantial increase in Odisha.

The Mahanadi Basin lies in a relatively high rainfall region of India, receiving 1291 mm of annual rainfall. Of the total annual average flow of the Mahanadi river of 66.8 BCM, about 50 BCM is said to be utilisable. The inter-annual flow in the river is however highly variable, being as low as 20 BCM to as high as 70 BCM. Several studies after examining long term trends show that rainfall and as a result annual flows of water in the Mahanadi Basin are decreasing. To capture much of this annual flow, water resource projects in the Mahanadi Basin currently have a cumulative capacity of 13.72 BCM, with several new projects under construction since 2010.

Industries, especially thermal power have received a large number of environmental clearances since the mid 2000s. The thermal power capacity in Chhattisgarh and Odisha is now at 15802 MW and 7103 MW, respectively. Since the increase in industrial water allocations, the most immediate contestations between these two sectors are being seen around surface water sources, primarily large dams that serve major irrigation projects. Most notably, the Hasdeo, Mand and Ib river basins, where a lot of mines and thermal plants operate, face severe water issues.

Policy and Institutional Environment

There is no basin level tribunal for Mahanadi like some of the major interstate river basins. State specific policies and institutional arrangements determine water resource management and allocation within the basin. Both the states seem to be on an ambitious industrialization path and the major policies, institutions and instruments are in tune with this objective. Even though the agriculture sector still plays a crucial role in water allocation decisions, the framework for these decisions and relevant norms are not well established.

Odisha State Water Policy primarily prioritises drinking and domestic water needs followed by ecological needs and then irrigation, hydropower, industries and agro-industries and lastly navigation. The ground reality however does not follow the priorities. In Odisha, state level institutions abound for the planning and allocation of water resources. Overall responsibility for planning (including river basin plans) in the state lies with the Orissa Water Planning Organization (OWPO), a nodal agency under the Department of Water Resources (DoWR) of Orissa. River Basin Organizations (RBOs), which are largely comprised of bureaucratic and technical representation, aid in this planning by vetting river basin plans devised by the OWPO. The DoWR implements various policy provisions. A Water Allocation Committee (WAC) prepares estimates of the net water demand across various sectors including irrigation, urban use and industrial use. The accelerated industrialisation initiative of the state which introduced the single window clearance for industries at district and state level, influenced water allocations irrespective of the various institutional mechanisms in place, as narrated by civil society stakeholders.

The Chhattisgarh draft State Water Policy (2012) does not elaborate on allocation priorities but only states that water would be held by the state under public trust doctrine to achieve food security, livelihood, and equitable and sustainable development for all. In comparison to Odisha the policies and institutional mechanisms in Chhattisgarh are not as well developed. The State Water Resource Department is the responsible agency for water resource management. Tentative assessments have been made of the total water resources (both ground and surface water) demand. The Industrial Policy of the state assumes that the rivers are capable of satisfying the needs for drinking water, agriculture as well as industrial units. It also states that for industrial projects, water supply arrangement initiatives will be made by public-private partnership (PPP) model. Chhattisgarh too has a single clearance window which functions for industrial water

sanctions with State Investment Promotion Board as the secretariat. Nodal officers liaison with Water Resource Departments and Project authorities on behalf of industries to address the issues of water allocations.

Case Studies

To understand in depth the factors shaping water allocations and use, the unit of analysis chosen was individual major irrigation/multipurpose projects. Given the density of industrial development in the vicinity of the Minimata Bango project situated in Korba, Chhattisgarh and Hirakud in Sambalpur, Odisha, these projects were chosen for detailed studies.

Minimata (Hasdeo) Bango

The Minimata Bango is situated on the Hasdeo river, in Korba district. The dam and barrage system operate together to provide water to industries in the vicinity and also largely irrigates rice in parts of Janjgir-Champa and small parts of Korba and Raigarh. The annual yield of Minimata Bango project at 75% dependability is 3213 MCM after accounting for upstream use in irrigation and/or industrial use. Of this amount, about 2578 MCM is the planned allocation for gross irrigation of 433,500 ha and 452 MCM to industrial + urban use. The story of this project is however one of massive under-utilization. Analysis of the reservoir levels in the Minimata Bango reservoir over the years (from 1995 to 2014) shows that large amounts of water, often 50% or more is left unused in the reservoir at the end of the summer. At the same time analysis show that Rabi irrigation has not been provided for the last 10 years (2004-05 to 2013-14). An approximate estimation of water use from the Hasdeo project since 2004-05 would be around 1332 MCM annually for agriculture, 439 MCM for various industries and 14 MCM for Korba town. This would total to 1785 MCM. After evaporation losses are factored this would be 2014 MCM. This means that water is left unused in the reservoir, since average annual inflows are about 2793 MCM. During much of the same period (2005-06 to 2014-15) discharges from the dam during the months of Feb-May average about 483 MCM. This raises the question of what this water is being used for, if not for Rabi irrigation.

Many reasons are cited for not providing water for Rabi irrigation. During the course of field visits, government officials cited reasons such as the need for canal maintenance works, the lack of demand from farmers for Rabi irrigation because farmers traditionally allow animals to graze in the second season. Discussions with farmers in six villages of the command area revealed that the latter claim was not true and that there was in fact a demand for water. Some officials also claimed that water was not being provided because farmers insisted on only growing rice whereas, the project design did not allow for rice cultivation in the Rabi or summer seasons. The claim of civil society groups in the region is that the current pattern of operation of the reservoir is because other industries, located further downstream of Hasdeo Barrage, are being assured a steady flow of water. This claim though unproven appears the most likely probability.

Hirakud

The Hirakud project holds tremendous importance for irrigation in Odisha and the fact that it supplies water to many industries makes it interesting to study. Situated in Sambalpur district on the Mahanadi river, the Hirakud dam was completed in 1957 and has been supplying water for irrigation since then.

Unlike the Minimata Bango the waters of the Hirakud are fully utilized. The estimated average storage capacity of the reservoir in 2015 is assumed to be 4.34 BCM. Rainfall in the catchment area however has fallen over the years. This has partially contributed to a reduction in the inflows into the reservoir since its construction. Since 2006-07 monsoon inflows have averaged only 24.7 BCM. Non-monsoon inflows have increased over the years and now average about 4 BCM. This could possibly be due to upstream land use changes, changes in reservoir elevation-capacity curves (i.e. parameters used to measure inflow) or the influence of upstream structures by Chhattisgarh.

By the methodology adopted by the dam authorities, non-monsoon water availability is calculated as 6270 MCM i.e. 4340 MCM + 1920 MCM (at 90% dependability). While official allocation for irrigation is unknown, over the period from 1982-83 to 2006-07, data shows that the annual water released for non-monsoon irrigation has been 1682 MCM, with area irrigated in the Kharif season matching the project design area and irrigated area in the Rabi is now far exceeding the designed capacity. Water already allocated to industries from the project amounts to 423 MCM, between 21 industries, nearly the amount permitted by the Department of Irrigation, Government of Odisha. After accounting for evaporation and urban demand, the remaining balance for power production in the non-monsoon season is about 3384 MCM. Water released for hydropower production in the non-monsoon season has been lower than average in recent years. This shows that if industrial allocations increase, hydropower production is likely to suffer. The competition for water from industries may affect its availability for irrigation in the future. While the competition has so far been successfully resisted by farmers, ongoing pressure from industries for water shall continue to pose a threat to agriculture in the command area of the Hirakud.

Agricultural and Industrial Water Use Trends

Cropping Patterns

Both Chhattisgarh and Odisha predominantly grow rainfed rice (making up about 70–75 per cent of the gross cropped area). The larger picture from the analysis shows evidence of acceleration in the development of agriculture across Chhattisgarh. This development has been aided with Kharif season surface irrigation in the plains of Dhamtari, Durg, Raipur and Janjgir-Champa districts, whereas groundwater has contributed greatly to development in Bilaspur, Kawardha and Durg districts. Rabi irrigation in Chhattisgarh is also increasing but is still not as prevalent as in Odisha. Chhattisgarh's agriculture also shows an observable trend of diversification, with the percentage of land under rice (presently 77 per cent of gross cropped area) falling as compared to the other crops such as pulses and oilseeds, which are Rabi crops.

Odisha's agriculture on the other hand appears to be in decline, with the net area sown having fallen during the last two decades. The rise in culturable wastelands and fallow lands explains most of this changing land use as per available land use statistics. Irrigation is more prominent in the delta and in western Odisha, and the potential area irrigated has increased greatly over time. In Odisha, the proportion of area under rice (presently 53% of gross cropped area) has remained more or less the same, whereas that under pulses has increased and oilseeds has decreased.

Irrigation

The development of irrigation in the Mahanadi Basin has been much more rapid in Chhattisgarh as compared to Odisha. Chhattisgarh's major surface irrigation projects, the Mahanadi reservoir complex, Tandula tank (on the Seonath) irrigate large parts of their command areas in central Chhattisgarh in the Rabi season. The Kharang and Maniyari tanks irrigate the district of Bilaspur consistently whereas the Minimata Bango provides only Kharif irrigation water in its command area in Janjgir Champa. Chhattisgarh in 2013-14 irrigated about 48 per cent of its gross cropped area in the Mahanadi Basin. The total surface water allocated by Chhattisgarh to surface irrigation projects in the Mahanadi basin as of 2013-14 amounts to 5.48 BCM. The state's dependence on groundwater for irrigation has also risen. In 2000-01, canals irrigated 68 per cent and wells 21 per cent of the gross irrigated area, whereas in 2013-14 it was 58 per cent and 36 per cent respectively.

In the delta region of the Mahanadi, districts receive irrigation waters in the Kharif season, though they are not as well irrigated in the Rabi season. In contrast in the interior regions, the command areas of the Hirakud and the Upper Indravati projects are well irrigated in the Rabi season. Odisha's gross irrigated area in 2013-14 amounts to 41 per cent of its gross cropped area in 1993-94. Estimations show that the total surface water allocated by Odisha to major and medium projects in the Mahanadi basin amounts to 8.23 BCM. Odisha is still not heavily reliant on groundwater for irrigation, only about 19 per cent of its irrigated area in 2008-09 was irrigated by wells, whereas for canals it was about 64 per cent.

This exercise shows that the surface water use for irrigation in the Mahanadi Basin amounts to approximately 13715 MCM i.e. 20 per cent of the 66.87 BCM annual average flow (27.4 per cent of the estimated utilisable surface water of 50 BCM) of the river. This is a rise of 24 per cent from 11057 MCM in 2000-01.

Industrial Water Allocations

To develop an accurate idea of the effect that industrial expansion might be having on water allocations in the river basin, estimates of the scale and the spatial variation in use of water by industries was essential. For this purpose, a detailed database of industries in the Mahanadi Basin was prepared using the environmental clearances by the Ministry of Environment and Forests. Based on these estimates, the total amount of water in the Mahanadi basin allocated to large industries is about 1130 MCM in Chhattisgarh and

944 MCM in Odisha. This amounts to 2074 MCM of water for industrial use or about 4 per cent of the total utilisable surface water in the Mahanadi Basin. About 1661 MCM (80 per cent) of water is allocated to thermal power generation alone, an increase from 364 MCM in 2007. This water is allocated for an estimated 55 gigawatt (GW) of thermal capacity in total, although not all of this thermal power capacity has been commissioned yet. The current (2016) thermal power capacity in both states stands at about 23 GW (some of this thermal capacity is located outside the Mahanadi Basin). Hence current Actual Water Use for thermal power in the Mahanadi Basin may be well below 1661 MCM. Besides thermal power another 413 MCM is allocated towards the iron and steel industry. A smaller percentage of this is also meant for aluminium industries.

Future Water Use Scenarios

The estimates of agricultural and industrial water allocations developed in this study, shown below, were used to project water use scenarios for 2040. These scenarios were evaluated under three conditions, 1) Business as Usual (BAU) Scenario, where the current water use norms were used, 2) Water saving practices are implemented on a small scale and 3) Biomass based approach, where water is allocated on a household basis and not on the basis of project. The last scenario is developed only for agriculture.

Surface water availability	50,000 MCM of utilizable water
Irrigation use	13,715 MCM (27.4%) of utilizable water
Industrial use	2,074 MCM (4%) of utilizable water

These scenarios suggest that under a BAU, agricultural water allocations in the Mahanadi Basin for surface water, would rise from current 13715 MCM to 20572 MCM by 2040. For industrial water allocations, the projections are a lot more uncertain, largely due to uncertainties about the future of thermal power in India. If solar power were to prevent more new allocations of water to thermal power, as it has been seen in 2017, then the future water use for thermal power may not rise above the currently allocated figure of 1661 MCM. The second scenario estimates that with partial implementation of best practices, water savings of almost 4000 MCM in agriculture and 831 MCM in thermal power is possible. Lastly within the biomass based scenario agricultural water allocations would rise to about 22,000 MCM. This scenario however assumes a condition wherein all families living in the basin would be allocated water, unlike the BAU scenario wherein many would still not have access to water for agriculture.

Way Forward

The pressure on existing water resources is increasing, especially in some parts of the Mahanadi basin, like Mand, Hasdeo, Ib sub-basins and the main stem of the Mahanadi. Industries and farmers are in a conflict, over water for their opposing needs. The resolution of these conflicts needs efforts at multiple levels. It raises the question of how much water

should be allowed to be consumed and how much water must flow in the river. How much of the water used should be used for irrigation and industry and water use can be made more efficient? The scale and localized intensity of industrial water use that is sustainable must be raised in democratic multi-stakeholder forums. Nested institutions such as Water User Associations at smaller levels and RBOs are ideal for these dialogues. Though such institutions exist currently, the form they take is not truly representative of the multiplicity of stakeholders that have a stake in equitable water allocations.

To compound issues, the absence of norms based on which water allocations are made are not at all clear nor specified in any open documents. This leads to inconsistent decisions in the water allocation process and increases the probability of conflicts. The development of norms means going much beyond the simple listing of priority of each sector and instead laying out protocols of allocations for different years and rainfall regimes. These norms too should be decided in participative forums. To aid with participative decision making in water resource management, the requirement also exists for accurate estimations of water availability (in groundwater, soil moisture, surface water) for different river basins capturing seasonal and inter-annual variations. Water demand estimates of basin or regional crop water use and industrial water use are also not easily available. Studies must be encouraged to understand crop water use better and incorporate it into planning processes. Industries must be encouraged to publish water use data in the public domain. Both states must also agree to common metrics to gauge the status of water resources. For example, in the recently concluded inter-state discussion, the figures for water availability used by both the states were the same, but the contestation arose as each state chose its own metric of importance, which allowed them to argue for more water.

The water resource planning and projections of water demand and supply in both the states need to be revisited. The projections of water demand are built on questionable assumptions. Both states assume that there is sufficient water to be exploited for the development without taking into considerations the real water resource situations, the changes resulting from biophysical factors like land use changes (especially mining, deforestation), irrigation withdrawal, changes in rainfall patterns, etc. Equally important in water planning is a change in focus towards a conservation based approach to stem water demand rather than simply a supply side approach of building more water structures.

1

Introduction and Research Methodology

This study delves into the subject of inter-sectoral water allocations, specifically water allocations between agriculture, the largest sectoral user of water, and industry, which has a significant and growing share. With secondary data analysis, it develops estimates for the quantum of water actually used in each of these sectors in the Mahanadi Basin. The study explores the thinking and policy that shapes the nature of these allocations and the ground reality of the governance processes by which water planning and allocations actually occur. It also examines, using a case study approach, the extent to which actual water supply patterns follow official allocations on paper, and finally, it examines through literature review and field work, the processes by which water is used and reused and the nature of return flows to the environment in these sectors. The objective here is to understand the efficiency of the use of water and potential gains from switching to better practices, both in agriculture and industry. With this understanding, the Forum for Policy Dialogue on Water Conflicts in India (henceforth, Forum) attempts to outline some broad protocols for the use and allocation of water by these sectors which, if implemented, could lead to greater water security and equity in distribution.

Study Background

The geographical focus of the Forum's thematic research in the third phase of its work, (beginning April 2013) has been the Mahanadi river basin. In its previous phase, the Odisha State Centre of the Forum had undertaken action research on conflicts around the Hirakud in Odisha, and came out with a report titled 'Floods, Fields and Factories: Towards Resolving Conflicts around Hirakud Dam' (Choudhury Sandbhor & Satapathy, 2012). This report detailed multiple issues related to water allocations and water pollution caused by industries in the Hirakud catchment. Through the course of that work, the Forum had built rapport with multiple stakeholders on the ground in Odisha and Chhattisgarh, especially in the former. A platform of active stakeholders therefore already existed in the river basin.

Besides this, of equal relevance, is the fact that unlike the other major rivers of peninsular India, the waters of the Mahanadi have not yet been fully allocated across sectors. There are still flows in the river at many stretches that are relatively untouched. With rapid urbanisation and industrial development in the region, this is set to change. Water in other parts of the country being allocated to industrial and urban uses is leaving lesser flows in the river and also lesser quantum of water available for irrigation, and competing uses (Menon, 2013). The developing states of Chhattisgarh and Odisha, we hypothesise, will face similar challenges. Given this, there is still much scope for advocacy for effective

policy changes to ensure more equitable allocation and distribution of the basin's water resources. With this motive in mind, the Forum chose the Mahanadi river basin as an ideal unit for thematic studies, of which one theme chosen was 'Agricultural and Industrial Allocation and Use'.¹ By understanding the nature of governance and use of water by agriculture and industries, the Forum hopes to provide insights that lead to more equitable inter-sectoral distributions of water in the river basin.

Research Questions

A preliminary review of literature reveals the rapid acceleration of 'development', primarily industrial development, with a major thrust on extractive mineral-based industries in the states of Chhattisgarh and Odisha, which constitute almost the entirety of the Mahanadi Basin. These states have consistently ranked low on income and human development indicators, such as health and literacy, whereas they outshine other states with their wealth of natural resources (Bhushan & Hazra, 2008). The population in these states are largely rural cultivators, most of whom are dependent on just the Kharif crop for their livelihood. Water usage in irrigation command areas in these states is known to be inefficient, with flood irrigation being widely applied. While some of this water recharges the groundwater table and is used for supplemental irrigation in subsequent crop seasons, an argument can also be made for meeting other concerns, such as increasing the irrigated area in the same season or provisioning water for environmental flows in the river. Similarly, industries, especially the thermal power plants and integrated steel plants that are common in the basin, are largely inefficient in their water consumption (Bhushan, Bhati, & Kanchan, 2015), in comparison to the global standards. The study started out with the basic assumption that rapid industrialisation of water intensive, extractive industries may be negatively affecting the availability of water for agriculture and that there is still a lot of potential for reducing the aggregate water demand from these sectors, with implementation of better technologies and practices of water use.

In attempting to further explore these themes, research questions and sub-research questions were drafted along the following lines:

1. To what extent is increased industrial water use affecting agriculture?
 - a. Is surface water from major irrigation projects being diverted from agriculture towards industrial use?
 - b. Is there a downward trend in water supply to major irrigation project commands which are in close proximity to major industrial projects?

1. With Chhattisgarh increasingly starting to make greater use of the river's water in the upper reaches, lesser monsoon flows are now reaching Odisha whereas non-monsoon flows are increasing. During the course of this study, there started to emerge issues between the two states over the sharing of water between them (The New Indian Express, 2016). The findings of this study also serve in part to answer questions of allocation of water between the two states although this was not the original intention.

2. How are governance processes actually shaping water allocations?
 - a. How are governance decisions about water allocations being made? Are there protocols that take into account the ground realities or are these allocations ad-hoc?
3. What is the scope of water savings in the irrigated agriculture and industrial sectors?
 - a. Do there exist efficient water use and reuse practices which, if implemented, can lead to significant water savings?
 - b. What would be the limitations to implement better practices and what might an alternate scenario of water distribution look like, if these practices were to be implemented?
 - c. Furthermore, given the trends in industrial, agricultural and water policies in the states, what might the scenario of water allocation look like a few decades from now?

Methodology

This study was envisioned as an exploratory study on sectoral water use (agriculture and industry) in the Mahanadi Basin. With that in mind, it does not envisage one concrete path forward but instead presents a range of possible ways forward. In this study, we have made a conscious effort to bring stakeholders' opinions into the different stages of the study. This research does not imagine or view local stakeholders simply as subjects in the study but also as live actors whose opinions and critique can be sought, and with whom research findings must be shared to reap the full benefit. Farmers possessing local knowledge, civil society groups and others are often aware of phenomenon and trends relating to the field that cannot all be envisioned by the researcher alone. Their knowledge is therefore put to use in developing a preliminary understanding of the study area and also in shaping research questions and validation of findings during the course of the study.

Besides this, certain other methodological choices had to be made with respect to administrative boundaries, time periods and depth of analysis. These are explained further below.

Changing Administrative Boundaries

The state of Chhattisgarh has 27 districts whereas Odisha has 30. Odisha's districts have remained unaltered over the last two decades. However, Chhattisgarh has split its districts from 16 when it was newly formed to the 27 existing districts. These splits created issues of consistency for the datasets for analysis across different time periods. Hence, to simplify, the data for the new split districts have been aggregated to compose datasets with the same original 16 districts. Of these 16 and 30 districts of Chhattisgarh and Odisha respectively, 15 districts of Chhattisgarh and 22 districts of Odisha lie fully or partially in the Mahanadi Basin (See Annexure 7 for more) (Ministry of Water Resources, 2014). Similarly, alternative names of each district that are found in different datasets have been mentioned.

Time Spans

In temporal span, most of the analyses have been limited to the last one decade and a half since the state of Chhattisgarh was formed in 2000, with an emphasis on ensuring that the latest available data has been presented. In many cases the latest data that was available was for the year 2013-14; however, in some cases, the latest goes as far back as 2010.

Levels of Analysis

The study was thus conducted at two levels of analysis: first, at the primary level for the selected sites (Minimata-Bango in Chhattisgarh and Hirakud in Odisha) and then at the secondary level, for the basin as a whole.

Much of the data presented, including industrial water allocations, detailed project reports (DPRs) and data on water releases from certain reservoirs, has been obtained as physical copies from government offices. However, given the vast scale of the Mahanadi Basin, it would have proved immensely difficult to cover more than a few project sites within the basin. Hence two project sites were chosen, one in Chhattisgarh and another in Odisha, which were representative of the scenarios that were sought to be understood. These were the Minimata Bango irrigation project in Korba, Chhattisgarh and the Hirakud project in Odisha. While these projects have been serving irrigation purposes for more than three and six decades respectively, they also happen to be situated in close proximity to rapidly expanding industrial areas. These projects therefore provide an ideal opportunity to study the effect of this development on water allocations. These sites were visited for field observations and multiple stakeholders were interviewed, the details of which have been documented as separate case studies within the report.

Besides the Mahanadi Basin level analysis done in this report, an effort has been made to study this issue at the national level. This will be elaborated in a subsequent report by the Forum.

The Process

Since this was a study for a region of large geographical extent, with multiple actors, including two state governments, water management authorities of different irrigation projects, and many industrial groups and farmers' unions, it was thought to be important to look at the theme holistically and engage with various stakeholders at work—government, civil society, farmers' groups, industries' groups, media outlets and academia (a full list of stakeholders consulted during the study through field visits and stakeholder meetings is attached as Annexure 9). This holistic perspective would give a well-rounded understanding of how different processes interact to determine how water is used and distributed in a river basin.

To begin with, the Forum held a meeting of diverse stakeholder groups which brought together about 50 people at each meeting in Raipur, Chhattisgarh and Sambalpur,

Odisha. These meetings helped to narrow down locations for intensive field study in both the states as well as establish contacts with more grassroots organisations, academics, journalists and activists, who helped guide the research.

Following these meetings, academic literature and newspaper coverage on relevant issues pertaining to sectoral water use was reviewed. Besides this, quantitative data analysis with secondary data was also undertaken to gain an understanding of trends at the macro level in the Mahanadi Basin. This included an analysis of data on land use, cropping patterns, irrigation infrastructure, industrial expansion, etc. Adopting a quantitative approach with secondary literature and data alone would have been perilous. However, certain questions of trends at the macro level were best explored using quantitative approaches. Inferences drawn from this data were also shared with stakeholders for validation and new datasets were gathered over the course of the field visits.

Literature Review

The preliminary literature review consisted of review of academic literature, popular media and government reports, to build an initial picture of water use in the river basin. It was identified that rice was the primary crop grown across most parts of the basin and also that it was a very water intensive crop. Thus, understanding trends in the production of rice and different techniques employed to irrigate rice crops, was thought to be of importance. Also, while considering water saving practices for efficiency of water use in agriculture, rice has been the main crop considered since it dominates in command areas where surface irrigation is applied.

Note on Water Use Efficiency

The literature on water use efficiency debates at great length the use of the word efficiency in the context of irrigation. Early definitions defined the concept of efficiency as the ratio of the quantum of water required and consumed by the crop (to avoid water stress) to the water available at the reservoir (Bos & Nugteren, 1982). Others later pointed out that this definition led to the implication that all water applied to the field and not used by the crop was necessarily wasteful (US Interagency Task Force, as cited in (Perry, 2007)). This was not always the case. Water not used by the crop ('lost' water) gets either evaporated, consumed by weeds, used up in recharging the aquifers (shallow and deep, freshwater and saline) or drained back into streams. The argument put forth was that some part of the water that reaches the aquifers or drains into streams is potentially recoverable and, in many cases, it is actively recovered by farmers through borewells for irrigation, in the same or the next crop season (Willardson, Allen, & Frederiksen, 1994). In these cases, the water is not lost and therefore irrigation is not inefficient the way it is perceived. This is something that proponents of improvements in 'water use efficiency' miss. Improving canal conveyance efficiency by lining and field application efficiency by alternatives to flood irrigation would decrease infiltration

and groundwater recharge to the detriment of the users of groundwater in the command areas. These are valid arguments that must be taken into consideration, and such recovered flows should be quantified to know the true extent of water use. If the quantum of 'lost' water (via weeds or evaporation) is high, it would automatically imply that improving efficiency is to be given priority. However, if the quantity of recovered water (via groundwater pumping for irrigation or drinking water) in a command area was found to be large, it does not automatically imply that such seepage should be allowed. The quantification of groundwater use would allow an evaluation of the benefits of this use versus alternative options, i.e. improving efficiency and allowing for larger irrigation coverage or greater environmental flows in the river. This, however, would have to be a normative decision that could be taken only after engaging with multiple viewpoints.

This report uses the term water use efficiency in agriculture with this understanding, that water is stored in reservoirs with the objective of being controlled, to serve the design requirements of the project. Since this is the case, knowing where all the water eventually ends up, ensures that it meets the project's design requirements and the extent to which water 'loss' actually exists that can be saved for other uses.

Similarly, literature showed that thermal power and iron and steel industries, in particular, were rapidly gaining importance in the river basin and both these industries were water intensive (Centre for Science and Environment, 2004). To add to these, it was decided to also explore the extent of mining in the river basin as well as pursue the literature on effects of mining, since water courses and availability of water for other uses could be greatly altered with the increasing scale of mining. To understand where in the river basin water allocation issues were cropping up, popular news articles provided a good reference. Government reports were consulted to get a clearer picture of what policy proposals were focused on and how the governance of water was envisioned in the official documents.

Secondary Data Analysis

Secondary data was used to study macro level trends in water allocation over time (both for agriculture and industry) in the basin. While much of the data put together in the course of this study is from government sources, most of this data was not easily accessible or in a format amenable for analysis. Several of these datasets have been put together in a manner that allows for easy comparison and understanding of variables of interest such as agricultural land use, irrigation, crop types and industrial spread. The juxtaposition of industrial and agricultural datasets allows for a contextual understanding of the pressures on water resources across the basin. It also allows for a direct comparison of water allocations from different surface irrigation projects, which is one of the focal points of this study.

The analysis of water allocations and use presented in this report is limited to the agricultural and industrial sectors. Within agriculture, only major surface irrigation projects have been studied since it is only here that water is essentially 'allocated' and governance is by the state, not by private individuals. When examining industry, the major industrial sectors present within the Mahanadi Basin, i.e. thermal power, integrated iron and steel, and mining, have been considered. Other large industries also exist in the basin but to limit the scope of the analysis, only these three were focussed upon.

An attempt has been made to the greatest extent possible to show both spatial (with maps) as well as temporal trends in these water allocations using secondary data.

Field Work

Field work was undertaken to interact with various stakeholders, understand different existing perspectives on water use, fill in data gaps as well as to validate secondary data. The field study has taken a largely qualitative approach, with physical observation and detailed interviews of different groups as well as larger consultative meetings. Adopting qualitative data collection approaches proved important for the goal of secondary data validation and allowed for pursuing an understanding of a wider range of trends in the areas of study.

These steps of literature review, secondary data collection, data analysis and field visits followed each other in iterative steps, with the first preliminary review leading to the formation of research questions, which were further refined and answered with subsequent field visits and stakeholder consultations. Local actors thus helped guide the course of the research. The method of triangulation, which is essentially corroborating data with different sources, has been used to establish its validity and reliability.

Data Sources

To gain a better perspective in answering these questions, secondary data on multiple relevant parameters was put together, including land use patterns, cropping patterns, crop water requirements, irrigation source, agricultural and industrial water allocations from chosen projects, and estimated actual water use by agriculture and industry from chosen projects. The data was collected through desk appraisal and, also, mainly through direct field contact with various government departments, agencies etc.

In addition to these secondary sources of data, primary data was obtained from interviews of different groups of stakeholders, including farmers, movement leaders, government officials etc. and field observations have been used to draw insights throughout the course of this study. Articles from regional newspapers were also referred to in developing an understanding of the emerging issues around water resources of the basin in the respective states.

Table 1: List of Major Datasets Referred to

Dataset	Temporal range	Spatial resolution	Source	Method
Land use pattern (CG)	2000-01–2013-14	District	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Land use pattern (OD)	2000-01–2013-14	District	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Field visit
Land use raster map	2004-05–2013-14	1:250,000	National Remote Sensing Agency	Formal application
Cropping pattern (CG)	1997-98–2013-14	District	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Cropping pattern (OD)	1993-94–2013-14	District	Statistics Cell, Department of Agriculture, GoO	Field visit
Major and medium irrigation projects (CG & OD)	Current	Project-wise	Water Resources Information System (WRIS), India (original source Central Water Commission)	Website
Irrigation by source (CG)	2000-01–2013-14	District-wise	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Irrigation by source (OD)	2000-01–2013-14	District-wise	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Crop-wise irrigation (CG)	2000-01–2013-14	District-wise	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Crop-wise irrigation (OD)	2000-01–2013-14	District-wise	Directorate of Economics and Statistics, Ministry of Agriculture, Gol	Website
Industrial water use in the Mahanadi Basin (Environmental Clearance) ²	1980–2015	Project-wise	Ministry of Environment and Forests, Gol	Website

-
2. No consolidated information on water clearances given to the industries, with the year of approval, was available with either state government. Hence, the MoEF was used as source for this information.

Dataset	Temporal range	Spatial resolution	Source	Method
Water resource projects in Chhattisgarh areas falling under the Mahanadi Basin	Current and Planned	Project-wise	WAPCOS Report	Field visit
Large dams in the Mahanadi river basin	Current	Project-wise	National Register on Large Dams	Website
Crop based water requirement (Rice)	NA	NA	NALMI	Field visit and Website
Allocations of water from Minimata Bango project (Detailed Project Report)	2015-16	NA	Hasdeo Bango Circle Office, Bilaspur, Chhattisgarh	Field visit
Actual water releases from Minimata Bango project	2011-15	NA	Hasdeo Bango Circle Office, Bilaspur, Chhattisgarh	Field visit
Flood Report of the Hirakud Dam	2014	NA	Department of Water Resources, GoO	Field visit
Allocations of water from the Hirakud project	2014-15	NA	Government of Odisha	Website
Actual water releases from the Hirakud project	1958–2014	NA	Water Resource Department, GoO	Field visit

Limitations and Guide to Interpreting Findings

The limitations of this study must be mentioned with the intent that findings be interpreted with the appropriate perspective. This section highlights the ways in which the study's scope is limited, be it geographically, in temporal span, or in methodology. It also aims to serve as a guide to interpret data cited in the report, highlighting possible inaccuracies and gaps.

Data Availability for Hydrological Boundaries

In socio-hydrological studies such as this, the river basin is considered the ideal unit of analysis since the focus is on the availability and distribution of water resources, especially surface water resources. However, the decisions about what datasets to consider cannot strictly be dictated by river basin boundaries. For one, datasets in India, for many variables of interest, land use, cropping, irrigation, industrial presence etc., are available at different administrative boundary levels but not at the basin level. Wherever possible, these datasets have been made to fit the basin boundaries (for example, in estimating the total water infrastructure or large industries in the basin) but, in many cases, this was not possible. In such cases, a factor was applied to district-wise data which represents the proportion of the district's area that falls within the boundaries of the Mahanadi Basin. The proportions for each district are given in Annexure 7.

Methodology and Data Inconsistencies

Given that primary data collection for this report was undertaken for only two project sites, it must be understood that some of the report's findings for the Mahanadi Basin are based on extrapolations of known data (for example, water allocations from major and medium surface water projects across the basin is estimated from known allocations from four projects in the basin).

Data is not consistent across different data sources. In fact, though the area of the basin as per the Ministry of Water Resources is 141,589 km², the area revealed by land use statistics maintained by Chhattisgarh and Odisha is about 146,210 km². If we add the corresponding land use statistics for Jharkhand, Maharashtra and Madhya Pradesh, this difference will be even higher. Analysis using geographical information system (GIS) shows the area of the river basin to be around 145,000 km². While the correct figures may be disputed for the purposes of the analysis in this report, what is important is the figures for irrigated area, classified by season, source and crop. These base irrigation figures allow us to estimate the total volume of water used for irrigation in the river basin. If the figures taken within this report need to be corrected, the same formulae can be applied to refine the estimate of volume. Similarly, the estimates for industrial allocations and use of water can be further refined if newer information becomes available. In the absence of this, however, we adhere to the available data.

Other data related anomalies are footnoted at various sections in the report. Assumptions have been stated where data gaps were observed.

Stakeholder Consultations

While an effort was made to involve a wide and diverse array of stakeholders, there were limitations faced in approaching certain stakeholders, especially industrial representatives. Representatives of thermal power plants as well as industrial federations declined to meet or share their data on water management within their sector. Other stakeholders including media, government and academia, were consulted in detail although this

required individual meetings in most cases, due to their unavailability for attending larger stakeholder consultations. Farmer groups were consulted at larger stakeholder meetings as well as through field visits.

Report Roadmap

This first chapter of the report introduces the study and discusses the methodology used. Following this, the second chapter details the profile of the Mahanadi river basin and sets the context for further exploring water use in the agricultural and industrial sector. The third chapter is a review of the policies, laws and institutions, primarily at the state level, that have shaped water allocations in the Mahanadi Basin.

The fourth and fifth chapters are case studies on the interplay between the agricultural and industrial sectors over water at two chosen locations in the basin, the Minimata Bango project in Chhattisgarh and Hirakud project in Odisha, where there is potential or recent conflict due to the close proximity of these competing users.

The sixth and seventh chapters use secondary data to take a detailed look at agricultural and industrial trends in the river basin as a whole.

The eighth chapter contains a discussion on established potential water saving practices, both in the agricultural and industrial sectors, as relevant to the Mahanadi Basin. It explores what practices on the ground would need to change to see them implemented successfully, while also acknowledging the limitations of such water saving practices. The chapter also attempts to further project the implications of current developmental trends for water use in the Mahanadi Basin and explores alternate scenarios where water saving practices are implemented.

The ninth and the final chapter wraps up the report, with recommendations for the development of norms for more sustainable and equitable use of water allocations in the river basin.

2

Profile of the Mahanadi River Basin

In this chapter, a general overview of the characteristics of the Mahanadi river basin is provided with a focus on land use and water resources availability and development. This is intended to set the context for a discussion on the nature of inter-sectoral water use in the basin, which is delved into detail in later chapters. For a detailed profile on the Mahanadi Basin, one may look at the ‘Mahanadi Basin Situation Analysis’ (Forum for Policy Dialogue on Water Conflicts in India, 2017), which presents a wholesome picture of the Mahanadi Basin and different issues in the basin.

The Mahanadi Basin lies almost entirely within the states of Chhattisgarh and Odisha, in Central and Eastern India. The river Mahanadi starts out near Pharsiya village in the hilly, largely tribal, forested regions of Southern Chhattisgarh and initially flows in a northern direction, down into the plains of Central Chhattisgarh, before veering east towards the state of Odisha, where it flows down into the plains, flanked both on the northern and southern sides by forested zones, and then into its large delta region before meeting the Bay of Bengal. The river drains a basin of about 142,000 km² which is one of the larger river basins in peninsular India. The Seonath (also known as Shivnath) is the Mahanadi’s largest tributary, joining the river in the plains; the Hasdeo and Mand are also major tributaries that flow north to south and join the Mahanadi in Chhattisgarh. The Ib, Ong, Tel and Jonk rivers join the Mahanadi in the state of Odisha. The Tel and Ib rivers are the second and third largest tributaries of the Mahanadi, respectively, with the Tel joining on the right bank of the Mahanadi, downstream of the Hirakud reservoir and the Ib joining upstream of the Hirakud, on the left bank.

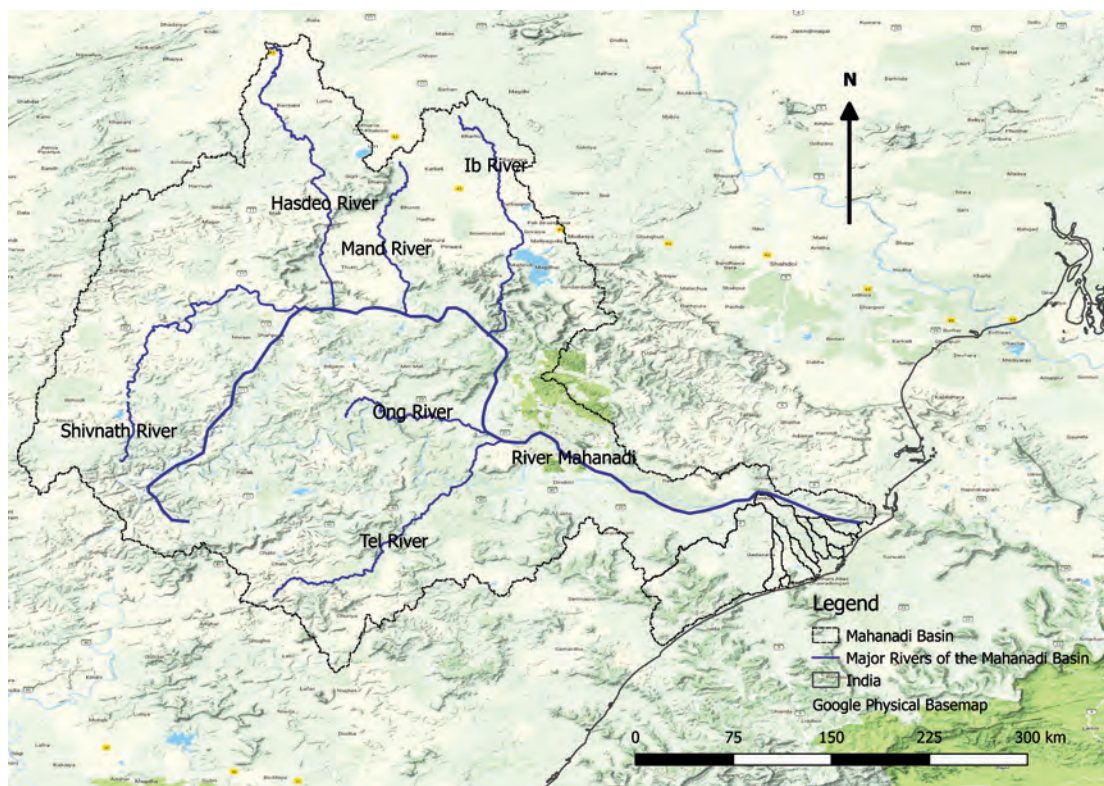
Table 2: Characteristics of the Mahanadi Basin

Total area	About 141,589 km ² (73,214 km ² in CG and 65,847 km ² in OD, 2,528 km ² across Jharkhand, Maharashtra and Madhya Pradesh) [1]
Length of River	851 km [1]
Average Annual Runoff	66.8 BCM [3]
Major Tributaries	Seonath, Hasdeo, Mand, (CG) Ib, Ong, Tel and Jonk (OD) [1]
Major Water Resource Projects	Hirakud Reservoir, Minimata Bango Project (Minimata Bango reservoir and Hasdeo Barrage), Mahanadi Reservoir Complex (Ravishankar Sagar, Murrum Silli, Dudhawa Reservoirs)
Population	38,660,665 [2]

Social Composition	16.5% (Scheduled Castes), 19.2% (Scheduled Tribes) [2]
Employment	30% - Cultivators, 27% - Agricultural Labourers, 3% - Industrial Workers
Rainfall	1291 mm [2]
Soil	Red and Yellow Soils
Major Crops	Rice, Gram, Khesari
Irrigation	76 Projects (22 Major and 54 Medium), estimated 1711 Th Ha of culturable command area under major projects ³
Major Cities	Raipur, Bilaspur (CG); Bhubaneshwar, Cuttack (OD)
Major Industries, Industrial Zones	Thermal Power, Iron and Steel, Mining (Coal and Bauxite)

Sources: [1] Central Water Commission, 2011 [2] Ministry of Water Resources, 2014 [3] Central Water Commission, 2012

Figure 1: Rivers of the Mahanadi Basin



Source: Derived from the Digital Elevation Model of the Mahanadi Basin (GTOPO) by analysis in QGIS.

3. Culturable command area of Odisha's Mahanadi Basin projects is uncertain because of lack of information in the public domain.

The major crops grown in the river basin are rice in the Kharif season and gram, khesari and vegetables in the Rabi season. The region has red or yellow soils and the annual average rainfall is 1291 mm. The major water resource projects, two of which have been studied in this report, are the Hirakud project in Odisha and Minimata Bango in Chhattisgarh. The river basin has an abundance of thermal power projects, iron and steel, and mining which are the major industrial sectors of the two states.

A total of 38.6 million people are estimated to live in the total area of 142,000 km² of the Mahanadi Basin, with a density of 271 people per km². About 77 per cent of the population of the basin is rural. Of the basin's total population, 30 per cent are cultivators and 27 per cent are agricultural labourers. Both these groups have decreased in proportion to the total employed since the 2001 census. About 19 per cent of the population belongs to the Scheduled Tribes and 16 per cent to the Scheduled Castes. This proportion of tribals is much higher than the average in India (about 8 per cent) because of the larger proportion of forests that fall within the basin. These tribal groups are especially vulnerable to new expanding mining and industrial development in the basin.

Agricultural Land Use

The cumulative area of the basin emerging from the analysis of land use statistics given by the Ministry of Agriculture (MoA) is about 14,695 Th Ha.^{4,5} The dominant land use in the Mahanadi Basin (Directorate of Economics and Statistics, MoA) is agriculture, with approximately 40 per cent of the land area (5820 Th Ha in total, 3251 Th Ha in Chhattisgarh and 2569 Th Ha in Odisha) of the basin counted as 'Net Area Sown'.^{6,7}

The cultivable uncultivated land (i.e. culturable wasteland + fallow lands) stands at 7.1 per cent (438.2 Th Ha in Chhattisgarh and 601.9 Th Ha in Odisha) of the basin area. Non-agricultural land is about 1129.7 Th Ha or 7.6 per cent (610 Th Ha in Chhattisgarh and 519.7 Th Ha in Odisha)

4. The total area and area under different land classes in the river basin varies according to different sources. The Water Resources Information System web portal of the CWC, MoWR notes the area to be 14158.9 Th Ha whereas the Mahanadi Basin Report also published by the CWC, MoWR notes the area to be 13968.1 Th Ha. Hence, the inconsistency across different sources is one problem that had to be dealt with. The Land Use Statistics, MoA dataset was chosen as the basis for determining land use trends since it is the only available source for cropping and irrigation trends as well. Wherever issues of data consistency have arisen, they have been pointed out in the footnotes of this document.
5. The Land Use Statistics of the Mahanadi Basin were compiled taking the selected 37 districts of the two states and taking the value for each land class and multiplying by the percentage area of the district that lies within the Mahanadi Basin. This method has its shortcomings since the land classes in each district are not spatially distributed uniformly. However, it gives a reasonable approximation for our understanding.
6. The land use statistics (LUS) for Odisha pertain to 2008-09 since the Odisha dataset is inconsistent after this year. The LUS for Chhattisgarh is updated to 2013-14. One inconsistency due to the incompatibility between datasets is that Net Area Sown (NAS) appears to be less than area under Kharif crops in both the states, an issue that could not be reconciled. Hence, this LUS data must be used with caution.
7. Forest area is 2974 Th Ha and 2400 Th Ha in Chhattisgarh and Odisha respectively.

Table 3: Agricultural Land Use Statistics by the Ministry of Agriculture

Land Use Class	Chhattisgarh (2013-14) (in Th Ha)	Odisha (2008-09) (in Th Ha)	Mahanadi Basin (in Th Ha)
Net Area Sown	3251.7 (41.2%)	2569.4 (37.7%)	5821.1 (39.6%)
Cultivable Uncultivated	438.2 (5.5%)	601.9 (8.8%)	1040.1 (7.1%)
Agricultural Land = Net Area Sown + Cultivable Uncultivated	3689.9 (46.7%)	3171.3 (46.6%)	6861.2 (46.7%)
Total Cropped Area	4110	4319.5	8429.5
Total Reporting Area	7888.5 (53.6%)	6806.5 (46.3%)	14695

Source: Ministry of Agriculture, 2000–2012

Due to the possibility of large errors in this MoA dataset, arising from the method of data collection, land use classes were also verified using a composite land use map generated by the National Remote Sensing Centre (NRSC) from satellite images of the Mahanadi river basin. The results obtained are given below. The thematic land use map of the NRSC shows the Mahanadi Basin as being largely under agricultural land use, with about 6871.9 Th Ha (48 per cent) of its geographical area cropped.⁸

Table 4: Agricultural Land Use Statistics by the NRSC

Mahanadi Basin	% of total geographical area (in 2004-05)	% of total geographical area (in 2013-14)
Net Area Sown (Kharif only and Double/Triple cropped)	42.9 (6147.6 Th Ha)	48 (6871.9 Th Ha)
Current fallow	17.3 (2474.9 Th Ha)	10.8 (1550.7 Th Ha)
Total Geographical Area	14324 Th Ha	14324 Th Ha

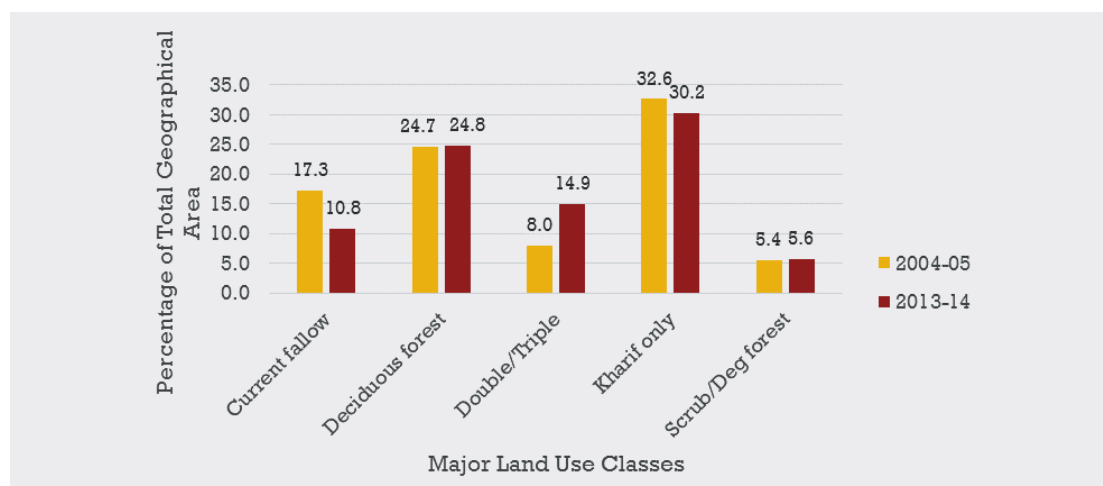
Source: National Remote Sensing Agency, 2013-14

8. Source: Land use land cover (LULC) Thematic Maps (2004-05 to 2013-14) (1:250k) Bhuvan Thematic Series, National Remote Sensing Centre, Hyderabad. (Analysis done with the QGIS, Semi-automatic classification plugin tool). The NRSC figure is substantially larger than the 5821 Th Ha Net Sown Area as given by the MoA dataset and could help reconcile the inconsistency. However, even the NRSC data cannot be assumed to be perfect—the accuracy of these maps varies and is about 79 per cent for cropped lands and 98 per cent for water bodies.

In the last decade, since 2004–05, land cropped in the Kharif season only (i.e. largely rainfed land) has decreased marginally to 30 per cent and land cropped multiple times (i.e. land having access to some form of irrigation) has increased substantially, from about 8 per cent to 15 per cent. The largest increases in irrigated land are in the plains of Chhattisgarh, with the development of major irrigation projects in the upper reaches of the Mahanadi and the Seonath rivers. Fallow lands in the basin have decreased from about 17 per cent to about 11 per cent (1550.7 Th Ha) of the total geographical area in the last five years or so. This is in contrast to the MoA data which shows that fallow + culturable wastelands are about 7 per cent (1040.1 Th Ha) of basin area.

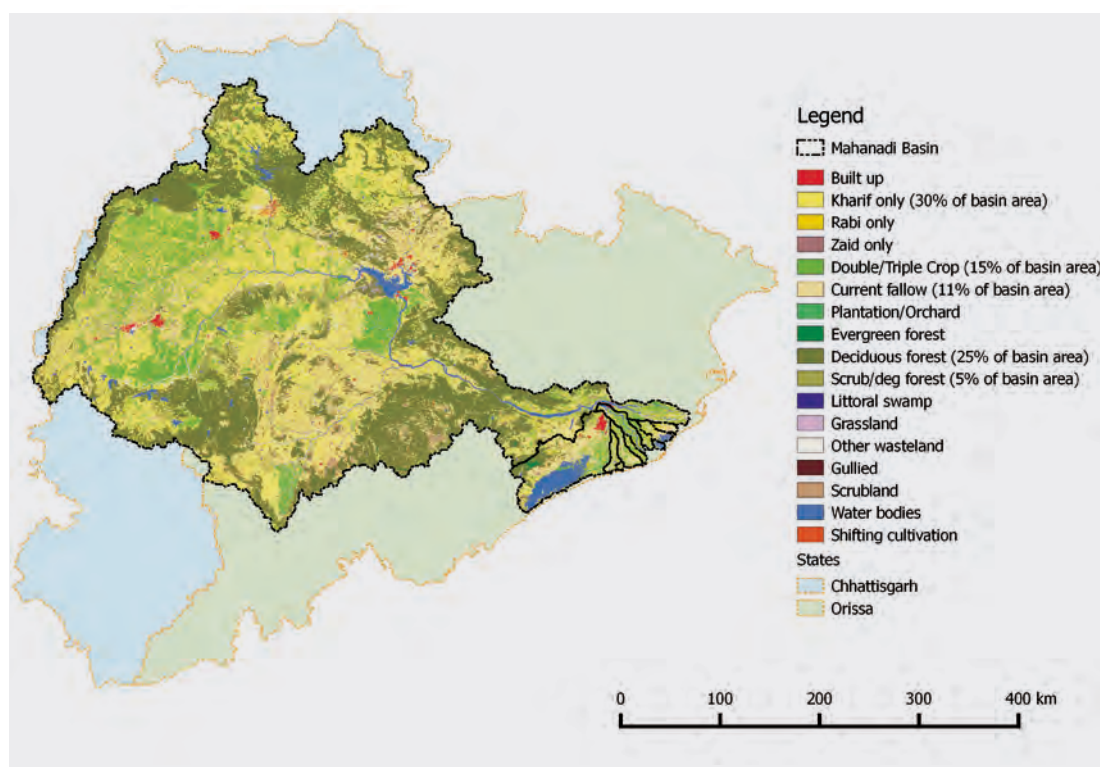
The comparison of land use classes given by both the NRSC as well as MoA datasets shows differences, even in the major classes. The NRSC shows that the double/triple cropped area (i.e. irrigated area) has gone up, while net area sown has also gone up, indicating that existing agricultural land is being brought under more intensive cultivation with the assistance of irrigation. For our understanding of actual land use and land cover in the basin, the figures produced by the NRSC provide only a point of reference. Land use classification data made available by the MoA, however, need not necessarily correspond to the actual land use, since for any given plot of land, the land use might change while the classification on paper may remain the same.

Figure 2: Trends in Land Use in the Mahanadi Basin (NRSC)



Source: Derived from LULC maps obtained through Bhuvan Thematic Services by analysis in QGIS, National Remote Sensing Agency, 2013-14

Figure 3: Land Use Map of the Mahanadi Basin



Source: National Remote Sensing Agency, 2013-14

Water Resources: Availability

The average annual flow in the Mahanadi is estimated to be 66.88 BCM and the average annual flow at Tikarpara, the last gauging station⁹ in the basin, is 47.5 BCM.¹⁰ Of this total annual average flow, about 50 BCM is said to be utilisable (Central Water Commission, 2013, p. 5). When taking into account the population of the Mahanadi river basin, the per capita utilisable water is much higher than other major peninsular rivers such as the Godavari, Krishna and Cauvery rivers. By modeling estimates, the annual natural flows (if storage reservoirs were absent) was estimated at about 77 BCM for 1972 and 81 BCM for 2003 (Dadhwal, Aggarwal & Mishra, 2010). In comparison, the 2007 Jeyaseelan report, by the Government of Odisha (GoO), suggests that the average annual flows add up to 59.16 BCM (29.90 BCM from the catchment in Odisha and 29.26 BCM from Chhattisgarh's catchment) (Water Resource Department, GoO, 2007). Of this, 32.2 BCM (average value up to 2013-14) is the annual inflow into the Hirakud reservoir, which lies just within Odisha near the Chhattisgarh border.

9. Although Tikarpara in Angul district is the last gauging station in the basin it is still far from the delta region itself. Hence the catchment area at Tikarpara and annual flow at Tikarpara is much less than the estimated annual flow in the entire Mahanadi Basin.

10. 75% dependable flow at Tikarpara (1972–2011) is 27.7 BCM.

The inter-annual flow in the river is also highly variable, being as low as 20 BCM to as high as 70 BCM (Central Water Commission, 2012, p. 168). At 75 per cent dependability, annual flows in the Mahanadi are 53.78 BCM (Ministry of Water Resources, 1999).

Though the figure for average annual flows is not undisputed¹¹ in the remainder of this report, we rely on the Central Water Commission (CWC) figures for mean average annual flow to discuss inter-sectoral allocations.

Table 5: Surface Water Availability and Storages in Major Peninsular River Basins

River	Catchment Area (km ²)	Population (2010) in million	Average Water Resources Potential (in BCM)	Utilisable Surface Water Resources (in BCM)	Surface Water Storages (in BCM) including projects under construction (2013)
Mahanadi	141,589	36	66.88	50	14.46
Godavari	312,812	74	110.54	76.3	43.4
Krishna	258,948	83	78.12	58	54.8
Narmada	98,796	20	45.64	34.5	24.45
Cauvery	81,155	40	21.36	19	9.09

Source: Central Water Commission, 2013, pp. 5,33,34

Long term data from 1900 to 2004 also shows a reduction in precipitation in the Mahanadi river basin as a whole (Forum for Policy Dialogue on Water Conflicts in India, 2017, p. 5). There has also been significant reduction in rainfall during the time period from 1951 to 2004 (Ghosh et al., 2016). In one study of long term seasonal rainfall patterns (1871–2005), Chhattisgarh stands out as the region that shows the largest long term decrease in rainfall of about 1.33 mm/year (Kumar, Jain & Singh, 2010). Spatial variation is also substantial in changing precipitation patterns: the northern parts of the river basin over the forests of Odisha and Chhattisgarh show a substantial decline in annual rainfall whereas the delta area of the Mahanadi shows an increase (Asoka, Gleeson, Wada & Mishra, 2017). Long term models also predict a trend in the temporal variation of precipitation during the course of the year (Asokan & Dutta, 2008).

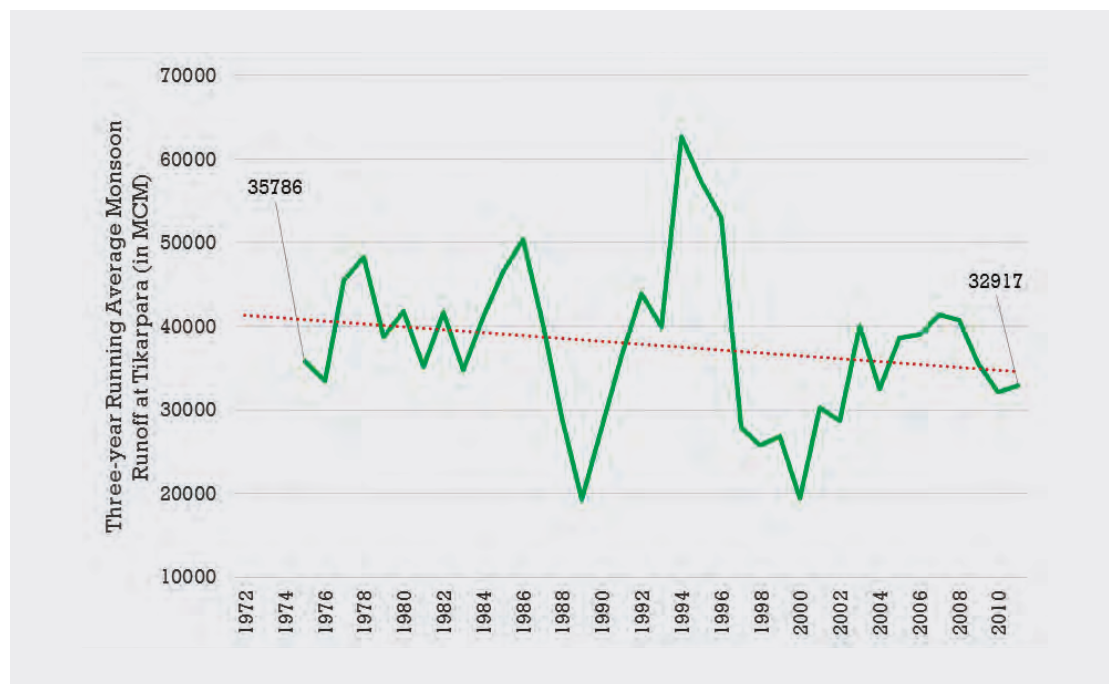
A recent study by Indian Institute of Technology (IIT) estimates a 10 per cent reduction in annual flows in the Mahanadi river basin as a result of precipitation changes since 1951 (Ghosh et al., 2016). Though the annual flows have reduced the increasing frequency of extreme rainfall events and reducing forest cover act as drivers that contribute to increased runoff. One study that developed future projections based on precipitation projections showed that monthly runoff in September, for example, is expected to increase by an average of 38 per cent during 2075–2100 and runoff in April would decrease by 32.5

11. Other sources have estimated by modeling approaches the average annual flow to be 88 BCM and 135.8 BCM for the period 1951–80 (Zade, Ray, Dutta, & Panigrahy, 2005; Gupta, Panigrahy, & Parihar, 2011).

per cent by 2050–2075 (Asokan & Dutta, 2008). Another study which uses a hydrological model to estimate the effect of change in land cover on flows, found that changing land cover, primarily from forest cover to agriculture, can be attributed to have increased flows by 4.5 per cent in the time period 1972–2003 in the Mahanadi Basin (at Mundali in the delta) (Dadhwal et al., 2010).

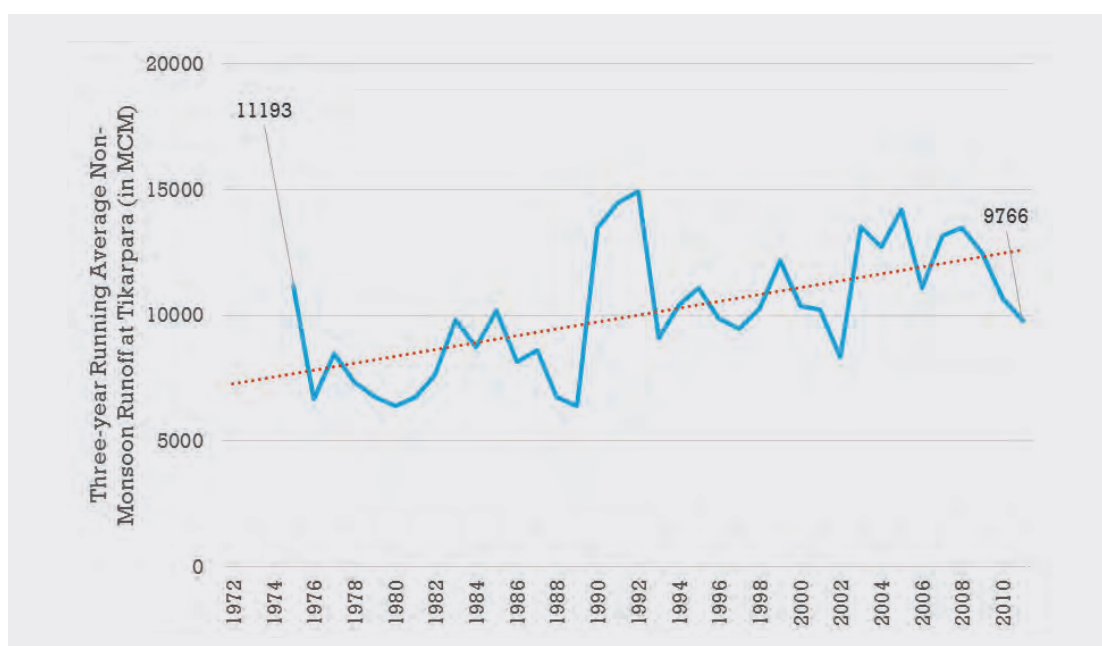
While these different factors affect the annual water availability in their own ways, the primary factor affecting annual flows is long term trends in the human use of water for irrigation and industrial use. To examine the cumulative trend in river basin flows, due to human uses as well as land use and climatic factors we analysed the discharge data from Tikarpara gauging station, the station closest to the Mahanadi delta, where data was openly available. This data, available for the period from 1972 to 2011 shows a very marginal decline in the long term annual runoff. When we disaggregate this trend seasonally, we see a substantial decrease in monsoon runoff and an increase in the non-monsoon runoff (See Figures 4 & 5). This could be a consequence of increased storage in reservoirs which is released in the non-monsoon season.

Figure 4: Three-year Running Average Monsoon Runoff at Tikarpara



Source: Hydrological Gauge Station Data, CWC, uploaded to Water Resources Information System, Central Water Commission, 2016a

Figure 5: Three-year Running Average Non-monsoon Runoff at Tikarpara



Source: Hydrological Gauge Station Data, CWC, uploaded to Water Resources Information System, Central Water Commission, 2016a

Water Resources: Development

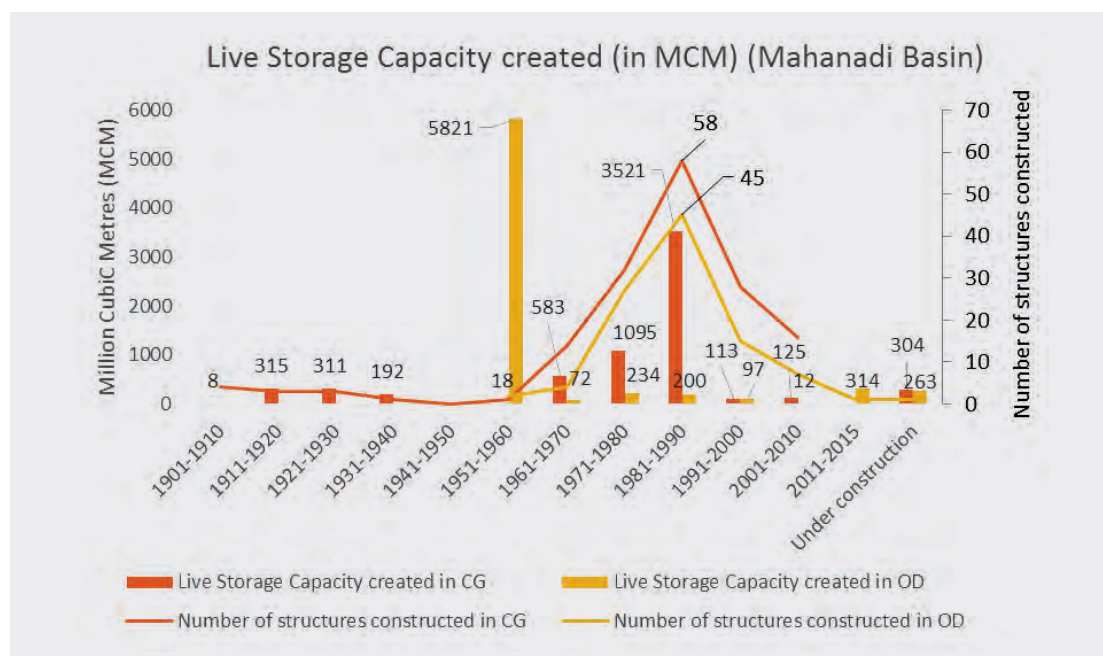
About 13 BCM of storages had been created by 2013 with another 1.46 BCM under construction (Central Water Commission, 2013). More projects were under consideration which would together result in a total of 24 BCM or 36 per cent of the surface waters of the Mahanadi being stored (Central Water Commission, 2012). Our own estimation shows that, by 2014, the storage completed was 13.72 BCM, 6.61 BCM in Chhattisgarh and 7.11 BCM in Odisha (not including the barrages in the delta)¹².

The Chhattisgarh portion (or erstwhile Madhya Pradesh half) of the Mahanadi Basin, witnessed the development of its water resources much earlier than Odisha, with several large dams (much smaller in capacity than Hirakud) being constructed in the pre-independence era. The Tandula Tank constructed on the Tandula river (a tributary of the Seonath) in the Durg district and completed in 1920, was the largest dam in terms of live storage capacity of about 312 MCM. The Murrum Silli (162 MCM) in the hills where the Mahanadi originates and the Maniyari (148 MCM) and Kharang dams (in the Seonath basin) were built in 1923, 1930 and 1931, respectively. The Dudhawa (284 MCM) and Ravi Shankar Sagar (767 MCM) were completed in 1963 and 1979, respectively and together with the Murrum Silli form the 'Mahanadi Reservoir Complex'. This Mahanadi

12. Based on data from the National Register of Large Dams (2014), WRD (Chhattisgarh) and Water Resources Information System of India (CWC).

Reservoir Complex irrigates large areas of the districts of Durg, Dhamtari, Raipur whereas the Maniyari and Kharang tanks irrigate the district of Bilaspur, which constitute the majority of the plains of Chhattisgarh.

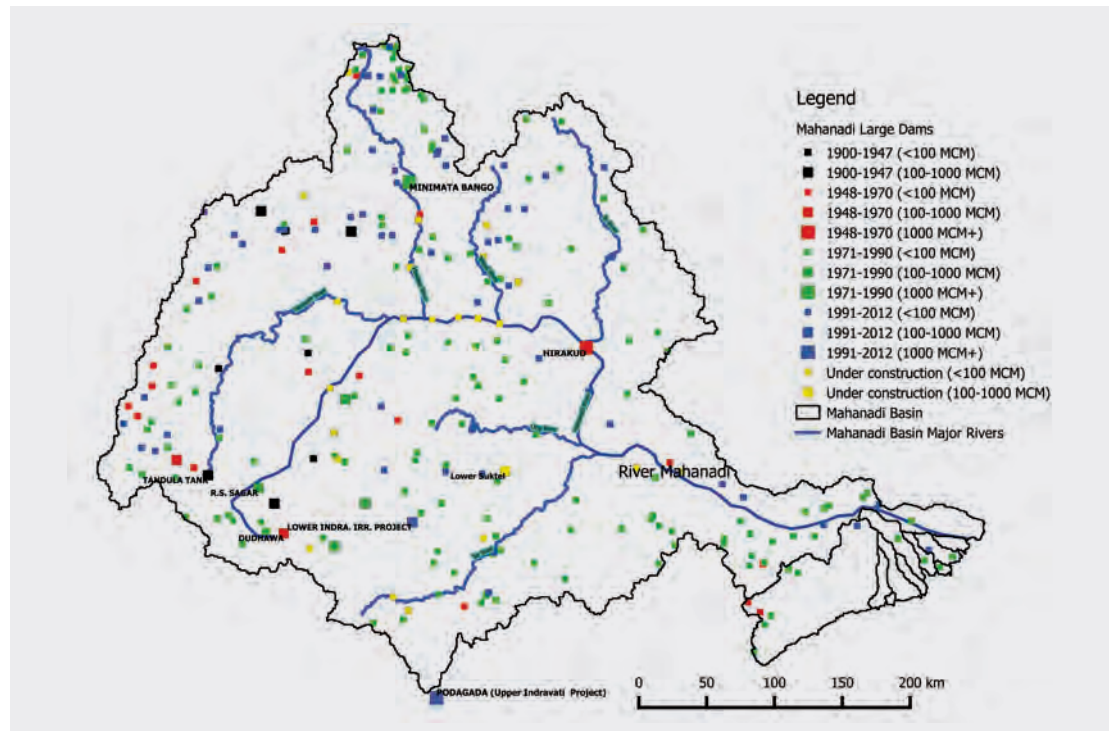
Figure 6: Live Storage Capacity in the Mahanadi Basin (MCM)



Source: Central Water Commission, 2014; Water Resources Department of Chhattisgarh, 2015; Central Water Commission, 2016b

The Minimata Bango (3046 MCM), the largest irrigation project in Chhattisgarh, was completed in 1990. It largely serves the district of Janjgir-Champa. The first and largest dam in Odisha and in the Mahanadi Basin was the Hirakud dam (5818 MCM), completed soon after independence in the year 1957. It serves the districts of Bargarh, Sambalpur and Sonepur in Odisha. Odisha saw a spurt of large dams built in India's big dam era, between 1970 and 1990. Similarly, Chhattisgarh saw many large dams built in Kanker, Rajnandgaon and especially in the Koriya district in the Upper Hasdeo Basin. In comparison, the post liberalisation era until 2012, has not seen the completion of very large projects (Live Storage Capacity [LSC] > 1000 MCM). The most recent large project being the Lower Indravati dam (314 MCM). One inter-basin transfer of water, through the Upper Indravati Project, which consists of a series of dams on the Indravati River (just south of the Mahanadi Basin), supplies water for irrigation to Kalahandi district. Altogether, the CWC lists 253 dams and 24 barrages/weirs/anicuts in the Mahanadi river basin. Of these structures, 74 of them are either major or medium irrigation projects, covering a potentially gross irrigable area of 32.8 Lakh Ha, 15.4 Lakh Ha in Odisha and 17.4 Lakh Ha in Chhattisgarh. This is 40 per cent of the 82.3 Lakh Ha Gross Cropped Area (GCA) in the river basin.

Figure 7: Large Dams and Major Irrigation Projects in the Mahanadi Basin



Source: Central Water Commission, 2014; Water Resources Department of Chhattisgarh, 2015; Central Water Commission, 2016b

This report does not delve in depth into groundwater resources availability and development. However, a preliminary understanding of groundwater resources, based on secondary data of the Central Groundwater Board (CGWB) reveals highest degree of groundwater development in western Chhattisgarh and the delta region of the basin. At the same time, groundwater use in the plains of Chhattisgarh is moderate and increasing, and, in central and western Odisha, is still relatively low, owing largely to the nature of the low yielding hard rock aquifers in these regions. These conclusions generally agree with the data on irrigation and cropping, which is analysed later in this report (Forum for Policy Dialogue on Water Conflicts in India, 2017, p. 28).

Agriculture

The two states of Chhattisgarh and Odisha are largely agricultural economies and the Mahanadi river basin is important to both from an agricultural standpoint. Rice is by far the most dominant crop in both the states, even more so in irrigated areas due to its water intensive nature. Agriculture in the Mahanadi Basin in Chhattisgarh is concentrated in the western uplands (Kawardha, Rajnandgaon, Bilaspur) and central plains (Durg, Dhamtari, Raipur, Mahasamund, Janjgir-Champa). In Odisha, agriculture is extensive in the western districts (Balangir, Bargarh, Nuapada and Subarnapur) and coastal parts (Cuttack,

Jagatsinghpur and Puri) of the state. In these regions, agriculture is supported by large-scale irrigation infrastructure, through major and medium projects. The northern and southern extremes of Chhattisgarh as also the central regions of Odisha in the Mahanadi Basin are more heavily forested and have smaller-scale rainfed farming systems.

Cropping trends show that the gross cropped area in Chhattisgarh has increased since the formation of the state in 2000, with both the Kharif and Rabi seasons showing increases in area sown. In Odisha, the opposite trend is observed, gross cropped area has decreased, largely due to a fall in the Kharif sown area. Pulses are gaining in importance in Chhattisgarh as well as in Odisha, with the area under gram and khesari on the rise. Area under oilseeds and vegetables in Odisha has however decreased. Irrigated area in both the states has increased but Chhattisgarh shows a stronger shift towards groundwater irrigation as compared to Odisha where surface irrigation projects have increased the area irrigated. Flood irrigation as a technique is most common in irrigated areas, especially in the Mahanadi Basin, which potentially offers much room for water savings.

Industry

Both states in the Mahanadi Basin are rich in natural resources which have made them hubs for extraction of mineral resources and production of thermal power and iron and steel, among other goods.

Industry like thermal power is concentrated in certain regions of the river basin. Chhattisgarh is a power hub of India, with 14982 MW being the third largest state in terms of installed coal power capacity after Maharashtra and Gujarat. Odisha also has a large capacity of about 7103 MW.

Mining is predominantly seen in the forests of northern and southern Chhattisgarh in the Koriya, Surguja, Raigarh and Bastar districts and in the Angul, Keonjhar, Sundargarh and Jharsuguda districts of Odisha. Coal mines dominate the districts of Surguja, Koriya and Raigarh in Chhattisgarh and Angul and Jharsuguda in Odisha. Bauxite is found predominantly in Bastar in Chhattisgarh and Keonjhar in Odisha. Both states produce about 20 per cent each of India's coal. Chhattisgarh produces about 20 per cent of the country's iron ore and 20 per cent of its cement as well. Odisha produces the lion's share, about 50 per cent of India's iron ore.

Sponge iron is a rapidly growing industry in Odisha, and steel manufacturing is already widespread in both the states. Raipur (Tilda, Urla & Siltara), Bilaspur (Sirgitti, Dagori & Silpahari) and Durg (Borai) districts are home to large industrial areas in Chhattisgarh aside from the Korba and Raigarh districts, which also have larger concentrations of industries. Vedanta, ESSAR, LANCO, Jindal, Monet, DB Power, National Thermal Power Corporation (NTPC), Steel Authority of India Limited (SAIL) and Bharat Aluminium Company Limited (BALCO) are just some of the companies operating in these states in mineral extraction, ore processing, power and steel production sectors.

Water Conflicts in the Mahanadi River Basin

Despite being one of the river basins which receives an annual average of almost 1291 mm of rainfall, above average in comparison with the rest of peninsular India, the Mahanadi Basin still has its fair share of conflicts over water. However, the availability of water may be less of a concern than its ease of access (due to competing users) and the quality of water. Until about the 1980s, the agricultural sector was largely uncontested for water resources by urban and industrial water demands. Contestations prior to this arose most often in the context of inadequate compensation and rehabilitation for project-affected families whose lands were submerged under reservoirs of irrigation projects. The Ravi Shankar Sagar dam in Chhattisgarh and the Hirakud dam in Odisha were some of the earliest examples. Project affected persons in the Ravi Shankar Sagar dam still continue their fight for adequate compensation, even after 42 years of its construction. The case of Hirakud dam is similar, wherein families displaced more than 60 years ago, still await compensation. The Ong medium project and Lower Suktel major irrigation projects are more recent examples of displacement leading to conflict. While each of these projects have ostensible benefits in terms of area irrigated, the fact of inadequate compensation and rehabilitation is still unsettling.

Water use even for irrigation until the 1980s was heavily skewed towards surface water sources, including canals and tanks which served most of the gross irrigated area in Chhattisgarh and Odisha. Since then the extent of irrigation potential created in both the states has rapidly expanded, with an emphasis on groundwater development. Since the 1990s, industrial and urban water demands have risen sharply. The most immediate contestations between these two sectors are being seen around surface water sources, primarily large dams that service major irrigation projects. Industrial water pollution also affects the usability of water sources for domestic water and causes conflict. Most notably, the Hasdeo, Mand and Ib river basins where a lot of mines and thermal plants operate face severe water pollution issues.

While urban water demand has not impacted the availability of water for agriculture, the incidences of indiscriminate sand mining in river beds across the basin to facilitate construction in urban areas is a cause for concern. The main stem of the Mahanadi in Kanker district witnessed local protests against sand mining in 2015-16. Similarly, incidents of illegal sand mining on the bed of river Kelo, bordering Chhattisgarh and Odisha, were reported in 2016.

Inter-state water issues are emerging in the basin, with Odisha objecting to several upstream projects in Chhattisgarh, including many large barrages under construction for industrial water allocations on the main stem of the Mahanadi, which it is said will affect inflows into the Hirakud project on which many farmers depend (The Pioneer, 2016). Though the capacity of these barrage reservoirs is only about 274 MCM¹³, their location

13. This figure is taken from on the data collected by the intern working with Forum. However, the figure is contested by the various stakeholders in the basin.

in the river basin is such that their annual yield is much larger and therefore annual use can be potentially much larger than their storage capacity. This conflict reached a crisis point in 2016 after a drought year led to severe water scarcity in Odisha and the water in Hirakud reservoir itself was not enough to meet all the competing demands. For several decades prior to this, no discussions on inter-state water allocations were felt needed by either state. A decision was taken in 1983 by Madhya Pradesh and Odisha to constitute a joint control board (JCB) to hold discussions on inter-state water projects to resolve conflicts. However, the resulting MoU between the two was never implemented (Memorandum of Agreement between Madhya Pradesh and Odisha, 1983). In 2016, matters escalated far too quickly for a successful inter-state dialogue. In September 2016, both the states, in discussions that were mediated by the Ministry of Water Resources (MoWR), presented contesting data about the actual annual use from these barrages, leading to the failure of the talks between them (Central Water Commission, 2016c). Later, Odisha filed a request for setting up a tribunal as per the Inter-State Water Disputes Act, 1956 (New Indian Express, 2016 & 2017). Odisha has gone even further to file an injunction plea against Chhattisgarh in the Supreme Court while the Centre decides on the formation of a tribunal (Times of India, 2016). Odisha also objects to the transfer of water by Chhattisgarh much further upstream on the Mahanadi from the Gangrel reservoir to Tandula.

Chhattisgarh also faces multiple questions on whether the extent of water being allocated to the industries has been considered for its holistic impact on the river. By some estimates, an additional 2700 MCM of water is the amount required for proposed projects in the state (Down to Earth, 2010). When this is considered in addition to an estimated 1000 MCM of water already allocated, it forms a large fraction of approximately 30,000 MCM of surface water availability in the Mahanadi river basin in the state. In Odisha too, farmers object to the state for allowing barrages for industrial water use, especially on the main stem of the river (Mahapatra R. , 2011). The Athamalik sub-division of Angul district is one such example where the deprivation of farmers continues while industries benefit, both from the Mahanadi and Brahmani rivers. This has led to shutdowns, to protest the allocations to industries, notably against allocation to JR Power in 2010. Farmers in the delta region also face issues with silted canals being unable to carry water to some fields, with water allocations to industries from the Mahanadi barrage exacerbating this condition (Down to Earth, 2012).

It is likely that the reality of water conflicts in the river basin is far greater than that laid out above. Conflicts reported only in the regional media would not have been captured sufficiently in our literature review. However, there is enough news of water related conflicts to foretell a worrisome situation in the years to come.

3

Policy and Institutional Environment

Historically, agriculture has been a primary user of water stored in the majority of water resource projects in India. With increasing industrialisation and urbanisation, the demand for water for non-irrigation use is constantly increasing. This has given rise to conflicts between different sectors over water allocation. The Mahanadi river basin is no exception to this. However, in comparison to the other basins in India, the situation in the Mahanadi Basin is not as bad. It has been observed that the competition between industry and agriculture sectors for water has started increasing in the recent past. The emerging conditions show that the inter-state water conflict is coming to the forefront between two major riparian states, namely, Chhattisgarh and Odisha. Water being a state subject, the policies and the legal and institutional arrangements of the respective states not only impact the intra-state water resource management and allocations but also the inter-state issues of water resources. Keeping this in mind, an attempt has been made here to take a review of policy and legal frameworks governing the inter-sectoral water allocation in the Mahanadi Basin. Delving into the institutional structure helps in understanding the process of normative and technical decision-making. It also helps in understanding the nature of decision-making on allocation, in terms of democratic as well as bureaucratic instruments and mechanisms, which have long term consequences in governance and management of water resource. Analysis of the administrative framework and implementation process also helps in understanding the governance in practice.

Since hydrological boundaries differ from administrative boundaries, policies and other legal instruments are applicable to particular administrative boundaries, namely the state. Thus, an attempt is made to critically review the policy and legal frameworks governing inter-sectoral water allocation in the states of Odisha and Chhattisgarh through a detailed desk review of information available in the public domain. Through field observations, the team also tried to gather information on the same, besides trying to understand the processes of implementation.

Odisha

Water Resource Planning

The Orissa Water Planning Organization (OWPO), a nodal agency for planning water resource management in the state, under the Department of Water Resources (DoWR), had come up with a State Water Plan in the year 2004 (Department of Water Resources, Government of Orissa, 2004). The plan document takes year 2001 as the base year and makes an approximate estimate of the total water demand in Odisha till year 2051,

factoring issues like population growth and dynamics, irrigation and food security, industrial growth, environmental requirement (factored as 30 per cent of surface and 40 per cent of groundwater resources) and so on. The plan is a perspective document under which the water planning (and allocation) related decisions take place (Department of Water Resources, Government of Orissa, 2007a). As per the estimations in the plan, water resource availability in the state is and will be sufficient¹⁴ to satisfy the increasing demands from various sectors till the year 2051. It is assumed that by 2051, the population of Odisha will be at its peak, with no further net population growth¹⁵.

As per the projection, the total surface water requirement for various sectors in Odisha would be 64,152 MCM in year 2051 in comparison to 40,504 MCM in 2001, the base year. This is an estimated 58 per cent increase in the surface water demand; similarly, the plan predicts a 38 per cent increase in groundwater demand by the year 2051. Of the surface water, environmental needs are assumed to remain constant at 21,000 MCM. Agriculture demand is expected to grow from 18,000 MCM to 40,000 MCM, while industries would see an increased demand from 606 MCM to 1,750 MCM.

The feasibility of meeting this demand can be questioned, however, given that relatively insignificant surface water storage capacity has been added in the Mahanadi Basin in Odisha between 1990 to 2010. About 314 MCM of new capacity added since 2010 and another project of 263 MCM under construction shows that the effort to increase surface water storage is underway.¹⁶ The general trend observed in irrigation data in Odisha shows that minor lift irrigation projects and groundwater use have become much more prominent in irrigation. The plan also does not look realistic if we consider, for example, the current water use by industry.

State Water Plan

The Orissa State Water Plan (2004) was developed prior to the current water policy and cites that the document is a response to the 'expected provisions of the Orissa State Water Policy' being developed. The document identifies water-related issues that need to be addressed and proposes a coherent framework for the Government of Odisha to develop and undertake the interventions necessary to meet the needs of the water users while avoiding conflicts and maintaining the integrity of the environment'. It provides a roadmap for the water resource management in the state in terms of planning, projections, issues of sectoral demand and allocation, institutional mechanisms, legal and policy provisions. A detailed analysis of industrial water requirement at the basin scale, is one of the salient features of the water plan. However, the estimation and projections for water requirement for various sectors to some extent suffer from a lack of reliable and quality baseline data.

14. The estimation takes into account conjunctive development of surface + groundwater in terms of supply and demand.

15. The Plan assumes declining growth rate referring to National Population Policy, which aims to stabilize population by the year 2045.

16. See section in Chapter 2, Water Resources: Availability and Development.

State Water Policy

Considering the competing demands for a common pool of water resources, the State Water Policy provides the order of priority for water allocation in the state as follows:

- Drinking water and domestic use
- Ecology
- Irrigation, agriculture and other related activities including fisheries
- Hydro Power
- Industries including agro-based industries
- Navigation and other uses such as tourism

According to the ecology/environment requirement, such a high priority is laudable. This is in accordance with the Strategic Environmental Policy for Water Resources Planning and Development in Orissa, 2001 which states that the objective is 'to effectively integrate environment considerations in the development and implementation of the Integrated River Basin Plan . . . and operationalise the principles of sound environment planning in the water sector.' The Policy elaborates on various mechanisms to ensure water for drinking, domestic use, irrigation and industrial use as envisaged in the State Water Plan and for ecological needs. Water conservation, expansion of irrigation, improvement in irrigation delivery, participatory management of water resources, ensuring water quality etc. are some of the salient features highlighted in the policy. The State Water Policy also creates provisions for a perspective plan for development of water resources in the area, based on the available resources, people's needs, and preservation of ecological balance and enrichment of ecosystems. Other policies which have a bearing on the water resources are the State Agriculture Policy (2013), State Industrial Policy (2001 and 2015) and State Urban Water Supply Policy (2013).

Legal Instruments and Rules

Under Article 246(3) of the Constitution of India and entry 17 of List II of the seventh schedule, State Governments have the power to legislate in respect of 'water'. Two important legislations with respect to water resource management in the state are the Orissa Irrigation Act, 1959 (and amendments to the same in later years) and the Orissa Pani Panchayat Act, 2002.

Orissa Irrigation Act

The irrigation act primarily covers the legal aspect related to construction and maintenance of irrigation works. It also prescribes water supply mechanisms and the basic water rates to be made applicable to various class of irrigation system for which water is to be supplied by the Irrigation Department. However, with the 'Regulation and Use of Water from Government Water Sources' amendment in 1993, a mechanism to issue licences for industrial water use has emerged as we see in the detailed amendments to the Irrigation Rules in 2010 and 2015. As per the amendment, a new system for licensed allocation for

industrial and commercial purpose is brought into effect and it is projected as regulating such use for public interest. The amendment states that a Government Water Source means any water source created naturally or otherwise by collection or deposit of water at a fixed point any subsoil water or water in a running state such as rivers, nalas, springs, streams and alike, which is other than an irrigation work. The State Government may, in the public interest, regulate the use, diversion, collection or consumption of water from a Government Water Source for industrial and commercial purposes other than agriculture.

The amended rules prescribe that when any industrial, commercial or other establishment proposes to draw or lift water from a Government Water Source, (a) the Executive Engineer may earmark the bed and off-shore lands of the said water source free from encumbrances and set it apart for that purpose; (b) the Executive Engineer shall order installation of a Flow Meter or a suitable measuring device within a period of 90 days from the date of such order at the cost of the concerned industrial, commercial or other establishment to measure the quantum of water to be drawn from the water source.

Orissa Pani Panchayat Act

The Orissa Pani Panchayat Act, 2002, amended in 2008, proposes participatory irrigation management through irrigation beneficiaries as water users group known as Pani Panchayats. Initially, only landholders were part of this but the amendment in 2008 brought in the fisherfolk, who depend on water resources. The Pani Panchayat (PP) Rules 2003, amended in 2010, and 2015, elaborate various administrative and institutional mechanisms for the functioning of water user associations (WUAs) or Pani Panchayats. Studies show that even though the government was keen on having participatory irrigation management, the necessity for farmer participation arose from the government's assurance to the World Bank funded Orissa Water Resources Consolidation Project (OWRCP). As a component of this project, the Farmers Organisation and Turnover (FOT) programme has been given much significance. The main purpose of the FOT programme is to entrust some responsibility to the farmers through the formation of the WUAs or Pani Panchayats, which include the collection of water rates, distribution of canal water among water users, operation and maintenance of canals at lower levels such as minor, sub-minor and distributary (Mahapatra, 2006). This pilot was followed by the initiation of the Act leading to the transfer of tertiary irrigation networks (minor/sub-minors) to registered 'Pani Panchayats'. The responsibility of operation and maintenance (O&M) of the reservoir/diversion weir (as the case may be) dam, spillways, sluices, primary and secondary distribution networks etc. rests with the Department of Water Resources, whereas the responsibility of O&M of the tertiary systems (below minor/sub-minor) will be with the Pani Panchayats. The geographical extent of the programme covers the entire state, comprising of about 18.25 lakh hectares of major, medium & minor irrigation command areas in all the 30 districts of Odisha.

Orissa Industries Facilitation Act

Other relevant Acts which have a bearing on the water resources are the Orissa Industries Facilitation Act 2004 and its Rules enacted in 2005, along with its amendment of rules in

2015. They mainly deal with a single window clearance system for industry establishment and the government intends to facilitate various infrastructure facilities such as water, power, land etc. However, the onus of ensuring these facilities lies with the respective departments, such as the Water Services Unit under the DoWR for ensuring water allocations to industry. While the allocations to industry are cleared by the Water Services Department, they are also reviewed on an annual basis, based on the water availability in the relevant water structures. On some occasions, the water approved is less than the initially allocated amount—this process is called water rationalisation.

Institutions

Department of Water Resources

With the changing demand pattern, the Government of Odisha has also changed the institutional structures which manage water resources in the state, such as the Irrigation Department being converted to the Department of Water Resources in the 1990s. Surface water management have also undergone reforms under the World Bank funded 'Orissa Water Resources Consolidation Project (OWRCP)' programme with an aim to (a) improve the planning, management and development process for the state's water resources; (b) increase agricultural productivity through investments to improve existing schemes and complete viable incomplete schemes; (c) enhance the DoWR's institutional capability and, d) completion of dam safety work during 1994–2005 (Agriculture and Rural Development Unit, 2005). Under these structural reforms, water management is essentially changed from project-based management to basin-level management of water resources which include planning and development of water resources. The OWRCP also established various offices/institutions and processes such as the environmental cell, the environmental protection units to look after the clearances to safeguard the environment, OWPO, the river basin plans, the Integrated State Water Plan based on the river basin plans, the R&R directorate, the river basin organisations (RBOs) (Agriculture and Rural Development Unit, 2005). As a result, Odisha has become one of the first states in India to propose a bottom-up river basin planning, with basin as the hydrological unit for resource management as mentioned in the National Water Policy.

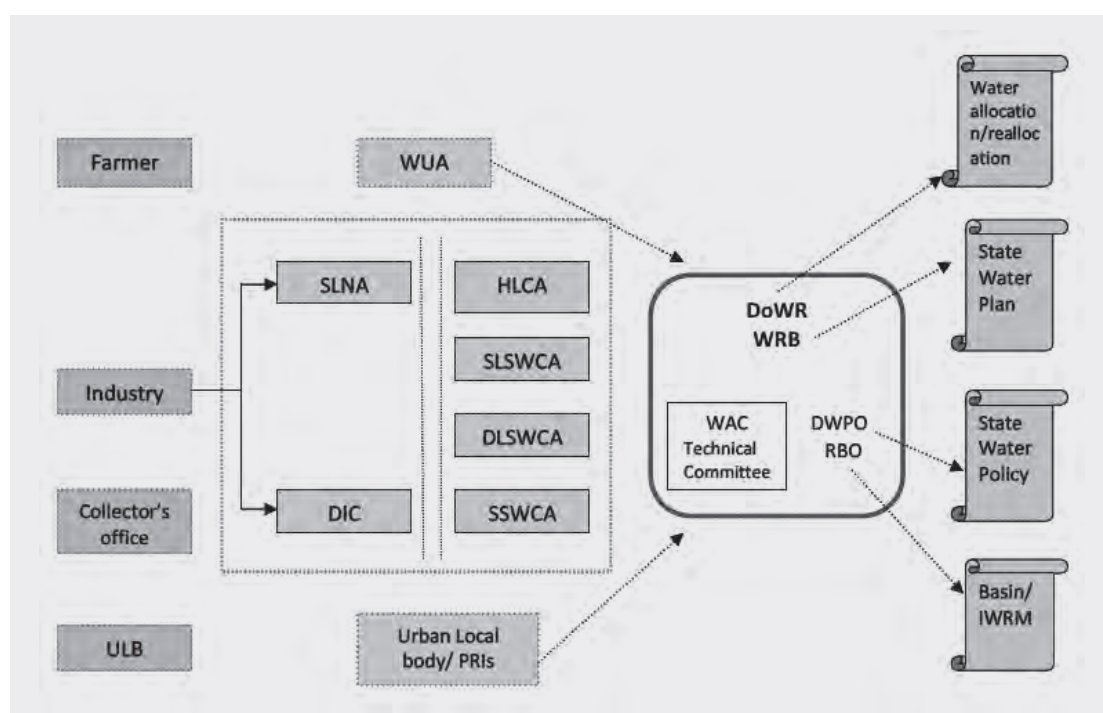
Orissa Water Planning Organisation

The overall planning of water resources in the state is done by the OWPO as a nodal agency. The OWPO is responsible for the preparation and updating of macro level multi sectoral river basin plans of the state. The OWPO is required to interact with various stakeholders for preparation of these plans. The OWPO then submits the draft basin plans to the RBOs for ground truthing and modifies the draft as per the comments of the RBO, before putting them up for approval. The river basin plans prepared by the OWPO and vetted by the RBOs are then placed before the Water Resource Board (WRB) for approval. The OWPO also comes up with the State Water Plan, based on the individual river basin plans of all the river basins—the latest being the State Water Plan, 2004. Figure 8 shows the various institutions relevant for decision-making, policy and planning, and affecting the inter-sectoral water allocation mapped together.

River Basin Organisations

The RBOs are multi-disciplinary organisations, formed in the state for the purpose of planning, monitoring and overseeing all water-related activities at the river basin level (The Orissa Gazette, Resolution No. 5788/WR-Irr.-I-WB-4/06, Department of Water Resources, 26 February 2007). The RBOs have a two-tier structure, with a planning body known as the Board, consisting of experts and professionals, along with a Council, to deliberate on action plans put up by the board and accord approval. The Councils have members such as the elected representatives of the parliament and legislative assembly of the basin areas, along with the district collectors and NGO representatives, whereas the Board has members from an engineering background, with a rank of superintendent engineer/deputy director in associated government departments (e.g. minor irrigation, hydrology, industries, etc).

Figure 8: Various Institutions Responsible for Decision-Making, Planning and Allocation, Odisha



Source: Compiled from various sources and mainly from the Annual report 2014-15 prepared by Department of Water Resources, Government of Orissa, 2015

Water Resources Board

The Water Resource Board (WRB) is the highest authority in the state for formulating policies and principles on water development (The Orissa Gazette, Resolution No. 5788/WR-Irr.-I-WB-4/06, Department of Water Resources, 26 February 2007) and the OWPO functions as its secretariat. The Government of Odisha, through the DoWR, has formulated the WRB to facilitate smooth decision-making in matters of water planning and allocation between the various sectors and to provide necessary advice to the Government

in the matter (The Orissa Gazette, Resolution No. 22496/IRR-Irr.-I-IPL-33/93, Department of Water Resources, 21 August 1993). As the highest body in the state for evolving policies and legal instruments for the water sector, it is run under the chairmanship of a Chief Secretary, along with Secretaries of other concerned departments as its members. The WRB is involved in the following matters of water resource policy and planning:

- i. Preparation of the Orissa State Water Policy
- ii. Integrated planning of state water resources
- iii. Allocation of water resources among user sectors
- iv. Prioritisation of the Water Resources Development Schemes
- v. Enforcement of the Environmental Management Plan (EMP), Acts and Rules regarding the Water Resources Development.

Water Allocation Committee

Water allocation is both a technical as well as normative decision-making problem. In the current set up, the WRB has the responsibility of the water allocation decision-making. The WRB is essentially a group of technical and bureaucratic members. The process of water allocation for the various sectors takes place through their individual institutional channels—for example, in case of agriculture, the institutional structure of the Pani Panchayat is used and in the case of industry, the institutional structure of the industry facilitation services is used. However, the ultimate decision rest with the WRB as the highest organisation for planning and policy making. The technical part of the allocation decision-making is further looked after by a technical committee formulated under the DoWR known as the Water Allocation Committee (WAC) (The Orissa Gazette, Notification No. 11027-Irr.-II-WRC-21/2010-WR, Department of Water Resources, 21 April 2010). The members of the WAC are essentially from a technical background. The purpose of the formation of the WAC lies in evolving guidelines for the allocation of water to competing users and increasing instances of allocation of water from government sources ‘in favour’ of industries/commercial and other establishments, with the increasing industrialisation in the state.

Key Insights and Issues

Keeping in mind the objective of balancing the water needs of different sectors while giving priority to drinking water as per the State Water Policy and avoiding inter-sectoral conflict, some key issues have been identified below.

Recognition of Shortcomings in Status Quo

Both the policy and plan also acknowledge the lacunae and the need of addressing issues such as: in-situ conservation, evolving procedures for irrigation water supply, issues of infrastructure maintenance (O&M), volumetric pricing, crop planning and agricultural water conservation, conjunctive management and use of surface and groundwater, and the need for strengthening the participatory management systems and local institutional capacity.

Well-developed Institutional Framework

There are several positive aspects in the policy and legal framework of the state of Odisha. The policy and institutional framework tries to maintain the balance between technical, political and normative aspects of decision-making.¹⁷ This is evident from the composition, functions and powers of the WAC, RBOs and WRB, besides the issues of prioritisation related to allocation.

Recognition of River Basin Approach

There is also an attempt to mainstream river basins as the unit of plan even though there is confusion regarding basin scale and the administrative scale of planning. The water policy talks about the establishment of river basin organisations, which are essentially multi-stakeholder decision-making bodies. Accordingly, two RBOs have been formed.

Need for Strengthening the Pani Panchayats and River Basin Organisations

Even though the policies and institutional mechanisms are innovative, the operationalisation and the processes look weak and a carry forward from the earlier administrative system. For example, various studies and our own field experience shows that the Pani Panchayats are very weak and most of the control rests with the bureaucracy. The Water Plan recognised this and noted that the Command Area Development Authority (CADA) agencies across the basin were yet to handover control to the local Pani Panchayats. The general awareness and the role of the farmers in the Pani Panchayats is also very low.

If a participatory, bottom-up approach to water resource planning at the state is the objective, then sub-basin and basin-level plans need to be in place. RBOs at present are not strategized to evolve as a democratic decision-making body and hence it is important to build it from the bottom, from watershed to sub-basin to basin level institutional structure, in a cascading manner. At present, there are proposals for river basin plans but it is unclear whether they have been completed. While two RBOs have been formulated, they are not fully functional.

Further Improving the Estimation of Water Availability and Demand

While the Orissa Water Plan is fairly comprehensive in its estimation of water demand and projections, it still needs improvements. The plan itself states that information is not available to the state about the location and number of existing industrial units, hence estimating the industrial water demand is difficult and can only be done based on the number of industrial workers in the state. This approach of using proxies to estimate specific regional demand, is inadequate, as we describe further in detail in Chapters 6 and 7. Our estimates of industrial and agricultural water demand vary significantly from the figures arrived at in the State Water Plan.

17. While these are innovative in comparison with Chhattisgarh, these are still limited because of the lack of multi-stakeholder involvement including civil society organisations and farmers' groups.

Improved methodologies for estimation would partially serve to address this issue. However, none of these plans are in the public domain and it is uncertain by when they will be. Lack of basin-wise information also handicaps the efforts of the RBOs to manage water at the river basin level.

Need for Continuous Review of Water Planning Strategies

If the State Water Plan is to be believed, Odisha is headed for major resources utilisation in the near future. It is apparent that major initiatives to improve the efficiency of use of water, better and more equitable distribution, both in agriculture and industries, is needed in conjunction with some increases in water storage capacity. Only after in situ options, such as, local storages (tanks, farm ponds, etc.) and soil moisture through watershed development etc., are considered, should one ideally think of increases in larger water storages because these come with known issues. The Plan, however, does not seem to have strategies for these. The Plan does offer some detail into different reforms needed, legal and policy, efforts in forest and water conservation, government and community capacity-building. However, with no continuous review process at the state and river basin level, it is unclear whether these strategies are even working. The Water Plan, for instance, came out in 2004 and, yet thirteen years later, no new review is available of the growing water demand. Our estimates in Chapter 7 serve to partially address this.

Lack of Sufficient Norms for Water Allocations

The State Water Plan of Odisha does take cognizance of water allocation priorities and offers a clearly laid out order of priority for allocation of water to different sectors. But what these priorities imply at the project level or basin level is not detailed. There are no clear norms for how the rationalisation of water between irrigation and industries might change in years of scarcity. The latest water allocation guidelines discussed in the Orissa Irrigation Act (Amendment) Rules, 2010, merely offer guidelines on how the uptake of water by the industries should be monitored and how much they should be charged. Principles of equity or sustainability should be incorporated into the guidelines. In the absence of these principles, actual water allocations tend to be dictated solely by economic cost recovery or political concerns. Allocations are based on such ad hoc strategies rather than institutionally managed principles. Farmers' demands to prioritise irrigation over industries is only heard when they are able to successfully organise at a large scale. The Hirakud farmer's movement's successes, as discussed later, are an example of this. Allocations are based on ad-hoc strategies rather than institutionally managed principles.

Chhattisgarh

Water Resource Planning

The Water Policy of Chhattisgarh (2012) mentions the need for a participatory approach for water resource planning in the form of master plans for large and medium projects. The policy proposes water allotment to various sectors by the end of year 2040. This

includes 3142 MCM for industry, 12569 MCM for domestic needs and 31422 MCM for agriculture. However, the water policy remains silent about the assumptions behind the allotment of water. It is not clear from the provisions how the numbers have been arrived upon. Further, it is calculated as a percentage of the usable water resource (both surface and groundwater), which is a very tentative provisioning (Section 4.1.7). Current water storage capacity under large dams and other major structures in the Mahanadi Basin in Chhattisgarh is 6.3 BCM, whereas to achieve the water allotment as per the policy, the state will have to add five times the current storage capacity in the next two decades. Most of the storage structures in the state have been constructed between 1971 to 2000, with the sole purpose of irrigation. However, the rate of industrialisation has increased rapidly after the year 2000. This rapid industrialisation is the result of the favourable policy and institutional structure in the state and it would demand substantial water, especially for the plan of thermal power generation. A total of 74 new thermal power projects have been proposed in seven districts of the state. This increase in industrialisation, with almost no capacity addition during the last decade, may result in a shift in water allocation priorities. The current surface water allocation for industrial purposes is 2.7 BCM in 2011, which already equals to 87 per cent of water requirement projected for industry till 2040. Considering the rapidly growing water demand of the industrial sector and the negligible number of new projects added in the last two decades, we may see either a shift in allocation patterns or a spate of new structures to serve this demand.

The Chhattisgarh Draft State Water Policy, 2012 is a recent initiative of the state and at this stage looks very tentative. With the increasing stress on industrialisation and irrigated agriculture, there are also many initiatives in these sectors which have a bearing on water resources. These would include the Industrial Policy (brought out every five years, the latest being for 2014–19), Agriculture Policy (2013) and Agro and Food Processing Industry Policy (2012–17).

State Water Resources Development Policy, 2001

The Chhattisgarh State Water Resources Development Policy (SWRDP) of 2001 identifies water as a community resource managed by the state under the public trust doctrine, to achieve food security, livelihood, and equitable and sustainable development of all users. The policy gives drinking water and agricultural utilisation the top priority (Clause 4.1.3). However, there is no clear prescription for the overall prioritisation amongst various competing sectors which suggests that the proposed State Master Plan on water resources (medium and large projects) to be developed, would spell out the requirement for industry and power besides the already prioritised needs of drinking water and agriculture. Apart from these provisions, there are no other provisions which can clearly lay down the water allocation use priority for all the major water uses.

In the absence of a clear-cut water use priority, the State Water Policy states that priorities and usage of water will be decided through the State Water Resources Utilisation Committee and the district/division-level Water Utilisation Committee (Clause 5.2.2). However, the overall responsibility rests with the WRD and its officers, such as the Chief

Engineer, Superintending Engineer, Executive Engineer, Sub-Divisional Officer, Canal Deputy Collector and Sub-Engineers. Based on the demands at the project level, they take decisions regarding water allocation to the various sectors.

The SWRDP mentions that ‘In view of the importance of agriculture in the development of the state, the State Government gives top priority to water resources development in the state’ (SWRDP – Sec. 4.2). On the issue of generating the necessary funds, the SWRDP states that ‘In view of the necessity of huge investment in water resources development, the private sector investment is to be encouraged’ (SWRDP – Sec. 4.2.2). And that, ‘in water distribution arrangements in the industrial sector, private investment will be welcomed’ (SWRDP – Sec. 4.3.3). The Industrial Policy states that ‘In industrial areas, for industrial projects, water supply arrangement initiatives will be made in PPP model’ (Industrial Policy – Sec. 4.1.3). Already there are private investments by the industries to develop their own water accessing structures. However, there are no specific stipulations with respect to protection or licensing issues, as we see in the case of Odisha. Thus, if the government chooses to take the path of promoting private sector investment, strict rules and regulations should be stipulated in order to protect the public interest. Currently, there is an absence of any such stipulations, or provision for such stipulations, in the policy.

Legal Instruments and Rules

Since Chhattisgarh is a relatively new state, policies and rules which were part of erstwhile Madhya Pradesh (such as the Madhya Pradesh Irrigation Act, 1931, or the Regulation of Waters Act, 1949 and so on) are often in use. Thus, unlike Odisha, many of the legal and institutional reforms are still in the nascent stage in the state. However, there are many new initiatives like the Chhattisgarh Participatory Irrigation Management Act and Rules, 2006, the Groundwater Regulation and Control of Development and Management Bill, 2012, etc. The Industrial Investment Promotion Act (2002) and Rules (2004) also have implications for water in the state.

Regulation of Waters Act, 1949

According to the Regulation of Waters Act, 1949:

‘All rights in the water of any natural source of supply shall vest in the Government...’ (Regulation of Waters Act – Sec. 3)

‘No local authority shall have any rights except in accordance with the rules in this behalf. . .’ (Regulation of Waters Act – Sec. 4.1)

Thus, the Government has full authority in water supply. Any local authority can have powers in accordance with the rules. However, no rules have been formed till date.

Irrigation Act, 1931

The Irrigation Act of 1931 states,

‘All rights are vested with the Government’ (Sec. 26).

‘Conditions for supply of water to industry shall be as agreed upon by the state government and the company (user) and fixed in accordance with the rules’ (Sec.40).

‘Executive engineer can give permission to industrial use up to 5 MAF from canal for non-irrigation.’

Participatory Irrigation Management (PIM) Act, 2002

There is an attempt to introduce participatory management of irrigation through the PIM Act 2002. This provides legal provisions for the formation of Water Users Committees (WUAs). The objective of the farmers’ organisations shall be to promote and secure equitable distribution of water among its users, achieve adequate maintenance of the irrigation system, efficient and economical utilisation of water to optimise agricultural production, to protect the environment, and to ensure ecological balance by involving the farmers, inculcating a sense of ownership of the irrigation system in accordance with the water budget and the operation plan. The farmers’ organisation may also engage in any activity of common interest to the members in the command area related to irrigation and agriculture, such as: procurement and distribution of seeds, fertilisers and pesticides; procurement and renting of agricultural implements; marketing and processing agricultural produce from the command area; and supplementary businesses like dairy and fishery. Provisions are made for the WUAs for not more than 2000 ha, Distributary Committee, Project Committee, and Federation of Farmers Organisation at the state level. The Canal Officer in charge at various levels, have a significant presence and decision-making role at all levels. There is also provision for a State Level Policy Committee.

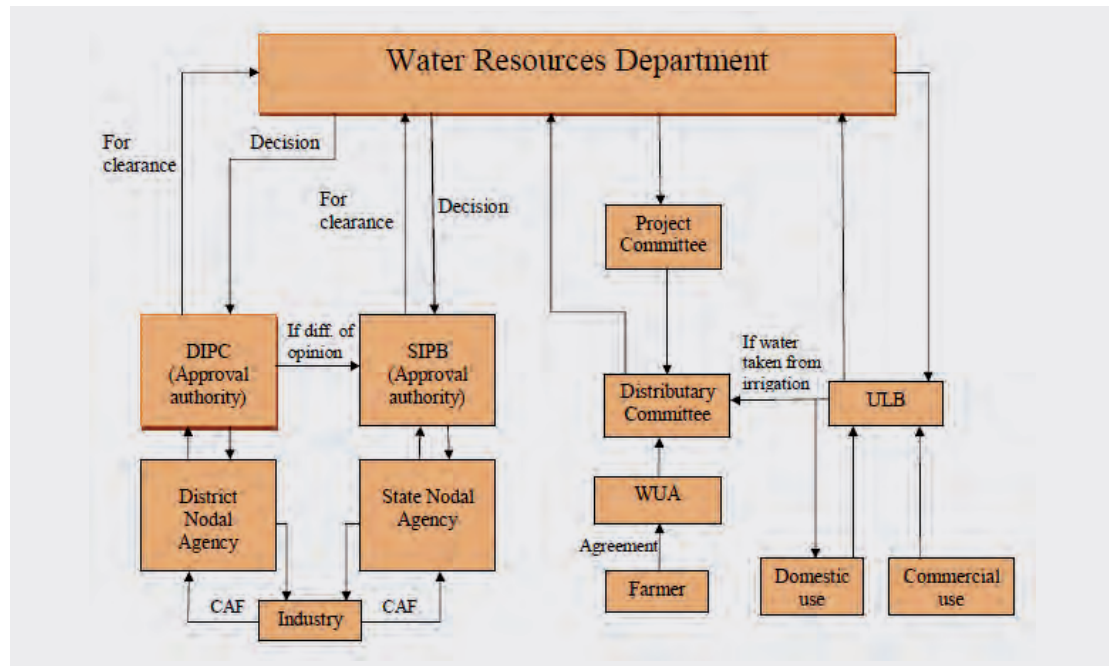
Institutions

The Irrigation Act and Regulation of Water Acts vest entire rights related to water resources and their allocation with the state government and the respective officers as mentioned earlier. In scarcity periods, the collector has the powers to reserve the water for drinking and domestic purposes.

However, these Acts remain silent about the details of inter-sectoral water allocation. At this point, the Investment Promotion Act and subsequent rules come into the picture. These legal instruments lay down procedures for availing approvals to set up an industry. Getting sanction for required water is one important component in the entire process.

Water for industrial purpose is supplied by the Chhattisgarh State Industrial Development Corporation (CSIDC), if the industries are established under the CSIDC. The CSIDC has set up several industrial zones near Raipur, Bilaspur and Durg, wherein they have a particular water quantum which they can allocate to individual industries within these zones. If industries are set up elsewhere, they must apply for individual water allocation to the WRD. The Principle Secretary of the Water Resource Department in his/her discretion can grant or deny the permission for water from the prescribed source. At the project level, there is specified allocations for various uses such as irrigation, industries, municipal use etc. Decisions at the project level are made by the State Water Resources Department in consultation with the Chief Engineers of each of the projects.

Figure 9: Various Institutions Responsible for Decision Making, Planning and Allocation, Chhattisgarh



Key Issues and Insights

Most of the policies and legal instrument with respect to water are either very tentative, without much thought going into it, as in the case of the State Water Policy and its projection for future needs, or, require timely revisions, as in the case of the Irrigation Act and Rules. The issues discussed below are a must if the state wants to balance the inter-sectoral needs and avoid water conflicts.

Failing Institutions for Participatory Irrigation Management

Participatory irrigation management has been introduced in the state and there are programmes to strengthen it such as an Asian Development Bank (ADB) funded project, but field visits in the course of this study found that its impact on the ground was not visible. It is the WRD officers who called the shot and the WUAs presence was very nominal. Implementation is weak and the law remains on paper. The World Bank supported 'National Hydrology Project' in the state tries to strength the planning and design of WRD, decision support and design aid by the use of data collection as well as by providing information about the availability and quality of surface and groundwater to different institutions and users. However, achievement in these areas or access to such information in the public domain or to intended users is found to be very limited.

Need for Legal and Institutional Reform

Legal reform is also much needed. The Irrigation and Regulation of Water Acts of Chhattisgarh have not seen any amendments in recent times and therefore do not reflect

the concerns of the implications of rapid industrial expansion on water resources in the state. Amendments to these Acts and Rules are necessary to ensure that water allocation is not arbitrary but follows norms that ensure equitable and sustainable water allocations.

The Water Policy also currently promotes private sector industrial investment in the development of water resources. There is a total absence of a strict set of rules and regulations which is necessary to protect public interest.

The institutional architecture for water resources in Chhattisgarh is also far behind in comparison with Odisha when it concerns the river basin approach to management and this must be considered a priority. Local institutions must also be strengthened to facilitate PIM to work towards the goal of better upkeep of irrigation systems and efficient irrigation water use.

Lack of a River Basin Approach

Unlike Odisha, there is little focus in Chhattisgarh's policies on developing a river basin approach to water resource management. A holistic water plan with a bottom-up approach where watersheds, sub-basin and basins as the focus of planning and management, would be the right direction for evolving a realistic and scientific water plan.

Need for Rigorous Estimations of Water Availability and Demand

The Chhattisgarh State Water Policy starts with the assumption that there is sufficient water to meet all the needs and currently it is not using as much as it could be for the development of industry and irrigation. The estimations of water availability in the policy, unlike those in Odisha's State Water Plan, do not offer any details on what approach has been used to determine availability.

The projections of future demand in the water policy are simplistic and do not stand any scientific scrutiny. Purely on an aggregated level it might appear true that more water is still available for utilisation, as the Mahanadi Basin does have more uninterrupted flows in comparison with other peninsular rivers. However, such claims need to be seen in the context of socio-economic changes, regional variations in industrial development, climate variation, livelihood situation, etc.

Our study shows, for instance, that most large industries in the state are concentrated in smaller pockets, many of which are in close proximity to surface irrigation structures which depend on water, especially in Raipur, Korba, Janjgir-Champa and Raigarh districts. This close proximity and overlapping dependency, along with realistic projections of sectoral growth, hints at the possibilities of future competitive uses of water, especially between industry and agriculture. For example, even with water being available during Rabi in the Minimata Bango project, it is not provided for Rabi irrigation as planned whereas the industries in the region continue to receive uninterrupted water. This unfulfilled commitment of water creates the potential for conflict.

Need for Water Plans and Clear Strategies for Water Management

At present, the storage developed is not adequate to cater to the estimated needs of the near future, both for agriculture and industry, and the state does not articulate a clear strategy of how it intends to meet these needs. The state requires a comprehensive scientific Water Plan to lay out strategies for meeting water demand, strategies to optimise water use efficiency, address water pollution that affects water availability for drinking and irrigation. The Water Policy of the state recognises these needs and mentions the Water Plan in the works. Much time has passed but the Water Plan is not in the public domain yet.

Our analysis in Chhattisgarh seems to show that a very low percentage of the surface irrigation potential, created in the Rabi season, actually receives irrigation. Sectoral water conflicts have not risen to the level but this presents a unique opportunity to the state to plan water from the early stages itself.

Lack of Sufficient Norms for Water Allocations

As is the case in Odisha, the state does not have clearly defined norms or principles for making decisions on water allocations. Merely suggesting that drinking water and irrigation are top priority, which the Water Policy does, is not sufficient. What these priorities imply for water allocations must be stated. For instance, as per our investigation, the Minimata Bango project meets its irrigation demand in 90-95 per cent of the years in the Kharif season but fails completely to meet Rabi irrigation needs while industries and urban needs are met in 100 per cent of the years. This implies that the state sees Kharif irrigation as top priority along with drinking water but Rabi irrigation as dispensable. These distinctions are blurred when a policy merely states that irrigation is top priority.

The absence of such norms also creates a scope for arbitrary allocations as per project level concerns of water availability or cost recovery, without considering how allocations of water in one region may affect availability elsewhere or how changes in groundwater use may affect surface water availability. These are important considerations that need to be developed further.

Summing Up

While the governance mechanisms are available for Odisha, even if on paper, there are hardly any proposed institutional mechanisms for planning and management of the river basin in Chhattisgarh. However, in both the states, sectoral allocations are made at the project level, but not on the basis of any prescribed norms or transparent rules or by taking into consideration the overall basin context. This is also evident in the projects as we see in case of Minimata Bango project, where farmers are denied water for a second crop even though sufficient storage is available. Pressure from industries as well as the state's stress on industrialisation, especially a water consuming one, has seen increasing allocations to the sector at the cost of agriculture and other needs. Most of the new projects in Chhattisgarh are aimed at providing water to the industries. In short, ad hoc-ism is seen in sectoral allocation along with economic and political clout of the sector in the overall political economic context of the respective states.

4

Case Study – Minimata Bango

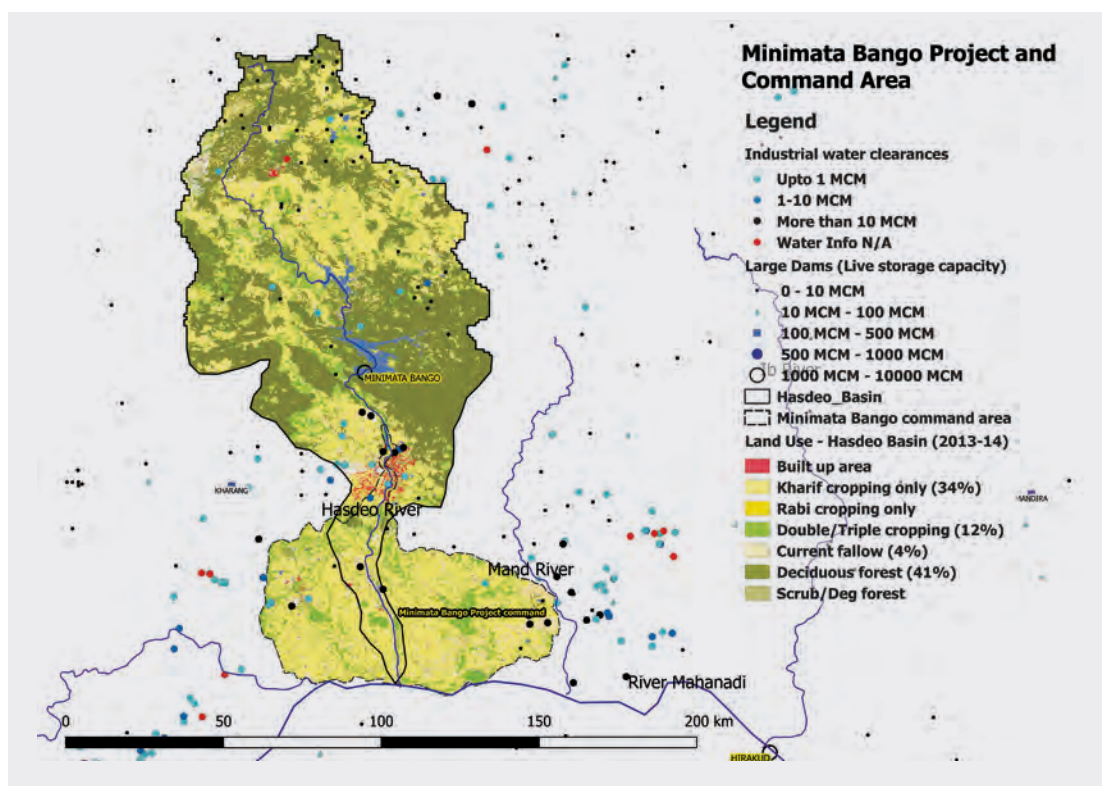
Context

This first case study discusses the use of water from the Minimata Bango project, Chhattisgarh's largest irrigation project, situated in Korba in the Hasdeo river basin. This project has itself changed the fortunes of the people of the river basin since its initiation in 1962 and, after its final completion in 2011, its impacts are still unfolding. Of the two districts most prominently impacted, the people of Janjgir-Champa have seen change largely for the better in terms of gross area cultivated and rising production and yields of rice while the people of Korba have seen it for the worse, with persistent water pollution issues from the multitude of large industries that operate in the district. This case study looks at how the project currently makes use of the water it stores and what must be considered for further improving the efficiency of use and equity in distribution of the projects waters.

The Hasdeo river, on which lies the Minimata Bango project, is the fourth largest tributary of the Mahanadi, with a catchment area¹⁸ of 9803 km² (Central Water Commission, 2012). This represents 6.9 per cent of the total catchment area of the Mahanadi Basin, feeding the main stem on the left bank and joining the river in Mauhadih village of the Janjgir-Champa district. The drainage area of the Hasdeo river is spread over Koriya, Korba and Janjgir-Champa districts from north to south, with Surguja and Bilaspur flanking the basin in the northeast and northwest, respectively. The catchment of Hasdeo is divided into eight sub-watersheds, namely, Upper Hasdeo, Bamni, Tan, Gej, Ahiran, Chornai, Lower Hasdeo and Lower Mahanadi Basin. The Hasdeo Basin also has several large dams in the uppermost watershed in Koriya, serving minor irrigation projects.

18. Some other sources estimate the catchment as 10457 km² (Singh, 2010).

Figure 10: Minimata Bango Project and Command Area



Source: Industrial water clearances - (Ministry of Environment and Forests, 2016); National Register of Large Dams (Central Water Commission, 2014); Land use statistics (National Remote Sensing Agency, 2013-14)

The catchment area of the Minimata Bango reservoir in the middle of the Hasdeo sub-basin is 6,730 km² and the average annual precipitation in its catchment is 1505 mm (maximum: 1920 mm and minimum: 940 mm). The mean annual evapotranspiration in the command area is about 1800 mm whereas the reported rainfall is about 1438 mm (for the period 1949–1975) (Government of Chhattisgarh, 2004, p. 41). More recent rainfall data shared by the Hydrology Project of the WRD of Chhattisgarh shows average annual rainfall of 1110 mm and 1317 mm for Manendragarh (Koriya) and Baikunthpur (Surguja) stations respectively, in the upper reaches of the watershed, 1195 mm at Tan-Magarha in the middle of the sub-basin and 1189 mm in Janigir near the confluence of Hasdeo and Mahanadi over the last decade. This is part of a larger basin-wide trend of decreasing rainfall as per official records since the 1950s.

The predominant soil type in the basin is loamy (above 65 per cent of the area consists of fine loamy to loamy soils) followed by different types of clayey soils and coarse skeletal loamy varieties. Clayey soils are mainly in the lowlands while the uplands most often consist of loamy soils. Soil surveys of the command area of the project indicate that large parts (66.9 per cent) of it have heavy deep Kanhar clay soils which are suitable for growing paddy. Most of the soils also have very low infiltration rates, which should support

high canal efficiency (Department of Water Resources, Government of Chhattisgarh, 2004, pp. 58–59).

Forest area makes up about 41 per cent of the basin. The watersheds of the Upper Hasdeo in Koriya and Tan, and Chornai in Korba district, have considerable forest coverage, mainly of the deciduous kind. Agriculture in the Hasdeo Basin consists largely of a single rainfed Kharif rice crop which makes up 34 per cent of the basin area whereas about 12 per cent of the basin is double cropped (National Remote Sensing Agency, 2013-14). Rice is less important in north Surguja, where it makes up 69 per cent of the gross cropped area, as compared to Koriya and Korba (79 per cent and 83 per cent, respectively) and Janjgir-Champa, where rice dominates, making up 91 per cent of the gross cropped area. Maize is another important Kharif crop in the central and northern parts of the basin. The important Rabi crops in the basin are khesari, rapeseed, mustard and wheat (Directorate of Economics and Statistics, Ministry of Agriculture, 2014).

The Minimata Bango is a complex dam-barrage system with the dam located in the middle of the basin, in the Tan sub-watershed, and the Hasdeo Barrage located 42 km downstream near Korba town in the Ahiran sub-watershed (Singh, 2013). Water from the dam is released daily, in the process of generating hydropower. All this water reaches the barrage and from here it is either lifted directly by the industries or diverted into the left and right bank canals, from where some water is lifted by the thermal plants and the remaining irrigates the command areas.

This project was chosen for a detailed study on its water use particularly because it was known to lie in the hotbed of coal mining and thermal power in Chhattisgarh. Coal mines dot the upper reaches of the sub-basin and several large thermal power plants lie in Korba, which were known to take water from the project itself. The northern parts of the sub-basin were known for coal rich areas, where more mining was planned. The project itself is Chhattisgarh's largest irrigation project in terms of live storage capacity and mainly irrigates Janjgir-Champa, the most highly irrigated district in the state. These factors together made the Minimata Bango project representative of the conditions which prompted our initial hypothesis and, therefore, it became an ideal site to explore the questions: Whether industrial water allocations were affecting distribution to irrigation? Was agriculture being given priority over industry in distribution? And, was distribution of water from the project actually following the official allocations of water on paper?

Process

Answering these questions required a mixed set of approaches. To begin with, field visits were conducted in the districts of Korba at the barrage and dam sites, and several parts of the command area in Janjgir-Champa, to see first-hand, the project, its scope and impacts. The research team also visited government offices of the Hasdeo water circle in Bilaspur, the dam office itself in Machadoli, Korba, the barrage records room in Darri, Korba, the divisional and sub-divisional offices of the project in Rampur and Darri, Korba respectively.

Very scanty details of the project itself are in the public domain, like the case with many other large projects in the country. The DPR of the dam, obtained from the Bilaspur office, provided crucial figures, such as the designed live and gross storage capacity of the reservoir, the 75 per cent dependable annual availability of water at the dam and the barrage site, the planned allocations of water from the project, season-wise, and the area to be irrigated. The Bilaspur office also provided details of the area irrigated in the Kharif and Rabi seasons since 2004-05. The dam office at Machadoli provided details of daily releases of water from the structure since 2005-06. The divisional office at Rampur, after much efforts, provided a year's worth of data on official releases of water to the industries from the barrage. The team also visited agricultural colleges in Bilaspur to learn more about agricultural practices of the region. Efforts were also made to visit thermal power plants in the region which were not successful. Officials at the NTPC Sipat thermal power plant were initially accommodating but turned away once they were made aware of the purpose of the visit. All observations gained through these interactions as well as secondary data analysis were put together to extract larger insights for the Bango project. For their feedback and further refinement, these insights were shared at a stakeholder meeting in Bilaspur, with the local groups including the Chhattisgarh Bachao Andolan in Raipur and Bilaspur, and the local journalists and community workers in the Korba district. After such group discussions, as also the ones with individuals knowledgeable about the local issues, the final insights were drawn from the case study. These have been presented here.

History and Project Specifications

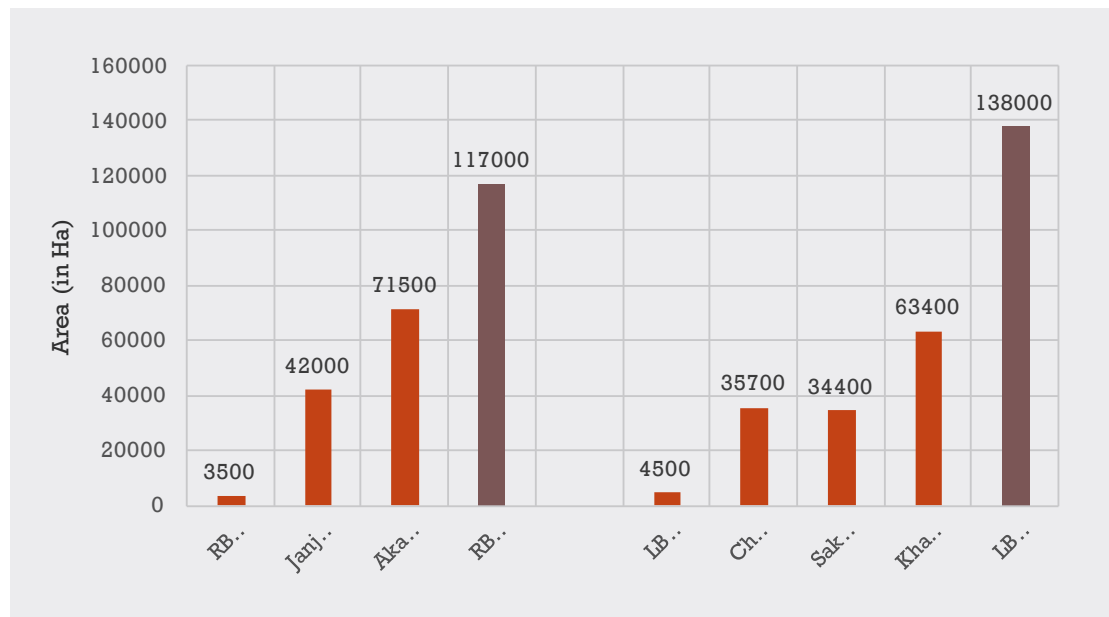
Phase I (1962–67) of the Minimata Bango project began with the construction of the Hasdeo Barrage on the river near Korba town and a 4.4 km long left bank canal to supply water to a thermal power station in Madhya Pradesh. The Hasdeo Barrage, further downstream, has a gross storage capacity of 78 MCM at a reservoir level of 286.585 m. Its fourteen gates allow a maximum discharge of 19,820 cumecs to the river.

Phase II (1967–79) was planned for the right bank canal, for irrigation water supply to 42,000 ha in Janjgir-Champa, with a limited irrigation potential possible through the Hasdeo Barrage. Irrigation water was released for the first time in the year 1978, about ten years after the dam first provided water to the Madhya Pradesh Thermal Power Project. The year-wise development of the irrigation potential in the command area had progressed steadily from 40,000 ha in 1978-79 to 154,000 ha in 1995-96 but then witnessed a fall in subsequent years until 2000-01 to 108,000 ha, possibly due to canal lining work (Department of Water Resources, Government of Chhattisgarh, 2004, p. 31). Later, however, irrigation was revived and reached in excess of 220,000 ha of the command area in the Kharif season.

In Phase III, which was approved in 1980, the Minimata Bango dam was constructed 42 km upstream of the barrage. The length of the dam is 554 metres and it has 11 gates, cumulatively designed for a maximum spillway discharge of 23,975 cumecs to the river besides three penstock gates for releasing water for power generation. The elevation of water in the reservoir is 359.66 m above mean sea level (MSL) at Full Reservoir Level

(FRL), with a live storage capacity at construction of 3046 MCM (Department of Water Resources, Government of Chhattisgarh, 2004). The dam also has a provision for hydropower generation of 120 MW. Power generation began in the year 1992. Phase III also included the lining and extension of the irrigation canals¹⁹ on both flanks of the barrage. The branch canals of the system include Janjgir, Akaltara on the right bank, and Champa, Sakti and Kharsia on the left bank. The plan was to add 255,000 ha to the Net Irrigable Area and 433,500 ha annually to the designed Gross Irrigated Area, with required changes in cropping pattern.

Figure 11: Minimata Bango Project – Canal-wise Net Irrigable Area



Source: Government of Chhattisgarh, 2004

Phase IV of the project, with Accelerated Irrigation Benefits Programme (AIBP) funding the envisioned completion of the balance of the excavation and lining work on distributaries incomplete in Phase III, large parts of the Champa, Sakti and Kharsia branch canals had been left unlined after World Bank funding dried up in 1991 and also the provision of additional water allocation to industry, totalling to 441 MCM and Korba town (14 MCM). Phase IV was only recently completed in 2010-11 (Department of Water Resources, Government of Chhattisgarh, 2004). However, the CADA, which was supposed to undertake the field channel works, has not done so and wherever it was taken up, it is no longer functional. By estimates of the DPR, canal lining will require replacement in 40 years (i.e. 2030).

19. This included the Singhra and Kurda distributaries (LBC) and Parsahi LIS (RBC). It also included balance lining of the LBC and RBC systems to achieve 2.55 lakh NIA (up to 40 Ha Chak., and micro-minor distribution system up to 8 Ha Chak. field channels).

Status of Water Resources: The Minimata Bango Project

As cited earlier, rainfall patterns in the Mahanadi river basin and the annual inflows into the Minimata Bango reservoir are estimated to be 3023 MCM at 75 per cent dependability (3917 MCM at 50 per cent and 2066 MCM at 90 per cent). The catchment area of the barrage downstream is 7720 km² and yields inflows of 3467 MCM at 75 per cent dependability (4492 MCM at 50 per cent and 2370 MCM at 90 per cent). These figures were obtained using relationships derived from observed discharge data at the dam site between 1959 and 1975.

Since then the CWC has recommended revision of the yield figures based on inflow data updated until 1999. This revision resulted in an increase in the annual yield at 75 per cent dependability to 3124 MCM at the dam site and 3536 MCM at the barrage site. After accounting for evaporation loss, the available water at the dam is estimated to be about 2895 MCM.

Since then, the data on actual inflows and outflows from the dam, obtained from field visits to the dam site, was used to further update these numbers. The data shows us that average annual inflows during the period from 2005-06 to 2014-15 was about 2793 MCM. These numbers show a reduction in annual yield of the reservoir since earlier figures, as we would expect with the falling rainfall in this region.

Of the inflows, about 2278 MCM is the monsoon inflow and 515 MCM the post-monsoon figure. An average of 47 per cent of the monsoon inflows (about 1065 MCM of water) are stored in the dam each year. The reservoir levels generally do not dip below 800 MCM at the end of the summer and, most recently in 2014, the reservoir levels at the end of the summer were 2313 MCM.

In terms of outflows from the dam to the Hasdeo Barrage, an average of 1213 MCM is released in the monsoon each year and 1120 MCM is released in the post-monsoon season. In addition to this, about 200 MCM flows in from the Tan River into Hasdeo Barrage annually and half of this is monsoon flow, the remaining being post monsoon flow.

Table 6: Yield at Different Dependability at Minimata Bango Dam (Catchment 6730 km²) and Hasdeo Barrage (Catchment km²)²⁰

Details	Dam Site		Barrage Site	
	Period: 1936–75	Period: 1949–99	Period: 1936–75	Period: 1949–99
Catchment area (km ²)	6730		7720	
50% dependability (MCM)	3917.1	3488.6	4492.9	4116.4
75% dependability (MCM)	3023.2	3124.7	3467.5	3536.6
90% dependability (MCM)	2066.9	1318.8	2370.4	3124.7

Source: Government of Chhattisgarh, 2004

20. This yield estimate does not include upstream use and evaporation. Allocation for upstream use (323 MCM) would further reduce yield. Similarly, the project estimates an average evaporation loss of 229 MCM per year.

Water Availability

The total known quantified water availability at Hasdeo Barrage is thus about 1313 MCM in the monsoon and 1220 MCM in the post-monsoon season. The corresponding 75 per cent dependability figure is 1031 MCM in the monsoon and 820 MCM in the post-monsoon. These figures could be very different however if the reservoir were to be operated in a different manner altogether.

Allocation of Water Resources

Agriculture

The allocations of water from the project, however, were made based on the earlier available figures of 3536 MCM annual water availability at 75 per cent dependability (3213 MCM after deducting upstream use). The planned agricultural water allocation for the project is 2578 MCM (Kharif: 1004 MCM, Rabi: 720 MCM, Summer: 404 MCM and Perennial: 450 MCM). In the DPR for Phase IV, it was proposed that irrigation will be provided with 95 per cent dependability in Kharif and 90 per cent dependability in Rabi after the completion of lining work (Department of Water Resources, Government of Chhattisgarh, 2004, p. 32). Therefore, in years of water shortage, summer irrigation and perennial crops would suffer. Moreover, this designated allocation of 2578 MCM was realised to be insufficient after the World Bank initially withdrew its aid for lining the canal system and the new requirement was calculated to be 2844 MCM annually. We can assume, therefore, that after the lining of the project was completed in 2011, the requirement would have again rightly been 2578 MCM.

Table 7: Minimata Bango Project – Season-wise Planned Irrigation Water Allocations

Season	Area to be Irrigated	Water Allocated
Kharif	234600 ha (92% of NIA*)	1004 MCM
Rabi	127500 ha (50% of NIA)	720 MCM
Perennial	20,400 ha (8% of NIA)	450 MCM
Summer	51,000 ha (20% of NIA)	404 MCM

*NIA, Net Irrigable Area,

Source: Government of Chhattisgarh, 2004

The allocated water was meant to irrigate about 255,000 ha of net irrigable area of the project. The total Gross Irrigable Area of the project is 433,500 ha, giving a potential irrigation intensity of 170 per cent.

Table 8: Minimata Bango Project – Project Design

Gross command area (GCA)	342,000 ha
Cultivable command area (CCA)	285,000 ha
Net irrigable area (NIA)	255,000 ha
Gross irrigable area estimated (GIA)	433,500 ha
Irrigation intensity proposed	170%

Source: Government of Chhattisgarh, 2004

The proposed cropping pattern for the Minimata Bango project is 234,600 ha of rice in the Kharif season, 20,400 ha of perennial sugarcane and banana, 70,125 ha of wheat, 39,525 ha of gram, 12,750 ha of potato and 5,100 ha of berseem in the Rabi season; and, cumulatively, 51,000 ha of groundnut, moong and maize in the summer season.

The seasonal crop water requirement for the command was estimated with an efficiency factor of 55 per cent in Kharif and 58 per cent in Rabi and hot weather. For lined canals, the overall irrigation efficiency was worked out at 59.50 per cent (Department of Water Resources, Government of Chhattisgarh, 2004, p. 35). This was broken down as a field application efficiency of 85 per cent and conveyance efficiency of 70 per cent for a lined canal.

Industry and Urban

Industries in the Hasdeo Basin are predominantly coal mines and thermal power plants. Many South Eastern Coalfields Limited (SECL) mines dot the upper districts of Koriya and Surguja including Chirmiri, Hasdeo Arand and also the district of Korba (Kusmunda, Gevra) in the middle of the basin. The largest concentration of power plants is in Korba, including the largest ones such as NTPC, Korba, the Chhattisgarh State Electricity Board (CSEB) East, West and South. BALCO's aluminium plant is also located in Korba. Most of the large industries in the basin take water directly from the Hasdeo Barrage, some from the canals of the project and others from the anicuts further downstream of the barrage, but none from the dam itself.

Within the planning process for Phase III and IV of the project, the allocation to industries was increased from 400 MCM to 441 MCM of water. Later, however, it was reworked to 418.95 MCM, after factoring the siltation loss and re-estimation of the utilisable live storage capacity of the project from 3046 MCM to 2894 MCM. An additional 20.24 MCM water is also allotted to Vandana Electricity and Steels from a location in the river above the barrage, which totals to 438.7 MCM. Unlike in the case of agriculture, the earmarked water for industry is reserved and ensured. Besides the project allocations, another 99.94 MCM of water is also allotted to the industries through 11 anicuts built on various locations in the upper Hasdeo river and its tributaries. Thus, in the Hasdeo Basin, upstream of the barrage, a total of 539 MCM of water is allotted to the industries as per the official sources.²¹

21. Correspondence with government officials at Bilaspur Water Resources Circle office.

In addition to this, a large number of industries—such as, Dhiru Power Generators, Vandana Industries, Swastik Power and Minerals, KJSL Coals Limited, Aryan Coals, Sarda Energy, GD ISPAT, CSEB (Madwa), Chhattisgarh Steel Power Limited, Prakash Industries Limited, LORDs Power Pvt Limited, Suryachakra Global Enviro Power Ltd, Madhya Bharat Paper Mill, Jain Energy Limited etc.—draw water from 11 water impounding structures (10 anicuts and the Bamnidih barrage) built on the river. Besides, 14 MCM water is given to Korba town. This would imply 553 MCM water allocated to non-irrigation use.

Table 9: Minimata Bango Project – Industrial Water Allocations (as on 31 August 2014)

Name of the Industry	District	Source	Quantity (MCM)
CSEB, East	Korba	Main right bank canal	21.00
CSEB, West	Korba	Barrage near observation office	23.00
BALCO	Korba	Main right bank canal	6.60
IOL (IBP), Gopalpur	Korba	From the barrage, near Gopalpur village	0.078
SECL	Korba	Main right bank canal	0.963
SECL Kusmunda	Korba	Main left bank canal	1.490
SECL Gevra	Korba	Main left bank canal	1.260
BALCO Extension	Korba	Main right bank canal	16.50
NTPC Korba	Korba	Main left bank canal	110.00
NTPC, Seepat	Bilaspur	Main left bank canal	120.00
Shyam Prasad Mukherjee, CSEB, East	Korba	Main left bank canal	21.00
CSEB West, Extension	Korba	From the barrage near village Darri	26.00
CSEB, South	Korba	From the barrage near village Darri	40.00
BALCO Power Plot	Korba	Right bank canal 8 MCM Hasdeo river 16 MCM River Tan 4 MCM	28.00
SECL, Dipka	Korba	Right bank canal	1.66
SECL, Kusmunda	Korba	Right bank canal	0.985
Vandana Power and Steel	Korba	From Hasdeo river upstream of barrage	20.24
Total			438.77

Source: Chief Engineer, Minimata (Hasdeo) Bango Project, 2014

Reservoir losses including evaporation and seepage were estimated to be an additional 229 MCM. Of the annually available water, 323 MCM was set aside for upstream utilisation, but, as of 2003, the upstream reserved water had only been partially exploited, with one minor irrigation scheme of 23 MCM capacity. Moreover, it is unclear whether the 99 MCM allocated to the industries upstream takes water from the agricultural allocation. As per the project plans in 2004, however, the remaining 300 MCM is still available for further irrigation in the upstream areas (Department of Water Resources, Government of Chhattisgarh, 2004, p. 21).

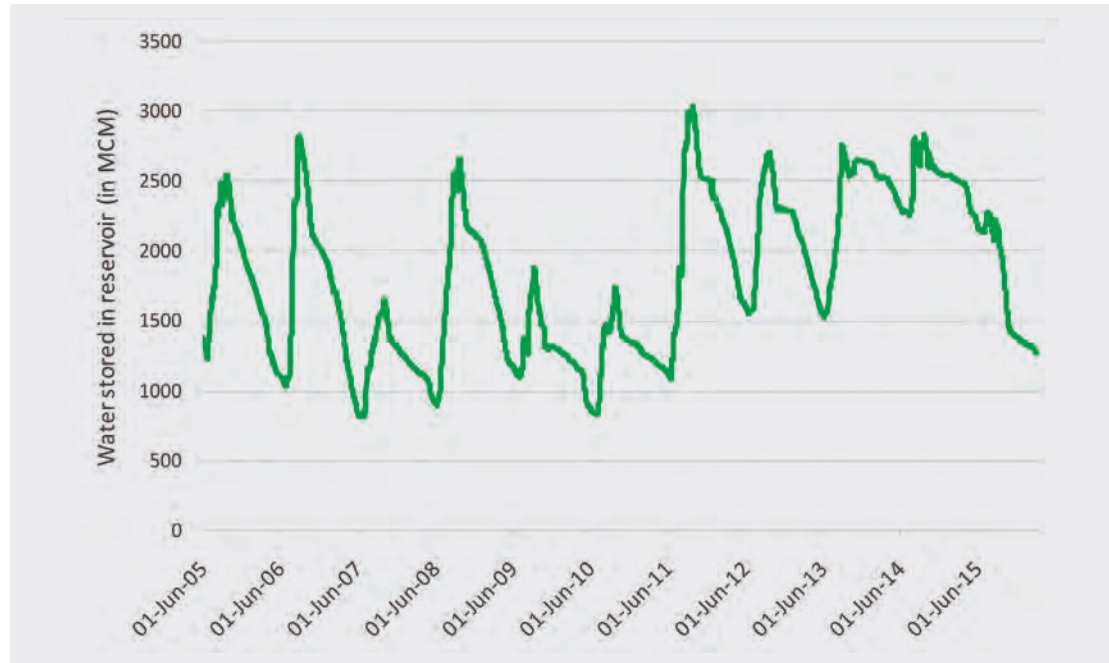
Water Use

Precisely estimating the amount of water used by agriculture from the project and how this has changed over the years, is crucial to understand the effect of industrialisation in this region. The nature of the project design and the overlapping of the modes of distribution of water, and points of uptake of water and return (in the case of some industries) make it extremely difficult to accurately estimate the actual quantum of water going towards agriculture vis-à-vis the allocated amount. Direct measurements of water released by the Minimata Bango project authorities (referred to earlier) is available as a daily figure for the year's 2005-06 till 2014-15. This however tells us nothing about the breakup or distribution of water towards each end use. Similarly, at the Hasdeo Barrage office in Korba, a log is maintained for the rate of outflow of water into each branch canal and into the river. This data however was extremely detailed, showing water releases every time the position of the barrage gate changed, which was several times a day. This data was moreover available only for viewing, not for photocopying. A concise version of this barrage water release data was available at the Bilaspur circle office of the project but it merely mentioned the rate of discharge from the barrage, recorded each day at 8 am. This is problematic since the rate of discharge from the barrage, unlike the dam, varies constantly throughout the day. Even if accurate time series data for volume of water released from the barrage were available, it would still not be enough since, part of the water released into the canals was still taken up by the industries.

Water use therefore had to be estimated not by volume of water but by area irrigated in the project's command area. This data was obtained from the Bilaspur office and corroborated to the best extent possible using satellite image analysis. Besides the area irrigated, the data for reservoir levels in the Bango dam and the monthly releases over the years was used to estimate the nature of aggregate water use from the project.

Analysis of the reservoir levels in the Minimata Bango reservoir over the years (from 1995 to 2014) shows that large amounts of water is left behind in the reservoir at the end of the summer. 20 per cent of the water in the reservoir is meant as 'carry over' water that is kept in the reservoir unused in case the next year's rainfall is insufficient and/or there is a late setting-in of the monsoon. However, the reservoir storage levels data shows that almost every year, the quantity of water left behind the reservoir is 30 per cent or more at the end of May. Figure 12 shows the data for the last ten years.

Figure 12: Minimata Bango Reservoir – Daily Reservoir Levels (in MCM)



Source: Executive Engineer, Minimata Bango Project, 2016

Hydel power is generated throughout the year with a continuous, cumulative outflow of at least 9000 cusecs that runs three generators of 40 MW each. When this is difficult to maintain, the flow is reduced to 1500 cusecs for 12 hrs/day or a minimum outflow of 125 cusecs for 8 hrs/day.²² However, it seems the reservoir is operated in such a manner so as not to store all the monsoon water inflows. If we assume that the total quantum of water that is released from the dam + inflows from the Tan river in the monsoon (June to September)—i.e. 1479 MCM of water—goes towards Kharif irrigation and industrial use, we can estimate that about 1333 MCM of water is being used for Kharif irrigation (on a pro-rata basis, 146 MCM must be the monsoon industrial water requirement). The analysis of satellite imagery and official figures of actual area irrigated (see Table 10) shows that nearly 90-100 per cent of the targeted Kharif area (about 220,000 ha) is being irrigated. As per the DPR, however, 1004 MCM is dedicated to Kharif irrigation and another 450 MCM is dedicated to the perennial crops like banana and sugarcane. Ground observations though show that there is no undertaking of perennial cropping.

As opposed to this, the figures for the post monsoon season show that 1124 MCM is the total water available at the Hasdeo Barrage from October to the end of May. However, the corresponding irrigation data and satellite imagery analysis show that practically negligible Rabi cropping is taking place.

22. Based on conversations with the dam officials at Machadoli, Korba.

Table 10: Minimata Bango Project – Kharif and Rabi Irrigation (Target vs. Actual)

Year	Kharif Irrigation (Targeted) In Hectares	Kharif Irrigation (Actual)		Rabi Irrigation (Targeted) In Hectares	Rabi Irrigation (Actual)	
		Hectare	% of Target		Hectare	% of Target
2004–05	247,400	182,651	73%	173,100	83	0.04%
2005–06	247,400	207,395	84%	173,100	246	0.14%
2006–07	247,400	214,394	86%	173,100	31,008	17.9%
2007–08	247,400	210,834	88%	173,100	0	0%
2008–09	247,400	221,047	89%	173,100	3200	1.84%
2009–10	247,400	220,861	89%	173,100	–	NA
2010–11	247,000	–	NA	173,100	–	NA
2011–12	247,000	221,000	89.5%	173,100	35,297	20.39%
2012–13	247,000	221,260	89.5%	173,100	35,200	20.33%
2013–14	247,000	122,500	90%	173,100	2,061	1.19%

Source: Chief Engineer, Minimata Bango Project, Bilaspur Water Resources Circle, 2015²³

We see that around 35,000 ha of area was irrigated in both 2011-12 and 2012-13. Interaction with the local level water management division officials suggest that there has been very little Rabi irrigation during the life cycle of the project. For the Rabi season, 127,500 ha was the proposed area for irrigation requiring 720 MCM water and, similarly, for 51,000 ha of summer irrigation, 404 MCM of water was required. Thus, even after the completion of the canal command lining in 2011, though the design and investments had proposed irrigation of 433,500 ha annually covering all three seasons, the current situation falls abysmally low in comparison.

While time series data for the release of water to the industries was not easily available, we were able to obtain one year's worth of data on water provided to the industries from the project, from the water billing information at Rampur, Korba. This data showed that water released to these projects, mainly thermal power plants, steel and aluminium plants, were as per official allocations of water and not in excess. Hence, we can assume that 455 MCM water to the industries and town needs is ensured without changes.

While in other multipurpose projects it may be the case that irrigation needs are sometimes not met because the water in the reservoir falls short of requirement, in this case it is interesting to note that in each of the last ten years until 2013-14, there was no irrigation or minimal irrigation (See Table 10) provided in the Rabi or Summer season while, at the same time, the water in the dam was ample, which could have contributed to more irrigated area if it had been so allotted.

23. Some small corrections were made in this table. The original data was incorrect for the year 2005–06 Kharif. The Rabi targeted area figures are also more than area mentioned in the DPR. This needs to be verified.

There are many reasons for the coverage being lower than what was designed and estimated. The reasons are technical/structural, those that are related to the cropping pattern and crop water efficiency, irrigation and cropping practices, preferences for non-agricultural sectors and even cultural dimensions. From field interactions, both with project officials and farmers, the following observations were noted.

The method of irrigation is field to field flood irrigation and it is 'protective' in character. Water is mainly provided during the flowering and seed formation stage during September and October. Water is also given during sowing or biasi/transplanting operations, if required. The canal system in most places is constructed only up to 40 Ha chak²⁴ and thereafter water flows from field to field which is not efficient. Such a system forces the farmers to mainly go for a rice crop since it alone can withstand excess water in the field. Lack of assurance for regular and periodic water supply restrains the number of options available to the farmers. The farmers have the tendency to keep about 10 cm of water for the paddy crop when it may require only 5 cm, according to the research institutions working in the area.²⁵ This calls into questioning the top down planning and decision making regarding the rule curve of the reservoir. One can make the case that if WUAs in the command areas were cooperatively managing the project's water and deciding irrigation scheduling then the quantum of actual water use can be brought down without requiring technological changes.

About 95 per cent of the area under Kharif irrigation is paddy, the rest is under vegetables and fruits. Even the projected cropping pattern at full development proposes 92 per cent of the Kharif area (234,600 ha) under paddy, with an estimated water requirement of 1004 MCM. Farmers take long duration paddy crops in the area and by the time they reach flowering and seed formation, it is the post monsoon phase and applied water is required.

Rabi cultivation is very rare in the command. Wheat, bengal gram, groundnut, linseed and other pulses are cultivated in small patches. The main reason suggested by the research agencies for this was the lack of availability of water for Rabi cultivation. The traditional habit of the local farmers to take only a single crop and let the animals graze post the Kharif harvest, is also suggested as one reason for the low coverage of Rabi cultivation. Essentially the claim made is that the farmers do not ask for water for a second crop. Some others stated that because according to the project design water was not permitted for a rice crop in the Rabi season, the farmers who asked for water for rice could not be provided water.

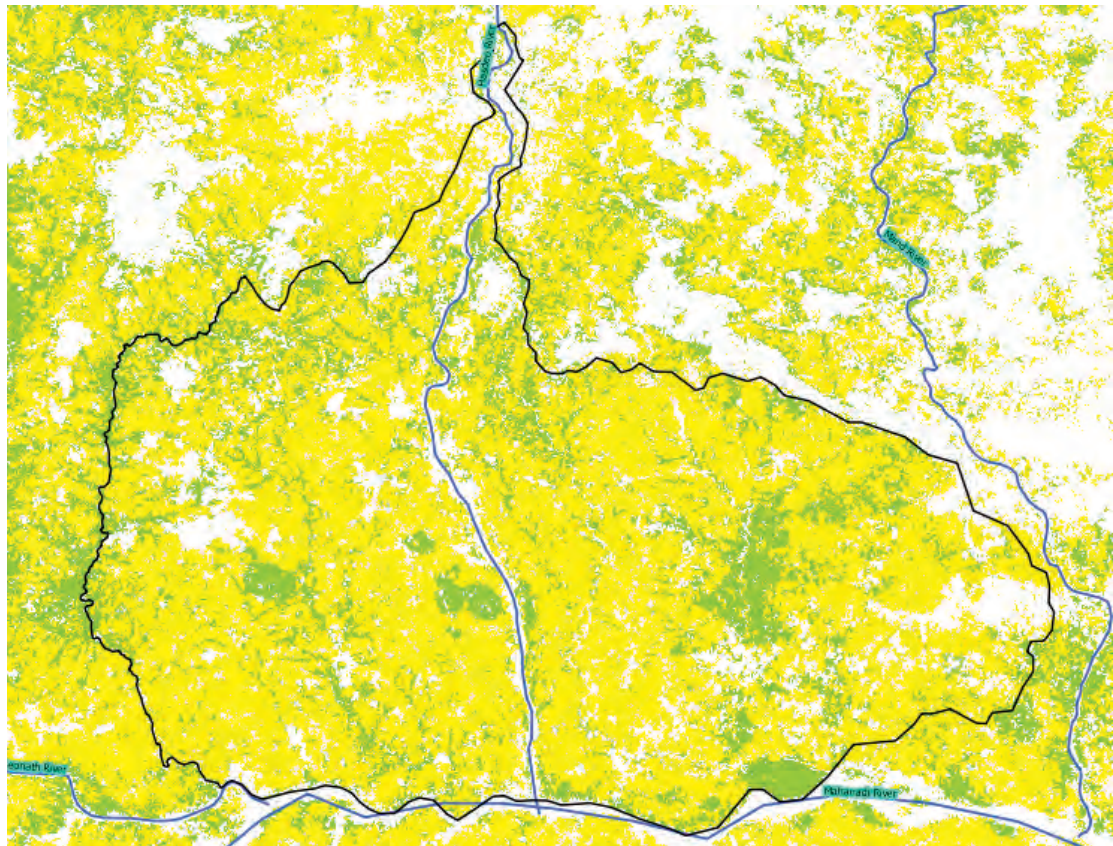
The first reason obviously is proved invalid based on the observation of the data. The second is also dubious. In course of a ground survey of the command area, our research team visited four villages where Rabi cropping takes place and two where no Rabi

24. Chak is the area of land either on one side of a canal or below the tail, with a single outlet of water to irrigate farms.

25. Thakur Chhedilal Barrister College of Agriculture and Research Station (TCB CARS), Bilaspur

cropping occurs, and engaged the farmers and panchayat leaders in a discussion on local cropping patterns (See Figure 13). The villages where Rabi cropping was observed were all dependent on groundwater irrigation because being close to smaller rivers in the command area water, the yield from the borewells was enough to take up a Rabi rice crop or vegetables most commonly. In contrast, in the villages where no Rabi cropping was happening, the villagers said that the farmers did in fact make a demand for water for a Rabi rice crop but this water was not provided. After many years of non-provisioning, the farmers in the area began undertaking seasonal migration to the towns due to lack of water. The claim of civil society groups in the region is that the current pattern of operation of the reservoir is such because other industries further downstream of the Hasdeo Barrage have built anicuts at Pithampur and Madwa, from where they draw water. To ensure that these barrages always have a constant water supply available, a steady flow of water is ensured from the Hasdeo Barrage into the river throughout the year. This explanation, although it cannot be proved absolutely with the data available, certainly seems like the most plausible one for why Rabi irrigation does not take place and where the water released from the dam post monsoon is going.

Figure 13: Map of Minimata Bango Command Area – Rabi Irrigation Coverage



Source: Landuse for the command area of the Minimata Bango project (2013-14), green is where Rabi irrigation occurs. (National Remote Sensing Agency, 2013-14).

In Conclusion

An approximate estimation of water use from the major and minor measures on the Hasdeo project would be around 1332 MCM for agriculture provided in the Kharif season²⁶, 438 MCM for various industries and 14 MCM for Korba town. This would total to 1784 MCM. If we factor the evaporation loss, 229 MCM (as factored by official agencies), the total water available would be 2013 MCM. This leaves a large quantum of water being unused in years when the reservoir is filled to the capacity, where water is not even being allocated for Rabi cultivation. Local actors feel that it is surreptitiously given to industries located downstream.

At present, no apparent conflict in water allocation to agriculture and industry is reflected, but the possibility of the farmers rising in conflict remains very real. The position of the farmers, asking for water for rice crops is reasonable given that rice is culturally the main crop in the region and a pre-decided alternative cropping pattern decided by project authorities won't easily force the farmers to change these practices. Besides, rice has a procurement system and minimum support price, including the state bonus of Rs. 300/quintal²⁷. The lack of irrigation systems maintenance at the field level, which facilitate other patterns of irrigation other than flood irrigation (such as system rice intensification [SRI]), is also a factor in favour of a rice crop. It also shows that there is little coordination across the departments of water resource, agriculture and extension, and the CADA, to devolve management of the command area down to the water user associations at the farm level.

Even if we buy the rice argument as the reason for not provisioning Rabi irrigation, the question that arises is, why is the dam being operated the way it is currently. A detailed and integrated water balance analysis of the catchment and command, which would also include the provisioning of water from the various sources in the river and its water bodies, is required to understand the issues further. Also required is a detailed analysis of the water use in the industries. However, restrictions on obtaining such detailed data prevented this study from estimating actual water use by the industries.

26. The estimation is arrived at using the average irrigation over the years and water requirement as assessed by the irrigation department for various crops in different season.

27. A circular issued by central government suggests that this support would be removed since 2015.

5

Case Study – The Hirakud Project

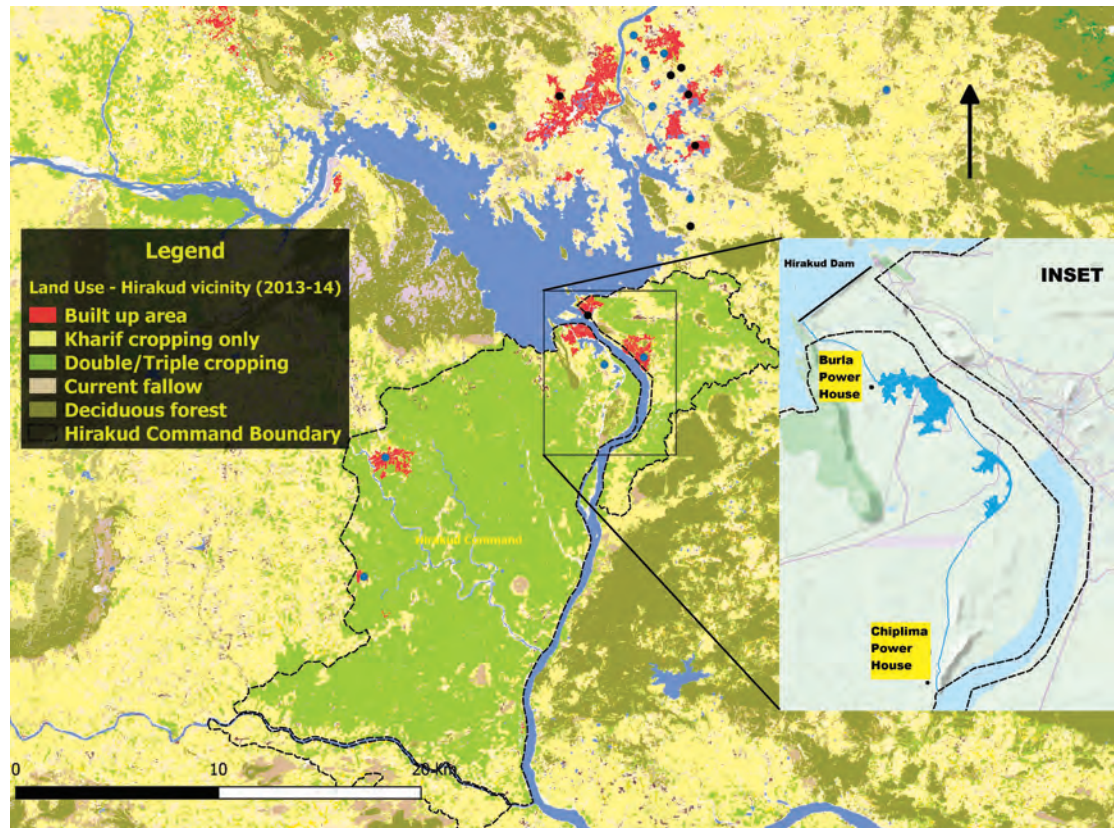
Context

This case study focuses on Odisha's largest multipurpose project, the Hirakud dam and reservoir. Given its historical importance for irrigated agriculture and current importance for industrial development in Western Odisha, allocations of water from this project have grown to become critical and contested. The project is located in the central region of the river basin, where it receives a large quantum of monsoon flow that far exceeds its storage capacity. Given this fact, the idea that the water available in the reservoir might fall scarce was not seriously contemplated by those benefiting from the project. The area irrigated from the project also continued to rise substantially, crossing its design area for irrigation in the Rabi season. However, with the advent of liberalisation in 1991, the picture began to change. The concentration of industries which drew water from the reservoir began to grow. This was coupled with the failure of water provision in the Sason canal command area in 2006-07. A major protest erupted, led by the farmers of the *Paschim Odisha Krushak Sangathan* (Western Odisha Farmer's Movement). This union, which initially formed to take up issues of minimum support price (MSP) on behalf of the farmers, now rose to address water allocation issues. The lack of transparency and efforts to facilitate farmer participation in the Hirakud reservoir management processes led to a deep mistrust of the government by the farmers. Farmers believed that the failed irrigation water provision was the direct result of industrial uptake of water. About 20,000 farmers from the neighbouring districts came together and joined hands in a show of resilience, demanding that their first right over the Hirakud reservoir's water be preserved. This case study documents the rapid industrialisation in the vicinity of the project and its scale in terms of water use that has brought these two users of water in confrontation with each other and also how things have unfolded since then.

The Hirakud dam is the largest dam in the Mahanadi river basin, with almost the entire reservoir lying just east of the border of Chhattisgarh and Odisha on the main stem of the river. Its current live storage capacity of about 4.7 BCM is miniscule in comparison to the estimated 34.4 BCM of water that flows through the river annually, which diminishes its flood protection potential. The dam, completed in 1957, is one of the earliest of independent India and since then has been the backbone of the rural economy of Odisha. The structure itself was built near the confluence of the Mahanadi and the Ib river in the Sambalpur district, effectively diverting the latter into the reservoir of the project. The reservoir extends back into the Jharsuguda and Bargarh districts of Odisha.

The banks of the Ib river near the confluence in Jharsuguda, are a major hub for thermal power and iron and steel industries, which take water from the project. The water allocations from the Hirakud project have increased over the years. Given its significance in the agricultural economy of Odisha, it is important to understand the status of water use from the project and how it might have changed over the years since its initiation.

Figure 14: Hirakud Project and Command Area



Source: LULC (1:250K) (2013-14) (National Remote Sensing Agency, 2013-14)

Process

As discussed in the methodology, the insights published in the report, 'Floods, Fields and Factories' provided a starting point for the research team to explore the operations of the reservoir. The research team visited the site of the dam in Burla, Sambalpur, interviewed project officials and obtained data from them. They also surveyed the command area of the project. Much of the following insights into the Hirakud's water use have been compiled from two sources, the Jeyaseelan Committee Report (2007) by Odisha's Water Resource Department and an analysis of the raw data from the Flood Report of the Hirakud Reservoir (2014), produced annually by the Hirakud dam control authorities. The latter provides a detailed look at the distribution of water from the project since the beginning and has proved immensely useful. In addition, field visits to the project command area and satellite imagery analysis helped validate findings.

History and Project Specifications

After the severe floods in the delta region of Mahanadi in 1937, M. Visveswaraya, an eminent engineer of the time, advised the Odisha government to take up detailed investigations for preparing plans for the construction of storage dams for flood control and other uses. The recommendations of the Flood Advisory Committee (1938–42) were accepted in the Flood Conference of 1945 at Cuttack. Subsequently, a proposal was made by the CWINC (now CWC) in 1947, suggesting the construction of three dams at Hirakud, Tikarpara and Naraj on the Mahanadi, of which the Hirakud was started in 1948 and began its operation in 1957. Filling of the reservoir started in 1956. Power generation, flood control, domestic water supply and irrigation started from 1957 and irrigation achieved its full potential by 1966. Since then the actual irrigation in the Kharif and Rabi seasons has exceeded the design irrigation of the project. The Hirakud is the single largest multipurpose project in Odisha (Department of Water Resources, Government of Orissa, 2007b).

The Hirakud dam intercepts 83,400 km² of the Mahanadi's catchment and is situated in the central zone of the Mahanadi Basin. The main dam, having an overall length of 4.8 km, spans between the hills Laxmi-dungri on the left and Chandli-dungri on the right. The dam is flanked by 21 km long earthen dykes on both sides, to close the low saddles beyond the abutment hills. It has the distinction of being, at one time, the longest earth dam in the world. Its outlet provisions include 40 sluices and 21 spillways in the left concrete dam, and 24 sluices and 13 spillways in the right concrete dam. Three canals take off from the reservoir: the Bargarh canal, the Sason canal and the Sambalpur distributary. The planned gross irrigable area from the project is about 254,000 ha; 157,000 ha in the Kharif season and 97,000 ha in the Rabi season.

As per the Jeyaseelan Committee Report, the reservoir capacity has been revised in the year 2000, based on estimates of sedimentation. The original live storage capacity of 5.82 BCM, as estimated in 1957, was revised to 4.82 BCM in 2000 while the gross storage was revised to 5.90 BCM from the original estimation of 8.14 BCM.

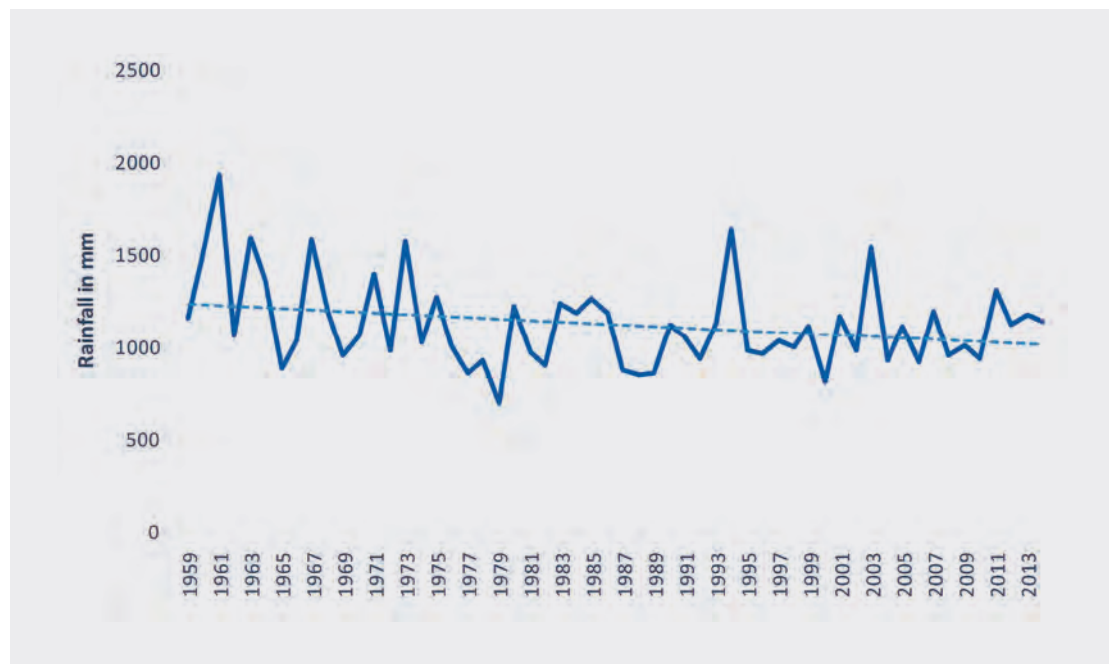
A 1995 assessment by the CWC shows that the average loss of gross, live and dead storages was found to be 0.64 per cent, 0.41 per cent and 1.22 per cent per annum, respectively. At this rate of sedimentation, live storage capacity of the reservoir in 2007 was estimated to be 4,647 MCM (3.77 MAF). The loss in live storage in 50 years was 20.12 per cent. The rate of loss of storage reduces with time, as compared with the initial years of observation (Department of Water Resources, Government of Orissa, 2007b, p. 22). The dam also has considerable power generation capacity of 347 MW due to two power stations at Burla and Chiplima. The power capacity was increased in stages and reached its maximum in 2006.

Status of Water Resources: The Hirakud Project

The rainfall regime in the region has witnessed substantial change since the pre-construction era of the dam. Long-term rainfall records prior to the construction of the dam show that the Sambalpur area received an average of 1381 mm of rainfall

(maximum of 1809 mm in 1902 and minimum of 940 mm in 1919) (Figure 15) (Department of Water Resources, Government of Orissa, 2007b, p. 17). This average is much greater than the rainfall received at Sambalpur post the construction of the dam, which is an average of 1177 mm annually, and a median of 1048 mm (Department of Water Resources, Government of Orissa, 2014). The 75 per cent dependable rainfall has been relatively stable at about 950 mm since about 1990 and the mean rainfall has remained approximately 1050 mm for the last three decades (Department of Water Resources, Government of Orissa, 2014).

Figure 15: Hirakud Project – Historical Monsoon Rainfall



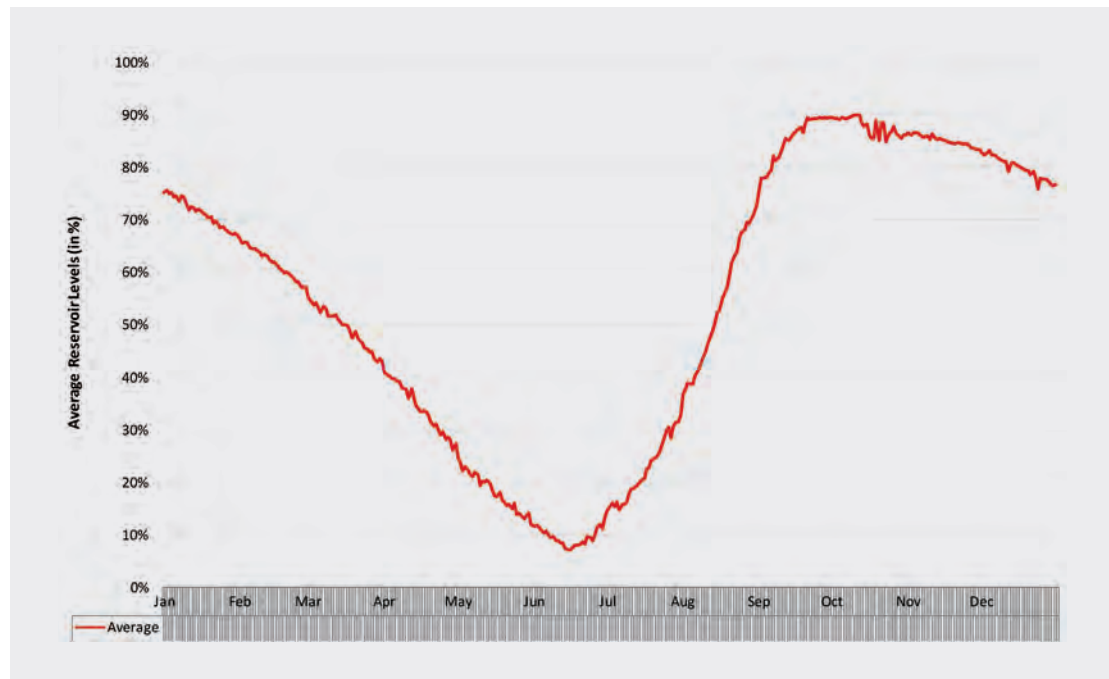
Source: Government of Orissa, WRD, 2014

The Jeyaseelan Report's analysis shows that the average annual inflows (also called 'runoff') from the catchment have decreased in the post construction era. Pre-construction (1926–52), the average runoff was 39.7 BCM (Department of Water Resources, Government of Orissa, 2007b, pp. 17–18). The runoff into the reservoir since construction (1959–2006) has been 33 BCM (26.9 MAF) on an average, with a maximum of 91 BCM (in 1961) and minimum of 11.3 BCM (in 2000), whereas the 75 per cent dependable inflows is 24.4 BCM. In comparison, the reservoir's live storage capacity was estimated at only 4.82 BCM in the year 2000. This poses a flood control challenge for the dam authorities since much of the inflow during the monsoon must be allowed to flow through.

The CWC Rule Curve of the reservoir (1988) provides guidelines for the operation of the reservoir, which require two objectives to be fulfilled: first, the reservoir's flood releases + runoff from downstream of the reservoir should not exceed 28,300 cumecs at the delta

head of the Mahanadi at Naraj/Mundali; second, the reservoir fills up to its Full Reservoir Level by the 1st of October, to provide the maximum water for irrigation and power generation (Department of Water Resources, Government of Orissa, 2007b, p. 15). For this to occur, the reservoir must generally be brought to its Dead Storage Level by the 1st of August, after which it must start filling. In most years, however, the rule has not been observed and, on an average, the reservoir has started filling by mid-June each year. This poses increased risks for flooding, with extreme climate and unexpected weather events becoming more common. Civil society has called for the 1988 rule curve to be relooked at to incorporate these concerns (Choudhury et al., 2012a).

Figure 16: Average Weekly Reservoir Levels in the Hirakud Reservoir (1983–2011)



Source: Central Water Commission, 2016a

The analysis of the Flood Report (2014) data reveals that the mean values of the annual runoff into the reservoir has dropped since the construction of the reservoir; however, the 75 per cent dependable value has risen, indicating fewer years of extremes in runoff (either high or low) (Table 11). The mean monsoon runoff has similarly reduced since construction and is now about 27.7 BCM. The 75 per cent dependable value for runoff is about 24.4 BCM. The mean non-monsoon runoff has seen a sharp rise in the last 20 years to almost 2 BCM (Department of Water Resources, Government of Orissa, 2014).

The reducing monsoon inflows and rising non-monsoon inflows over the years according to the Jeyaseelan Committee Report may be attributed to the state of Chhattisgarh constructing structures to divert water upstream (Department of Water Resources, Government of Orissa, 2007b).

Table 11: Hirakud Project – Historical 75% Dependable and Mean Runoff into the Reservoir

Years	Runoff (in BCM)					
	75% Dependable			Mean Runoff		
	Annual	Monsoon	Non-Monsoon	Annual	Monsoon	Non-Monsoon
1959–1968	19.4	18.7	0.8	36.9	35.7	1.2
1969–1978	25.7	25.1	0.9	34.4	33.2	1.2
1979–1988	21.5	19.9	0.8	28.3	27.1	1.2
1989–1998	25.8	23.3	1.7	33.4	30.7	2.6
1999–2008	25.6	24.4	1.2	29.6	27.7	1.9

Source: Department of Water Resources, Government of Orissa, 2007b

Water Availability

The total non-monsoon water availability is estimated as the sum of the reservoir capacity plus non-monsoon inflows into the reservoir, which add up to 6272 MCM (6.27 BCM) at 90 per cent dependability (Department of Water Resources, Government of Orissa, 2007b, p. Annexure G). This figure from the Jeyaseelan report has been derived by adding the average projected reservoir capacity between 2007 to 2022, i.e. 4346 MCM. The 90 per cent dependability of 1926 MCM for the non-monsoon period (October to May) was calculated for the period, 1982 to 2006. This total figure is the amount available for Rabi irrigation, non-monsoon power generation as well as industrial use. Hence the relative allocation is made based on this total.

This storage of the reservoir is completely utilised. From 1983 to 2011 (the period for which data on reservoir levels is available), the levels of the Hirakud reservoir reached between 90 and 95 per cent in most of the years by the end of monsoon. In all the years, the reservoir levels at the end of summer reached between 5 and 15 per cent.

Allocations of Water Resources

The DPR of the Hirakud project, which would clearly outline the allocations of water to different uses, could not be obtained. Industrial water allocations from the project, obtained from the Water Services Department, Government of Odisha, is discussed below. For agricultural allocations, we refer to the numbers mentioned in the Jeyaseelan report (2007) and relate this to the targeted area for irrigation in each season. Allocations are not specified clearly for power generation; however, we can assume that the amount of water allocated to the projects in the Mahanadi delta downstream would be the same as that meant for power generation at the Hirakud. The Hirakud Flood Report (2014), an annual publication by the Government of Odisha, reveals the numbers for actual use of project waters for irrigation and power generation (Department of Water Resources, Government of Orissa, 2014).

Agriculture

The Hirakud project was originally designed to irrigate 153,750 ha in the Kharif season and 76,875 ha in the Rabi season, mainly through the Bargarh canal (133,539 ha) and the Sason canal (21,468 ha). The total length of the Bargarh and Sason canal are 88 km and 22 km, respectively. The Kharif season extends from 15th June till 30th October. The water requirement for irrigation in the Kharif season is only estimated after 30th of September, when the gates are closed. Prior to this, the waters released for Kharif irrigation are not quantified or 'allocated' per se. The estimated Kharif water requirements for the month of October are 324 MCM and for the entire Rabi season, from 15th December to 30th April, are estimated as 1130 MCM.

In the Mahanadi Delta project stage I and II of the project's command areas, the water used for power generation at the Hirakud dam goes on downstream to irrigate 303,000 ha in the Kharif season and 168,000 ha in the Rabi season, for which the water requirement is 1751 MCM and 1585 MCM, respectively (Department of Water Resources, Government of Orissa, 2007b).

Industrial Water Allocations

There are altogether 21 industries which draw water from the Hirakud Reservoir as listed in Table 12. The Water Services Division under the WRD of the Government of Odisha decides the amount of water to be rationalised to the industries each year. The allocations of water to each industry is fixed, the 'rationalisation', which is the actual amount of water given to an industry, changes from year to year. The water rationalised is described in terms of cusecs and this rate of flow of water is given to the industries for up to 243 days of the year, from October to May. Water is also given during the monsoon but this water is not counted within the allocations since the inflows into the reservoir far exceed the capacity needed by the industries in those months.

Table 12: Hirakud – Water Allocations to Industries

No.	Company	District	Water Rationalised (cusec)
1	ACC Ltd Bargarh Cement Works	Bargarh	1.577
2	Action Ispat & Power Ltd.	Jharsuguda	1.512
3	Aditya Aluminium Ltd.	Sambalpur	52.730
4	Aryan Ispat & Power Ltd.	Sambalpur	4.410
5	Bargarh Cooperative Sugar Mills	Bargarh	0.290
6	Belpahar Integrated Township (BIT)	Jharsuguda	7.000
7	Bhusan Power and Steel Ltd.	Sambalpur	45.00

No.	Company	District	Water Rationalised (cusec)
8	Daruka and Sons	Sambalpur	0.005
9	Hindalco Industries Ltd.	Sambalpur	20.000
10	ITPC Ltd.	Jharsuguda	52.980
11	Ind Barath Energy Ltd.	Jharsuguda	42.000
12	MSP Metallica Ltd.	Jharsuguda	4.080
13	NTPC, Darlipali	Sambalpur	95.000
14	Orissa Integrated Power Project	Jharsuguda	150.000
15	SE Railways	Jharsuguda	2.470
16	Sesa Sterlite Ltd.	Jharsuguda	72.000
17	Shyam Metallica & Energy Ltd.	Sambalpur	4.830
18	SMC Power Generation Ltd.	Jharsuguda	2.450
19	SPS Steel and Power Ltd.	Jharsuguda	3.730
20	Vedanta Alumina Ltd.	Jharsuguda	40.900
21	Viraj Steel and Energy Ltd.	Sambalpur	1.500
	Total		604.46

Source: Water Services, Government of Odisha, 2015

The rationalised allocations of water from the Hirakud as of 31 January 2015 amounts to 604.46 cusecs. The rationalised amount of 604.46 cusecs applies only to 243 days of non-monsoon. This amounts to a total of 359.51 MCM (0.3 MAF).

In addition to these industries, there are another four industries—National Aluminium Company (NALCO, Sundargarh), Mahanadi Basin Power Limited, Odisha Power Generation Corporation (OPGC, Manoharpalli) and Action Ispat (II Phase)—which are in the process of being allocated a total of 106.89 cusecs (Water Services, Government of Odisha, 2015). This takes the total rationalised allocations to the industries to 711.35 cusecs or 423 MCM.

In 1990, the Department of Water Resources, Government of Odisha had stated that the maximum quantity of water that can be permitted to be allocated from the Hirakud to the industries is 726.16 cusecs (0.35 MAF or 432 MCM). Thus, the total allocations to the industries is nearing its maximum. Many of the industries that have been allocated water are located on the banks of the Ib river in Jharsuguda, near the confluence of the Ib and the Mahanadi.

Water Use

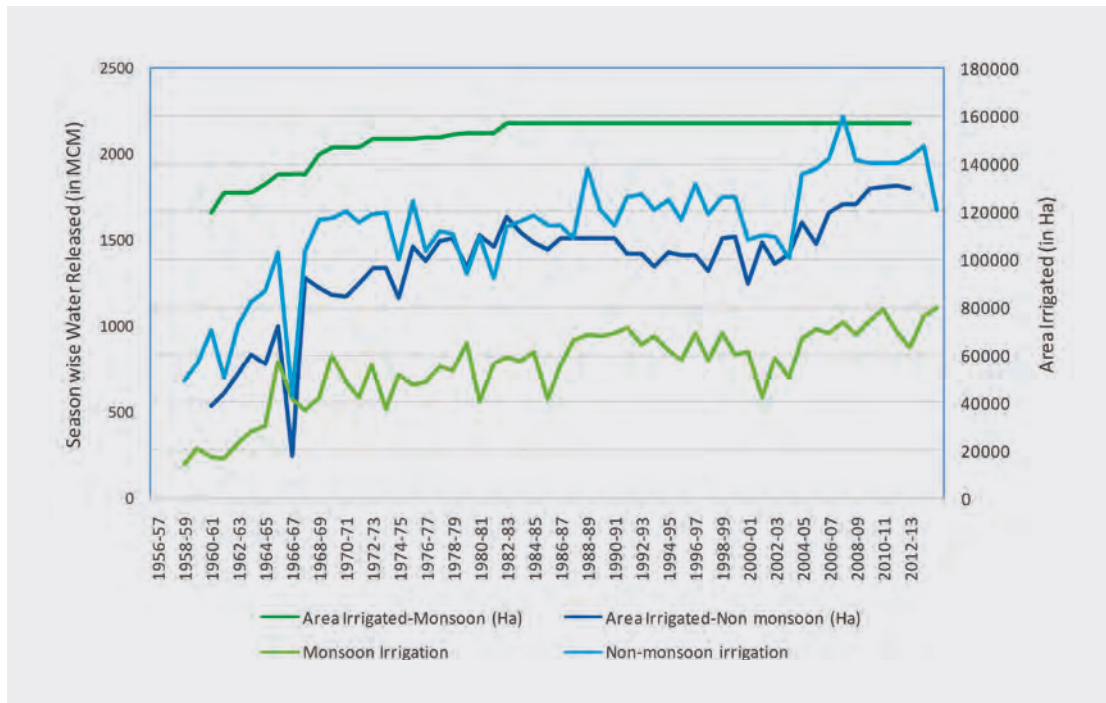
Agricultural Water Use

The Jeyaseelan report states that the two main canals of the Hirakud, Bargarh and Sason, and the Sambalpur distributary, cumulatively irrigate 159,100 ha in the Kharif and 106,820 ha in the Rabi season annually as of the year 2006. With 98 per cent of the cultivated area under paddy cultivation in Kharif and 95 per cent in the Rabi season, the average annual water supplied for irrigation is about 2309 MCM, 687 MCM during June–September and 1622 MCM from October–May (Department of Water Resources, Government of Orissa, 2007b).

The data from the Flood Report (2014) shows that the 'Actual Area Irrigated' has achieved maximum potential since 1967 and since then the Kharif area has maintained its maximum coverage at about 157,000 ha, whereas the Rabi season coverage has continued to rise and is now 123,670 ha. Since the mid-1980s, there have been increasing water releases for agriculture, without a proportional increase in area under irrigation. The total water supplied for irrigation has also risen, to more than 1000 MCM in the monsoon season (June to September) and 2000 MCM in the post monsoon season (October to May) after the gates are closed (See Figure 17). If one were to go by the Kharif and Rabi cropping periods, the quantum of water now released for Kharif cropping (June to October) is 1383 MCM and Rabi cropping (December to April) is 1478 MCM. This corresponds to more than 700 mm/ha of water released for Kharif irrigation and 1200 mm/ha of water for the Rabi irrigation (See Figure 18). While the efficiency of Kharif irrigation seems to be falling sharply, the efficiency of Rabi irrigation is more or less the same since the 1970s.

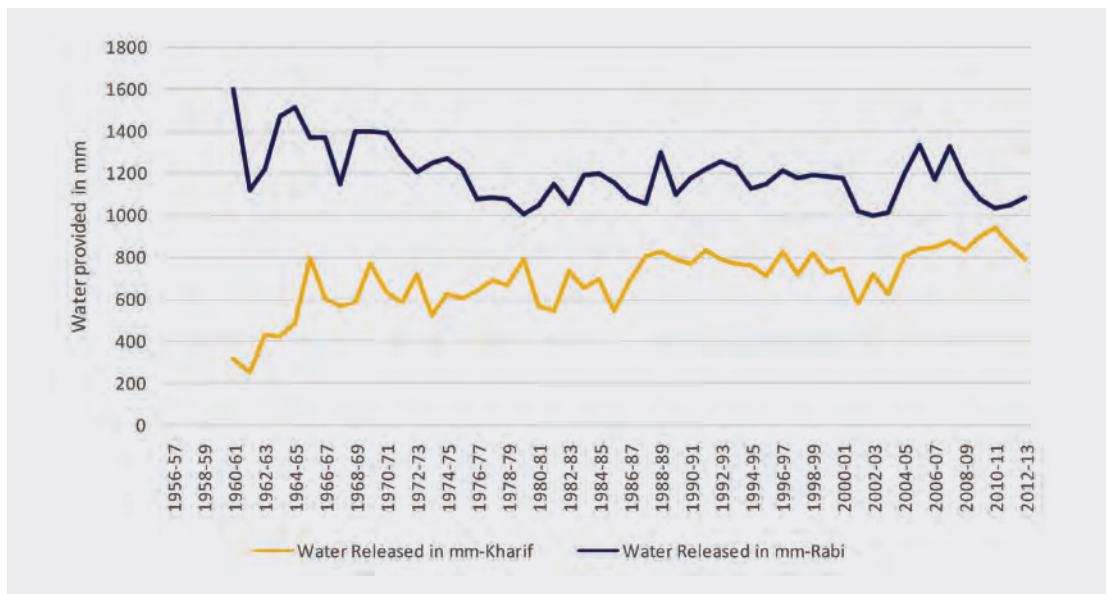
The nature of the analysis above hides spatial variation in irrigation across the command area because of the aggregate nature of the data available. The nature of the Hirakud reservoir at the locations of its two main gates, the left bank canal (LBC) that irrigates the Sason command and the right bank canal (RBC) that irrigates Bargarh district, is highly varied. While the point at which the RBC directs water out of the reservoir is relatively unaffected by siltation, the LBC gate is heavily prone to siltation from incoming silt of the Ib river. Moreover, the confluence of the Ib and the Mahanadi just behind the Sason canal gate has a large concentration of industries seeking to draw water from the reservoir. Several of them, including, prominently, Bhushan Steel and Vedanta, have made attempts to sink intake wells deep into the reservoir's dead storage thereby affecting water availability for irrigation and leading to the protests of 2006-07 (Centre for Science and Environment, 2007; Choudhury, Sandbhor, & Satapathy, 2012b). Since then, this has been strongly and successfully resisted by the farmers. In the summer of 2016, following a harsh drought year, two thermal power plants on the banks of the Ib were forced to shut down power production. While aggregate project figures available show that Rabi irrigation has been on the rise, the fact remains that such spatial variation in the project's design and ongoing pressure from the industries for water will continue to pose a threat, more probably in the Sason command.

Figure 17: Hirakud – Area Irrigated and Water Released for Irrigation



Source: Department of Water Resources, Government of Orissa, 2014

Figure 18: Season-wise water provided for irrigation

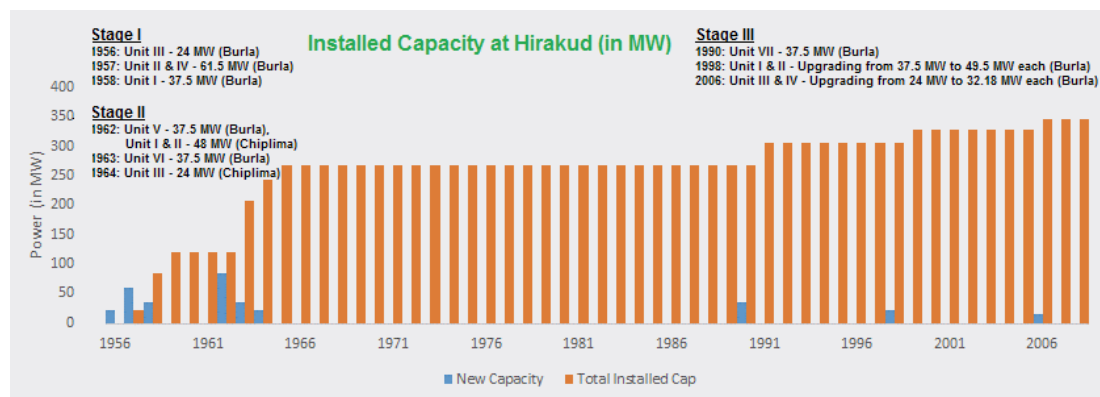


Source: Department of Water Resources, Government of Orissa, 2014

Water for Hydro Power Production

The power production capacity at Hirakud now stands at a total of 348 MW: 276 MW at the Burla powerhouse and 72 MW at Chiplima powerhouse. This capacity was installed in three stages, beginning in 1956.

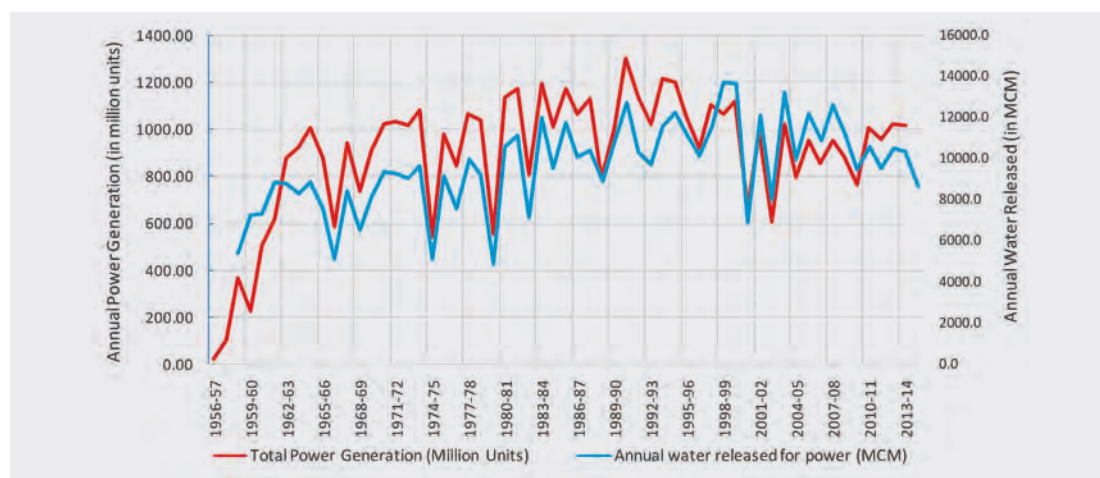
Figure 19: Installed Capacity at Hirakud for Power Generation



Source: Department of Water Resources, Government of Orissa, 2014

Annual releases of water for power have been much higher than average during 1998-99 to 2007-08, at about 11,300 MCM. The total power production however had fallen from 1090 million units (in the 1990s) to below 850 million units annually during that period. The decline was a result of operational issues in the Chiplima hydropower station due to which power generated there fell drastically. Power generation at the Burla station, during the same period, was higher than average. Since 2010, however, power production from Chiplima rose again after maintenance and repair works restored its production capacity. Since then, water allocations for hydropower have also fallen back to an average of about 10,300 MCM annually.

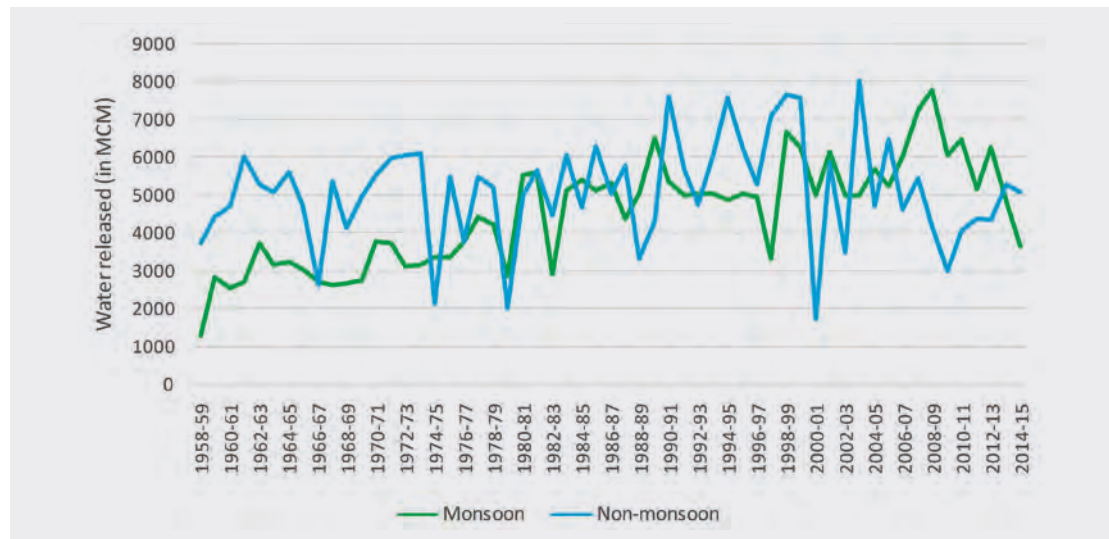
Figure 20: Hirakud – Annual Power Generated (Million Units) and Water Released (MCM)



Source: Department of Water Resources, Government of Orissa, 2014

In the monsoon season (July–September), releases have seen a steady rise from an average of 2600 MCM in the initial years of the project to its current average of 5260 MCM from 2010-11 to 2014-15. The releases for power in the non-monsoon season (October–May) have remained steady at about 5000 MCM. Some large year-to-year fluctuations have been observed with releases being much above average in years 1995, 1996, 1998 and 2004, and below average in 2001, 2003 and 2009 (Figure 21).

Figure 21: Hirakud – Seasonal Releases of Water for Power (MCM)



Source: Department of Water Resources, Government of Orissa, 2014

In Conclusion

It is seen that in the Hirakud reservoir about 6272 MCM of the annual yield can be made available for different uses (at 90 per cent dependability). Of this, water lost to evaporation is estimated as 479 MCM and 4.93 MCM is the urban water supply requirement. The remaining is available for distribution in the last month of Kharif irrigation (October), the full season of Rabi irrigation (December–April), non-monsoon power generation and industrial supply (October–May). The Jeyaseelan committee had estimated the water requirement for one month of Kharif irrigation to be 324 MCM and another 1130 MCM for Rabi irrigation (Department of Water Resources, Government of Orissa, 2007b, p. Section 5.2). In addition to this, 1585 MCM is the Rabi irrigation requirement in the delta of the Mahanadi for which the same amount has to be released. This 1585 MCM would also generate power at Burla and Chiplima power stations. This leaves about 2749 MCM of additional water available for power generation, maintaining e-flows and industrial water requirements. The Water Services department had put a cap of 432 MCM of water allocations to the industries (Department of Water Resources, Government of Orissa, 2007b). The Jeyaseelan committee prescribes a minimum of 3693 MCM for power generation annually because of the needs of the delta irrigation.

Vis-à-vis these figures, it is seen that the current irrigation patterns show water requirement of about 1680 MCM for Rabi irrigation (based on Jeyaseelan figures of Rabi irrigation allocations from 1982-83 to 2006-07). Since 2006-07, the Rabi irrigation water releases have in fact been much higher, at almost 2000 MCM, while the area under Rabi irrigation has also increased. Similarly, non-monsoon water use for power generation (October to June) has been about 4616 MCM in the last five years and monsoon water use for power generation has been about 5200 MCM. These figures imply a scenario of excess, but it must be noted that much of the non-monsoon runoff is concentrated in October when the reservoir is near FRL. The 90 per cent dependable figure for non-monsoon runoff after October is 830 MCM in comparison with 823 MCM for the month of October. This limits the quantum of non-monsoon runoff available for use. In a below average monsoon year, the water availability in the Hirakud would be only about 5200 MCM. This calls into question the plan for water allocation in water scarce years.

While this analysis looks at water supply for irrigation in the aggregate, its main constraint is that it cannot say much about spatial uniformity of irrigation across the command area. Farmers' groups also mentioned that besides the quantity of water supplied, the timing for releasing water is also essential. Due to the late monsoon and delayed releases of water from the project, there were some areas where crop growth suffered. Farmers have been fighting to ensure that the dead storage of the reservoir is protected from several industries that have attempted to put their intake wells directly into it. This the farmers believed would help ensure that even with a delayed monsoon, the Kharif crop is not affected as the water that remains in the reservoir's dead storage from the previous year, is available for use.

On the whole, the figures show that there is a lot of potential for increasing the efficiency of irrigation in the Hirakud project. This fact is admitted by irrigation and agricultural officers themselves in command area districts. An argument can be made that if not with technological changes then simply with introducing more certainty in the irrigation scheduling, water can be used more efficiently. Surveys of the command areas of the project show that the level of minors and field channel maintenance is very poor. This partially explains the inefficient irrigation. However, water in much of the Hirakud command is seen as abundant and there is little incentive to save. Some farmers also opine that due to excessive water logging in their fields, they have contemplated not irrigating and allowing the land to go fallow for one season²⁸. However, this has to be a decision taken together by several farmers since, given the nature of flood irrigation, one farmer choosing not to irrigate would not work. In other areas of the command area, towards the tail adjacent to the Mahanadi river, several villages do not receive canal water and instead they irrigate by lifting water directly from the river. Other areas that are not officially part of the command area, also benefit from the project waters. According to a proposal in the 1960s, the Government of Odisha had suggested extending the command area of the project further to other drought-prone areas of the Bargarh district.

28. As discussed in the meeting of a Western Odisha farmer's union held at Sambalpur in October 2016.

However, this never materialised. The farmers' movements continue to ask as to why this idea was abandoned.

Groundwater use in the command area is not very prominent. The geology of the command area is highly variable and does not offer large groundwater yields. However, some tehsils do have increasing numbers of borewells, incidentally in areas where canal waters are also available in plenty. This is due to the highly variable nature of the local aquifers. The Jeyaseelan report suggests that some groundwater potential exists in the command area to explore conjunctive water use to a small degree. The civil society in the region observes that while the focus of the media has been on the Hirakud, the water provision from this project has not faltered. However, other smaller projects in western Odisha now face intermittent water supply issues. They are now advocating for increased electricity subsidies for groundwater pumping in such areas where surface water supply is unreliable.

With the threat of falling water inflows into the Hirakud reservoir, bringing in reform for more efficient water use in agriculture and industry, while limiting the scale of water use in the first place, will be the need of the hour to prevent long term inter-state conflict.

6

Agriculture and Its Water Use in the Mahanadi River Basin

In both Chhattisgarh and Odisha, the majority of people depend on agriculture for their livelihoods. Both states predominantly grow rainfed rice (making up about 70-75 per cent of the gross cropped area). In areas which are irrigated, rice makes up more than 90 per cent of the area sown. In this chapter, the broad state of agriculture and water allocations and use within agriculture across the Mahanadi Basin is described. Issues like trends in total cropped area, types of crops sown and irrigation over the last two decades are explored to develop the water use scenarios in this sector in the coming decades. The analysis in this section is largely based on secondary government data published by the Directorate of Economics and Statistics, MoA, Gol. Later sections of this report draw upon field observations, to further refine the picture and qualify the trends observed through secondary data.

The larger picture that emerges from this analysis shows evidence of acceleration in the development of agriculture across Chhattisgarh. This development has been aided with Kharif season surface irrigation in the plains in the Dhamtari, Durg, Raipur and Janjgir-Champa districts, whereas groundwater has contributed greatly to development in Western Chhattisgarh in the Bilaspur, Kawardha and Durg districts. Rabi irrigation in Chhattisgarh is also increasing but is still not as prevalent as in Odisha.

Odisha's agriculture on the other hand appears to be in decline, with the gross cropped area having fallen during the last two decades. The rise in culturable wastelands and fallow lands explains most of this changing land use as per available land use statistics. Irrigation is more prominent in the delta and in western Odisha, and the potential area irrigated has increased greatly over time.

Chhattisgarh's agriculture also shows an observable trend of diversification, with the percentage of land under rice falling as compared to the other crops such as pulses and oilseeds, which are Rabi crops. In Odisha, the proportion of area under rice has remained more or less the same, whereas that under pulses has increased and oilseeds has decreased.

Seasonal Variations in Cropping

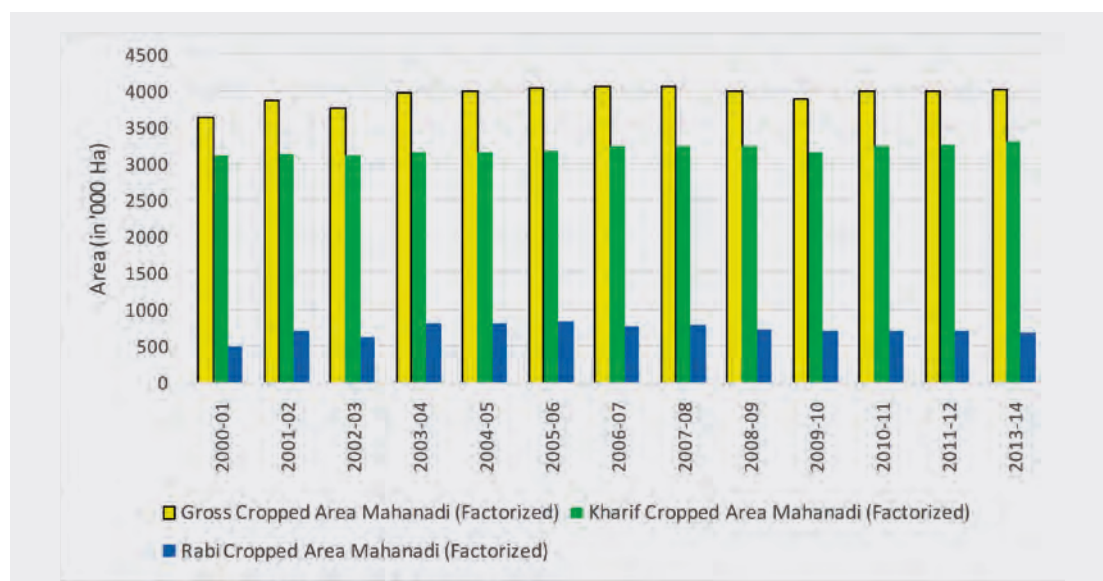
Chhattisgarh

Statistics published by the Directorate of Economics & Statistics, MoA, Gol (2013-14) show a gross cropped area of about 4010 Th Ha²⁹ for the 15 districts of Chhattisgarh

29. As per National Remote Sensing Centre (NRSC), GCA in 2013-14 is 5783 Th Ha, Kharif is 4189 Th Ha and Rabi is 1590 Th Ha for the year 2013-14.

within the Mahanadi Basin. Of this, the Kharif cropped area amounts to 3296 Th Ha and Rabi about 693 Th Ha.³⁰ This indicates that the cropping intensity in the Chhattisgarh half of the Mahanadi is about 121 per cent. The Kharif cropped area has seen a steady increase of about 200 Th Ha since the formation of the state of Chhattisgarh, whereas the Rabi cropped areas peaked in the year 2005-06 and have decreased since then.

Figure 22: Season and Gross Cropped Area – Chhattisgarh part of Mahanadi Basin



Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 – District-wise, Season-wise Cropped Area, Chhattisgarh

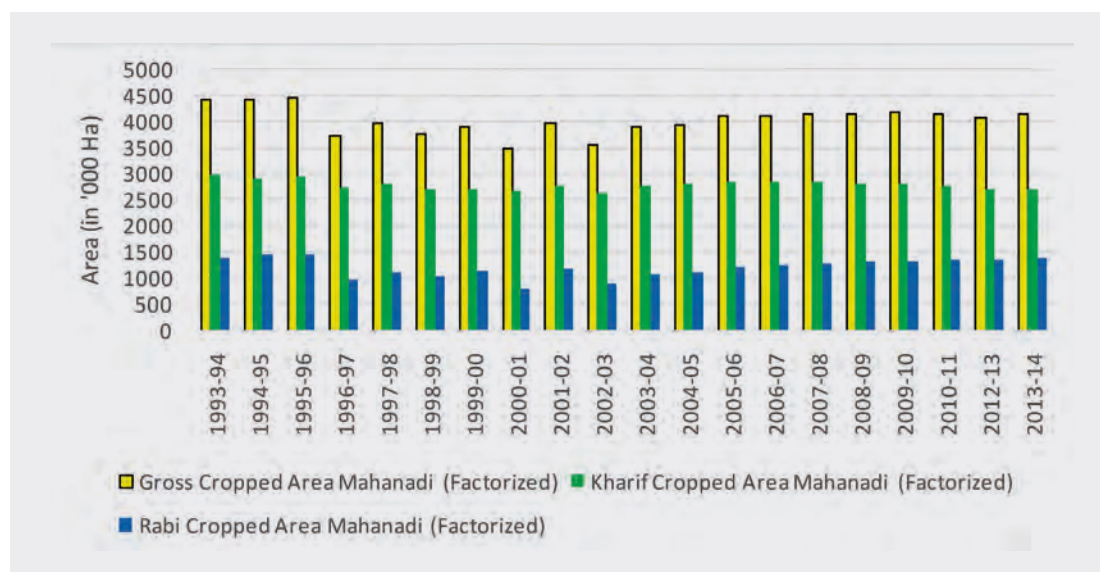
Odisha

In comparison, the Mahanadi districts of Odisha shows a decrease in the gross cropped area from 4506 Th Ha to 4122 Th Ha (2013-14)^{31,32,33} or a fall of about 8.5 per cent. In the land use data, this decrease is explained by a shift towards fallow lands or culturable

30. This cropping dataset does not contain data for summer cropping, whereas the irrigation dataset also mentions rice cropping under the summer season. The proportion of crops classified as 'Whole Year' is very minimal.
31. As per NRSC, gross cropped area is 3203 Th Ha, Kharif is 2262 and Rabi is 911 Th Ha respectively.
32. Not including horticultural crops since this data is available only from the year 2006-07 onwards.
33. The analysis for Odisha is largely done using data from the Statistics Cell of the Agricultural Dept. (Government of Odisha) up to the year 2010-11 for which the raw data was available. Another dataset available is that of the Directorate of Economics and Statistics (DES), Odisha which uses a different methodology for estimating cropped area. The Statistics Cell, covers 100 per cent of Odisha's villages, uses an eye-survey estimate methodology and counts all 40 types of crops, whereas the DES, Odisha uses a stratified sampling technique to sample 20 per cent of villages each year, in which they accurately measure cropped area for 13 major crops. The DES estimates a gross cropped area of about 5500 Th Ha for all of Odisha whereas the GCA as per the Statistics Cell is about 9000 Th Ha.

wasteland. The total Kharif cropped area is about 2712 Th Ha and Rabi cropped area is 1396 Th Ha, indicating a cropping intensity as high as 151 per cent. The Kharif cropped area has decreased substantially from 3066 Th Ha to 2712 Th Ha, whereas the Rabi cropped area has risen again to 1396 Th Ha, after falling sharply in the late 1990s.

Figure 23: Season and Gross Cropped Area – Odisha part of Mahanadi Basin



Source: Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise Cropped Area, Odisha

Geographical Variations in Cropping

Kharif Season

Districts in the plains of Chhattisgarh have more than 50 per cent of their geographical area sown in the Kharif season, Durg, Mahasamund and Janjgir-Champa being the highest (Annexure 1). Durg and Raipur districts together account for 1/3rd of the Kharif cropped area of Chhattisgarh. These areas receive irrigation from surface irrigation projects on the main stem of the Mahanadi, the largest of which is the Mahanadi Reservoir Project.

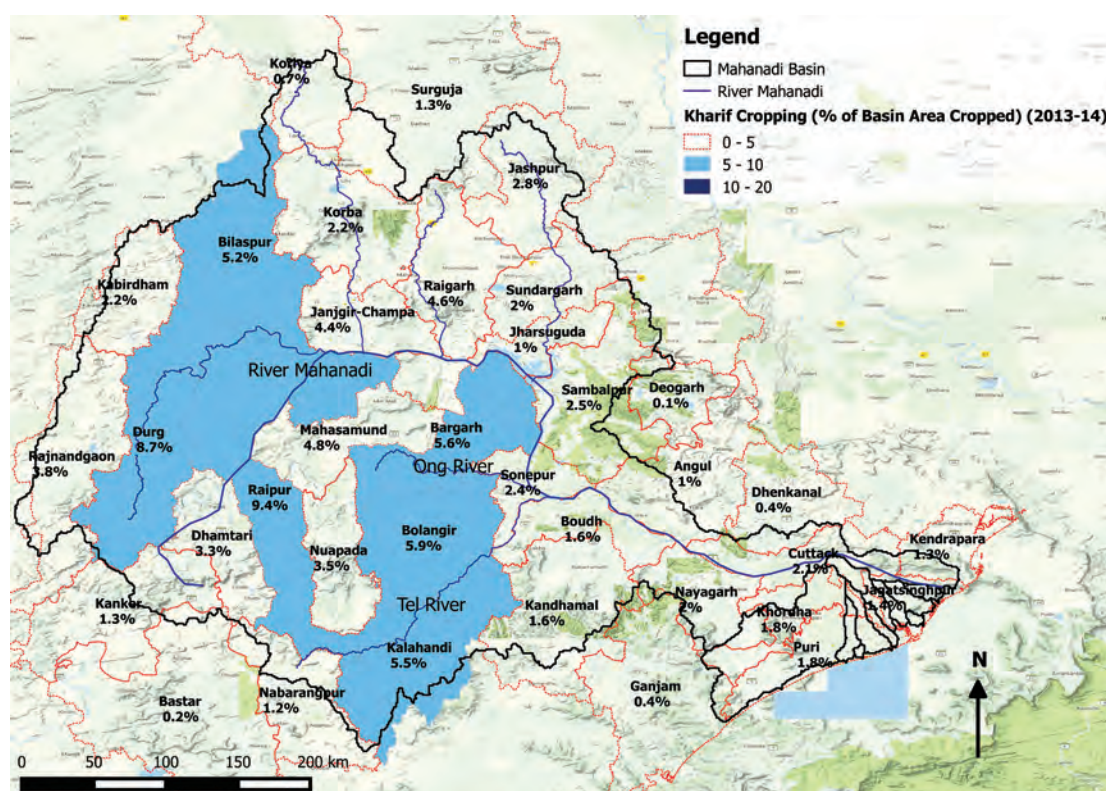
Other districts in the uplands of Chhattisgarh in the north and south (Koriya, Surguja, Kanker and Bastar) are largely forested. Districts at higher elevations in Western Chhattisgarh –Bilaspur, Kawardha and Rajnandgaon have 40 per cent or less of their geographical area sown. These districts do not have the same scale of surface irrigation infrastructure though groundwater irrigation is increasing there.

Balangir, Bargarh, Nuapada, Kalahandi and Subarnapur districts in the western plains and Kendrapara on the coast are the largest districts in terms of percentage of their geographical area under Kharif cropping in Odisha (Annexure 2). An average of 60

per cent of their geographical area is sown in the Kharif season. Balangir, Bargarh and Kalahandi together account for 38 per cent of the Kharif cropped area in Odisha. Much of this land is rainfed but it also receives Kharif irrigation from large surface projects such as the Hirakud, Indravati and the Mahanadi Delta project.

Jharsuguda and Sambalpur which are adjacent to the Mahanadi, and Boudh, Kandhamal, Nayagarh and Angul in central Odisha, in comparison, have larger proportions of forested land and lesser irrigation potential. The percentage area sown in other coastal districts (Cuttack, Jagatsinghpur, Puri) in the Kharif season is about 40 per cent. Kharif cropping in the delta region is vulnerable to flooding and is therefore unlike other parts of the state.

Figure 24: Kharif Cropping (as percentage of Basin Cropped Area)



Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 and Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise Cropped Area, Chhattisgarh & Odisha

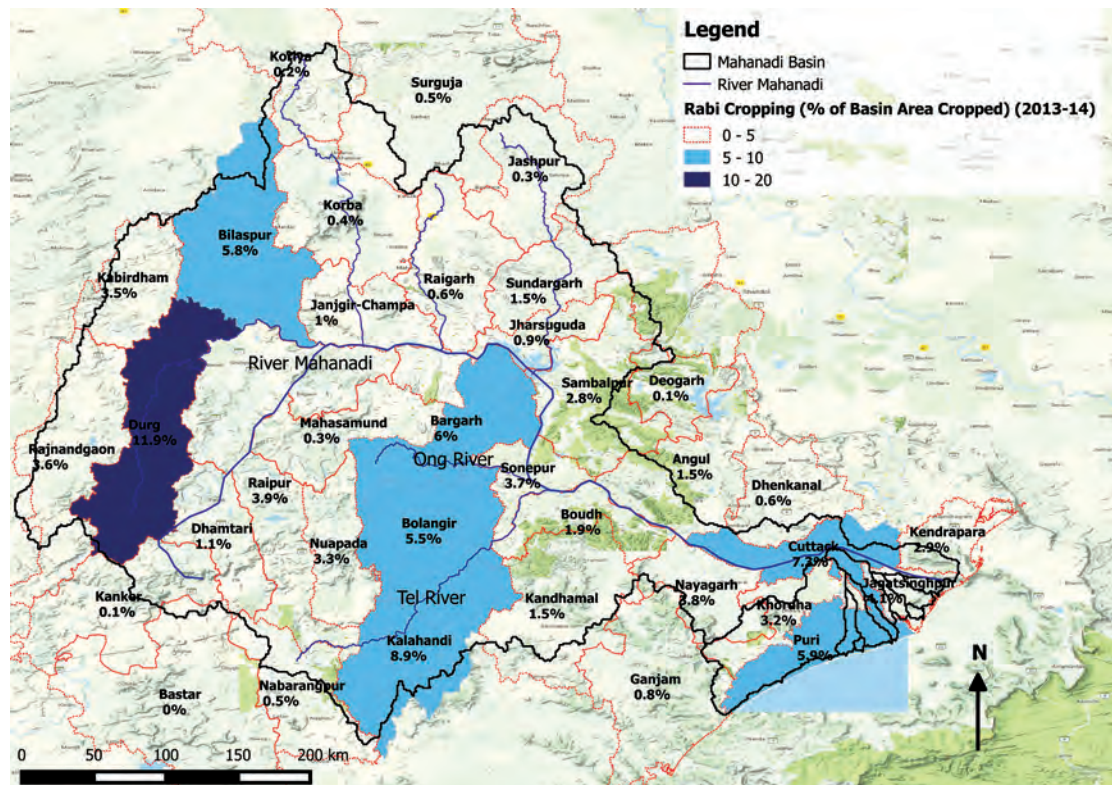
Rabi Season

In Chhattisgarh, the western districts of Durg, Kawardha and Bilaspur are cropped the most in the Rabi season (about 29 per cent, 19 per cent and 16 per cent, respectively, of their area). In comparison, the districts in the plains such as Raipur, Mahasamund and Janjgir-Champa, which are highly irrigated in the Kharif season, receive much less

irrigation in the Rabi season and hence have less than 5 per cent of their area under Rabi cropping (Annexure 1). The Durg and Bilaspur districts together make up about 53 per cent of the Rabi cropped area of Chhattisgarh.

In Odisha, the small low lying coastal districts of Cuttack, Jagatsinghpur and Puri have the largest proportion of their geographical area under Rabi cropping. About 40 per cent or more of their area is sown in the Rabi season (Annexure 2). Large parts of these districts are irrigated by the Mahanadi Delta project. Rabi cropping in the western Odisha districts of Bargarh, Sonepur, Sambalpur and Kalahandi is heavily dependent on surface irrigation, of which the largest project is the Hirakud. The geographical area sown in the Rabi season is a mere 20–25 per cent (as compared to 60 per cent in the Kharif). The most important districts in the Rabi season, Cuttack and Kalahandi, together account for 25 per cent of the Rabi cropped area in Odisha.

Figure 25: Rabi Cropping (as percentage of Basin Cropped Area)



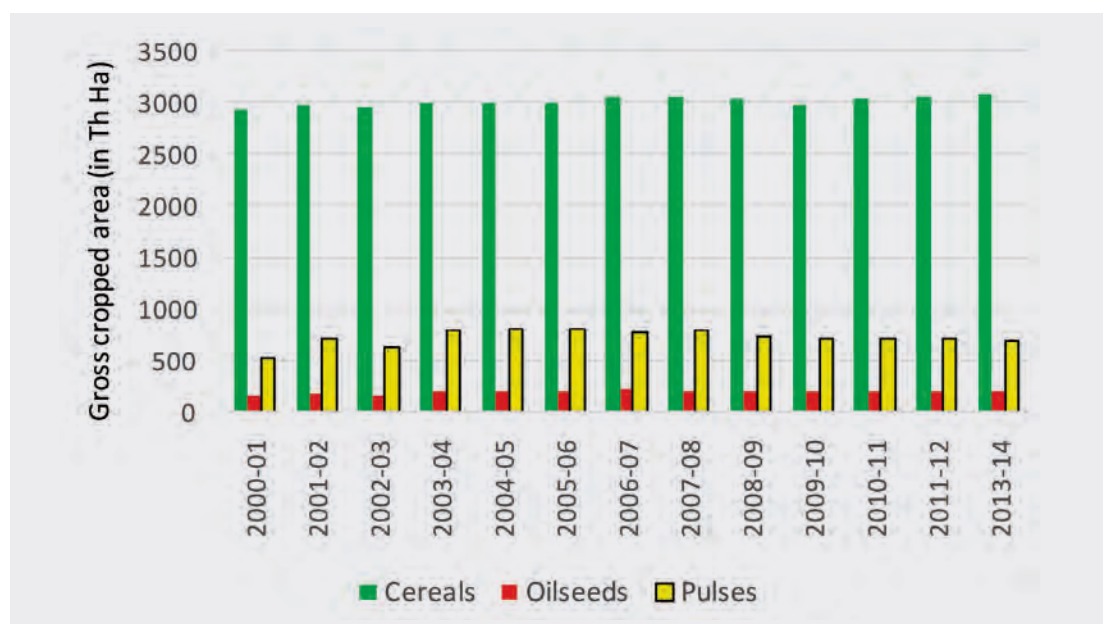
Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 and Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise Cropped Area, Chhattisgarh & Odisha

Cropping Patterns

Chhattisgarh

Since 2000-01, there has been a rise in the total gross cropped area in Chhattisgarh, from 3620 Th Ha to 4010 Th Ha. There has been little change in the gross cropped area under cereals, from 2942 Th Ha (81 per cent) to 3090 Th Ha (77 per cent), and a large rise in the area under pulses, from 508 Th Ha (14 per cent) to about 692 Th Ha (17 per cent) (Annexure 5).

Figure 26: Major Crop Groups in Chhattisgarh (Gross Cropped Area in Th Ha)



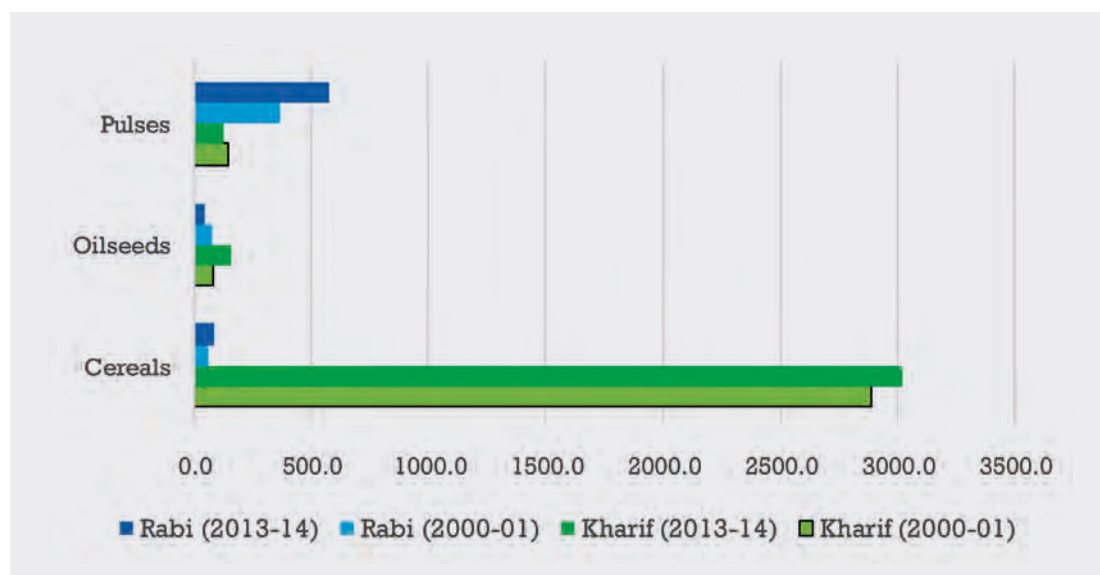
Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 – District-wise, Year-wise, Crop-wise, Cropped Area, Chhattisgarh.

Cereals make up about 3015 Th Ha (91 per cent) of the 3296 Th Ha sown area in the Kharif season. Of this, rice alone makes up 2932 Th Ha (89 per cent) of the sown area. Oilseeds and pulses make up about 5 per cent and 4 per cent of the Kharif sown area, respectively. This Kharif area cropped under cereals has increased since 2000-01 when cereals were sown on 2888 Th Ha (93 per cent) of the Kharif sown area. The proportion of oilseeds in the Kharif season has risen from 2 to 5 per cent in the same period.

In the Rabi season, pulses (mainly gram and khesari) make up the largest group, accounting for 573.5 Th Ha (83 per cent) of the area sown; cereals and oilseeds represent 11 per cent and 6 per cent, respectively. Pulses make up most of the expansion in the total Rabi area sown since 2000-01, when it was only 366 Th Ha (74 per cent). Oilseeds on the other hand have diminished, from 15 per cent in 2000-01.

Raipur and Durg together are the largest cereal growing districts (together 34 per cent of sown area). Durg also has the highest share of area under pulses, 33 per cent while Bilaspur stands second at 16 per cent.

Figure 27: Season-wise Crop Groups – Chhattisgarh part of Mahanadi Basin



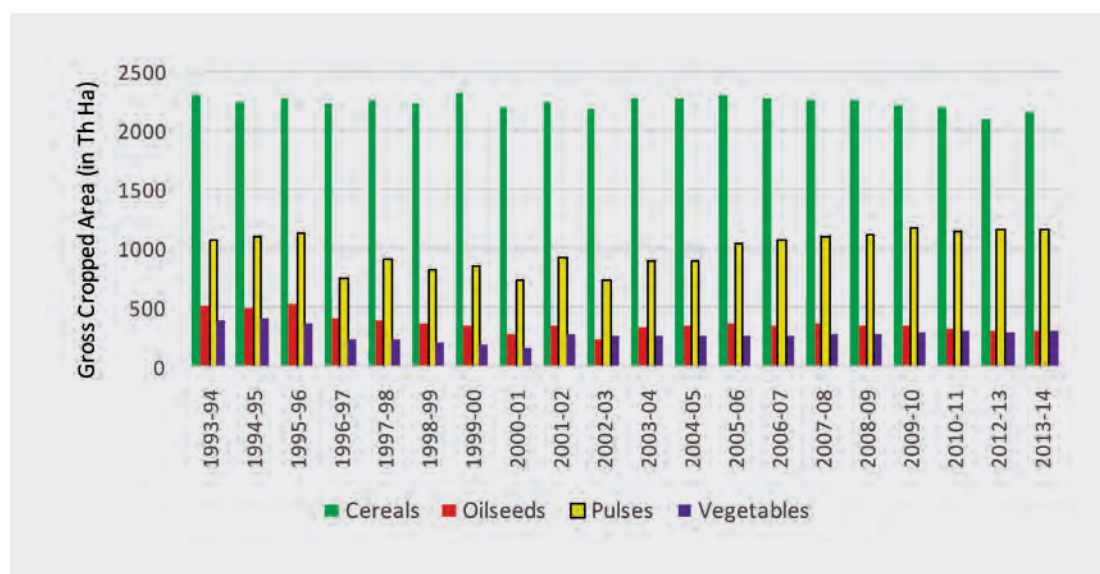
Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 – District-wise, Season-wise, Crop-wise, Cropped Area, Chhattisgarh

Odisha

The gross cropped area in Odisha has fallen from 4414 Th Ha to 4122 Th Ha. In Odisha, like Chhattisgarh, cropping is predominantly rice (paddy). There are three growing seasons for paddy—Autumn, Winter³⁴ and the Rabi season. The gross cropped area under cereals has decreased marginally from 2304 Th Ha (52 per cent) in 1993-94 to 2167 Th Ha (53 per cent) in 2013-14, whereas the same area under pulses has increased marginally from 1076 Th Ha (24 per cent) to 1163 Th Ha (28 per cent) in the same period (Annexure 6). The area under cereals in Odisha is much smaller as compared to Chhattisgarh whereas area under pulses is much larger in Odisha.

34. In the raw data for agricultural cropping, there are three seasons given for Rice: Autumn, Winter and Rabi. The Autumn (also known as early Kharif) and Winter (also known as late Kharif) season together constitute the Kharif season.

Figure 28: Major Crop Groups in Odisha (Gross Cropped Area in Th Ha)



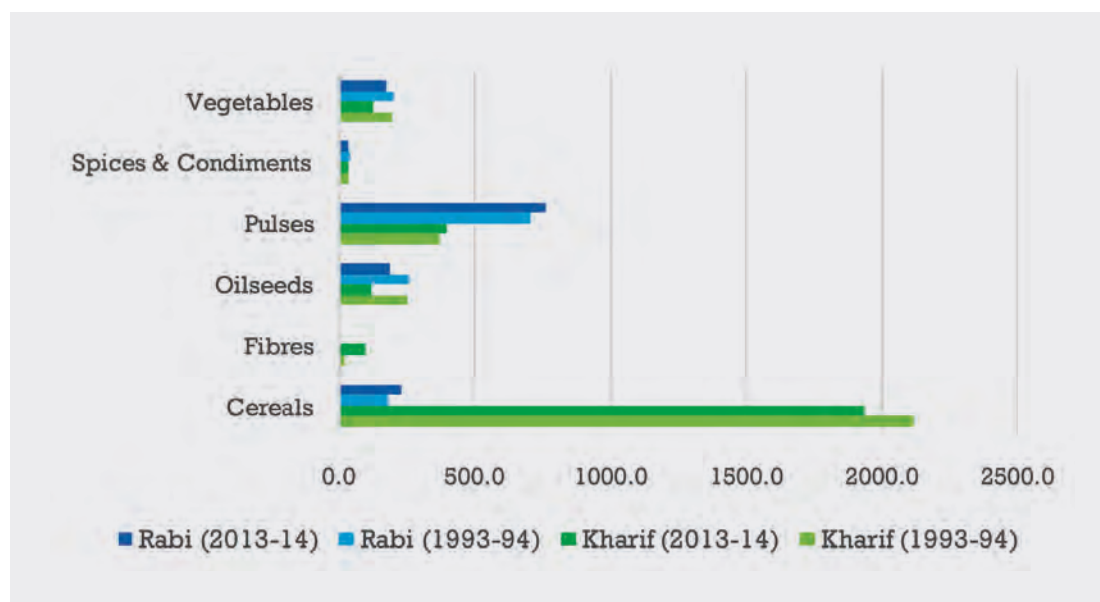
Source: Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Year-wise, Crop-wise, Cropped Area, Odisha

The percentage Kharif (Autumn + Winter) area under rice has fallen from 2011 Th Ha to 1833 Th Ha (67 per cent) from 1993-94 to 2013-14. This is out of the total Kharif area under cereals, which is about 1938 Th Ha (71 per cent). Other crop groups of the Kharif season are pulses, oilseeds and vegetables, which make up about 396 Th Ha, 120 Th Ha and 124 Th Ha, respectively, of the total Kharif cropped area of 2712 Th Ha. Of all crop groups, pulses and fibres have increased in area since 1993-94, whereas all other crop groups (oilseeds, vegetables, etc.) have decreased.

The area under crops in the Rabi season is about 1395 Th Ha or half of the area in the Kharif season. Pulses dominate, comprising 766 Th Ha (55 per cent) of the total cropped area in 2013-14, with cereals at 16 per cent, oilseeds at 14 per cent and vegetables another 13 per cent. Rice, in comparison, represents only 216 Th Ha (15 per cent) of the Rabi cropped area.

Balangir, Bargarh and Kalahandi together are the most important cereal growing districts in Odisha, comprising about 35 per cent of the gross area under cereals, whereas Kalahandi is the largest oilseeds and pulses growing district.

Figure 29: Season-wise Crop Groups – Odisha part of Mahanadi Basin³⁵



Source: Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise, Crop-wise, Cropped Area, Odisha

Irrigation Coverage – Seasons and Crops

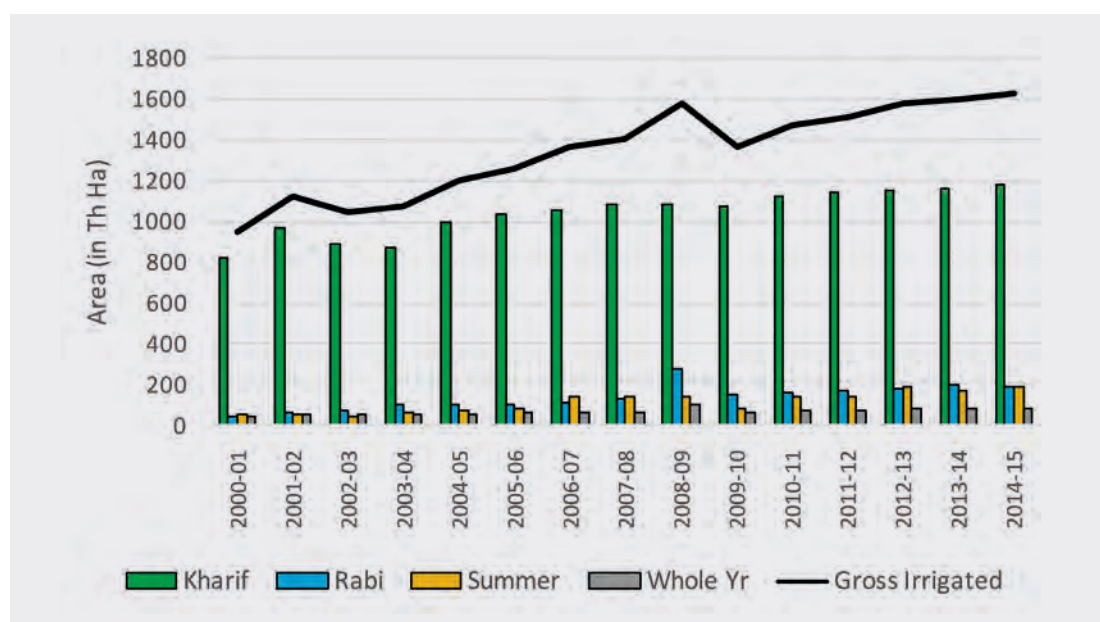
Chhattisgarh

Large tracts of the plains of Chhattisgarh in the Mahanadi Basin have the infrastructure for irrigation. The state government is making concerted efforts to intensify agriculture in the state, having increased the irrigated area (surface + groundwater) from 950 Th Ha in 2000-01 to 1597 Th Ha in 2013-14. Irrigation in the Kharif season amounts to 35 per cent (1163 Th Ha of 3296 Th Ha) of the Kharif sown area and in the Rabi season amounts to 27 per cent (190 Th Ha of 693 Th Ha) of the Rabi sown area.³⁶

35. In this analysis, perennial crops (sugarcane and tobacco) have been left out, since they cumulatively make up less than 0.5 per cent of the GCA.)

36. In the irrigation data, area is also reported in the 'Summer' and 'Whole Year' seasons, amounting to 169 Th Ha and 74 Th Ha, respectively. In the cropping data, however, Summer cropping is not and Whole Year crops are negligible. This discrepancy should be noted.

Figure 30: Season-wise Irrigation in Mahanadi Basin - Chhattisgarh



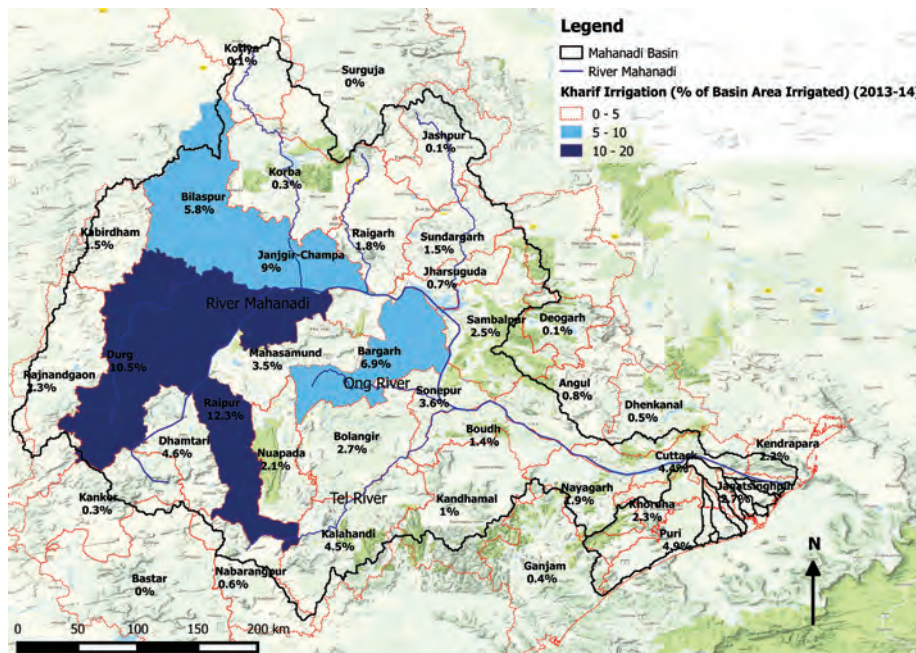
Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 – District-wise, Season-wise, Source-wise, Irrigated Area, Chhattisgarh

Bilaspur, Durg, Dhamtari, Janjgir-Champa and Raipur in the plains of Chhattisgarh are the most highly irrigated districts in the Kharif season, with about 50 per cent of their sown area being irrigated and 75 per cent in the case of Janjgir-Champa. Kawardha in western Chhattisgarh is highly irrigated in the Rabi season, with about 49 per cent of its sown area receiving irrigation. Besides, most of the Rabi irrigation is located at Kawardha and Durg districts (See Figure 32).

Rice makes up nearly 100 per cent of the irrigated area in the Kharif season (1159 Th Ha) as well as the summer season (169 Th Ha). Rabi irrigation is used largely for wheat and gram. Gram has gained importance over the years. In 2000-01, it made up about 10 per cent of the Rabi irrigated area, whereas in 2013-14 it had risen to about 60 per cent. In the same period, the share of wheat decreased from 68 per cent to 30 per cent. Fruits and vegetables constitute the largest share (about 70 per cent) of the 'whole year' crops irrigated.

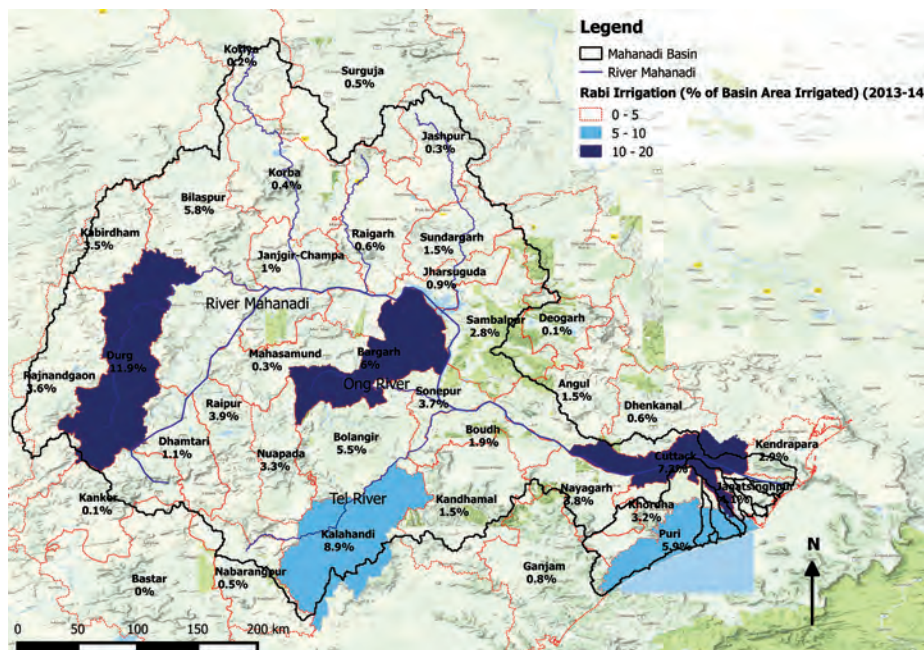
On an aggregate level, there has been diversification in the crops irrigated. While in 2000-01, rice represented about 91 per cent (868 Th Ha) of the gross irrigated area, in 2013-14, it amounted to about 83 per cent (1330 Th Ha) while pulses (including gram) had risen from 1 per cent (7 Th Ha) to 8 per cent (123 Th Ha). Raipur, Durg and Janjgir-Champa are the districts with the largest percentage of irrigated cereals. Almost 60 per cent of the irrigated cereals in Chhattisgarh is found in these districts. The Durg district is the largest in terms of irrigated area under pulses as well as vegetables. About 57 per cent of the irrigated pulses in Chhattisgarh is grown in Durg.

Figure 31: Kharif Irrigation (as percentage of Basin Area Irrigated) 2013-14



Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 and Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise, Irrigated Area, Chhattisgarh & Odisha

Figure 32: Rabi Irrigation (as percentage of Basin Area Irrigated) 2013-14

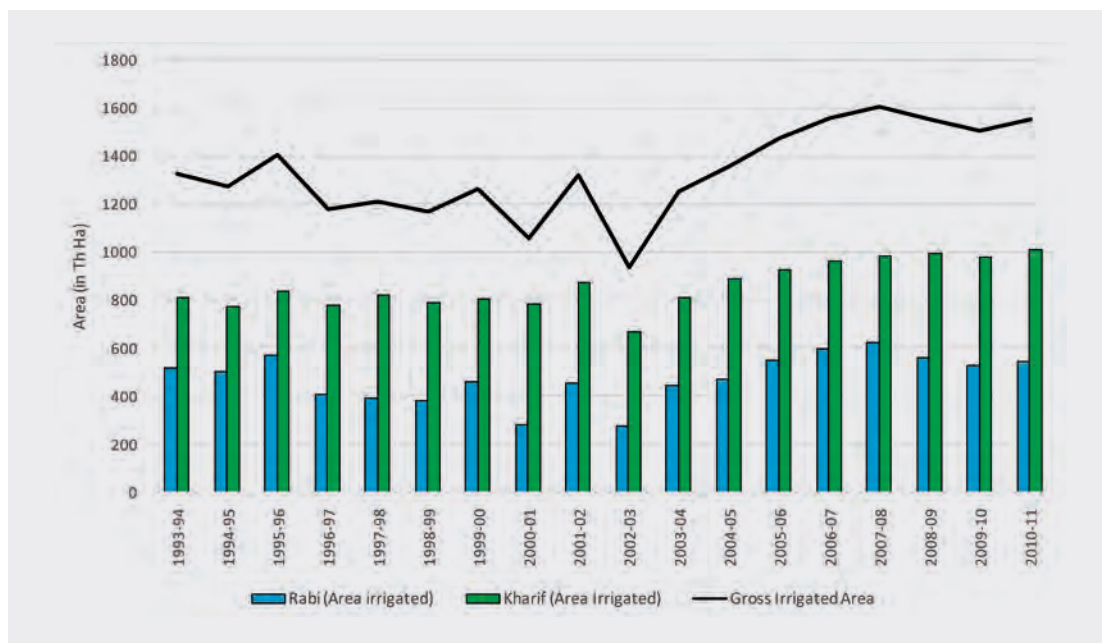


Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 and Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise, Irrigated Area, Chhattisgarh & Odisha

Odisha

The Odisha part of the Mahanadi Basin is well irrigated³⁷. The area under irrigation has increased since 2003-04; prior to this, a declining trend was observed. Currently, an average of 39 per cent (1065 Th Ha out of 2712 Th Ha) of the Kharif sown area and 47 per cent (658 Th Ha out of 1395 Th Ha) of the Rabi sown area receives irrigation.

Figure 33: Season-wise Irrigation in Mahanadi Basin - Odisha



Source: Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise, Source-wise, Irrigated Area, Odisha

In the delta region of the Mahanadi, which covers the districts of Cuttack, Jagatsinghpur and Puri, more than 70 per cent of the sown area is irrigated in the Kharif season, making them the most highly irrigated districts. In comparison, the Western Odisha districts of Bargarh (79 per cent), Nabarangpur (73 per cent) and Sambalpur (61 per cent) are the most highly irrigated in the Rabi season. Bargarh, Kalahandi and Cuttack in Odisha are where most of the Rabi irrigated area in the basin is concentrated (See Figure 32).

The major irrigated crop in the Kharif season is rice with about 894 Th Ha (84 per cent) of the total Kharif irrigated area and, in the Rabi season, it is both rice and vegetables, which make up 215 Th Ha (32.6 per cent) and 172 Th Ha (26 per cent) each of the total irrigated area.

37. The source of data on irrigation is the Statistics Cell of the Department of Agriculture, GoO (2011) unlike the rest of the data which is available for 2013-14.

The Gross Irrigated Area (2010-11) under rice is about 70 per cent. The proportion of rice under gross area irrigated has risen from 64 per cent (851 Th Ha) in 1993-94 to 70 per cent (1088 Th Ha) in 2010-11, being as high as 80 per cent in the early 2000s. This is unlike Chhattisgarh where the proportion under rice is falling. The proportion under vegetables has risen again to 14 per cent (224 Th Ha) in 2010-11, after being as low as 8 per cent (75 Th Ha) in 2000-01 and 2002-03. Bargarh, Kalahandi and Puri districts together grow about 42 per cent of the irrigated cereals while Balangir and Cuttack districts together grow almost a quarter of the irrigated vegetables.

Sources of Irrigation

Chhattisgarh

The majority of surface irrigation in Chhattisgarh is achieved through 12 major irrigation projects and 29 medium irrigation projects, which totally cover a culturable command area of 1254 Th Ha (1103 Th Ha – Major projects and 151 Th Ha – Medium projects) and an Ultimate Irrigation Potential of 1237 Th Ha (1076 Th Ha – Major projects and 161 Th Ha – Medium projects).

Table 13: Major Projects in the Mahanadi River Basin – Chhattisgarh

Name of the project	Irrigation Potential Created (Th Ha) (2014-15)	
	Culturable Command Area (Th Ha)	Ultimate Irrigation Potential (Th Ha)
Jonk Diversion	15.5	14.57
Hasdeo-Bango	285	433.5
Kelo (ongoing)	24.39	22.81
Kharang	66.4	56.3
Kodar (ongoing)	21.7	23.47
Mahanadi	301	264.31
Mand	11.10	13.1
Maniyari	64.77	55
Pairi	33.6	42.98
Rajeev Samvardhan Yojana	28	28
Sondur Reservoir Project	12.26	38.47
Tandula	246.3	84
Total	1103	1076

Source: Central Water Commission, 2016b

In terms of actual area irrigated year-on-year, canal irrigation has increased to cover about 918 Th Ha (2013-14), a 43 per cent rise since 2000-01. In the same period, well irrigation has almost tripled, from 198 Th Ha to 589 Th Ha. It now makes up 36 per cent of the gross irrigated area in Chhattisgarh, whereas canal irrigation makes up 58 per cent. Thus, there is a very clear push visible towards groundwater-based irrigation where earlier the dependence was very low. Dependence on tanks and other sources is low, at about 2 and 3 per cent respectively. The difference in source of irrigation across districts is evident. Raipur, Durg and Janjgir-Champa make up about 67 per cent of the gross canal irrigated area in Chhattisgarh. Bilaspur, Durg and Kawardha districts together constitute about 57 per cent of the gross well irrigation in Chhattisgarh (Annexure 3).

Odisha

Surface irrigation in Odisha is enabled by 11 major irrigation projects (Table 14) and 29 medium irrigation projects, totally covering a culturable command area of 738 Th Ha (Major: 611 Th Ha and Medium: 126 Th Ha) and an Ultimate Irrigation Potential of 641 Th Ha (Major: 520 Th Ha and Medium: 121 Th Ha).

Table 14: Major Projects in the Mahanadi River Basin – Odisha

Name of the Project	Irrigation Potential Created (Th Ha) (2014-15)	
	Culturable Command Area (Th Ha)	Ultimate Irrigation Potential (Th Ha)
Hirakud	157.8	261.2
Delta Stage I, II ³⁸	78.3, NA	NA
Lower Indra	29.9	38.8
Lower Suktel	31.8	29.8
Mahanadi Birupa Barrage	NA	NA
Mahanadi Chitrotpola	19.54	25.16
Naraj Barrage	183.2	NA
Salki	19.9	20.1
Sunder	4.6	6.07
Upper Indravati	76.27	125.08
Total	601.3	506.21

Source: Central Water Commission, 2016b

In Odisha, sources of irrigation are classified as, 1) Major and medium flow projects (canal irrigation), 2) Minor flow projects (canal/tank irrigation), 3) Minor lift projects (well irrigation), and 4) Other sources (private lift irrigation, shallow tube wells, WHCs, creeks,

38. The CCA for the second Delta Irrigation project is not available.

dugwells and others). Of these, the first two are equivalent to canal irrigation and the third, we assume, is groundwater irrigation. The fourth category is a mix of both surface and groundwater sources, the precise proportion of each is not available. However, it is safe to assume that groundwater makes up a larger proportion of 'other sources' as well (Ministry of Agriculture, Government of Odisha, 2014).

The gross potential created in Odisha^{39,40} amounts to 5005 Th Ha of which the actual area irrigated amounts to 3521 Th Ha, about 70 per cent. The potential created under major and medium projects has almost doubled from 1110 Th Ha (1980-81) to 2014 Th Ha (2013-14). Its proportion in the state's total irrigation potential has dropped from 66 per cent to 40 per cent. The potential under minor flow projects has risen from 287 Th Ha to 682 Th Ha in the same period. Minor lift potential has risen the most rapidly from 33 Th Ha to 1059 Th Ha. It now makes up 21 per cent of the state's irrigation potential and Other Sources from 255 Th Ha to 1249 Th Ha (Ministry of Agriculture, Government of Odisha, 2014).

In Odisha, canal irrigation is very concentrated. Bargarh, Kalahandi, Cuttack and Puri districts make up about 89 per cent of the major and medium irrigation potential. Groundwater irrigation potential created is high in most districts receiving canal irrigation, namely Bargarh, Kalahandi and Cuttack. Besides these, Balangir and Jagatsinghpur also have large groundwater potential.

Estimated Water Allocations and Use

An estimate of water allocations and water use is necessary to foresee trends in water availability for different uses within the river basin in the years to come. Information is available on the actual number of water resource projects in the river basin and their capacity, obtained from the National Register of Large Dams (CWC). However, there is no consolidated secondary online information that tells us how the water from each of these projects is allocated between the different sectors. Similarly, there is no consolidated information on how these water sources were actually used, vis-à-vis the allocations. This information was obtained through field visits to some of the largest projects in the basin and then extrapolated to develop estimates for water allocations and use for the entire basin.

The water allocation for irrigation from the four largest irrigation projects in the Mahanadi Basin (the Mahanadi Reservoir project, Minimata Bango, Hirakud and Mahanadi Delta)

39. The actual area irrigated in 2013-14 was 3521 Th Ha, about 70 per cent of the total potential created. The state of Odisha does not provide the source-wise distribution of actual area irrigated.

40. Figures stated in this section are for all of Odisha's 30 districts. Disaggregated information for the 22 districts that lie within the Mahanadi Basin was not possible due to the non-availability of district-wise data until the year 2006-07. For the year 2013-14, the potential created within the 22 districts of the Mahanadi Basin amounted to 2414 Th Ha, 48 per cent of the state of Odisha and actual area irrigated is 1724 Th Ha.

were used to derive an estimate of water allocation for irrigation in the entire Mahanadi Basin. The known allocations for these projects, obtained from various project reports, were as follows.⁴¹

Table 15: Design Water Requirements for the Major Projects in the Mahanadi Basin

Project	Design Allocation to irrigation (in MCM)	Design Area to be irrigated (in Ha)	Design Water allocated per unit area (in mm)
Mahanadi Reservoir Project			
Kharif	1935	385,410	502
Rabi	706	130,974	539
Minimata Bango			
Kharif	1454	234,600	620
Rabi	720	127,500	565
Summer	404	51,000	792
Hirakud			
Kharif	1300	153,750	845
Rabi	1400	76,875	1821 ⁴²
Mahanadi Delta Stage 1			
Kharif	965	167,000	578
Rabi	949	100,960	940
Mahanadi Delta Stage 2			
Kharif	786	136,000	578
Rabi	636	67,622	940

Source: Government of Chhattisgarh, 2004; Department of Water Resources, Government of Orissa, 2007; Babu, Shrivastava, & Dikshit, 2015

The figures above give us the average amount of water allocated for irrigation per unit area, in the Kharif and Rabi seasons in Chhattisgarh and Odisha.

Estimates of the actual area irrigated by surface water sources in the Kharif and Rabi seasons in both states was developed in the section 'Irrigation Coverage – Seasons and Crops'. The estimated water allocation was then calculated by multiplying the actual area irrigated by the 'estimated design water allocation per unit area'.

41. The figures for design water allocation for the Hirakud project were not available. Hence the actual water releases for Kharif and Rabi irrigation are given in the table. However, since these actual water releases are far greater than the design allocation of the other projects, these figures were not used to estimate the Mahanadi Basin allocation for irrigation.

42. As per the Jeyaseelan report, the allocation for the Rabi figure is not allocation per se, but 'water released for delta irrigation'

Table 16: Changes in Area Irrigated and Source of Irrigation in the Mahanadi Basin

	Chhattisgarh			Odisha		
Source-wise irrigated area (in Th Ha)	2013-14	2000-01	Project-wise irrigated area (in Th Ha) ⁴³	2013-14 ⁴⁴	2000-01 ⁴⁵	1993-94 ^{46,47}
Canal Irrigation	918	641	Major Flow	759	635.5	569
Well Irrigation	589	199	Minor Flow	206	191	183
Tank Irrigation	42	45	Minor Lift	353	239.9	179
Other Sources	46	65	Other Sources	373	339.85	322
Total	1595	950	Total	1691	1406.95	1254
Season-wise irrigated area (in Th Ha)	2013-14	2000-01	Season-wise irrigated area (in Th Ha)	2013-14	2000-01	1993-94
Kharif	1163	821	Kharif	1066	898.95	809
Rabi	191	41	Rabi	658	567.65	519
Summer	169	47				
Whole Year	74	41				
Total	1597	950	Total	1724	1466	1328

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, 2014 and Statistics Cell, Ministry of Agriculture, Government of Odisha, 2015 – District-wise, Season-wise, Source-wise/ Project-wise, Year-wise Irrigated Area, Chhattisgarh and Odisha

Chhattisgarh irrigates about 1596 Th Ha annually. About 983 Th Ha (61 per cent) of its gross irrigated area is irrigated by surface water sources (including canals and tanks and 50 per cent of other sources). In 2000-01, the gross irrigated area for surface sources would be about 718 Th Ha. Of the gross irrigation, 1163 Th Ha (73 per cent) happens in the Kharif season, 191 Th Ha (12 per cent) in the Rabi season, 10.5 per cent in the Summer season and the remaining 74 Th Ha are crops cultivated all year round.

43. Source-wise irrigation for Odisha is not available but project-wise irrigation potential is.

44. Project-wise actual irrigated area is about 70 per cent of the irrigable potential for Odisha state, hence a similar proportion is taken to estimate the actual irrigated area in the Mahanadi Basin in Odisha.

45. The values given here for 2000-01 are not actual but interpolated values since 2000-01 was an anomaly year.

46. The year 1993-94 is considered here instead of 2000-01 (as it was for Chhattisgarh) because the years from 1999-00 to 2001-02 for Odisha were anomalies where there was low cropping and irrigation.

47. The project-wise irrigable potential for 1993-94 is not available district-wise but as an aggregate figure for Odisha state. The irrigable potential for the Mahanadi Basin in Odisha is estimated as 50 per cent of the irrigable potential of the state as a whole. This proportion is taken based on available figures for 2013-14. To estimate the actual irrigated area in the Mahanadi Basin part of Odisha, it is calculated as 70 per cent of the irrigable potential.

If we assume the same proportion of surface irrigation (73 per cent: 12 per cent: 10.5 per cent) occurs in the Kharif and Rabi season then we can calculate surface water use in each season in 2013-14 (Table 17). Similarly, the ratio of surface irrigation across seasons in 2000-01 would be—86 per cent: 4 per cent: 5 per cent.

Table 17: Estimated Surface Water Requirement for Irrigation, Season-wise, in the Mahanadi Basin - Chhattisgarh

	Kharif	Rabi	Summer
Area irrigated by surface water sources (Chhattisgarh) 2013-14	= 73% of 983 Th Ha = 718 Th Ha	= 12% of 983 Th Ha = 118 Th Ha	= 10.5% of 983 Th Ha = 103.2 Th Ha
Surface water use for irrigation in (Chhattisgarh) 2013-14	= 718 Th Ha*0.561 m = 4028 MCM	= 118 Th Ha*0.539 m = 636 MCM	= 103.2 Th Ha*0.792 m = 817.3 MCM
Area irrigated by surface water sources (Chhattisgarh) 2000-01	= 86% of 718 Th Ha = 617 Th Ha	= 4% of 718 Th Ha = 29 Th Ha	= 5% of 718 Th Ha = 36 Th Ha
Surface water use for irrigation in (Chhattisgarh) 2000-01	= 617 Th Ha*0.561 m = 3461 MCM	= 29 Th Ha* 0.539 m = 156 MCM	= 36 Th Ha* 0.792 m = 285 MCM

Source: Derived from Tables 15 and 16

The total estimated annual surface water use for irrigation thus amounts to 5481 MCM, the bulk of the water being used in the Kharif season.⁴⁸ This value has increased from 3902 MCM in 2000-01.

Odisha, on the other hand, irrigates about 1724 Th Ha annually. About 1151 Th Ha or 66 per cent of its gross irrigated area is irrigated by surface water sources (including major and minor flow projects and 50 per cent of other sources). In 2000-01, the gross irrigated area for surface sources would be about 996 Th Ha. Of the gross irrigation, 1066 Th Ha (62 per cent) happens in the Kharif season and 658 Th Ha (38 per cent) in the Rabi season. Assuming a similar proportion of surface irrigation (62 : 38 per cent) occurs in the Kharif and Rabi season, we can then calculate surface water use in each season (Table 18). Similarly, the ratio of surface irrigation across seasons in 2000-01 would be—61: 39 per cent.

48. The water use for Whole Year crops has not been estimated since reliable figures for crop water allocation for this season is not available.

Table 18: Estimated Surface Water Requirement for Irrigation, Season-wise, in the Mahanadi Basin - Odisha

	Kharif	Rabi
Area irrigated by surface water sources (Odisha) 2013-14	= 62% of 1151 Th Ha = 714 Th Ha	= 38% of 1151 Th Ha = 437 Th Ha
Surface water use for irrigation in (Odisha) 2013-14	= 714 Th Ha * 0.578 m = 4127 MCM	= 437 Th Ha * 0.94 m = 4107.8 MCM
Area irrigated by surface water sources (Odisha) 2000-01	= 61% of 996 Th Ha = 607 Th Ha	= 39% of 996 Th Ha = 388 Th Ha
Surface water use for irrigation in (Odisha) 2000-01	= 607 Th Ha * 0.578 m = 3508 MCM	= 388 Th Ha * 0.94 m = 3647.2 MCM

Source: Derived from Tables 15 and 16

The total estimated annual surface water use for irrigation in Odisha thus amounts to 8234 MCM⁴⁹, approximately half in the Kharif and half in the Rabi seasons. This value has increased from 7155 MCM in 2000-01.

This exercise shows us that the surface water use for irrigation in the Mahanadi river basin amounts to approximately 13715 MCM, i.e. 20 per cent of the 66.87 BCM annual average flow (of which 50 BCM is utilisable surface water) of the river up from 11057 MCM in 2000-01, a 24 per cent increase in 13 years (or 1.84 per cent per year). At this rate, the estimated surface water use in 2040 would be 20,572 MCM.

Rice, as noted earlier, makes up about 882 Th Ha (83 per cent) of the Kharif irrigated area in Odisha and 1159 Th Ha (100 per cent) of the same in Chhattisgarh in 2013-14. In 2000-01, the proportion of crops irrigated was the same in Chhattisgarh. Thus, to simplify the estimation, it can be assumed that all the 4028 MCM of Kharif surface water use in Chhattisgarh, 817 MCM of the Summer water use and 3425 MCM (83 per cent of the Kharif surface water use) in Odisha is used to irrigate rice in the Kharif season.⁵⁰ Similarly, in the Rabi season, rice is irrigated on approximately 207 Th Ha (32 per cent) of the sown area. If we assume that 32 per cent of the Rabi water requirement is used for

49. For comparison, the figures for the state of Odisha in the Odisha Water Plan state that agricultural water demand in 2001 stands at 22688 MCM, with approximately 18000 MCM of surface water demand. This it is said will rise to 49408 MCM in 2051, with the dependency on surface water staying constant at 80 per cent of the total. These numbers have been estimated using modeling approaches but not enough of the details are presented in the Plan to gauge their robustness. The corresponding figures for the Mahanadi river basin are not given in the state plan but if we assume that approximately 2/3rds of the water requirement is in the Mahanadi Basin (since 2/3rds of the cropping of Odisha is in the Mahanadi Basin), we get a figure of 12000 MCM (in 2001) for surface water requirement for agriculture in the Odisha part of the Mahanadi Basin.

50. This is a reasonable assumption since most rice in Chhattisgarh and Odisha is irrigated by flood irrigation practices, which require ample amounts of water that available only through surface irrigation.

rice, we get a figure of 1314 MCM.⁵¹ This totals to 9584 MCM of water requirement for rice, based on the current cropping pattern, i.e. rice uses up about 64 per cent of the total 13715 MCM of surface water irrigation in the basin. If we assume that the rate at which rice water requirement expands is the same as general surface water requirement for all crops (i.e. 24 per cent since 2000-01) then it means that the rice water requirement was about 7729 MCM in 2000-01 and will be 14376 MCM in 2040. These figures have been used in Chapter 8 to establish the water balance in the Mahanadi river basin in BAU scenarios and scenarios where water saving practices are implemented.

51. This assumption can be questioned and improved on.

7

Industries in the Mahanadi Basin

Overview

Industrial development has been a key solution put forward by state and central governments for economically poorly developed states such as Chhattisgarh and Odisha to find their way to greater material prosperity. A glance at figures of Gross State Domestic Product (GSDP) of the two states shows that the size of the entire economy has grown massively⁵² in Chhattisgarh by 100 per cent and Odisha by 75 per cent since 2004-05 in real terms. In Chhattisgarh, agricultural output has doubled and in Odisha it has increased by 23 per cent in the last decade. It must be noted however that Chhattisgarh's agricultural output was half of Odisha's a decade ago. Growth in the mining sector has been much larger in Odisha at 91 per cent while Chhattisgarh's at about 31 per cent. Construction growth has been large in Odisha at about 76 per cent and exponential in Chhattisgarh at 316 per cent. The tertiary sector has grown by about 110–120 per cent in both the states (Directorate of Economics and Statistics, Government of Chhattisgarh, 2015, p. 18; Planning and Coordination Department, Government of Odisha, 2015, pp. Annexure - 2/8). While industrial development has contributed to some of the prosperity in the two states, the simultaneous rise of the tertiary services sector is thus seen to be a bigger driver of growth and prosperity.

In Chhattisgarh, the share of industry in GSDP output (at current prices) has fallen from 44.1 per cent to 38.8 per cent whereas in Odisha it has stayed relatively constant at around 23.5 per cent. The share of the tertiary sector in GSDP has risen by about 5 per cent in both the states. This growth in the tertiary sector however still represents skewed development since it employs relatively fewer people and the largest part of the population still depends on agriculture (Directorate of Economics and Statistics, Government of Chhattisgarh, 2015, p. 17; Planning and Coordination Department, Government of Odisha, 2015, pp. Annexure - 2/4). The share of agriculture in the economy has grown by 1.5 per cent in Chhattisgarh, keeping pace with the overall growth in the state, and in Odisha it has fallen by 3.4 per cent. A state-wise discussion is provided below, derived largely from the Economic Surveys of both the states. This section puts the spotlight on the secondary industrial sector, more specifically on the power, manufacturing (Iron & Steel) and mining industries since these represent a significant share of the demand for water resources and their allocations need further review.

52. This growth is considered on the basis of 2004-05 constant prices and hence takes into account inflation. The figures presented thus represent 'real' growth in output.

Chhattisgarh

- Chhattisgarh's GSDP (current prices) was million Rs. 1,856,820 in 2013-14, a rapid increase from million Rs. 478,620 just a decade ago. This represents an annual growth rate of 14.5 per cent in nominal terms and about 10 per cent in real terms. The largest part of this GSDP (about 40 per cent) is now represented by the tertiary sector, including services such as transport, communication, banking and real estate. A similar 39 per cent is made up by the industrial sector (secondary sector and mining) composed of power, steel, mining, construction etc.
- Rapid growth in the agricultural sector has been eclipsed by even more rapid growth in the tertiary services sector.

Table 19: Chhattisgarh Economy – Statistics

Chhattisgarh	2004-05 (current prices) (In million Rs.)		2013-14 (constant 2004-05 prices) (In million Rs.)		Increase in real output (in %) from 2004- 05 to 2013-14	2013-14 (current prices) (In million Rs.)	
GSDP	478620	100%	952620	100%	99%	1856820	100%
Agriculture (including animal husbandry)	70570	14.7%	139200	14.6%	97%	301500	16.2%
Mining	53670	11.2%	88060	9.2%	64%	164300	8.8%
Manufacturing	104790	21.8%	137880	14.5%	31%	229580	12.3%
Construction	32740	6.8%	136470	14.3%	316%	254270	13.7%
Electricity, Gas, Power	21000	4.3%	41310	4.3%	97%	75880	4%
Tertiary Sector ⁵³	164810	34.4%	366460	38.5%	122%	736630	39.6%

Source: Directorate of Economics and Statistics, Government of Chhattisgarh, 2015

- Chhattisgarh is a power surplus state. Power sales hence add to the state's revenues. The Korba district in Chhattisgarh is known as the 'power capital of India'. The entire state of Chhattisgarh itself has about 10683 MW in thermal power production capacity as of January 2015, of which 6413 MW is private and 4270 MW is owned either by the state or centre (Directorate of Economics and Statistics, Government of Chhattisgarh, 2015, p. 99). This total figure rose to 15802 MW by January 2017, indicating the rapid rise in installed coal thermal power capacity (Central Electricity Authority, 2017, p. 16).
- Mineral resources also play a big part in the development of both the states. Chhattisgarh's central location and the abundance of mineral resources have played an important part in pulling resource intensive and exploitative industries to the state. Chhattisgarh produces about 22.6 per cent of the country's coal (127 MT) and 19.8 per cent of its iron ore (30 MT) and 7.6 per cent of limestone (21 MT) which are its

53. Tertiary includes railway, transport, communication, banking, real estate etc.

three biggest minerals⁵⁴. It also produces about 20 per cent of India's cement and is the only tin ore producing state in the country. The number of mines in Chhattisgarh total to 202 (in 2013-14). Mining of major minerals contributes to about 9 per cent of the states' GSDP, down from 11 per cent in 2004-05. However, its share in the states' revenues is much higher, at 25.5 per cent (million Rs. 30,280). This has doubled from million Rs. 15,540 just few years ago in 2009-10. The total value of minerals produced in the state was million Rs. 195,660 during 2013-14 (Directorate of Economics and Statistics, Government of Chhattisgarh, 2015, p. 81).

- The state-owned SECL is the largest mining company in operation in Chhattisgarh, with its largest mines in the Korba district and many others in Surguja and Koriya. Vedanta, ESSAR, LANCO, Jindal, Monet, DB Power, NTPC, Steel Authority of India Ltd (SAIL), BALCO are the major companies in Chhattisgarh in the mineral, power, steel and aluminium businesses.
- The state also has many large industrial areas principally around Raipur (Tilda, Urla and Siltara), Bilaspur (Sirgitti, Dagori and Silpahari) and Durg (Borai) cities. Korba is another industrial centre and Raigarh is being further developed as a power and mining hub.

Odisha

- Odisha's economy had a GSDP of million Rs. 272,979 in 2013-14 (at 2004-05 prices), a jump from million Rs. 777,290 in 2004-05 i.e. an annual nominal growth rate of 13.4 per cent and real growth rate of 7.5 per cent. The tertiary sector comprises about 47 per cent of the GSDP and the secondary sector, which represents industries, construction etc., comprises 34 per cent. This shows that Odisha's economy is more skewed towards the services as compared to Chhattisgarh.

Table 20: Odisha Economy - Statistics

Odisha	2004-05 (current prices) (In million Rs.)		2013-14 (constant 2004-05 prices) (In million Rs.)		Increase in real output (in %) from 2004-05 to 2013-14	2013-14 (current prices) (In million Rs.)	
GSDP	77729	100%	137468	100%	77%	272979	100%
Agriculture (including animal husbandry)	14603	18.8%	17972	13.1%	23%	42188	15.4%
Mining	5861	7.5%	9169	6.7%	56%	29828	10.9%
Manufacturing	9369	12%	17929	13%	91%	28742	10.5%
Construction	8092	10.4%	14288	10.4%	76%	27901	10.2%
Electricity, Gas, Power	3197	4.1%	4090	3%	28%	6726	2.4%
Tertiary Sector	32950	42.4%	69586	50.6%	111%	128168	47%

Source: Planning and Coordination Department, Government of Odisha, 2015

54. Making it first in the nation for coal production and third for iron ore—see Economic Survey 2014-15 (Planning and Coordination Department, Government of Odisha, 2015).

- Odisha has about 7100 MW of coal thermal power capacity installed, of which 5000 MW is private and the remaining is either state or central government operated (Central Electricity Authority, 2017, p. 16).
- Both the states are mineral rich. Odisha has about 52 per cent of the country's bauxite reserves, 44 per cent of its manganese reserves, 33 per cent iron ore reserves and 24 per cent of its coal reserves. Of the mineral reserves of Odisha, 88 per cent is comprised of coal, about 60 per cent of which is extracted currently from the Angul district and the remaining from the Jharsuguda, Sundargarh and Sambalpur districts. Coal extraction in 2013-14 amounted to 108 MT. Iron ore extraction of about 77 MT on the other hand is mostly confined to Keonjhar (71 per cent) and Sundargarh (25 per cent) and bauxite mining to Koraput. Out of 595 signed mining leases in Odisha, 102 are currently in operation, covering an area of 46788 ha (Planning and Coordination Department, Government of Odisha, 2015, pp. 4-32–4-35).
- Rourkela is the largest steel plant in the state with a capacity of 4.5 metric tonnes per annum (MTPA). The state government has signed 49 MoUs with steel producers for a total of 83.6 MTPA of production capacity, although current production stands at only 12.6 MTPA. Another 11.4 MTPA of sponge iron production capacity is already operational in the state. Other major companies including Vedanta, Posco, Jindal, Tata, Essar have set up plants in the state (Planning and Coordination Department, Government of Odisha, 2015, pp. 4-4–4-5).
- Jharsuguda is the state's major hub for sponge iron and thermal power plants. Keonjhar and Sundargarh districts have about 50 per cent of the states' mineral deposits.

Estimating Water Allocations and Use

To develop an accurate idea of the effect that industrial expansion might be having on water allocations in the river basin, estimates of the scale and the spatial variation in use of water by industries was essential. However, no comprehensive, consolidated database of large industries was available for this purpose. Such a detailed database of industries in the Mahanadi basin that have been given environmental clearances by the Ministry of Environment and Forests (MoEF) (along with the water requirement of each industry) has been prepared. Based on these estimates, the total amount of water in the Mahanadi basin allocated to large industries is about 1130 MCM in Chhattisgarh and 944 MCM in Odisha. This amounts to 2074 MCM of water for industrial use.^{55,56,57}

55. It must be noted that these are merely environmental clearances, and not a list of the industries that have actually been given a consent to operate by the respective state governments. Nevertheless, it allows us a reasonable estimate of industrial water allocations.

56. Most environmental clearance documents specify a water requirement for an industry in units of m³/day. To obtain an estimate of annual water allocations to these industries the given value is multiplied by 365 days. Most industrial units have some down time, hence the actual water use will be only about 2/3rds of this allocated amount.

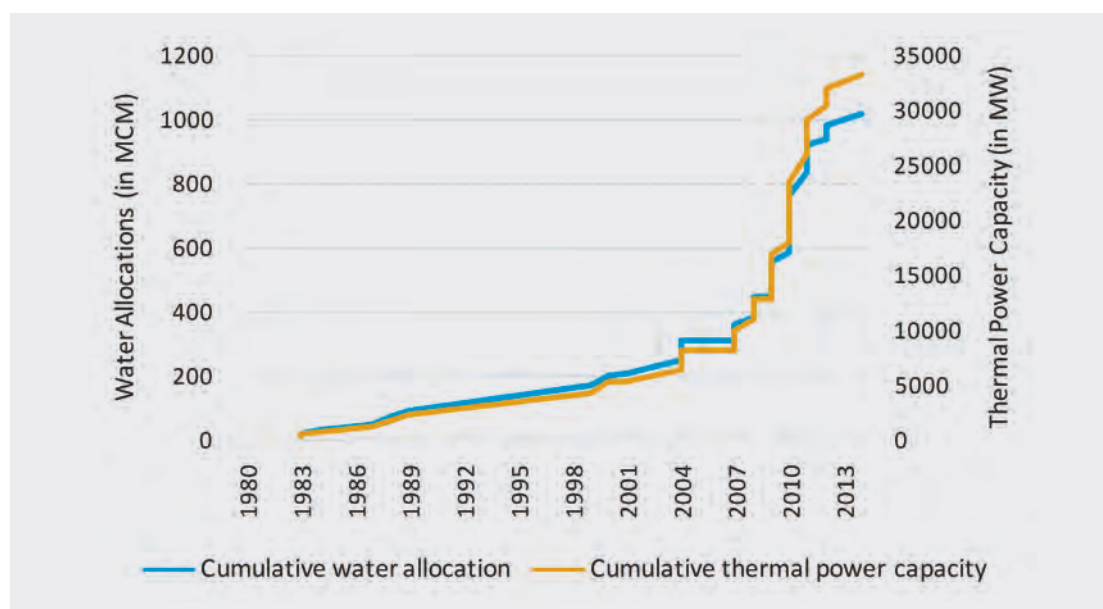
57. Other figures for industrial water allocations (viewed recently from the State Pollution Control Board of Chhattisgarh) show a higher quantum of water allocations of about 2000 MCM for industries in Chhattisgarh itself. These figures were not compared with figures given in this report.

A large quantum (about 274 MCM) of these recent water allocations have been approved by Chhattisgarh for industrial water use from several large barrages on the main stem of the Mahanadi. These new allocations are proving to be the crux of the inter-state dispute between Chhattisgarh and Odisha.

Chhattisgarh

Industrial expansion in the Chhattisgarh half of the Mahanadi basin has accelerated in the last decade. Water allocations for coal thermal power alone (as per Environmental Clearances) have jumped from 307 MCM to 1017 MCM in the space of a decade. The total capacity of thermal power plants would be 33268 MW if all these clearances led to power plants being commissioned. This is a sharp rise from 8000 MW in environmental clearances since 2007. These plants have a water requirement of 30.5 MCM per 1000 MW on average.

Figure 34: Cumulative Water Allocations to Thermal Power Plants vs. Cumulative Thermal Power Capacity Installed in Chhattisgarh in the Mahanadi Basin



Source: Ministry of Environment and Forests, 2016

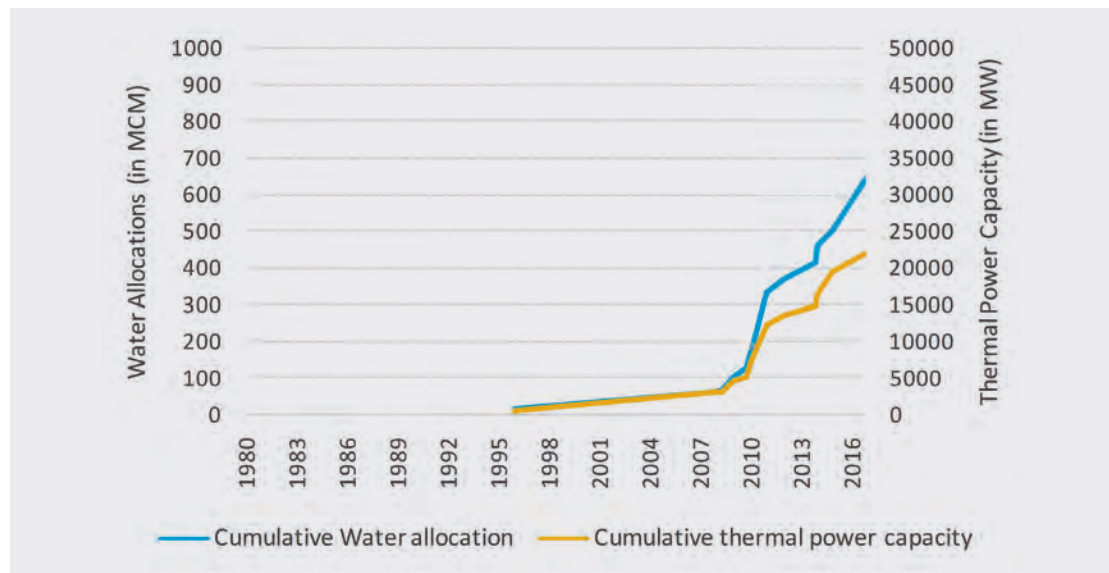
In addition to this, water allocations for Iron and Steel plants were second, at about 193 MCM for a total of 34 MTPA of steel production capacity. This is an increase from a production capacity of 10 MTPA in 2007, more than a threefold rise. Based on these known figures, it could be estimated that water allocations in 2007 for iron and steel plants were about 60 MCM. These water allocations would also be used to run the captive thermal power plants of these Iron and Steel plants whose capacity totals to about 3568 MW (of which 3048 MW has been given clearance since 2007). Another 9 MCM of water allocation has been provided for aluminium plants.

Mines of all minerals have been allocated 65 MCM of water, with a total capacity of 339 MTPA. The capacity of mines with clearances has more than doubled since 2007, with new mines and expansions being given clearances for 177 MTPA. The total quantum of water allocated to industries in Chhattisgarh in the Mahanadi basin is therefore 1284 MCM. This figure we can extrapolate backwards to estimate the quantum of water allocated in 2007, which amounts to 400 MCM.

Odisha

Coal thermal power makes up the dominant component of industrial water use in Odisha as well. Thermal power expansion in Odisha however began much after Chhattisgarh. In terms of total amount of water allocated for thermal power as well, Odisha stands at about 644 MCM, a sharp rise from a mere 57 MCM in 2007.

Figure 35: Cumulative Water Allocations to Thermal Power Plants vs. Cumulative Thermal Power Capacity Installed in Odisha in the Mahanadi Basin



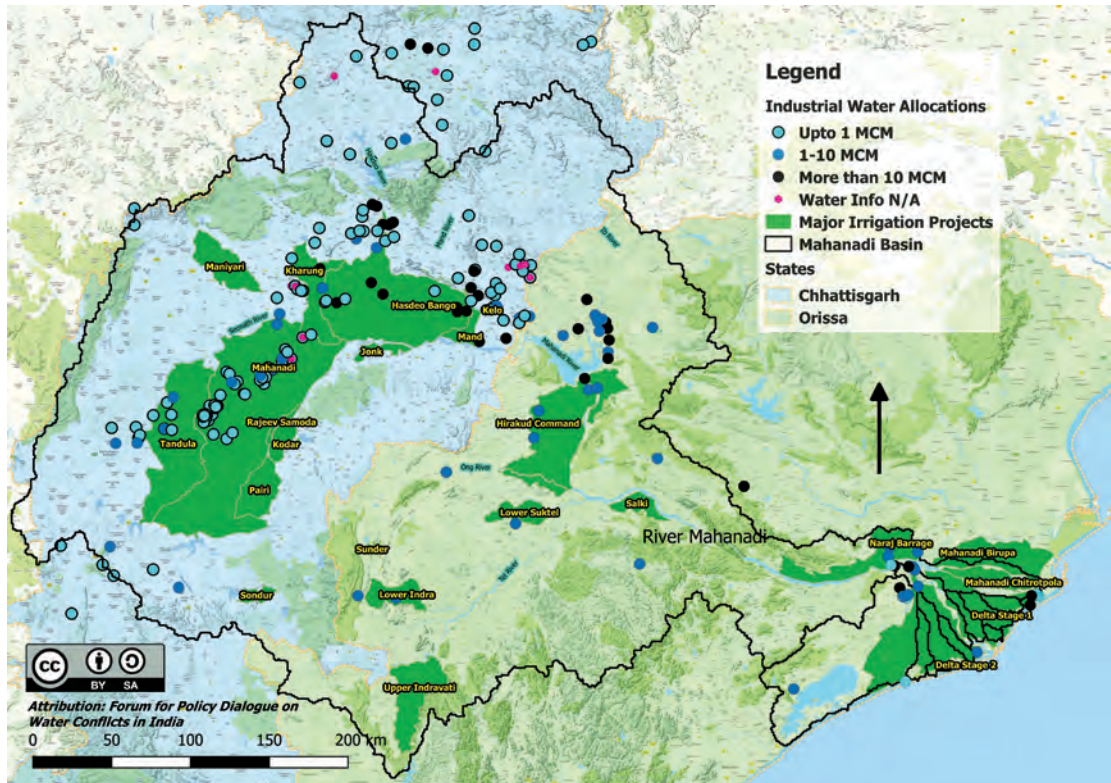
Source: Ministry of Environment and Forests, 2016

In comparison, allocations to the iron and steel industry stand at about 179 MCM, the largest allocations which are reserved for Bhushan Steel, Essar Steel, Shyam DRI (amounting to about 100 MCM) have all been allocated after 2007. Hence allocations for this industry show a similar uptick in the last decade. In addition to this, about 120 MCM has been allocated towards the Aluminium industry.⁵⁸ Thus, a total of 944 MCM (not including water allocations to mines) is seen for Odisha. This figure has risen sharply from about 200 MCM in 2008.

58. Besides this current data for water allocations to towns in Odisha is also available which shows amounts to 122 MCM as of the year 2015.

The Odisha Water Plan (2004), in contrast, estimates that water demand by industries in the Mahanadi Basin in 2051 would be 335 MCM, after taking into account that industries would be able to reduce their footprint per worker to 650 litres per capita per day (lpcd) from the current estimated value of 900 lpcd. These numbers versus the current allocation reveals a huge gap in water resources.

Figure 36: Industries and Irrigation in the Mahanadi Basin



Source: Ministry of Environment and Forests, 2016

8

Potential Avenues for Water Savings and their Basin-wide Implications

In this chapter, we explore some avenues for water savings in the two sectors of agriculture and industry, more specifically rice cropping and water use in thermal power, mines, and iron and steel industries. We explore the extent to which the magnitude of water use with current practices could be reduced if these water-saving practices were implemented. Later the figures developed in this section are used to develop scenarios for more optimal water allocations in the river basin.

Agriculture

Rice Cultivation

The rice crop is a very sensitive plant and less amount of water can affect its productivity. An estimated amount of 2500 litres is the global average required for growing one kg of rice. Of this, about 60 per cent is consumed through evapotranspiration and another 40 per cent represents non-consumptive use, through seepage and percolation into the ground (See Annexure 8).

Climate change is altering the rainfall patterns and thereby affecting the availability of water. Moreover, increasing population and the demand for water for uses other than agriculture, are creating a stress on the existing freshwater resources. In the future, with scarce water resources, growing water intensive crops like rice is going to be difficult, thereby threatening the food security of India, where rice is the staple diet of more than 90 per cent of the population. It therefore becomes crucial to adopt water saving technologies for growing rice. Some of the well-known technologies include system rice intensification (SRI), alternate wetting and drying (AWD), ground cover rice production systems, raised bed-saturated soil culture method and intermittent irrigation methods (Duttarganvi n.d.; Tabbal, Bouman, Bhuiyan, Sibayan & Sattar, 2002).

The International Rice Research Institute (IRRI) suggests the following four steps to increase the efficiency of water used in preparing the land.

Step 1 - Construction of field channels from the source of water to the field: This ensures control over the water to be delivered to an individual field.

Step 2 - Preparing the land to minimise the water loss: This involves tiling the land to fill in the cracks, so that less water will be required to soak the land. Although puddling the field itself consumes a lot of water, it is considered as a better method to control weeds. Removing weeds from the field also demands more labour inputs.

Step 3 - Levelling of land: This is the most important step as unlevelled land consumes 10 per cent more than the actual water requirement of the crop. It is recommended to plough the field twice before levelling and the second ploughing should be preferably done in standing water to identify the high and low areas.

Step 4 - Constructing bunds and repairing cracks: High bunds of at least 20 cm size should be constructed at the starting period of the season to avoid water loss. Care should be taken to compact the bunds with bunds to avoid any holes.

While an abundance of practices exists, the SRI is gaining wide acceptance at many places as it gives better results in terms of water saving as well as crop yield. The SRI method is discussed in detail below.

System Rice Intensification

The System Rice Intensification, first identified in Madagascar by Father Henri de Laulanié, is considered as a convenient alternative method to grow rice and is now being adopted and practised in many countries (Uphoff, 2003) defines SRI not as a technology but as a method that is based on several principles which farmers adapt to, depending on the conditions of the agriculture ecosystem. The core principles of the SRI are:

- improving plant establishment,
- significantly reducing plant population,
- improving soil conditions and
- reducing irrigation water application (Styger, 2012)

The main steps in the SRI include:

1. The transplanting of rice seedlings is done when they reach 2-leaf stage. It takes about 8–12 days for the rice seedling to reach this stage, depending on the climate and soil conditions. Like the conventional method, the seedlings are grown on a separate nursery bed in unflooded conditions.
2. In SRI, one seedling is transplanted per hill, instead of clamping 3–5 seedlings per hill. This reduces competition and less water is consumed per plant. It also helps the seedling to establish roots easily. Seedlings are generally placed in a square pattern, of 25×25 cm, to facilitate and ease the process of weeding. It is recommended to increase the spacing if the soil is fertile (Uphoff, 2006; Styger, 2012).
3. While transplanting the seedling, one must be careful of planting the seedling gently and at a shallow depth of 1–2 cm, for tillers to emerge and develop quickly (Styger, 2012).
4. After the transplantation, it is recommended to have the field irrigated intermittently, also known as the alternate wetting and drying method. The SRI when coupled with the AWD method has shown to give a better yield and it also results in saving more water. It is advised to keep the field flooded only 1–2 cm

deep after the initiation of the panicle, until the water pond disappears. The next batch of water is supplied when a slight crack develops in the soil. Thus, the intermittent supply of water allows the crop to grow in aerobic conditions, helping the plant to give more yield due to increased availability of nutrients (Ceasay, Reid, Fernandes, & Uphoff, 2006).

5. When the field is not flooded, there is a chance for weeds to grow rapidly. Hence weeding in the SRI is to be done after every 10 days. Regular weeding helps to aerate the soil. Uphoff (2006) recommends the usage of the 'rotating hoe' for weeding, which not only aerates the soil but also churns the weed in the soil for further decomposition and making nutrients available.

Table 21: Comparison of the SRI with the Conventional Method of Growing Rice

Features/ Criteria	Conventional Practices	System Rice Intensification
Development of seedlings	25–30 days	8–12 days
Seed line	20×10 cm	25×25 cm
No. of seedlings	Multiple and hence large plant population	Single and hence sparse plant population
Water application	Paddies are kept flooded throughout the growing cycle of the plant	Soil is aerated through alternative wetting and drying
Control of weeds	Through flooding, hand-weeding	Use of rotary weeder
Use of water for plant	2500 litres/ kg	30–50% decrease

Source: Palanisami, Karunakaran & Amarasinghe, 2012; Uphoff, 2006

Table 22: Average Grain Yields in Conventional and SRI Methods

Sr. No.	State	Year	Season	Grain Yield (tonnes/ha)			Percentage increase
				Conventional	SRI	Increase	
1	Tamil Nadu	2003-04*	Rabi	5.7	7.2	1.5	26.3
		2007-08	Rabi	4.4	5.7	1.3	29.5
2	Andhra Pradesh	2003	Kharif	4.9	8.4	2.5	51.0
		2003-04	Rabi	5.5	7.9	2.4	43.6
		2007	Kharif	5.0	6.2	1.2	24.0
		2007-08	Rabi	5.2	6.6	1.4	26.9
3	Tripura	2006	Kharif	4.5	7.0	2.5	55.6
4	Himachal Pradesh	2007	Kharif	2.8	5.5	2.7	96.4
5	Uttarakhand	2007	Kharif	2.9	5.3	2.4	82.7
6	Bihar	2004-06	Kharif	3.8	4.7	0.9	23.0

* Tamil Nadu 2003-04 data was collected from 100 farmers and 2007-08 data from 1456 farmers. Rest of the data is from state status reports received.

Source: ICRISAT, 2008

The SRI was first introduced in India in 2000 in Tamil Nadu and Andhra Pradesh. The International Crops Research Institute for Semi-Arid Tropics (ICRISAT) conducted a study in collaboration with WWF on monitoring the yield of crops using the SRI method in selected states of India. The results are summarised in Table 22. There are also many experiments in India which show that the SRI helps to improve the overall plant morphology and the physiological process. The plant has more tillers per plant, increased plant height, longer and wider leaves and more grains per panicle. Thus, the SRI results in higher grain yield and water productivity (Mishra & Salokhe, 2011; Styger, 2012; Thakur, Rath, Patil & Kumar, 2011).

Limitations to the SRI Approach

Currently the use of the SRI is very limited as farmers are not ready to experiment yet. But with increasing scarcity of water, it will be necessary for policy makers to introduce the SRI to farmers on a larger scale with the requisite incentives. Constructing proper field channels, levelling the land and water management are the key requisites for the SRI for which adequate infrastructures are required. There is a need for the government to provide these infrastructures at lower rates. Moreover, tie-ups with local partners, like researchers and NGOs, are required to ensure that such technologies reach more farmers.

One of the two main disadvantages of the SRI method is the control of weeds. However, appropriate weeders are available in the market and these can be controlled. The second disadvantage is the availability of agriculture labourers, as growing rice is a labour-intensive job. But through appropriate compensation or use of technology, the labour demand can decrease.

Industry

This section looks at how water is used in three types of large industries – coal thermal power plants, mining and iron & steel plants – that are dominant in the Mahanadi Basin. Water use in these industries is particularly intensive and impacts water availability and water quality in the surrounding environment.

In each of these industries the potential ‘water saving practices’ for improving their efficiency of water use was looked into. The estimates of potential reductions in water use by these industries can provide us a basis in later chapters for developing different scenarios for water use and allocations in the basin as a whole. However, not all the water saving practices provide a quantitative figure for reduction in the quantum of water use. Some are simply oriented towards the objective of improving the quality of water discharged.

Thermal Power

By the estimates of the Central Electricity Authority (CEA), coal plants in India consume about 5–7 m³/MWh in all their processes. Recently, however, plants have been designed that consume much less, up to 3.5–4 m³/MWh (Central Electricity Authority, 2012). Super critical plants are designed to be highly efficient as opposed to current plants which run on sub-critical technology.

An estimated 64 per cent of the consumptive water use of thermal power plants is accounted for by the cooling system, and another 21 per cent by the process of ash handling⁵⁹ (Bhushan et al., 2015). These proportions can vary from one plant to another, especially since certain plants reuse cooling water for ash handling and, in other cases, water from ash handling is also recycled. Some estimates of water consumption in coal thermal plants do not count, water use for ash handling as a separate consumptive use since it is water from the cooling process which is reused (Central Electricity Authority, 2012, p. 3). In this case, water consumption for cooling would account for about 85 per cent of the plant's water needs. In most cases, however, these two processes in the thermal power plant represent the biggest opportunities for intervention with potential water saving practices.

Hence, we look at potential water saving practices for cooling as classified under these two categories: cooling and ash handling.

In Cooling

Water Cooled Thermal Plants

These are good practices that despite still requiring water as the cooling medium, nevertheless represent significant potential savings of water.

Abandoning once-through cooling plants

Once-through cooling (OTC) systems are not the norm anymore. They are impractical in most regions where water supply is uncertain. Withdrawal can be as high as 70–200 m³/MWh and actual water consumption can be about 1 per cent of this, i.e. about 1.5 m³/MWh (Smart & Aspinall, 2009, p. 14). These plants require availability of large storages to meet this continuous demand. This has implications for environmental flows in rivers if large quantities of water must be impounded. The water requirement for OTC may be lower than the water requirements for many closed cycle cooling systems, hence abandoning these OTC systems do not present us with potential water savings. However, the benefit gained is in the form of lesser damage to the surrounding environment.

Reduce requirement of make-up water in closed cycle thermal plants

Cycles of concentration (COCs) indicate the ratio of dissolved solids in the blow-down water to the dissolved solids in the make-up water. If the dissolved solids in the make-up water is lower (i.e. if the water is purer) then the thermal plant will need less of the make-up water to be added in place of the blow-down water. Hence overall water consumption of the plant will be lower. This essentially means treating the make-up water to some degree to remove some dissolved solids before mixing it with cooling water. The most common form of treatment is using lime to lower the starting total dissolved solids in the make-up water. Similarly, to reduce the need for make-up water, COC plants can also treat blow-down water with reverse osmosis to reduce the concentration of dissolved solids.

59. These are average figures for the 47 plants sampled by CSE in its Green Rating Project (GRP) for thermal power, 2014-15.

The tradeoff here is between water and power. Hence if water is obtained for a relatively low cost, then power plants prefer not treating make-up water and going with a low COC. Older thermal plants have low COCs of 2.5–3.5, newer ones have 4–5 and advanced ones with COCs of 7–10 have installed water treatment systems (Bhushan et al., 2015, p. 36). A typical plant that operates on COC of 5 requires make-up water that is 2.1 per cent of the cooling water flow in the plant. Of this, 1.7 per cent is meant as replacement for water that evaporates away, another 0.05 per cent represents drift loss and 0.35 per cent is water blown down. Thus, taking an average flow rate of 120 m³/MWh for a power plant, the make-up water requirement is 2.5 m³/MWh (Central Electricity Authority, 2012).

On an average, power plants that have COCs between 2.5 to 3.5 consume about 4 m³/MWh of water in cooling whereas those that have COCs of 6 or more consume only about 2 m³/MWh of water for the cooling process (Bhushan et al., 2015).

Forced draft cooling towers in closed cycle thermal plants

Cooling towers in thermal power plants can be designed to either operate on natural draft or forced draft principles. Natural draft systems only rely on natural pressure and temperature differences to draw air into the cooling tower to cool water. These systems however can be inefficient in hot areas since the surrounding air is not able to draw the cooling water temperature down adequately. Hence more cooling water is required in the system. Instead of relying on natural draft, the principle of forced draft cooling relies on a cooling tower fitted with fans that generate additional pressure difference and draw in more air into the tower. This design is able to lower the temperature of the cooling water to a greater extent, thus lowering the overall water requirement for cooling. The disadvantage of this approach is that it represents higher capital as well as operating costs as compared to natural draft systems. Forced draft systems can require about 1.5–2 MW of power for a typical 420 MW power plant (Smart & Aspinall, 2009, p. 9).

Air Cooled Thermal Plants

In water stressed areas around the world, air-cooling is increasingly being used as the medium of choice. From just an efficiency perspective, water is a better cooling medium than air—its rate of heat conductivity is higher so it absorbs heat more effectively than air. Moreover, the temperature of water available for cooling does not fluctuate on a day-to-day basis as much as the ambient air temperature does.

Going with air as the medium hence involves some trade-offs. The efficiency with which the turbine generates electricity is lower for an air-cooled plant, or, conversely, the plant must be operated longer to generate the same amount of electricity as that produced by an equivalent water-cooled plant. However, if this trade-off is accepted, it can lower the water requirement for cooling down to only 0.1 m³/MWh. Air cooled condensers are now being rapidly adopted in China (about 158 GW as of 2015) and South Africa (about 8.5 GW as of 2013) (Bhushan et al., 2015). Air cooling by other estimates can reduce cooling water requirements by up to 90 per cent but increase CO₂ emissions by 6 per cent and reduce energy efficiency by around 2–3 per cent (Smart & Aspinall, 2009, p. ix).

In India, however, air cooling is limited in capacity, mostly being used by captive power plants and smaller thermal power units (Central Electricity Authority, 2012).

Hybrid Cooling

The loss in efficiency in opting for air cooling is greater on hot summer days. To deal with these issues some plants employ a hybrid approach. Air cooled condensers are additionally fitted with water sprays that can be used to assist with cooling on hot days. These measures increase the plant's efficiency and marginally raise water requirements (Central Electricity Authority, 2012).

In Ash Handling

In a power plant, ash is generated at the top of the flue stack as combusted gas escapes into the atmosphere. Ash is also generated at the bottom of the furnace which needs to be cleared from time to time. Ash from the flue stack should ideally be removed by electrostatic precipitators which take advantage of the fact that the ash particles are charged to attract oppositely charged electrodes. Ash from the bottom of the furnace must be initially cleared away with water for the process to be effective, but this water can be drained away from the ash, treated and then reused. Meanwhile, the compactly packed ash can be carried away on conveyor belts. If water is deemed essential to transport the ash away, it must be in the form of a high concentration slurry.

Effectively reducing the amount of water required can mean potential savings of about 4 m³/MWh by bringing down average consumption from 8 m³/MWh to 4 m³/MWh. Plants in India use coal that generates an average ash content of about 300 kg/MWh (Bhushan et al., 2015). Recycling ash water is another approach to water savings.

Table 23: Summary of the Water Saving Practices (Thermal Power)

Coal thermal water saving practices	Percentage of water savings	Trade-offs
Air cooling	90% of cooling water requirement ⁶⁰	Higher capital costs and operating costs. Higher CO ₂ emissions, Lower electricity generation
Water cooling		
Reducing make-up water requirement	50% of cooling water requirement	Higher degree of treatment required for make-up water. Higher capital and operating costs.
Hybrid cooling	Between 50% to 90%	Same as air cooling trade-offs
Ash Handling	Up to 50%	Higher capital costs for treatment and reuse of ash handling water.

Besides the above mentioned alternatives, there is also a potential for water savings in domestic water use at power plants and also in plugging general leaks, through a water audit of the plant. If even some of the above options were considered, potentially about 50 per cent of the water consumption of the plant could be saved, and if air cooling were considered, this number could be even higher.

60. Cooling water makes up about 60-90 per cent of the water requirement in most coal thermal plants.

Mining

The impacts of mining on water resources, unlike other large industries, are not felt by way of consumption of large quantities of water. Many of the negative impacts of mines play out through other means. This section explores first these negative impacts and then practices which can mitigate the negative impact of mining on water resources. Understanding these processes are essential if case studies are to be undertaken to determine how local impacts of mining in the Mahanadi basin can be reduced.

The Impact

Mining to be certain affects water sources in many ways. It destroys watersheds by removing tree cover, top soil and changing the natural drainage patterns. This causes rapid acceleration in soil erosion and siltation in lower watersheds. Water quality in neighbouring areas can be severely affected by mine discharges. It also results in water being drawn into the mine pit and thereby lowering the groundwater table in areas surrounding the mine. These are impacts that are felt over the life of the mine and cannot easily be undone even after mine closure and reclamation.

Pollution of water sources due to mining can be classified into three broader categories,

- Sedimentation
- Acid mine drainage
- Metals deposition.

Sedimentation is the overloading of nearby streams with organic material and sediment from waste at a mine site. These sediments can reduce the water quality, change the natural course of streams and result in flooding if it lowers the depth of the stream. In certain cases, stream banks can also be destabilised by the mining process (Miranda et al., 2003, p. Appendix 2). Streams serve as sources of drinking water for the tribals in the forested areas of Chhattisgarh and Odisha.

Acid mine drainage is a serious impact that occurs when minerals containing large amounts of pyrite or sulphide deposits interact with water and oxygen to form pyrite acids or sulphuric acids, respectively, with a pH as low as 2–4. These acids can poison nearby streams since aquatic life cannot tolerate even mildly acidic waters. The process can continue unabated for as long as there are sulphuric minerals. Large waste piles of rock at mine sites serve as a source for these minerals (Miranda et al., 2003; Yadav & Jamal, 2015, p. 1009).

Deposition of metals from mine sites into water sources is another pollution threat. Heavy metals including cadmium, iron, lead, cyanide and mercury, which are either the mineral being mined or used in processing mineral ores find their way into the water bodies. Large quantities of metal tailings can introduce toxicity into streams and kill aquatic life.

Stories of mines devastating water sources across Chhattisgarh and Odisha are common. Iron ore mines in Bailadila in Dantewada in Southern Chhattisgarh have turned the local river Shankhini into red colour, on which about a hundred villages depend. Drinking

water wells in the area have run dry too (Mitra, 2006). Water borne diseases are also common in this region and could be linked with water quality issues (DNA, 2015). In the Raigarh district, the Gare Palma coal mines currently run by the SECL have witnessed large demonstrations and blockades in 2016 by villagers agitating over land and water concerns. The water table in these areas has fallen by more than 100 feet and in some villages by up to 150 feet since the mines have begun operating. In the Janjgir-Champa district, large scale limestone mines run by Ultra Tech Cement Ltd. (UTCL) have devastated the capacity of the local Paraswani reservoir which provided water for irrigation. The farmers in the region have now been forced to sign an MoU with UTCL to accept their polluted water for irrigation. The groundwater resources in the region have likewise been depleted because of limestone mining. Polluted water from the mines have also resulted in a large number of cattle deaths (Purohit, 2013). Water quality testing studies reveal that most coal bauxite and iron ore mines fail to meet discharge standards for several physical (dissolved and suspended solids), chemical (pH, nitrate, phosphate, sulphates), metallic as well as organic parameters. Iron is one contaminant present in high concentrations in discharges. Likewise, lead, copper, zinc, chromium and cadmium are other heavy metals that have contaminated drinking water sources in Bishrampur, Bhatgaon, Kushmi and Mainpat areas tested in Surguja, Chhattisgarh (Shukla, 2014). Many mines in the Ib valley region of Odisha have failed to meet chemical discharge standards and acid mine drainage has been observed as a result (Rout & Das, 2012, p. 59).

Potential Water Saving Practices

Preventive Measures

To prevent loading of mine waters with sediment, organic material and other excessive debris, certain measures can be taken which reduces this to some extent. Siltation fencing/ sedimentation ponds can be constructed surrounding the overburden dumps so that water from nearby streams or rainwater does not bring along its own sediment and neither does it wash away overburden into streams (Yadav & Jamal, 2015, p. 1014). For water that does enter the site, whether groundwater or rainwater, every effort must be made to prevent uncontrolled releases of water from the site itself. This requires treatment of the water in one way or another. Prior to treatment, water is stored on site in a reservoir. These reservoirs must be designed well enough to handle flood events and must also not allow untreated water to permeate into the ground. In the pre-treatment, the process of sedimentation takes place in these reservoirs to remove larger particles of suspended solids (Central Pollution Control Board, 2007, pp. 5–55). Overburden dumps should not be stacked too high and too steep. This leads to a greater likelihood of material being washed away (Central Pollution Control Board, 2011, p. 18).

Treatment of Acid Mine Drainage

Treatment of acid mine drainage can be active or passive in nature. Active treatment needs less space but is resource intensive and requires continuous attention. Passive treatment choices are self-maintaining systems such as limestone ponds or wetlands which are less resource intensive.

Active Treatment

Filtration

Plain physical filtration is a first effective step in removing organic matter and other suspended solids from mine discharge. It is an effective and low cost first step for treatment. Filtration alone however may not be enough, depending on the quality of the mine water and the desired discharge quality.

Neutralisation

Acid in mine drainage can be reduced largely by introducing minerals that neutralise the acids, such as carbonates or limestone. However, for such measures to be taken up, mine operators would need to take pre-emptive steps to estimate the ratio of acid generating minerals to neutralising minerals on site. The quality of mine water would need to be established before it is sent for treatment. In the lime treatment process, hydrated lime in a dry or slurry form is mixed with mine water which causes iron to be removed at a suitable pH level. The process also requires ammonia, caustic soda, calcium peroxide, limestone, fly ash, kiln dust etc.

Recovery

For certain types of mine tailings, such as iron ore, the ore can be separated out from tailings by existing technologies. The economics often though does not support the recovery of the iron. The Wet High Intensity Magnetic Separation method (WHIMS) and Slow Speed Classifiers (SSC) are two such technologies. The WHIMS method makes use of a strong magnetic field to separate out iron fines by concentrating it together. It can reduce the quantity of tailings produced by about 50 per cent. Slow speed classifiers also recover iron fines in the beneficiation process which results in purer tailings. The classifier works on the principle of separating out particles by size. As the slurry enters the classifier, it rotates the heavier larger particles and the smaller particles separate out, leaving the larger particles to be filtered out. (Central Pollution Control Board, 2007, pp. 5–27)

Passive Treatment

Limestone ponds work by letting mine discharge flow through limestone and the subsequent reaction that takes place removes iron and aluminium from the water.

Wetlands work on biological principles that allow agents such as bacteria and algae to work to remove contaminants in the water as it flows slowly from one pond to another. The bottom of the pond is lined with an impervious membrane or clay so that the surrounding groundwater table remains unaffected. Wetlands require lower capital costs to set up and running costs to maintain, and may be the best option available where land is available relatively cheaply. (Yadav & Jamal, 2015, p. 1013)

Disposal of Mine Drainage

Disposal of water from mine sites can happen in one of three ways: evaporation to the atmosphere, controlled discharges of treated water into nearby streams or groundwater

recharge. Which of these choices is opted for depends on a lot of different factors such as the surrounding topography, geology, air temperature etc. Where water gets disposed also affects the quality of water in the neighbourhood of the mine.

Table 24: Summary of Mining Practices to Preserve Water Quality Near Mines

Mining Practices	Benefits
Siltation fencing/sedimentation ponds designed for flood events	Prevents water from passing through mine site, mixing with overburden and polluting water bodies
Filtration	Removes organic matter and suspended solids
Neutralisation	Makes acid mine drainage neutral and therefore less harmful
Recovery	Recovers metal ores from mine tailings by advanced methods such as magnetic separation and classification
Limestone ponds	Reaction with limestone helps remove Iron and Aluminium from the water
Wetlands	Biological principles allow agents such as bacteria and algae to work to remove contaminants in the water
Controlled disposal	Evaporation, controlled release of treated water to streams or groundwater recharge as per location of mine

Iron and Steel Plants

Steel plants are estimated to on average use about 3.5 m³ of water per tonne of steel produced. i.e. one MTPA capacity steel plant would require about 3.5 MCM of water. This is based on a Blast Furnace–Basic Oxygen Furnace (BF–BOF) plant design. The worldwide best practice achieved with this design is however as low as 1 m³ per tonne of steel. The amount of water consumed is much larger, about 11 m³ per tonne of steel, if one were to count the water use in thermal power plants attached to iron and steel plants. This is called the ‘total water consumption’ of steel plants (Agrawal, Kanchan, & Umashankar, 2012).

BF–BOF is the dominant design for steel production across the world. It relies on iron ore conversion to iron in a Blast Furnace (BF) following which the iron is purified further by removing carbon to produce steel in a Basic Oxygen Furnace (BOF). BF–BOF production is more energy intensive than Direct Reduced Iron–Electric Arc Furnace (DRI–EAF) designs for steel production which are the alternative. Direct Reduced Iron (DRI) furnaces take a large fraction of scrap metal which is recycled to produce steel. The energy required to melt this scrap metal is only about 40 per cent of the energy required to transform iron ore into iron in a BF–BOF design (Laplace Conseil, 2013). India is the world’s largest producer of DRI iron (also called sponge iron). However, the growth of this industry has slowed down in recent times and DRI still represents only 40 per cent of India’s steel production (Sponge Iron Manufacturer’s Association, 2012).

Much of the water consumption in iron and steel plants is related to this choice of plant design and the choice of fuel. Both BF–BOF and DRI–EAF can use either coal or natural gas as fuel. Using coal in furnaces instead of natural gas can significantly increase its

water consumption. Similarly, choosing DRI–EAF over BF–BOF (if both use natural gas) will mean lower water consumption (Agrawal, Kanchan, & Umashankar, 2012). Most plants across the world use natural gas whereas India happens to use largely coal. If India were to change its form of production towards both DRI–EAF and natural gas, it would lead to lower water usage in the long run. Limitations do exist however, for instance in the procurement of scrap raw materials of adequate quality and availability of natural gas. DRI plants also employ fewer people and are perceived to be more polluting hence there is opposition on the ground (Sponge Iron Manufacturer’s Association, 2012).

Energy and therefore water can also be saved by regulating the processes and temperature of materials in production better. Besides these choices, water consumption can also be reduced by exploring other areas where water is consumed. i.e. in cooling products obtained after casting of molten steel into billets, sheets, rods etc., in descaling of hot steel just after casting, in scrubbing of flue gases etc. (See Annexure 8). Water can also be saved by reusing water that has been consumed in the wet quenching process in the coke plants (where coal is converted to coke) and sinter plants (where coke is pelletised). Water consumption can also be reduced in cases where blast furnaces have open loop cooling systems (Çağın & Yetiş, 2011). Steel plants must generally move towards lower water consumption by treatment and recycling as much process water as possible and moving towards becoming zero discharge units.

Future Water Use Scenarios

Within this section, an attempt is made to estimate what future water demand would look like in 2040 based on current trends in the agriculture and industrial sectors.

Business-as-Usual (BAU) Method

Under simple business-as-usual (BAU) scenarios, the surface water demand for irrigation, which is currently 13715 MCM in the Mahanadi basin, would increase to 20572 MCM, based on the current rate of increase of 1.84 per cent per year (i.e. a 49.5 per cent further increase from 2013-14 to 2040-41). This would be approximately 41 per cent of the utilisable flow of the river.⁶¹

Currently in the Mahanadi basin, about 1130 MCM of water in Chhattisgarh and 944 MCM of water in Odisha, is estimated to be allocated to the large industries. This totals to 2074 MCM (about 4 per cent of the utilisable flow). Of this, about 1661 MCM are clearances to thermal power alone for cumulative thermal capacity of 55.2 GW in both Chhattisgarh and Odisha in the Mahanadi Basin. However, of these clearances, the current installed capacity of coal thermal power in the year 2017 was only 22.9 GW⁶² (7.1 GW in Odisha and 15.8 GW in Chhattisgarh) (as cited in Chapter 7).

61. Projections of reduced flow in 2040 have not yet been considered.

62. This figure is for the entire state of Chhattisgarh and Odisha, not simply the parts of these states in the Mahanadi Basin.

As of now, projections for what industrial water allocations might look like in the year 2040 hold a great degree of uncertainty, since changes in this sector are much more dynamic and less predictable. A lot would depend on the magnitude of global economic growth and the progress of renewable energy and energy efficiency measures. The CEA in its Draft National Electricity Plan (2016) revised its estimates of electricity demand stating that given the commitments already made for construction of hydro power, nuclear power and renewable energy sources, no new thermal power capacity would be needed to meet the electricity demand in 2022. However as of 2016, about 50 GW of coal thermal power capacity projects are already under construction across India. These plants, like many of the existing coal thermal power plants in India, are likely to operate far below their full capacity (Central Electricity Authority, 2016).

Many coal thermal power projects, amounting to almost 14 GW, have been cancelled in May 2017 due to various factors including lack of demand for power and the competitive pricing of solar power (Upadhyay & Singh, 2017). Hence, developments such as these, shine light on the fact that the growth of coal thermal power is on the decline, making the prediction of its growth rate difficult. In this case, we assume the BAU Scenario would therefore lead to an installed thermal power capacity equal to the current quantum of clearances given, which is about 1661 MCM. The total quantum of water allocated to the industries (including those other than coal thermal power) is likely to be more than the current clearances of 2074 MCM, if the growth in the steel and aluminium sectors continue. In case of these industries too, large amounts of water gets consumed in the process of generation of power and hence the water consumption of these sectors too is indirectly dependent on the growth of the coal power sector.

Use of Water Saving Technologies

If water savings technologies such as SRI, which improve water efficiency by about 30 per cent, were to be implemented on even 20 per cent of the area irrigated under rice, we could see the water demand decrease by about 3984 MCM, giving us about 16588 MCM of surface irrigation requirement in total. Alternatively, the water used for irrigation could remain the same while bringing in more area under irrigation.

If water saving technologies for thermal power alone were to be implemented we could see savings of about 50 per cent in this sector. This would mean about 831 MCM of water savings and reduction to 1243 MCM of total industrial use as per current allocations (in the year 2016).

Use of Biomass-based Approach

One way of estimating the water requirement for livelihoods, especially for agriculture-based livelihoods, is through the biomass route. As per this approach, a typical farmer's family of five members can meet all its needs like food, fodder, fuel, recyclable biomass for the agriculture system and some surplus biomass for cash income if it can either produce or get access to about 18 tons (T) of biomass (dry weight) in a year (See box for details).

Method of the Biomass-based Approach

Biomass refers to the total mass of all living beings/things within an ecosystem. Life is organised as part of a food chain where photosynthetic activity of the primary producers produces the total amount of food in the ecosystem and regulates the number of organisms that can live within the ecosystem. For our purposes therefore, we use the term 'biomass' to mean the sum total of all vegetative matter—photosynthetic biomass—produced in the ecosystem. All parts of a plant or a crop are biomass and not merely the harvestable portion.

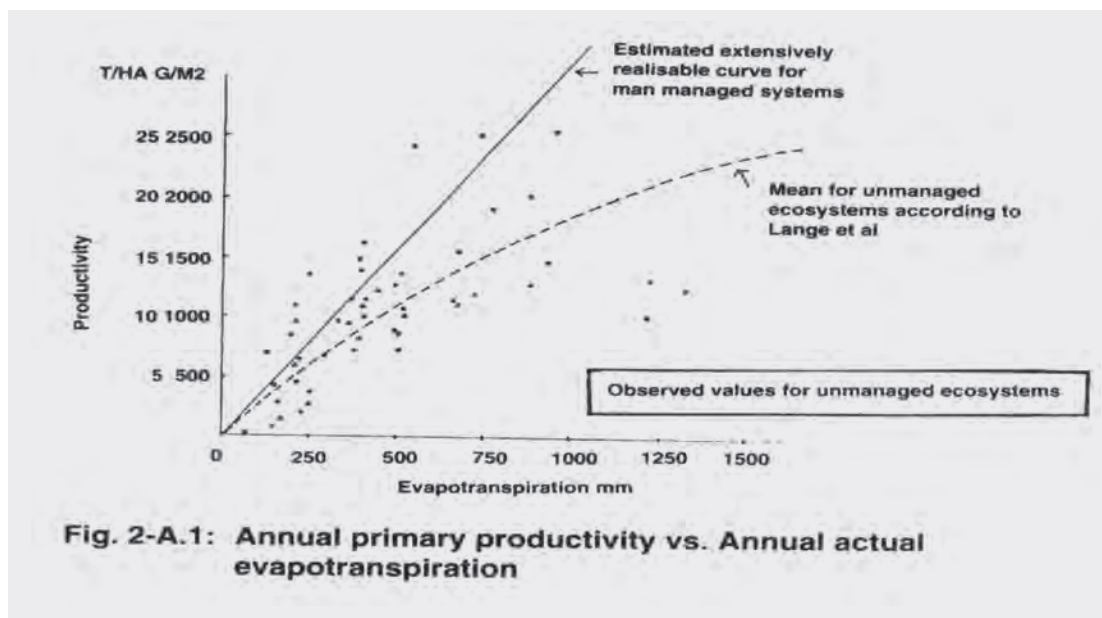
Biomass has been the main provider of human societies: some biomass is consumed directly in the form of food, some used indirectly (as fuel, fodder) and some biomass is sold in the market to meet cash income needs (or also processed for value addition).

As per this approach, a typical farming family of five members can meet all its needs like food, fodder, fuel, recyclable biomass for the agriculture system and some surplus biomass for cash income if it can either produce or get access to about 18 tons (T) of biomass (dry weight) in a year: food and allied needs 2 T, firewood 2 T, fodder 5 T, recyclable biomass 6 T and biomass for cash income 3 T. The above estimate is in line with a reasonable upper bound approach (keeping higher values than those actually required) with ample scope for optimisation. For example, if the cattle herd is rationalised and two families share one pair of bullocks then about 2.5 T in fodder can be saved. Similarly, if the families can shift to fuel efficient devices and methods then part of the biomass earmarked for fuel could be saved.

Biomass production and ecosystem productivity in relation to human needs have two distinct but related aspects, namely, potential biomass productivity and its partitioning. Potential biomass productivity represents the total photosynthetic biomass produced within the system while partitioning of this biomass between different products gives us different use values. Potential biomass productivity depends on the sum total of all ecosystem relationships and is determined by factors like soil conditions and moisture holding capacity, the total water regime within the ecosystem, and the amount of biomass and nutrients that flow and re-circulate through the ecosystem. How much of this potential biomass productivity is realised and how it is partitioned into different use values is a much more individual matter, depending on species selection, crop and water management, nutrient management, etc. (Paranjape and Joy, 1995; Datye et al., 1997).

We can estimate how much water is required to produce this 18 T of biomass. For this, we need to take into account the water productivity, meaning the quantity of biomass that can be produced by using a certain unit of water. Water productivity studies show that 1 ha-mm (1 ha-mm = $10 \text{ m}^3 = 10,000 \text{ litres}$) can produce about 3 kg biomass. While we have only taken average (or median) productivity, much higher values of productivity are also reported (Figure 37).

Figure 37: Annual Primary Productivity vs. Annual Actual Evapotranspiration



Source: Based on (Lange, Kappen, & Schulze, 1976) as cited in (Paranjape & Joy, 1995).

This is the type of productivity that is reported by farmers for Jowar in rainfed areas with average rainfall regimes of 500 to 600 mm/year, provided the rainfall is even distributed over the Kharif season. With this norm, the total water requirement to produce 18 T of biomass comes to 6000 m³. Of this, about 50 per cent (3000 m³) the crops/plants use directly from the rainfall (evapotranspiration or in-situ use forms the available soil moisture and this component can be further increased with better soil amelioration measures that can increase the water holding capacity of the soil and improve the local water regimes through watershed development activities, addition of biomass into soil, etc.). The remaining 3000 m³ could be provided as applied water from surface storages or groundwater. Of course, this division between the in-situ water use and applied water could change as per the local conditions, but it gives us a broad estimate. In addition to this, 400 m³ to satisfy domestic and livestock water requirements would be met locally.

In fact, this norm of 6000 m³ per family to meet livelihood needs is also in broad agreement with global estimates which say that 1000 m³ of water per person is required to lead a dignified life and if the water availability goes below 1000 m³ per person per year then it is often described as scarcity conditions. Using this approach, the total current and projected water requirements for the entire rural population of the Mahanadi Basin was calculated, which is about 22 BCM in the year 2040. This is more than the estimate we arrive at in the BAU scenario. However, one must note that in this scenario, theoretically, the livelihoods of all rural populations would be more secure as opposed to the BAU scenario, where only the livelihoods of those with access to irrigation facilities is secure.

9

Way Forward

Within this section, we first answer our initial research questions and then elaborate on what this implies for the river basin as a whole. The Mahanadi river basin is seeing fundamental changes both in its economy and ecology that will bring forth important questions of water allocations and use in the coming years. Further below we discuss a few elements of what could be a way forward to ensure that the future water resource planning, allocations and use are in line with concerns like equity, sustainability and democratisation.

Water Allocations and Distribution between Agriculture and Industry

To answer our initial research question about industrial water allocation adversely affecting availability of water for irrigation in the Mahanadi Basin, we go back to our findings from the two case studies.

In case of the Minimata Bango project, despite water being available in the reservoir, the Rabi irrigation requirements for the command area are not being met; in fact, they have not been met since the completion of the full canal network. The most plausible explanation is that water is being constantly released from the reservoir to fill anicuts downstream of the project through which several industries are being supplied with water. If these anicuts were not provided with regular water releases, they would in fact run dry. Despite these releases from the reservoir, there still exists enough water to meet at least partial irrigation needs. The lack of Rabi supply has led to large scale seasonal migration of people to the cities and outside Chhattisgarh in search of work. Organised resistance by farmers and conflict over this non-allocation, cannot be ruled out. While we have not studied in detail the performance of other surface irrigation projects in Chhattisgarh, state data does show that irrigated area from surface projects falls far below the potential created, in comparison with even Odisha. These projects need to be studied separately to understand the driving factors.

Contrastingly, in the Hirakud case study, water is being provided in more than the required quantities to the command area, and these quantities have been on the rise. This is partially due to the increase in the Rabi irrigation area, above the project design, but there are also inequities in water distribution within the command area itself. The Hirakud project has ample waters available, on account of its position in the centre of the river basin. In this case, the total allocation of water to agriculture does not seem under any immediate threat. However, due to mismanagement of the reservoir operations and industries pushing to access the dead storage of the reservoir, the timing of water releases to agriculture might be

affected. In fact, it was such issues and non-transparency on the part of the dam authorities that led to a serious conflict in 2006-07 and not necessarily any reduction in quantities of water being supplied for irrigation. Though irrigation may not be affected, adverse effects on flows in the river downstream of the Hirakud cannot be ruled out if industrial allocations continue to rise. This will be especially relevant in drought years where annual flows can dip as low as 10 BCM (as in 2000-01) or 15 BCM (as in 2002-03).

Besides the issue of actual allocations and distribution of water between these two sectors, we also find that there is a large potential for improvements in efficiency of water use, across the basin, both in irrigated agriculture and especially in thermal power. The distribution of water between these two sectors need not be a zero-sum game. Scenarios we have explored show that there is scope for both improving the flows of water in the rivers as well as bringing in larger populations into irrigated agriculture if water use is planned and used more locally, responsibly and equitably.

Moreover, we also stress the importance of broad and transparent multi-stakeholder processes of water allocation. As it stands currently, allocation processes are still very much top-down, merely inviting inputs from farmers within the WUAs, but not engaging with others dependent on the river directly, including fishermen, river-bed farmers etc. These processes are also non-transparent. Lack of transparency creates uncertainty which leads to conflict. We outline some more specific thoughts and recommendations below for consideration.

Policy and Legal Issues

The water policies of both the states, Chhattisgarh and Odisha, recognise the range of issues within water governance that need addressing—from increasing demands by various sectors including irrigation, large industries, urban and rural domestic demand to pollution (from urban and industrial sources), water logging and salinisation, grassroots participation in water management and so on. Odisha also now recognises the lack of in-situ conservation and conjunctive use, crop planning, etc., besides the need for a river basin approach to water management.

Neither Chhattisgarh nor Odisha, however, recognise the root cause of the rising water scarcity, inefficient water use, in both agriculture and industry. Surface irrigation in the Mahanadi basin, where flood irrigation for rice is the norm, has large potential for efficiency improvements. Thermal power plants, of which there are many in the basin, are gross misusers of water in comparison with global standards. Of course, there are also the larger questions like why are such a large number of thermal power plants coming up in the Mahanadi basin and what is their relevance. If these inefficiencies are not recognised in policy, strategies to address the problem will be inadequate and will always lean towards supply-side approaches.

Participation of local user groups in the development of water resources, operation and maintenance of the water distribution system and in the actual water allocations and

distribution of water, is essential. Though the state departments might have the technical capacity for the reservoir operations and maintenance, the water resource planning and management needs to be in close collaboration with the local community. While there are legal provisions in both the states for formation and handing over canal irrigation management at various scales to the WUAs and Pani Panchayats through participatory irrigation management, they do not seem to be very effective and very often have nominal existence. In both the states there is a Participatory Irrigation Management Act in vogue. Odisha has also amended the law to include even fisherfolks in the local WUAs. However, the problem is with the way these organisations are formed and the extent to which they are actually allowed decision-making powers. The WUAs are basically designed as 'co-management' institutions and, very often, all the decisions are taken by the Water Resources Department, while the WUAs are reduced to being tariff collection agencies. They are formed as it is a legal requirement and as part of the conditionality of external agencies like World Bank and Asian Development Bank rather than based on a commitment to genuine decentralised governance.

The state needs to adopt an approach wherein it views the role of the WUA as the governor of water resources and facilitator of local decision-making with equal importance. At present, it takes only the former role seriously. To be an effective facilitator to local groups for water resource planning, the states must adopt a transparent process with respect to data and information of water resources. They must also put much more emphasis on capacity building of local groups for understanding the local resource and the governance functions required.

While Odisha has a much more evolved institutional set-up for water resource management at various levels, its compositions, formation and functioning are yet to be streamlined. The issue is also with respect to how representative these institutions are with reference to the concerns and needs of the stakeholders. For example, even though the RBOs are proposed in the sectoral reforms project (and in Odisha at least one RBO has been formed on the Baitarani river), they are not genuine multi-stakeholder platforms for the planning and management of water resources, including decisions on allocation issues. While on paper they have the responsibility for ensuring integrated water resource management at basin scale, evolving perspective plans for the basins as well as finalising the allocation for various end uses, their very composition fails to address genuine issues around the participation of various stakeholders. It is predominantly a bureaucratic/technical platform with representation of elected members and an occasional NGO representation. It is not visualised as a platform that enables various stakeholders in the river basin to negotiate and work towards the planning and management of the water resources. For becoming a genuine and participatory platform, larger level consultations, representations of all stakeholders and reorganisation with focus on genuine participation and devolution of resources and authority are needed.

Institutions and Norms for Determining Water Allocation and Use

Institutions in both the states exist for determining water allocations for various uses. In Chhattisgarh, it is the Water Resources Department which decides allocations. However, the norms based on which water allocations are prioritised and made are not at all clear. In Odisha, the institutional mechanism is more developed (like the Water Resource Board overseeing planning and allocation) and more informed by policy priorities. However, even this mechanism is far from ideal. The policy priorities for water allocations need to be further developed to outline norms for water allocation for various uses. As showed in the case studies, in the absence of well-developed norms, it tends to be financial factors such as cost recovery which dictate water allocation priorities. Further, the overall developmental trajectory and the political economy centred on urbanisation and industrialisation also determine the direction in which water would flow. Both these states (Odisha and Chhattisgarh) are in the forefront of rapid industrialisation. The development of norms means going much beyond the simple listing of priority sectors to which water will be allocated. It means laying out what protocols would practically take place when the rainfall in a particular year falls below normal, meaning water allocation protocols need to be put in place for different rainfall regimes like normal, below normal and above normal years. The absence of clear norms of water allocation is an important cause for the conflict around agriculture–industry water allocations.

A related issue is the absence of transparent and participatory processes of water (re)allocations. It is this absence of transparency and unwillingness to take the stakeholders into confidence while deciding allocations that is causing much of the conflict. The question is would local water institutions be allowed the freedom to develop their plans for water from the ground up, with the state providing the resources and support necessary to facilitate this process. Alternately, would decisions on the quantum of water allocated be made at the level of state bureaucracy, with local groups being given the freedom to decide choice of crop. As it stands currently, the state decides both the quantum of water and the choice of crop while only taking inputs from local stakeholder groups during project feasibility processes. The final say is still in the hands of the respective water resource department of these states.

The water resource planning and projections of water demand and supply in both the states need to be revisited. At present, it looks a very tentative plan and projection in the absence of appropriate baseline, few data points and variables, and scenarios of sectoral growth and water demands. Both states assume that there is sufficient water to be exploited for development without taking into consideration the real water resource situation, the changes resulting from biophysical factors like land use changes (especially mining, deforestation), irrigation withdrawal, changes in rainfall patterns, etc. For example, it has been noticed that since the 1960 there has been a reduction in the average rainfall in the catchments of the Hirakud. Such changes need to be factored in and be part of the projection of water resource availability and allocation for various uses.

Knowledge Gaps

Water planning requires accurate estimations of water availability (in groundwater, soil moisture, surface water) for different river basins capturing seasonal and inter-annual variations. While some estimations of water availability do exist, the September 2016 meeting between the governments of both the states shows that there is no agreement on the figures. The Integrated Hydrological Data Book (Central Water Commission, 2012) the only resource in the public domain which provides information on estimation of the surface water resource in the Mahanadi Basin, estimates that the average annual flow is 66.8 BCM. However, no information is provided on 75 per cent dependability or 90 per cent dependability flow for the river basin as a whole. Moreover, no information is available on how these figures were estimated. Odisha's State Water Plan mentions the use of the hydrology software tool HYMOS (Hydrology Modelling System) and basin simulation model RIBASIM (River Basin Simulation Model) for their estimations. However, as long as the data used within these models remains closed, the estimation cannot be validated and improved on by different stakeholders. Odisha also estimates its groundwater resource availability in its Water Resources Plan, after assuming that up to 60 per cent groundwater development is safe. Moreover, the baseline data used for these estimates is the minor irrigation census of 1986-87. Needless to say, more than 30 years later, given the changing rate of groundwater development, these estimates must be continuously reviewed.

Chhattisgarh is several steps behind in closing these knowledge gaps. It does not provide any estimates of basin-wise water availability in the public domain. Neither state attempts to provide estimates of soil moisture levels nor seasonal estimates of groundwater levels in different parts of the basin. If these figures are not measured seriously then decentralised approaches to water provision, such as watershed development and restoration of local tanks and springs, will not ever prove successful.

Water Resources Planning

In Odisha, water resource demands for the future are likewise projected but in ways which are not very transparent. We have critiqued their approach to estimate basin-wise industrial demand for water based on the number of industrial workers and not the actual production capacity (See Chapter 7). These critiques could be developed even further if the underlying data for decisions were made available. Moreover, current industrial water allocations in the Mahanadi river basin in Odisha (as per state figures) are already more than double of the estimated water demand in 2050. This poses serious questions for how future water demand can be met. In Chhattisgarh, actual figures of water allocations to industries are hard to find and one source which mentions industrial allocations, can be seriously questioned.

Odisha's water resources planning is more detailed as compared to Chhattisgarh. It discusses future population projections, the estimated area of land that will need to be irrigated to achieve food security and the estimated future industrial demand. While each

of these figures can be questioned, it is nevertheless commendable that the details are at least partially transparent. What is lacking is a discussion of the intensity of water use for irrigation in the state. The total water requirement for irrigation is stated after calculating the total area that requires irrigation, but no discussion takes place on the scope for reducing the water intensity of irrigation. Moreover, the state water resource plan appears to be a one-time evaluation of the water resources of the state. What is really required is an ongoing evaluation of the water resources and what the state has achieved with respect to its goals.

The water resources planning for Chhattisgarh is currently being taken forward in a very non-transparent manner. Visits to the offices of the Water Resources Department in Raipur reveal that the task of planning water resources is simply being brought down to the question of where more structures can be built. A water resources plan for the state is being developed by WAPCOS Consultancy and has not yet been finalised. This draft plan appears to approach water resources from a very supply-side perspective and looks only at the possibility of developing new reservoirs (storage systems) for major, medium and minor irrigation projects, which could also augment water supply capacity for the industries. Change in rainfall patterns in the country and the Mahanadi river basin do not figure in the water plans, hence to what extent this may affect available water resources is unknown. This also brings in the issue of stationarity⁶³, as the average availability of water is estimated on its basis. In the light of the growing uncertainties in rainfall, rapid changes in land use and land cover, and increasing upstream uses, the long-term averages do not hold true. These multiple concerns bring to light current inadequacies in water resources planning.

The Issue of Conflict Framing

Presently, the contestation and conflict around water allocation in the Mahanadi basin (more so around the Hirakud dam) is broadly framed as one of agriculture versus industry. Such a framing has both strengths and limits. For example, it can help to organise the entire peasantry against its common 'foe', the industry. It helps to transcend the internal divisions and contradictions within the peasantry and consolidate them as one block in a hegemonic way. This did take place in case of the Hirakud as the entire peasantry of the Hirakud command got mobilised against increasing water allocations to industries under the banner of Pashchim Odisha Krushak Sanghatan. Even the tail-end farmers, who are not getting water, got mobilised against industrial water allocation. It should be said that due to the struggles of the farmers' movement, the Government of Odisha was forced to roll back some of the allocations and became a little more defensive when it came to water allocation to the industries.

63. The assumption of stationarity implies that the average of a particular statistic, in this case annual rainfall, stays constant over time. In the Mahanadi basin, however, the average annual rainfall is decreasing with each passing year. Hence, in this case, assuming stationarity for purposes of water resources planning will lead to an over assumption of water availability.

However, because of such a framing, some of the other substantive issues remained unattended. The internal divisions and contradictions within the peasantry, tail-ender deprivations, unsustainable cropping pattern (for example paddy-on-paddy-on-paddy type of cropping pattern), agronomical practices (use of chemical fertilisers, pesticides) and unsustainable water use, water footprint and so on, do not become serious agenda for the movement. Also, there is the issue of how we look at industries. Are we saying that water should not be allocated to the industries, or, are we saying that water should not be allocated to certain type of industries (for example mining, thermal power plants etc.)? Also, under what conditions could water be allocated to the industries and to what level? For example, can we not insist that industries can demand fresh water only if they exhaust all options like recycle and reuse, and be encouraged to adopt local water harvesting (like roof top water harvesting), water efficient technologies and so on, thus forcing them to move towards socially responsible water use paradigm? In the present framing of agriculture versus industry, all these and other substantive issues do not become part of the discourse. The way we frame the conflict gives legitimacy to certain interests at the expense of others and very often the solutions that we look for are also embedded in it. All these call for a more nuanced framing of the conflict.

Bibliography

- Agrawal, K., Kanchan, S., & Umashankar, S. (2012). *Stained steel*. Retrieved June 24, 2017, from Down to Earth, Centre for Science and Environment: <http://www.downtoearth.org.in/coverage/stained-steel-38359>
- Agriculture and Rural Development Unit (2005). *India-Orissa water resources consolidation project*. World Bank.
- Asoka, A., Gleeson, T., Wada, Y., & Mishra, V. (2017). Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India. *Nature Geoscience*, 10, 109-117. doi:10.1038/ngeo2869
- Asokan, S., & Dutta, D. (2008). Analysis of water resources in the Mahanadi river basin under projected climate conditions. *Hydrological Processes*, 22(18), 3589-3603. doi:10.1002/hyp.6962
- Babu K., A., Shrivastava, R., & Dikshit, M. (2015). Optimal operating policies for Ravishankar Sagar reservoir. *Journal of Indian Water Resources Society*, 35(1).
- Bhushan, C., & Hazra, B. (2008). *Rich lands, poor people: Is sustainable mining possible?* Centre for Science and Environment, New Delhi.
- Bhushan, C., Bhati, P., & Kanchan, S. (2015). *Heat on power: Green rating of coal based thermal power plants*. Centre for Science and Environment, New Delhi
- Bos, M., & Nugteren, J. (1982). *On irrigation efficiencies* (4th ed.). International Institute for Land Reclamation and Improvement (ILRI), University of Agriculture, Wageningen, The Netherlands.
- Bouman, B. (2009). How much water does rice use? *Rice Today*, 8(1). Retrieved March 31, 2017, from <https://www.scribd.com/document/34622848/Rice-Today-Vol-8-No-1>
- Cabangon, R., Lampayan, R., Bouman, B., & Tuong, T. (2011). *Water saving technologies for rice production in the Asian regions*. International Rice Research Institute, , Crop and Environment Science Division, Philippines. Retrieved from http://www.ftc.agnet.org/library.php?func=view&id=20140303145242&type_id=4
- Çağın, V., & Yetiş, Ü. (2011). Water reuse strategies: Iron and steel industry case study. In A. Atımtay, & S. Sikdar (Ed.), *Security of industrial water supply and management*. NATO Science for Peace Security Series C: Environmental Security. Springer, Dordrecht. doi:10.1007/978-94-007-1805-0_10
- Ceesay, M., Reid, W., Fernandes, E., & Uphoff, N. (2006). The effects of repeated soil wetting and drying on lowland rice yield with system of rice intensification (SRI) methods. *International Journal of Agricultural Sustainability*, 4(1), 5–14.
- Central Electricity Authority (2012). *National Electricity Plan*. Ministry of Power. Government of India. Retrieved from <http://climateobserver.org/wp-content/uploads/2015/01/National-Electricity-Plan.pdf>

- Central Electricity Authority (2016). *Draft National Electricity Plan*. Ministry of Power, Government of India. Retrieved from http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf
- Central Electricity Authority (2017). *Executive summary for the month of January, 2017*. Ministry of Power, Government of India. Retrieved from http://www.cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-01.pdf
- Central Pollution Control Board (2007). *Comprehensive industry document on iron ore mining*. Ministry of Environment and Forests, Government of India. Retrieved from http://cpcb.nic.in/upload/NewItems/NewItem_105_iron_ore_mining_31.07.08.pdf
- Central Pollution Control Board (2011). *Impact of coal mine wastewater discharge on surroundings with reference to heavy metals*. Ministry of Environment and Forest, Government of India. Retrieved from <http://cpcb.nic.in/CoalMineWW2011.pdf>
- Central Water Commission (2011). *Mahanadi*. Retrieved June 2017, from Water Resources Information System: <http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Mahanadi>
- Central Water Commission (2012). *Integrated hydrological data book (non-classified river basins)*. CWC, Government of India.
- Central Water Commission (2013). *Water and related statistics*. CWC, Government of India. Retrieved June 24, 2017, from <http://www.cwc.nic.in/main/downloads/Water%20and%20Related%20Statistics-2013.pdf>
- Central Water Commission (2014). *National register for large dams*. Retrieved from <http://www.cwc.nic.in/main/downloads/New%20NRLD.pdf>
- Central Water Commission (2016a). *Hydro-observation stations*. Retrieved June 24, 2017, from Water Resources Information System of India: <http://www.india-wris.nrsc.gov.in/HydroObservationStationApp.html?UType=R2VuZXJhbA==?UName=>
- Central Water Commission (2016b). *Major and medium projects in the Mahanadi river basin*. Retrieved from Water Resources Information System of India (WRIS): http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=Major_Medium_Irrigation_Projects_in_Mahanadi_Basin
- Central Water Commission (2016c). Minutes of the meeting of Hon'ble CM of Odisha and Chhattisgarh (September 2016).
- Centre for Science and Environment (2004). *To use or to misuse*. Down to Earth Supplement, CSE, New Delhi. Retrieved June 24, 2017, from <http://www.cseindia.org/dte-supplement/industry20040215/misuse.htm>
- Centre for Science and Environment (2007). 30,000 farmers demand Hirakud dam water. Down to Earth, CSE, New Delhi. Retrieved March 12, 2017, from <http://www.downtoearth.org.in/coverage/30000-farmers-demand-hirakud-dam-water--7037>
- Chief Engineer, Minimata (Hasdeo) Bango Project (2014). *Industrial water allocations from the Minimata Bango project* (August 2014).
- Chief Engineer, Minimata Bango Project, Bilaspur Water Resources Circle (2015). *Minimata Bango project – Kharif and rabi irrigation (target vs. actual)*.
- Choudhury, P., Sahoo, B., Sandbhor, J., Paranjape, S., Joy, K.J., & Vispute, S. (2012a). *Water conflicts in Odisha: A compendium of case studies*. Forum for Policy Dialogue on Water Conflicts in India, Pune

- Choudhury, P., Sandbhor, J., & Satapathy, P. (2012b). *Floods, fields and factories: Towards resolving conflicts around the Hirakud Dam*. Forum for Policy Dialogue on Water Conflicts in India, Pune.
- Cullet, P., Paranjape, S., Thakkar, H., Vani, M., Joy, K.J., & Ramesh, M. (2012). *Water conflicts in India: Towards a new legal and institutional framework*. Pune: Forum for Policy Dialogue on Water Conflicts in India.
- Dadhwal, V., Aggarwal, S., & Mishra, N. (2010). Hydrological simulation of Mahanadi river basin and impact of LULC change on surface runoff using a macro scale hydrological model. In W. Wagner, & B. Székely (Ed.), *International Society for Photogrammetry and Remote Sensing (ISPRS) VII- Symposium , XXXVII, Part 7B*. Vienna, Austria.
- Datye, K.R., Paranjape, S., & Joy, K.J. (1997). *Banking on biomass: A new strategy for sustainable prosperity based on renewable energy and dispersed industrialisation*. Centre for Environment Education (CEE), Ahmedabad.
- Department of Water Resources, Government of Chhattisgarh (2004). *Minimata Bango project – Detailed project report vol. I*.
- Department of Water Resources, Government of Chhattisgarh (2015). *Allocations of water to industries from planned barrages on Mahanadi river*.
- Department of Water Resources, Government of Orissa (2004). *Orissa state water plan*. Orissa Water Planning Organisation, DoWR, Government of Orissa.
- Department of Water Resources, Government of Orissa (2007a). *State Water Policy, 2007*. Retrieved from DoWR, Government of Odisha: <http://www.dowrorissa.gov.in/SWP2007/SWP%202007.pdf>
- Department of Water Resources, Government of Orissa (2007b). *Report of the high level technical committee to study various aspects of water usage for Hirakud reservoir*. Retrieved from DoWR, Government of Orissa: <http://www.dowrorissa.gov.in/NEWS/HirakudHLC/Report.pdf>
- Department of Water Resources, Government of Orissa (2014). *Flood report of the Hirakud dam*. Superintending Engineer, Hirakud Dam Circle, Burla, Government of Odisha.
- Department of Water Resources, Government of Orissa (2015). *State's Water Resources: An Overview*. Annual Report, 2014-15, DoWR, Orissa.
- Directorate of Economics and Statistics (2012). *Yield per hectare of major crops*. DES, Department of Agriculture and Cooperation. Retrieved from, <https://data.gov.in/catalog/yield-hectare-major-crops>
- Directorate of Economics and Statistics, Government of Chhattisgarh (2015). *Economic survey, 2014-15*. Retrieved May 14, 2017
- Directorate of Economics and Statistics, Ministry of Agriculture (2014). *Land use, cropping and irrigation statistics (1993-94 to 2013-14)*. Retrieved from DES, Ministry of Agriculture and Farmers Welfare, Government of India: <http://eands.dacnet.nic.in/>
- DNA (2015). *Red water forces people in Chhattisgarh's naxal hotbed to migrate*. Retrieved from <http://www.dnaindia.com/india/report-red-water-forces-people-in-chhattisgarh-s-naxal-hotbed-to-migrate-2099007>
- Down to Earth (2010). *Monopoly on Mahanadi: Chhattisgarh industrial water withdrawals*. Retrieved from <http://www.downtoearth.org.in/coverage/monopoly-on-mahanadi-1869>

- Down to Earth (2012). *In deep distress*. Retrieved from <http://www.downtoearth.org.in/coverage/in-deep-water--36036#1>
- Duttarganvi, S. (n.d.). *Enhancing water productivity in rice through different methods of rice cultivation*. WALAMTARI.
- Executive Engineer, Minimata Bango Project (2016). *Daily water inflows, releases and storage of Minimata Bango Reservoir (2005–2015)*.
- FAO (2004). *Rice and water: A long diversified story*. FAO factsheet of rice. Food and Agriculture Organization, United Nations
- FICCI (2011). *Water use and efficiency in thermal power plants*. Federation of Indian Chambers of Commerce and Industry. Retrieved June 24, 2017, from <http://ficci.in/spdocument/20147/ficci-Water-use.pdf>
- Forum for Policy Dialogue on Water Conflicts in India. (2017). *Situation analysis of the Mahanadi river basin*. Pune: Forum for Policy Dialogue on Water Conflicts in India.
- Ghosh, S., Vittal, H., Sharma, T., Karmarkar, S., Kasiviswanathan, K.S., Dhanesh, Y., Sudheer, K.P., Gunthe, S.S. (2016). Indian summer monsoon rainfall: Implications of contrasting trends in the spatial variability of means and extremes. *PLOS ONE*. doi:<https://doi.org/10.1371/journal.pone.0158670>
- Gupta, P., Panigrahy, S., & Parihar, J. S. (2011). Impact of climate change on runoff of the major river basins of India using global circulation model (HadCM3) projected data. *Indian Society of Remote Sensing*, 39(3), 337–344.
- ICRISAT. (2008). *SRI factsheet of India*. Andhra Pradesh: International Crops Research Institute for the Semi-Arid Tropics. Retrieved from ICRISAT-WWF Project.
- Joy, K.J., Gujja, B., Paranjape, S., Goud, V., & Vispute, S. (2008). *Water conflicts in India: A million revolts in the making*. Routledge.
- Joy, K.J., Sangameswaran, P., Latha, A., Dharmadhikary, S., Prasad, M., & Soma, K. (2011). *Life, livelihoods, ecosystems, culture: Entitlements and allocations of water for competing uses*. Forum for Policy Dialogue on Water Conflicts in India, Pune
- Kumar, V., Jain, S. K., & Singh, Y. (2010). Analysis of long-term rainfall trends in India. *Hydrological Sciences Journal*, 55(4), 484–496. doi:<http://www.tandfonline.com/action/showCitFormats?doi=10.1080/02626667.2010.481373>
- Lange, O., Kappen, L., & Schulze, E. (1976). *Water and plant life – Problems and modern approaches* (Vol. Ecological Studies 19). Springer-Verlag, Berlin.
- Laplace Conseil (2013). Impacts of energy market developments on the steel industry. Retrieved June 24, 2017, from <https://www.oecd.org/sti/ind/Item%209.%20Laplace%20-%20Steel%20Energy.pdf>
- Macknick, J., Newmark, R., Heath, G., & Hallett, K. (2012). Operational water consumption and withdrawal factors for electricity generating technologies: A review of existing literature. *Environmental Research Letters*, 7(4). Retrieved March 31, 2017, from <http://iopscience.iop.org/article/10.1088/1748-9326/7/4/045802/meta;jsessionid=F4BFCC348D4A3A044F703FEAC10048D3.c5.iopscience.cld.iop.org#erl444337s4>

- Mahapatra, R. (2011). *Barrages spur protests*. Retrieved from Down to Earth: <http://www.downtoearth.org.in/news/barrages-spur-protests-33972>
- Mahapatra, S. (2006). Functioning of Water Users Associations or Pani Panchayats in Orissa: Principle, procedure, performance and prospects. *Workshop on 'Water Law and the Commons'*. Delhi: International Environmental Law Research Centre (IELRC). Retrieved from www.ielrc.org/activities/workshop_0612/content/d0609.pdf
- Memorandum of Agreement between Madhya Pradesh and Orissa (1983, April 28). Bhubaneswar. Retrieved from <http://www.india-wris.nrsc.gov.in/wrpinfo/images/7/7f/65.pdf>
- Menon, M. (2013). *Irrigation water diverted for industries and domestic use in Maharashtra*. The Hindu. Retrieved from <http://www.thehindu.com/news/national/other-states/irrigation-water-diverted-for-industries-and-domestic-use-in-maharashtra/article4609969.ece>
- Ministry of Agriculture (2012). *Land use statistics- 2000-2012*. New Delhi.
- Ministry of Agriculture, Government of Odisha (2014). *Agricultural statistics (2006-07 to 2013-14)*.
- Ministry of Environment and Forests (2016). Environmental clearance reports of industries in the Mahanadi basin. MoEF, Government of India. Retrieved from <http://environmentclearance.nic.in/>
- Ministry of Mines (2015). *Exploration and mining opportunities in India: An investor guide*. Retrieved June 24, 2017, from <http://www.mines.nic.in/writereaddata/UploadFile/ExplorationandMiningEbook.pdf>
- Ministry of Water Resources (1999). *Reassessment of water resources potential of India*. Central Water Commission, MoWR, Government of India.
- Ministry of Water Resources (2014). *Mahanadi basin report*. MoWR, Government of India. Retrieved June 24, 2017, from <http://www.india-wris.nrsc.gov.in/Publications/BasinReports/Mahanadi%20Basin.pdf>
- Miranda, M., Burris, P., Bingcang, J.R., Shearman, P., Briones, J.O., La Vina, A., & Menard, S. (2003). *Mining and critical ecosystems: Mapping the risks*. Washington DC: World Resources Institute.
- Mishra, A., & Salokhe, V. (2011). Rice root growth and physiological responses to SRI water management and implications for crop productivity. *Paddy and Water Environment*, 9(1), 41–52.
- Mitra, M. (2006). *Rivers Shankhini and Dankini in Chhattisgarh run dry*. Retrieved from Down to Earth: <http://www.downtoearth.org.in/coverage/rivers-shankhini-and-dankini-in-chhattisgarh-run-dirty-8894>
- National Remote Sensing Agency. (2013-14). *Land use statistics*. India: NRSC, Indian Space Research Organization Government of India.
- Palanisami, K., Karunakaran, K., & Amarsinghe, U. (2012). *Impact of the system of rice intensification (SRI): Analysis of SRI practices in 13 states of India*. IWMI-TATA Water Policy Program.
- Paranjape, S., & Joy, K. (1995). *Sustainable technology making the Sardar Sarovar project viable*. Ahmedabad: Centre for Environment Education, Nehru Foundation for Development.

- Perry, C. (2007). Efficient irrigation, inefficient communication, flawed recommendations. *Irrigation and Drainage*, 56, 367–378.
- Planning and Coordination Department, Government of Odisha. (2015). *Economic survey, 2014-15*. Retrieved May 14, 2017
- Purohit, M. (2013). *Ultratech cement mines limestone (and villagers) in Chhattisgarh*. Retrieved from India Water Portal: <http://www.indiawaterportal.org/articles/ultratech-cement-mines-limestone-and-villagers-chhattisgarh>
- Rout, S., & Das, S. (2012). *Assessment of water quality around mines*. Department of Mining Engineering, National Institute of Technology, Rourkela
- Shukla, A. (2014). Toxicity of heavy metals in the water samples of north-eastern coal field region of Chhattisgarh. *Indian Journal of Scientific Research*, 4(1), 82–85.
- Singh, A. K. (2010). *Watershed management and fire monitoring by using remote sensing and GIS in Hasdeo river basin area of Chhattisgarh*. Doctoral Thesis report, Department of Forestry Wildlife and Environmental Science. Guru Ghasidas University.
- Smart, A., & Aspinall, A. (2009). *Water and the electricity generation industry: Implications of use*. Australian Government, National Water Commission.
- Sponge Iron Manufacturer's Association (2012). *Sustainability of Indian DRI industry*. International Conference on Indian Steel Industry. Retrieved June 24, 2017, from <http://steelfurnaceindia.com/pdf/Mr.D.Kashiva-SIMA.pptx>
- Statistics Cell, Ministry of Agriculture, Government of Odisha. (2015). *Land use and cropping statistics (1993-94 to 2013-14)*.
- Styger, E. (2012). *Increasing rice yields and saving water: Lessons for policy and practice – The system of rice intensification (SRI)*. New York: SRI International Network and Resources Center, Cornell University.
- Tabbal, D., Bouman, B., Bhuiyan, S., Sibayan, E., & Sattar, M. (2002). On farm strategies for reducing water input in irrigated rice, case studies in Philippines. *Agriculture Water Management*, 56, 93-112.
- Thakur, A., Rath, S., Patil, D., & Kumar, A. (2011). Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance. *Paddy and Water Environment*, 9(1), 13–24.
- The New Indian Express (2016). *Mahanadi issue: Odisha CM meets representatives of eight political parties to discuss future actions*. Retrieved March 14, 2017, from <http://www.newindianexpress.com/states/odisha/2016/sep/19/Mahanadi-issue-Odisha-CM-meets-representatives-of-eight-political-parties-to-discuss-future-actions-1522416.html>
- The New Indian Express (2017). *Centre constitutes negotiation committee on Mahanadi river water use*. Retrieved March 14, 2017, from <http://www.newindianexpress.com/states/odisha/2017/jan/19/centre-constitutes-negotiation-committee-on-mahanadi-river-water-use-1561342.html>
- The Orissa Gazette, Notification No. 11027-Irr.-II-WRC-21/2010-WR, Department of Water Resources (21 April 2010).
- The Orissa Gazette, Resolution No. 22496/IRR-Irr.-I-IPL-33/93, Department of Water Resources (21 August 1993).

- The Orissa Gazette, Resolution No. 5788/WR-Irr.-I-WB-4/06, Department of Water Resources (26 February 2007).
- The Pioneer (2016). *Shivrinarayan barrage will supply water to industrial units*. Retrieved from, The Pioneer: <http://www.dailypioneer.com/state-editions/raipur/shivrinarayan-barrage-will-supply-water-to-industrial-units.html>
- Times of India (2016). *Mahanadi issue: Odisha moves SC against Chhattisgarh*. Times of India. Bhubaneswar. Retrieved March 15, 2017, from <http://timesofindia.indiatimes.com/city/bhubaneswar/Mahanadi-issue-Odisha-moves-SC-against-Chhattisgarh/articleshow/55791681.cms>
- Upadhyay, A., & Singh, R. K. (2017). *Cheaper solar in India prompts rethink for coal projects*. Retrieved from Bloomberg: <https://www.bloomberg.com/news/articles/2017-06-01/cheaper-solar-in-india-prompts-rethink-for-more-coal-projects>
- Uphoff, N. (2003). Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability. *International Journal of Agricultural Sustainability*, 1(1).
- Uphoff, N. (2006, March). The system of rice intensification (SRI) as a methodology for reducing water requirements in irrigated rice production. *International Dialogue on Rice and Water: Exploring Options for Food Security and Sustainable Environments*. International Rice Research Institute. Retrieved from <http://www.agrecol.de/dokumente/SRI-Water-Reduce-Paper.pdf>
- USGS (2016). Schematic diagram of a coal power plant. United States Geological Survey, Retrieved from <https://water.usgs.gov/edu/wupt-coalplant-diagram.html>
- Water Services, Government of Odisha (2015). Allocations of water to industries from Hirakud Reservoir (2014-15). Retrieved November 2015
- Willardson, L., Allen, R., & Frederiksen, H. (1994). Eliminating irrigation inefficiencies. *USCID 13th Technical Conference*, (p. 15).
- World Steel Association (2013). *Overview of steelmaking process*. Retrieved from <https://www.worldsteel.org/publications/bookshop/product-details.~Overview-of-the-steelmaking-process~PRODUCT~Poster2011~.html>
- Yadav, H., & Jamal, A. (2015, October). Impact of mining on water resources in India. *International Journal of Advanced Research*, 3(10), 1009–1015.
- Zade, M., Ray, S., Dutta, S., & Panigrahy, S. (2005, April 25). Analysis of runoff pattern for all major basins of India using remote sensing data. *Research Communications*, 88(8).

Annexures

Annexure 1: District-wise, Season-wise Area Sown, Chhattisgarh (2013-14)

District	Kharif Area Sown (Th Ha) 2013-14	Rabi Area Sown (Th Ha) 2013-14	Geographical Area (Th Ha)	Kharif Area Sown % (2013-14)	Rabi Area Sown % (2013-14)
Bastar	12	0	58	20	0
Bilaspur	315	121	768	41	16
Dhamtari	197	23	422	47	5
Durg	522	248	869	60	29
Janjgir-Champa	263	20	447	59	4
Jashpur	166	7	453	37	2
Kabirdham	131	73	379	35	19
Kanker	76	2	224	34	1
Korba	130	8	715	18	1
Korea	39	4	232	17	2
Mahasamund	291	7	496	59	1
Raigarh	278	12	654	43	2
Raipur	565	81	1345	42	6
Rajnandgaon	231	75	565	41	13
Surguja	80	11	263	30	4
Chhattisgarh (Total)	3296	693	7888	42	9

Source: Ministry of Agriculture, Gol

Annexure 2: District-wise, Season-wise Area Sown, Odisha (2013-14)

Districts	Kharif Area Sown (Th Ha) 2013-14	Rabi Area Sown (Th Ha) 2013-14	Geographical Area (Th Ha)	Kharif Area Sown % (2013-14)	Rabi Area Sown % (2013-14)
Angul	63	31	190	33	16
Balangir	354	116	644	55	18
Bargarh	339	126	568	60	22
Boudh	93	40	296	31	13
Cuttack	126	153	372	34	41
Deogarh	7	3	27	28	11
Dhenkanal	23	14	67	33	20
Ganjam	24	17	54	45	32
Jagatsinghpur	85	85	180	47	47
Jharsuguda	57	18	162	35	11
Kalahandi	328	185	624	53	30
Kandhamal	94	31	627	15	5
Kendrapara	79	60	133	59	45
Khurda	106	67	280	38	24
Nabarangpur	73	11	178	41	6
Nayagarh	123	80	390	31	21
Nuapada	211	70	386	55	18
Puri	108	124	280	39	44
Raygada	3	1	11	26	7
Sambalpur	148	58	540	27	11
Subarnapur	146	77	219	67	35
Sundargarh	123	31	438	28	7
Odisha (Total)	2713	1396	6665	41	21

Source: Ministry of Agriculture, Gol

Annexure 3: District-wise, Source-wise Gross Area Irrigated, Chhattisgarh (2013-14)

Districts	Gross Irrigated area (ha)	Gross Canal Irrigated area (ha)	Gross Tank Irrigated area (ha)	Gross Well Irrigated area (ha)	District Canal % to State Canal %	District Tank % to State Tank %	District Well % to State Well %
Bastar	0	0	0	0	0	0	0
Bilaspur	151	59	8	83	6	20	14
Dhamtari	160	122	0	36	13	1	6
Durg	362	156	9	192	17	21	33
Janjgir-Champa	218	199	3	13	22	6	2
Jashpur	6	3	0	2	0	1	0
Kabirdham	80	15	0	63	2	0	11
Kanker	11	2	1	7	0	2	1
Korba	9	5	0	1	1	1	0
Koriya	3	2	0	1	0	0	0
Mahasamund	107	41	7	55	4	15	9
Raigarh	69	20	5	36	2	12	6
Raipur	337	259	7	63	28	16	11
Rajnandgaon	74	35	2	35	4	4	6
Surguja	9	1	0	1	0	1	0
Chhattisgarh Total	1597	918	43	589	100	100	100

Source: Ministry of Agriculture, Gol

Annexure 4: District-wise and Source-wise Gross Area Irrigated, Odisha (2013-14)

Districts	Gross Irrigation (ha)	Gross Canal Irrigation (ha)	Gross Tank Irrigation (ha)	Gross Well Irrigation (ha)	District Canal % to State Canal %	District Tank % to State Tank %	District Well % to State Well %
Angul	3	3	0	1	0	0	1
Balangir	10	0	0	9	0	1	10
Bargarh	190	168	4	18	24	41	19
Boudh	24	20	1	4	3	8	4
Cuttack	86	72	1	13	10	6	14
Deogarh	10	9	0	1	1	4	1
Dhenkanal	1	1	0	0	0	0	0
Ganjam	11	8	2	0	1	24	0
Jagatsinghpur	53	50	0	3	7	0	3
Jharsuguda	2	0	0	2	0	0	2
Kalahandi	102	97	0	5	14	1	5
Kandhamal	3	3	0	0	0	0	0
Kendrapara	30	26	0	3	4	0	3
Khurda	26	24	1	2	3	7	2
Nabarangpur	3	1	0	2	0	0	2
Nayagarh	4	2	0	2	0	0	2
Nuapada	16	14	0	1	2	2	1
Puri	89	71	0	18	10	0	20
Raygada	1	1	0	0	0	0	0
Sambalpur	46	41	0	5	6	3	5
Subarnapur	83	80	0	3	11	0	4
Sundargarh	8	6	0	2	1	0	2
Total	800	698	10	92	100	100	100

Source: Ministry of Agriculture, Gol

Annexure 5: Year-wise and Season-wise Crop Groups in Chhattisgarh

Annual	Cereals	Oilseeds	Pulses	Kharif	Cereals	Oilseeds	Pulses	Rabi	Cereals	Oilseeds	Pulses
2000-01	2941.9	149.9	508.3	2000-01	2888.4	77.5	142.6	2000-01	53.5	72.4	365.7
2001-02	2983.0	160.6	697.5	2001-02	2912.1	78.2	139.3	2001-02	71.0	82.4	558.2
2002-03	2951.8	153.7	626.8	2002-03	2883.6	82.8	145.0	2002-03	68.2	70.9	481.8
2003-04	2996.2	179.3	780.3	2003-04	2918.1	94.2	139.8	2003-04	78.1	85.1	640.6
2004-05	2994.9	181.7	798.8	2004-05	2922.3	100.6	141.7	2004-05	72.7	81.1	657.1
2005-06	2995.1	197.7	811.9	2005-06	2924.6	113.8	136.7	2005-06	70.5	83.9	675.2
2006-07	3052.6	203.6	765.9	2006-07	2986.2	127.5	136.7	2006-07	66.5	76.1	629.3
2007-08	3052.2	196.6	776.7	2007-08	2983.4	131.4	132.7	2007-08	68.8	65.2	643.9
2008-09	3048.3	195.0	727.4	2008-09	2980.2	135.6	129.6	2008-09	68.1	59.4	597.8
2009-10	2975.7	194.0	694.0	2009-10	2894.1	135.6	129.8	2009-10	81.6	58.4	564.2
2010-11	3051.1	195.6	708.1	2010-11	2973.9	145.8	127.7	2010-11	77.2	49.8	580.4
2011-12	3057.5	197.8	703.8	2011-12	2980.2	149.8	124.1	2011-12	77.3	48.0	579.8
2012-13				2012-13				2012-13			
2013-14	3093.7	192.2	692.9	2013-14	3015.4	151.4	119.4	2013-14	76.4	40.8	573.5

Source: Ministry of Agriculture, GoI

Annexure 6: Year-wise and Seasons-wise Crop Groups in Odisha

Annual	Cereals	Oilseeds	Pulses	Kharif	Cereals	Oilseeds	Pulses	Rabi	Cereals	Oilseeds	Pulses
1993-94	2303.9	510.3	1075.9	1993-94	2124.5	251.7	368.2	1993-94	179.3	258.6	707.6
1994-95	2243.1	506.1	1108.0	1994-95	2043.5	242.1	368.6	1994-95	199.6	264.0	739.4
1995-96	2276.6	526.5	1126.4	1995-96	2073.4	272.9	381.3	1995-96	203.2	253.5	745.0
1996-97	2230.1	408.7	753.8	1996-97	2036.7	231.9	291.5	1996-97	193.4	176.8	462.4
1997-98	2264.9	395.5	914.3	1997-98	2101.0	228.9	296.4	1997-98	163.8	166.6	617.9
1998-99	2231.7	360.7	824.1	1998-99	2049.2	202.3	277.9	1998-99	182.5	158.4	546.2
1999-00	2329.9	351.8	858.9	1999-00	2073.0	183.3	283.5	1999-00	256.9	168.5	575.4
2000-01	2203.7	280.1	731.8	2000-01	2058.6	161.9	311.4	2000-01	145.1	118.2	420.4
2001-02	2250.1	355.7	931.4	2001-02	2044.9	184.7	317.9	2001-02	205.1	171.0	613.4
2002-03	2187.8	240.7	730.1	2002-03	2050.5	117.0	275.8	2002-03	137.3	123.6	454.2
2003-04	2277.8	331.6	893.1	2003-04	2074.1	174.1	355.8	2003-04	203.6	157.6	537.3
2004-05	2286.3	353.8	898.4	2004-05	2069.7	204.3	347.8	2004-05	216.5	149.5	550.6
2005-06	2308.6	363.5	1039.5	2005-06	2069.7	206.4	397.1	2005-06	238.9	157.1	642.5
2006-07	2283.4	354.9	1067.8	2006-07	2045.6	191.9	403.9	2006-07	237.9	163.0	664.0
2007-08	2261.5	362.0	1096.1	2007-08	2023.2	191.5	410.3	2007-08	238.4	170.4	685.8
2008-09	2259.6	353.8	1120.1	2008-09	2011.4	181.1	422.8	2008-09	248.2	172.7	697.2
2009-10	2224.2	349.0	1175.5	2009-10	2015.2	177.0	433.9	2009-10	209.0	172.0	741.6
2010-11	2202.6	325.5	1144.9	2010-11	1979.9	153.0	409.0	2010-11	222.7	172.6	735.9
2011-12	N/A	N/A	N/A	2011-12	N/A	N/A	N/A	2011-12	N/A	N/A	N/A
2012-13	2098.8	315.6	1158.5	2012-13	1883.8	135.8	418.4	2012-13	215.0	179.8	740.1
2013-14	2167.0	309.1	1162.6	2013-14	1938.0	120.1	396.0	2013-14	229.0	189.0	766.6

Source: Ministry of Agriculture, Gol

Annexure 7: Proportion of Each District Lying in the Mahanadi Basin

District, Chhattisgarh	Alternative Names (alt) and New Districts (new)	% of District Lying in the Mahanadi Basin
Bastar	Kondagaon (new), Narayanpur (new), Bastar	3.4
Bilaspur	Mungeli (new), Bilaspur	89.6
Dhamtari		99.7
Durg	Balod (new), Bemetara (new), Durg	99.6
Janjgir-Champa		100
Jashpur		70.2
Kanker	Uttar Bastar (alt)	34.7
Kawardha	Kabirdham (alt)	85.3
Korba		100
Koriya	Korea (alt)	38.8
Mahasamund		100
Raigarh		100
Raipur	Baloda Bazaar (new), Ghariaband (new), Raipur	100
Rajnandgaon		70.4
Surguja	Surajpur (new), Balrampur (new), Surguja	16.4

Source: Our interpretation of the data from various sources

District, Odisha	Alternative Names (alt) and New Districts (new)	% of District Lying in the Mahanadi Basin
Angul	Anugul (alt)	33.6
Balangir	Balangir (alt)	100
Boudh	Bauda (alt), Baudh (alt)	100
Bargarh	Bargarh (alt)	100
Cuttack		96.9
Deogarh	Debagarh (alt)	10
Dhenkanal		15.3

District, Odisha	Alternative Names (alt) and New Districts (new)	% of District Lying in the Mahanadi Basin
Ganjam		6.1
Jagatsinghpur		100
Jharsuguda		100
Kalahandi		86.1
Kendrapara	Kedrapara (alt)	54.1
Khurda	Khorda (alt)	92.8
Nuapada	Naupada (alt)	100
Nabarangpur	Nowarangpur (alt)	31.6
Nayagarh		92.1
Phulbani	Kandhamal (alt)	74.7
Puri		100
Rayagada		1.5
Sambalpur		81.28
Subarnapur	Sonepur (alt)	100
Sundargarh		42.1

Source: Our interpretation of the data from various sources

Annexure 8: Norms for Water Use in Agriculture and Industry

Rice Cultivation

The rice crop, also known as the aquatic crop, is grown all over the world where there is ample freshwater source and good amount of rainfall. In India, rice is grown in the lowland areas (coastal areas), flooded areas and in the hilly regions/upland areas (slope forms a natural terrain for water to flow), where the weather is hot and humid. The average temperature required for rice throughout its life period varies between 22–37°C. Thus, rice, being a tropical crop requires abundant water during its various stages of growth. Some of this water is 'consumed' by the crop via evapotranspiration. This is considered as the beneficial component. Depending on the location where rice grows, seepage and percolation may or may not be seen as non-beneficial components (Cabangon, Lampayan, Bouman, & Tuong, 2011). In areas where water is consumed by groundwater irrigation downstream, it is seen as a beneficial non-consumptive use. In places where it isn't, this non-beneficial component requires a detailed analysis as therein lies a large scope for conserving water. To grow 1 kg of rice, approximately 2500 litres of water is required on average globally, with large variations, from as low as 800 litres to as high as 5000. Of this, the consumptive component in the form of evapotranspiration is about 1430 litres (global average) whereas the remaining is seepage and percolation (Bouman, 2009). Often the actual water supplied to the crop is in excess of these requirements, which represents potential for savings. Table A8.1 shows the water requirements for irrigated rice through its various stages

The Conventional Method of Cultivating Irrigated Rice

Rice is generally grown by flooding the field for days where plants grow in anaerobic condition. It is generally transplanted manually. A lot of water management and land maintenance is required before pre-planting the seedlings in the field. The main objective of preparing the land is to develop optimum conditions for the rice to grow and give maximum yield. Land preparation generally involves ploughing and tilling, levelling the land to ensure water reaches all the crops and soaking the land enough to retain moisture of the soil.

Once the land is prepared, it is flooded with 2.5–3 cm water. In the transplanting method, seedlings are grown in a separate nursery bed. Depending on the variety of seeds and soil it takes about 25–30 days to develop into seedlings. The germinated seedlings are then transplanted in the flooded field, in a line planting of 20×10 cm, where water level is gradually increased as per the height of the plant (5–10 cm). About 3–5 seedlings are clamped in one hill. The field is then drained 7–10 days prior harvesting.

Table A8.1: Water Requirements for Irrigated Rice

Purpose of Water Use	Consumptive Use (mm/day)		Remarks
	Low	High	
Land preparation	150	200	raising soil moisture, ploughing and tilling
Evapotranspiration	500	1200	
Seepage and percolation	200	700	Maintaining water ponding
Mid-season drainage	50	100	Refilling basin after drainage
Total	900	2250	

Source: FAO, 2004

The direct seeding method is a better method than transplanting, as it requires less labour, the plant matures faster and the plant is not subjected to stress. The only disadvantage of this method is the continuous control of weeds. The direct seeded method can be categorised into dry and wet direct seeding. Dry direct seeding method is usually done in rainfed ecosystems, where the germinated seed is sowed on dry soil surface. Methods like broadcasting, dibbling and drilling are used to sow seeds. In the wet direct seeding method, seeds are sowed in wet fields either by broadcasting or drilling.

Proper nutrients, application of herbicides and weed control are necessary during the life cycle of the rice plant. Usually, it takes about 115–120 days for the rice crop to completely mature after the establishment of the crop in the field. The rice crop is then harvested and different threshing methods are used to separate the grains. The yield of rice depends on the soil fertility, water and nutrient management and variety of rice. In India, in 2011-12, the average yield of Kharif rice was 2284 kg/ha and that of Rabi rice was 3275 kg/ha (Directorate of Economics and Statistics, 2012).

Thermal Power Production

Coal Thermal Power Plants

Coal power is the most abundantly used means to generate electricity in India, largely due to its economic viability in comparison with alternatives. This form of generating electricity however comes cheap but not without externalities. In comparison with other energy sources, coal thermal power ranks the highest in terms of water consumption (Macknick, Newmark, Heath, & Hallett, 2012)

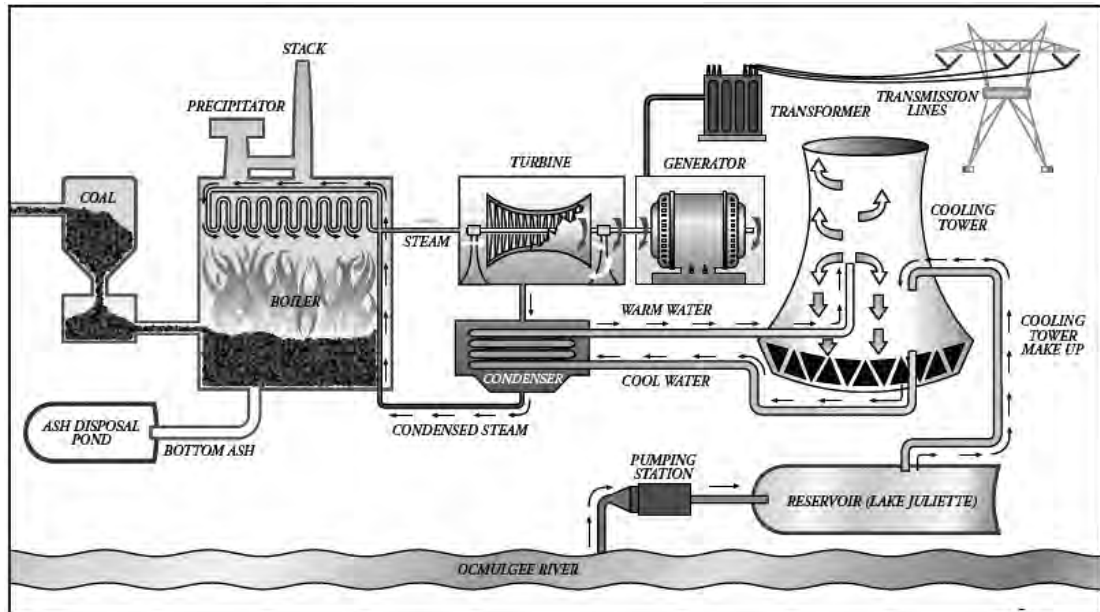
The Process

Water is used in thermal power plants in three major phases of its operations (besides the domestic water requirements of its employees).

- i. Loop 1 - Boiler → Turbine → Condenser → Boiler
- ii. Loop 2 - Condenser → Cooling tower → Condenser
- iii. Water for ash handling

A schematic diagram of the major components of a thermal power plant shown below describes the cycling of water through the plant's operations

Figure A8.1: Schematic Diagram of a Coal Thermal Power Plant



Source: USGS, 2016

Loop 1: Boiler

Boiler → Turbine → Condenser → Boiler

The boiler requires the least water of all the phases of the power plant's operations. Boiler water is also required to be of high quality and can only be used after the demineralisation process removes all minerals that may cause the interiors of the boiler to scale. The actual quantum of water required in boilers of a coal thermal power plant is estimated at about 0.12 m³/MWh for a typical 1000 MW plant (Central Electricity Authority, 2012). This water passes in one closed loop through the main boiler, where burning coal converts the boiler water to superheated steam, which rotates turbines to generate electricity. Due to the closed nature of this loop, water is reused and the aggregate use of water in this phase is minimal.

Loop 2: Cooling System

Condenser → Cooling tower → Condenser

The condenser is where cool water passes over pipes carrying steam exiting the turbine. After absorbing heat this water is directed towards the cooling towers where it rises upwards and cools in the process, transmitting its heat to the surrounding air. The water once cooled flows back down towards the bottom of the cooling tower. In the process, some water is lost to evaporation. The remaining water, at the bottom has a higher

concentration of dissolved solids. Some of this water is then 'blown down' (i.e. removed from the loop) and new 'make up' water is added to the loop to lower the concentration of dissolved solids. This water is then circulated back to the condenser. The level of Total Dissolved Solids (TDS) in cooling water is generally maintained below 2000 ppm (Smart & Aspinall, 2009). Higher TDS in 'make up' water will require more water to be 'blown down' each time and hence raise the overall consumption of water.

The Centre for Science and Environment's recent study (Bhushan et al., 2015) on environmental impact of coal thermal power plants, from a sample of 43 power plants in India, determined that the average water consumption for freshwater consuming recirculating cooling systems is about 4 m³/MWh. In Australia, another water scarce country, in the cooling process of recirculating cooling plants, it is estimated that water is consumed at a rate of 2.2 m³/MWh. This amounts to 15 MCM of water per year consumed by a typical 1000 MW plant (Smart & Aspinall, 2009, p. 14). A similar cooling system in Indian power plants operates much less efficiently, consuming about 18 MCM per year for a 660 MW plant, generating much less electricity in the process (FICCI, 2011).

Aside from the process described above, there are once-through-cooling (OTC) plants which do not have cooling towers and instead withdraw water directly from source and pass it over the condenser before releasing the same water back to sink. Although this represents very little water loss in percentage terms (about 1 per cent) (Bhushan et al., 2015, p. 36) the water returned to source is at a much higher temperature, representing a threat to the aquatic ecosystem. OTC plants draw anywhere between 70–200 m³/MWh of water withdrawn from source (Smart & Aspinall, 2009; Macknick et al., 2012; Bhushan et al., 2015). After taking into consideration 1 per cent of water lost due to evaporation, the actual consumption amounts to anywhere between 0.7–2 m³/MWh. By these estimates, therefore though withdrawals of water in OTC plants is high, the actual water consumed via evaporation is less than the water required for closed loop recirculating cooling plants.

Ash Handling

Thermal power plants use different mechanisms for ash disposal. The ash that remains after the burning of coal is removed from the bottom of the boiler periodically. The best available technological option for ash disposal in a 'dry' manner without the use of water involves using the ash to manufacture bricks and other forms of construction material. Where ash is not converted into another material, it is disposed of in an ash pond. This requires a lot of water to turn the ash into slurry which can then be transported via pipes to the ash pond. Water used for ash handling is most often water that is 'blown down' from the cooling tower.

Slurry concentrations determine the amount of water used to manage ash disposal. Concentrations vary from as low as 5 per cent to as high as 60 per cent. On average 8 m³ of water is required for a tonne of wet ash. Plants in India use coal that has generates an average ash content of about 300 kg/MWh. Thus, per MWh, the water consumption amounts to about 2.4 m³.

Mining

This section describes the nature of water use in mining and delves into the extent to which water use in the sector can affect water availability for other uses, either due to loss of groundwater or pollution of water sources.

The Process

Although the specifics of the mining process may vary for different kinds of minerals the general process involves five major steps:

- Exploration – In this step geologists prospect in search for deposits of minerals
- Mine Design – A plan for production, processing of the ore on site as well as an environment management plan are developed.
- Mine Construction – The building of access roads, railways to transport the ore, power facilities, factories for processing the ore and establishment of community relations is initiated.
- Production – Extraction and processing wherein minerals are separated from their ores.
- Closure of the mine facilities and reclamation for other purposes.

Types of Mines

Opencast mines and underground mines are the two major types of mines. Opencast are more common wherein the mineral to be excavated is close to the surface and the overlying earth is removed to get to the mineral. This type of mining creates a significant amount of overburden waste that must be disposed of. Underground mining on the other hand seeks to mine minerals much deeper below the surface of the earth and miners reach underground by tunnelling. These mines produce less visible environmental hazards.

Iron and Steel Production

The Process

Pre-processing: Converting Coal to Coke

Low ash, low sulphur bituminous coal i.e. coking coal is converted to coke by heating in the absence of oxygen. This allows the volatile gases, oil and tar in coal to escape without allowing the coal itself to burn. Coke is what is left behind. This coke contains a higher percentage of carbon (about 90 per cent) than the original coal and therefore it burns clean in a manner required for steel making.

Pre-processing: Beneficiation of Iron Ore

Iron ore that comes from mine sites often need to be pre-processed before they can be fed into a furnace. If the ore itself is of high quality then the beneficiation process is not required. However, in many cases, the ore is processed in a beneficiation plant to increase the iron content. This involves crushing and screening the iron ore into smaller granules

so that the waste material can be physically separated. The balance that remains is rich in iron content and is fired in a furnace to produce pellets.

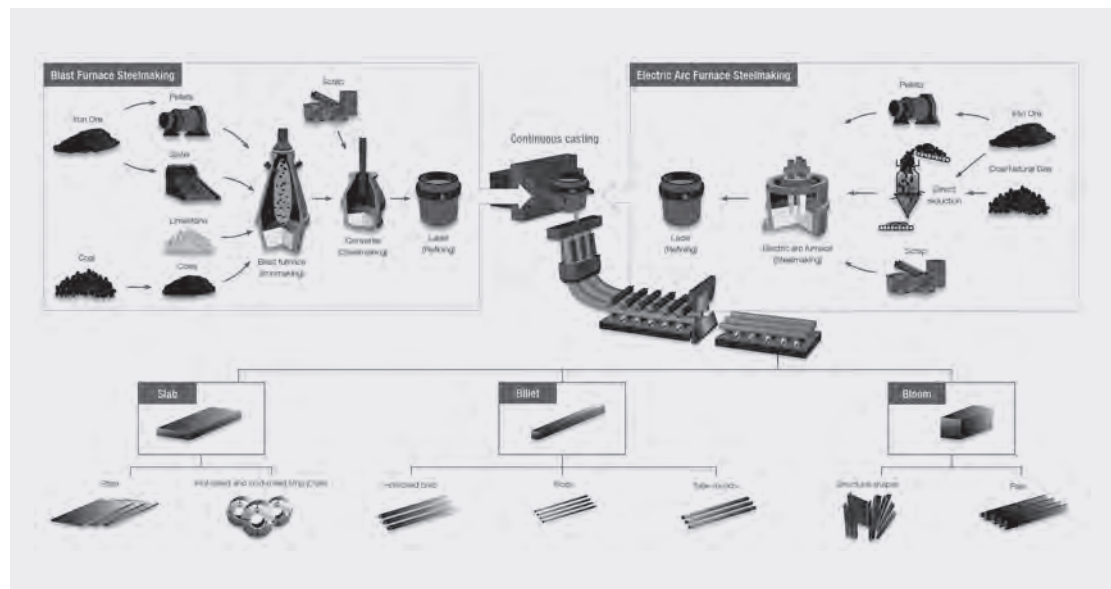
Besides the raw ore and pellets, sinter is another product prepared for the furnace. Sinter is a mix of raw ore, coke, limestone and waste from the steel plant that is fused together in a gas furnace to small pieces required for the blast furnace.

Pre-processing: Limestone

Limestone is also screened into pieces about an inch in diameter to be used in the blast furnace as flux. This limestone flux is meant to remove impurities in the ore by reacting with them. The impurities separate out as a slag on top of the molten metal at the bottom of the furnace.

Iron Ore to Iron

Figure A8.2: Schematic Diagram of Conversion of Iron Ore to Steel



Source: World Steel Association, 2013

The Blast Furnace: Production of Iron

In a blast furnace, iron ore is converted into iron. The raw ingredients, iron ore, limestone and coke, are dropped in from the top and are met with a blast of preheated air coming in from the bottom which ignites the coke. This coke serves as a high quality fuel to evenly heat the mixture and melt it into molten iron and slag. The slag floats on top of the liquid iron and is removed separately. The molten iron is then drawn out into billets or rods or any other shape required. This is called pig iron. Pig iron is much harder than pure iron because of its carbon content, which can be as high as 3-4 per cent as a result of the reaction with coke.

Direct Reduced Iron

Besides the blast furnace iron can also be produced as Direct Reduced Iron (DRI) or Sponge Iron, which is so known since it contains small pores that resemble a sponge. In this process limestone is not used as flux hence the iron that is obtained contains a greater percentage of impurities than pig iron. Its surface area is also greater due to the pores created by oxygen that has escaped. This iron is useful for certain manufacturing processes.

Iron to Steel

If the industry is an integrated iron and steel plant then the iron from the earlier processes is taken away to be converted into steel. Steel is essentially an alloy of iron and carbon. Its carbon content however is lower than that of pig iron, usually less than 2 per cent. Hence given the input of pig iron, the carbon content must be lowered.

Steel is produced using one of two different technologies. The Basic Oxygen Furnace or the Electric Arc furnace. The Basic Oxygen furnace is conventional technology which requires molten iron as input but can also accept as input about 20-30 per cent of steel which is meant to be recycled. The Electric Arc furnace on the other hand is newer technology which is now coming to dominate the steel production industry. This furnace accepts largely steel waste as input and thus produces steel which has recycled content as high as 80-90 per cent.

The Basic Oxygen Furnace

The Basic Oxygen furnace accepts molten iron and about 20-30 per cent of scrap steel as inputs into the furnace where oxygen is blown in at high speed. This oxygen oxidises the carbon and sulphur content in the iron and steel thus releasing heat in the process. It also lowers the carbon content thus making the molten iron into molten steel. This steel is then cast into sheets or billets or mixed with other elements in finishing processes to make a variety of different steel products.

The Electric Arc Furnace

This furnace takes largely scrap steel and small amounts of direct reduced iron and melts it at 1650°C in an electric arc furnace. The steel takes 60 mins to turn molten. Some oxygen is also blown in to remove impurities and melt it quicker. Additives are added to the molten steel which is then drawn out to form billets.

Annexure 9: Stakeholders Consulted during the Course of this Research

Stakeholder Group	
Farmers	<ul style="list-style-type: none"> • Sambalpur (Sasan Canal), Bargarh (Kumalsingha Sriramnagar, Turum, Attabira Branch Canal) • Janjgir-Champa (Mohandikala, Nayapara, Dhaneli, Sioud, Khaira, Saradih), Korba (Sonpuri, Bhatgaon)
Civil Society	<ul style="list-style-type: none"> • Paschim Odisha Krushak Sangathan (Western Odisha Farmer's Union) • Water Initiatives, Odisha • Chhattisgarh Bachao Andolan (Save Chhattisgarh Movement) • Participatory Research in Action (PRIA), Raipur, Chhattisgarh • PRADAN, Raipur, Chhattisgarh • Srijan Kendra, Kharsia, Janjgir-Champa, Chhattisgarh • Social Revival Group of Urban, Rural and Tribal (SROUT), Korba, Chhattisgarh
Government	<ul style="list-style-type: none"> • Superintendent Engineer., Water Resource Department, Raipur, Chhattisgarh • Chief Engineer, Hasdeo Circle, Water Resource Department, Bilaspur, Chhattisgarh • Executive Engineer Minimata Bango Project, Machadoli, Korba, Chhattisgarh • Executive Engineer, Hasdeo Canal Water Management Division, Janjgir-Champa • Deputy Director of Agriculture, Janjgir-Champa, Chhattisgarh • Deputy Director of Agriculture, Korba, Chhattisgarh • Chief Engineer, Upper Mahanadi Basin and Lower Mahanadi Basin, Department of Water Resources, Odisha • Director of Water Services, Department of Water Resources, Odisha • Chief Statistician, Directorate of Agriculture and Food Production, Government of Odisha • Joint Director of Administration, Bureau of Statistics, Government of Odisha • Superintending Engineer, Hirakud Dam Circle, Burla, Odisha • Deputy Director of Agriculture, Bargarh, Odisha • Executive Engineer, Bargarh Canal Division, Odisha
Media	<ul style="list-style-type: none"> • Samay Press, Sambalpur, Odisha • Deccan Chronicle, Raipur, Chhattisgarh
Academia	<ul style="list-style-type: none"> • Director of Research, Indira Gandhi Krishi Vishwavidyalaya (Indira Gandhi Agricultural University), Raipur • Senior Scientist, Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya (Indira Gandhi Agricultural University), Raipur • Head of Soil and Water Engineering Department, College of Agricultural Engineering, Raipur

Academia	<ul style="list-style-type: none"> • Chief Scientist, Barrister Thakur Chhedilal College of Agriculture & Research Station (TCB CARS), Bilaspur, Chhattisgarh • Krishi Vigyan Kendra, Korba, Chhattisgarh • Dean of Odisha University of Agriculture and Technology, Bhubaneswar • Senior Scientists of Odisha University of Agriculture and Technology, Bhubaneswar • Senior Scientists, Indian Institute of Water Management (IIWM), Bhubaneswar • Research Team in Green Rating for Thermal Power Plants Project, Centre for Science and Environment, New Delhi
Industry	CII, FICCI, NTPC (Attempts were made to engage with industry stakeholders but these were unsuccessful.)

The Forum and Its Work

The Forum (Forum for Policy Dialogue on Water Conflicts in India) is a dynamic initiative of individuals and institutions that has been in existence for the last ten years. Initiated by a handful of organisations that had come together to document conflicts and supported by World Wide Fund for Nature (WWF), it has now more than 250 individuals and organisations attached to it. The Forum has completed two phases of its work, the first centring on documentation, which also saw the publication of 'Water Conflicts in India: A Million Revolts in the Making', and a second phase where conflict documentation, conflict resolution and prevention were the core activities. Presently, the Forum is in its third phase where the emphasis is on backstopping conflict resolution. Apart from the core activities like documentation, capacity building, dissemination and outreach, the Forum would be intensively involved in right to water and sanitation, agriculture and industrial water use, environmental flows in the context of river basin management and groundwater as part of its thematic work. The Right to water and sanitation component is funded by WaterAid India. Arghyam Trust, Bangalore, which also funded the second phase, continues its funding for the Forums work in its third phase.

The Forum's Vision

The Forum believes that it is important to safeguard ecology and environment in general and water resources in particular while ensuring that the poor and the disadvantaged population in our country is assured of the water it needs for its basic living and livelihood needs. The Forum is committed to the core values of equity, environmental sustainability, efficiency, livelihood assurance for the poor and democratisation.

The Forum's Mission

The Forum's mission is to influence policies and actions at all levels and work towards resolving, and preventing water conflicts in an environmentally and socially just manner, and creating awareness for achieving participatory, equitable, and sustainable water use. The Forum aims to carry out these through stakeholder interactions, knowledge creation, policy advocacy, training, networking and outreach.

Contact

Forum for Policy Dialogue on Water Conflicts in India

c/o SOPPECOM, 16 Kale Park, Someshwarwadi Road,

Pashan, Pune 411008, Maharashtra, India

Phone: 0091-20-2025 1168, 2588 6542

Fax: 0091-20-2588 6542

URL: www.waterconflictforum.org; www.conflicts.indiawaterportal.org