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Getting More from Less

Story of India's Shrinking Water Resources

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Indian Council for Research on International Economic Relations
(ICRIER)

About the Report: India is facing an unprecedented stress on her water resources arising from changing pattern of Indian monsoon, declining per capita availability and changing sectoral allocation of water demand. The most challenging situation for the policymakers to tackle is, however, shrinking of per capita availability and also the water resources per se, in India. The available resources are shrinking quantitatively due to infrastructure inadequacies and exploitative extractions and weak policies, regulations and insufficient funds; and qualitatively due to widespread pollution, contamination and decay of rivers, water bodies, wetlands and groundwater resources. The gap is widening at all the three levels- gap between availability and utilization of the resources, gap between potential created and utilized, and gap between demand and supply of the resources.

In this background, this report, in two parts, addresses main challenges in agricultural water through ground water and canal water- covering almost 87 percent of India's net irrigated area. The cost of ground water and canal water (creation and utilization) has been computed and time and cost-over runs of selected canal irrigation projects evaluated in this report. It also highlights fast depleting groundwater resources in certain regions of India.

Possible policy measures suggested in the report with hope of assisting policymakers to implement proper management practices in order to make the irrigation water sector more efficient and sustainable.

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CONTENTS

LIST OF TABLES, FIGURES AND MAPS

Tables

Figures

Maps

ABBREVIATIONS USED

AE	Agricultural Entrepreneurs
AIBP	Accelerated Irrigation Benefit Program
APFAMGS	Andhra Pradesh Farmer Managed Groundwater Systems
APWell	Andhra Pradesh Groundwater Borewell Irrigation Schemes
AWD	Alternate Wet and Drying Moisture Regime
BaU	Business as Usual
BCM	Billion Cubic Meter
BCR	Benefit Cost Ratio
bgl	below ground level
BMP	Best Management Practices
CAD&WM	Command Area Development & Water Management
CAG	Comptroller and Auditor General (of India)
CAGR	Compound Annual Growth Rate
CCA	Culturable Command Area
CCAFS	CGIAR research program on Climate Change, Agriculture and Food Security
CGIAR	Consultative Group on International Agricultural Research
CGWB	Central Ground Water Board (of India)
CLA	Central Loan Assistance
CWC	Central Water Commission (of India)
DBT	Direct Benefits Transfer
DBTE	Direct Benefits Transfers through Electricity
DDUGJY	Deen Dayal Updhayay Gram Jyoti Yojana
DES	Directorate of Economics and Statistics (of MoA&FW)
DISCOM	Distribution Companies
DSUUSM	Dhundi Saur Urja Utpadak Sahakari Mandal
ERM	Extension, Renovation, Modernization
FAO	Food and Agriculture Organization of the United Nations
FiT	Feed in Tariff
FYP	Five Year Plan
GCA	Gross Cropped Area

GEB	Gujarat Electricity Board
GoI	Government of India
GRACE	Gravity Recovery and Climate Experiment
GW	Ground Water
IARI	Indian Agricultural Research Institute
ICA	Irrigable Command Area
ICT	Information and Communication Technology
IMD	India Meteorological Department
IPC	Irrigation Potential Created
IPU	Irrigation Potential Utilized
IRWR	Internal Renewable Water Resources (of India)
ISP	Indira Sagar Project
IWMI	International Water Management Institute
JGY	Jyotir Gram Yojana
KUSUM	Kisan Urja Suraksha evam Utthaan Mahabhiyan
KVAh	Kilo Volt Ampere hour
KW	Kilowatt
Kwh	Kilo Watt hour
LIS	Lift Irrigation Scheme
LTIF	Long Term Irrigation Fund (of NABARD)
LUS	Land Use Statistics
MGNERGA	Mahatma Gandhi National Rural Employment Guarantee Act
MGVCL	Madhya Gujarat Vij Company Limited
MI	Minor Irrigation
MMI	Major and Medium Irrigation
MoA&FW	Ministry of Agriculture & Farmers' Welfare
MoWR	Ministry of Water Resources
MoWR,RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
MP	Madhya Pradesh
MU	Million Units
MW	Mega Watt
NABARD	National Bank for Agriculture and Rural Development (of India)
NFSM	National Food Security Mission

NMMI	National Mission on Micro Irrigation
NIA	Net Irrigated Area
NWDT	Narmada Water Dispute Tribunal
OFD	On-Farm Development
PAU	Punjab Agricultural University
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PSPCL	Punjab State Power Corporation Limited
RBI	Reserve Bank of India
SCI	System of Crop Intensification
SPF	Standard Project Flood
SPICE	The Solar Pump Irrigators' Cooperative Enterprise
SRI	System of Rice Intensification
SSNNL	Sardar Sarovar Narmada Nirman Limited
SSP	Sardar Sarovar Project
TAC	Technical Advisory Committee
TISS	Tata Institute of Social Sciences
UGPL	Under Ground Pipe Line
UIP	Ultimate Irrigation Potential
UK	Uttarakhand/ Uttaranchal
UN	United Nations
UP	Uttar Pradesh
USA	United States of America
UTFI	Underground Taming of Floods for Irrigation
WPI	Wholesale Price Index
WUA	Water User Associations

FOREWORD

Water is one of the most critical resources necessary for sustenance of life and central to socio-economic development. India, with 2.4 per cent of the world's total geographical area and 18 per cent of the world's population, has only 4 per cent of the world's total fresh water resources. The growing population and economy, combined with the impact of climate change is making water scarcity a major threat in many parts of the country. We are witnessing severe damage to livelihoods, human health and ecosystems. Severe scarcity of water during droughts affects agriculture and farmers' welfare leading to loss in agricultural output and manifests itself in acute agrarian distress.

Government of India has put explicit emphasis in ensuring efficiency in usage of water. Since almost 78 per cent of India's total freshwater demand (Central Water Commission, 2010) comes from agricultural sector, GoI has announced an umbrella scheme - the Pradhan Mantri Krishi Sinchayee Yojana, for better monitoring and implementation of irrigation projects. NABARD has been playing an active role in this important initiative. Targeted to be completed by December 2019, these identified 99 priority projects are expected to create additional 6.8 million hectare (original target was 7.6 million ha) of irrigation potential in India. More recently, 'Jal Shakti Abhiyan' a campaign for water conservation and water security has been launched by the GoI. NABARD will be contributing significantly to this initiative as well. NABARD through its Rural Infrastructure Development Fund (RIDF) since 1995-96 has supported irrigation and drinking water supply sector and projects close to one lakh crore rupees have been sanctioned to various State Governments.

There exists a gap in irrigation potential created and utilized by major and medium irrigation projects and this obviously has inefficiency connotations. On the other hand, the major problem that ails the ground water sector is the over extraction of the resource resulting in depletion/decline in ground water table in many areas of the country. To delve deeper into the matter, NABARD initiated a project to study these issues in collaboration with Indian Council for Research on International Economic Relations (ICRIER), New Delhi, with Prof. Ashok Gulati in the lead.

I appreciate the work done in this report highlighting the challenges in ground water and canal water irrigation sectors, working out the costs of ground water extraction and irrigation potential creation. The Hindi proverb "Jal hai to Kal hai" means that - our future is safe only if there is water - aptly captures the concerns that emerge from the issues that face the sector. We hope that the results of the study would be useful for many stakeholders including policymakers, state governments and researchers for solving the problems of India's irrigation sector and ground water markets.

Dr. Harsh Kumar Bhanwala
Chairman
NABARD

FOREWORD

India is facing an unprecedented water stress situation. Per capita water availability which was more than 5178 cubic meters per year in 1951 has come down to 1544 cubic meters a year in 2011 and is estimated to further shrink to 1174 cubic meters per year by 2051. Meanwhile ground water level in certain parts of India (especially the north-western region) is on a declining trajectory and to top it all, owing to the global incidence of climate change, India has witnessed a negative departure in rainfall from its Long Period Average in thirteen of the last nineteen years. In the current situation, efficient management of available water resources in the country becomes more important than ever.

In this background this report attempts to address the main challenges in India's major sources of irrigation- which happens to be the sector to constitute 78 per cent of the country's freshwater demand. Irrigation through canal water and ground water are the two major sources of irrigation in India- covering around 87 per cent of net irrigated area- of which ground water is 63 per cent. Although ground water covers most of the net irrigated area, canal irrigation accounts for a significant amount of public expenditure. However, both these sectors have their own problems. On the one hand, over extraction of ground water has caused depletion (and/or decline) of the said water level and on the other hand delay in completion of canal irrigation projects has resulted in considerable cost over-runs. This report looks into the challenges in ground water and canal water sectors and at the same time identifies reasons behind the problems faced by them. The report captures the key of the land and computes the cost of ground water and canal water (creation and utilization) and evaluates the time and cost-over runs of selected canal irrigation projects. It highlights fast depleting groundwater resources in certain pockets and possible policy measures have been suggested in the report to make the irrigation water sector more efficient and sustainable. I am sure this will be of immense use to policy makers and other stakeholders engaged in studying and analyzing India's water woes.

This report is a part of study on “Issues Related to Water Use in Agriculture” under NABARD Research in Agricultural Economics in ICRIER. I appreciate the support given by NABARD and look forward to more intensive collaboration in the years to come with them.

Dr. Rajat Kathuria
Director and Chief Executive
ICRIER

PREFACE

In today's world, water crisis is not only a looming threat- it is already a reality that is haunting quite a few countries. Many parts of the world including South Asia and especially India are facing problems due to declining per capita availability of usable water resources. Interestingly, in a large part of India one of the reasons behind India's water stress situation is lack of resource management- rather than physical absence of water resources. This means that ensuring its efficient management, particularly in the irrigation sector- which accounts for 78 per cent of India's freshwater consumption, requires special attention.

India receives a considerable amount of rainfall but it varies widely temporally and spatially. So, importance of construction of dams and/or rainwater harvesting cannot be ignored in a country like India. Unfortunately, with change of climate all over the world, India received less than normal rainfall in thirteen of the last nineteen years. In the current year also, water levels in main reservoirs were only 24 per cent of their live capacity as on 18th of July, 2019 when the average of the corresponding date for last ten year is 28 per cent of live storage capacity. That, along with the fact that in parts of India (more specifically in the north-western states- Punjab, Haryana, Delhi and Rajasthan), more ground water is being withdrawn than is replenishable in a year, indicates that India's water resources are shrinking on per capita basis. Given that India is going to surpass China to become the most populous country in the world very soon (by 2027, as estimated in United Nations Population Projection 2019), getting more from less (from shrinking water resources) needs to be the overarching goal to cater to the growing needs of her people.

Irrigation has played a crucial role in increasing crop productivity and thereby profitability of farmers in India. But even after seventy years of independence, only around 49 percent of India's gross cropped area is irrigated. There are various sources and methods of irrigation adopted in the country, but canal water and ground water irrigates 87 per cent of the net irrigated area, of which 62 per cent is from ground water. Canal water used to be the main source until early 1970s but the overall inefficiencies existing in the surface irrigation system and subsidy in power supply to the agriculture sector has prompted farmers to shift towards groundwater sources for meeting the irrigation requirements of their crops. However, ground water sector also has problems of its own. The report tries to focus on the main challenges in both the sectors and suggests some policy measures to rectify the situation.

With annual groundwater draft of 253 BCM, India is now the largest groundwater user in the world. But this increase in groundwater irrigation coverage has been at the cost of negative externality associated with continuous groundwater depletion in large areas. Part I of the report aims to provide insights into groundwater scenario, and its decline and depletion across major Indian states. It also identifies the main reasons responsible for this; quantifies the cost of groundwater extraction; explore best practices for sustainable groundwater use, and formulate suitable demand side and supply side policies to promote sustainable groundwater use in agriculture. The study of groundwater in Part I finds that since power supply to agriculture is heavily subsidized, especially in states like Punjab, Rajasthan, Tamil Nadu and Maharashtra, the actual operating cost of groundwater extraction is rarely felt by farmers. This results in negligence in realizing the scarcity value of ground water which in turn leads to inefficient management of a crucial resource. Farmers need to realign their cropping pattern considering the economic value of ground water. Policy-makers should also consider economic value of

ground water extraction along with aquifer characteristics of a particular region before announcing perverse power subsidies causing depletion (or decline) in ground water resources.

In case of canal water, it is interesting to observe that creation of large public irrigation system constituted the main thrust of public expenditure on irrigation under the planned development of India. Yet, there is a large gap between India's irrigation potential creation (IPC) and its utilization (IPU), mainly through major and medium irrigation (MMI) projects since long and it has stubbornly increased over time, especially since 1980s. This means under-achievement of the planned targets, low returns on large investments and the farmers facing continued scarcity of irrigation water. In Part 2 of the report, the current gap between potential creation and utilization is assessed and costs of IPC and IPU estimated. It also looks into cases of selected MMI projects now being funded through NABARD's Long Term Irrigation Fund (LTIF) to observe the time and cost over runs. The study finds that although some of these projects have picked up speed in terms of potential creation, little advancement (or, no available information about current status) is there regarding irrigation service delivery. There is a good chance that the gap between IPC and IPU would continue to remain high. Part 2 also suggests some policy measures to bridge the increasing IPC-IPU gap for more efficient use of public money as well as water resources.

In our world of shrinking usable water resources, nothing is truer than the fact that "A*ll the water that will ever be is, right now*" (National Geographic, 1993). We need to make sure to use that water judiciously to ensure a sustainable development for generations to come. It is absolutely necessary to enforce proper management of all natural resources, especially management of a crucial, renewable but finite resource like water to achieve that goal.

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We thank Dr. Dipankar Saha, Former Member Central Ground Water Board, MoWR, RD & GR, Government of India (Former Member Secretary, Central Ground Water Authority) and Dr. Alok Sikka (Country Representative-India, International Water Management Institute, New Delhi Office) for reviewing the studies on groundwater and canal water, respectively and sharing their insightful comments and suggestions. We would also like to thank Mr. Amarjit Singh (former Secretary, Ministry of Water Resources, River Development and Ganga Rejuvenation), Mr. Rajesh Kumar (Director, ISM II, CWC) and Mr. S. K. Rajan (Director, P&P, CWC) for guidance and discussion during the preparation of Part 2 of the report.

We thankfully acknowledge the ICRIER agriculture team for their insightful suggestions and comments during our internal presentations. Needless to say, the responsibility of facts, figures, analysis and views expressed in this publication fully rests with the authors.

EXECUTIVE SUMMARY

The Issue: Why this Study?

We live in a time when we are looking at an imminent water crisis situation world-wide and efficient water management is an absolute necessity. Sustainability of human development, and also of irrigated agriculture, is being threatened by growing scarcity of water in India. Water is now increasingly being discussed in national politics and policy corridors. As witnessed in the past and more recently in the summer of 2019, water shortages will compromise nation's ability to sustain its economic growth through deficit supplies and more conflicts, with negative social and political consequences. Several experts of water planning are of the view that India is a water stressed country but most of her stress is originated from lack of resource management- and less from the physical scarcity of water *per se*. Agriculture is the biggest user of water. The largest share of India's freshwater consumption (78 per cent in 2010) comes from the agricultural sector (CWC, 2014). But the sector is facing competition for water due to increased urbanization and industrialization in the country. Unfortunately, even after 70 years of planned development and large public and private expenditure, only about 49 per cent of the cultivated area has access to irrigation. About 87 per cent of irrigated agriculture is through two main sources: (a) groundwater (64 per cent) and (b) canals (23 per cent). Though surface water in the canals and groundwater through wells and tubewells has inherently different characteristics, economics and growth trajectories in the country, both are under severe physical, economic and environmental stress *albeit* due to different reasons. Whereas, huge public expenditures (Rs.58,450 crore in 2013-14; Government of India 2015a) were made and still being incurred in the construction of large surface irrigation projects; massive private investment through savings and loans were made in drilling more than 20 million wells and tubewells in the country (approximate size of groundwater economy ~ 10 billion US$). How we manage these two precious resources is, therefore, crucial for our future agriculture, food, drinking water & sanitation and even industrial and environmental planning, policies and investments. Urgent and effective action and innovative policies are required to manage India's water resources.

As per the existing technology, India's Ultimate Irrigation Potential (UIP) is 139.9 Mha of which 46 per cent is from ground water and the rest is from surface water. Interestingly, 64 per cent of irrigated area is now irrigated by ground water. The significant over dependence of Indian agriculture on groundwater resource for irrigation dates back to early 1970s. At present India is the largest groundwater user globally. India extracts almost 253 Billion Cubic Meter (BCM) of groundwater per year followed by USA and China. Almost 90 per cent of the groundwater extracted annually is used for agriculture. The poor efficiency of the canal irrigation system as against timeliness of groundwater supply, flexibility on account of private ownership of groundwater structures and the substantive electricity subsidies/ free energy supply to the tubewells existing across states have immensely enhanced the development of groundwater irrigation in India.

In India, surface and ground water- both sectors face specific challenges. For ground water sector, rapid increase in groundwater use has been at the cost of negative externality associated with continuous and irreversible desaturation of aquifers and decline of water levels in large areas. The north western India comprising of Punjab, Haryana, and parts of Rajasthan has been

globally identified as a critical water risk hotspot due to the unsustainable groundwater over exploitation being practiced in these regions. The repercussion of the negative externality is spreading to other states as well. Almost 16 per cent of the total groundwater assessment units (blocks/talukas/Firkas) in India have been categorized as over exploited where the annual rate of groundwater extraction exceeds the annual recharge. Apart from Punjab, Rajasthan and Haryana, states like western UP, Tamil Nadu and Karnataka have also reported higher share of over exploited blocks than the all India average. This uneven development of groundwater across the country, especially unsustainable and high development in the intensive agriculture production regions of India, has large costs for the farmers and the state. The situation is further complicated when the state intervention is made through populist energy policies of free or highly subsidised energy which provides little incentive for groundwater or energy conservation. These policies along with the exigency of national food security have caused large scale adoption of water-intensive crops like paddy and sugarcane even in the semi-arid regions which are overwhelmingly dependent on groundwater irrigation.

For surface water, more specifically, government constructed major and medium canal irrigation systems, the main challenge is ever increasing gap between irrigation potential created (IPC) by the system agencies and engineers and actually utilised (IPU) by the farmers. This widening gap between IPC and IPU is making public irrigation more costly to the country than it should be, had the gap been closed. It is also proving costly to the farmers as in spite of the resource and main system construction they do not have access to the resource and have to resort to costly groundwater extraction for meeting the crop water needs. In the end, this process is also leading to environmental damage due to water-logging and salinization in the irrigation commands and over extraction of groundwater in the non-command areas. It will only be wise to take up the issue of closing or at least bringing down the gap between IPC and IPU proactively. It will be a good policy as it will bring larger social, environmental and economic benefits.

The capital expenditure and working expenses on Major and Medium Irrigation (MMI) systems were Rs. 36597.13 crore and Rs. 21853.08 crore respectively, in 2013-14 in current prices (Government of India, 2015a). The problem with public irrigation is not in the amount of money spent *per se* but in creating suitable mechanisms, institutions and last mile service delivery system of canal water. That, along with the fact that the head-users of canal water use the same to produce water-intensive crops results in inequity of water distribution between head and tail-end users and enlarge the gap between IPC and IPU. According to the erstwhile Ministry of Water Resources, there was a gap of 22.5 per cent between the IPC and IPU (till the end of 11th Five Year Plan). The cumulative percentage gap was above 27 per cent when only Major and Medium Irrigation (MMI) projects were taken into consideration. If the slow pace in command area development to date is to be considered, the gap, in all probability, has only increased in the last few years. This is also substantiated by decline in the area under canal irrigation (~ 5 lakh ha) during the last decade.

Agriculture sector is guilty of using irrigation water very inefficiently. The levels of efficiency are 55 per cent for ground water and 30 per cent for surface water (Central Water Commission 2014). This issue needs to be addressed urgently with a view to promote sustainable irrigation development in Indian agriculture. It is against this backdrop, that this study delves deeper into two aspects of water use in agriculture- the challenges of groundwater and canal irrigation sectors and factors behind these challenges. It also aims at suggesting potential physical, economic and policy interventions for '*getting more from less*', *i.e.*, making the best use of India's shrinking per capita water resources.

Our Approach and Key Findings

Keeping in consideration the huge share of ground water in total irrigated area, we first address the challenges in groundwater sector. Thereafter, we take up the key issues in surface water irrigation, primarily through Major and Medium (canal) Irrigation schemes. It is this segment which receives the largest chunk of of public investment in irrigation, and has been the darling of Indian irrigation planners, engineers, contractors and policy makers. We summarize here the key objectives and findings of these two components of Indian irrigation:

As far as groundwater is concerned, our objectives are to:

i. Understand the status of groundwater development across major agrarian states of India.

ii. Identify the main reasons of groundwater depletion and decline.

iii. Estimate the cost of groundwater extraction in major Indian states.

iv. Explore the best practices for optimal groundwater use and formulate suitable demand side and supply side policies to promote sustainable groundwater use for agriculture development in the country.

For the **first objective**, the analysis has been based on the Central Ground Water Board (CGWB) data on the state-wise stages of ground water development and state-wise status of wells in various minor irrigation censuses. On the basis of gross irrigated area status, ground water level and extraction status (considering region specific criteria arising from different aquifer characteristics and recharge possibilities), 18 states were selected and grouped into four regions. Their ground water status are discussed in detail in the report. In accordance with the declining ground water levels, states like Punjab, Haryana, and Rajasthan have seen huge increase in deep tube wells over various minor irrigation censuses (starting in 1986-87). But almost 41 per cent of the total wells and 43 per cent of deep tube-wells in India are concentrated in the peninsular region of the country characterized by hard rock aquifers marked by poor groundwater storage and yield capacity. Ground water development stage (overall) of all the states in this group (Tamil Nadu, Karnataka, Telangana, Andhra Pradesh, Maharashtra) except for Tamil Nadu, however, are in the safe zone which is not the case for states like Punjab, Haryana and Rajasthan. The later three states extract excessively more groundwater than their annual replenishable ground water resources and are thus over-exploited.

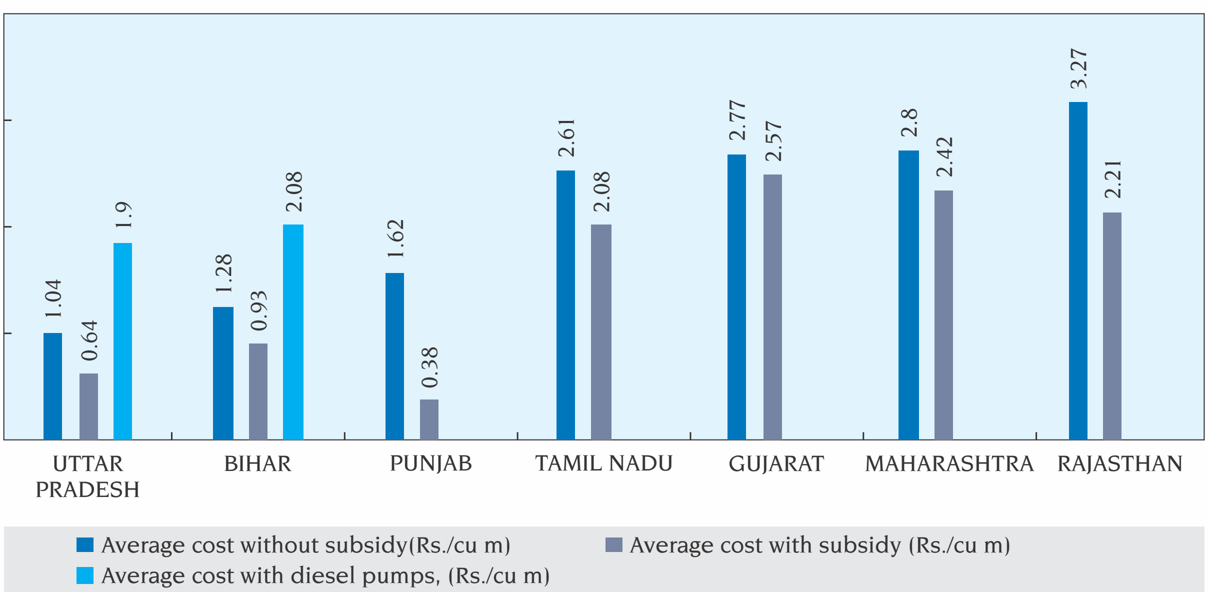
To address the **second objective**, we aimed to explain the possible reason behind the major challenge in the ground water sector, namely, depletion or decline of groundwater table. It is implicit that the nature and scope of groundwater resource management is associated with the existing regional and local aquifer characteristics and hydrological status. However, misaligned energy policies and cropping pattern supported by high and assured minimum support prices for the cereals and assured procurement have played a damaging role in accelerating the over-exploitation of groundwater and altering the stage of groundwater development much beyond the natural course.

This brings us to the **third objective**. In a situation where we need to stop the over extraction of a critical natural resource like water, it becomes essential to understand the economic cost of groundwater extraction to relate to the scarcity value of the resource across the states, in order to ensure effective management to overcome the manmade instability caused in the system. To address this particular objective, we ventured in estimating that cost across selected states

(Bihar, Uttar Pradesh, Punjab, Tamil Nadu, Gujarat, Maharashtra and Rajasthan). In our study we have estimated the cost of groundwater extraction in selected states per hectare of groundwater irrigated area as well as per cubic meter of water extracted (Figure 1). This helps to assess how the energy subsidies and cropping pattern in a region can affect the groundwater situation existing in a state.

Most of the states reporting groundwater over exploitation are characterized by wells fitted with electric pump sets. Among the seven states identified for estimating groundwater extraction cost, Punjab reports the highest level of electricity subsidy per hectare of groundwater irrigated area (Rs. 12194/ ha) followed by Tamil Nadu (Rs. 6667/ha), Rajasthan (Rs. 3677/ha) and Maharashtra (Rs. 3015/ha). These states despite having stressed groundwater resource and declining water levels, cultivate water guzzler crops like rice and sugarcane, mainly due to the existence of the perverse electricity subsidies and assured markets through minimum support prices (MSP) in case of paddy and fair and remunerative prices (FRP) in case of sugarcane . It is interesting to note that in case of Punjab, cost of groundwater extraction will go up four times if power subsidy is phased out. This will automatically bring down profitability in crops like paddy, and thus help in arresting depleting water table in Punjab. On the other hand eastern states like Bihar with safer groundwater development stage have lesser share of electric pump sets (7 per cent), particularly due to the low level of electrification in rural areas as well as the meagre rate of electricity subsidy existing per hectare of groundwater irrigated area (Rs. 121/ha). These cases reveal the effect that perverse power subsidies can have on groundwater over exploitation. Due to the existence of power subsidies, the actual operating cost of groundwater extraction is rarely felt by farmers. As a result the scarcity value of the resource is neglected with little incentive for its sustainable management. Farmers need to be sensitized about the actual economic value of groundwater resource and thereby the need for realigning their irrigation and cropping pattern, accordingly. In order to sustainably manage the depleting groundwater resource, policies must be framed not just looking at aquifer characteristics but also after considering the economic value of the groundwater resource across different regions.

Figure 1: Average cost of groundwater extraction in the selected groundwater using states in India



Source: Authors' Calculation

In the section on Surface Irrigation systems, the points of focus are to:

i. Find out the status of gap between irrigation potential created (IPC) and irrigation potential utilised (IPU): state-wise, region-wise, plan-wise and resource-wise.

ii. Estimate the cost of public irrigation potential creation and utilization.

iii. Estimate time and cost over-runs of selected irrigation projects and comparing their performances before and after NABARD started to fund them through Long Term Irrigation Fund (LTIF) as part of the P*radhan Mantri* K*rishi* S*inchayee* Y*ojana*- H*ar* K*het ko* P*ani* component.

iv. Suggest suitable policies to reduce IPC- IPU gap.

For the **first objective**, we have looked into the irrigation potential creation and utilization situation in detail. We have considered IPC and IPU situations state-wise and plan wise for both Major and Medium Irrigation (MMI) and Minor Irrigation (MI) separately. For the study, only those states are selected which have already created more than one million hectare of irrigation potential till the end of eleventh Five Year Plan (FYP) (2007-12).

For state-wise IPC and IPU in MMI, we have used Central Water Commission (CWC) publication titled "Water and Related Statistics" as a source and plotted graphs to represent the gap situation in selected states from the sixth FYP Period (1980-85) to the 11th FYP period (2007-12). We observe that, for the period of consideration (or at least since the end of the 9th FYP, i.e., 2006-07), most of the selected states experience increasing gap in IPC and IPU. The states in western region have very high percentage gaps. Undivided Bihar (Bihar+ Jharkhand) has high percentage gap among the eastern states. Tamil Nadu has done a commendable job in utilizing the entire created irrigation potential in that it has very small gap both in terms of absolute and percentage values. It has created all its estimated Ultimate Irrigation Potential (UIP) long back.

Assessing the state-wise gap between IPC and IPU in MI was a bit difficult in that there was data discrepancy between data obtained from different sources (such as CWC reports and Ministry of Water Resources' reports). To overcome that, we considered MI census data and used linear interpolation to find IPC and IPU figures for the years in between surveys. For the selected states, gaps are actually declining, at least since the end of 9th FYP (2006-07) for MI- Punjab, Gujarat and undivided Uttar Pradesh (UP+ Uttarakhand) being the exceptions. In Punjab, the gap is increasing but the actual percentage gap is low.

For the **second objective**, to find out the costs of IPC and IPU, we considered the CWC publication "Financial Aspects of Irrigation Projects in India" and Reserve Bank of India (RBI) State Budget Finances. There are two types of costs involved in an irrigation project, namely, Capital Costs and Operation and Maintenance Cost (or, Working Expenses). While the former is a stock concept, the latter is a flow concept. So, the procedures to calculate per hectare costs for these two are different.

For calculating per hectare Capital Costs using CWC data, we look at the yearly expenditures during 2002-03 through to 2013-14, convert them to 2017-18 prices using an all India wholesale price index (WPI), collate these expenditures and divide them by the total irrigation potential created and utilised during that period. Our analysis is limited upto 2013-14 here, as there is no proper information on state-wise IPC and IPU after 2013-14 in public domain. To have a broad idea about what is the situation after 2013-14, we have considered expenditure data from RBI state budget finances (for 2002-03 to 2017-18) and converted them to 2017-18 prices like before. Ministry of Water Resources has created an Accelerated Irrigation Benefit Programme (AIBP)

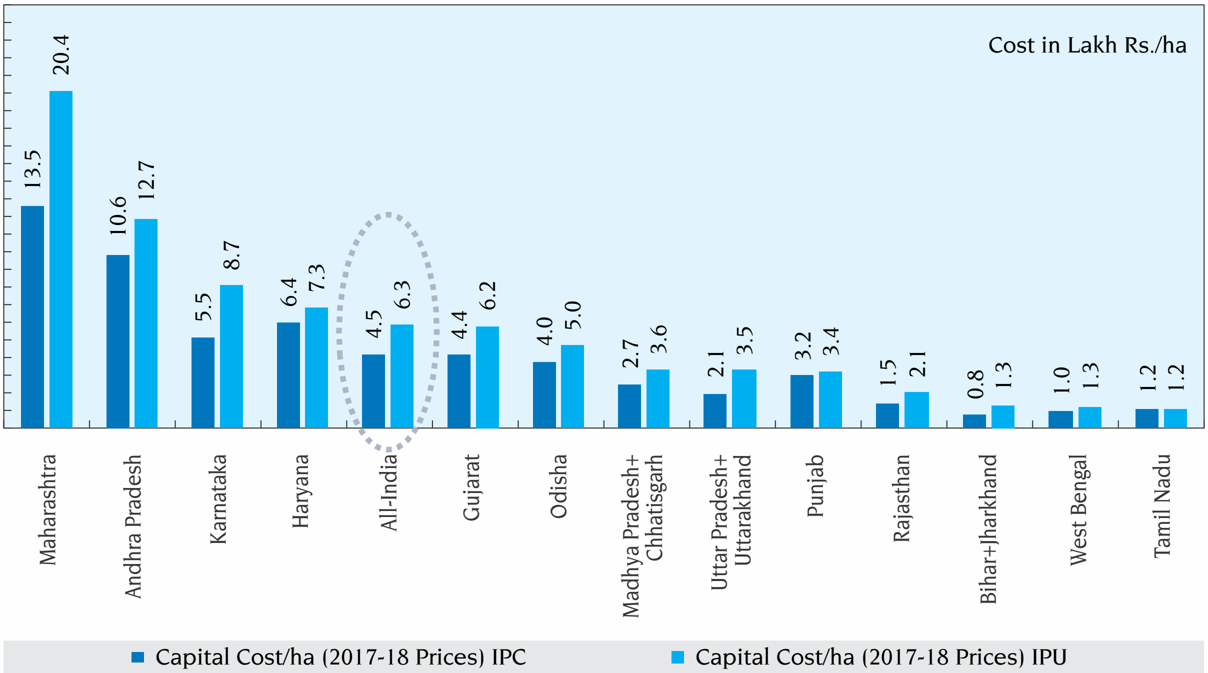
Dashboard where the status of 99 priority projects under the scheme is updated. We considered IPC mentioned there as the progress after 2013-14, add that to the IPC upto 2013-14 and divide the total expenditure by total cost to find out per ha cost for the elongated period. We find that, in both the cases, Maharashtra has the highest per ha cost (Rs 20.4 lakh/ha of IPU following the first method) and that is more than 3 times higher than the All-India average (Rs 6.3 lakh/ha following the first method). However, the cost following the second method is bound to be overestimated to some extent, since it considers IPC after 2013-14 as only IPC through 99 priority projects (due to absence of consolidated data on IPC and IPU from CWC after 2013-14).

For calculating per ha working expenses, we first collate the cost figures from CWC from 2002-03 to 2013-14, convert them to 2017-18 prices using all-India WPI. We then divide expenditure for each year by the cumulative IPC and IPU till that year (since working expenses are used towards maintaining the whole IPC/IPU upto that point to find expenditure per ha for each year). Average of those figures for the entire period under consideration gives us the average working expenses per ha for that period. Working expenses are, as expected, much lower than capital costs (Fig. 2 and 3). For an all-India level, average working expenses per ha of IPC and IPU for the period under consideration were around 1 per cent of capital costs per ha.

For the third objective, we have selected six representative irrigation projects from the '99 priority projects' under AIBP announced in 2016 which are targeted to be completed by December 2019. The selected projects are: Sardar Sarovar (Gujarat), Indira Sagar (Madhya Pradesh), Gosikhurd and Krishna-Koyna Lift (Maharashtra), Saryu Nahar (Uttar Pradesh) and Polavaram (Andhra Pradesh). All these projects started several decades back and were not completed at the time of their inclusion in priority status. Sardar Sarovar and Polavaram are two projects which were conceptualised 60-70 years ago. Others also have not been completed in more than 30 years of conceptualization/approval/foundation laying. All of these together are supposed to create around 3 million hectare (Mha) of irrigation potential. Since they are ongoing for long, there have been considerable cost escalations for each of these projects. Our analysis shows that the cost over-runs for the six analyzed projects varied from 2.2 times to 40.1 times. Unfortunately, potential created was very small or negligible in some cases even after more than 20 years of their start. In case of Sardar Sarovar, for example, only 27 percent of the targeted potential was created after 50 years of its inauguration. In terms of potential creation, all six of them have now picked up some pace. However, there is still little or no information available as to how much On-Farm Development (OFD) work has been completed. That is, it is still mostly unknown as to how much of the potential created is actually being used by the farmers.

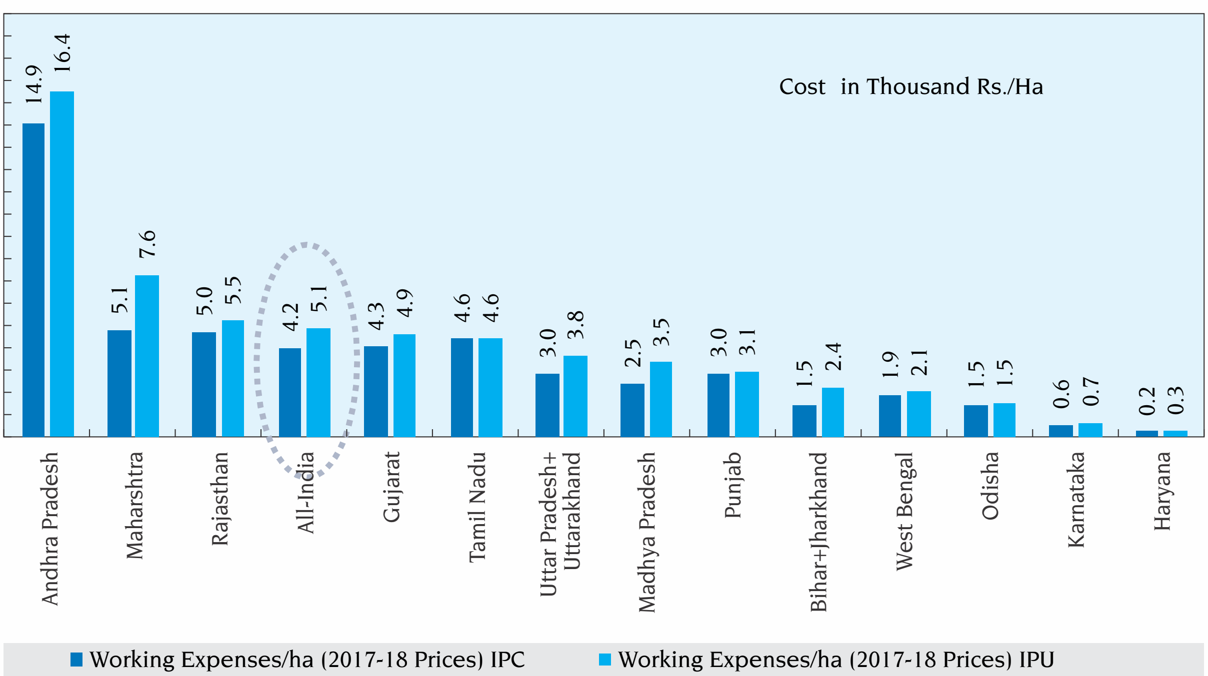
A later section of this chapter also discusses in detail possible reasons behind this IPC-IPU gap. The infamous gap arises due to incongruity in the definition and understanding of IPC and IPU and inconsistency in available data from different official sources on one hand and inordinately long periods for completion of the main system, delay/ deferment in equipping the command area for 'actual access' to the water resource, changes in cropping systems and the amount of applied irrigation in the *ex-post* scenario as compared to the *ex-ante* estimation, inefficient public delivery system and lack of participatory irrigation management system in the commands on the other.

Figure 2: Capital cost per hectare of irrigation potential created and utilized: selected states (2002-03 to 2013-14)



Source: Authors' calculation based on data from CWC

Figure 3: Working expenses per hectare of irrigation potential created and utilized: selected states (2002-03 to 2013-14)



Source: Authors' calculation based on data from CWC

Way Forward

In this section, we present a glimpse of our main recommendations for addressing the challenges in two of the India's major irrigation sources.

Main Recommendations for Addressing Groundwater Challenges

1. *Price reforms in power sector*

Electricity subsidy has been one of the major causes of groundwater overexploitation particularly in states where groundwater structures are majorly powered by electricity. States like Punjab and Tamil Nadu supply free electricity to agriculture. No wonder they also report very high percent of over exploited groundwater blocks. Power needs to be priced at its full cost of production. Synchronising power supplies to the seasonal crop water demands, incorporating the scarcity value of the resource in the state, will encourage farmers to use the resource more judiciously and sustainably.

2. *Direct Benefit Transfer* (DBT) *of power subsidy*

Direct Benefit Transfer (DBT) of electric subsidy to farmers' accounts is one alternate solution where in the resource is priced at its full cost but at the same time farmers are supported directly through an income policy approach rather than the traditional price policy approach. This is expected to change farmers' behaviour and use power only when needed. Through this rational use of power, they can save money, and in the process also save groundwater. In Punjab a similar policy was notified on 14th June, 2018 under the name "*Paani Bachao Paise Kamao*". This pilot was initiated in six electricity feeders across three districts, and supported by the World Bank. Encouraged by the early findings, the number of feeders being covered under the scheme in Punjab has increased to 250 now, and it is also expected to be launched in Rajasthan. Hopefully, such a policy will enable farmers to realise the scarcity value of the resource and encourage them not only to judiciously use the resource but also to realign their cropping patterns in tune with the availability of the resource.

4. *Identification and adoption of sustainable groundwater use and water saving practices*

Several demand side and supply side best management practices have been discussed in the paper. Some of the effective demand side practices include *Jyotir Gram Yojana* of electric feeder segregation for agriculture and household power supplies in Gujarat, *community management* of groundwater resource in Andhra Pradesh and regulation for delayed transplanting of paddy, and DBT *scheme* in Punjab which are emerging effective alternatives in realising better use of power in groundwater extraction. Adoption of micro irrigation structures at the delivery point of groundwater structures can help to improve application efficiency of the irrigation system and thereby reduce water use in crop cultivation. For developing groundwater irrigation in eastern states where the potential for groundwater use is much higher than the present utilisation, mainly because of low electricity access and high diesel cost, rural electrification and solar irrigation can emerge as a suitable option. The depth and efficiency of markets and price support in the eastern region also need considerable improvement. Artificial recharge of the aquifers and rain water harvesting is yet another option to address the sustainable management of groundwater resource from the supply side. Financial institutions like NABARD can contribute in providing the necessary monetary support in scaling up these best management practices after analysing their economic feasibility and hydrological suitability.

For enhancing community participation in water conservation measures, there is a need to initiate mass awareness programmes like NABARD's "water campaign" for farmers and other stakeholders at village level.

Main Recommendations to Address IPC-IPU Gap

1. *Accelerating* AIBP *and* CAD

Even though pace of the completion of the '99 prioritized projects' has picked up, the current status of many of these makes one question whether the goal of completing all of them by December 2019 is really achievable. As per our analysis and tracking of the progress of these 99 projects, this goal of their completion by December 2019 does not seem feasible. Even to complete them by say 2020 or 2021, the speed of work needs to be further accelerated- not only in terms of completing the primary and secondary canals, but also ensuring that enough field channels are created so that water is actually being delivered to the end users. There are some good examples of innovative and concerted efforts from governments of Madhya Pradesh, Gujarat and Telangana to rejuvenate the irrigation departments which other states can follow.

2. U*nderground pipe line and canal based micro irrigation*

One of the reasons behind the slow pace of CAD is farmers' unwillingness to give up land for field channel creation as most of them have small and marginal land holdings. Underground pipe line (UGPL) for water distribution can help to address that problem. As mentioned earlier, the average cost of field channel creation is about half than using this UGPL, but keeping in mind the higher efficiency, long term benefits and also chance of bypassing one of the main reasons of delay in CAD, government could consider scaling-up this innovative water-conveyance and conservation technique for the suitable geographies, subject to favourable cost calculations in relation to potential benefits. A robust Benefit-Cost analysis by third party is therefore critical for such schemes before considering their scaling up. The system can be further coupled with micro-irrigation systems for improved land and water productivity and crop diversification.

3. *Priority to address the underprivileged geographies*

In eastern India, much of population is poor, most of the diesel-based irrigation is costly, irrigation needs are small but critical and cost of irrigation creation is low. Enhancing irrigation coverage in this region shall also reduce food security pressure from the depleted aquifers of northwestern region. Such a prioritized program of irrigation, both canal based as well as solar based groundwater extraction, is likely to harness quick and cost-effective benefits for the large but under-privileged population and help in ushering the Second Green Revolution for the eastern region

4. M*ake aggressive use of* ICT *in developing a modern and responsive irrigation system*

Absence or lack of communication between the irrigation department and the farmers and other stakeholders is a serious constraint in efficient management of the irrigation service delivery. Enhanced adoption of ICT is suggested to ensure accuracy in data estimation and make the irrigation bureaucracy and field staff responsive to the needs of the farmers.

5. U*nshackle the* I*rrigation* S*ector- Transform it as* P*ublic* G*ood* I*nfrastructure*

Irrigation service like all the other public welfare services of roads, electricity, telecom, railways need to be managed efficiently and professionally, especially when most of the beneficiaries are poor farmers. Whereas, government has introduced professionalism and reasonable

efficiency in all the other service sectors, only irrigation has been left behind and still used as a popular political tool. It is true that the nature and characteristics of the resource and objectives of providing access to this resource are different from other sectors, but the ultimate objective is to provide maximum benefits to the maximum number of users. To that goal, creation of a modern, responsive, efficient and economically viable "N*ational* I*rrigation* A*uthority of* I*ndia* (NIAI)" is suggested which will be responsible for construction, maintenance, operations and management of the major and medium irrigation and flood control projects in active consultation and collaboration with the states and other relevant stakeholders, especially large private sector entities. Such an NIAI can be a catalyst of change in bringing resources and competition from the private sector as was done in case of airlines or telecom industry or building and operating airports, national highways, etc. It is time to think out of the box, bring in some principles from other sectors, unleashing investments, better management, and providing best possible irrigation services to farmers at affordable costs.

WATER SITUATION IN INDIA: A SNAPSHOT

Introduction

Water is an important sector in its own right, but at the same time water is a part of almost any conceivable economic sector as well as the lifeline of ecosystems and the planet's life supporting system. The world's water resources are increasingly under pressure. As per assessment of the United Nations (2017, 2019) among almost 7.7 billion residents of this world in 2019, more than 2 billion live in such countries which are going through severe water stress situations. One out of nine persons in today's world lack access to safe water. And by 2050, at least one out of four persons in the world is likely to reside in a country with chronic or recurring water shortages. The situation will get only worse as the demand for water accelerates because of expansion of global population and increased wealth, urbanization, industrialization and the need to save the environment. Considering the graveness of the situation, UN declared ensuring access to water and sanitation for all as one of its Sustainable Development Goals (SDG). Society is both the cause, beneficiary and victim of this unprecedented global challenge which is more severe for developing, populous and water-stressed countries like India. Still, we plan for development and growth assuming that water will be there when and where it is needed – and that the water sector will simply catch up with the rest of the economy. But the water sector is not catching up. Recent report by the Indian government cautions, " by 2030, the country's water demand is projected to be twice the available supply and the deficit shall cause six per cent loss in the country's GDP; India is facing a national groundwater crisis with 54 per cent of wells declining in water level due to exploitative groundwater use; already 600 million people face high to extreme water stress; 75% of households do not have drinking water on premises and 84% of rural households do not have piped water access (NITI, 2018)". Additionally, water quality situation is even more frightening as Indian cities produce some 40,000 million liters of sewage daily but barely 20% of it is treated. With additional pollution loads from industries, about 70% of the country's water is contaminated- India is currently ranked 120 among 122 countries in Water Quality Index.

Water Resources of India

The water availability of a region or nation is largely determined by the availability from annual precipitation which is modified by the regional hydro-meteorological and geological factors and the development of water infrastructure to ensure water access and water security. With an average rainfall of 1105 mm over an area of 329 Mha, the annual estimated water resources of India are about 3880 BCM. A remarkably stable phenomenon, making its appearance every year without fail, the Indian summer monsoon climate exhibits a rather small year-to-year variation (the standard deviation of the seasonal mean being 10% of the long-term mean), but it has proven to be an extremely challenging system to predict and has large temporal and spatial variation (Goswami and Chakravorty, 2017). Such variation of southwest summer monsoon is likely to further intensify: long periods of no rain and then torrential, record breaking deluges for a few days (as happened in the current season of 2019). Droughts and floods happen within the same region and the same season.

Out of these total water resources of India, the average annual water resource of the 20 major river basins for the study period of 30 years (1985-2015) has been assessed as 1999.20 BCM (Government of India (GoI), 2019). Further, due to topographic and distribution constraints, only about 1122 BCM can be actually utilised-690 BCM through surface water and 432 BCM through groundwater resources. Studies predict that several basins will reach physical water-scarce condition by 2050, where the remaining utilizable water supply cannot be developed further without making a severe impact on the environment and riverine water users downstream. The

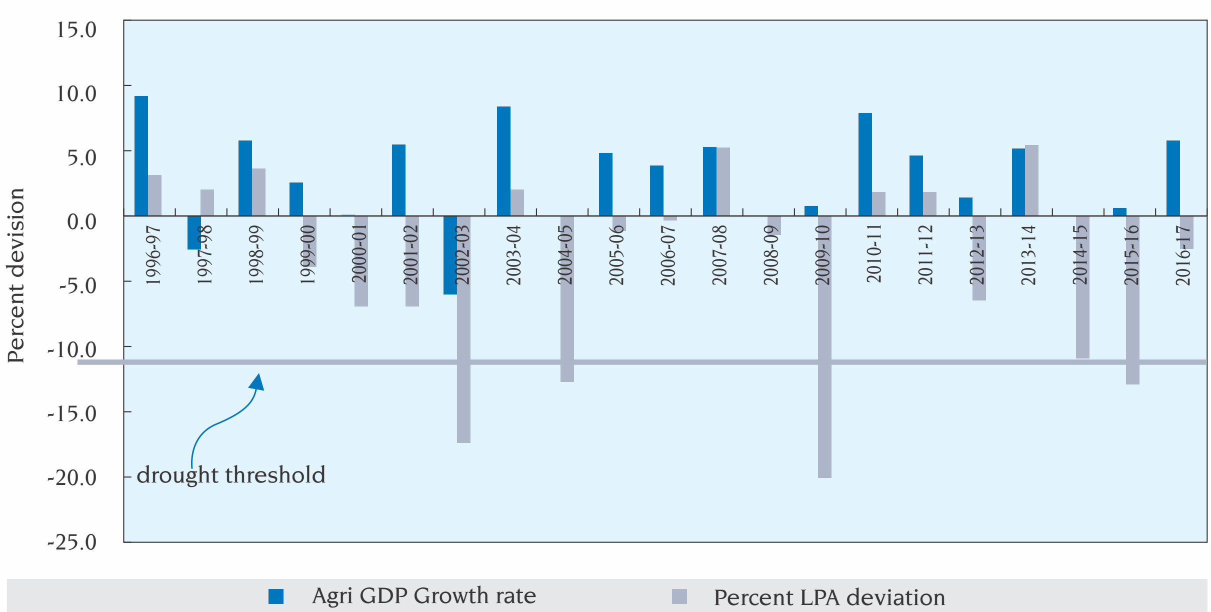
current consumption in the country estimated in 2009 was about 793 BCM. Resilience to seasonal and annual water deficits is largely met through water storages which is an issue of serious concern in India.

Importance of Efficient Use of Water Resources for Agriculture in India

There are three main reasons for which efficient use of water in agriculture in India is crucial. The first one is large dependency of Indian economy and rural population on the Indian monsoon. Indian agriculture remains vulnerable to monsoon shocks and more so for water-insecure and generally poor rainfed farmers. Monsoon rains are vital to the agriculture sector which accounts for 14.4 per cent of the national economy and around 50 per cent of the employment. Econometric modelling shows that agriculture-GDP falls by about 0.35 percent with every 1% fall in long-period average of monsoon rains as evidenced by several recent years of rainfall deficiency and especially the drought years (Fig. 4). Not only the total rainfall, but its proper distribution to coincide with the critical growth stages of the crops is also important for crop production.

The second important factor is the scarcity of water resources. Water demands in India will exceed all sources of supply by 2050. Since 1951, India's per capita water availability decreased from about 5178 cubic meter to 1544 cubic meter (GoI 2017b) in 2011 (Fig. 5). That is, India is moving fast from being water stressed country[1] to water scarce country[2]. Several of the Indian basins like the Indus, Sabarmati, Pennar and Krishna are already 'closed' with little opportunity for further development. Unfortunately, most of the water stress in India is largely due to management crisis and to a lesser extent due to physical scarcity per se as several countries with availability lesser than this threshold have performed better. Thus, the need for developing and managing water resources has assumed tremendous significance in Indian context.

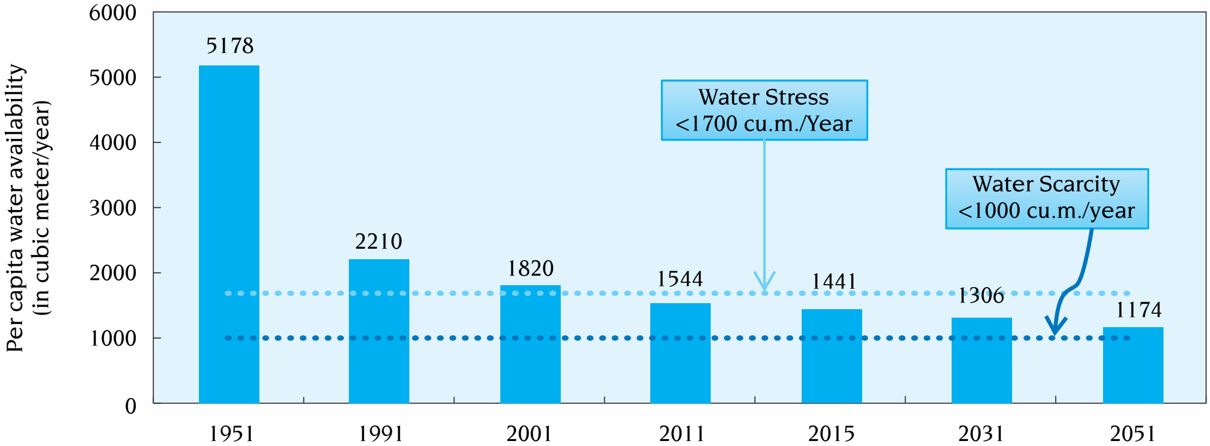
Figure 4: Variation of agri-GDP with percent long-period average Indian Summer Monsoon Rainfall (ISMR) deviation in India



Source: *Authros' calculations based on data from* IMD *and* CSO; *updated from* Saini *and* Gulati, 2014

[1]Per capita water availability less than 1700 cubic meter- Falkenmark et al 1989
[2]Per capita water availability < 1000 cubic meter- Falkenmark et al 1989

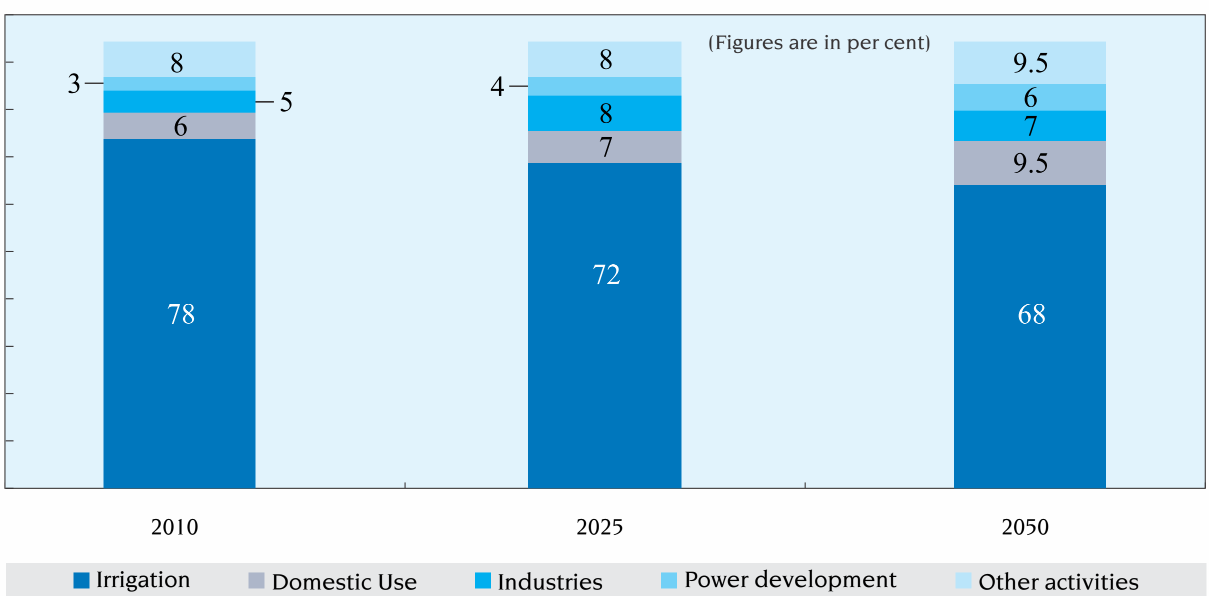
Figure 5: Annual per capita water availability in India



Source: Authors' compilation based on data in GOI 2017b

The third one relates to the fact that India's water demand patterns are fast changing. In 1960, water withdrawal for three most water consuming sectors- agriculture, industry and domestic use was 277 BCM (Shiklamanov, 1977). This has since increased to about 793 BCM in 2009. The Business-as-Usual (BaU) scenario, based on the PODIUMSIM analysis, projects that the total water demand will increase by another 150 BCM, or 22 % by 2025; and a further 69 BCM or 8 % by 2050 (Amarasinghe et al. 2007). Agencies of the Government of India project that water demands shall vary between 694-710 BCM in 2010, 784-843 BCM in 2025 and 973-1180 BCM in 2050, with irrigation accounting for 78, 72 and 68 percent of the total demand, respectively (Fig. 6). The demand for water from non-irrigation sectors will grow rapidly over the next 40 years. The demand for water in the domestic sector will grow 2.6 times, energy 3.7 times, and industry 2.2 times during 2010–50 (Thatte et al. 2009). Hence, it is absolutely necessary to ensure efficient use of water in agriculture and irrigation to increase rural incomes by increasing land and water productivity of crops (Sharma et al., 2018).

Figure 6: Changing patterns of sectoral demand of water in India



Note: Data labels indicate sectoral water demand as a percent of total water demand
Source: GoI 2014, State of Indian Agriculture 2017

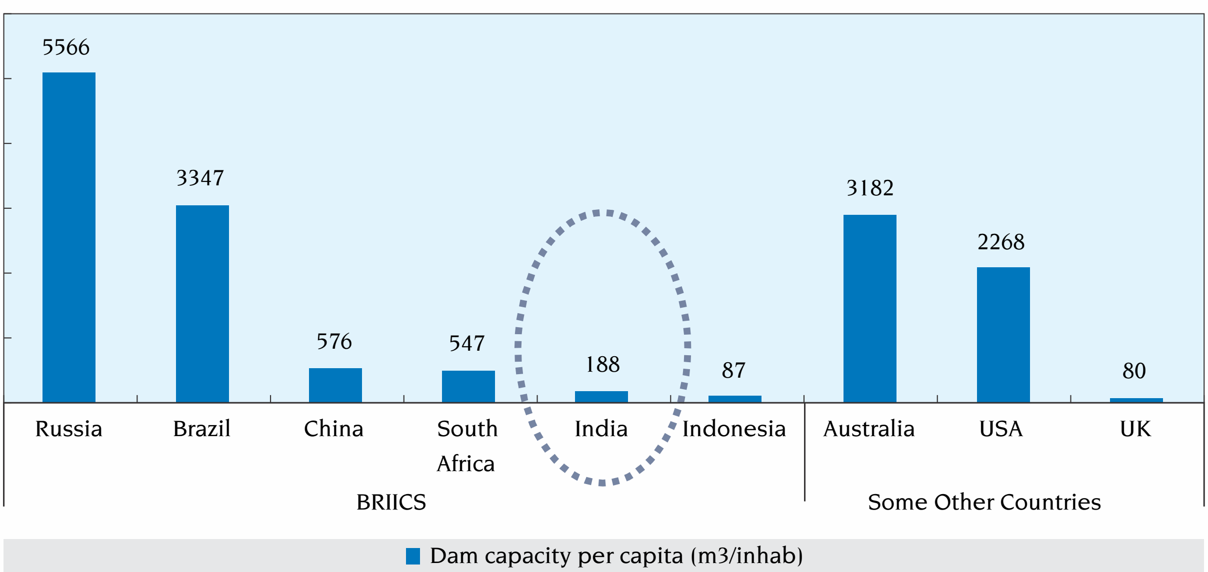
Shrinking Water Resources of India

Besides the changing patterns of Indian monsoon, declining per capita availability and changes in the sectoral allocations of the available water resources, the most worrisome feature is the shrinking of water resources (on per capita basis) of India. The available resources are shrinking quantitatively due to infrastructure adequacies and exploitative extractions and weak policies, regulations and insufficient funds; and qualitatively due to widespread pollution, contamination and decay of rivers, water bodies, wetlands and groundwater resources. The gap is widening at all the three levels- gap between availability and utilization of the resources, gap between potential created and utilized, and gap between demand and supply of the resources. Some of the important concerns include the following:

i. Low and shrinking large water storage

India can be water secure only when it does one thing well- manage its monsoons. Save and store water when in excess, and use the saved surplus water efficiently in the dry season. This means India should have well developed and distributed water storage and distribution system. With large public expenditure and strong government support for the large public surface storage and irrigation during the initial five decades of planned development canal irrigation enjoyed a place of eminence and pride. Later on pace of construction of dams was interrupted by shift in priority, the dispute of settlement issues for displaced people, drying up of multi-lateral funding, environmental concerns and other factors. As a consequence, dam capacity per capita of India became abysmally low. In 2019, India's per capita water storage capacity was 188 cubic meter (m3) as against 576 m3 of China. As compared to other BRIICS countries, India is ahead only of Indonesia (87m3). The others fare much better than India (Fig. 7). Compared to some developed countries, India's per person water storage capacity is much lower than that of Australia (3182m3) or USA (2268m3), but more than UK (80m3). However, comparison with figure 4 shows us that the countries which receive more rainfall have lesser dam capacity per capita in general and vice versa. For example, in case of India and China, India's average rainfall is more than China and China stores more water per capita in its dams. But while India's rainfall is 1.8 times that of China, China's per capital water storage is more than 3 times that of India. That means, India could and should do better in terms of increasing this capacity.

Figure 7: Dam capacity per capita: selected countries



Note: Except for India and China, figures for all other countries are for 2015. India's figures is for 2019 and China's for 2013

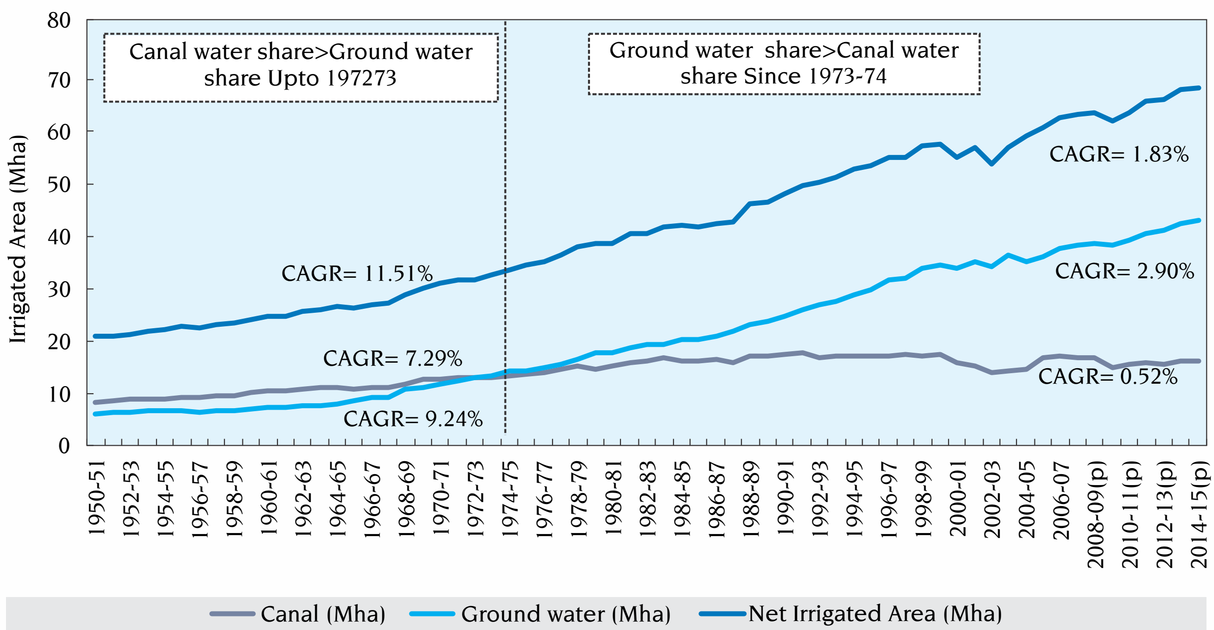
Source: 1. *All except for India: FAO*
2. *For India: CWC; World population Projection 2019, United Nations*

Besides the agricultural distress, bad urban planning has turned the monsoon into a problem for our cities. Monsoon floodwater collects in the city's low lying areas and is supposed to be discharged through drains to the nearby streams, rivers or sea. Generally, these drains are clogged and encroached and as such flooding cannot be avoided. Large urban storage reservoirs and the concept of 'sponge cities- which absorb most of the floodwater' could be the answer. Construction of large urban freshwater reservoirs and recharge structures based on the urban catchment can be a win-win solution. The flooding problem will reduce dramatically and freshwater storage shall help to mitigate the domestic water supply stress which even forced closure of industries and workplaces in large cities like Chennai and Bengaluru.

ii. Shrinking of canal command areas

Up until early 1970s, canal water was the main source of irrigation. However, widespread sub-optimal operations and management, poor maintenance and an unwieldy financial model for the system led to its deterioration and large gap in creation and utilization of the potential. The system was unable to meet the rising aspirations and on-demand supply of water for intensive and diversified agriculture. In spite of the massive public investments, CAGR of canal systems which grew at 7.29 per cent upto 1974-75, shrank to negative and now stands at meagre 0.52 percent for the period upto 2014-15 (Fig. 8). The gap between potential created and utilized for the major and medium systems is large and increasing. Several old and new programs like Command Area Development, creation of Water User Associations (WUAs), Accelerated Irrigation Benefit Program (AIBP) and the much-talked about *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) have not been able to satisfactorily address the maladies of canal irrigation system and the public irrigation systems continue to struggle with poor management, crumbling infrastructure and shrinking command areas.

Figure 8: Status of irrigation in India (1950-51 to 2014-15)



Source: LUS, DES, MoA

iii. Depletion of groundwater resources

Food security and drinking water supplies in India are now critically dependent on its groundwater resources. Presently, 64 per cent of irrigation demand, 85 per cent of rural drinking need and more than 50 per cent of urban water need is met from groundwater. It is estimated that about 9 per cent of India's GDP is directly linked to groundwater. More than 21 million privately owned wells are in operation in agriculture sector alone. CGWB estimates that India's groundwater extraction at 250 BCM is largest in the world- more than a quarter of the global total. The positive impact of this massive resource is that water availability has been improved and spread widely; the supply remains adequate even in drought years as the country largely depends on its aquifers *albeit* with dreadful negative externalities. Cheap pumping and lack of regulation gives farmers an incentive to use groundwater as if there were no tomorrow. Relentless and unplanned extraction of groundwater, often exceeding the recharge, has resulted in irrecoverable damage and depletion of the natural resource. The adverse effects are desaturation of aquifers- manifested in widespread declining of water levels, drying up and failure of wells and diminishing well yields with higher expenditure of energy, deteriorating water quality and elevated concentration of contaminants. The recent Government of India Assessment reveals that about 16 per cent of the total 6,600 assessment units of the country are affected by over-exploitation and are in 'critical'/ 'semi-critical' stage of development. As per NASA GRACE Satellite based study the decadal annual depletion in groundwater resource recorded in North Western India, between January 2003 and December 2012 was 20.4±7.1 km3/year. The more worrying feature is that most of the over-exploited blocks are located in the states of Punjab, Haryana, Rajasthan and western Uttar Pradesh which are the same states which produce surplus food for the country (Fig. 12). The average decline in water table in Punjab in the past six years (2013-18) was 0.37 m per year; the badly hit areas of Central Punjab experienced a fall of 0.49 m per year. The current water deficit in Punjab is 9 BCM/annum.

The situation is further complicated when the state intervention is made through populist energy policies of free or highly subsidized electricity supply for agriculture which provides little incentive for groundwater or energy conservation. These policies along with the exigency of national food security have caused large scale adoption of water-intensive crops like paddy and sugarcane in the regions which are water stressed and prone to groundwater depletion.

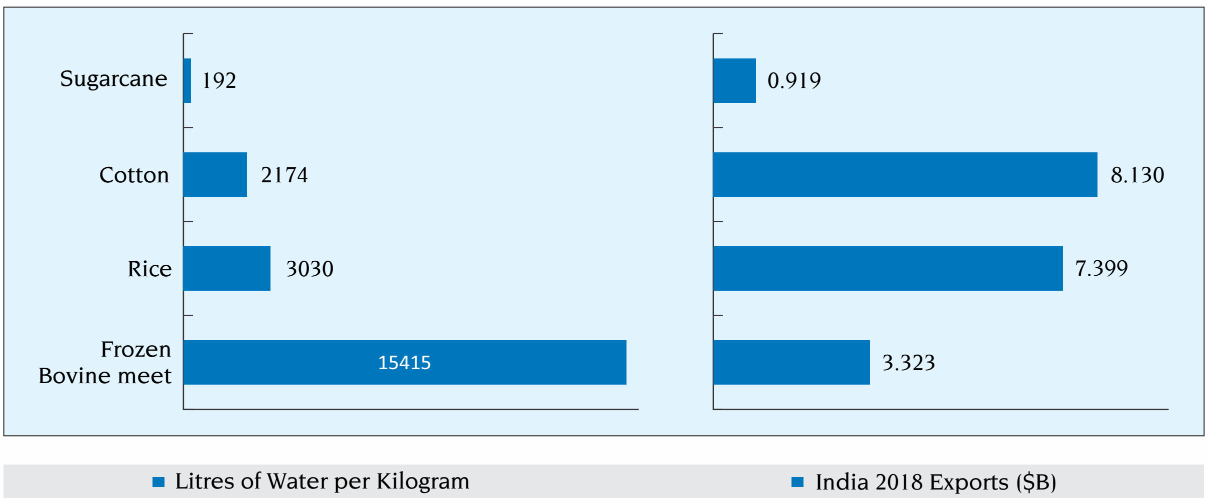
This uneven and unsustainable development of groundwater across the country, especially in agriculturally significant regions, triggering misaligned cropping pattern has large costs for the farmers and the state.

iv. Low water productivity and large export of water-intensive commodities

Out of the 4 per cent share of global freshwater availability, about 78 per cent share of water is consumed by the agriculture sector alone. Further, water-intensive crops of paddy and sugarcane use more than 60 per cent of the irrigation water available in the country and are being cultivated in the most water scarce regions of the country *albeit* with low water productivity. Irrigation water productivity in the most food-surplus states of Punjab and Haryana is abysmally low at 0.22 kg/m3 indicating inefficient use and thus depletion of water resources. Similarly, irrigation water productivity of sugarcane in the sub-tropical belts of Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh is very poor and thus creates water scarcity for other crops and sectors. Taking together all economic sectors of water use, India has one of the lowest values of water productivity – USD 3 per cubic meter of fresh water withdrawal as compared to USD 14 in China, USD 8 in Indonesia, USD 65 in Australia and USD 1493 in Singapore (ADB 2016). Actually, India is cultivating much larger area through extensive use of water to sustain its food security and large agriculture exports.

Recent estimates have shown that India exports more water-intensive goods than any other country in the world. The virtual water exports – the amount of water embedded in exported goods, alongside those rendered unusable by the production of those goods – amount to a net 95.4 billion cubic meters a year (Water Footprint Network, 2019). This makes India a bigger exporter of water than far better-endowed countries such as Brazil, Russia, the U.S. and Canada, and represents nearly four times the 25 billion cubic meters consumed by India's households and industrial enterprises. India's largest agricultural exports of rice, cotton, sugar and buffalo meat require thousands of liters of water for every kilogram of product (Fig. 9). Even if one considers only the consumptive use of water for these commodities, India is virtually exporting large quantities and depleting its domestic water resources. Even within India, the surplus food for the public distribution system is produced in the water scarce regions and transferred to water abundant states leading to water crisis in the donor regions. This mismatch needs to be reversed through appropriate technical measures and trade policies.

Figure 9: India's agricultural exports and liters of water exported per kilogram of the commodity



Source: *National Bank for Agriculture Development, International Trade Centre and Bloomberg Opinion calculations*

v. Water pollution and waste water

Estimates show that out of all the freshwater that is withdrawn, only 44% is actually consumed and remaining 56% with highly deteriorated quality is released to the environment as urban waste water, industrial effluents and agricultural drainage. Water scarcity is caused not only by the physical scarcity of the resource but also by the progressive deterioration of water quality in several basins, reducing the quantity of water that is safe to use. Water pollution is a serious problem in India as almost 70 per cent of its surface water resources and a growing percentage of the groundwater resources are contaminated with biological, organic, inorganic and toxic pollutants (Niti Aayog, 2018). According to a recent assessment by the Central Pollution Control Board of India (CPCB, 2018), there are 351 polluted river stretches in the country (up from 302 in 2015) with 45 of them being critically polluted. Top five states with the most polluted riverine lengths are Maharashtra, Assam, Madhya Pradesh, Gujarat and West Bengal. The estimated polluted riverine length in India is 12,363 km, about 5 times the length of Ganga main stem. Data of total 222 Central Water Commission water quality monitoring sites indicated that water quality at 67 locations (~ 30 percent) is beyond the permissible limit. More than 38,000 million

litres of untreated urban waste water goes into the major rivers, water bodies and even percolates into the ground every day. Over and above this there are massive industrial effluents for which no measurements are in place. The data on the raw sewage from rural areas and volume of polluted waters from agricultural fields and livestock rearing (non-point sources of pollution), which is generally much large as compared to domestic and industrial effluents, is not available. Expansion and intensification of agriculture will further increase the degradation of water resources. The conditions shall become extremely challenging if adequate measures are not put in place through a circular agricultural economy.

These wastewaters can be used for crop irrigation after primary treatment and other requisite safeguards. Non-treatment options for use of wastewater in agriculture include crop restrictions and diversification, appropriate irrigation methods and management, and harvest and post-harvest management of the produce. With proper planning and management, cities can provide assured source of irrigation water for the peri-urban agriculture and city landscaping. Most Indian cities discharge the city wastewaters into natural rivers, streams and *nullahs*. Assuming that 50 per cent of the generated wastewater will be used for irrigation, about 1.4 lakh ha could be irrigated with assured wastewater. Delhi has the largest potential irrigable area of 32,000 ha with assured and perennial source of wastewater irrigation.

vi. Policies, regulations and institutions

There are several policy, regulatory, and institutional issues related to India's water sector. However, the following seem to be really critical ones:

i. *Land Easement Act and water as a common property resource allowing free access to the farmers for owning and pumping any amount of groundwater*: This Act goes back in history (1882), when there were literally no pressures on groundwater. Today, groundwater is depleting fast, and there is need to rethink and change the Act accordingly. Groundwater is essentially a common property resource of a particular region in a particular hydrological set up. For example, if one farmer digs a big tubewell and starts extracting water, s/he can easily tap the groundwater of farmers in neighbouring fields as water will keep flowing to this well. So, some sort of group agreement has to be there to extract water by anyone farmer. The regulatory principles to exploit this common property resource will be different than that of private property. This is the fundamental change that is needed in the law.

ii. *Free and subsidised energy policy*: This competitive populism amongst several states to provide free power for extracting groundwater is one of the primary factors leading to deterioration of groundwater situation in the country. The problem is most serious in Punjab-Haryana belt, which also have assured procurement policies for rice, which is the real water guzzler. Although power pricing is a state subject, the Centre has ample scope to persuade these states not to subsidize power through cheap prices of power, but instead give that subsidy money directly to farmers' accounts and charge full cost of power. The Centre will have to take lead in such reforms, and if some states don't come forward for change, the Centre can always stop procuring rice from districts that are over-exploiting groundwater.

iii. *Free/ minimal tariffs for canal water supplies and lack of efficient system for water supply*: No system can really achieve efficiency in service delivery if it is not charging even its operation and maintenance (O&M) expenses. While capital cost in canal networks is often treated as

sunk cost, it must be imperative on states to charge full cost of O&M. Currently, the departments are not collecting even 20 percent of the O&M expenses of canal networks. No wonder service delivery remains of poor quality, and growth in canal irrigation has slowed down dramatically. A reform council comprising of states and the centre is a must to take up these issues in an earnest manner, and one of the best options is that all these subsidies be given directly to farmers' accounts as income, and then prices of canal water or power for groundwater must be recovered at full cost of O&M.

iv. *Absence of framework and policies for water sharing and water cooperation among the states and neighbouring countries*: Already, many states are on thin ice as far as sharing of river waters is concerned. So far, the approach to settle these inter-state disputes over water sharing has been piece meal. A more comprehensive approach, with water professionals in an inter-state body needs to work on basic principles of water sharing, more on the lines of inter-country river basins. And based on these principles, shares of each state in the water of major rivers be decided for the next 15-20 years, and then again it can be revisited say every 15 years or so.

v. Conditions are not conducive for private sector participation in large rural and domestic water supplies. Introduction of small water enterprises may be an efficient solution to tide over the recurrent crisis. Laws also need to be changed to make it easier for private sector to participate not only in the overall development of this resource, but also in its distribution in a manner that is equitable and can ensure efficient usage. Learnings from other infrastructure sectors like national highways, airports, telecom, etc can be applied to water sector also to make it a vibrant and more productive sector.

It is true that there are other sources and methods of irrigation- including traditional sources like tanks, ponds, springs and other traditional methods. But the majority of area (about 87 percent) is irrigated by these two sources, namely, canal water and groundwater. Though ground water takes up the lion's share of NIA, construction of canals involves a considerable amount of public money. Or, in other words, both of these sources are important in their own way. Needless to say, both of them have their own challenges as well. This report deals with the challenges and ways forward for these two sectors. In Part 1, we discuss the challenges of ground water sector, cost of extraction of ground water as well as best management practices while in Part 2, we look at the main challenge of canal water irrigation- the gap between irrigation potential creation and utilization and the ways to bridge the gap.

It is interesting to note that the new government has shown its sincerity and commitment to address the water resources and management challenges by strengthening the Ministry and rechristening it as "*Jal Shakti*" which will address water problems more comprehensively. However, we must not forget that this is only the beginning of a new era of water conservation and management. We must do much more, and we must do it now. Stepping up action has never been more urgent.

The study is an earnest attempt to look at the problems of groundwater and canal irrigation and suggest way forward for managing both the surface and groundwater resources in such a way so as to increase their efficiency and sustainability- getting more from using less water- in a time when water scarcity is no longer a distant nightmare. It is right there.

PART 1

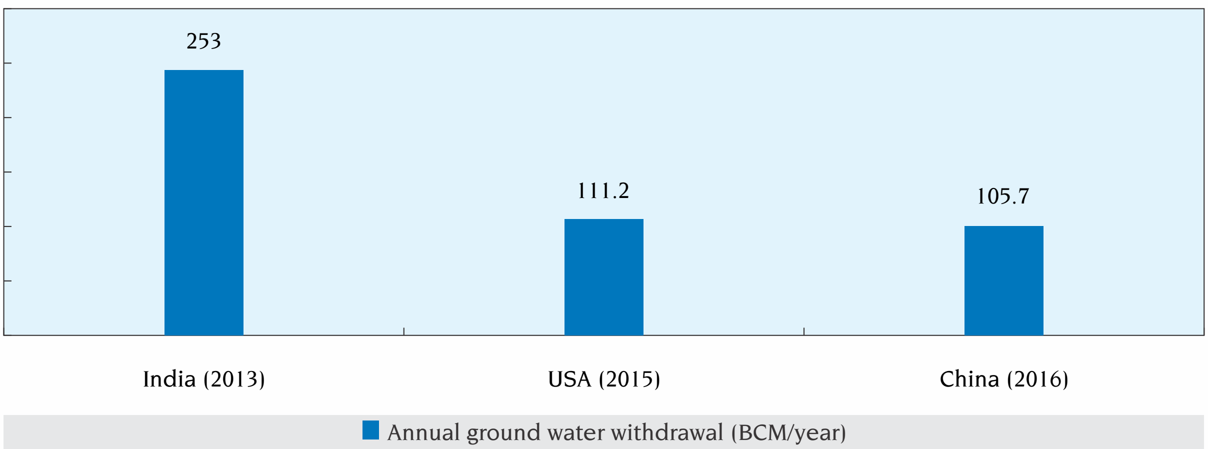
ADDRESSING GROUNDWATER CHALLENGES IN INDIAN AGRICULTURE

ADDRESSING GROUNDWATER CHALLENGES IN INDIAN AGRICULTURE

1.1 Introduction

Groundwater in India is a crucial resource for socio economic development of the country. Globally, India has been identified as the largest groundwater user in the world abstracting about 253 BCM of groundwater per year followed by USA and China (Fig. 10). India shows one of the most diverse hydrogeological framework in the world both in terms of aquifer hydraulic characteristics and groundwater resource availability (Saha et al 2017, Saha and Roy 2018). Almost 64 per cent of the net irrigated area (68 million hectare) in India receives irrigation water from groundwater sources. Also, 85 percent of rural water supply and 45 per cent of urban water supply are met through ground water resource. With the increasing population and urbanisation, the sectoral pressure on water in general and groundwater in particular is going to increase further in the future.

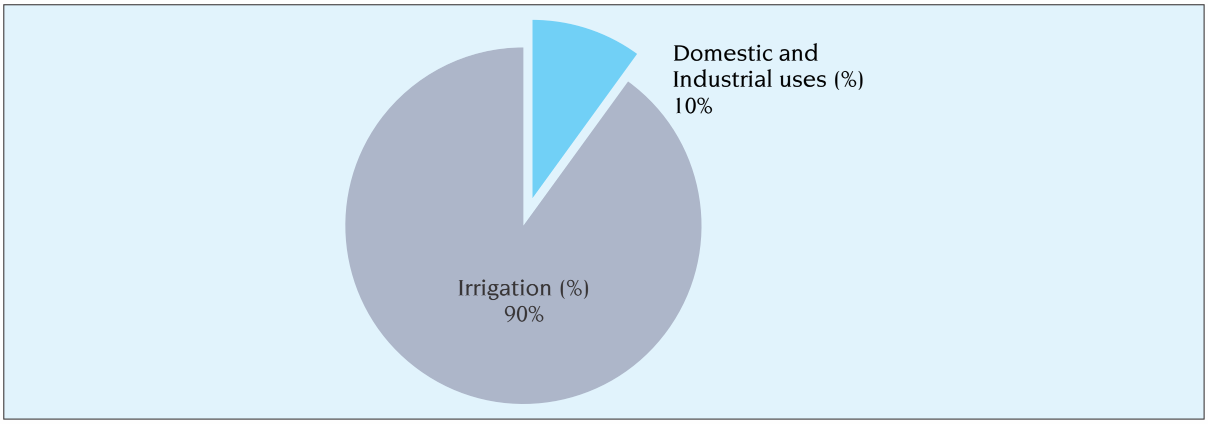
Figure 10: Top three ground water abstracting countries (BCM/year)



Source: *India* (CGWB), USA (USGS), *China* (NBS)

Agriculture is the major user of groundwater resource in India. Major share of groundwater withdrawn is diverted towards irrigation use (90%) and the rest towards domestic and industrial use (Fig. 11). Over the last four decades, the area brought under irrigation has increased at the rate of 1.83 percent. Interestingly in that the area irrigated by groundwater source growing at 2.9 percent annually, while canal irrigated area growing at 0.52 percent only (Fig. 8). The overall inefficiencies existing in the surface irrigation system and availability of subsidized power in agriculture has prompted farmers to shift towards groundwater sources for meeting the irrigation requirements of their crops. But this increase in irrigation coverage in line with increased groundwater use has been at the cost of negative externality associated with groundwater decline and depletion.

Figure 11: Share of annual groundwater draft (%)



Source: CGWB
Note: *Annual ground water withdrawal* = 253 BCM/*year*

An assessment of the future water risks hotspots by OECD identifies India (particularly North West India) as one of the three leading countries most exposed to future water risks along with China (Northern China Province) and USA (Central valley), posing significant negative impact on agriculture production with broader food security and socio- economic consequences (OECD, 2017). As per NASA GRACE Satellite based study the decadal annual depletion in groundwater resource recorded in North Western India - our food bowl, between January 2003 and December 2012 was 20.4±7.1 km^3/year (Chen et.al. 2013)[4]. Similar GRACE satellite based studies in California Central Valley (USA) and Northern China Province revealed the groundwater depletion occurring at 4.8±0.4 km3/year (Famiglietti et.al., 2011, Chen et.al. 2014) and 8.3±1.1 km3/year respectively (between 2003 and 2010) (Feng et.al., 2013, Chen et.al. 2014). Thus compared to the other regions across the world facing critical groundwater exploitation, India tops the list in terms of groundwater depletion risk as well.

The Central Ground Water Board has reported that as on 31st March 2013, almost 16 per cent of the groundwater assessment units in India were under the over exploited category[5] (GoI, 2017a)(Map 1). Fig. 12 displays the status of groundwater development stage across the major states identified in the study. In agrarian states like Punjab, Rajasthan, Haryana, Tamil Nadu and Karnataka with >= 90 per cent of the groundwater draft is consumed by irrigation. The percentage of over exploited blocks also exceeds the national per state average over exploited blocks (Fig. 13). The situation is more distressing in states like Punjab, Rajasthan, Delhi and Haryana where the percentage of over-exploited blocks has exceeded in 50 percent of total blocks (Fig. 14). Unlike the extensive urban groundwater extraction in Delhi, the reason for groundwater over exploitation in the other three states is mainly due to irrigation draft.[6]

A recent study by Bhanja et.al., 2017 has brought some solace as the researchers have come up with the observation that in Gujarat and Andhra Pradesh the groundwater has been replenishing at the rate of 2.04 ± 0.20 km3/year (in 2002–2014) and 0.76 ± 0.08 km3/year (in 2003–2014)

[3]GRACE = The Gravity Recovery and Climate Experiment (GRACE) was a joint mission of NASA (The National Aeronautics and Space Administration) and the German Aerospace Center which was started in March 2002 and ended in October 2017.

[4]As per the estimate given by Matt Rodell, Groundwater continues to be depleted in the Indian states of Rajasthan, Punjab, and Haryana by about 16.0 km 3 / yr, reduced slightly from previous (2002-08) estimate of 17.7 ±4.5 km 3/yr (Rodelletal 2009). China records a depletion rate of 4.9 km3/year.

Source: http://www.worldbank.org/content/dam/Worldbank/Feature%20Story/SDN/Water/events/AWP/AWP2014-Session-5-Estimates-Groundwater-Depletion-MatthewRodell-Dec9.pdf

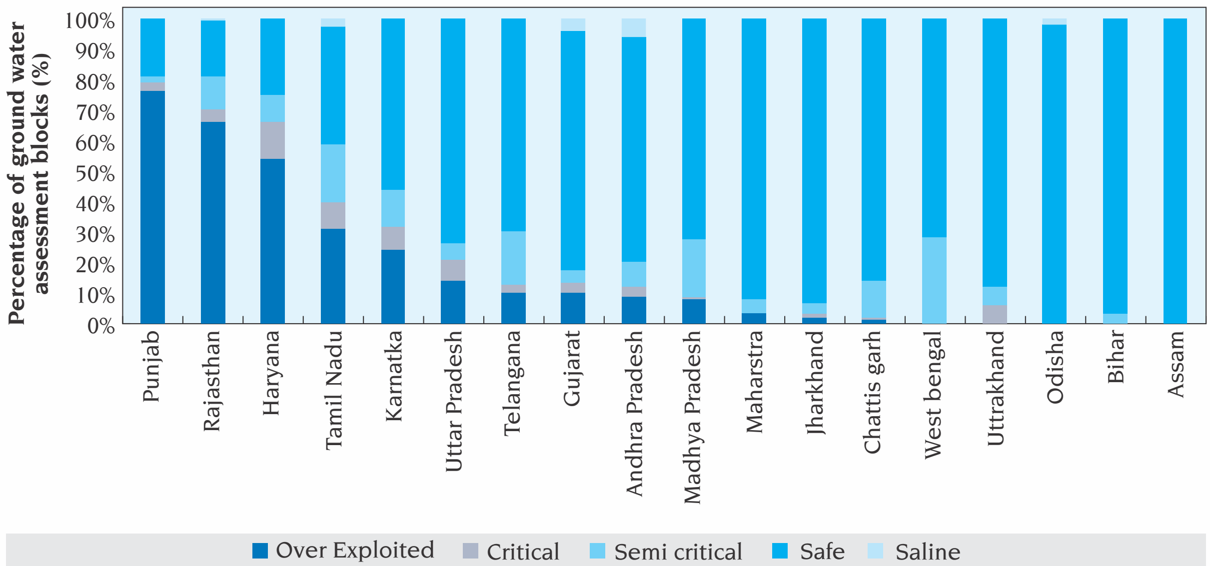
[5]Over exploited : For overexploited administrative units, stage of groundwater development is more than 100 per cent. Source: Report of the Working Group on "Ground Water Management and Ownership", Planning Commission, 2007.

[6]Groundwater development

compared to the depleting trend of −5.81 ± 0.38 km3/year (in 1996–2001) and −0.92 ± 0.12 km3/year (in 1996–2002) respectively. Policy driven factors were responsible for such positive trends in these study areas, which will be discussed in detail later in the paper.

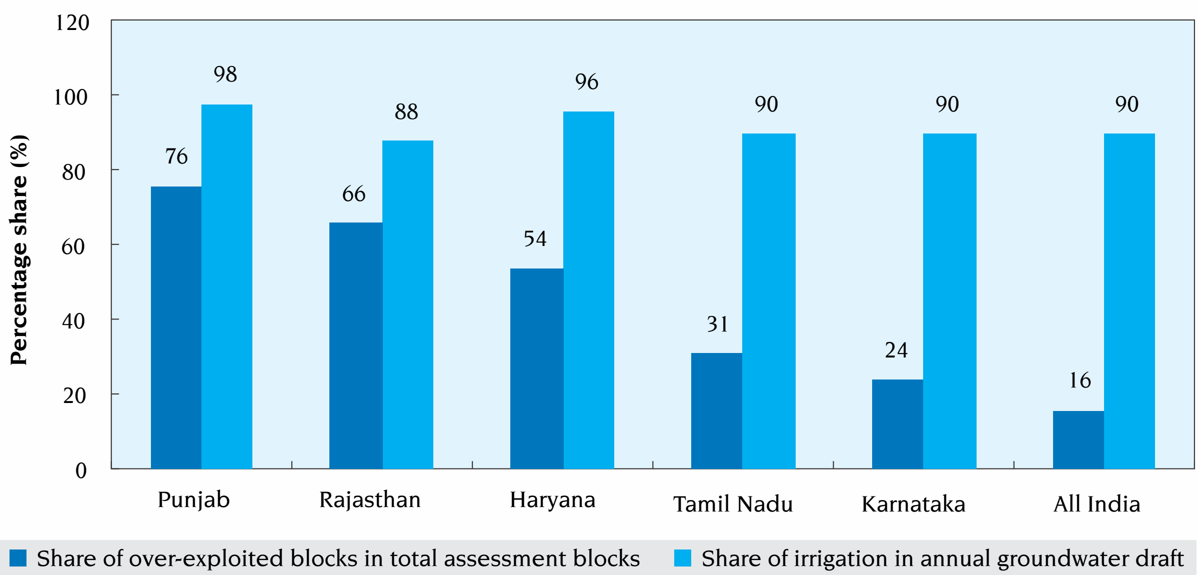
In our study, we aim at formulating suitable demand side and supply side policies to promote sustainable groundwater development in the country by addressing the groundwater challenges in agriculture sector, the major groundwater gulper in India. We intend to achieve this by evaluating the economic feasibility and hydrological suitability of groundwater irrigation practiced across the major cropped areas and learning from the best sustainable groundwater management practices followed across globe and within the country.

Figure 12: Status of groundwater development stage in selected states (2013)



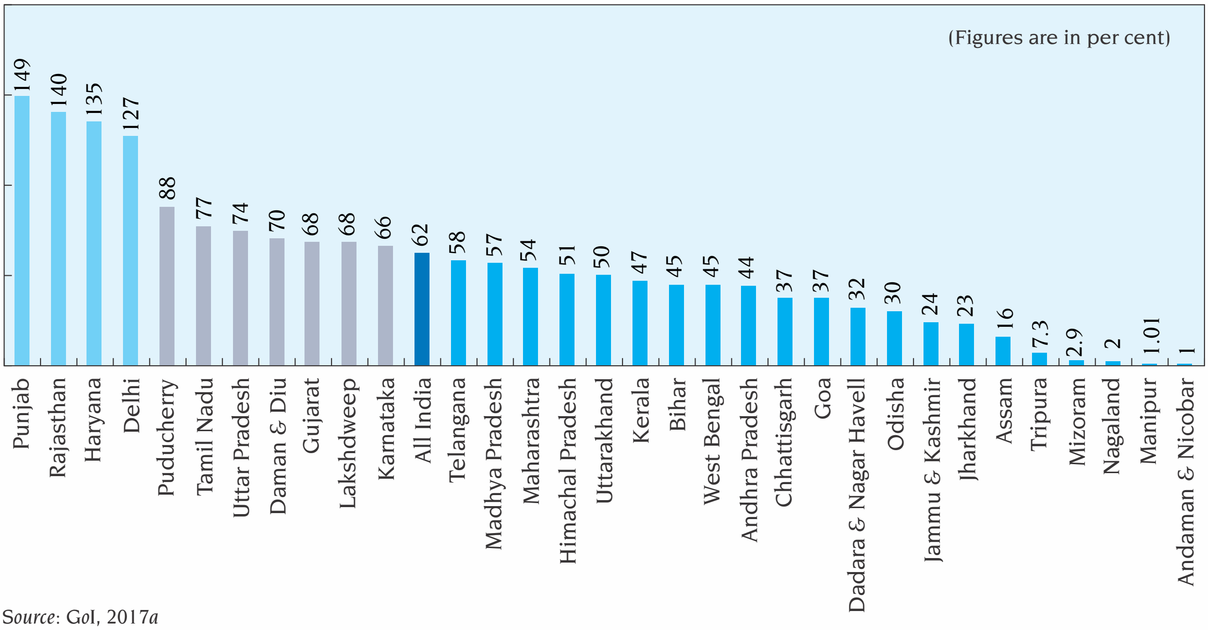
Source: GoI, 2017a; *Planning commission*
Note: *It is assumed that only 70% of the total agriculture power subsidy is diverted for farm use, remaining 30% gets diverted for farm household use.*

Figure 13: Distressing groundwater situation in major agrarian states in India (2013)



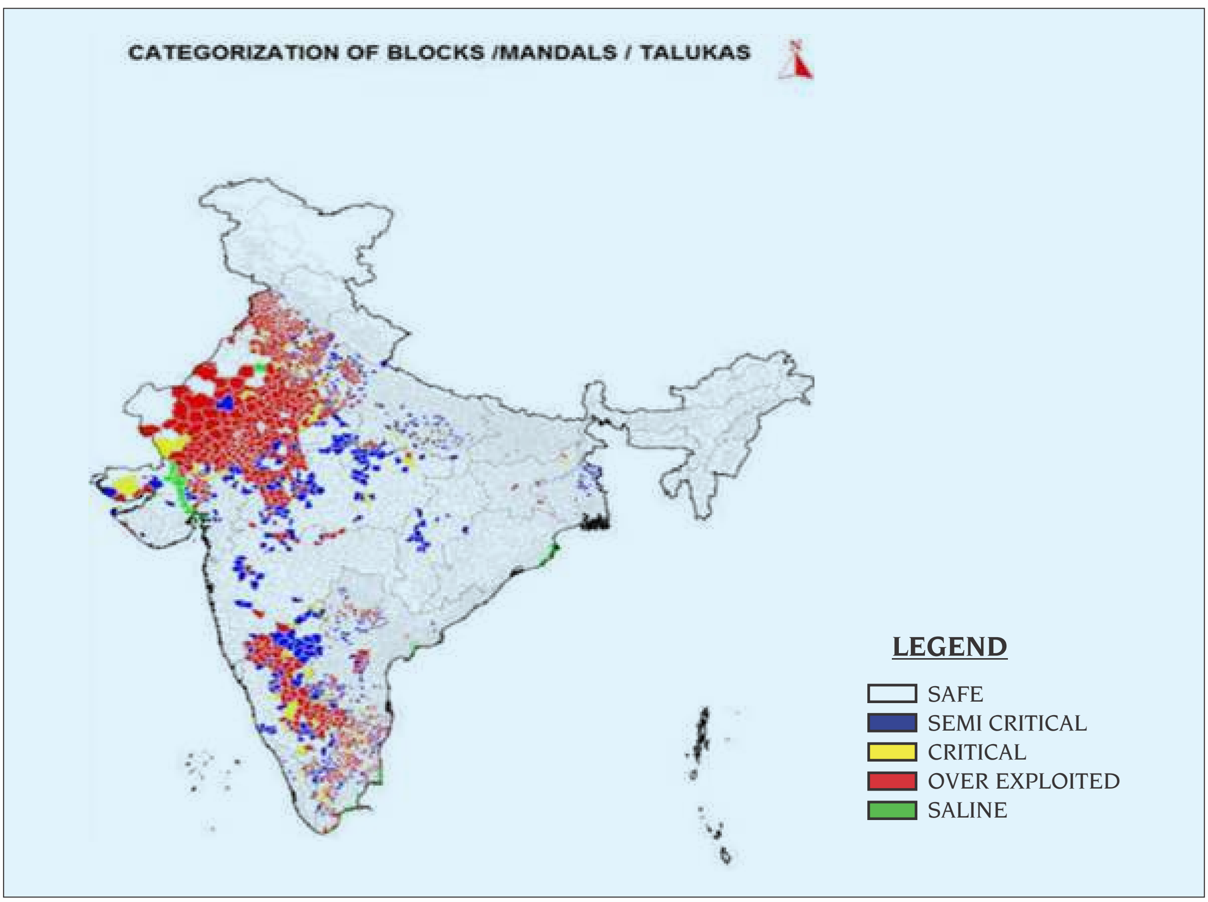
Source: GoI, 2017a

Figure 14: State-wise status of groundwater development stage (2013)



Source: GoI, 2017*a*

Map 1: Spatial status of groundwater development stage in India (As on March 2013)



Source: CGWB

1.2 Status of groundwater use in India

The issues associated with groundwater irrigation in India can be broadly grouped into three categories based on the regional hydrological status.

- In the north-western regions of India, including Punjab, Haryana and Western UP, the over-exploitation of the replenishable groundwater resource is the major issue. In India, about 16 percent of the administrative blocks assessed by CGWB come under the overexploited category (where groundwater draft is more than the availability) and it goes to as high as 76 percent in Punjab and 54 percent in Haryana.
- In western parts of the country, mainly in parts of Rajasthan and Gujarat, due to scanty rainfall and arid climate, the groundwater recharge is limited adding stress on the already overexploited groundwater resource.
- In the southern peninsular region comprising of Karnataka, Andhra Pradesh, Telangana and Tamil Nadu, due to poor water holding capacity of aquifer, groundwater availability is low.

1.2.1 Energy usage for groundwater extraction

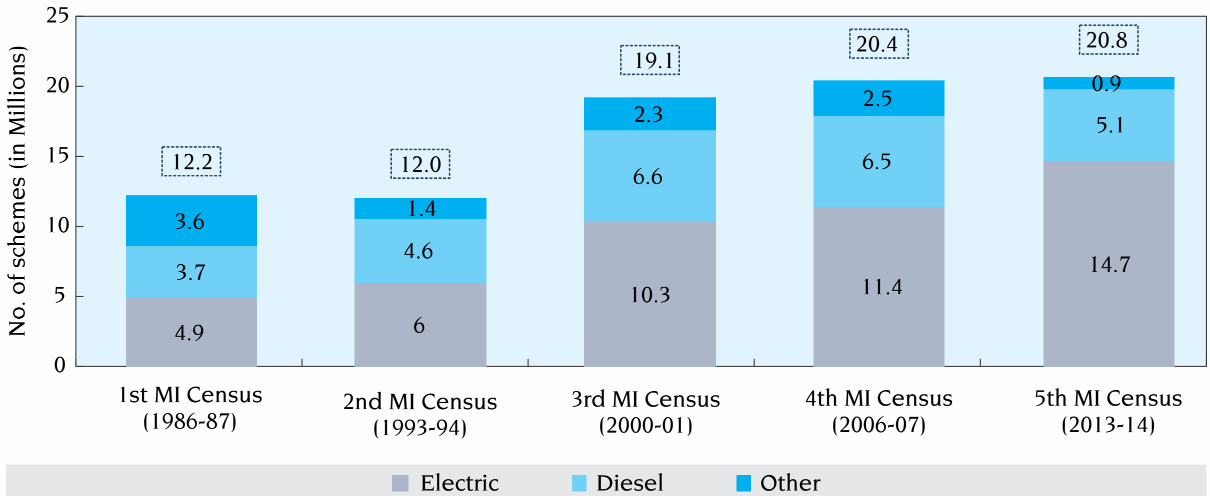
Ministry of water Resources in India conducts Minor Irrigation (MI) census in certain intervals which enumerates, among other things, the number of minor irrigation schemes using different energy sources. The first census was done in 1986-87 and was followed by four others in 1993-94 (2nd MI Census), in 2000-01 (3rd MI Census), in 2006-07 (4th MI Census) and in 2013-14 (5th MI Census). Over the course of time, there was significant improvement in the number of total MI schemes (ground and surface lift taken together) only in between the 2nd and the 3rd MI census- it increased from 12 million to 20.4 million in 7 years. Since the 3rd MI census in 2000-01, the number increased only marginally. The total number of MI schemes stands at 20.8 million in 2013-14- including both ground water and surface lift irrigation (Fig. 15).

Over the last few decades under consideration, noteworthy shift is detected in terms of using energy sources. While during the First MI census only 4.9 million (39.9 per cent) of MI schemes were powered by electricity, by the time of the 5th Census, the number and the percentage observed a jump to 14.7 million and 70.9 percent respectively. It seems that increase in power supply in rural areas along with increasing power subsidies played a crucial role in this shift. Consequently, the use of diesel pumps has declined- share of schemes using diesel pumps declined from 31.7 percent to 24.8 percent over the same period. However, as 5th MI census report points out, use of diesel for minor irrigation has actually undergone a 5 percent increase as compared to the 4th MI census in Eastern Indian Plains. In fact, most of the energy used for minor irrigation in that region (74 percent) comes from diesel. In the latest MI census, we observe that the use of solar energy has also increased[7]- although with respect to use of electricity and diesel that is almost negligible.

Most of the deep tubewells are concentrated in the western plains and peninsular hard rock regions of India due to the low (or free) pricing of power supplied to the agricultural sector. According to the 5th MI census report, availability of electricity has "*...played a key role in substantial increase in number of deep tubewells in Western Indian Plains and Peninsular Hard Rock region facing depletion of ground water level. While low access to electricity in Eastern Plains has led to lower growth of tubewells (shallow, medium and deep) inspite of abundant ground water potential available*." This clearly indicates the need for an immediate policy shift in those regions regarding pricing of electricity for ground water extraction so as to incentivize sustainable use of the resource.

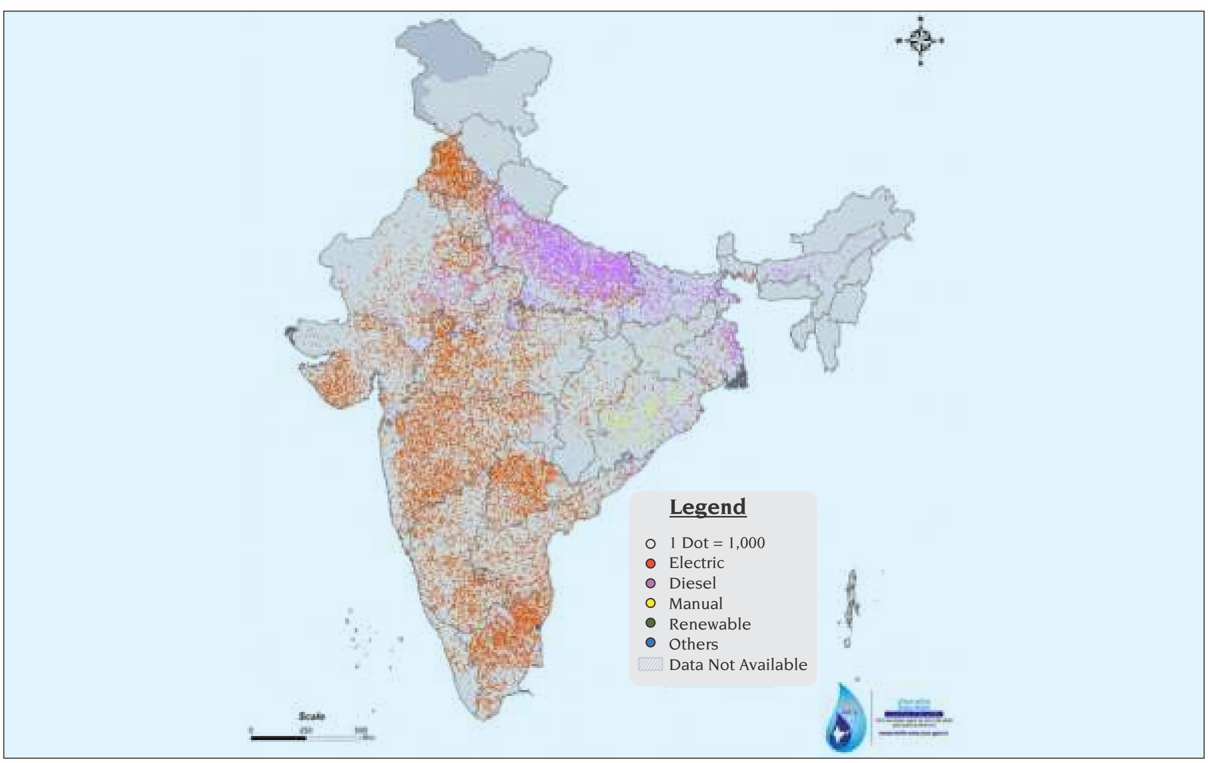
[7]Especially in eastern and western plains

Figure 15: Distribution of MI schemes with respect to energy source



Source: Calculated using data in MI Census tables
Note: 1. The numbers inside bars denote no. of MI Schemes (in million) using that source of energy
2. Numbers above bars denote total number of schemes (in million)

Map 2: Various types of energy usage in MI schemes across the aountry (5th MI Census)



Source: 5th MI Census Report

1.2.2 Grouping of states – Sample design

For understanding the status of groundwater use for irrigation in further detail, we have selected 18 major states based on their gross irrigated area status. The list of states selected for the study is given in Table 1. The selected states cumulatively occupy about 98.4 per cent of the gross irrigated area in India for 2013-14 (LUS, DES). Rather than considering the states with high cumulative share in groundwater irrigation, we have used gross irrigated area as a benchmark for the first level of sampling (Fig. 16), so that the irrigation scenario existing in eastern states can also be brought into the picture. The eastern regions mostly possess high potential for groundwater irrigation due to favourable aquifer characteristics and assured groundwater recharge owing to abundant rainfall. However across eastern India, due to the poor and unreliable supply of electricity in agriculture, pumping ground water is a costly affair for the farmers and hence it is left underutilized. In our study we attempt to highlight how groundwater irrigation, if prudently used, will turn out to be a sustainable option for improving agricultural productivity in the eastern region, especially for the water intensive crops. The cumulative share of the 18 selected states in groundwater irrigation in India accounts to 99.7 per cent. The data for share in groundwater irrigation has been taken from the 5th Minor irrigation survey with the reference year of 2013-14, (GoI, 2017e) as the data on gross irrigated area with groundwater irrigation for West Bengal and Odisha was recorded as nil in the land use statistics.

For clear understanding of the issues associated with groundwater availability and utilization, we have further clustered the states into different groups based on the existing variability in the groundwater resource characteristics (Fig. 16). Uttar Pradesh, Rajasthan, Gujarat, Punjab, Karnataka, Haryana, Tamil Nadu are the states where the groundwater use has reached the semi critical stage and above (> 70% stage of groundwater development) at least once in the last four reference period considered (GoI, 2017c). These regions are either in the brim of facing the threat of groundwater over exploitation or are already facing it. Since these states have different aquifer characteristics and recharge possibilities because of varied rainfall, we need to adopt region specific criteria and policies to ward off the groundwater exploitation issue.

Table 1: States selected for the study (Data based on 2013-14)

Sl. No.	States	Share in total Gross Irrigated Area (in %)	Share in total groundwater irrigation of the country (in %)
1	Uttar Pradesh	21.3	26.5
2	Madhya Pradesh	10.4	9.6
3	Rajasthan	10.3	10.1
4	Gujarat	6.2	5.7
5	Punjab	8.0	9.8
6	Karnataka	4.3	3.9
7	Maharashtra	4.8	7.9
8	West Bengal	5.9	2.7
9	Haryana	6.0	5.2
10	Bihar	5.4	5.3
11	Andhra Pradesh	4.3	2.2
12	Tamil Nadu	3.5	5.3
13	Telangana	3.3	2.8
14	Chhattisgarh	1.8	1.1
15	Odisha	1.6	0.4
16	Uttarakhand	0.6	0.6
17	Assam	0.4	0.3
18	Jharkhand	0.3	0.3

Source: *LUS, MoA and 5th Minor Irrigation Census*

Note: *Kerala and Jammu and Kashmir have irrigation share more than some of the states listed here. However the groundwater irrigated area in these two states are 0.1 per cent and 0.02 per cent of the total groundwater irrigation share. Hence they have not been considered in the study.*

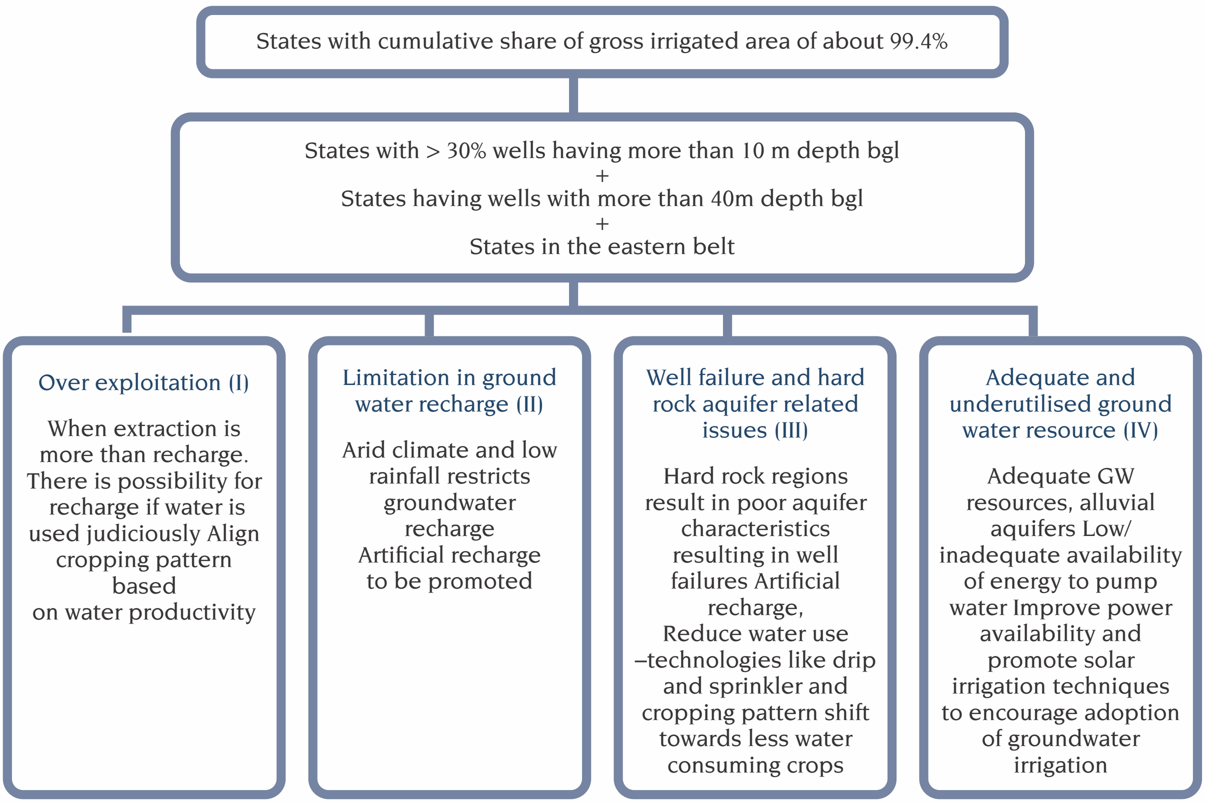
Apart from the stage of groundwater development the depth to water level and its spatial and temporal behaviour reflects upon the groundwater stress existing in the country. Majority of the wells representing the shallow aquifer system in India (43per cent) during pre-monsoon 2017 were characterized with a depth ranging between 5-10 metres below ground level (m bgl) (GoI, 2017c). About 30 per cent of the wells have water level depth more than 10 m bgl. In the north western and western regions majority of the wells have depth in the range of 10 - 40 m bgl or > 40m bgl. Punjab has 54 per cent of its wells at this depth showing the critical ground water over use existing in the region. The maximum depth to water level in India is found in Bikaner district of Rajasthan at 134.2 m bgl. At certain places in private wells in Karnataka and Gujarat, water table depths > 150 m have been reported.

In order to incorporate the criteria of depth to water level while selecting the sample states, we have included the states having either more than 30 per cent wells with depth greater than 10 m

bgl or having wells with more than 40 m depth bgl or both. The 18 selected states adhere to these criteria as well.

As per the Minor Irrigation survey, the numbers of deep tube wells that operate at a depth of 70 m and above have grown exponentially since 1987 from 0.1 million to 2.6 million in 2013-14. Most of these deep tube wells are located in the north western, western and peninsular regions of the country which are also the regions of severe groundwater exploitation (Rajan & Verma, 2017).

Figure 16: Sample design for selecting states for the study



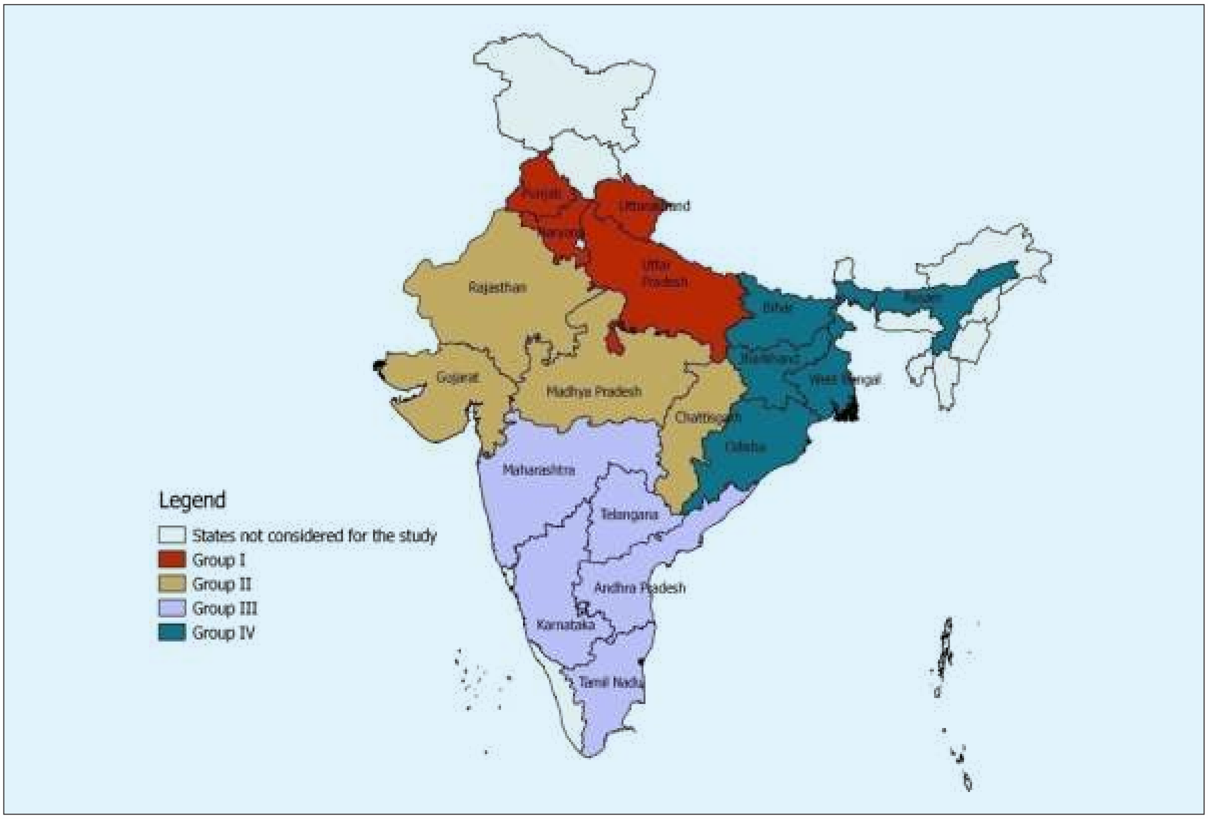
1.2.2 Grouping of states and broad groundwater status existing across the groups

We have categorized the 18 states into 4 categories considering the aquifer characteristics and existing groundwater depletion scenario (Map 3). Though groundwater and aquifer characteristics are not restricted within a state's boundary with overlapping occurring across the neighbouring states, yet considering the ease of policy framing and implementation, we have assumed state boundaries to study the groundwater scenario across the country. A brief description about the groundwater scenario existing across the groups is given in the following subsections.

Group I/ Region I includes the states which are bestowed with good replenishable groundwater resource availability, but yet are facing the threat of over exploitation. The north western regions and western parts of India comprising of states like Punjab, Haryana, western Uttar Pradesh, parts of Uttarakhand can be categorized into this group. The injudicious rate of groundwater

extraction, especially in Punjab and Haryana, majorly to meet the irrigation requirement of the misaligned cropping pattern, has left these states in a groundwater stressed situation. As a part of ensuring prudent groundwater use, there is a need to look beyond land productivity and concentrate on water productivity while determining the cropping pattern and the crop calendar in the region. For this the policies must aim at making the markets right for the suitable "water smart crops" in the region.

Map 3: Grouping of states based on groundwater characteristics



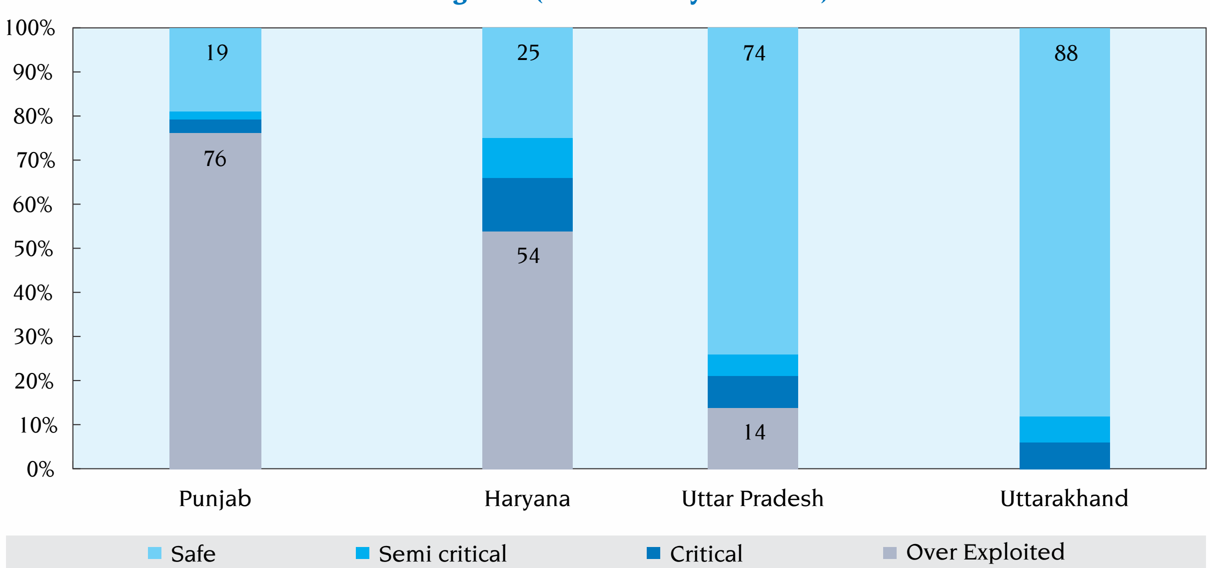
Among the group I states, the average stage of groundwater development in Punjab and Haryana states are a whopping 149 and 135 percent respectively. This indicates that in Punjab the groundwater exploited in the assessment blocks identified by GoI (GoI, 2017a) is 49 per cent more than the net annual recharge to the aquifers, while in Haryana it accounts to 35 per cent. The north western India comprising of primarily Punjab, Haryana (and Delhi) of region I and Rajasthan of region II have been identified globally as one of most critical water risk hot spots. Several national and international organisations have been critically reviewing the situation of groundwater exploitation in the north western India. Rodell et. al. in 2009 reported groundwater depleting at the rate of 4.0 ± 1.0 cm equivalent height of water annually (volumetrically equivalent to 17.7 ± 4.5 km^3 per year) from the north western region (comprising of Rajasthan, Haryana, Punjab and Delhi) of India for reference year between 2002 to 2008. Later Chen et.al, in 2014 reported the new estimate of groundwater depletion rate for the same region as 20.4±7.1 km3/ year for the 10 year period from January 2003 to December 2012. The study also reported that the depletion rate was higher in the initial 5 years (between

2003 and 2007) at 29.4±8.4 km3/year. These values correspond to the loss in the groundwater storage in the country over the years which are irrecoverable and leads to constant decline in groundwater table accelerated by ineffective recharge and unchecked shifting of farmers from surface to groundwater sources for irrigation.

The long term decline in groundwater table of the representative monitoring wells as recorded by the Central Ground Water Board (CGWB) is also used to support the categorisation of the stage of groundwater development of the block. The CGWB classifies a block as critical or over-exploited when there is also more than 0.1-0.2 metre per year decline in a long tern scenario (~10 years). (Sishodia et.al, 2016).In India, about 16 percent of the groundwater blocks assessed come under the over-exploited category (where groundwater draft is more than the groundwater availability) and the percentage of over exploited blocks goes up to 76 percent in Punjab and 54 percent in Haryana (GoI, 2017a) (Fig. 17). The comparison of depth to water level of pre-monsoon 2017 (November to May) to the decadal mean (pre- monsoon 2007 to 2016) (GoI, 2017a), indicates the groundwater levels to be falling for 85 per cent of wells in Punjab, 67 per cent in Haryana, 71 per cent in Uttar Pradesh and 52 per cent of wells in Uttarakhand. Studies have reported incidence of groundwater declining at the rate of 70cm to 120 cm annually in the north western regions (particularly in Punjab) of India (The World Bank, 2010; Jain 2013).

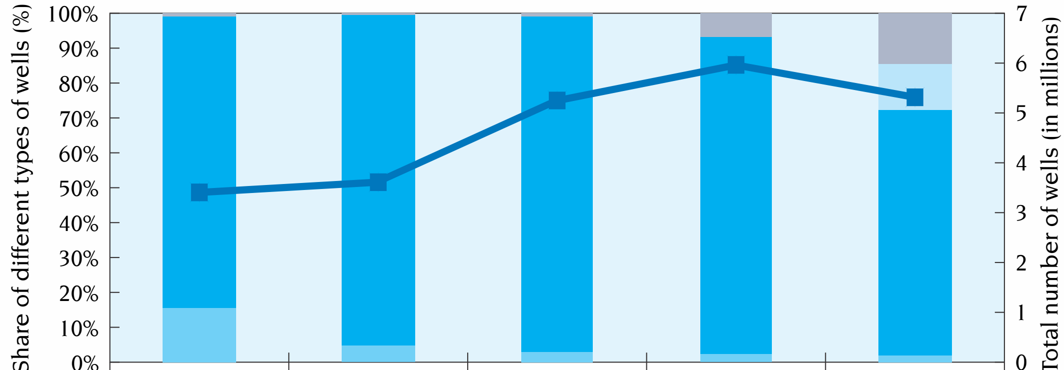
As per the various minor irrigation censuses, the total number of wells in region-I have increased by 1.5 times since the first census ((reference year 1986-87). However the increase in number of deep tube wells (depth >70m) has increased by almost 27 times in the same time period. This is in accordance with decline in water levels with time, prompting the farmers to tap deeper zones. On the contrary the dug wells has decreased from 15.3 per cent in 86-87 to 2.1 per cent in 2013-14.This also indicates the immense pressure on groundwater resource in region I (Fig. 18).

Figure 17: Categorisation of groundwater assessment blocks (% share) across states in Region I (Reference year 2013)



Source: GoI, 2017a

Figure 18: Status of ground water schemes (wells) across the years in Region I

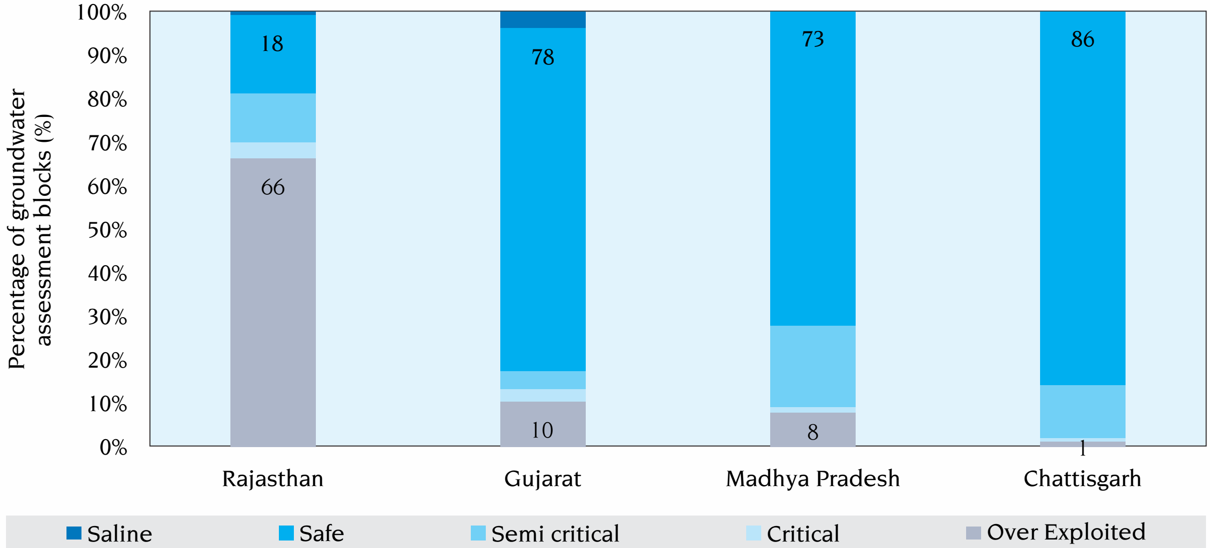


	1986-87	1993-94	2000-01	2006-07	2013-14
Deep TW	0.9	0.6	1.3	7	14.7
Medium TW	0	0	0	0	13.1
Shallow TW	83.9	94.6	95.9	90.9	70.1
Dugwells	15.3	4.8	2.8	2.2	2.1
Total No.of wells (Millions)	3.41	3.62	5.24	5.95	5.3

Source: Minor Irrigation Censuses

Group II/ Region II includes the states like Rajasthan, Gujarat, and Madhya Pradesh which are majorly characterised by limitation in groundwater recharge as well as declining water levels. Owing to the arid climate in large part of the region, natural groundwater recharge is a constraint. Thus artificial recharge needs to be promoted in these states particularly in Rajasthan and Gujarat to reduce stress on the groundwater resources. In Rajasthan the groundwater development stage has reached 140 per cent, while in Gujarat, though the stage of development is recorded as 68 percent a large chunk is overexploited. In Madhya Pradesh and Chhattisgarh the stage has been recorded as 57 per cent and 37 per cent respectively for the year 2013 (Fig. 19). These two states also require to adopt rainwater harvesting as ascending groundwater extraction curves would result in higher stage of development in near future. Though Gujarat, Madhya Pradesh and Chhattisgarh are in safe zone, yet the assessment of fluctuation in depth to water level in pre-monsoon 2017 compared to the decadal average (2007 to 2016) indicates majority of the monitoring wells facing fall in water depth. In almost half of the wells in Rajasthan (49.8 per cent) and Madhya Pradesh (49.9 per cent), fall in depth to water level was reported. In Gujarat, about 60 per cent of wells showed declining depth to water level, while in Chhattisgarh the percentage of wells with fall in depth was reported as 61 percent.

Figure 19: Categorisation of groundwater assessment blocks (% share) across states in Region II (Reference year 2013)

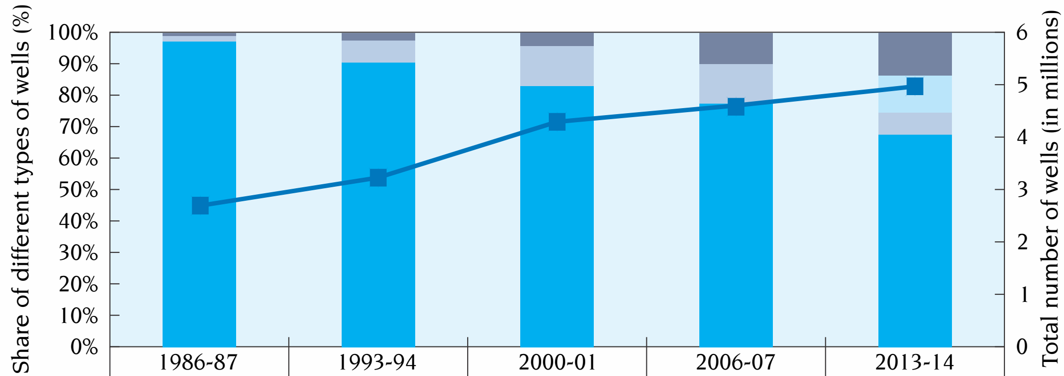


Source: GoI, 2017*a*

The total number of irrigation wells in Region II has almost doubled between 1986-87 and 2013-14, from 2.7 million to 5 million (Fig. 20). Among them, the increase in number of deep tubewells has been tremendous, about 24 times, while the shallow and medium tubewells together increased by 17 times. In the initial years of comparison the number of deep tubewells in Gujarat (reported in 1986-87) was almost 12 times more than that in Rajasthan. By 2013-14, the deep tubewells increased by almost 206 times in Rajasthan, while in Gujarat the number increased by only 1.29 times. The situation was reversed by 2013-14 and the number of deep tubewells in Rajasthan was 13 times more than that in Gujarat. A study by Bhanja et.al. (2017) using GRACE satellite data, it was shown that the groundwater resources have been declining at the rate of -0.92±0.12 km3/ year between1996-2002 and replenishing at the rate of 2.04±0.20km3/year in 2002-2014 in Gujarat. The study emphasised the improvement in groundwater status to be driven by effective water management policies like *JyotigramYojana*[8] directed towards improved, dedicated but limited hour power supply for irrigation and massive groundwater recharge program. Granger causality analysis used in their study showed that there is a negative causal relationship between agriculture electricity usage and groundwater storage in Gujarat. The simulation results estimated an increase in groundwater storage (GWS) by 3.2 to 4.4 km3/year during 2003-2014 in comparison with the GWS for 1996-2002. Such effective policies need to be implemented in other states also to combat the critical sustainability issue faced by groundwater sector in India. In Madhya Pradesh and Chhattisgarh taken together, the total number of wells increased 97 times but the number of deep tubewells reported an increase by 2.3 times. In Gujarat, Madhya Pradesh and Chhattisgarh, the increase in shallow and medium tubewells has contributed more towards the overall increase in tube wells unlike Rajasthan were there has been an alarming increase in the number of deep tubewells.

[8]The JyotigramYojana ensures eight hours/day full voltage power supply to tubewell owners on a pre-announced schedule. The scheme was introduced by the government of Gujarat in September 2003.

Figure 20: Status of ground water schemes (wells) across the years in Region II



	1986-87	1993-94	2000-01	2006-07	2013-14
Deep TW	1	2.6	4.5	9.7	13.4
Medium TW	0	0	0	0	11.5
Shallow TW	2	6.7	12.3	12.6	6.8
Dugwells	97	90.7	83.2	77.7	65.8
Total No.of wells (Millions)	2.69	3.24	4.31	4.62	4.98

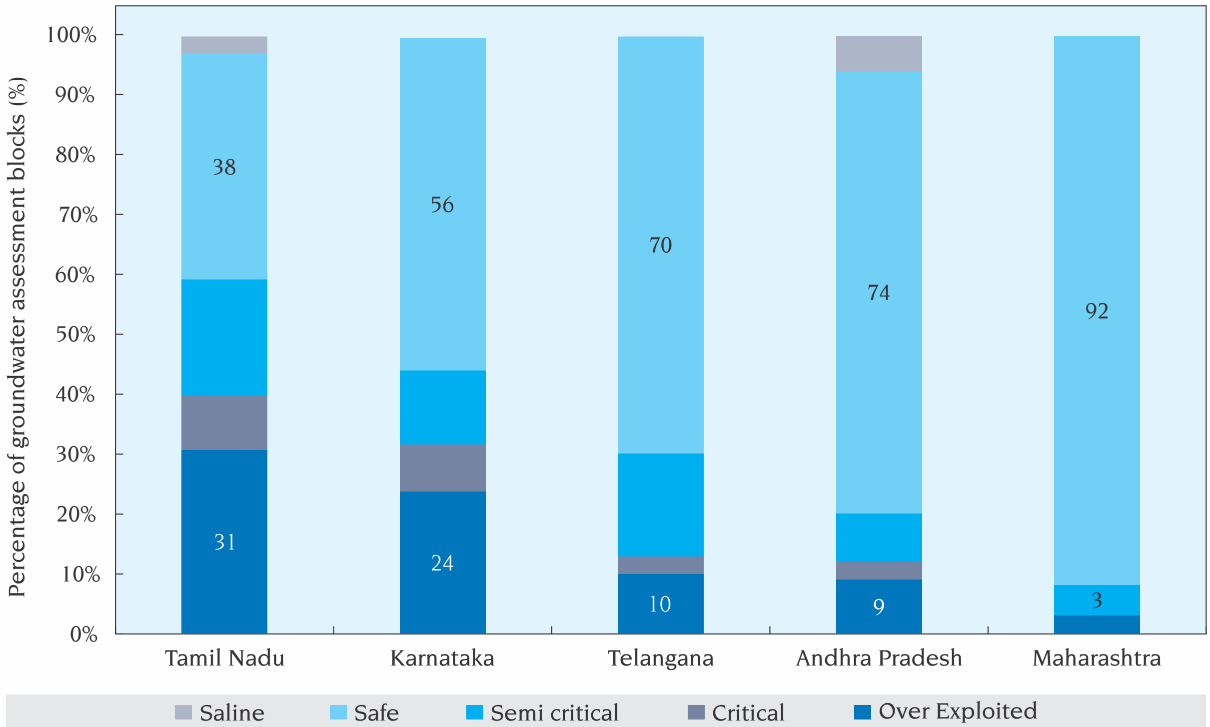
Source: *Minor Irrigation Censuses*

Note: **1986-87 census doesn't give data on number of wells in Rajasthan. Similarly the 1993-94 census doesn't give data on number of wells in Gujarat. For Rajasthan, the 1986-87 data have been taken from Census II and for Gujarat the missing data has been taken from census III. These values might be different from the actual value existing in the reference year due to change in functioning wells reported in the next reference year used*

Group III/ Region III comprise of states in the peninsular region which are characterized by hard rock aquifers marked by poor groundwater storage and yield capacity. Discontinued discharge from wells and recurring well failure is major issue in this region making dependency on groundwater irrigation highly uncertain for the farmers. Demarcating regions suitable for groundwater irrigation and ensuring artificial recharge on a science based plan is a must in these states. Further owing to the poor aquifer characteristics, sensible water use in agriculture through adoption of suitable cropping pattern as well as efficient water use – technologies like drip and sprinkler irrigation must form part of the water management strategy. In our study we have classified states like Tamil Nadu, Maharashtra, Andhra Pradesh, Telangana and Karnataka in this group.

Among the Group III states, the overall groundwater development stage in all states except Tamil Nadu was in safe zone. In Tamil Nadu the stage of groundwater development is in semi critical stage (77 per cent as a whole) in 2013, but about 31 per cent blocks of the state are over exploited. The percentages of over-exploited blocks are 24 per cent in Karnataka, 10 per cent in Andhra Pradesh, 9 per cent in Telangana and 3 per cent in Maharashtra (Fig. 21). In all the states in the group, except Telangana, the proportion of wells with falling water level was reported to be higher than the wells with rising water levels. In Tamil Nadu, almost 87 per cent of the wells were reported with fall in water level in 2017 over the decadal average. While in Andhra Pradesh, Karnataka and Maharashtra the percentage of wells registering fall in water level in respect of decadal mean was 75, 69 and 57 per cent respectively. Majority of the wells were showing the fall in the range of 0-2 m.

Figure 21: Categorisation of groundwater assessment blocks (% share) across states in Region III (Reference year 2013)



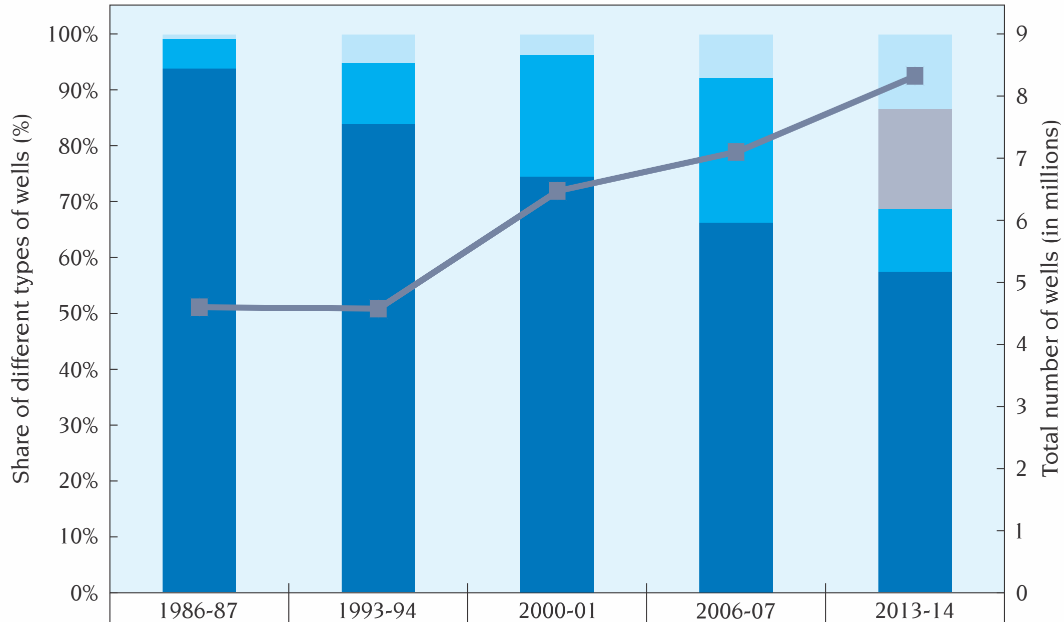
Source: GoI, 2017*a*

Almost 41 per cent of the total wells and 43 per cent of deep tubewells in India are concentrated in region III. The total number of wells in region III has almost doubled (1.8 times) between the first and the latest minor irrigation censuses (Fig. 22). The number of wells per gross cropped area (1.5) is highest in region III as compared with the other regions considered in the study. The reason may be anisotropic aquifer distribution and desperation of the farmers to drill additional wells as the yield diminishes. The share of deep tubewells in Andhra Pradesh (including Telangana) was one percent in 1986-87, which rose to almost 27 per cent by 2013-14 growing at the rate of 24 per cent annually. The compound annual growth rate in the number of deep tubewells between 1986-87 and 2013-14 in Tamil Nadu, Karnataka and Maharashtra were 23 per cent, 17 per cent and 21 per cent respectively. The study by Bhanja et. al. (2017) showed that in Andhra Pradesh, the groundwater storage replenished at the rate of 0.76±0.08km3/year in 2003-2014, bringing in a reversal in the declining trend (decreasing at the rate of -0.92±0.12km³/year) that existed between 1996 and 2002. The study attributed the positive change in groundwater storage mainly to the sustainable water management policies of UN FAO program called Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS)[9] carried out between 2004 and 2008 and the APWELL project[10] (conceived in late 1980s and completed in March 2003) linked with groundwater management in Andhra Pradesh.

[9]APFAMGS – The project aimed at empowering and equipping groundwater users with necessary data, skills and knowledge to sustainable manage the available groundwater resource.

[10]APWELL project – It was a project initiated by the state government to increase agriculture production through groundwater development. In the early stage of the project itself groundwater depletion due to excessive pumping was recognised as a constraint. Hence the groundwater development in the project was limited to safer zone.

Figure 22: Status of ground water schemes (wells) across the years in Region III

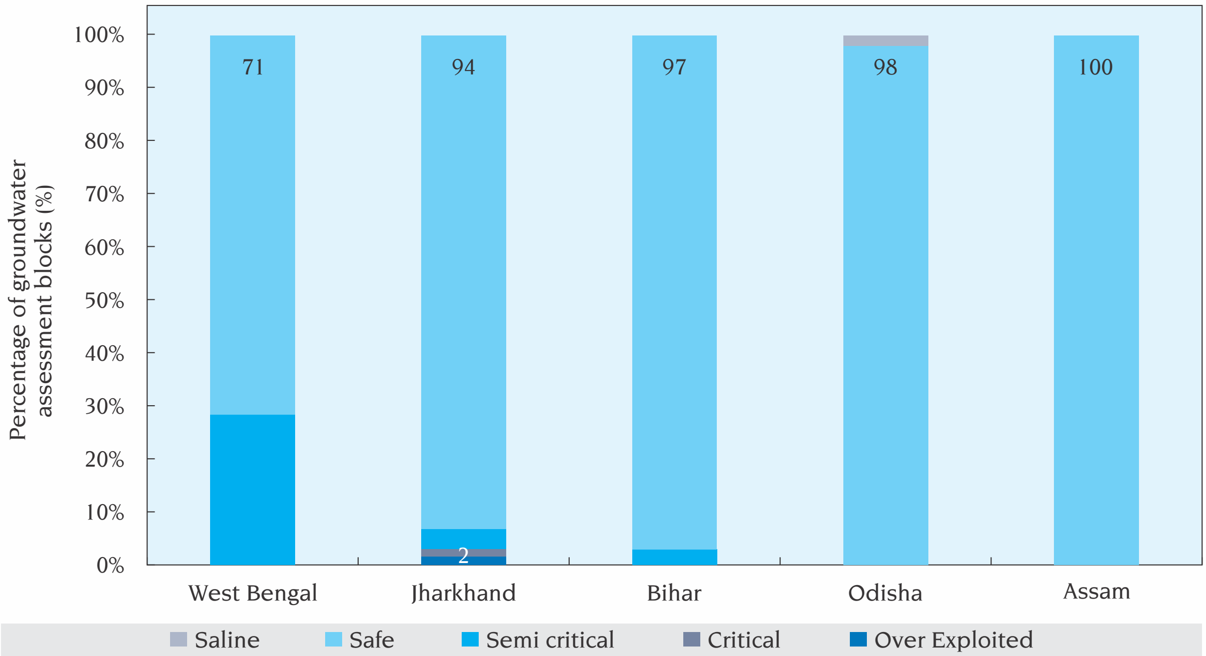


	1986-87	1993-94	2000-01	2006-07	2013-14
Deep TW	0.7	5.2	3.8	7.7	13.5
Medium TW	0.0	0.0	0.0	0.0	17.8
Shallow TW	5.5	10.8	21.6	26.1	11.2
Dugwells	93.9	84.0	74.6	66.2	57.5
Total No. of wells (Millions)	4.59	4.58	6.48	7.1	8.32

Source: *Minor Irrigation censuses*
Note: **1993-94 census* (Census II) *doesn't give data on number of wells in Maharashtra. The missing data for Maharashtra has been taken from census III.*

Group IV/ Region IV includes the Eastern and North eastern states characterized by abundant surface and ground water, but low share in groundwater irrigation. The uncertain and unaffordable energy availability for pumping the resource has resulted in low penetration of groundwater irrigation in these regions. It is expected that affordable, innovative and efficient technologies backed by suitable agri-market reforms will enable improvement of existing groundwater based irrigation scenario of the eastern and north eastern states. Thus efforts need to be directed towards identifying and framing supportive policies to achieve this.

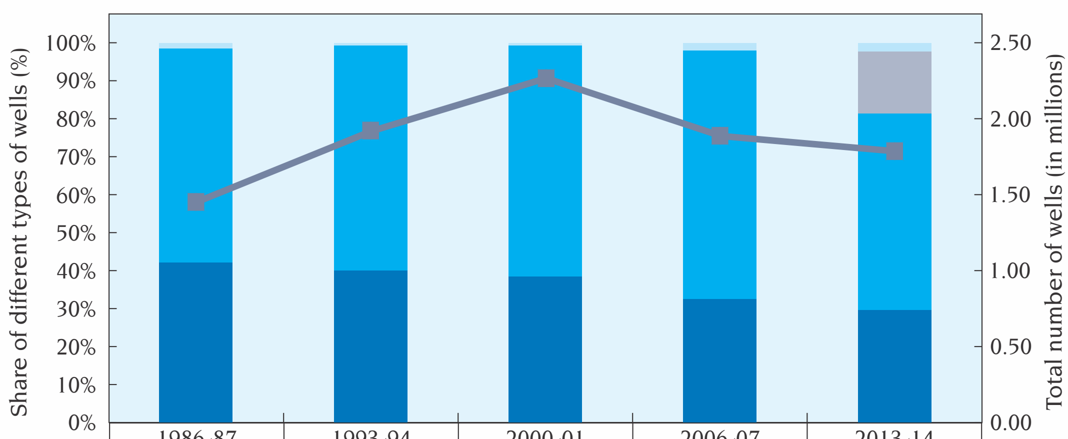
Figure 23: Categorisation of groundwater assessment blocks (% share) across states in Region IV (Reference year 2013)



Source: GoI, 2017*a*

In Region IV, the groundwater development stage is in the safe zone, i.e. <70 per cent. Overall, only about 9 per cent of the total wells in India are concentrated in region IV. Fig. 24 shows the share of different types of wells in region IV. The share of deep tubewells in region IV comes to a meagre 0.02 per cent to the all India total. Sustainable groundwater development in region IV can emerge as a step towards improved agriculture development.

Figure 24: Status of ground water schemes (wells) across the years in Region IV



	1986-87	1993-94	2000-01	2006-07	2013-14
Deep TW	1.3	0.7	0.7	1.9	2.1
Medium TW	0	0	0	0	16.4
Shallow TW	56.5	59.2	60.7	65.6	51.9
Dugwells	42.2	40	38.6	32.5	29.5
Total No. of wells (Millions)	1.45	1.92	2.27	1.89	1.79

Source: *Minor Irrigation censuses*

1.3 Causes of groundwater depletion and decline

Higher and dependable water needs on one hand and inefficiency in canal irrigation system on the other has shifted farmer's interest towards ground water irrigation over the years. In India, almost 30-35 per cent conveyance loss has been reported in canal system of irrigation. Added to this is the loss due to inefficient irrigation method like flood irrigation which leads to only one-third of the water released from the dams and reservoirs actually reaching the farmers field. Further, the absence of timely availability of canal waters leaves the farmers with no other options than drilling wells to extract the groundwater resource. However, with the uncontrolled drilling of wells further catalyzed by the agriculture power subsidy policy has led to the over-use and unsustainable groundwater exploitation in many parts of India.

Misaligned cropping pattern existing in the country with water intensive crops being cultivated in water scarce regions has emerged as yet another reason responsible for increased stress of groundwater resource in the country. Over the years the cropping pattern in India has been decided looking majorly at the land productivity aspect, often overlooking the other parameters like water productivity and overall agricultural sustainability. But now with the water resource getting depleted at a globally alarming rate, we need to focus upon not just productivity but agriculture sustainability and make viable decisions as to what to cultivate, where to cultivate and how optimally to cultivate. Paddy in Punjab is a classic case which reflects the negative impact of unsustainable crop planning on agriculture-groundwater nexus in India (Gulati and Mohan, 2018). Punjab state consumes two times more water than West Bengal and almost three times more water than Bihar for producing the same amount of rice. However because of the efficient procurement system existing in Punjab, despite the disturbing groundwater scenario, water guzzler paddy crop is still the preferred crop in the state.

1.4 Annual cost of groundwater extraction

The Riparian doctrine associated with groundwater use in India has left its users unaware of the future consequences of such uncontrolled groundwater over-exploitation. Thus evaluation of annual groundwater extraction cost which remains as a shadow price affecting the sustainability of the resource is necessary to make policy makers, farmers and other stakeholders realise the severity of the situation existing in the states.

In our study we aim to assess economics of groundwater irrigation in the states as follows:

A. Evaluate and compare the annual cost of the groundwater extraction in the states (per cubic metre of water extracted (Rs./cu.m) and per hectare of groundwater irrigated area (Rs./ha))

B. Cost of groundwater extraction per unit of water extracted (Rs./cu.m) (using electric pump sets)

= [Capital cost of wells and pump set + Net present value of operating cost of pump sets + Net present value of maintenance cost of GW unit (pump set+ wells)] ÷ [Volume of water pumped out by the pump set in a year per hectare of groundwater irrigated area]

- Cost is calculated *with and without electricity subsidy*
- In *with subsidy* scenario, operating cost = 0.
- Discount rate considered for arriving at present value of investment= 12%, 10.5% and 7% (Based on existing loan repayment rate and deposit rates)

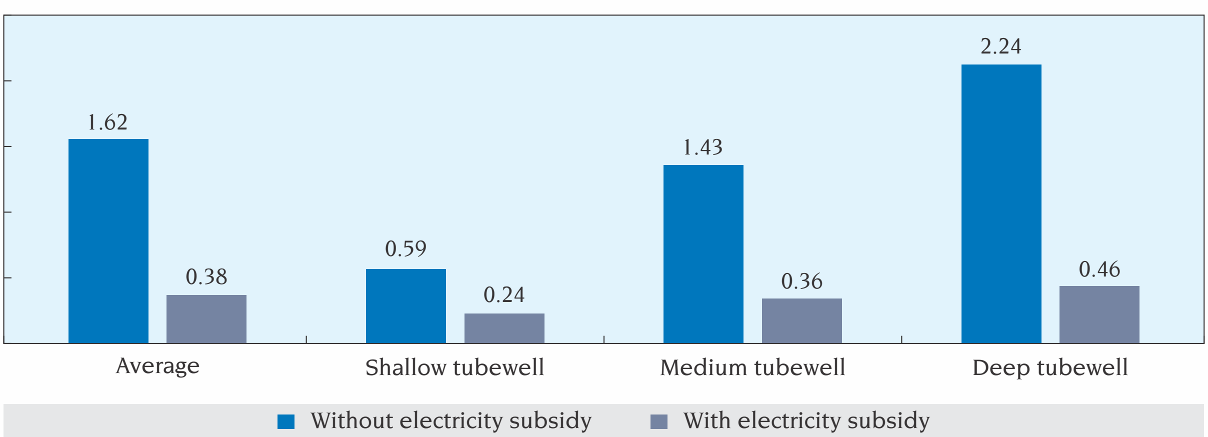
The cost of extracting groundwater across states will vary considering the average depth of groundwater table which is reflected by the average depth of wells in the states.

1.4.1 Cost of groundwater extraction in Punjab

Punjab has been globally noted as one of the states critically affected by groundwater over exploitation. The share of over exploited blocks in the total assessment blocks was reported to be highest for Punjab (76 per cent). Despite this critical situation existing in the state, water intensive paddy crop occupies 36 per cent of the gross cropped area of the state. With subsidised electricity and free groundwater availability farmers and other stakeholders are rarely concerned about the depleting groundwater reserve. This situation if left unchecked may lead to horrendous water scarcity situation. However, unless and until the value of resource being used is realised, little will be done for its conservation. In an attempt towards this, we have evaluated the cost of groundwater extraction in Punjab. As per the fifth minor irrigation census, majority of the pumps in Punjab are operated using electric power (85 per cent of shallow tubewells, 98 per cent of medium tubewells and 99 per cent of deep tubewells). Hence we have evaluated the cost of extraction of groundwater using an electric pump in the presence and absence of electricity subsidy.

Punjab has almost one million tubewells, of which about 20 per cent are shallow, 35 per cent are medium and 45 per cent are deep tubewells. Assessing the data published in the fifth minor irrigation census, we have assumed the horsepower of lifting devices used in shallow, medium and deep tubewells to be 5, 7.5 and 10 respectively. Almost 96 per cent of the wells are energised by electric pump sets in Punjab. Our calculation shows that the average annual cost of extracting groundwater per hectare of groundwater irrigated area in Punjab using an electric pumpset is Rs.15746 without power subsidy and Rs. 3552 with power subsidy. Taking into account the irrigation water applied per hectare, the average annual cost for extracting one cubic metre of groundwater in Punjab (considering a discount rate of 10 per cent) using an electric pumpset is about Rs. 1.62 in the absence of power subsidy, while it comes to only Rs. 0.38 in presence of power subsidy. Fig. 25 shows the cost of groundwater extraction from a shallow, medium and deep tubewell in Punjab at discount rate of 10 per cent with and without power subsidy. Detailed calculations with assumptions (including calculations for discount rates like 12 per cent and 7 per cent) are included in the appendix after this part.

Figure 25: Cost of groundwater extraction in Punjab (Rs. /cu.m) @ 10% discount rate (2017-18)



Source: Authors' calculation

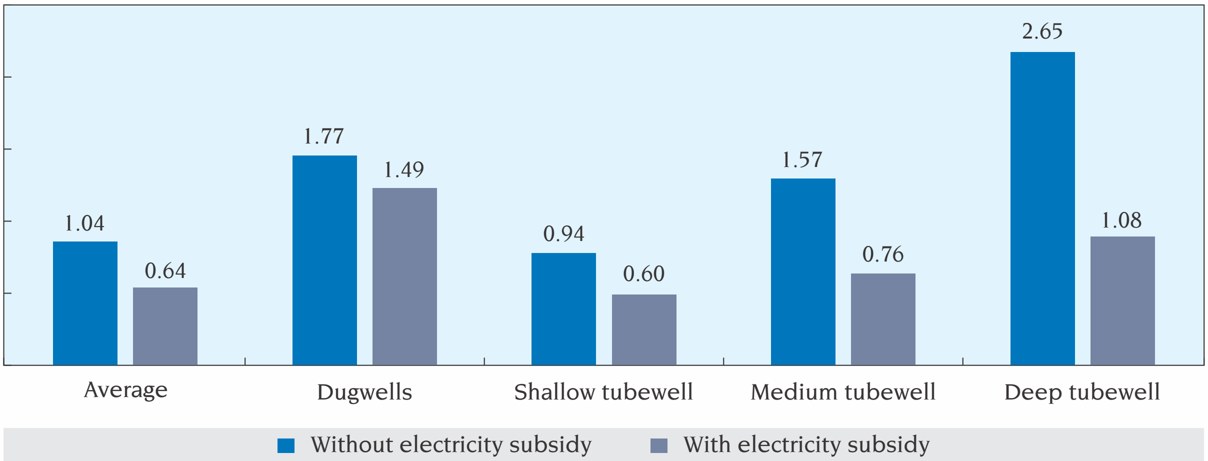
Availability of agriculture power supply at zero cost in Punjab brings down the cost of groundwater extraction to almost 23 per cent of its actual cost. For the water guzzler rice crop in Punjab, we calculated the groundwater extraction cost per hectare of the rice area to understand the cost reduction as a per cent of gross value of output of the crop in the state. The result showed that in Punjab the groundwater extraction cost was almost 20 per cent of the gross value of output of rice (calculated at MSP (2017-18) = Rs. 92474 per hectare) before subsidy, while it accounted to only 3 per cent after electricity subsidy. The cost of groundwater extraction for paddy crop thus reduces to almost 14 per cent of the actual cost due to existence of free electric power for agriculture in Punjab. Thus for the farmers in Punjab water is an easily accessible, cheap economic good, which in turn results in over exploitation of the commodity with limited or no judicious control. Existence of free agriculture electric supply thus makes sustainable groundwater management a tedious task in states like Punjab.

Similar calculation has been replicated for 6 other states namely Uttar Pradesh, Gujarat, Rajasthan, Maharashtra, Tamil Nadu and Bihar. These states represent the group I, group II, group III and group IV regions identified in our study. The costs have been compared to evaluate the sustainability of groundwater use across different aquifer regions in India. In Uttar Pradesh and Bihar diesel pumps are majorly used for groundwater extraction. Hence in these two states the cost of extraction of groundwater using diesel pumpsets is also calculated.

1.4.2 Cost of groundwater extraction in Uttar Pradesh

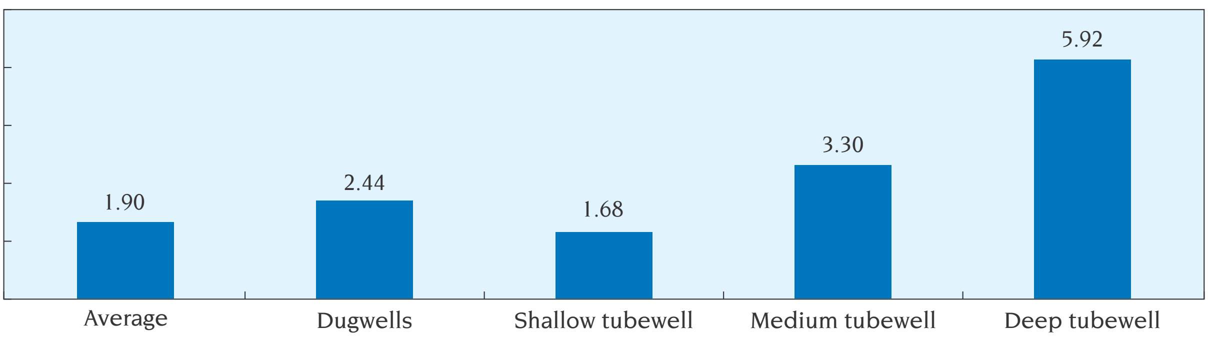
Uttar Pradesh has been grouped under region I, characterized by alluvial aquifers similar to Punjab. In Uttar Pradesh almost 16.5 million hectare cropped area is groundwater irrigated, with only 2.5 million hectare powered by electric pumps. Of the total 0.5 million electric powered wells in Uttar Pradesh, almost 63 per cent are shallow tubewells with average depth of 18 metres. Considering the irrigation water applied for major crops, we estimated that on an average 6160 cubic metre of water is applied for irrigating one hectare area in Uttar Pradesh. Thus considering the proportion of electric pumpsets (15 per cent) and diesel pumpsets (85 per cent) in the state, we assume that 946 cubic metre of water is pumped out using electric pumpset and the remaining 5214 cubic metre is pumped using diesel pumpsets. The cost of groundwater extraction per hectare of groundwater irrigated area (electric and diesel pumpsets together) in Uttar Pradesh with power subsidy comes Rs. 10659 and without subsidy comes to around Rs. 11188. Fig. 26 gives the cost of groundwater extraction (per cubic metre) in Uttar Pradesh for different types of groundwater structures. On an average the annual cost of groundwater extraction using electric pumpset per cubic metre of water extracted comes to Rs. 1.04 without subsidy and Rs. 0.64 with subsidy. While the annual cost of groundwater extraction using a diesel pumpset per hectare of groundwater irrigated area is Rs. 1.90 (Fig. 27).

Figure 26: Annual cost of groundwater extraction in Uttar Pradesh (Rs./cu.m) @ 10% discount rate (2017-18)



Source: Authors' calculation

Figure 27: Cost of groundwater extraction in UP (Rs./cu.m) @ 10% discount rate (2017-18) in diesel pumpset irrigted area



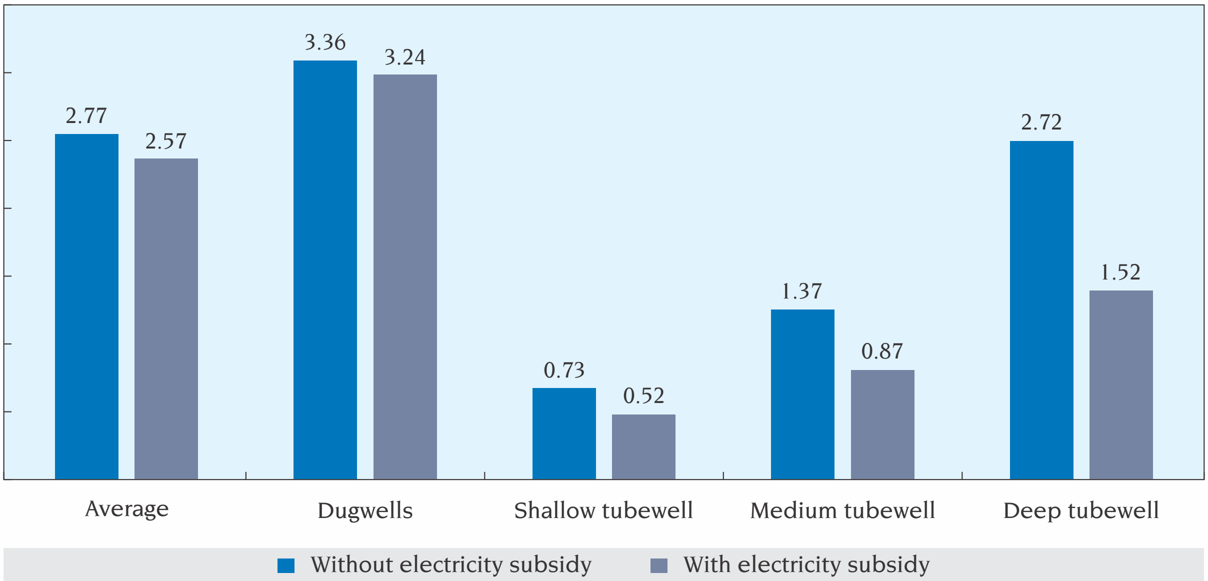
Source: Authors' calculation

1.4.3 Cost of groundwater extraction in Gujarat and Rajasthan

Gujarat belongs to region II and due to its arid climatic condition possesses limitation in groundwater recharge. Cotton, wheat, oilseeds are the major irrigated crops in the state, together covering almost 60 per cent of the irrigation coverage in the state. Almost 99 per cent of the wells in Gujarat are connected to electric pumpsets. On an average one hectare of representative irrigated area in Gujarat requires almost 6128 cubic metre of irrigation water. Majority of the wells in Gujarat are dug wells (73 per cent) with an average depth of 12 metres. The average cost of groundwater extraction in Gujarat comes to Rs. 2.77 per cubic metre without subsidy and Rs. 2.57 with subsidy (Fig. 28).

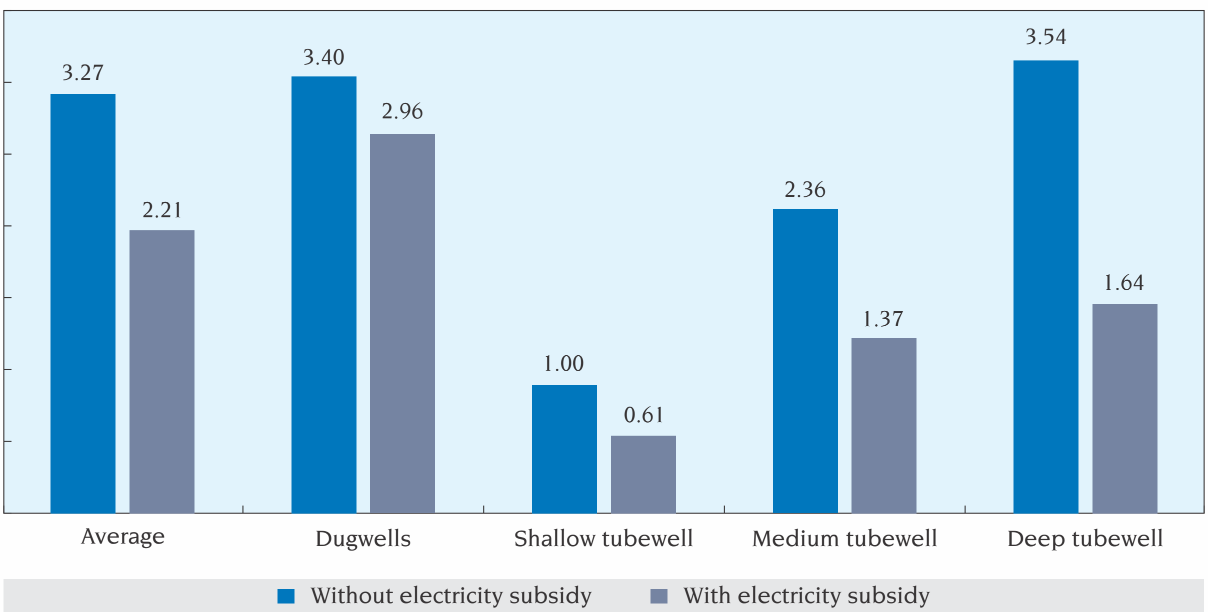
Rajasthan reports one of the highest rate of groundwater extraction cost per cubic metre of water among the 6 states analysed due to higher number of deep wells requiring large capital cost and higher share of deep tubewells. The state records the largest number of wells, 1.4 million, of which almost 70 per cent are powered by electricity. Dugwells (48 per cent) and deep tubewells (38 per cent) occupy the major share of wells in Rajasthan. The average cost of groundwater extraction in Rajasthan goes up to Rs. 3.27 per cubic metre without subsidy and Rs. 2.21 with subsidy (Fig. 29). Thus region II, characterised by arid climatic condition exhibit highest groundwater extraction cost compared to all other states.

Figure 28: Cost of groundwater extraction in Gujarat (Rs./cu.m) @ 10% discount rate (2017-18)



Source: Authors' calculation

Figure 29: Cost of groundwater extraction in Rajasthan (Rs./cu.m) @ 10% discount rate (2017-18)



Source: Authors' calculation

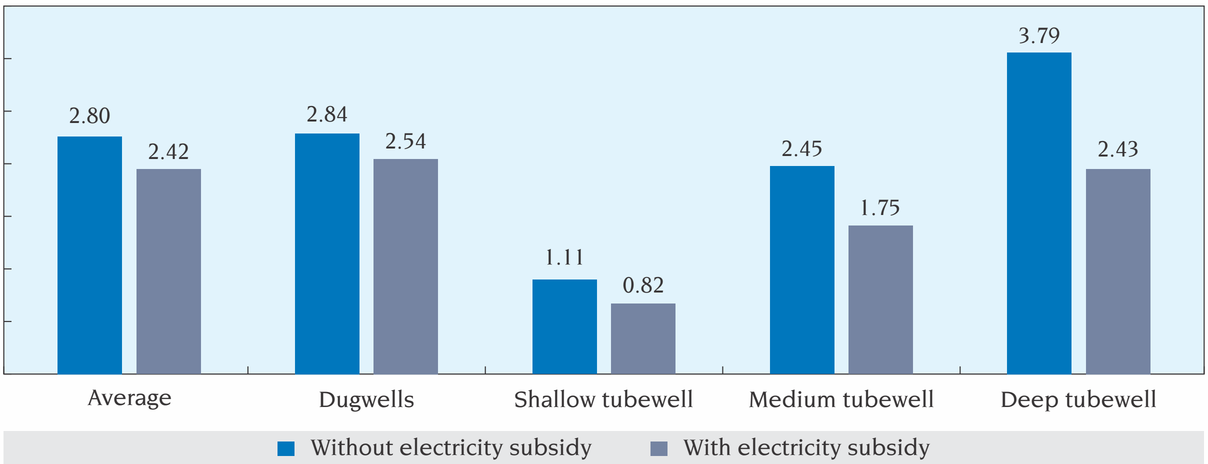
1.4.4 Cost of groundwater extraction in Maharashtra and Tamil Nadu

In region III, the cost of groundwater extraction in Maharashtra and Tamil Nadu states have been worked out. Maharashtra and Tamil Nadu are characterised by large number of dugwells with its share in total wells going up to 86 per cent and 78 per cent respectively. Sugarcane (21 per cent) and fruits and vegetables (20 per cent) occupy the major share of irrigated area in Maharashtra,

while almost half of the irrigated area in Tamil Nadu is covered by rice crop. As discussed in section 2, region III is characterised by hard rock aquifers. As such due to the high incidence of well failure the life of wells in region III is reduced to almost half that in other regions. The groundwater extraction cost in Maharashtra comes to Rs. 2.80 without subsidy and Rs. 2.42 without subsidy (Fig. 30).

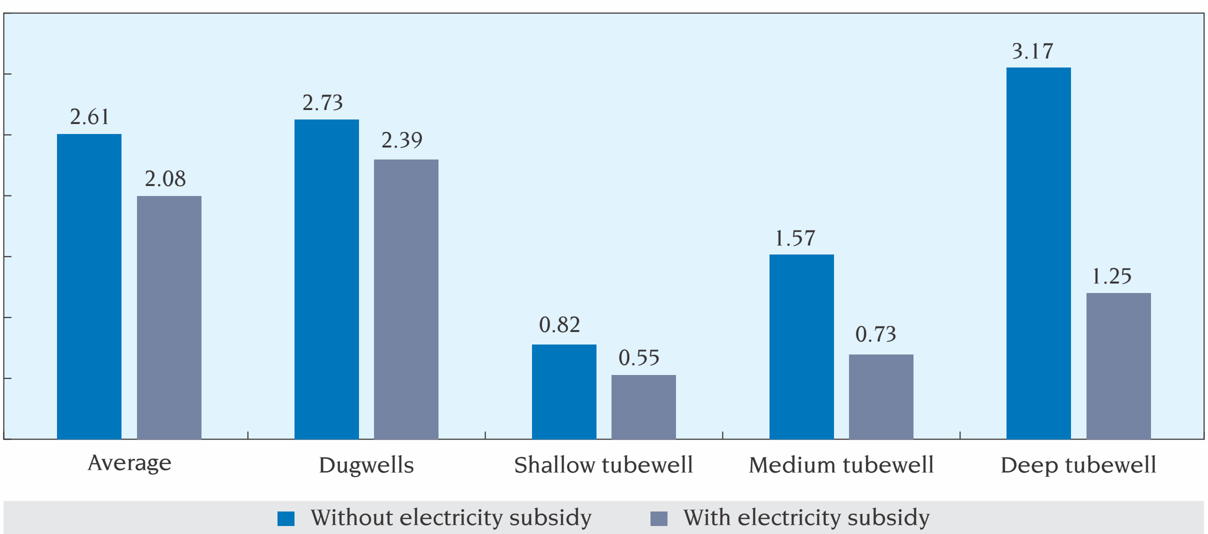
Like Punjab, electricity is free in Tamil Nadu which has resulted in high groundwater over draft in the region. The cost of groundwater extraction in Tamil Nadu comes to Rs. 2.61 per cubic metre with subsidy and Rs. 2.08 per cubic metre without subsidy (Fig. 31).

Figure 30: Cost of groundwater extraction in Maharashtra (Rs./cu.m) @ 10% discount rate (2017-18)



Source: Authors' calculation

Figure 31: Cost of groundwater extraction in Tamil Nadu (Rs./cu.m) @ 10% discount rate (2017-18)

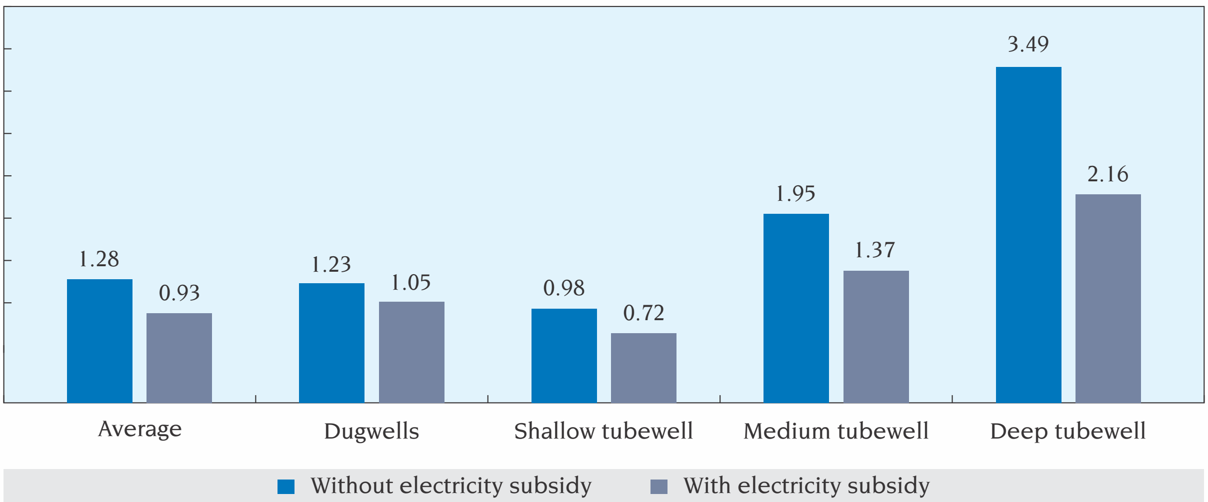


Source: Authors' calculation

1.4.5 Cost of groundwater extraction in Bihar

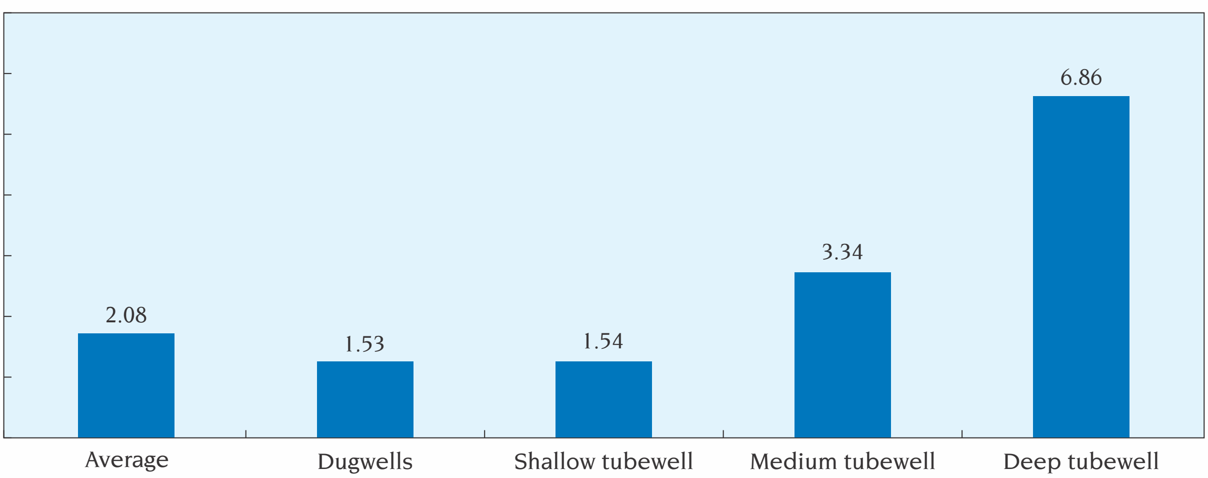
The cost of groundwater extraction per hectare in Bihar which belongs to region IV (Eastern states) is much lower than the other 3 regions. Eastern states are characterised by good reserves of groundwater resource which is mostly left underutilised. Only 7 per cent of the wells in Bihar are powered by electric pumpset and 89 per cent are powered by diesel pumpset. Hence we have worked out the cost of groundwater extraction using an electric pumpset and diesel pumpset (Fig. 32 and 33).

Figure 32: Cost of groundwater extraction in Bihar (Rs./cu.m) @ 10% discount rate (2017-18) in electric pumpset irrigated area



Source: Authors' calculation

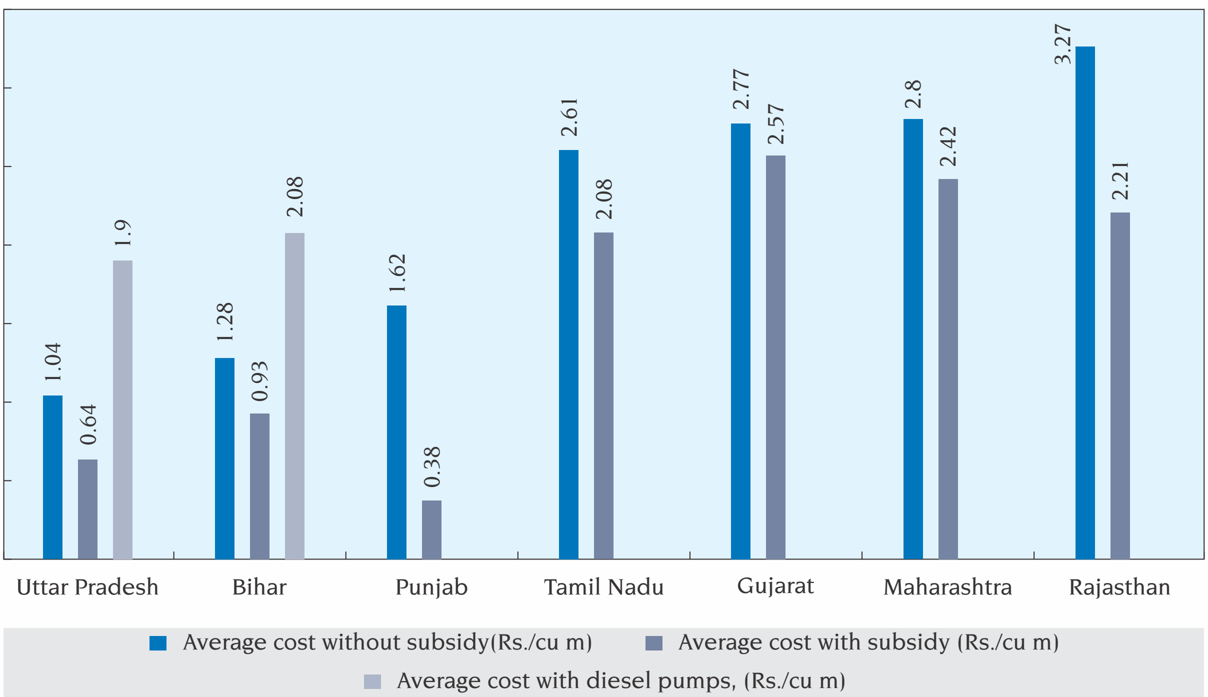
Figure 33: Cost of groundwater extraction in Bihar (Rs./cu.m) @ 10% discount rate (2017-18) in diesel pumpset irrigated area



Source: Authors' calculation

Thus it can be seen that states with alluvial aquifers (Region I) and eastern states (region IV) have less groundwater extraction cost when compared to states with hard rock aquifers and low rechargeable aquifers (Fig. 34). Uttar Pradesh, Bihar and Punjab states are characterised by low groundwater extraction cost due to their alluvial aquifer characteristics which makes the cost of well construction lower as compared to hard rock areas. With electricity subsidy a comparatively rich farmer in Punjab gets 40 per cent cheaper water as compared to a poor farmer in Uttar Pradesh and 60 per cent cheaper than a very poor farmer in Bihar and 83per cent cheaper than a farmer in Rajasthan. In reality, the actual cost of water from a diesel operated pump, which are the most prevalent, is 5 times higher in Uttar Pradesh and 5.5 times higher in Bihar. No wonder that the poor farmers in these states economise on the use of irrigation water in spite of resource abundance and the farmers in Punjab over-exploit the water resource in spite of the region facing damaging groundwater stress. Due to prevailing energy policy, the cost of groundwater for the farmers is the lowest in Punjab.

Figure 34: Average cost of groundwater extraction in the selected groundwater using states in India



Source: Authors' calculation

1.5 Best Management Practices (BMPs) in Groundwater Management

Some of the best management practices (BMPs) in groundwater use existing across the globe and within the country are discussed in this section. These BMPs can help to formulate feasible policies for sustainable groundwater management. The BMPs have been grouped based on their *modus operandi* for groundwater management as "Demand-side management" and "Supply-side management". In India, focus had been largely on the supply side management of agriculture-water use. However in case of groundwater resource, the major issue hovers around its sustainable use either due to over exploitation (as in the case of north-western India) or because of under use (as is witnessed in the eastern belt). Hence spotlight upon demand side management is also equally, if not more, important for its judicious use.

Under the demand side management the focus will be on how best demand on groundwater be regulated (in case of over exploitation) or promoted (in case of underutilisation) depending upon the availability of the resource in the specific region. The supply side management practices will focus upon how best the supply can be modulated depending upon the existing and future demand situations. The aim is thus to speak in the light of how best the groundwater resource can be put to optimal use without any negative externalities.

1.5.1 Demand-side BMPs

Almost 72.6 per cent of the water lifting devices operating (with single source of energy) in India are energised by electricity (GoI, 2017). Except in eastern India where 74 per cent of the energy requirement for irrigation is met from diesel fuel, all other parts of India depend on electricity as the major source of energy for carrying out irrigation activity. As groundwater use in India follows the Riparian doctrine, with the owner of the land enjoying the right on the water beneath, the price for groundwater use remains as a shadow price with its owners paying nothing for the resource as such. The only cost borne by the owners is the resource extraction cost, which depends on the extraction structure installed and its operation costs. Once the investment involved in installation of well and pump sets are made, the recurring cost to be borne by the owners will be the operating cost which includes the price of the energy used for extraction and the maintenance cost of the extraction structures. Under fast groundwater depletion scenarios, the farmers also have to incur cost for deepening of the structure at frequent intervals. Large transitional costs have to be incurred when the centrifugal pumpset installed on the shallow tubewells/ wells need to be replaced with costly submersible pumpsets for medium and deep tubewells. Operational cost for groundwater extraction using electricity energised pumps is nil or negligible in many states in India as electricity is available either at flat rates (fixed based on capacity of pumps and not based on consumption of power) or free of cost since early 1970s. This makes the marginal cost of groundwater extraction to be almost zero, making the resource a free good. The “free good” nature of the groundwater resource makes its use value negligible and accelerates its exploitation. In parts of India where electric power is barely or erratically available, farmers depend on the next popular source of energy, diesel fuel. Due to the high price of diesel fuel the groundwater resource in these regions are mostly left underutilised for crop production. This scenario of underutilised groundwater resource exists mostly in the eastern parts of the country. Thus it becomes clear how important it is to manage energy use to manage the demand of groundwater resource in India. Thus necessary policy tweaking with respect to groundwater-energy nexus is a must for demand side management of the resource. Awareness regarding the use value of the resource among its users is also essential to manage the resource judiciously. Rationing of groundwater and technologies and innovations to reducing irrigation water use and water wastage in crop cultivation can also aid in demand side groundwater management in the country. Some of the BMPs that have been adopted on scale in certain regions/ states, keeping in mind these principles are discussed below:

Jyotir Gram Yojana (JGY) in Gujarat

The *Jyotir Gram Yojana* was initiated by the *Gujarat* U*rja* V*ikas* N*igam* Ltd. (formerly Gujarat Electricity Board, GEB) and implemented by the Government of Gujarat in 2003-04. Two main objectives of the scheme – 24-hour power supply to rural households/ industries and 8 hours of 3-phase high-quality electricity supply to agriculture at pre-announced schedule, not only revolutionised rural electrification but also played a significant role in demand side management of groundwater extraction in Gujarat. The bifurcation of the feeders for agriculture

and non-agriculture uses benefitted the rural households from getting uninterrupted power supply which was earlier getting robbed for farm use. Power theft in rural areas in Gujarat was reported to be about 70 per cent in early 2000s (PWC, 2016). Prior to JGY, farmers were illegally using capacitors (locally called '*tota*') to convert the single phase power supplied to rural households into three phase power to run pumps for irrigating their fields. Regulatory measures were adopted to abolish use of these capacitors which in effect reduced the power theft in rural areas. The rationed but pre-scheduled agriculture power supply also helped to control the over exploitation and to effectively manage the groundwater resource in the state. The study by Bhanja et.al. 2017 analysed and observed that groundwater abstraction is directly proportional to electricity consumption in the study area, Gujarat. After the adoption of *Jyotir GramYojana* in 2003 a notable reduction in the groundwater depletion was observed in Gujarat. The groundwater resource which was getting depleted at -5.81±0.38 km3/year (between 1996-2001) saw a reversal in trend, getting replenished at the rate of 2.04±0.20km3/year (between 2002-2014) (Bhanja, et al., 2017).In 2012 World Water Week, Stockholm International Water Institute remarked Jyotir GramYojana as a creative non-price solution towards groundwater management. It credited the scheme for focussing on providing subsidies rationally, where needed and pricing, where possible thereby bringing down the power subsidy in agriculture by almost half (Jagerskog & Jonch Clausen, 2012).The JGY has helped to establish real-time co-management of electricity and groundwater irrigation in Gujarat. It has liberated the domestic and non-farm rural electricity supply from a perverse political economy of farm power subsidies. Thanks to the JGY, Gujarat has made significant progress in placing its electricity industry on a financially viable footing in just over 5 years. A significant breakthrough achieved is the control that the government now has on the size of the farm power subsidy: before the JGY, capacitor-using tubewell owners subject to flat-tariff availed of all the power they wanted while the government and electricity board remained mute spectators. Now, things have changed; tubewell owners have to manage with the daily power ration they are provided. In this sense, the JGY has transformed what was a degenerate flat-rate power pricing regime into a rational one (Shah et al., 2008).

Indirectly, the price of groundwater supplied by tubewell owners in the informal markets was increased by 30-50 per cent which served as an indicator of more rational and stingy frugal use of groundwater in the region (Jagerskog & Jonch Clausen, 2012). This was mainly due to restriction in power supply, which ultimately resulted in lesser supply in the existing demand situation alleviating the water price for water buyers. A possible argument against the increased water rates was that small and marginal farmers, who were the major water buyers in the informal market, were affected most because of the rise in water price (Bhatt & Bazar, 2008). However looking from the sustainability perspective, this was a positive step and an effective means to attach user value to a scarce resource. Thus the JGY worked on the principle of effective groundwater rationing giving the scope for indirectly pricing groundwater use, wherever possible.

By and large JGY is regarded as a success story in Gujarat and several other states which have partially implemented this intervention. This success motivated the Union Government to scale-up the scheme at all India level in 2015 under the name *Deen Dayal Updhayay Gram Jyoti Yojana* (DDUGJY). The performance evaluation of the scheme needs to be done to analyse how successful the principle of feeder segregation and net metering has been in reducing groundwater over draft across India.

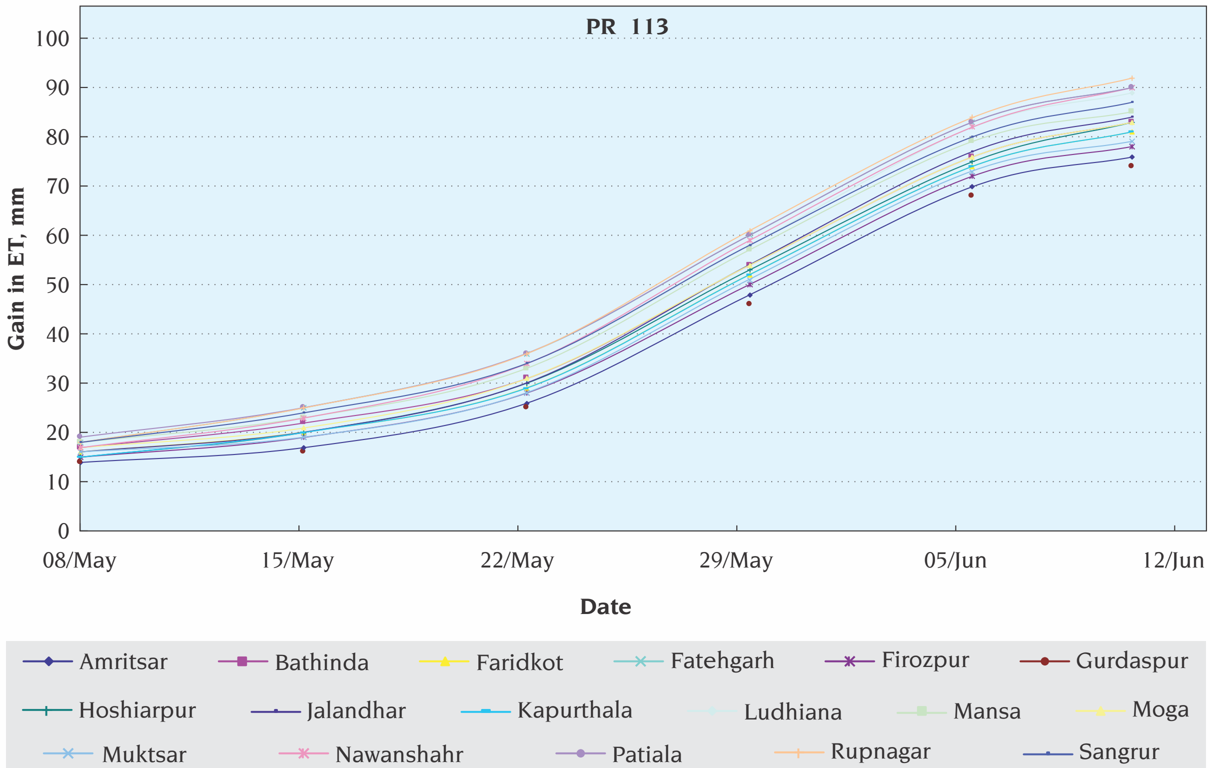
Delayed Transplanting of Paddy: The Punjab Preservation of Sub-soil Water Act, 2009

The unregulated exploitation of the groundwater resource had brought Indian Punjab into a state of acute water crisis. Homogenized cropping followed in the state, with water-intensive rice being the highly favoured crop in *kharif*, is the most to blame for this resource crisis. The general tendency among farmers in Punjab was to go for paddy transplanting in the hot month of May after immediate harvest of wheat crop due to shortage of labor at later months. High temperatures in the month of May (around 45° Celsius) necessitate more frequent irrigation, causing farmers to pump more from the already depleted groundwater resources. Evaporation accounts for 60 per cent of the actual total water depletion (ET) for rice during the crop growth period. Hence real water savings are possible only by reducing this non-beneficial water loss through rescheduling the transplanting dates. Transplanting rice seedlings late in June would also serve as a coping strategy in case of delayed monsoons.

Alarmed by the state-wide deteriorating groundwater situation and to work out effective solutions for groundwater over-pumping issues and consequent water table declines in Punjab, the state Government with recommendation from the research institutes and Punjab State Farmers Commission (Singh, 2009), promulgated an Ordinance in 2008 followed by the act, “The Punjab Preservation of Subsoil Water Act” in March 2009. Through the main provisions of this Act, it has been made mandatory for all farmers not to sow paddy nursery before May 10 and not to go for transplanting before June 10. The Act also carries a stringent penalty clause for the defaulters (a fine of INR 10,000 per hectare of the transplanted field plus the cost of uprooting the crop). Previous advisories on water savings and even water saving practices have made little dent on groundwater depletion. Results of this intervention showed an increasing trend in water savings as farmers delay the transplanting date by 1-6 weeks (Fig. 35).The increasing trend is noticeable in all districts of the state. The ET gains from 14 mm to 90 mm could be achieved for the long duration variety by a delay of 1 and 6 week respectively (Sharma and Ambili, 2010).

Since the savings at field level are the non-productive evaporation loss, the savings get aggregated at higher scales. If the whole rice cropped area (2.62 million ha) of Punjab follow late transplanting by 10th of June, water savings that could be achieved would be around 2,180 MCM. Additional studies indicated rice yields obtained by shifting the transplanting dates to be higher than the state average of 5.5 t/ha (Chahal et al., 2007).It is also estimated that farmers growing long duration rice could save approximately 175 million KWh of electricity by checking real water loss. This would mean an average of around 2 per cent savings in total agricultural electricity consumption (8229.49 million KWh).The energy savings are translated to cost savings for the State Electricity Board, which has been burdened with added cost on account of subsidies on agricultural pumping. Delayed transplanting offers a very promising solution to arrest and even revert back the water table decline, experienced in majority of the state. Subsequently, a similar Act was also promulgated by the neighbouring Haryana state. It is encouraging to note that implementation of the Act has been satisfactorily effective. A periodic evaluation is, however, necessary to ensure whether the expected reduction in groundwater depletion is achieved. Delaying the transplanting of paddy also demands research need for early maturing varieties, so as not to affect the sowing time of the following wheat crop.

Figure 35: Effect of delayed transplanting of paddy on evapo- transpiration gains in Punjab



Direct delivery of power subsidy to manage energy–groundwater–agriculture nexus in Punjab

Under the prevailing conditions in Punjab, all the stakeholders – energy companies, farmers and other power users are trapped in a continuous downward spiral of deteriorating power service delivery, near-bankrupt power utilities, declining ground water levels, and stagnant or declining agricultural productivity. Yet, the dynamics of electoral politics has made it almost impossible to realise any electricity tariffs. To come out of this stalemate, Punjab Government and the World Bank has launched a pilot project for providing direct delivery of the power subsidy to farmers in a cost-effective, transparent and targeted manner. The project makes use of segregated electricity feeders, minimum energy support for farmers, smart metering and subsidy delivery via ICT-based instruments in order to maximize benefits for all stakeholders by offering a better power supply and transparent subsidy delivery mechanism to reduce inefficiencies in the current system and breakout of the downward spiral (Gulati and Pahuja, 2015).Under the proposed scheme, farmers would have a choice-either to continue with the current system of limited hours of free/subsidized power supply, or to adopt the new system of longer, more convenient, hours of supply-still free/subsidized but the subsidy would be denominated in quantity of electricity instead of hours of supply. It is proposed to deliver subsidy directly to the beneficiaries through an ICT-based instrument such as smart card/bar-coded voucher or direct transfer to the beneficiary bank account. The proposed approach would help provide better estimates of agricultural power consumption and of losses, and can potentially reduce the subsidy burden on the government while maintaining or increasing the subsidy benefits to the farmers (Gulati and Pahuja, 2015). Government of Punjab is now satisfied with the scheme provisions and has notified the same through an order dated 14thJune, 2018. The project is

named as "*Pani Bachao, Paise Kamao* (Save Water, Earn Money)" and has been launched in 6 AP feeders in 3 districts of the state. It is too early to comment on the success or shortcomings of the pilot. It has been reported that till date almost 27 per cent (249 out of 940) farmers have opted for the scheme, with the Punjab State Power Corporation Limited (PSPCL) disbursing Rs.8,46,595 directly into bank accounts of farmers. Further in a meeting held on December 17th 2018 under the Chairmanship of Chief Secretary, Government of Punjab, it was decided to set up 1000 demonstration farms in Punjab to facilitate large scale adoption of water and electricity saving farm technologies across 200 agricultural feeders. In a workshop organised by Punjab Agricultural University (PAU), several crop-wise agronomic as well as infrastructural interventions were proposed for the setting up of such demonstration farms in Punjab. Some of the crop specific agronomic interventions proposed for demonstration included laser levelling of paddy field before sowing, direct seeding of rice, ridge/bed planting of maize and potato, wider spaced (about 4 feet) paired row trench planting for sugarcane, planting short duration cultivars in rice, surface and sub-surface drip irrigation and fertigation for all major cropping system, alternate drying and wetting in rice crop etc. Infrastructural interventions for demonstration were smart metering of agricultural pumpsets under DBTE which enables remote measuring of technical parameters of energy supply and use, mobile applications to operate pumpsets remotely to optimise the utilisation, power factor correction capacitor (energy allocation will be in kwh but consumption will recorded in kVAh), five star rated energy efficient pumpsets connected to feeders (25 per cent subsidy available for 5 star rated pumpsets connected to DBTE feeder), underground pipeline system etc. However, it may bring some semblance to the spiralling energy use and subsidy, the real savings in groundwater will happen only when area under rice crop is reduced and managed more efficiently.

Community Groundwater Management*: APFAMGS *in Andhra Pradesh

Theory tells the best way to manage groundwater is through 4 means: Regulatory measures, economic instruments, groundwater property rights and community groundwater management. Rationalizing groundwater has been a type of regulatory measure which has seen some light at least in Gujarat. However the main hurdle that stops the adoption of the groundwater management practices is the mind-set of the stakeholders, political sentiments and largely the lack of awareness with respect to the sustainability issue of an invisible resource. In the wake of such a situation community groundwater management has emerged as a relief, the success of which has been well witnessed in Andhra Pradesh through the Andhra Pradesh Farmer Managed Groundwater System (APFAMGS).

APFAMGS is a groundwater management system operating in Andhra Pradesh started and implemented in 2004 by various Non-Governmental Organisations with the support from Food and Agriculture Organisation (FAO) of the United Nations. The basic principle of this system of management was voluntary self-regulation in groundwater use, rather than an external entity setting the limit for groundwater extraction (Verma, Krishnan, Reddy, & Reddy, 2012). It succeeded the APWELL (Andhra Pradesh Borewell Irrigation Scheme) project which was initiated in 1987 by Government of India in Andhra Pradesh with a view to develop groundwater use in the drought affected regions of Andhra Pradesh without compromising the sustainability parameter. The community owned wells under APWELL project were supported financially by government which was however discontinued in the APFAMGS project. The APFAMGS project was implemented in the same villages identified in the APWELL project under the principle of participatory hydrology monitoring and the philosophy that 'farmers' understanding of groundwater dynamics makes a difference'. The village level groundwater resource estimation, crop water budgeting and cropping pattern changes brought in the region as a result of the

APFAMGS has been commendable. It has been reported that area under paddy cultivation has been brought down and crop diversification has taken place in favour of pulses, oilseeds, fruits and vegetables, flowers and other high value crops in the region (Reddy, Reddy, & Rout, 2014). The groundwater storage in Andhra Pradesh got replenished at the rate of 0.76±0.08km3/year in 2003-2014 when compared to the declining trend of -0.92±0.12km3/ year that was noted between 1996 and 2002. Policy interventions like APWELL and APFAMGS have been found to have significantly contributed towards this positive outcome (Bhanja, et al., 2017).

However, long term sustainability of the impacts after the project period is uncertain. The remnants of practices from APFAMGS and their likely impacts in 2012 reflect poorly on the long term sustenance of efforts, after the project ended and the local support organizations withdrew. This offers lessons for APFAMGS and all similar efforts on whether farmers can willingly, voluntarily and sustainably manage their groundwater resources without long-term external support (Verma et al., 2012).This is mainly because though the principles of APFAMGS are in line with most of Ostrom's Common Pool Resource Management principles, yet it was handicapped because of the lack of the main principle “graduated sanctions for violators”. As such scaling up of such a management system is questionable in India where the riparian doctrine holds in case of groundwater resource. For effective and sustainable outcomes elsewhere in India, the concept of treating groundwater as a common pool resource will require long term institutional and financial support and strict legal interventions against the violators.

***Solar irrigation*: A *means to promote groundwater development in the east and curb power subsidies depleting groundwater in rest of* India**

The ease of access to electric power has influenced groundwater development in India, in a very contradictory manner, especially in the east, northeast and rest of India. Majority of eastern India witnesses lack of regular electric power supply which has resulted in poor groundwater development in the region despite the resource richness. On the contrary, the rest of India especially north western states have been deluged with electric power supply in agriculture because of the prevailing huge subsidies. The energy-water association witnessed in groundwater development has created negative externality in the north-west and other over-exploited states, while it has undermined agriculture development in the east. Some authors have even termed it as 'energy divide' (Agnihotri and Maithani, 2015).

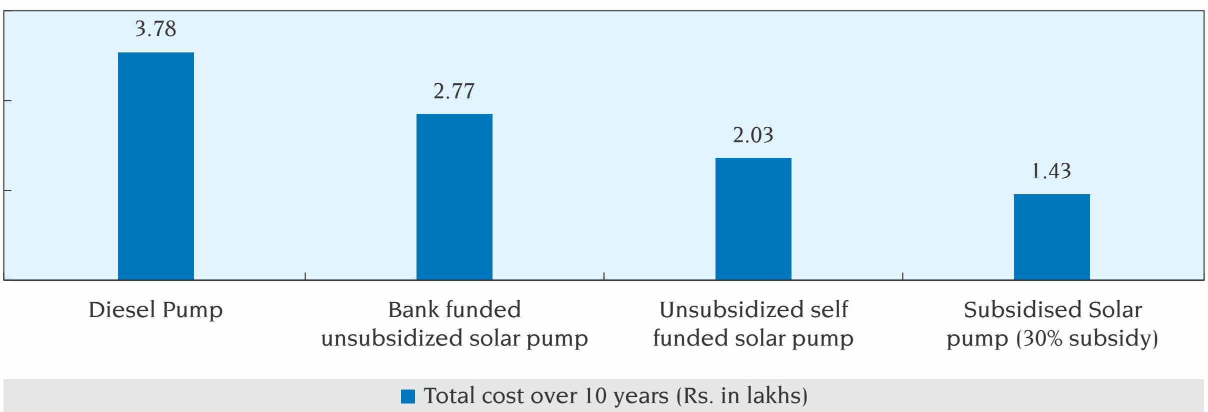
In order to develop the groundwater use in eastern region, (which currently depends on the costly diesel power) there is a need to develop a cheaper and sustainable energy source for pumping. Solar power can be the best alternative considering the extent of existing government support and policy intervention like K*isan* U*rja* S*uraksha evam* U*thaan* M*ahabhiyan* (KUSUM). Moreover it can be a sustainable solution because of its renewable nature. In rest of India where electricity is available at subsidised rates, solar power can emerge as an alternative provided assured grid connection for the surplus solar power generated is ensured. Studies have shown that for best socio-economic outcomes, solar irrigation producers substitute existing diesel and electric pumps rather than complement them, as is currently happening, For the 5.3 million farmers in using diesel irrigation pumpsets in eastern India, 60 percent capital subsidy under KUSUM may emerge to be a strong incentive to shift towards solar energy based irrigation pumpsets (Shah, 2018). Otherwise the situation will emerge as a classic case of Jevons paradox, where-in the solar irrigation can lead to excessive groundwater exploitation and over draft through the use of cheap and renewable energy source.

The issue of high upfront capital cost, loss of land resource and non-payment of dues by financially constrained DISCOMS for the surplus power generated had been some of the

constraints witnessed in adoption of solar powered irrigation in India. As suggested by the standing committee on energy (2017-18) under Ministry of New and Renewable energy, there needs to be development of proper mechanism to ensure the timely payment. Innovations in solar powered irrigation existing within and outside the country can be developed and scaled up to solve the issues constraining its adoption. Some of these are discussed below:

Innovative ideas like "solar as third crop" could solve the challenge of acquiring land for setting up solar panel. The total land requirement to set up a solar plant of 500 KW is around 2 acres. Instead, setting up solar panels at a height of 15-20 feet from the ground on farmers' field as a third crop in addition to the standing crop can save wastage of land resource meant for agriculture use. Further, the "Solar crop" in presence of assured provision to feed-in the surplus power back to grid, can additionally act as a source of income insurance to farmers at times of crop failure. On evaluating the economic feasibility of 500 KW solar plant, it was observed that the benefit cost ratio comes to 1.16 with payback period of 5 to 7 years, assuming zero subsidy condition (Upcoming paper Gulati, Kapoor & Mohan). Further the analysis carried out in the study reveals that though initial investment cost of solar pumps is 8-9 times higher than diesel pumps, over the lifecycle (approx. 10 years) the cost of diesel powered pumps is higher than solar powered pumps, even in the absence of subsidies (Fig. 36). This can serve as a foundation to lay the argument that diesel pumps must be replaced with solar pumps in eastern India.

Figure 36: Economic feasibility of solar pumps over diesel pumps



Source: Upcoming paper Gulati, Kapoor & Mohan

Adoption of solar pumps among small and marginal farmers will still be argued as a challenge owing to the high upfront installation cost of solar pumps. However uberisation of solar pumpsets can solve this issue. Mobile solar pumpsets operating under principle of "pay as you go" has already been introduced in parts of Bihar by companies like Claro Energy. Instead of installing the solar panel by individual farmers, there can be provisions to hiring the solar panels on rental basis (like the rental UBER cab service) to generate energy required for pumping required irrigation water for the crops. The portable solar pump developed by CLARO provides affordable, convenient, and on-demand irrigation to the farmers. The farmer can do the booking through a toll-free number, make the payment through the pay as you go digital payment card and schedule irrigation service at his field as per his convenience and the availability of the service. Depending upon irrigation water requirement of the crop and depth of groundwater level, the number of units required to irrigate unit land varies. For every unit of solar energy used for pumping, the farmers pay Rs. 3/ Unit (1 unit energy generate about 1000 litres of water

on an average). Presently Claro is operating in some of the districts like Muzzafarpur, and Samastipur of Bihar on a pilot basis. The project aims to make solar irrigation accessible to the small and marginal farmers and farmers with fragmented land holdings, especially in regions where electricity availability for agriculture is not continuous. Claro claims that savings in irrigation cost in mobile solar pumps in comparison to the diesel pumps comes to around 30- 40 per cent. The funds saved on the purchase of diesel can be invested on more efficient technologies. Assured irrigation will further help farmers to increase their agriculture productivity (13 per cent for wheat and 7.5 per cent for rice in case of solar irrigation) and income, while decreasing GHG emissions. Further, the proposed project creates employment in rural, agricultural communities, as villagers get the opportunity to become local irrigation service providers.

Effective implementation of such innovative interventions is still a challenge in India. Training and developing a section of agricultural entrepreneurs at village level can help to overcome this challenge of last mile delivery to a large extent. Syngenta Foundation of India has taken lead in developing such agricultural entrepreneurs (AE) across India. So far 500 AE have been trained and deployed to different parts of the country. They aim at developing 1lakh more agri-entrepreneurs in India by 2025. These agri entrepreneurs have helped in deploying innovations associated with farm mechanization, agriculture marketing and even cropping pattern. The advantage of such agri entrepreneurs is that they are trusted by the villagers as they are one among them, which helps in easier adoption of new technologies and innovative ideas. Such AEs can be assigned the task of implementing solar irrigation especially the uberisation model among the small and marginal farmers. Further the concept of solar drive micro irrigation can also be implemented in a much promising level through such village level Aes.

The Solar Pump Irrigators' Cooperative Enterprise (SPICE) in Gujarat is yet another worthwhile model that can be followed and scaled up. This solar irrigation cooperative in Dhundi in Anand district of Gujarat called as *Dhundi Saur Urja Utpadak Sahakari Mandal* (DSUUSM) with help of International Water Management Institute (IWMI) entered into 25 year power purchase agreement with the *Madhya Gujarat Vij Company Limited*, allowing farmers to sell back surplus power at the rate of Rs 4.63 per kWh equivalent of solar energy[11]. IWMI and CCAFS (CGIAR research program on Climate Change, Agriculture and Food Security topped up the MGVCL FiT (Feed in Tariff) with a Green Energy Bonus of Rs.1.25/kWh and a Water Conservation Bonus of another Rs.1.25/kWh, thus making the total FiT to Rs. 7.13/kWh[12]. A solar cooperative helps to reduce high cost of procuring power from an individual farmer, thereby reducing the deterrent for discoms buying power from the local producer of solar energy (Shah et. al., 2018).

Similar efforts have been floated in Karnataka where a scheme was launched in 2014 to deploy solar power irrigation systems on metering basis. The scheme, "*Surya Raitha*" encourages farmers to "grow" solar power as a remunerative cash crop. The scheme offers guaranteed buy back of surplus solar power from solar irrigation pump owners at an attractive FiT. With guaranteed buy-back of surplus power, a small farmer would have an incentive to raise the productivity of ground water as well as energy by investing in micro-irrigation systems so that a maximum surplus can be generated which then can be sold to generate additional income. It is important that such and similar schemes should be explored in all states and should be offered to both off-grid as well as grid-connected farmers who are willing to surrender their grid connections.

[11]Indian Express, May 10, 2016. 'CM honours farmer's cooperative that sells solar power to discoms"

[12]http://www.iwmi.cgiar.org/iwmi-tata/PDFs/iwmi-tata_water_policy_research_highlight-issue_10_2016.pdf

Technology interface for groundwater management through water saving: System of Rice Intensification (SRI), System of Crop Intensification (SCI) & Micro irrigation technology

a. **SRI AND SCI:** The System of Rice Intensification (SRI) and System of Crop Intensification (SCI) (for wheat, maize, millets, mustard, soybean, sugarcane and vegetables) are innovations that have been developed to modify the conventional practices through improved management of resources like water, soil, and nutrients to increase the productivity of land, labour, water and energy. Rice cultivation in India is one of the most water intensive agriculture cultivation practice existing. Almost 3000-5000 litres of irrigation water is required to produce 1 kilogram of rice through the conventional flood irrigation method. Studies show that SRI system in India has more than doubled the rice yield with only half as much water required in conventional methods[13]. In groundwater irrigation system, water saving through SRI can be an advantage to reduce over-exploitation of the resource. The number of irrigations, pumping hours and water application is almost halved (~52 per cent) in SRI over Non-SRI[14]. Sugarcane yet another water intensive crop cultivated in India requires 800 to 3000 litres of irrigation water to produce 1 kg of sugar. Sustainable Sugarcane Initiative (SSI), a component of SCI has been identified as a possible opportunity to increase the profitability in Odisha with 40 per cent less water, 30 per cent less labour together with increased yield of 10 tons per acre over the conventional method[15].

It has been reported that over three million farmers across the country have adopted these practices[16]. However, the actual area brought under SRI or SCI are rarely available. In 2011, Indian Agricultural Research Institute (IARI) reported that almost 0.75 million hectare area is under SRI in India[17]. However it formed only 1.7 per cent of total rice area cultivated and 2.9 per cent of total irrigated area under rice. Thus adoption level of SRI is relatively low, despite its innumerable advantages reported. The SRI component included in National Food Security Mission (NSFM) for increasing rice production was also found to be insignificant in increasing its adoption rate among farmers (Varma, 2016).

Apart from lack of skilled labour and high labour cost for the cultivation practice and lack of extension service to promote the system another major reason responsible for reduced adoption of SRI in India was the lack of effective irrigation infrastructure. Though SRI is a water saving innovation, farmers require their own irrigation facility for the purpose of proper water management (Varma, 2016). Considering this drawback, we have also discussed how linking SRI with drip technology can be an effective solution.

[13]http://sri.ciifad.cornell.edu/countries/india/extension/InPratyush_SRIposter2011.pdf

[14]Facts and Figures on SRI: Extracts from Reports of Sub-Group Constituted for 12th FYP Under Various Working Groups and Others. Background notes for discussion in the Round Table Discussion on SRI, 13th January, 2012 at CSD, Delhi. (www.sri-india.net/Round_Table_Discussion/Documents/FACTS_FIGURES_SRI.pdf)

[15]http://sri.ciifad.cornell.edu/countries/india/index.html#progress

[16]Summary of the Proceedings and Recommendations if the National Consultative Meeting on Up-Scaling SCI/SRI on 10 September 2016 at NAAS, New Delhi.
(http://sri.ciifad.cornell.edu/countries/india/India_Natl_Consult_on_Upscaling_SRI_091016.pdf

[17]Status of SRI in India: Upscaling

b. Micro irrigation for water saving

Micro irrigation plays an important role in water saving by increasing the application efficiency of irrigation system. Compared to the traditional flood irrigation system micro irrigation system has almost 40-50 per cent higher application efficiency. Drip and sprinkler irrigation, the two major modes of micro irrigation have reported efficiency of 85 per cent and 90 per cent respectively in water application. The water saved over flood irrigation method can be used for bringing additional area under irrigation and more importantly in critically groundwater stressed areas would help in enhancing groundwater resources. Rice and sugarcane, two of the water guzzling crops in India constituting one-fourth of the gross cropped area, takes away almost 64 per cent of irrigation water available in the country. Rice cultivation in Punjab has been identified as one of the major cause of groundwater depletion in the region. Recent studies reveal that adoption of drip system of irrigation in rice and sugarcane can lead to water saving which can indirectly lead to putting a cap on groundwater over-exploitation. Apart from water saving, drip-fertigation in rice can lead to an yield enhancement of 14.7 per cent to 29.9 per cent over flood irrigation, irrespective of cultivar, season, planting method and location , which can motivate farmers to adopt the technology.

However the point of argument has always been what if it encourages the farmers to use the saved water to cultivate more of the water guzzler profitable crops. This will in effect nullify the water-saving principle of the technology altogether. The solution is "set the markets right". It is always profitability and productivity that farmer aims at rather than sustainability. Hence it is necessary to set the markets right for the less water intensive crops in the groundwater exploited and water scarce regions, so that the opportunity cost (of foregoing rice or sugarcane cultivation) will not subjugate the sustainability concept.

Incorporating drip technology into SRI not only results in better water productivity of the crop (Rao, et al., 2017), but may even trigger faster adoption of the water saving technology in rice. Since it is claimed that SRI/SCI are low cost resource management innovations designed majorly for the benefit of small and marginal farmers, there is a sure chance of debate on the idea of clubbing the costly micro irrigation technology to the system. However, if the existing subsidies on micro irrigation under P*radhan* M*antri* K*rishi* S*inchai* Y*ojana* (PMKSY) are linked to this process the uncertainty with respect to high cost can be overruled to some extent.

National Mission on Micro Irrigation (NMMI) evaluation study shows that for almost all crops the benefit cost ratio (BCR) of using the micro irrigation system was found to be greater than 1, indicating its economic feasibility. Our own evaluation of economic viability of drip technology in sugarcane crop in Maharashtra revealed BCR to be more than one, with a payback period of less than 3.5 years to recover the investment made for installation and use of the technology (Gulati & Mohan, 2018). The benefit cost ratio of the SRI with drip irrigation system was found to be 1.88 in a field experiment conducted at Odisha (Mahapatra, 2015) substantiating the economic viability of integrating the two technologies.

Agronomic management through varietal improvement, direct seeding and alternate wetting and drying

Besides the improved methods of irrigation, efficient agronomic management for the cultivation of crops can save substantive amounts of groundwater. In fact, crop management for higher crop yields is the most efficient strategy for improved water productivity. These include adoption of suitable tillage practices including zero or minimum tillage, raised bunds around the rice fields, planting/ transplanting of the kharif crops to synchronise with the onset of monsoons to save on

irrigation water, and adoption of high yielding and short duration varieties so as to achieve real savings in evapotranspiration losses. Studies have shown that cultivation of short duration paddy (PR115) as compared to the medium duration PR113 helped to reduce irrigation needs by about 10 percent and ET losses by 6-7 percent. Same is true for other water intensive crops like sugarcane where the annual crop in northern region consumed almost 20 per cent less water as compared to Adsali crop in Maharashtra for the comparable yield levels (Sharma et. al., 2018).

Rice is generally planted after intensive wet tillage and puddling of the rice fields during hot summer months requiring about 30 per cent of the total rice water needs. Technologies and special cultivars are now available for direct seeding of rice as an upland crop and raised as 'aerobic rice'. The weeds in the aerobic rice fields may be controlled with hand or mechanical weeders and selective use of the weedicides. Water productivity of direct seeded rice is about 25 per cent higher as compared to transplanted rice. Additional studies have also conclusively shown that unlike the conventional practice of keeping the rice fields always irrigated/ submerged with about 5 cm depth of water, a successful rice crop can be cultivated by following 'alternate wet and drying moisture regime (AWD)'. In this practice, after the first fortnight of rice transplanting, the crop needs to be irrigated only when the ponded water has disappeared from the rice fields. Most studies have reported a water saving of 25-30 per cent with AWD practice as compared to the traditional practice of continuous submergence of paddy fields.

1.5.2 Supply-side BMPs

Artificial Recharge

Under normal field conditions a part of the rainfall and irrigation water, after meeting the ET and other needs, infiltrates into the soil surface percolates downwards and finally meets the water table to recharges the aquifers below. The rates of recharge vary greatly depending upon the soils and hydro-geological characteristics of the vadose zone and topographic conditions. CGWB estimated the rates of recharge may be 20-25 per cent in sandy soils, 1.-20 per cent in clayey regions, 5-10 per cent in weathered rocks and just 3-10 per cent in hard rock regions. Unlined canals and channels also recharge groundwater at a rate of about 15-20 ha-m/running day/ 10^6 sq m of wetted area; and these rates fall to 20% once the canals are lined. About 35 per cent of canal water and 30 per cent of the groundwater delivered at the farm also percolates down. Generally, these rates should suffice to maintain a good water balance but problems arise when we abstract/ over-exploit groundwater for irrigation purposes and other usage than the natural recharge. This is what is happening in the urban clusters and large parts of the irrigated areas in north-western and peninsular India. Artificial recharge is one measure to restore the balance between recharge and abstraction.

Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the rate of natural replenishment or percolation of surface water into groundwater aquifers, resulting in a corresponding increase in the volume of groundwater available for extraction. Artificial recharge may be enhanced through direct measures like spreading of surface water over large areas (surface basins), flooding in pits and dug-out shafts or in case of deeper layers through injecting surface water directly into aquifers through boreholes and dugwells. At domestic level, and also in urban areas, artificial recharge can be obtained through harvesting of the rainwater over the roof-tops and using it for recharge through specially constructed structures. Roads, paved surfaces and other utilities also generate large amount of surface runoff for recharge.

Central Ground Water Board (CGWB) of India prepared a "National Perspective Plan for Recharge to Ground Water by utilizing Surplus Monsoon Run-off" in 1996. The availability of non-

committed surplus monsoon run-off in 20 river basins of the country was analysed vis-a-vis the sub-surface available space under different hydrogeological situations for saturating the vadose zone to 3m below ground level. It was estimated that it is possible to store 21.4 M.ha.m of surplus monsoon runoff in aquifers, out of which 16.05 M.ha.m can be utilized. Further CGWB prepared a Master Plan for Artificial Recharge to Ground Water earlier in the year 2002. The Master Plan envisaged the number of feasible artificial recharge and rain water conservation structures in the country as 39 lakh at an estimated cost of Rs. 24,500 crores. Based on the above, various State Agencies and CGWB have taken up the construction of artificial recharge structures on a large scale under State/Central sector schemes. A revised and updated Master Plan has been prepared on the basis of hydrogeological parameters and hydrological data base available for each State (http://cgwb.gov.in/documents/masterplan-2013.pdf). In a countrywide detailed assessment, considering the aquifer characteristics, water table position and non-committed source water available for recharge, a total area of about 9.415 lakh sq.km. has been identified in various parts of country where artificial recharge to ground water is feasible. It is estimated that annually about 85,565 MCM of surplus run-off is can be harnessed to augment the ground water resource. This revised Master Plan assessed that about 1.11crore artificial recharge structures are feasible in urban and rural areas at an estimated cost of about Rs. 79,178 crores. This comprises of around 88 lakh recharge structures/ facilities utilizing rain water directly from roof top and around 23 lakh artificial recharge and rain water harvesting structures for conserving surplus runoff and recharging ground water in aquifers. The program shall have synergies with the ongoing programs of the central and state governments, MGNERGA funds and also contributions by the industry, foundations, and several civil society organisations. Several of the state governments like Delhi, Haryana, Rajasthan, Tamil Nadu etc have enacted new bye-laws under which all new buildings with roof area greater than the prescribed limit are mandated to construct roof-top rain water harvesting structures. These all are good measures and shall be helpful but not sufficient to check the declining water tables and depleting groundwater resources in the country.

U*nderground* T*aming of* F*loods for* I*rrigation and* G*roundwater* B*anks*

Water-related disasters like heavy rains, floods, and droughts have significant social, environmental and economic impacts, and there is mounting scientific evidence to suggest that their frequency and severity will continue to increase. Thus solutions to heavy rains and flooding issues can also create new opportunities during drier periods that can yield significant benefits for augmenting groundwater recharge and improved agricultural production. A novel form of such conjunctive water use management referred as "**U*nderground* T*aming of* F*loods for* I*rrigation*- UTFI**" has been devised to address the twin issues of seasonal flooding and overuse of groundwater (Pavelic et al., 2015). The concept is to capture and store high wet season flows that potentially waterlog the soils or create a flood risk takes place through groundwater recharge structures installed in the upstream areas. UTFI is a specific and unique application of managed aquifer recharge. Central to UTFI is distributing recharge-enhancing interventions like recharge wells and shafts across hydro-geologically suitable (sufficiently thick vadose zone during the recharge period and good permeability of the formation so that the recharged groundwater laterally flows faster to make room for more recharge) strategic parts of the basin (ponds, depressions, common lands). The process would provide supplies to meet additional demand during the dry season, and for this water to be recovered via agricultural wells rather than allowing surface water to concentrate and be problematic in the floodplain areas.

The pilot study implemented in Ramganga sub-basin in Uttar Pradesh observed that in the first recharge season (2015) the total recharge by the system was on average 5,670 m3 /day and for

2016 recharge season the total recharge was 5,455 m3 /day for the whole system. For a 100 days of monsoon with an uninterrupted water flow, this system can supplement 1000 mm of water to irrigate 55 ha in dry season. These benefits are an indication and can vary depending upon the site, geological conditions and pattern of rainfall. The technology has the potential to be dovetailed with the on-going watershed development or groundwater recharge schemes and implemented at scale for larger benefits. The innovation has now been selected for developing the District Irrigation Plans of UP under the PMKSY.

Photo: A pilot study on Underground Taming of Floods for Irrigation in Rampur district, Uttar Pradesh

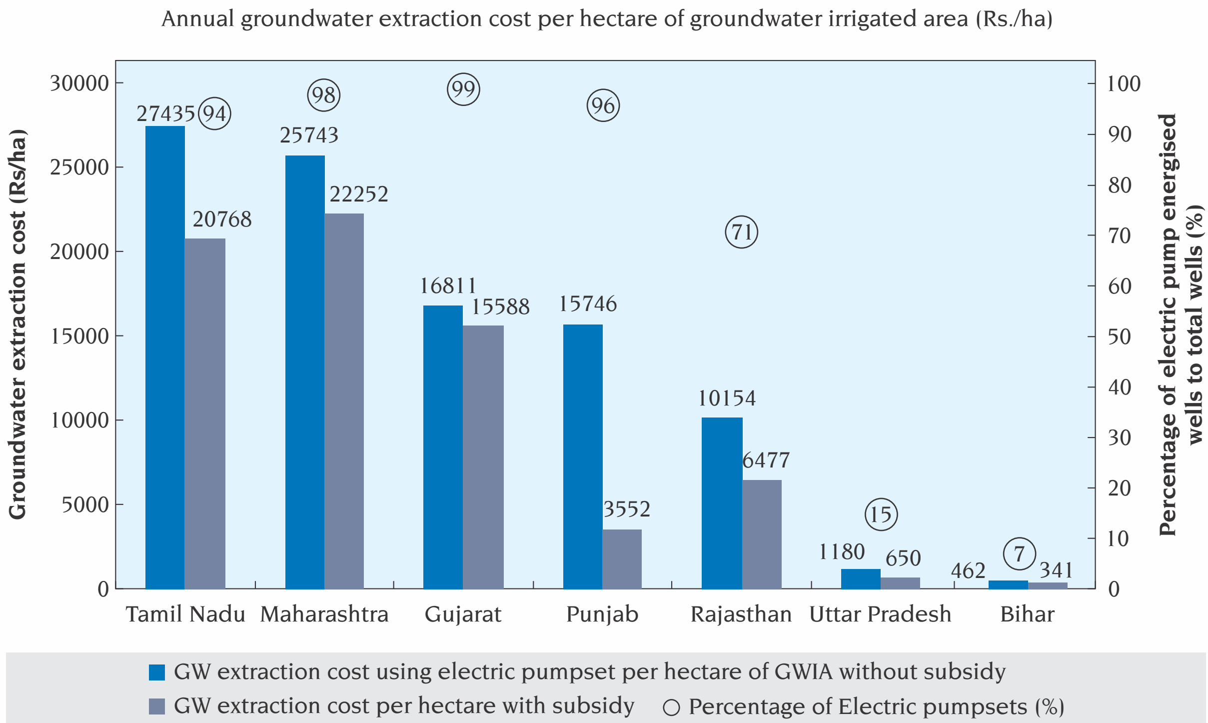
1.6 Conclusion

Irrigation has played a crucial role in increasing crop productivity and thereby profitability of farmers. By mid 1970s, groundwater irrigated area over took that of canal irrigated area and is still surging ahead with time. The inefficiencies in canal irrigation system, especially with respect to its timely availability, initiated the farmers to shift towards groundwater irrigation. Low priced and free electricity availability and high inclusiveness of the irrigators further eased the shift. Over the last four decades, the area brought under irrigation increased at the rate of 1.86 per cent mainly revolutionised by atomised groundwater irrigation through millions of wells. But this increase in irrigation coverage has been attached with negative externalities, threatening the sustainability of the groundwater resource itself as well as the agriculture.

The vulnerability of ground water resource has been associated with the existing regional hydrological status and aquifer characteristics, climate change and prevalence of perverse electricity subsidy. The cost of groundwater extraction in some of the states defined by unique aquifer characteristics were evaluated and compared with each other. Region I specified in the study correspond to states with alluvial aquifer, region II corresponds to states having semi-arid to arid climate and low recharging aquifers, region III corresponds to the states with hard rock aquifers and region IV are states mostly in the eastern region with abundant untapped groundwater resources. For cost comparison Punjab and Uttar Pradesh are taken from region I, Gujarat and Rajasthan from region II, Maharashtra and Tamil Nadu from region III and Bihar from region IV. Fig. 37 gives the summary table of the average annual cost of groundwater extraction per hectare of groundwater irrigated area powered by electric pumpsets across 6 states (with

and without subsidy). Tamil Nadu and Maharashtra having hard rock aquifers gave the highest cost values per hectare. For Uttar Pradesh and Bihar the per hectare cost of groundwater extraction was the least among the other states evaluated. However this cost corresponds to only 15 per cent of the groundwater irrigated area in Uttar Pradesh and only 7 per cent of the groundwater irrigated area in Bihar. The remaining major share of cost is contributed by diesel powered pumpsets. In Uttar Pradesh the average annual cost per hectare for diesel pumpset powered wells comes to Rs. 10,009 and in Bihar it comes to Rs. 8,905.

Figure 37: Annual cost of groundwater extraction per hectare of groundwater irrigated area (Rs./ha) powered by electric pumpsets



When compared based on cost per cubic metre of groundwater extraction, Rajasthan tops the list followed by Maharashtra and Gujarat. Wheat being the major crop cultivated in the state has lesser water requirement when compared to other major crops in other states compared. However due to the low recharge characteristic of the aquifers in states like Rajasthan, Gujarat, Maharashtra and Tamil Nadu, the proportion of dug wells with higher capital cost are predominant in these states. This leads to higher cost of groundwater extraction in these states (Fig. 38). These two reasons combined make the cost per cubic metre to be highest in Rajasthan followed by other states. Punjab, Uttar Pradesh and eastern state like Bihar with alluvial and easily rechargeable aquifers record the lowest costs among others.

Figure 39 shows the subsidy existing across states per cubic metre as well as per hectare of electricity powered groundwater irrigated area. The subsidy per cubic metre as well as the subsidy per hectare is found to be highest in Punjab. Tamil Nadu follows Punjab in terms of subsidy per hectare while Rajasthan follows in terms of subsidy per cubic metre. States like Punjab, Tamil Nadu and Maharashtra are also known for their cultivation of the water guzzling paddy and sugarcane crops. The perverse electricity subsidy existing in these states encourage

farmers to cultivate these water intensive crops, gravely threatening the groundwater resource in the state. While in states like Bihar where the groundwater availability is high with high rate of recharge, due to the low electricity subsidy per hectare the groundwater use is highly restricted. Only 7 per cent of the wells are powered by electric pumpsets in Bihar. Diesel being costlier option leads to increased cost for irrigation per hectare making farmers to opt out of the irrigating their field despite having abundant resource potential.

Figure 38: Annual cost of groundwater extraction per cubic metre of water extracted using electric pumpset in major states

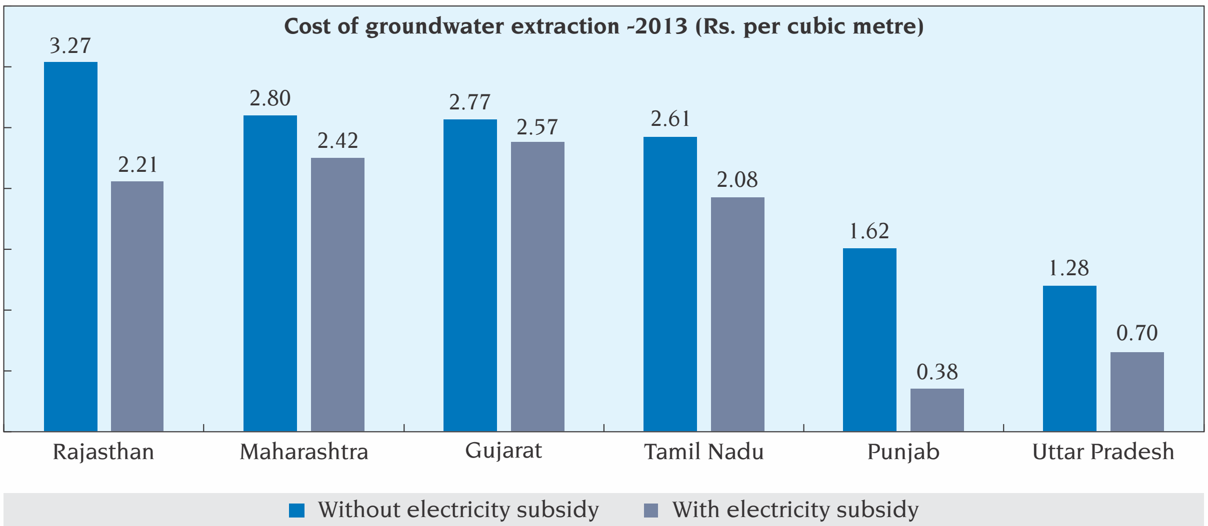
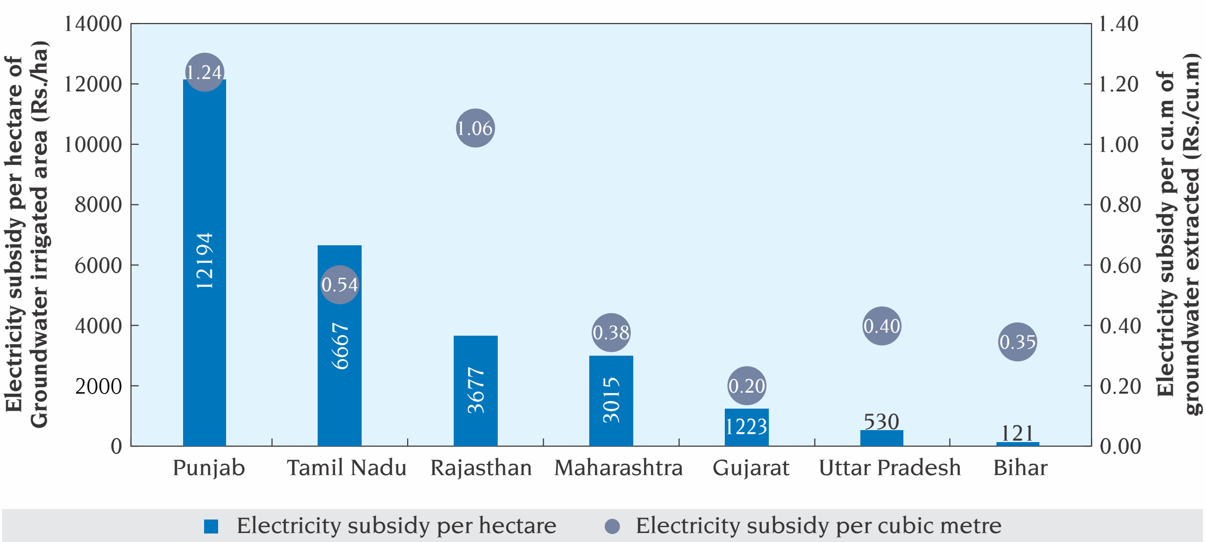


Figure 39: Electricity subsidy for groundwater extraction across major states (2017-18)



Source: Authors' Calculation

Thus sensitive and sensible policies must be adopted in the states looking into the aquifer characteristics and cost of groundwater irrigation to limit the injudicious groundwater exploitation happening in the country. It is necessary to understand that groundwater is not a free resource. In order to ensure its sustainable use, it is thus necessary to unleash and bring forth the cost of its extraction.

1.6.1 Way forward

Price reforms in power sector

Electricity subsidy has been a root cause responsible for undermining the value of groundwater resource particularly in states where the groundwater structures are majorly powered by electric pumpsets. As a result it has been difficult to inculcate the concept of sustainable groundwater use in the mind set as well as irrigation practices adopted by farmers. There is a need to bring out the cost of groundwater extraction in the states so that the community understands the wastage of water in terms of national loss and also the policy makers can frame suitable policies looking into the existing electricity price structure and subsidy pattern assigned for agriculture across states.

States like Punjab and Tamil Nadu which cultivate water intensive rice crop using groundwater resource explain the paradox between electricity subsidy and groundwater over exploitation most clearly. Not only these two states supply free electricity to agriculture but at the same time also report very high percent of over exploited groundwater blocks. On an average the cost of groundwater extraction per hectare of groundwater irrigated area powered by electric pumpsets is less by about 24 per cent than the actual cost in presence of free electricity in Tamil Nadu while it is less by about 77 per cent in Punjab. As a result despite the unsustainable groundwater exploitation in the states, farmers are reluctant to shift their cropping pattern towards less water intensive crop. The scarcity value of the resource is rarely felt in the states.

Hence price reforms have to be brought in electricity diverted towards agriculture in order to enlighten farmers about the scarcity value of the resource and encourage them to use it more judiciously and sustainably.

Direct Benefit Transfer of power subsidy

There is need to shift the price policy approach inclined towards the principle of input subsidisation to income policy approach of direct delivery of the subsidies to farmers account. This will enable market forces to determine the value of the groundwater resource reflecting the scarcity of the resource.

Re-aligning the cropping pattern with respect to sustainable groundwater use and productivity

The appropriate pricing of groundwater resource will enable the realignment of cropping pattern in tune with the availability of the groundwater resource. In regions with over exploited and critical groundwater reserve the cost of extraction will be higher in comparison with regions with abundant resource availability. This will help to shift the cropping pattern in tune with the groundwater resource availability thereby promoting sustainable resource management.

Identification and adoption of best sustainable groundwater use and water saving practices

Several demand side and supply side best management practices have been discussed in the paper which can be scaled up to different states after analysing their economic feasibility and viability and suitability to the hydrological status of the region. Investing more on innovative technologies like micro irrigation attached to groundwater systems help to reduce the groundwater use volumetrically through water saving.

"Solar as third crop" with assured feed in tariff support can serve as an opportunity to tap the abundant groundwater resource in eastern states. Replacing costly diesel pumps with solar pumps (installation or uberisation) in eastern regions will enable to increase farmers' access to groundwater resource in an economically viable way. Groundwater irrigation can help farmers to increase the area under irrigation and thereby increase the agricultural productivity and profitability.

Supply side management like constructing artificial recharge structures also enable in improving the status of existing groundwater reserve in the country.

Sensitising the community

Mass awareness building among the farmers is an effective mechanism for harnessing the voluntary actions and people's participation in water conservation, preservation, and recharging and efficient water utilisation using local technologies. Programmes like the "water campaign" initiated by NABARD can help in achieving this. Also, financial institutions like NABARD can play a significant role in setting up new projects and scaling up pilot projects gaining insights from such best management practices in suitable areas looking at the economic viability and feasibility of such projects.

APPENDIX TO PART 1

Technical Note: Annual cost of groundwater extraction

(Explained with example of cost calculation for Rajasthan)

The annual cost of groundwater extraction using electric pumpset per hectare of groundwater irrigated area is estimated as follows:

The cost of groundwater extraction has been calculated in the study mainly to emphasis the how existence of perverse electricity subsidy lead to groundwater exploitation across states. Hence the cost of groundwater extraction using electric pumpset has been calculated per hectare of groundwater irrigated area per year.

The annual maintenance cost, annual operating cost, amortised capital cost of wells and pumpsets are the main cost components used for the calculation. The different cost components have been adjusted for electric pumpsets per hectare of groundwater irrigated area.

Cost Components

1. Maintenance Charge:

Annual maintenance charge (for the groundwater extraction unit - pumpset and wells) mainly includes the repair cost of wells and pumpset, including well deepening cost. We have taken the maintenance charges as Rs. 2350 for shallow, Rs. 5900 for medium and Rs. 11800 for deep tubewells and Rs. 11800 for dugwells..

As per the 5th Minor irrigation census (reference year 2013), the maintenance charge for majority of the wells in different categories (shallow, medium, deep tubewells and dugwells) lie between Rs. 2000 to Rs. 10000, which on adjusting with All India CPI index becomes Rs. 2360 to 11800 for 2017-18. The cost of maintenance given as Rs. 17500, particularly for deepening of wells particularly in hard rock region in the NABARD published document titled “Unit cost for Investment activities for 2017-18”. However the document does not mention for which particular type of well this charge prevail.

Considering the cost values available from the two sources, we assume the maintenance charges to be around Rs. 2360 for shallow, Rs. 5900 for medium and Rs. 11800 for deep tubewells and Rs. 11800 for dugwells.

2. Capital cost for wells/ pumpsets:

The capital cost for wells/ pumpsets have been assumed as follows:

a. Dugwells

As per the NABARD's “Unit cost for Investment activities” document 2017-18, for a dugwell of depth 12m in hard rock areas, the cost comes to Rs. 154000. Further it is mentioned that for

deepening of wells the cost comes to around Rs. 10500 for 3m depth. Thus we consider that for every extra 1m depth, the cost of dugwells increases by Rs. 3500. This is the value we assume for the hard rock regions like Maharashtra and Tamil Nadu.

Similarly for alluvial formations (Punjab and Uttar Pradesh) for dugwells of depth 6m, the cost comes to Rs. 66500. Since alluvial formations will have lesser well deepening cost, we assume that for every 1m extra depth in dugwell, the cost increases by Rs. 2500.

For arid regions of Rajasthan and Gujarat we take the cost for 12m depth dugwell as the average of dugwell cost in the 2 regions (with hard rock and alluvial aquifers). This comes to Rs. 117750 for 12 metre depth .For every additional metre depth the cost is assumed to increase by Rs. 3000.

The depth of dugwells for the states is taken from the 5th Minor irrigation census.

b. Tubewells

Mainly 3 types of tubewells are considered in the study with reference to the details given in 5th Minor Irrigation Census. Shallow tubewells have depth <35m, Medium tubewells have depth between 35m and 70 m and Deep tubewells have depth >70m.

According to "Unit cost for Investment activities 2017-18", for a borewell of depth 80m the cost is taken as Rs.71000 for hard rock region. Since the depth mentioned is 80m, we take this as the cost of deep tubewell. It is further given in the document that for hard rock regions the cost increases by Rs. 700 for every additional one metre depth. It is also given in the document that for a 9m deep filter point tubewell the cost comes to Rs. 17000. Filter tubewells mostly operate in coastal areas and hence we assume this as the cost of tubewells in alluvial formations. Also we assume that in alluvial formations the cost increases by Rs. 500 per additional 1 m depth of wells (lesser than in Hard rock region). Thus in alluvial formation for 80 m depth tubewells we estimate the cost to be Rs. 52500. We take the cost in arid regions of Rajasthan and Gujarat to be an average of the cost in the other 2 regions and it comes to Rs. 61750 for 80 m deep tubewells, increasing at the rate of Rs. 600 for every additional 1 metre depth.

c. Pumpsets

We have assumed that 5 HP pump is used to pump water from a dugwell and shallow tubewell, while a 7.5 HP pump and 10 HP pump is used to pump water from a medium and deep tubewell. Cost for a 5 HP monoblock centrifugal electric pump is taken as Rs. 27500 (as given in NABARD document). Cost for a 5 HP Submersible pumpset (with accessories) is given as Rs.45000 in the document. For a 7.5 HP and 10 HP submersible pumpset (with accessories) we take a slightly higher value than the 5 HP pump and fix it to Rs. 48000 and Rs. 55000 respectively.

The capital costs and maintenance cost are further adjusted to get the cost per hectare of groundwater irrigated area. Once this is done the capital costs per hectare of groundwater irrigated area is amortised to get the annualised capital cost of wells/ pumpsets.

$$\text{Amortised cost} = \text{Capital cost X } \left\{\frac{r(1+r)^n}{(1+r)^n-1}\right\}$$

r = opportunity cost of capital

n = life of wells/ pumpset

Life of dugwells and tubewells are given as 12 to 16 years in the NABARD document. Based on this we assume life of dugwells is taken as 20 years, shallow tubewells = 10 years, medium tubewells = 15 years, eeptubewells = 20 years. In hard rock region where issue of well failures is high we assume the life of medium tubewells to be 10 years and for deep tubewells and dugwells we assume it to be 15 years.

Adjusting per hectare of electric pump irrigated area - Capital and maintenance cost

For capital cost of pumps and wells and the maintenance cost we carry out this adjustment as follows: (Source for data: 5th Minor irrigation census, reference year 2013).

(a) Firstly, divide the number of wells (dugwells/shallow tubewells/ medium tubewells/ deep tubewells) in the state (in use and temporarily not in use wells) with the area irrigated by these wells (potential utilised) for the year. This gives number of wells per groundwater irrigated area (WPGWIA)

(b) Secondly find the ratio of the number of wells operated with electric pumpset (one energy source) by number of wells in state (having one energy source). This gives the ratio of electric pumpset to all pumpset (REPAP) in state.

(c) Multiplying WPGWIA and REPAP gives the number of electric operated wells per hectare of groundwater irrigated area, represented as EWPGWIA.

The capital cost and maintenance cost are multiplied with EWPGWIA to find out the cost per hectare of groundwater irrigated area.

3. Operating cost of pumpsets

Operating cost is mainly the cost of electric power used for extracting water required for irrigating 1 hectare of groundwater irrigated area.

(a) Firstly, we estimate the weighted average of irrigation water applied per hectare for major crops in the state. The weights used are the ratio of irrigated cropped area (irrespective of source of irrigation) for ith crop (IACi) to gross irrigated area (GIA) in the state. We get the Irrigation water applied per hectare of irrigated area. We assume that electricity consumption in agriculture is only for irrigation. For instance in Rajasthan the value comes to 4172 cubic metre per hectare of irrigated area.

(b) This weighted average of irrigation water applied per hectare (4172 cubic metre) is assumed to come from groundwater source. Thus this becomes the irrigation water applied per hectare of groundwater irrigated area.

(c) However, all the groundwater used for irrigation is not pumped by electric pumpsets. We need to further adjust the value to get the quantity of groundwater water pumped by electric pumpset. For this we multiply it with REPAP. In case of Rajasthan REPAP = 0.71. Thus the total water pumped using electric pumpset per hectare of groundwater irrigated area becomes 2962 cubic metre.

(d) Energy required for pumping water is calculated as follows:

Energy required for pumping is calculated considering the horsepower of pumpsets and hours the pumpset is operated for extracting the given quantity of water.

Energy for pumping (kwh) = HP of pump X 0.75 Kw X Hours operated

(Conversion unit : 1 HP = 0.75 KW)

For calculating the hours operated we use the formula:

Hours operated by pumpset = [Quantity of water pumped (in cubic metre) X1000]÷ [Discharge rate of pumpset (in litres per second) X 3600]

Discharge rate of pumpsets is calculated from the formula given in the website (https://www.ajdesigner.com/phppump/pump_equations_discharge.php#ajscroll) by providing the horse power and the head of the pumpsets.

The horsepower for dugwells and shallow tubewells are taken as 5 HP, for medium tubewell it is taken as 7.5 HP and for deep tubewell it is taken as 10 HP.

(e) Energy required for pumping is multiplied with the cost of power supply(in Rs/ kwh) (Source: http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf) in state to get the pumpset operating cost without subsidy, while the energy required is multiplied by state -level agricultural tariff (in Rs./kwh) to get the operating cost with subsidy. The cost of power supply and agricultural tariff corresponds to the year 2013-14. We have adjusted it with CPI index of corresponding state to get the cost for 2017-18.

The operating cost thus pertains to water pumped using electric pumpset per hectare of groundwater irrigated area

The summation of the amortised capital cost of well and pumpset, operating cost of pumpset and the maintenance cost of groundwater extraction unit gives the cost of groundwater extraction per hectare of electric pump irrigated area.

This value when divided by the irrigation water pumped per hectare of electric pump irrigated area (for different types of wells), we get the cost of groundwater extraction per cubic metre of water pumped using an electric pumpset.

Inorder to calculate the cost of groundwater extraction per hectare of electric pumpset irrigated area we divide the "cost of groundwater etraction using electric pumpset per hectare of groundwater irrigated area" with REPAP.

Annual cost of groundwater extraction for Rajasthan (per hectare of electric pump irrigated area)

Part I: Operating cost of pumpset

Weighted average of irrigation water applied per hectare			
Crops	Weights (Proportion of irrigated area of ith crop to gross irrigated area)	Irrigation water applied per hectare	Weights * Irrigation water applied per hectare
Wheat	0.32	3750	1211
Oilseeds	0.30	3000	915
Fodder crops	0.09	11250	959
C&S	0.08	4500	363
Pulses	0.08	2250	175
Cotton	0.04	4500	167
Non-food crops	0.02	2250	44
F&V	0.02	15000	238
Bajra	0.02	2250	34
Barley	0.03	2250	68
Weighted average of irrigation water applied per hectare of groundwater irrigated area (cu.m)			4172

Share of electric pumpsets powered dugwells, shallow tubewells, medium tubewells and deep tubewells and the quantity of water pumped by the per hectare of groundwater irrigated area

	Dugwells	Shallow tubewells	Medium tubewells	Deep tubewells
REPAP	0.58	0.39	0.87	0.96
Quantity of water pumped by electric pumpsets (cu.m/hectare)	2420	1627	3630	4005

Groundwater discharge rate & Hours operated				
	Dugwells	Shallow tubewells	Medium tubewells	Deep tubewells
Litre per second	15	17	10	7
Hours operated for pumping 2962 cu.m water	55	48	82	118

Energy Consumed and electricity cost				
	Dugwells	Shallow tubewells	Medium tubewells	Deep tubewells
Hp of Pump	5	5	7.5	10
Hours operated	45	27	101	159
Energy consumed per hectare of electric pump irrigated area (kwh)	168	100	567	1192
Weights (used for wells)	0.48	0.01	0.12	0.38
Average energy consumed (kwh)				
Electricity charge without subsidy (paise/ kwh) = (operating cost)				
Total Electricity cost (Rs.) per hectare of electric pump irrigated area	1443	856	4869	10234
Average total electricity cost (Rs.) per hectare	4964			
Electricity charge = Electricity charge with subsidy (paise/ kwh)= (agricultural tariff)	214			
Total Electricity cost (Rs.) per hectare of electric pump irrigated area	374	222	1263	2654
Average total electricity cost (Rs.) per hectare	1287			

Part II: All costs used in estimating groundwater extraction cost

In rupees per hectare of electric pump irrigated area					
	Average	Dugwells	Shallow tubewell	Medium tubewell	Deep tubewell
Capital Cost of wells		29086	1850	8935	9426
Capital cost of pumpset		5008	1847	8834	7390
Operating cost without subsidy	4964	1443	856	4869	10234
Maintenance cost	1766	2149	175	1086	1586
Weights		0.48	0.01	0.12	0.38
Operating cost with subsidy	1287	374	222	1263	2654

Source: *https://www.ajdesigner.com/phppump/pump_equations_discharge.php#ajscroll*

Part III: Results

Cost of groundwater extraction per hectare of electric pump irrigated area and per cubic metre of water (Discount rate = 10%)

	Average	Dugwells	ST	MT	DT
Maintenance cost of well (Rs./ha)	1766	2149	175	1086	1586
Operating cost without subsidy (Rs./ha)	4964	1443	856	4869	10234
Amortised Capital cost of well (Rs./ha)	2400	3824	301	1175	1107
Amortised Capital cost of pumpset (Rs./ha)	1024	815	301	1438	1203
Total cost for pumping irrigation water per hectare without subsidy (Rs./ha)	10154	8231	1632	8568	14130
Water pumped (in cu.m) per hectare		2420	1627	3630	4005
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [without electricity subsidy]	3.3	3.4	1.0	2.4	3.5
Operating cost with subsidy(Rs./ha)	1287	374	222	1263	2654
Total cost of pumping with subsidy(Rs./ha)	6477	7162	998	4961	6549
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [with electricity subsidy]	2.2	3.0	0.6	1.4	1.6

Cost of groundwater extraction per hectare of electric pump irrigated area and per cubic metre of water (Discount rate = 8%)

	Average	Dugwells	ST	MT	DT
Maintenance cost of well (Rs./ha)	1766	2149	175	1086	1586
Operating cost without subsidy (Rs./ha)	4964	1443	856	4869	10234
Amortised Capital cost of well (Rs./ha)	2510	3894	327	1312	1262
Amortised Capital cost of pumpset (Rs./ha)	1113	886	327	1563	1308
Total cost for pumping irrigation water per hectare (Rs./ha)	**10353**	**8372**	**1685**	**8831**	**14390**
Water pumped (in cu.m) per hectare		2420	1627	3630	4005
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [without electricity subsidy]	**2.9**	**2.5**	**0.7**	**2.5**	**3.7**
Operating cost with subsidy	1287	374	222	1263	2654
Total cost of pumping with subsidy	**6676**	**7304**	**1051**	**5224**	**6809**
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [with electricity subsidy]	**2.3**	**3.0**	**0.6**	**1.4**	**1.7**

Cost of groundwater extraction per hectare of electric pump irrigated area and per cubic metre of water (Discount rate = 12%)

	Average	Dugwells	ST	MT	DT
Maintenance cost of well (Rs./ha)	1766	2149	175	1086	1586
Operating cost without subsidy (Rs./ha)	4964	1443	856	4869	10234
Amortised Capital cost of well (Rs./ha)	1915	2963	276	1044	960
Amortised Capital cost of pumpset (Rs./ha)	937	746	275	1317	1101
Total cost for pumping water per hectare (Rs./ha)	9583	7301	1582	8316	13881
Water pumped (in cu.m) per hectare		2420	1627	3630	4005
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [without electricity subsidy]	3.0	3.0	1.0	2.3	3.5
Operating cost with subsidy (Rs./ha)	1287	374	222	1263	2654
Total cost of pumping with subsidy (Rs./ha)	5906	6232	947	4709	6301
Cost of groundwater extraction per cu.m of water (Rs./cu.m) [with electricity subsidy]	2.0	2.6	0.6	1.3	1.6

PART 2

BRIDGING THE GAP BETWEEN IRRIGATION POTENTIAL CREATED AND UTILIZED

BRIDGING THE GAP BETWEEN IRRIGATION POTENTIAL CREATED AND UTILIZED

2.1 Introduction

Part 1 dealt with the challenges in ground water. In this part, point of focus shall be canal water which appropriates a sizable portion of public money. Before we get into the challenges, let us have a look at the overall canal irrigation situation in India.

As per the existing technology, India's Ultimate Irrigation Potential (UIP) is 139.89 Mha of which 46 per cent is from ground water and the rest is from surface water. Presently, India has a net irrigated area of 66.7 Mha which is 20.6 per cent of the world's total net irrigated area, next only to China at 69.0 Mha (21.3 per cent of the world share) (The World Factbook, 2012). However, share of surface irrigation to the net area irrigated by all sources has been on continual decline (Fig. 8) in India. In spite of massive public expenditure CAGR for canal irrigation has been only 0.6 per cent (1973-74 to 2012-13) due to system deterioration and poor operations, lag in completion of projects and farmers apathy due to poor service delivery. Interestingly, CAGR for groundwater development during the same period has been 2.95 per cent and 63 per cent of irrigated area is now irrigated by ground water as the users have better control and on- demand availability. A critical area of concern is improving the efficiency and performance of public canal irrigation systems by improving the conveyance and distribution of water to the farmers, reduce the unproductive losses at all levels and bridge the ever widening gap between irrigation potential created (IPC) and irrigation potential utilized (IPU) (Fig 40).

2.1.1 IPC-IPU Gap Situation in India

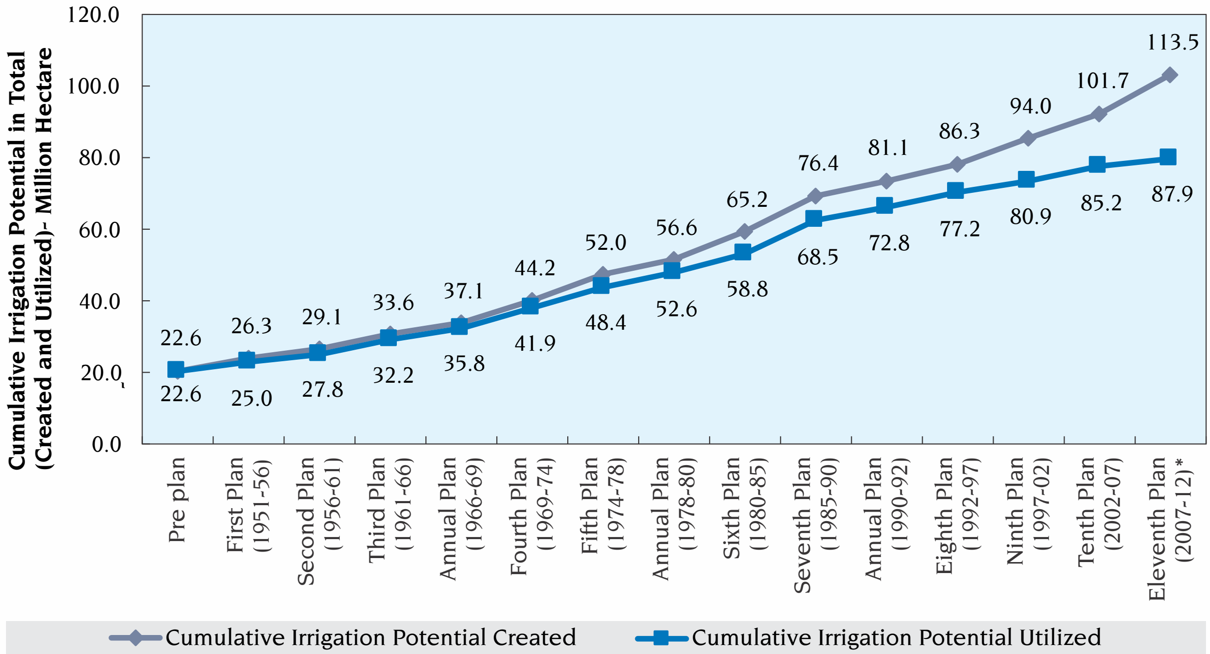
This gap is generally expressed as the difference between IPC and IPU as a percentage of IPC. According to the Ministry of Water Resources, there still is a gap of 22.5 per cent between the IPC and IPU. The cumulative percentage gap is about 27 percent when only MMI projects are taken into consideration. In the pre-plan period, there was no gap between irrigation potential created and utilized in India and all the created potential was fully utilized. In fact, for minor irrigation, there was no gap between IPC and IPU till start of the sixth plan (1979-80). For Major and Medium irrigation (MMI), however, we observe a completely different story. The gap between potential created and utilized started right from the beginning. In the first plan, there was 10 per cent cumulative gap between IPC and IPU (based on IPC) which declined continuously till 1968-69 (to 7.5 percent) and started rising thereafter. Till end of the eleventh plan, the gap was 27.1 per cent. The same gap for MI started from the sixth plan and at the end of 11th plan stands at 19.3 percent (Fig. 41).

The existing gap between Irrigation Potential Created and Irrigation Potential Utilized is 25.6 Mha (more than the net irrigated area of 20.2 Mha in Pakistan), amounting to 22.5 per cent of the total irrigation potential created in India.

This gap between IPC and IPU is making public irrigation costlier to the government than it should be had the gap been timely closed. It is also proving costly to the farmers in that they have to resort to expensive groundwater extraction for meeting the crop water needs. In the end, this process is leading to environmental damage due to water-logging and salinization in the irrigation commands, carbon-emissions through the use of power/fuel, and over extraction of groundwater in the non-command areas. Hence it is clear that closing or at least bringing down

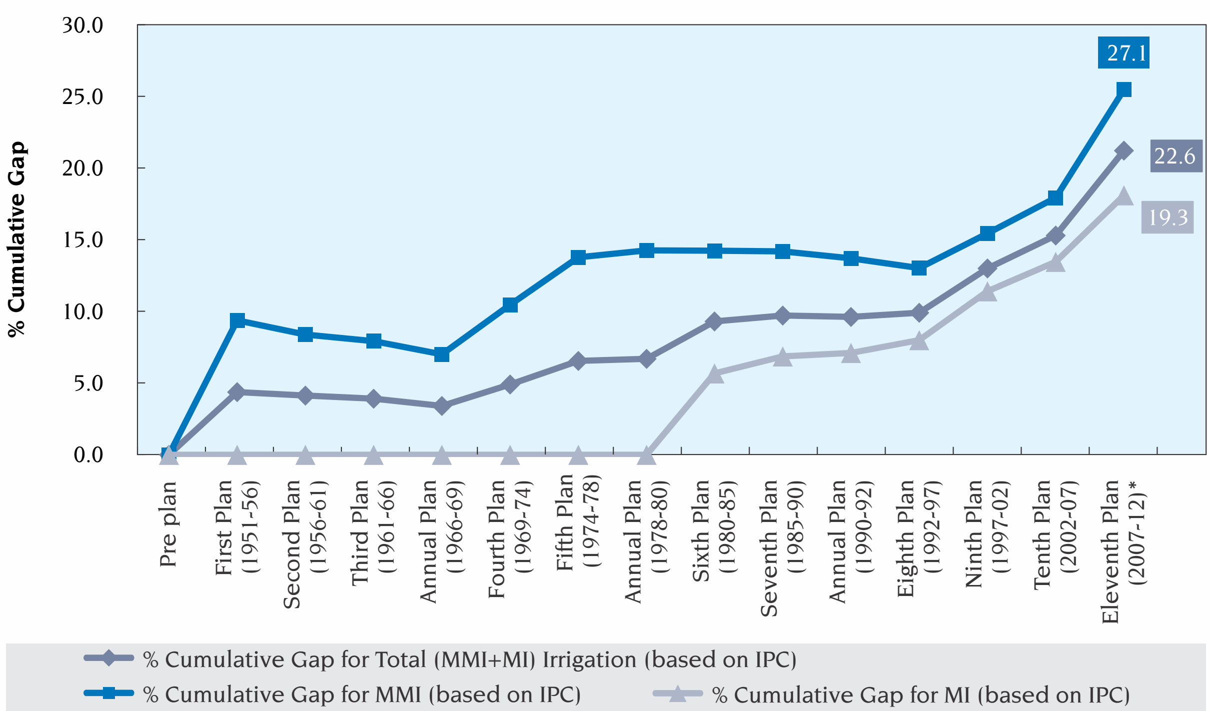
the gap between IPC and IPU proactively will be a good policy in that it will bring larger social, environmental and economic benefits.

Figure 40: Gap between IPC and IPU in India: Plan-wise



Source: Constructed using data from Central Water Commission

Figure 41: Plan-wise cumulative gap for MMI, MI and total irrigation: All-India



Source: Constructed using data from Central Water Commission

Governments, both central and state, each year, spend a lot on public irrigation systems. The capital expenditure and working expenses on Major and Medium Irrigation systems were Rs. 36597.13 crore and Rs. 21853.08 crore respectively, in 2013-14 in current prices (GoI 2015a). Even by very conservative estimates (ninth Plan cost values) the unutilized potential of created irrigation has a sunk cost of Rs. 3, 29,186 crore which can create huge benefits for the farmers when provided with assured irrigation.

The problem with public irrigation is not in the amount of money spent *per se* but in creating suitable mechanisms, institutions and interventions for last mile service delivery system of canal water. That, along with the fact that the head-users of canal water uses the same to produce water-intensive crops resulting in inequity of water distribution between head, middle and tail-end users, create a situation where there is gap between irrigation potential created (IPC) and irrigation potential utilized (IPU). According to the ministry of Water Resources, there still is a gap of 22.5 per cent between the IPC and IPU. The cumulative percentage gap is above 27 percent when only Major and Medium Irrigation projects are taken into consideration. Further sample studies of the irrigation projects have revealed that proportionately much larger gap exists for the Major Irrigation projects than the Medium Irrigation Projects. Based on a number of benchmarking studies for the irrigation projects, CWC concluded that overall efficiency of the surface water systems varies between 30-65 per cent, (CWC, 2014) with lower efficiency values for the MMI projects

There have been studies commenced by the Ministry of Water Resources (conducted by Indian Institutes of Management: Bangalore, Ahmedabad, Lucknow) to address the issues of widening gap between IPC and IPU. They have discussed various issues associated with IPC and IPU, gross irrigation and net irrigation, inconsistencies in data etc. They also attempted to identify irrigation potentials that are created but have never utilized/ not utilized regularly or have gone to disuse for different reasons. Their studies indicate that lack of proper operation and maintenance, incomplete distribution system, non-completion of command area development, changes in cropping pattern, and diversion of irrigated land to other purpose explained the gap. In their selected samples, 40 per cent of the gap was due to poor maintenance and 25 to 40 per cent due to incomplete distribution system. Both of these are in the control of the project authorities and available with better maintenance and execution of projects (Planning Commission, 2009). There have also been technical papers which assessed the IPU for major irrigation projects (Shanker 2017; for example). There has been stakeholders' consultation (organized by the World Bank group, 2018) regarding how to improve the service delivery system in India. But, there is a general lack of studies which look at the IPC-IPU Gap and assess the time and cost over runs of the projects and their economic implications.

2.1.2 Objective of the Study

In this background, Part 2 aims to look into the current delivery systems of water in public irrigation systems. The broad objective is to dig deeper into the issues of irrigation potential created and utilized and also to comment on the basic methodology for estimating the IPC itself in the first place. The study will also concentrate on time and hence cost over-run aspects of selected irrigation projects. More particularly, the points of focus of the study shall be:

i. Find out the status of gap between irrigation potential created (IPC) and irrigation potential utilised (IPU): state-wise, region-wise, plan-wise and resource-wise.

ii. Estimate the cost of public irrigation potential creation and utilization.

iii. Estimate time and cost over-runs of selected irrigation projects and comparing their performances before and after NABARD started to fund them through Long Term Irrigation Fund (LTIF) as part of the *Pradhan Mantri Krishi Sinchayee Yojana- Har Khet ko Pani* component.

iv. Suggest suitable policies to reduce IPC- IPU gap.

2.1.3 Structure of Part 2

This part is arranged as follows:

The next section describes the IPC-IPU gap story in India- state-wise, plan-wise and resource-wise. Section 2.3 deals with cost of creation and utilization of MMI projects. Section 2.4 describes the government initiatives taken towards bridging the gap, namely, Accelerated Irrigation Benefit Programme (AIBP) and its current status in detail. Section 2.5 discusses selected MMI irrigation projects in detail to find out their status before and after their recent prioritized status. It is followed by section 2.6 discussing possible reasons for the gap in creation and utilization and suggesting policy measures to bridge the gap.

2.2 IPC-IPU Gap Story: State-wise, Plan-wise and Resource-wise

2.2.1 Selection and Grouping of States

In the earlier section, we see that the gap story in MI basically starts from the 6th FYP. In this section we shall be observing trend in the same for selected states since the 6th FYP for MMI as well as MI. For the purpose of analysis of gap in this paper, we have grouped major Indian states in four regions:

(i) Northern Region: Consists of Haryana, Punjab and undivided Uttar Pradesh (Undivided UP; that is, the total area of Uttar Pradesh and Uttaranchal) which has a large irrigation coverage

(ii) Eastern Region: Comprised of undivided Bihar (Bihar + Jharkhand), Odisha and West Bengal, with comparatively low irrigation coverage but higher rainfall.

(iii) Southern Region: Consists of Andhra Pradesh, Karnataka and Tamil Nadu which place lot of emphasis on irrigation creation.

(iv) Western Region: Includes Gujarat, undivided Madhya Pradesh (undivided MP; that is Madhya Pradesh + Chhattisgarh), Maharashtra and Rajasthan have semi-arid climate, generally face droughts and have medium to low irrigation coverage.

Map 4 shows the grouping of the states.

It is to be noted that we have omitted some major states like Himachal Pradesh, Assam and Kerala from the gap analysis. The reason behind this is we have selected only those states under consideration for the analysis and policy formulation which have IPC of more than one million ha upto the 11th FYP. Above mentioned states meet that criterion.

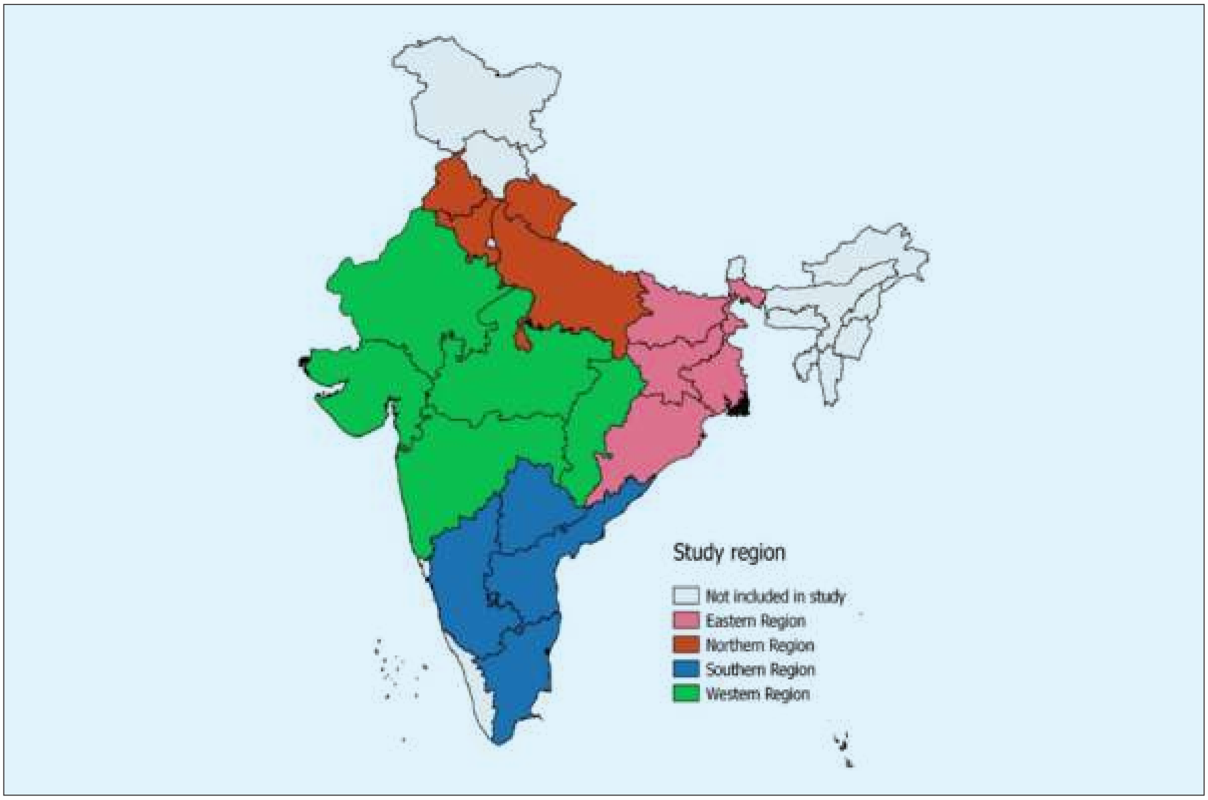
Although some states are not considered here, these thirteen states constitute a sizable proportion of total UIP[18] and IPC of the country. They consist of 96.1 percent of UIP in MMI and

[18]Ultimate Irrigation Potential (UIP): It is the gross area that can be irrigated from a project in a design year for the projected cropping pattern and assumed water allowance on its full development. The gross irrigated area will be aggregate of the areas irrigated in different crop seasons, the areas under two-seasonal and perennial crops being counted only once in the year. The UIP of India is the sum of all the potential irrigation projects in the country.

96.2 percent of UIP in MI. Additionally, these states account for 96.3 percent of the country's IPC in MMI and 98.8 percent of the same in MI.

If we look at the regions from the point of view of topography, most of the Deccan Plateau falls in the western and southern regions. On the other hand, eastern and northern region falls mostly under the Indo-Gangetic Alluvial Plains. Eastern and northern regions thus have the benefits of access to large perennial rivers while the other two regions depend on seasonal rainfed rivers and streams.

Map 4: Grouping of the selected states

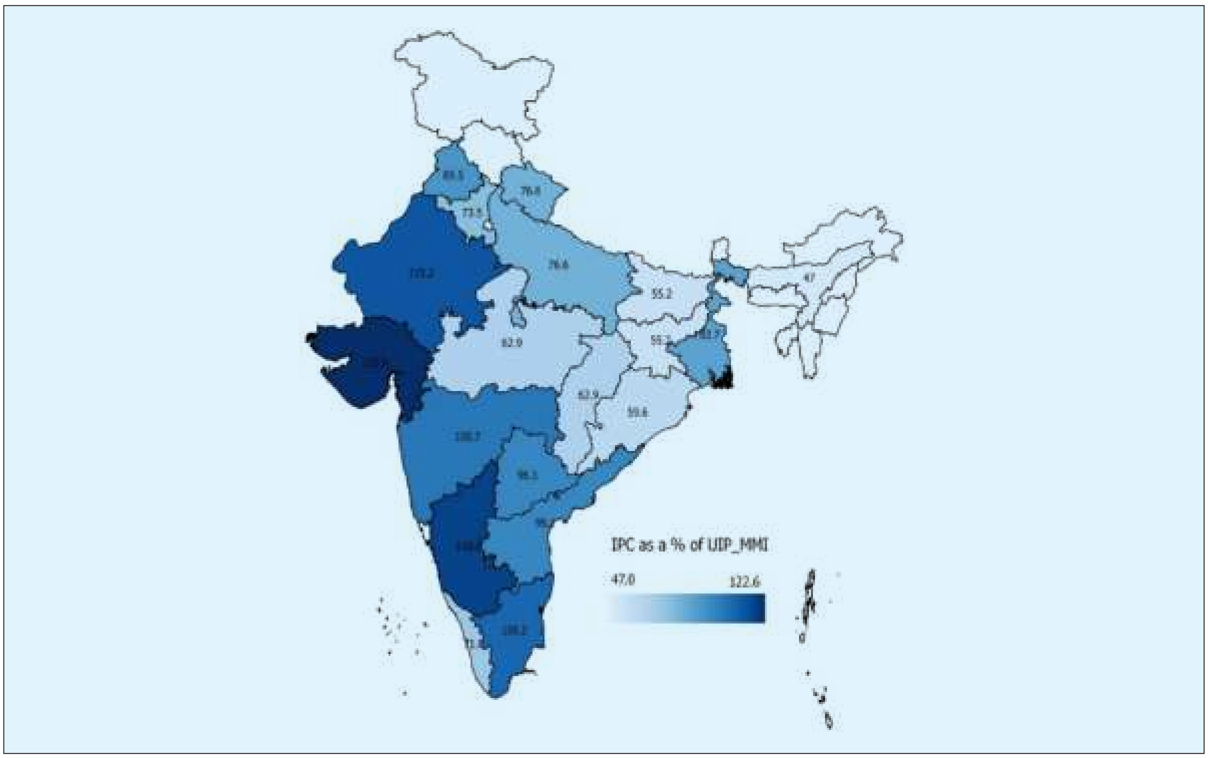


2.2.2 Gap between Irrigation Potential Created and Utilized in Case of Major and Medium Irrigation Projects

As mentioned earlier, India's Ultimate Irrigation Potential (UIP) is 139.89 Mha of which 46 per cent is from ground water and the rest is from surface water. The UIP from major and medium surface irrigation is 58.47 Mha of which 47.97 Mha has been created till end of the eleventh plan (2011-12). While cumulatively for all India, 82.05 percent of UIP has already been created till 2011-12 for major and medium irrigation (MMI), there is huge variation state-wise. There are seven states which apparently have created more than their UIP (namely, Jammu & Kashmir, Gujarat, Karnataka, Rajasthan, Chhattisgarh, Tamil Nadu and Maharashtra), there are states like Assam (47 percent) and Madhya Pradesh (52 percent) where around half of the UIPs have been created (Map 5; Appendix 1). States creating more than their UIPs might indicate that it is time to reassess the state-wise irrigation potentials, at least for those particular states.

Of course, not all of the irrigation potential created is utilized. At an all India level, almost 73 percent of potential created is being utilized for MMI. Again, there are huge state level variations. Tamil Nadu and Punjab use 98.7 percent and 93.5 percent of the created potential, respectively while there are states which use less than half of the potential they have created (Himachal Pradesh, Assam, Jharkhand and Madhya Pradesh use only 27, 46.2, 46.3 and 46.8 per cent, respectively (Appendix 1). Creation of suitable mechanisms, institutions and last mile service delivery system of canal water are lacking in India. That, along with the fact that the head-users of canal water uses the infrastructure to produce water-intensive crops resulting in inequity of water distribution between head and tail-end users, create a situation where there is the gap between irrigation potential created (IPC) and irrigation potential utilized (IPU).

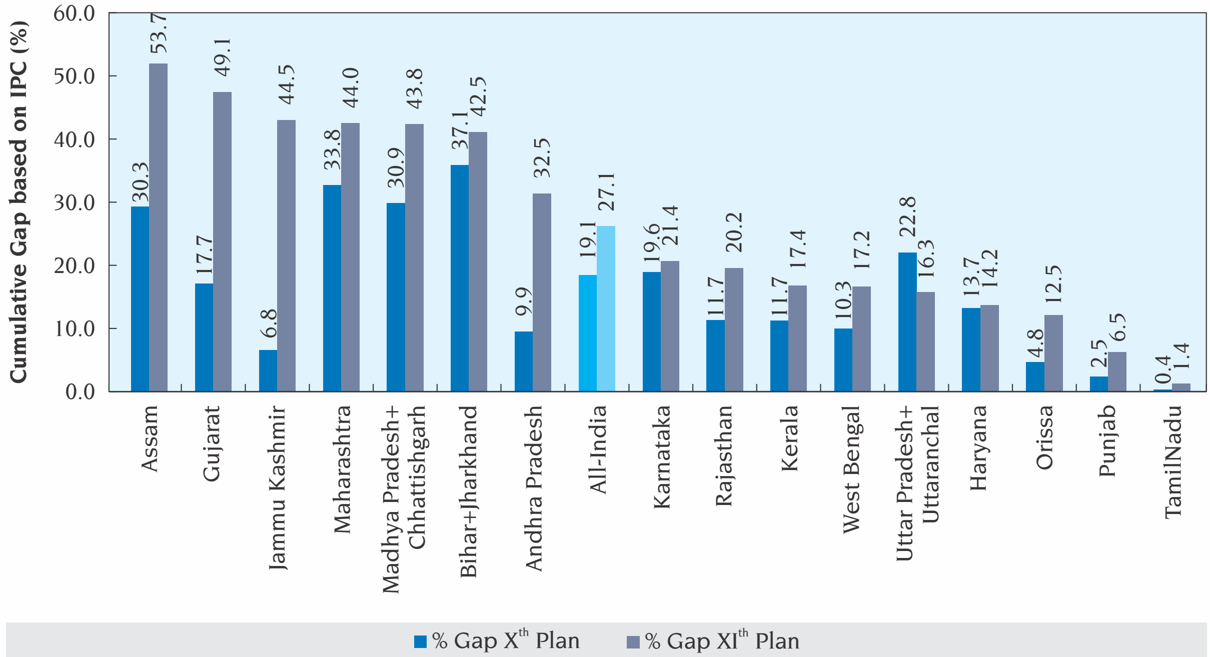
Map 5: IPC as a percentage of UIP for MMI



State-wise Percent Cumulative Gap:

As we have seen, at all-India level, at the end of eleventh plan, there was a 22.6 percent gap in IPC and IPU for MMI. State-wise, the gap varies a lot. In the 10th plan, the gap varied from 37.1 percent in the undivided Bihar area (for Bihar and Jharkhand; taken together) to 0.4 percent in Tamil Nadu. In the 11th Plan, however, the gap has risen significantly. This is mainly due to the fact that, although IPC has increased significantly in 11th plan for many states, IPU did not increase much over that period of time. In the 11th plan the percentage cumulative gap ranged from 53.7 percent in Assam to 1.4 percent in Tamil Nadu. (Figure 42)

Figure 42: State-wise percent cumulative gap between IPC and IPU for MMI in the X[th] and XI[th] Plan



Source: Constructed using data from Central Water Commission

Region-wise Variation in IPC-IPU Gap in case of MMI:

We also consider the region-wise cumulative percentage gap. The main reason for this is different regions having different soil types, cropping patterns and institutional mechanisms. Also, the IPC and IPU values in regions vary widely.[19] For this, we consider the important states in four regional divisions. The northern region consists of Haryana, Punjab and Uttar Pradesh (the area comprising Uttar Pradesh and Uttarakhand); the eastern region consists of Bihar (the area comprising Bihar and Jharkhand), Odisha and West Bengal; the southern region consists of Andhra Pradesh, Karnataka and Tamil Nadu; and the western region consists of Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. We leave out union territories, the north eastern states, Himachal Pradesh, Sikkim, Goa and Kerala because their potential created and utilized areas are very low. We consider the gaps in 11[th] plan.

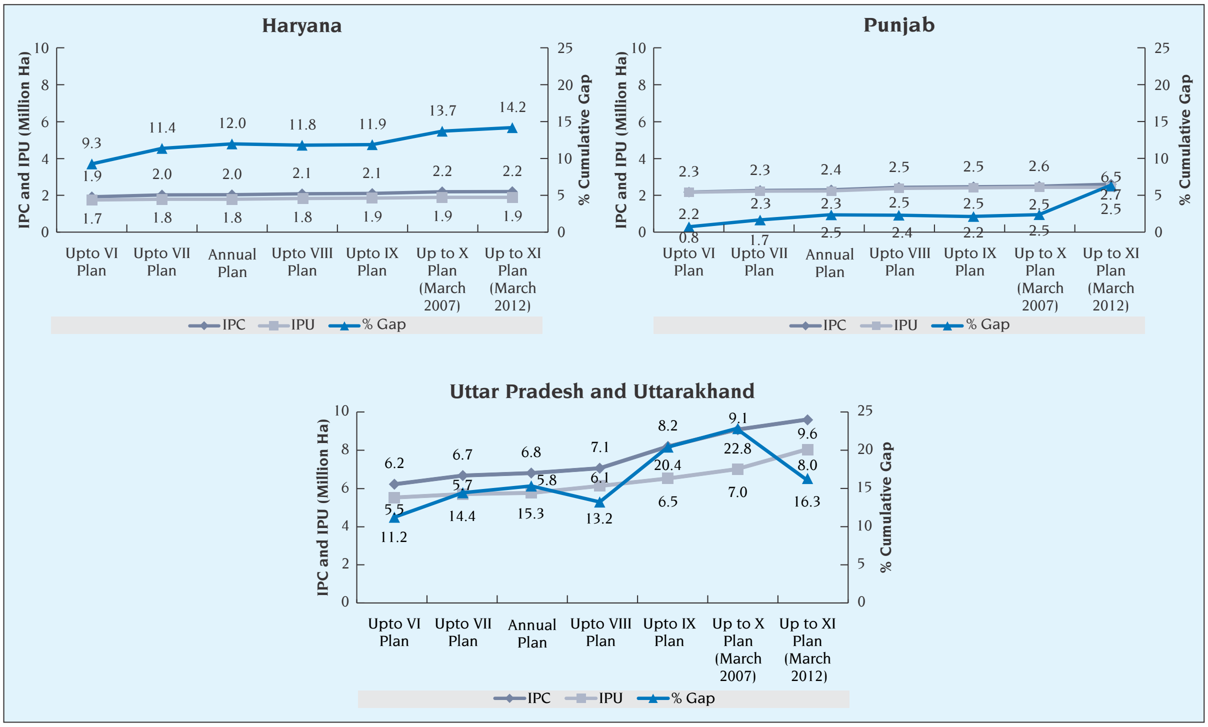
The main observation from the state-wise and region-wise analysis is that the gaps are increasing in general, or since the tenth plan. However, we should keep in mind that sudden jump in gap in 11[th] Plan in many states might be due to availability of only provisional data for IPU.

State-wise gaps are depicted in the following figures 43 to 46.

State-wise Gaps in MMI: Northern Region

[19] IPC and IPUs vary state-wise as well but because of topographical similarities region-wise, it makes more sense to compare the gaps region-wise rather than comparing all-states together.

Figure 43: State-wise IPC-IPU Gap in MMI: Northern Region

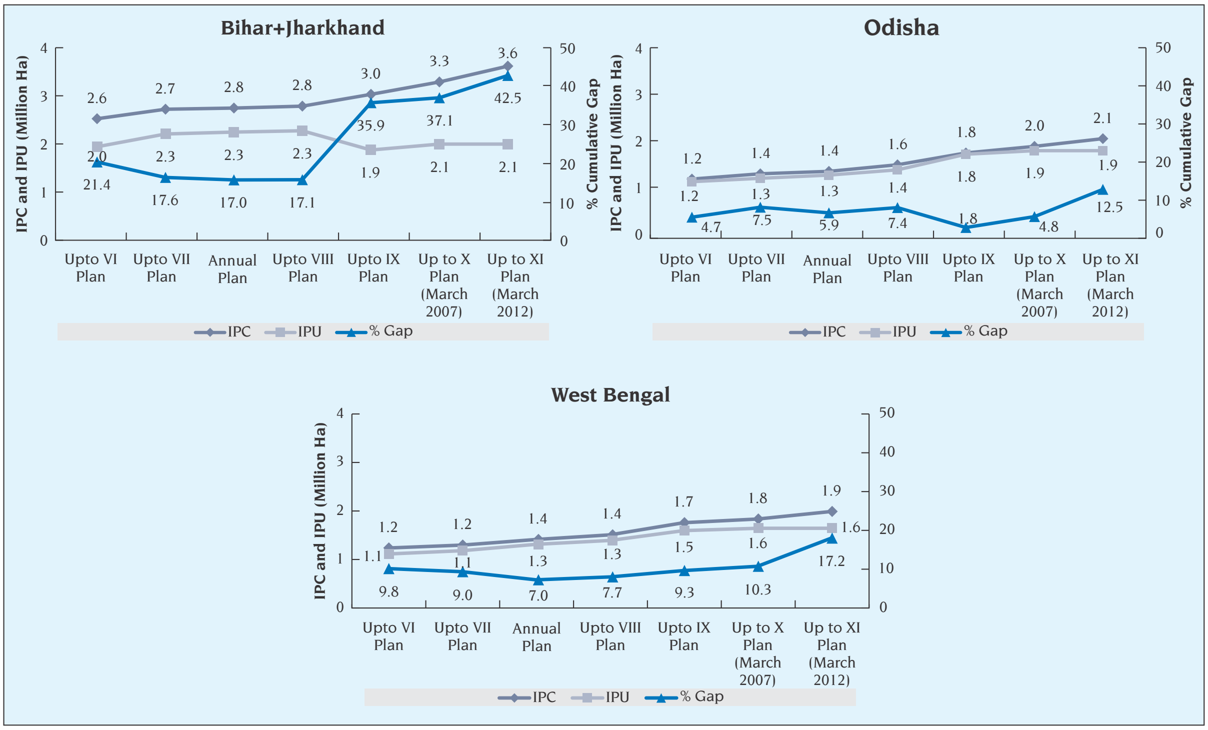


The highest and lowest percent gaps between IPC and IPU in northern region are observed in the undivided UP region and Punjab, respectively. However, the gap in the undivided Uttar Pradesh region has declined in the 11th Plan. This is a unique case for MMI. This is the only state in India which experienced a lowering of the gap.

Punjab has done really well in keeping the per cent gap at a low level. In fact, Punjab is the state with the lowest percentage gap in the region (6.48 percent) in 11th Plan as well as in the earlier plan periods in northern region. The gap was even lower in the earlier periods. However, even if the per cent gap has increased in the 11th Plan, the absolute gap between IPC and IPU in Punjab is really low (0.17 Mha). Among the thirteen major states considered in this paper for looking into their IPC-IPU gap situation, Punjab has the second lowest per cent gap-second only to the near perfect utilization of created potential situation in Tamil Nadu.

State-wise Gaps in MMI: *Eastern Region*

Figure 44: State-wise IPC-IPU Gap in MMI: Eastern Region



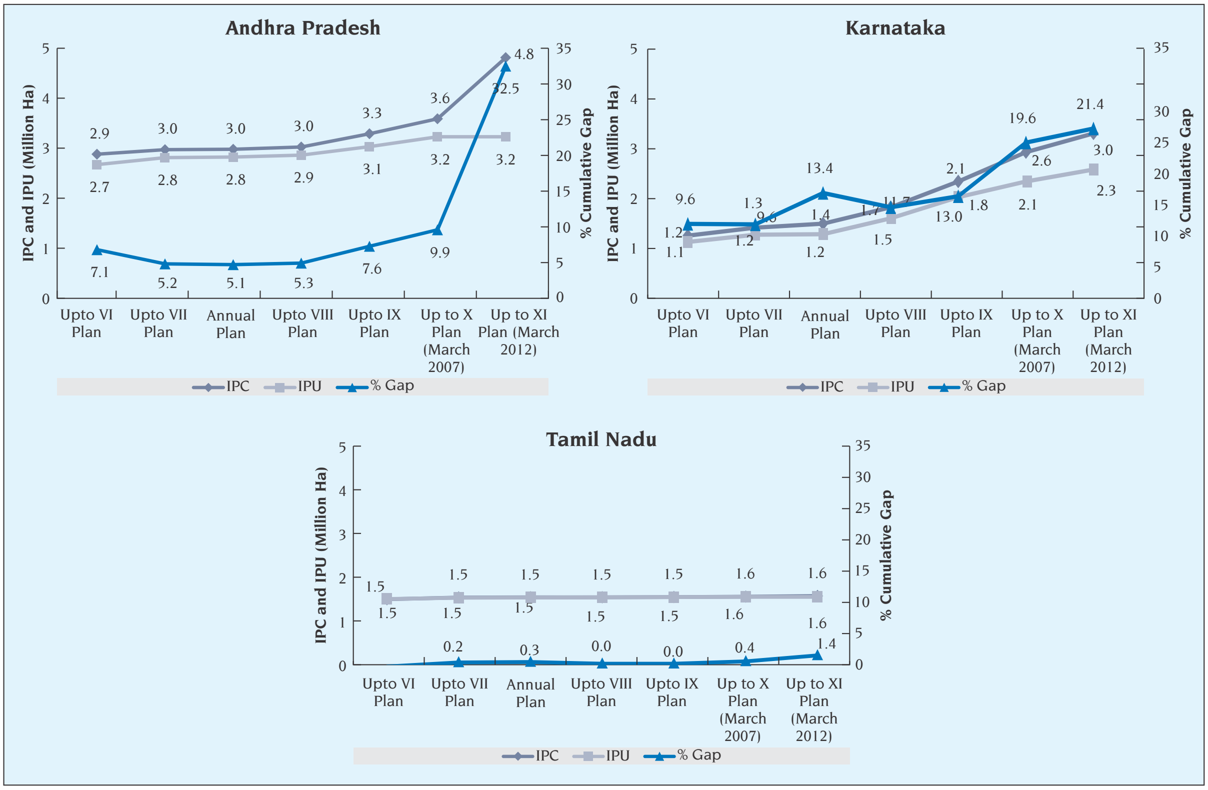
The highest and lowest cumulative percentage gaps in eastern region till 11th plan are in undivided Bihar region (42.52 percent) and Odisha (12.51 percent).

In the undivided Bihar region, Jharkhand has more percent gap than Bihar till the 11th Plan. It is a matter of concern that after the 8th FYP, per cent gap in the undivided Bihar region increased continuously. It reached 42.5 percent at the end of 11th FYP from 17.1 percent at the end of the 8th FYP. It goes without saying that immediate steps are needed to be taken in the direction of improving the situation.

Although undivided Bihar region and Odisha have the highest and lowest per cent gaps respectively in the region, the similarity between them is that both of them has created less than 60 percent of their estimated UIP. Undivided Bihar, and Odisha has created only 55.1 percent and 59.6 percent of their UIP respectively. Both are much lower compared to the other states in the region, West Bengal (83 percent) and the all India level (82 percent).

State-wise Gaps in MMI: Southern Region

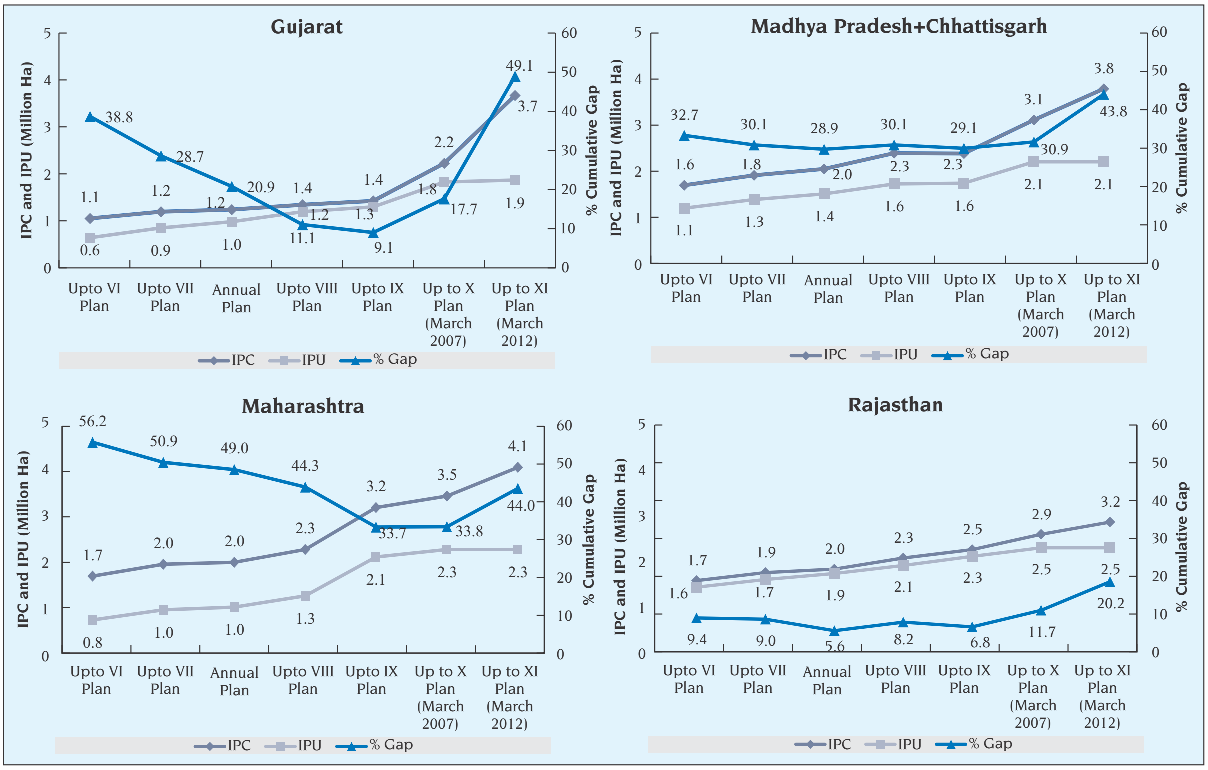
Figure 45: State-wise IPC-IPU Gap in MMI: Southern Region



The highest potential creation during 11th FYP in the region has happened in Andhra Pradesh. Andhra Pradesh also observes the highest per cent gap (32.5 percent) in the region. However, historically since the 6th FYP, Karnataka was the state with the highest per cent gap and except for during the 8th FYP, the per cent gap in Karnataka has been continually rising. Tamil Nadu is remarkable in that it has long since created its UIP and been utilizing all of it. Only in recent times, there is small gap (1.4 percent) in its IPC and IPU, which is minimal. Other states in the region should learn from Tamil Nadu about its best practices in resource creation and utilization.

State-wise Gaps in MMI: *Western Region*

Figure 46: State-wise IPC-IPU Gap in MMI: Western Region



All the four states in the western region had higher IPC-IPU gap as compared to other three regions considered in the study. The highest and lowest gap for the western region till the 11th Plan exists in Gujarat (49.1 percent) and Rajasthan (20.2 percent), respectively. Except for Rajasthan, gaps in all the other three states of the region exceed 40 percent.

It is to be noted that in Gujarat, decline of the per cent gap was commendable from the 6th FYP till the 9th FYP. Thereafter, the gap increased again. In the undivided MP region, IP creation during the 11th Plan in Chhattisgarh is more than that in Madhya Pradesh. In fact, Chhattisgarh has already created more than its estimated UIP is using almost 75 percent of it till the 11th FYP. This calls for reassessment of UIP in Chhattisgarh as well as some other states with the same characteristics. Maharashtra's per cent gap was also declining upto the 9th FYP (but still it was at a considerably high level), but it has also been increasing since then. Maharashtra has the largest number of completed and on-going irrigation projects as compared to all the other states in India. Lastly, it is unfortunate that, in Rajasthan, which enjoyed the lowest percentage gap in the region, the percentage gap started increasing after the 9th FYP.

Compound Annual Growth Rate (CAGR) *of* IPC *and* IPU *in case of* MMI:

In the 10th and 11th plan, IPC grew at CAGR of 2.4 percent and 2.9 percent respectively. Again, there are inter-regional and interstate differences. In the 10th Plan, IPC grew at 9.3 percent in Gujarat to 0.2 percent in Tamil Nadu. In the 11th Plan, the growth rate was highest in Jammu and Kashmir (11.7 percent) and lowest in Haryana (0.1 percent). The inter-regional variation is shown in Table 2 and the state-wise CAGRs for IPC in Xth and XIth plan are depicted in Fig. 47.

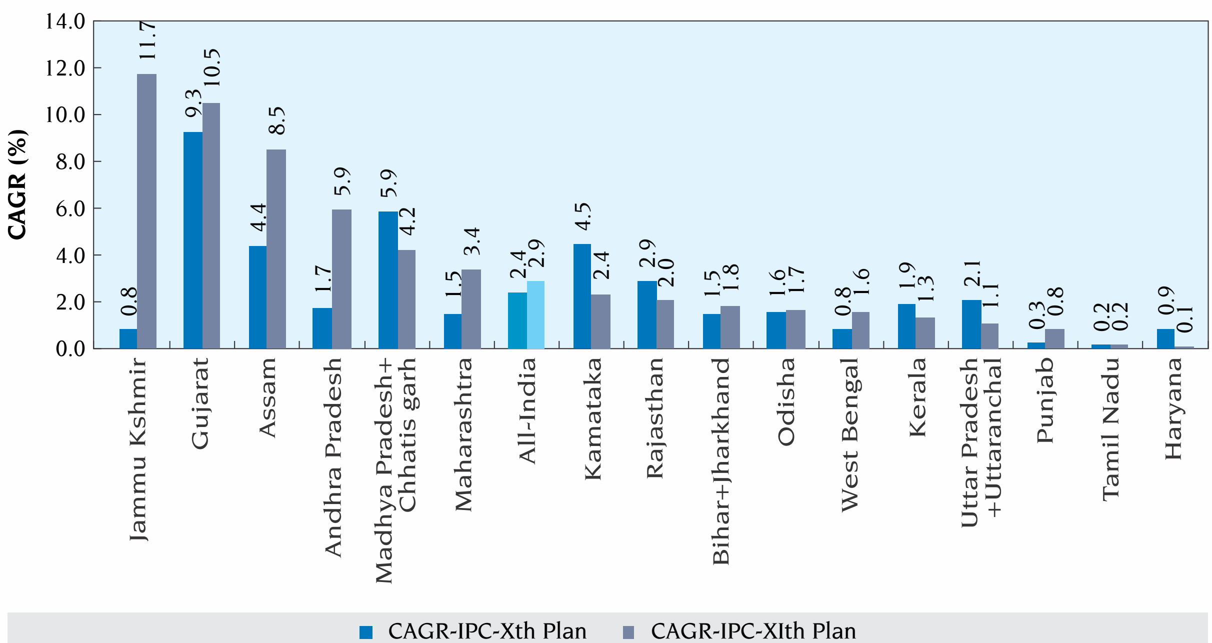
For most of the states, IPU remained either the same or a very little change occurred there in the 11th plan. In the 10th Plan IPU grew at 1.7 percent which declined to 0.7 percent in the 11th plan. In the 10th plan IPU in Gujarat increased at the highest pace (7.1 percent) and that of Tamil Nadu grew at the lowest pace (0.1 percent). The situation is represented in Fig. 48.

Table 2: Region-wise variation in CAGR of IPC-MMI for 10^{th} and 11^{th} Plan

Region	X^{th} Plan				Xi^{th} Plan			
	Highest CAGR		Lowest CAGR		Highest CAGR		Lowest CAGR	
	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)
Eastern	Assam	4.4	West Bengal	0.8	Assam	8.5	West Bengal	1.6
Western	Gujarat	9.3	Maharashtra	1.5	Gujarat	10.5	Maharashtra	3.4
Northern	Uttar Pradesh (UP+Uttarak hand)	2.1	Punjab	0.3	Jammu & Kashmir	11.7	Haryana	0.1
Southern	Karnataka	4.5	Tamil Nadu	0.2	Andhra Pradesh	5.9	Tamil Nadu	0.2

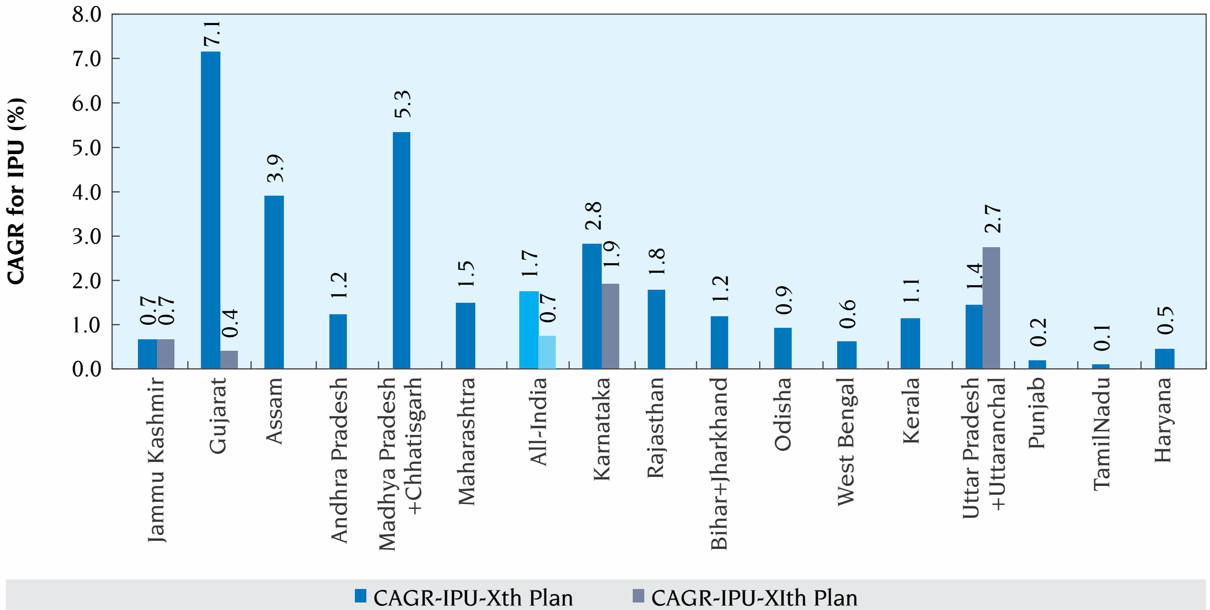
Source: CWC

Figure 47: State-wise CAGRs for IPC-MMI in Xth and XIth plan



Source: *Constructed using data from* CWC

Figure 48: State-wise CAGRs for IPU-MMI in Xth and XIth plan



Source: Constructed using data from CWC

2.2.3 Gap between Irrigation Potential Created and Utilized in Case of Minor Irrigation

Minor irrigation consists of two parts- Minor surface water irrigation and groundwater irrigation. For most of the discussion here, total MI consisting of both the components is considered.

Method of Estimation

The irrigation potential created and utilized data for MMI are available from Central Water Commission (CWC). But for minor Irrigation (MI), taking it from the same source becomes somewhat problematic due to discrepancy in data provided through their different publications[20]. To resolve this issue, data in various Minor Irrigation Census surveys are considered since these surveys are dedicated to collect data only on minor irrigation and are quite comprehensive. There are five MI census surveys available for the country (conducted for the years 1986-87, 1993-94, 2000-01, 2006-07 and the most recent one, 2013-14).

Simple linear interpolation method is used to find out the values of IPC and IPU for the in-between years. The gap in MMI was analyzed since ending of the sixth plan period, or, 1984-85. But the first MI census was conducted in 1986-87. Hence, to give a proper comparative picture of the IPC-IPU gap story for both MMI and MI, determining the figures for 1984-85 and 1985-86 was necessary. To that end, the data for the said two years have been estimated by extrapolation using the first interpolation factor of the series[21] and the data for 1986-87. The figures for the last years of the plan periods from the thus estimated series are taken into consideration to analyze the gap between IPC and IPU in MI.

[20] For Example, GoI 2015b and 2016

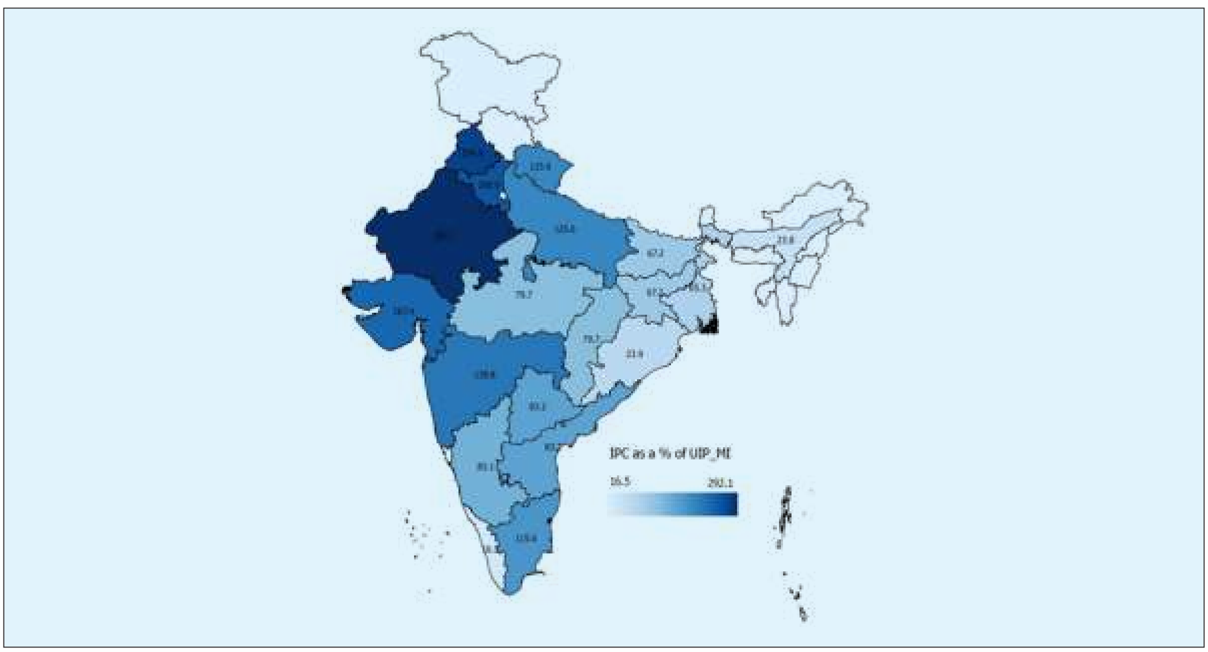
[21] That is, the interpolation factor for the years in between the first and second minor irrigation census years.

Ultimate Irrigation Potential for Minor Irrigation

The UIP for Minor Irrigation (MI) in India was estimated at 81.4 Mha whereas according to the calculation considering the MI census surveys, 84.9 Mha or 104 percent of the ultimate irrigation potential through MI had already been created till end of the eleventh plan (2011-12). If state-wise situation is considered, there are seven states, namely- Gujarat (167.4 percent), Haryana (200.9 percent), Maharashtra (138.8 percent), Punjab (254.9 percent), Rajasthan (292.1 percent), Tamil Nadu (115.6 percent) and undivided Uttar Pradesh region (125.6 percent) - have apparently already created MI potentials that are much higher than their estimated UIPs (Appendix 2). There is very strong case to revisit the methodology for assessment of UIP, especially for the minor irrigation and the new and emerging realities should be properly addressed. Map 5 (Appendix 2) shows IPC as a percentage of UIP for MI.

The utilization of created potential for MI irrigation is, however, better than the same for MMI. Whereas in some states, utilized area is less than half of the potential created in case of MMI, here all the major states use more than 60 percent of the potential created. This is most probably because of the much discussed reason of having more independence in deciding the time and amount of application of groundwater compared to surface water, and lower and private costs for constructing the minor irrigation also help in better utilization (Mukherji et al., 2013).

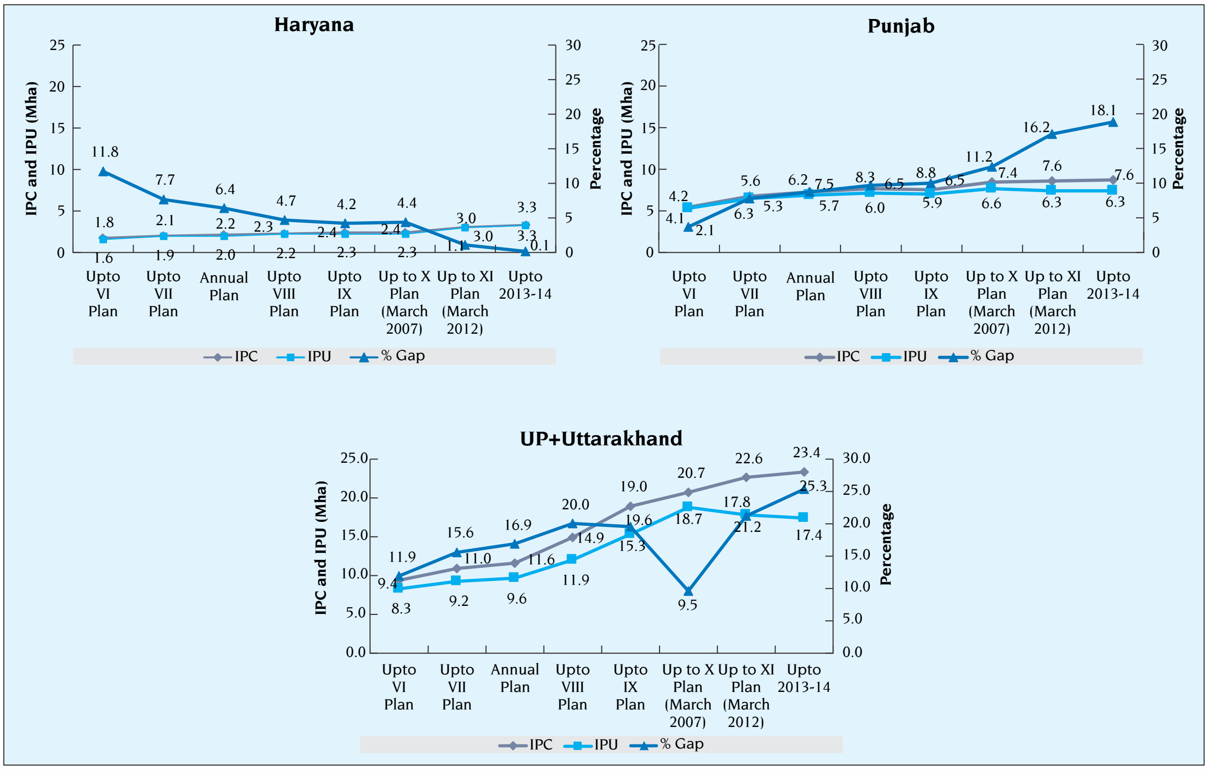
Map 6: IPC as a percentage of UIP for MI



State-wise and Plan-wise IPC-IPU gap in Minor Irrigation

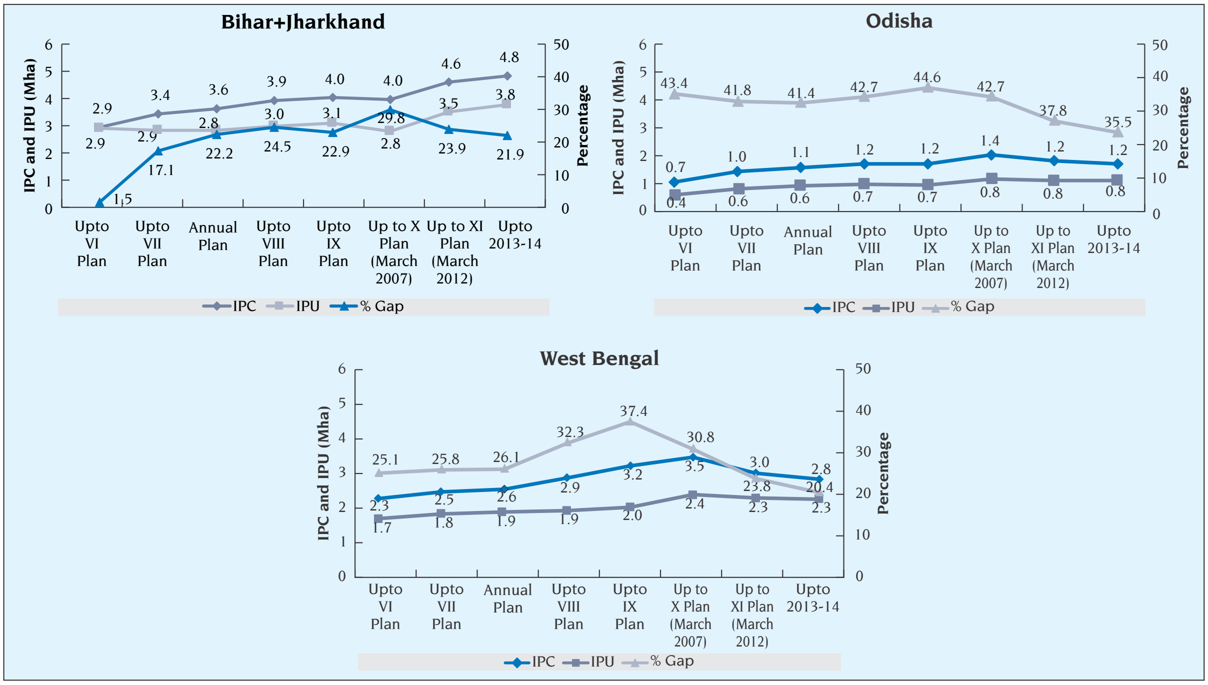
Following the methodology of estimation discussed above, IPC and IPU for MI are calculated for all the major states since end of the sixth plan till 2013-14. The percent cumulative gap is also calculated state-wise and plan-wise. All of these are represented in the graphs for region –wise comparison (Figure 49 to 52).

Figure 49: State-wise IPC-IPU gap in MI- Northern Region



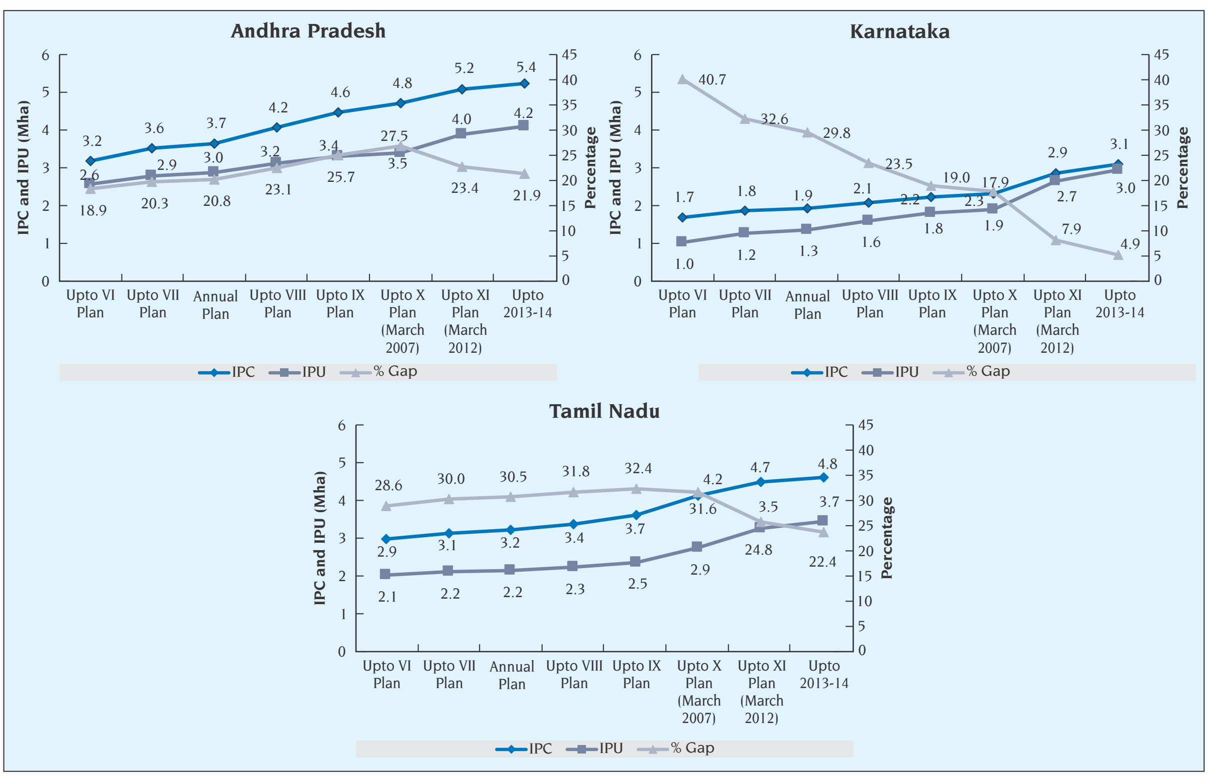
The per cent gap for MI schemes has declined since the 10th FYP in Haryana but increased in Punjab and undivided UP region. The gap is at a really high level in case of undivided UP. While Punjab's gap has been increasing fast since the 10th FYP, the absolute gap and the per cent gap both are at much lower level than in the undivided UP region. Punjab has already crossed its groundwater potential and the gap shall be mainly for some small surface irrigation schemes in the Kandi region.

Figure 50: State-wise IPC-IPU gap in MI- Eastern Region



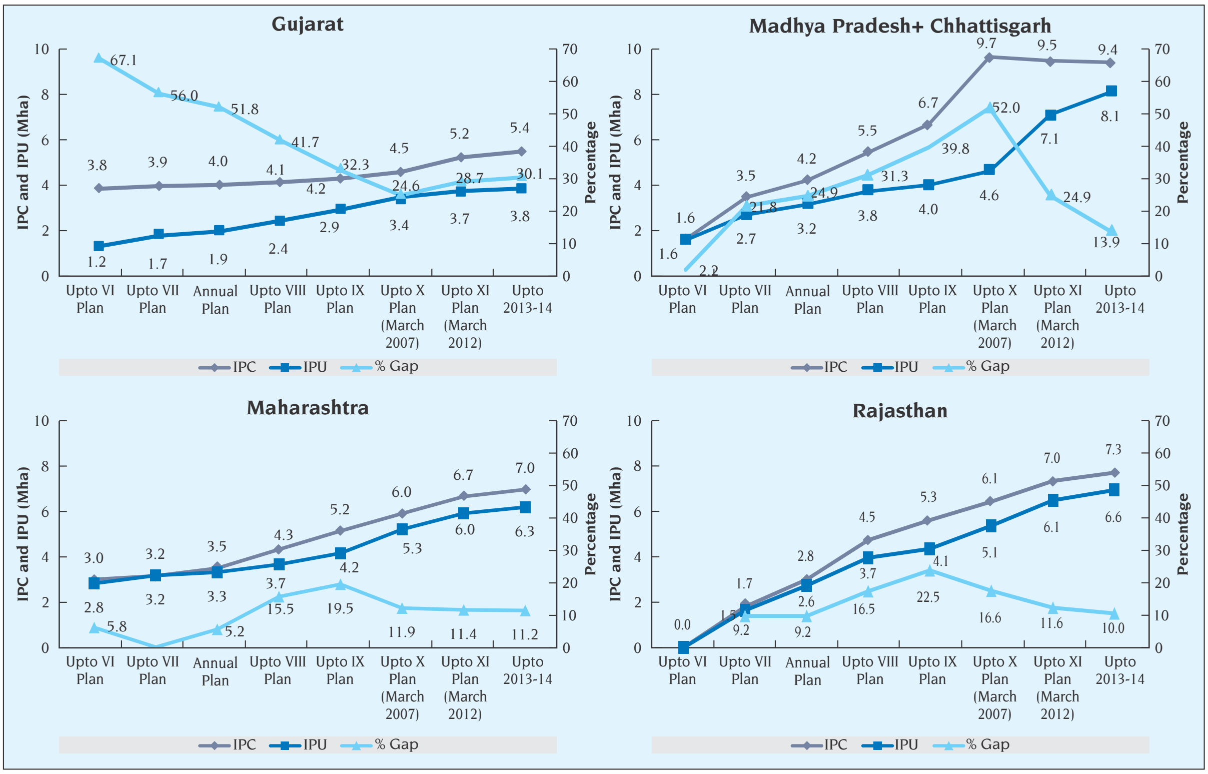
Highest percentage gap in this region is observed in Odisha although absolute gap as well as the amount of IPC and IPU created in this region is lowest in Odisha. The lowest per cent gap in this region is observed in West Bengal. In all states considered in this region, the per cent gap has declined after the 9th FYP but needs to be further paced up.

Figure 51: State-wise IPC-IPU gap in MI - Southern Region



Karnataka, among southern states has done a commendable job in bridging the gap between IPC and IPU of MI schemes. The cumulative per cent gap is lowest upto 2013-14 in Karnataka in the region (4.9 percent) possibly due to a strong World Bank aided program on watershed development in the state. The other two states, however, have a high gap both in percentage (more than 20 percent) and absolute (more than 1 Mha) terms, the states have all the technical skills and resources to bridge this gap on priority.

Figure 52: State-wise IPC-IPU gap in MI- Western Region



Source: Constructed interpolating data in various Minor Irrigation Census Surveys

Unlike MMI projects, all the four states in the region have made good efforts in closing the IPC-IPU gap for MI Projects. Gujarat, as in MMI, was experiencing very high gap in the 6th FYP. But it has brought down the gap since then. However, after the 10th FYP, the gap is increasing in Gujarat and at a considerably high level now (30.1 percent) which is also the highest of the region. The lowest gap in this region is observed in Rajasthan (10 percent). Madhya Pradesh and Maharashtra also have lower gaps for MI Projects.

In general, for most of the states, the gap between IPC and IPU has declined over last two plan periods, but there are some states which experience large gaps even after such declines. Each region has one or more major states which experiences large gaps. For somewhat more detailed explanation for the source of the gap (whether surface or groundwater is causing the gap), the states with cumulative gap more than 20 percent and absolute gap more than 1 Mha are considered. Five states fall under this category, namely, undivided Andhra Pradesh region

and Tamil Nadu from southern states, Gujarat from western states, undivided Uttar Pradesh region from northern states and undivided Bihar region from eastern states. Of these five states, most of the MI schemes consist of groundwater, as is the case for India as a whole. In three of them, viz., Gujarat (95.8 per cent), undivided Uttar Pradesh region (98.1 percent) and undivided Bihar region (93.5 percent), groundwater accounts for more than 90 percent of IPC. Ground water makes up 71.3 percent and 88 percent of IPC in undivided Andhra Pradesh region and Tamil Nadu respectively. Naturally, in Andhra Pradesh region, percentage gap in surface water has a more effect on the gap in overall MI compared to the same in other states under consideration and as it happens, percentage gap in surface water in the state is much higher than that in the ground water. In all the other states, percentage gap in groundwater is more than that in surface water.

Table 3: Source of Gap in MI for selected states with high gaps

State	Ground water IPC	Surface water IPC	Ground water IPC (as % of Total MI)	Surface water IPC (As % of Total MI)
	Mha	Mha		
Andhra Pradesh + Telangana	3.8	1.5	71.3	28.7
Tamil Nadu	4.2	0.6	88.0	12.0
Gujarat	5.2	0.2	95.8	4.2
UP + Uttarakhand	22.9	0.4	98.1	1.9
Bihar + Jharkhand	4.5	0.3	93.5	6.5

Source: MI *Censuses, Authors' Calculation*

It is curious that in some states, IPC created declined over time, especially in the 11th plan and after that. They are: Odisha, West Bengal and Kerala. While we can explain decline in IPU by increase in well failures, it is difficult to explain decline in IPC over time by only that. It might be there were some over reporting in the earlier MI census report. Then again, even if that explanation is accepted for Odisha and West Bengal, the case of Kerala indicates that there were over-reporting in two consecutive MI censuses.

There is decline in IPU as well during the eleventh plan for some states. They are: undivided Uttar Pradesh region, Punjab, Odisha, West Bengal and Kerala. Undivided Bihar region experienced decline in the same during the tenth plan period. But, while the declines in the other states are quite small, the decline in Kerala is considerably more. The situation is better understood through Figures 53 and 54.

Compound Annual Growth Rate (CAGR) *of* IPC *and* IPU *in case of* MI:

In the 10th and 11th plan, All-India IPC for MI grew at CAGR of 2.4 percent and 1.5 percent respectively. Again, there are inter-regional and inter-state differences. In the 10th Plan, IPC grew

at 7.6 percent in undivided Madhya Pradesh area to -3.8 percent in Kerala. In the 11th Plan, the growth rate was highest in Haryana (4.9 percent) and lowest in Kerala (-5.1 percent). The inter-regional variation is shown in Table 4 and 5 and the state-wise CAGRs for IPC and IPU in Xth and XIth plan are depicted in Figures 53 and 54.

Table 4: Region-wise variation in CAGR of IPC-MI for 10th and 11th Plan

Region	Xth Plan				Xith Plan			
	Highest CAGR		Lowest CAGR		Highest CAGR		Lowest CAGR	
	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)
Eastern	Assam	6.6	Bihar+ Jharkhand	-0.3	Bihar+ Jharkhand	2.9	West Bengal	-2.8
Western	MP+ Chhattisgarh	7.6	Gujarat	1.4	Gujarat	2.7	MP+ Chhattisgarh	-0.3
Northern	Punjab	2.7	Haryana	0.1	Haryana	4.9	Punjab	0.5
Southern	Tamil Nadu	3.0	Kerala	-3.8	Karnataka	4.5	Kerala	-5.1

Source: Calculated from data in various Minor Irrigation Censuses

Table 5: Region-wise variation in CAGR of IPU-MI for 10th and 11th Plan

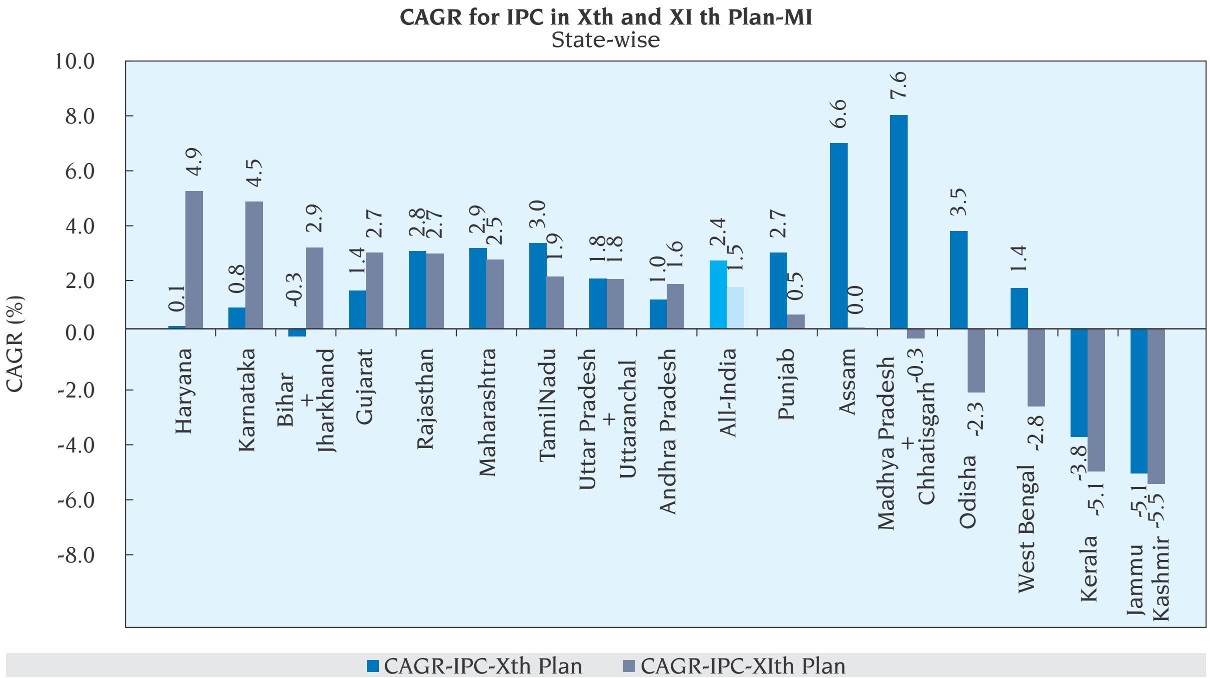
Region	Xth Plan				Xith Plan			
	Highest CAGR		Lowest CAGR		Highest CAGR		Lowest CAGR	
	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)	State	CAGR (%)
Eastern	Assam	4.6	Bihar+ Jharkhand	-2.1	Bihar+ Jharkhand	4.6	West Bengal	-0.9
Western	Maharashtra	4.7	MP+ Chhattisgarh	2.9	MP+ Chhattisgarh	9.0	Gujarat	1.5
Northern	UP+ Uttarakhand	4.2	Haryana	0.1	Haryana	5.6	UP+ Uttarakhand	-1.0
Southern	Tamil Nadu	3.3	Kerala	-3.2	Karnataka	7.0	Kerala	-5.3

Source: Calculated from data in various Minor Irrigation Censuses

To the government of India, the gap between IPC and IPU means huge cost implications since both the central and state governments spend considerable amount on construction and maintenance of public irrigation every year. To find out what does it cost of not bridging the gap, per ha costs of IPC and IPU- state-wise and region-wise are discussed in the next section (Section 2.3). The increasing gap and its perils lead the government to feel the need for a project which

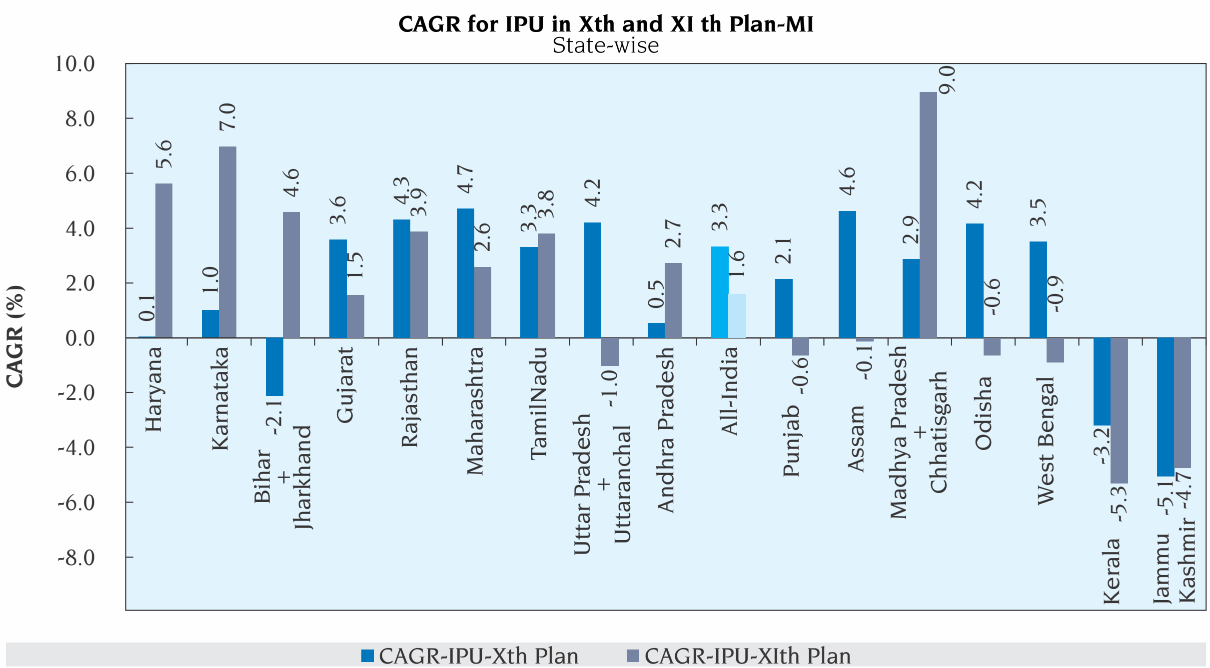
will help in completing irrigation projects in accelerated pace and supplying water to the intended beneficiaries. It is called the Accelerated Irrigation Benefit Programme (AIBP). Section 2.4 deals with the scheme in detail.

Figure 53: State-wise CAGRs for IPC-MI in Xth and XIth plan



Source of Figures 52 and 53: Calculated and constructed using data in MI Irrigation Censuses

Figure 54: State-wise CAGRs for IPU-MI in Xth and XIth plan



Source of Figures 52 and 53: Calculated and constructed using data in MI Irrigation Censuses

2.3 Costs of Irrigation Potential Creation and Utilization

As mentioned earlier, it is very important to find out the economic cost of the gap between irrigation potential creation and utilization since the gap between potential creation and utilization signifies that the cost normally put forward as the "cost of irrigation" is actually an underestimate. In this section we shall find out the per ha costs of irrigation potential creation and utilization- both in terms of capital costs and working expenses for the thirteen states considered in the earlier section and for all-India.

2.3.1 Capital Cost

We intend to estimate the capital cost of public irrigation in MMI for creating per ha of potential. To have an idea about the economic cost of the IPC-IPU gap, we shall also estimate the cost per ha of additional irrigation potential utilized over the same time period. The period under consideration is twelve years from 2002-03 to 2013-14. The method of calculation is described below:

S*tep* 1: Central Water Commission provides us the capital expenditure and working expenses of government irrigation projects (GoI 2015a). We take the capital expenditure of MMI projects for individual states and all-India. The expenditure figures are also converted into 2017-18 prices using Wholesale Price Index (WPI).

S*tep* 2: We get the IPC and IPU data upto 2001-02, i.e., till end of the 9th Plan from CWC (GoI 2015b) and the IPC upto 2013-14 from Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD&GR). The difference in IPC, obviously, gives us the additional IP created over the twelve years under consideration.

Since IPU data is available only till 2011-12, that too provisional, we estimate state-wise and All-India IPU upto 2013-14 considering the gap to be same as in the 10th Plan (upto 2006-07). Again the difference from the IPU till 2001-02 gives the additional IP utilized over the period under consideration.

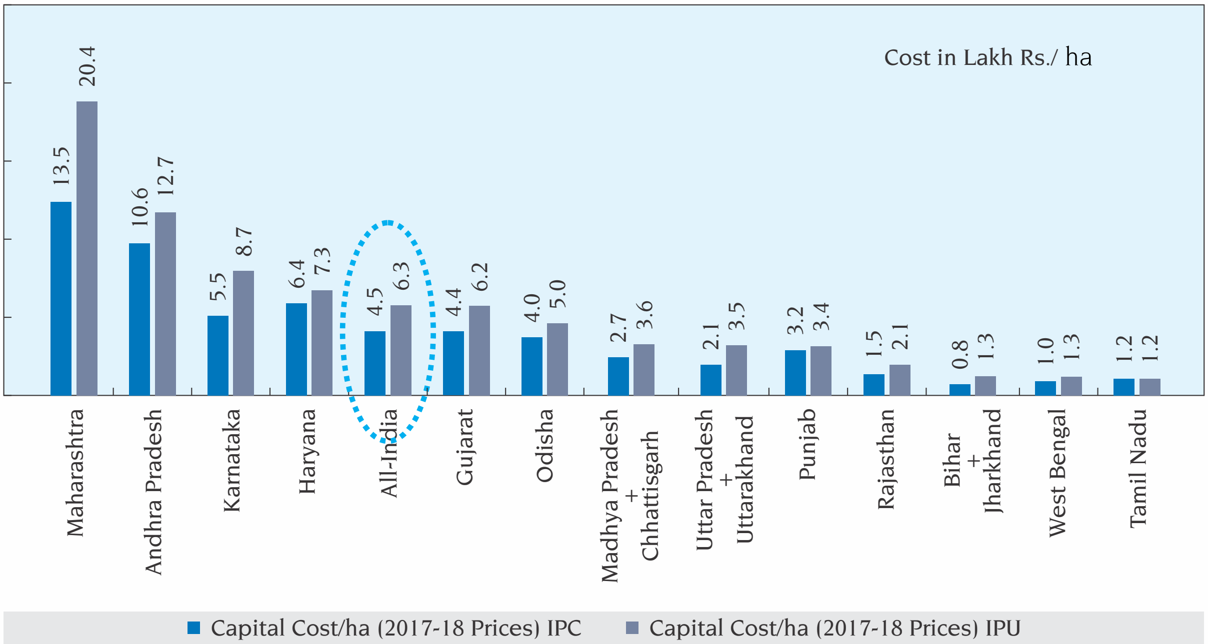
S*tep* 3: We divide capital cost incurred over the period (in current and constant 2017-18 prices) by additional IP created and utilized to arrive at the desired per ha costs.

It is to be considered that since we have taken the gap to be the same as the 10th Plan period and the analysis in the previous section suggests the gaps for MMI are increasing, the costs might have been, in fact, underestimated. However, some states, particularly Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh have alarmingly high rates of expenditure per ha of IPC and IPU for this estimate as well.

The highest cost per ha is incurred in the southern region followed by western, northern and eastern region. In all the regions except for the southern region, per ha cost of additional IP utilized is around 1.4-1.5 times the same for additional IPU. In southern region, it is 1.2 times.

Fig. 55 shows per ha capital costs of potential creation and utilization state-wise during 2002-03 to 2013-14.

Figure 55: State-wise per ha capital cost (in lakh Rs.)- 2002-03 to 2013-14 (2017-18 Prices)

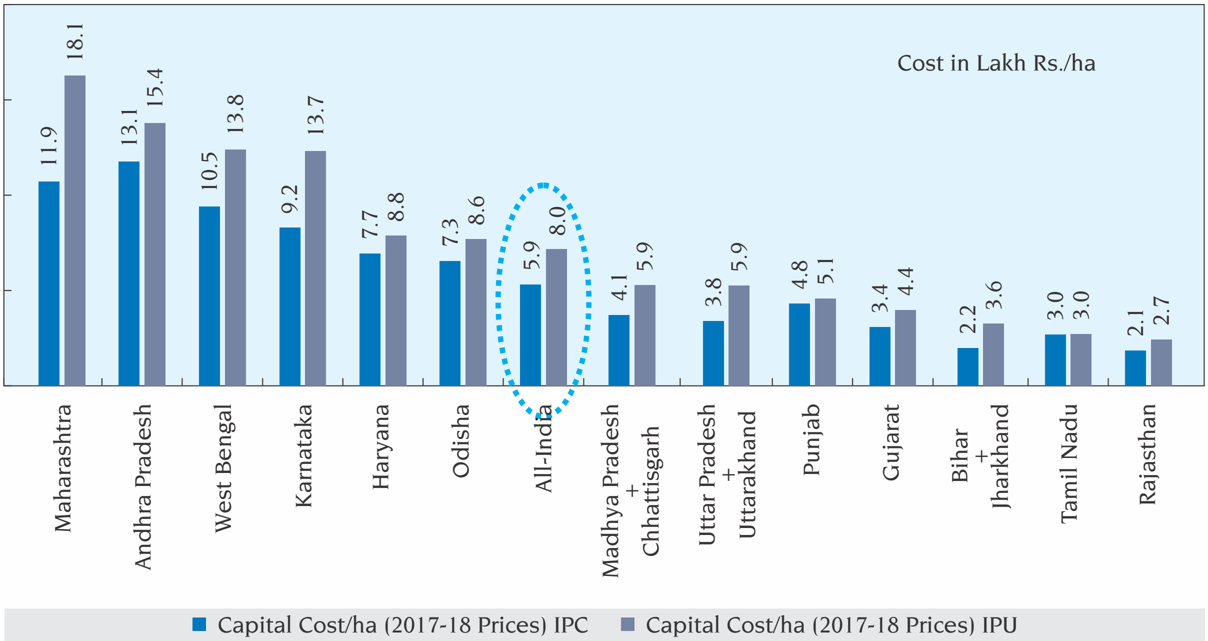


Source: Authors' Calculation based on CWC and MoWR data

Since 2013-14 data is almost 5 years old now and CWC's Latest Financial Aspects of irrigation projects in India provides data only upto 2013-14, we use RBI data to find out what is the situation in recent years. RBI State Budget Finances tabulates each state's yearly expenditure on various accounts which is available till 2018-19 budget estimates. We use the same method of per ha cost calculation- this time with the RBI data for expenditure (2002-03 to 2017-18 converted to 2017-18 prices) and considering the progress of different projects in a state given in Accelerated Irrigation Benefit Programme' s (AIBP) Dashboard as IPC for that state after 2013-14 till 2018. The results are summarized in Fig. 56.

It should be noted here that the data for capital expenses as given in CWC and RBI do not match. RBI data is typically higher than CWC data for all the states. While from 2002-03 to 2006-07 there is not much difference between the two datasets, from 2007-08, the difference is considerable. For some states (For example, West Bengal), there is high discrepancy till the start of the period under consideration. It is to be noted that, except for West Bengal and Odisha, the positions of different states as compared to all-India level are almost the same as when calculated with CWC data. In West Bengal, the likely over-estimation is resulting from no priority projects being assigned there (so, we have assumed creation after 2013-14 is zero) and higher cost figures mentioned in RBI.

Figure 56: State-wise per ha Capital Cost- 2002-03 to 2017-18 (2017-18 Prices)



Source: Authors' Calculation based on RBI *State Budget Finances and* MoWR *data*

Cost of construction of surface irrigation projects is exorbitantly high in the states of Maharashtra, Andhra Pradesh and Karnataka due to prevailing cost norms approved in the states. Though, higher cost of construction in dry hard rock regions may be one factor- there have been several reports, including CAG report, on rampant corruption, cost escalation and inefficiency in project management in these states (Upadhaya, 2013; Pallavi, 2015).

2.3.2 Working Expenses

The methods to determine capital and working expenses are different since capital is a stock concept and working expenses is a flow concept. In a particular year, the working expenses made goes towards maintenance of the cumulative potential created (or utilized) upto that year. Keeping that in mind, per ha working expenses are calculated using the following steps:

Step 1: The yearly working expenses in current prices are converted in 2017-18 prices using WPI

Step 2: We use the cumulative IPC and IPU data for the two years (2001-02 and 2013-14) to find the cumulative IPC and IPU for the years in-between employing the method of simple linear interpolation.

Step 3: We divide working expenses of each year by the cumulative IPC and IPU separately to find out the working expenses per ha incurred in a state in a particular year.

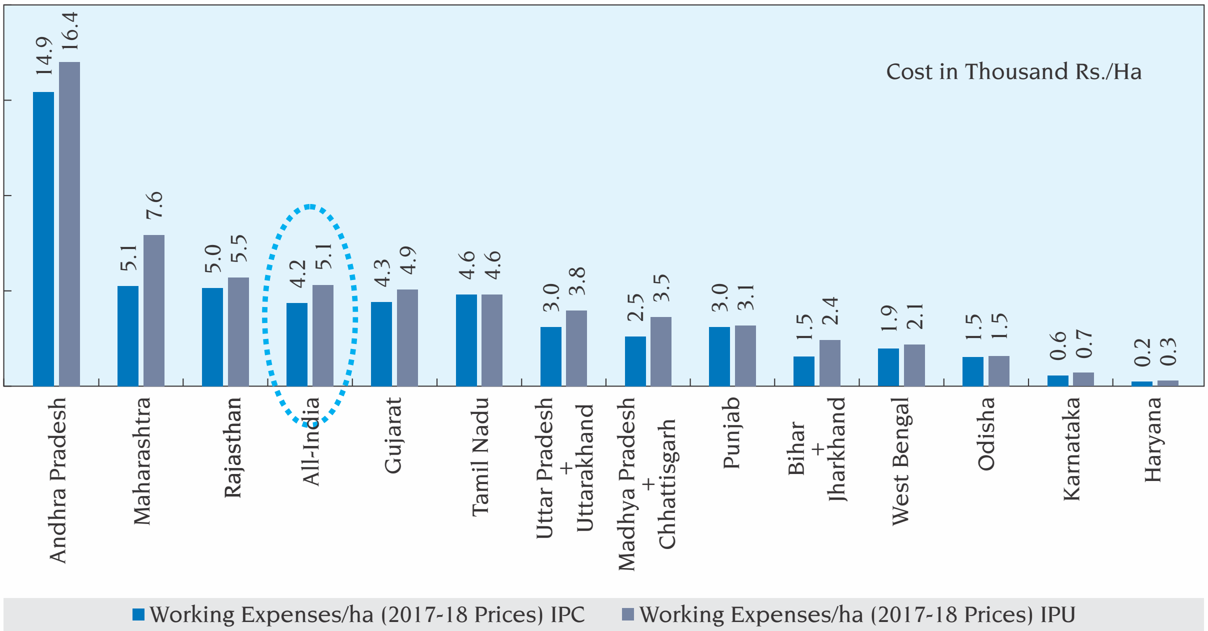
Step 4: We take average of all working expenses/ha over the 12 years under consideration to arrive at the desired per ha working expenses over that period by a particular state.

Fig. 57 shows average per ha working expenses incurred during 2002-03 to 2013-14.

Working expenses as a percentage of capital expenditure at an all-India level is 0.9 percent per ha of IPC and 0.8 per cent per ha of IPU. State-wise numbers, however vary from as low as 0.04

percent in Haryana to 4 percent in Tamil Nadu for IPC. As Tamil Nadu has long since created its UIP, working expenses incurred per ha of IPC/IPU as a percentage of capital cost per ha is understandably higher as compared to other states.

Figure 57: State-wise per ha working expenses: 2002-03 to 2013-14 (2017-18 Prices)



Source: Authors' Calculation based on CWC and MoWR data

Canal irrigation tariffs in various states of India are only a fraction of the working expenses incurred and nothing for the recovery of the capital expenditure. This is one of the root cause of the degradation and poor maintenance and operations of the canal irrigation systems in India-this will be discussed in detail in the subsequent sections.

2.4 Accelerated Irrigation Benefit Programme (AIBP)

2.4.1 Background and Objective

Irrigation in India is a state subject. So, the duty to formulate, execute and fund irrigation projects mainly fall under the state governments. In 1996, a review of implementation status for major and medium irrigation (MMI) projects in India was done. In the survey, it was revealed that, a considerably large number of the MMI projects commissioned were lacking timely and adequate funding from the respective state governments. This caused trouble in creating the last mile delivery system for the canal irrigation water. At the end of eighth Five Year Plan (FYP), that is in 1996-97, there were 171 major, 259 medium and 72 Extension, Renovation, Modernization (ERM) projects ongoing in India. They were at various stages of completion with a spillover cost of Rs. 75690 crore. This was recognized as a matter of concern which needed attention immediately. Although as mentioned earlier, irrigation is a state subject but due to the capital intensive nature of MMI projects and limitation of resources at the state level, it was being difficult for the states to complete the projects.

In this background, the government of India launched Accelerated Irrigation Benefit Programme (AIBP) in 1996-97. The objective of the scheme was to provide Central Loan Assistance (CLA) to the MMI projects to encourage and expedite the completion of ongoing projects. Only those projects were deemed to be eligible for inclusion in the project in which considerable progress had already been made but completing within a reasonable time period required central

assistance. This was also supposed to encourage completing last mile delivery systems so that benefits from these projects can actually be accrued to the intended beneficiaries, that is, the farmers.

2.4.2 Central Loan Assistance and Release Guidelines

At the start of the project, Central Loan Assistance (CLA) was to be distributed to the states on matching basis and released in two installments of 50 percent each. The second installment was to be provided only after the state has spent 70 percent of the first grant along with states' share and submission of the utilization certificate. From 1999-2000 onwards, it was decided that CLA could also be extended to minor surface irrigation schemes, as well. Further, funds were provided in the general states in the ratio of 2:1 (Centre: State) and in the ratio of 3:1 in the special category states[22].

The CLA was given at a rate of interest prescribed by the Ministry of Finance (@13 percent). The loan was to be repaid in 20 equal installments. Fifty percent of the loan enjoyed a 5 year grace period after which that was to be paid in 15 equal installments. At present the rate of interest is around 6 percent.

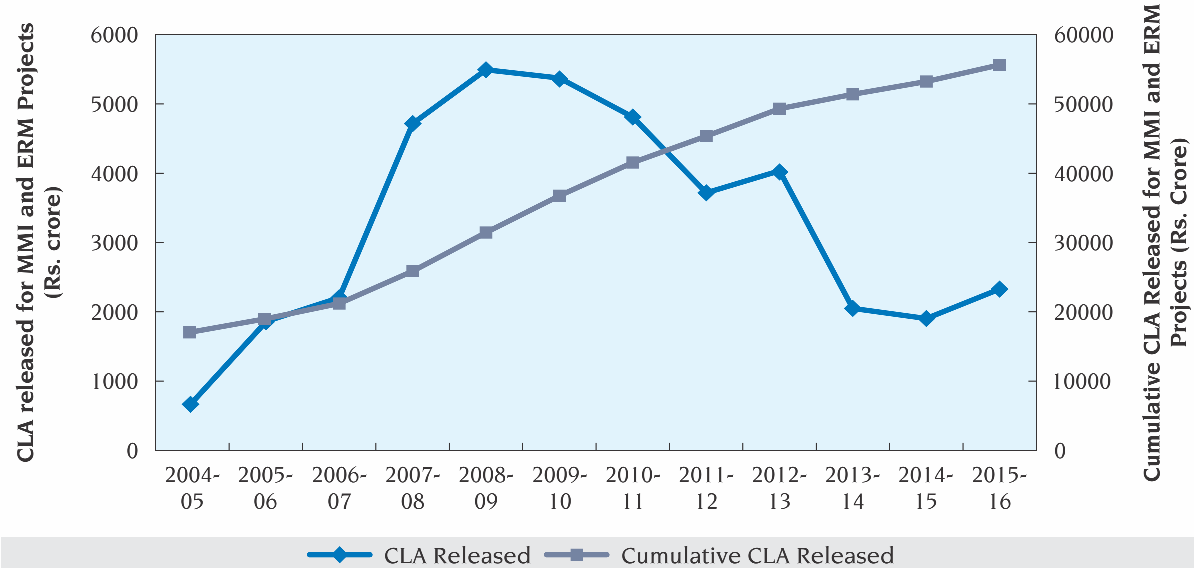
In 2005, the scheme was extended to drought prone areas and tribal areas as well and it treated them same as the special category states. In 2006, there was another modification in AIBP guidelines which included provisions like release of 90 percent of sanctioned grants in the first installments (the balance was to be released when 70 percent of the first installment is spent).

Table 6 highlights some of the periodic modifications made in the AIBP scheme.

2.4.3 Grants Released under the AIBP Scheme

Upto 2004-05 since inception, MMI and ERM projects included in the AIBP, received Rs. 16426 crore. Upto March 2016, cumulative grants released in MMI and ERM projects was Rs. 55601 crore. The following figure shows all-India release of grants since 2004-05.

Figure 58: CLA released for MMI and ERM projects in India



Source: Constructed using the data in Handbook on Water and Related Statistics, CWC, June 2017

[22] Special category states are: North Eastern states and Hilly states of Himachal Pradesh, Sikkim and Jammu & Kashmir. Also, the projects benefitting Kalahandi, Bolangir and Koraput (KBK) districts of Odisha came under the special category.

Figure 58 shows that the grants increased steadily till 2008-09 and then decreased for the years thereafter. GoI (2012) maintains that, "*As appearing from the inspection reports of* CWC *officers, a reason for this decline is non-achievement of desired physical/financial target in* AIBP *projects by the concerned states*." Figure 59 shows the grants released plan-wise in each state since the inception of the scheme in 1996-97 and Appendix 3 presents the amount released for each state year-wise. Similarly, Figure 60 shows the potential created plan-wise in each state since the scheme started and Appendix 4 presents state-wise and year-wise potential creation under AIBP.

Table 6: Periodic modifications made in AIBP implementation guidelines

	Oct-96	Feb-02	Apr-05	Dec-06	Oct-13	Oct-15	Jul-16
Selection Criteria	1. Multi-purpose projects costing over Rs. 1000 crore, relaxed to Rs. 500 crore in March of 1997 2. MMI projects in advanced stage of completio 3. Will provide assured water supply to 1 lakh hectare	1. Fast Track Projects (FTP) which can be completed in two agri-seasons- to be funded 100 percent by GoI 2. MOU to be signed with GoI for FTP and rationalization of water rates 3. Priority for inter-state projects and projects with larger irrigated area at marginal investmen 4. Projects cleared by the then Planning Commission	1. MI schemes- for non-special category states, preference to tribal and drought prone areas and with potential of 100 ha	1. MMI and ERM projects- cleared by the then Planning Commission, in advanced stage of completion (can be completed by next four financial years, not receiving any other form of financial assistance 2. For MI schemes in non-special category states, states were required to give undertaking to complete in two financial years and formation of water users association with post construction management.	1. ERM projects with investment clearance of Planning Commission related to projects already completed and commissioned at least 10 years earlier subject to conditions. 2. Exceptions to one to one rule allowed for projects in agrarian distressed districts identified under Prime Minister's package. 3. "Advanced stage" defined to mean project which had incurred expenditure of at least 50 per cent of the latest approved estimated cost and achieved at least 50 per cent physical progress in the case of essential works	1. AIBP – one of the four components of PMKSY. 2. MI schemes included in Har khet ko pani (water to every farm) component.	Out of 144 incomplete MMI projects and 5 national projects, 99 priority projects were marked for completion by December 2019.

	Oct-96	Feb-02	Apr-05	Dec-06	Oct-13	Oct-15	Jul-16
Funding Pattern	1. CLA to states on matching basis 2. Modified in 1997 - Centre: state in 2:1; further modified in 1999 as 3:1; in non-special category states 3. To be recovered in 20 equal installments at 13 percent interest per annum 4. CLA to be reimbursed on quarterly basis for expenditure actually incurred	1. Funding pattern 4:1; for the states which rationalize the water rates to recover full O&M costs. 2. Special category states of Odisha to be fully funded provided they underwent reform 3. If failed to carry out reforms after giving undertaking, entailed withdrawal of assistance under AIBP and recovery of loan with interest	1. GoI will release only grant componen t and loan componen t to be raised by states through market borrowin 2. For fiscally weak states, Center would raise loan financing for the loan component	1. 90 percent of project cost to be borne by Centre in case of special category states, 25 percent for non-special category states 2. 90 percent of total grant to be released immediately and 10 percent after expending 70 percent. 3. Funds for later years are contingent upon producing utilization certificates for the previous funding 4. Grant component and state share to be released within 15 days of its release by GoI	CA as grant reduced to 75 per cent of project cost in Special areas	Provision for 60 per cent CA of project cost in special area and 25 per cent for other areas.	Provision for funding of 99 Priority Projects & national Projects through NABARD by creation of Long Term Irrigation Fund (LTIF) with an initial corpus of Rs. 20,000 crore.

Source:

1. Performance Audit of Accelerated Irrigation Benefit Programme (AIBP), Report of the Comptroller and Editor General of India, for the year ended March 2008. Accessed from https://cag.gov.in/sites/default/files/old_reports/state/Uttarakhand/2008/performance_Audit_Uttarakhand_2008/ukAIBP07-08PA.pdf on 31.08.2018
2. Report No. 22 of 2018: Performance audit: Report of the Comptroller and Editor General of India on Accelerated Irrigation Benefit Programme (AIBP). Accessed from https://cag.gov.in/sites/default/files/audit_report_files/Report_No_22_of_2018_Accelerated_Irrigation_Benefits_Programme_Ministry_of_Water_Resources_River_Development.pdf on 31.01.2019

Appendix 4 tells us that, at an all India level, 58.5 percent of targeted potential under AIBP has been created till March 2016. Obviously, the progress varies widely among the states. On one hand, there are states like Jharkhand, Meghalaya and Uttarakhand where either absolutely no progress or very small progress have been made whereas on the other, states like Himachal Pradesh, Chhattisgarh, Goa and Kerala have travelled a long way to have already achieved or are approaching to catch up with the target. However, the "zero" achievements in states like Andhra Pradesh and Tamil Nadu should be judged in the light of the fact that they already had created all or almost all of their ultimate irrigation potential through MMI. Otherwise, they might be wrongly classified as laggard or non-performing states in terms of irrigation potential creation. Performance of all these states in terms of utilization of irrigation potential is another story which has been discussed in the earlier section.

The CLA received per ha of potential created differ widely from state to state and region to region (Table 7). Overall, at an all-India level, states received Rs. 62053.7 per ha of potential creation in current prices (Rs. 95114.3 in constant 2016-17 prices). Northern region received the lowest CLA per ha of potential creation followed by Western, Eastern, Southern and North Eastern states. Of course, the north-eastern states fall under special category states and are eligible for higher funding share from the GoI. The most potential creation happened in the western region, especially in Gujarat and Rajasthan. Per ha CLA used in Rajasthan is in fact lowest in the region.

On the other hand Maharashtra received maximum grants but still have the largest gap in IPC-IPU. As for the reason behind the slow pace of completion and high cost of projects in Maharashtra, according to CAG report of 2014 (report No 3 of 2014; page 103): "...recommendations of High Power Committee and Planning Commission was not followed leading to thin spreading of financial resources among many projects, time and cost overruns and delay in creation of the envisaged irrigation potential (IP)…." Additionally, taking up projects without proper surveys or even before getting environment and forest clearances or required land acquisition were mentioned in the report as the reason for time and cost over runs. The report also pointed the instances "where the Manual provisions and contract terms and conditions were violated resulting in granting of undue benefits to the contractors and incurring of avoidable extra expenditure."

In Northern region, we can see that Uttarakhand received Rs. 609 crore since the inception of the program but almost "zero" potential is created. This was also reflected in the performance audit report by CAG for the year 2008 for AIBP in Uttarakhand. The report revealed that there were major areas of concern in the state regarding AIBP implementation including planning, community participation in the program and financial management.[23] Eastern region created the second lowest potential through AIBP (after north eastern region). Per ha CLA used in the region, however, is higher than northern and western regions. Odisha received the highest total CLA whereas Jharkhand received highest CLA per ha of potential created.

[23] "Internal controls relating to utilization of funds and material are weak and carry the risk of fraud and misappropriation"-CAG Report, Government of Uttarakhand 2008

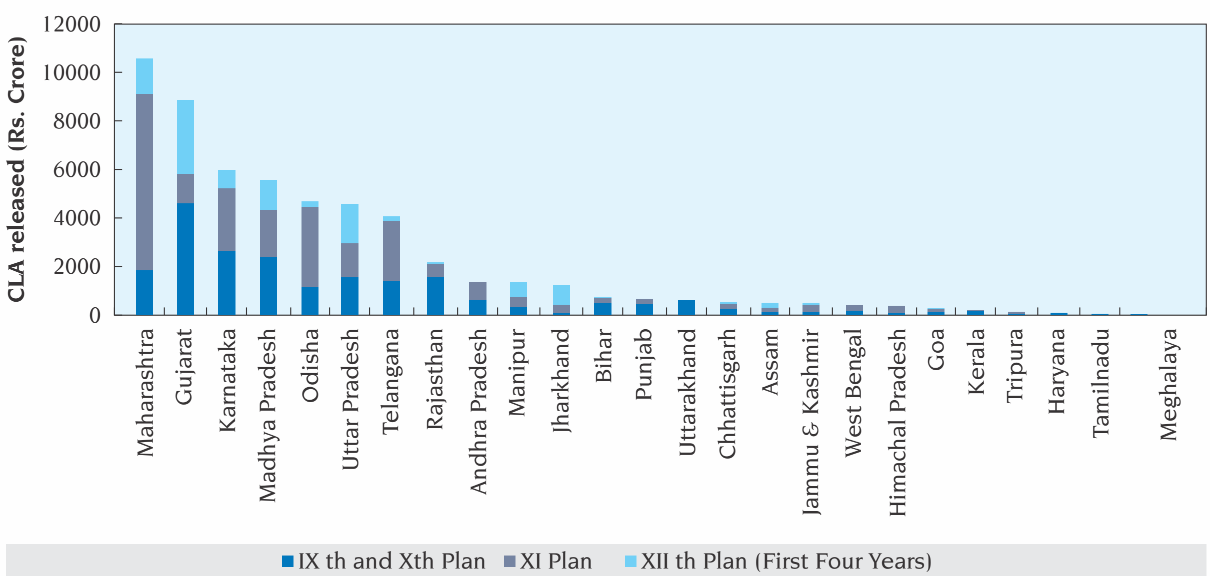
In other major states also, completion of irrigation projects under AIBP were being delayed. Main reasons behind this delay are explained in a recent CAG report on the performance of AIBP for the period 2008-17 (Report No. 6 of 2018; page vi). The said report observed that there are *"several deficiencies in the planning, implementation and monitoring of the programme... Deficiencies in preparation and processing of Detailed Project Reports (DPRs) such as inadequate surveys, inaccurate assessment of water availability, Irrigation Potential (IP) and Command Area, lack of activity wise construction plans, etc. and incorrect calculation of Benefit Cost Ratio of the projects led to modifications in design and scope of work and revision in cost estimates after commencement of work, also adversely affecting the schedule of implementation of the projects.*

"...There were deficiencies in works management such as delays in award of work, splitting of works, incorrect phasing of project implementation, execution of sub-standard work, undue benefits to contractors, etc. The extra financial implications seen in audit were to the extent of Rs. 1,337.81 crore towards irregular/wasteful/avoidable/extra expenditure and Rs. 303.36 crore due to undue favor to the contractor.

"...Monitoring by Central and State agencies was lax."

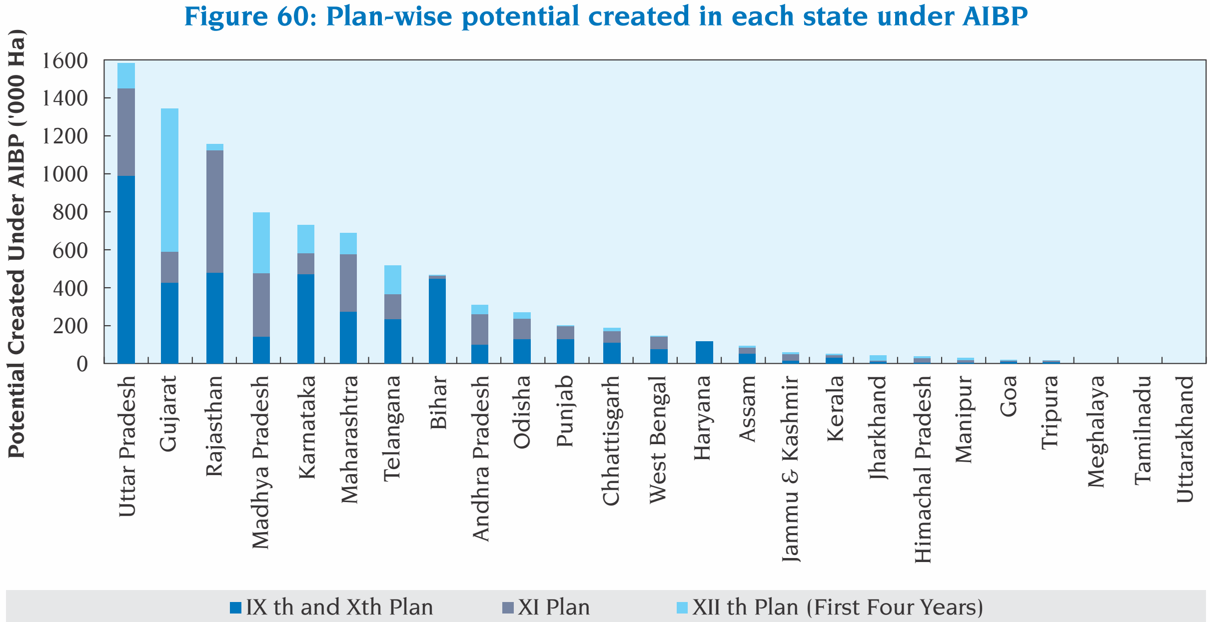
Since projects were not being completed at desired pace even 20 years after the commencement of AIBP, a need was felt to have a second prioritization and select 99 (or 106-including sub-projects) projects which can possibly be completed within the tenure of the present government, but that is not a possibility any more.

Figure 59: Plan-wise grant released to each state for implementation of AIBP



Source: Constructed using the data in Handbook on Water and Related Statistics, CWC, June 2017; See Appendix 3

Figure 60: Plan-wise potential created in each state under AIBP



Source: Constructed using the data in Handbook on Water and Related Statistics, CWC, June 2017; See Appendix 4

Table 7: State-wise receipt of CLA per ha for irrigation potential creation

State/ Region	IPC (Since 1996-97)	CLA (Since 1996-97)		CLA received per ha	
		Current Prices	Constant Prices (2016-17=100)	Current Prices	Constant Prices (2016-17=100)
	000 ha	Rs. Crore		Rs./Ha	
Southern Region					
Andhra Pradesh	310.33	1377.76	2220.60	44396.61	71556.02
Telangana	516.06	4075.70	6201.18	78977.25	120164.02
Karnataka	730.71	5987.37	9667.17	81939.07	132298.28
Kerala	50.07	201.12	390.58	40167.77	78007.64
Tamil Nadu	0.00	20.00	43.32		
Region Sub-Total	1607.17	11641.95	18479.53	72437.58	114981.83
Western Region					
Goa	20.46	273.18	471.81	133519.06	230598.76
Gujarat	1341.11	8881.68	14502.54	66226.33	108138.30
Madhya Pradesh	796.12	5557.14	8720.05	69802.79	109531.87
Chhattisgarh	188.83	518.48	899.94	27457.50	47658.82
Maharashtra	687.94	10583.63	14555.88	153845.25	211586.45
Rajasthan	1153.88	2173.47	4139.49	18836.19	35874.49
Region Sub-Total	4188.34	27987.58	43289.70	66822.61	103357.65

Northern Region					
Haryana	115.23	90.54	189.80	7857.33	16471.14
Himachal Pradesh	37.51	378.90	557.90	101013.06	148732.79
Jammu & Kashmir	59.31	513.66	740.88	86605.97	124916.42
Punjab	201.22	672.04	1227.10	33398.27	60982.77
Uttar Pradesh	1581.06	4589.80	6704.61	29029.89	42405.82
Uttarakhand	0.00	609.75	1303.77		
Region Sub-Total	1994.33	6244.94	9420.28	31313.47	47235.33
Eastern Region					
Bihar	467.38	761.89	1402.55	16301.30	30008.75
Jharkhand	42.42	1247.59	1422.17	294104.20	335259.49
Odisha	269.52	4689.74	6940.95	174003.41	257530.10
West Bengal	147.49	385.00	624.35	26103.46	42331.53
Region Sub-Total	926.81	7084.22	10390.02	76436.59	112105.17
North-Eastern Region					
Assam	93.78	514.76	697.16	54890.17	74340.29
Manipur	30.76	1367.47	1779.24	444561.12	578427.20
Meghalaya	0.00	4.00	8.66		
Tripura	16.82	126.29	196.36	75083.23	116742.06
Region Sub-Total	141.36	2008.52	2672.77	142085.46	189075.09
All-India	**8858.01**	**54967.21**	**84252.30**	**62053.68**	**95114.25**

Source: *Calculated using the data in Handbook on Water and Related Statistics, CWC, June 2017*

Note: *While calculating regional and all-India figures, Tamil Nadu, Uttarakhand and Meghalaya were omitted*

2.4.4 Current State-wise Status of 99 Priority Projects and Possibility of Completion within Targeted Timeline (December 2019)

AIBP was included in the *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) after its announcement in 2015. In 2016, Government of India identified 99 priority projects (106 in total if we consider sub-projects, separately) which were to be completed in mission mode within the timeline of December 2019. Since we have already crossed more than two years of the designated timeline and only around five months is remaining, it is imperative that we look into the progress of the scheme to assess the possibility of achieving the ambitious target.

In the budget of 2016-17, Central Government announced to create a Long Term Irrigation Fund (LTIF) with an initial corpus of Rs. 20,000 crore (which has been increased thereafter) to bridge the resource gap and enable completion of these priority projects within 2016-2020. According to NABARD, "*As per the proposal of MoWR, RD & GR approved by the Union Cabinet, the initial LTIF corpus shall comprise of a mix of various sources like Budgetary Allocation from Govt. of India (GoI)/ Extra Budgetary Resources through GOI fully serviced bonds to be raised by NABARD and direct market borrowings by NABARD.*

Upto 17th July 2019

In respect of GoI fully serviced bonds in the nature of extra budgetary resources, the Government of India will make budgetary provision each year for the entire period of the bond for coupon payments to bond investors." [24]

Upto March 2019, NABARD has sanctioned Rs. 75769.90 crore and released Rs. 34248.73 crore (including for AIBP and CAD&WM both).

Targeted irrigation potential to be created for these projects taken together is 7.6 million hectare (Mha). Initially government categorized these 99 projects in three ways according to given priority. Priority 1 projects were to be completed by 2016-17. There were 23 projects in this category. There were 31 projects in priority 2 and 45 projects in priority 3 which were to be completed within 2017-18 and December 2019, respectively.

There is a change in the categorization of projects as on the 4th of October, 2018. As per the AIBP dashboard, they are being divided into three categories now: completed on June 2018, to be completed by June 2019 and to be completed by December 2019. According to this categorization, 31 projects have been completed by June 2018. Number of projects to be completed by June 2019 and December 2019 are 32 and 43 respectively. There have been some changes in targeted potential as well. It has been reduced from 7.6 Mha to 6.8 Mha (a 10.5 percent decrease; mainly resulted from 0.8Mha decline in targeted potential in Uttar Pradesh). However, as will be evident from our analysis, it will be difficult for UP to achieve its reduced target as well.

Of the 7.6 Mha original targeted potential, 75.7 percent or 5.7 Mha is in five states, namely; Gujarat, Madhya Pradesh, Maharashtra, Telangana and Uttar Pradesh. Figure 61 shows the share of different states in the initial targeted potential.

Farmer can get access to canal water only when field channels are complete and water is delivered at the farm level. But, according to the CAD&WM Dashboard, 71 of the priority projects have only 0-10 percent progress in field channel creation and a total of 87 projects have created less than half of the targeted field channels. More than 90 percent progress is made in case of four projects only. We consider distributary canal status (upto 17th July 2019) to assess the possibility of completion of the priority projects. The projects are divided into five categories:

a. Where physical progress of distributary canals are equal to or more than 90 percent

b. Where physical progress of distributary canals are equal to or more than 70 percent but less than 90 percent

c. Where physical progress of distributary canals are equal to or more than 50 percent but less than 70 percent

d. Where physical progress of distributary canals are less than 50 percent

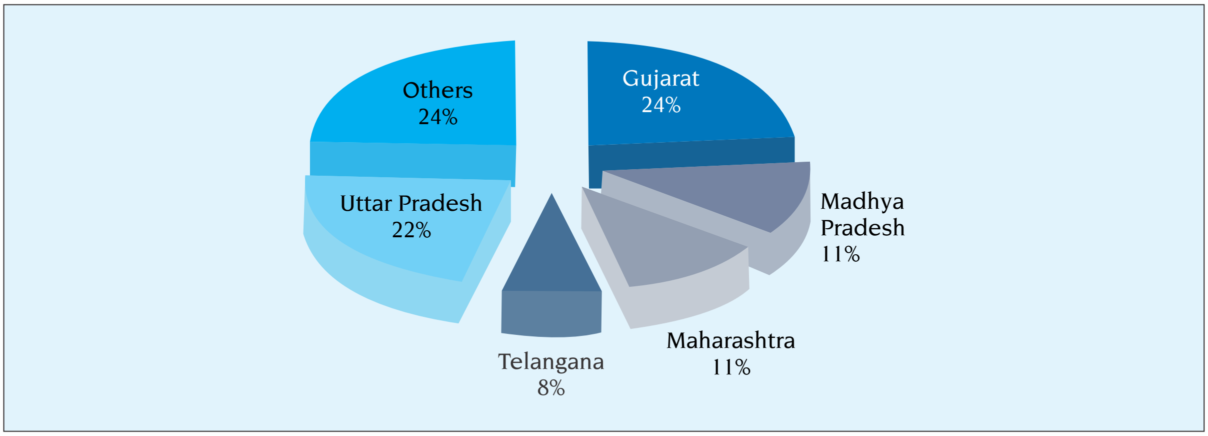
e. Where the data for distributary canals are not available

Out of total 106 projects, we do not have data on distributary canals for 20 projects (Fig. 62), that is, we cannot assess the possibility of completion of these projects within the stipulated timeline for 544 thousand hectares of targeted potential, or, 7 percent of total original targeted irrigation potential (Fig. 63). However, for 9 of these projects (having targeted potential 5.3 percent of total targeted potential)[25] the physical progresses of main canals are over 90 percent or, completed.

[24] https://www.nabard.org/auth/writereaddata/File/LTIF-material%20for%20website.pdf accessed on 25.08.2018

[25] They are: Rajpora lift in Jammu and Kashmir, Sindh Project Phase II and Mahuar Project in Madhya Pradesh, Tillari, Arjuna and Warna in Maharashtra, Upper Indravati in Odisha, Patiala Feeder in Punjab and Mathadivagu in Telangana. According to the dashboard, all of them (except for Tillari and Arjuna) are completed as on June 2018.

Figure 61: Share of states (initial) in targeted irrigation potential of the '99 Priority Projects'



Source: Ministry of Water Resources and Ganga Rejuvination (MoWR)
Note: Other states are the states having less than 100,000 ha in priority projects: Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Manipur, Orissa, Punjab and Rajasthan.

We can say that the projects in categories 'a' and 'b' have a fair chance of completion within the timeline; but for projects in category 'c' and 'd', the chance looks bleak. At an all-India level, 54.4 percent[26] of total targeted potential appears to be achievable by December 2019. For the states under consideration, Gujarat (100 percent) and Madhya Pradesh (70.7 percent) could achieve more than 50 percent of the same. For Uttar Pradesh however, 88.2 percent of the original targeted potential (76 percent of revised target potential) looks unattainable. (Table 8)

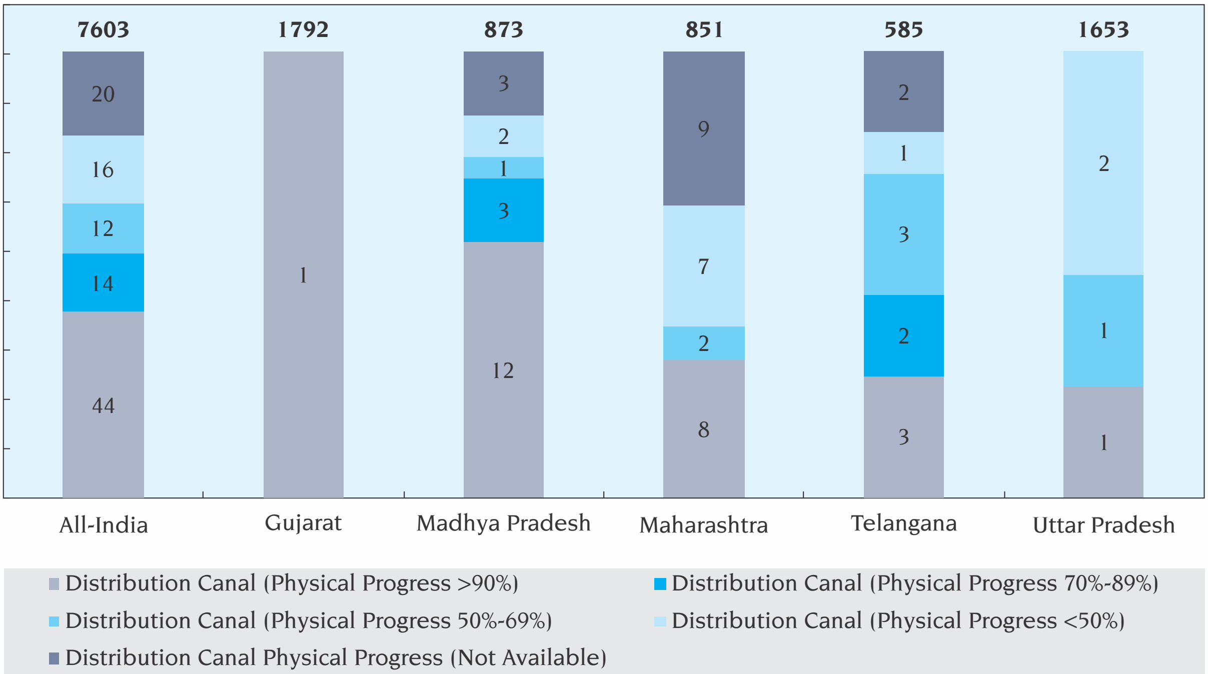
To sum up: it looks difficult to achieve the target of completing priority projects in the stipulated deadline. Even in the ***most optimistic*** scenario, around 40.3 percent of the total original targeted potential is likely to remain unattained.

We see, even after the second prioritization, the pace of completion of projects is not really satisfactory. This is also happening due to various reasons of which necessary funding is only one. Other reasons include "…*land acquisition, sometimes, railway crossing or road crossing*".[27] It appears that the reasons which ailed AIBP have not really left even after the second prioritization. The government should take proper steps without any delay to rectify the situation if the intention really is to complete these projects within the stipulated timeline and deliver benefits to the farmers. It should take lessons from the states which have made really good progress in terms of completing or nearly completing intended projects (like Gujarat and Madhya Pradesh). The situation needs to be properly monitored in Uttar Pradesh, Maharashtra and Telangana which account for 41 percent of the intended IPC of 99 priority projects and have very slow progress. The situation in Maharashtra among these states which lag in potential creation is particularly interesting. It contains the largest number of priority projects. We have also seen that the CLA release per ha is highest in Maharashtra among western region states of India and one of the highest in all-India. This study has found that the capital cost per ha of IPC in Maharashtra is also the highest in India during 2002-03 to 2013-14 (or, during 2002-03 to 2017-18). So, the situation there needs to be rectified immediately taking lessons from other states.

[26] Or, 59.7 percent; if in a very optimistic scenario, we consider the 9 projects mentioned in footnote 26 to be really completed (distributary and field channels included). However, according to the CADWM Dashboard, only Upper Indravati, Mahuar and Sindh project have managed some progress in field channel creation (first two created field channels significantly). For the other six projects, there is either no data or no progress for command area development.

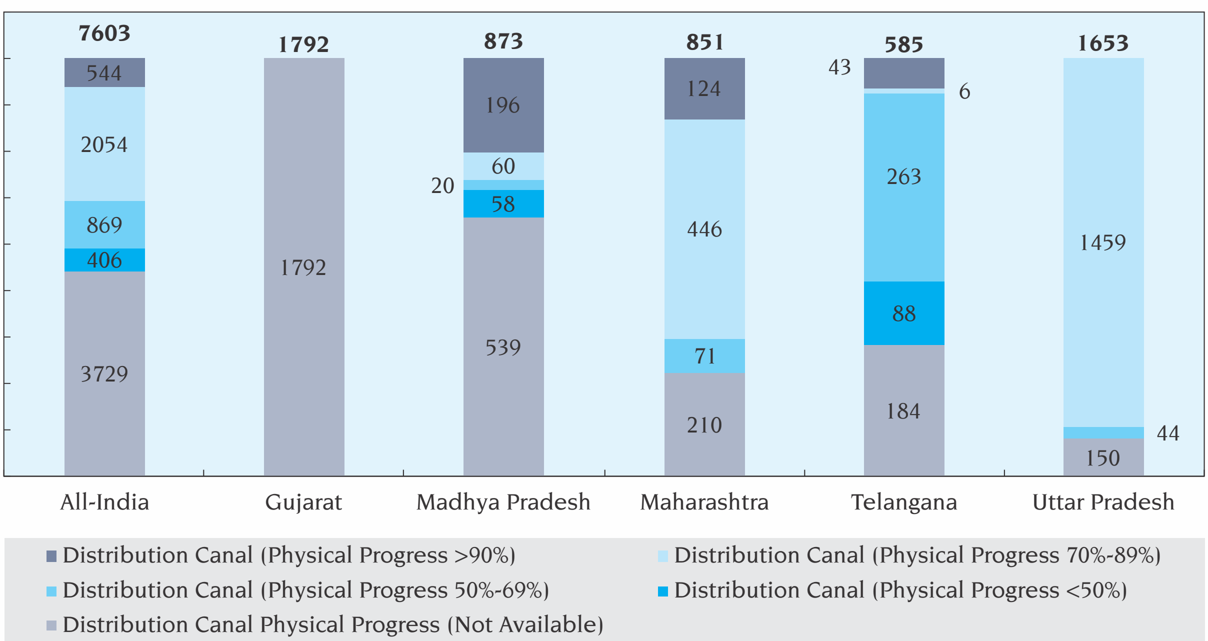
[27] Pp. 50, GoI 2018

Figure 62: Physical progress of construction of distributary canals- All India and Selected States: Numbers



Note: Data within bar denotes number of projects in the corresponding category and data on the outside end of bar represents total targeted potential (in Thousand Hectares)
Source: AIBP Dashboard

Figure 63: Physical progress of construction of Distributary canals- All India and Selected States: area (in thousand ha)



Source: AIBP Dashboard
Note: Data within bar denotes targeted irrigation potential of projects in the corresponding category and data on the outside end of bar represents total targeted potential (Both in thousand hectares)

Table 8: Physical progress of distributary canals- All India and Selected States: Area

Targeted IPC is in Thousand Hectares

Categories	All-India		Gujarat		Madhya Pradesh		Maharashtra		Telangana		Uttar Pradesh	
	Targeted IPC	%	Targeted IPC	%	Targeted IPC	%	Targeted IPC	%	Targeted IPC	%	Targeted IPC	%
Distribution Canal (Physical Progress >90%)	3729	49.1	1792	100.0	539	61.8	210	24.7	184	31.5	150	9.1
Distribution Canal (Physical Progress 70%-89%)	406	5.3	0	0.0	58	6.7	0	0.0	88	15.1	0	0.0
Distribution Canal (Physical Progress 50%-69%)	869	11.4	0	0.0	20	2.2	71	8.3	263	45.0	44	2.7
Distribution Canal (Physical Progress <50%)	2054	27.0	0	0.0	60	6.9	446	52.4	6	1.0	1459	88.2
Distribution Canal Physical Progress (Not Available)	544	7.2	0	0.0	196	22.4	124	14.6	43	7.4	0	0.0
Total	**7603**	**100.0**	**1792**	**100.0**	**873**	**100.0**	**851**	**100.0**	**585**	**100.0**	**1653**	**100.0**

Source: MoWR, RD&GR, AIBP *Dashboard*

2.5 Case Studies: Timely Completion of Irrigation Projects

Up until now, we were looking at the problem of IPC and IPU gap state-wise. We have seen that earlier studies rightly pointed out that one main reason behind this gap is lack of command area development in case of individual projects which seriously hampers the last mile delivery of irrigation water- thus keeping potential utilized at a lower level than created potential.

To delve deeper into this issue, we shall now look closely to select few projects. We have considered six important priority projects in different states, namely:

i. Sardar Sarovar Project on River Narmada for benefits to Gujarat, Rajasthan and Madhya Pradesh states.

ii. Indira Sagar Project on River Narmada for benefits to Madhya Pradesh

iii. Gosikhurd Project, Maharashtra

iv. Krishna- Koyana Major Lift Irrigation Project, Maharashtra

v. Saryu Nahar Pariyojana, Uttar Pradesh

vi. Polavaram Project (National Project), Andhra Pradesh

All of these projects have started long back. Sardar Sarovar and Polavaram are two projects which were conceptualized 60-70 years ago. The other projects, although younger in age as compared to the former two, have started more than 30 years ago. Most of them were in bad

shape before inclusion in AIBP. Even after inclusion in AIBP, none of them picked up considerable pace. Then, they were included in the '99 Priority Projects' (except for Polavaram, although special package was mentioned for it in 2014 Andhra Pradesh Reorganization Package). Our objective is to see whether there has been any improvement in the situation after the second prioritization.

One thing should be kept in mind that the stipulated time limit for completing a good number of the projects was December 2019. Of course, it is too early to definitively say anything about the end situation. But since already two-and-a-half years have passed after 99 projects were prioritized in 2016, analyzing current situations for some important projects could give us a broad idea about where do we stand; and from that what steps could be taken to further expedite the process to fulfill the ambitious dream of completing the projects by December 2019.

2.5.1. Sardar Sarovar Project (SSP)

Narmada rises from Amarkantak Plateau near Anuppur district. It forms the traditional boundary between North India and South India and flows westwards over a length of 1,312 km before draining through the Gulf of Khambhat into the Arabian Sea, 30 km west of Bharuch city of Gujarat. There are 30 large dams, 135 medium and 3000 small dams on Narmada as a part of Narmada Valley development project. The Sardar Sarovar project (SSP) in Gujarat on River Narmada is one of them.

2.5.1.1 H*istory*

Sardar Sarovar Project is one of the oldest projects in independent India. It was envisioned by the first deputy prime minister of India- Sardar Vallabhbhai Patel and its foundation stone was laid by the first prime minister-Pandit Jawaharlal Nehru on April 5, 1961. It is a multipurpose project with initial goals of irrigation and power generation. Drinking water was added to the "project benefits" in early 1990's.

However, SSP has remained in the center of disputes since its early days. In 1964, the central government appointed an expert committee for solving the disputes about sharing Narmada water among Gujarat and Madhya Pradesh. However, since government of Madhya Pradesh was not agreeable to recommendations of the committee, government of India constituted the Narmada Water Dispute Tribunal (NWDT) in 1969, under the Inter State River Water Disputes Act, 1956. NWDT gave its final award in December 1979 on resolving the conflict between water sharing between four states, namely, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. It also fixed height of SSP at 138.68 m. NWDT also laid down binding norms about rehabilitation of the project displaced persons (by giving them irrigable and cultivable land and alternate house plots with civic amenities).

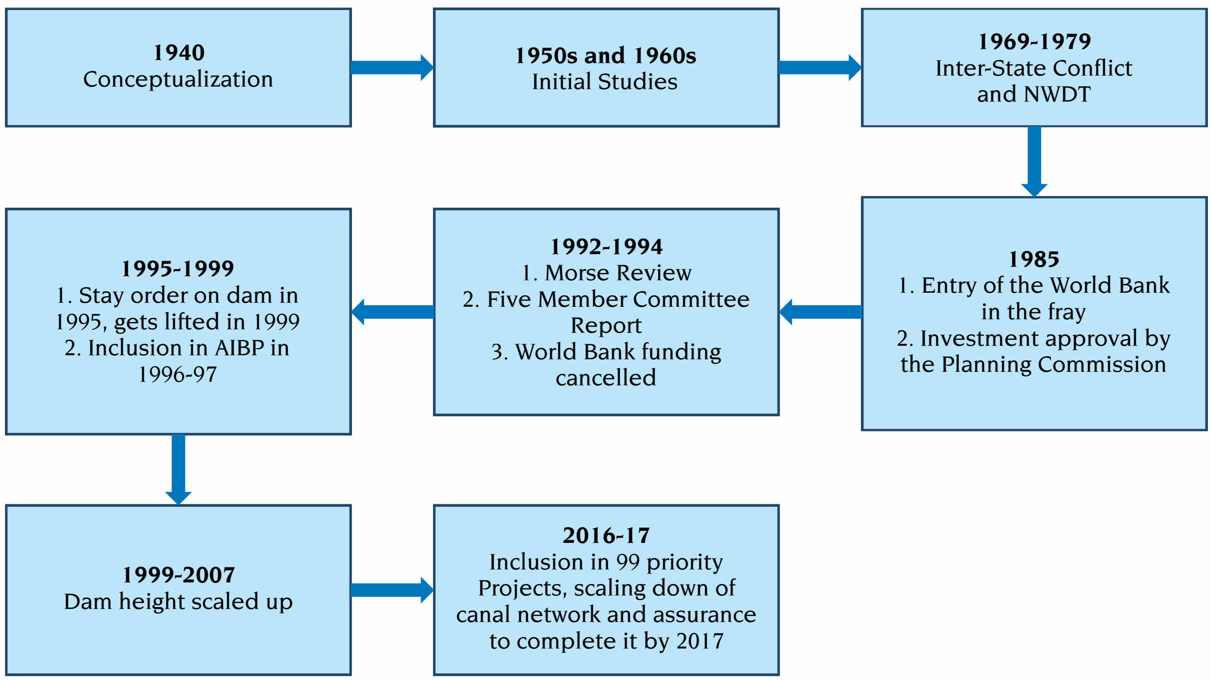
For the disputes, construction of the project was getting delayed. Also, in the late eighties and early nineties, the affected population started to form resistance. There were studies which were hopeful for the future of the project and saw it in positive lights (for e.g., Patel 1992). But around that time, a lot of studies also came up addressing the financial aspect of the project and insufficient rehabilitation of the displaced families; Kalathil 1988, Amte 1990, Thakkar 1993, Dharmadhikary 1993, Oza 1996; to name a few.

The unrest on the part of the affected section led to two reviews of the project: one by the World Bank (headed by Mr. Bradford Morse) and the other by the five member group constituted by the central Ministry of Water Resources. The Morse report found that under prevailing circumstances, due to inadequate assessment, the rehabilitation and resettlement of the displaced persons of the projects was not possible. The opposition of the project was mainly the result of failure to consult the people to be affected. Adequate measures were not considered to mitigate environmental effects. For these reasons, Morse report spoke against extending anymore support to the project. However, it was voted in meeting of World Bank's executive

directors to finance the project with a six-month action plan to address the environmental issues. Nevertheless, government of India announced that it does not want to continue with the grant when it was realized that the action plan would not be met after six months.

There was a writ petition against the construction of the dam following which the Supreme Court had put on a stay order on the construction in 1995. It was withdrawn in 2000 with the condition of *pari-passu* rehabilitation of the displaced. Timeline of the some of the important events in the history of SSP are shown in Fig. 64.

Figure 64: Timeline of events in SSP's history



2.5.1.2 *Planned benefits from the project and actual realization*

As mentioned earlier, the main goals of the project initially were to increase irrigated cultivation area in the riparian states and power generation. Drinking water came to the ambit of benefits from the project in the 1990s in order to assuage the strong demands of the project command villages and absence of alternate sources for drinking water.

Irrigation: As per the original design, the dam was estimated to irrigate 17.92 lakh ha of Gujarat. In Rajasthan, it was supposed to irrigate 73 thousand ha of land. At the first phase of command area development, 2.46 lakh ha was supposed to come under irrigation and after increasing the dam height to 121.92 meter, area (additional) under irrigation was estimated at 3.5 lakh ha. However, most of these estimates were not realized because of lack of creation of the canal network. The Gujarat government has brought down the originally planned canal network from 90,389 km to 71,748 km according to SSNNL latest status report of August, 2017. Even by these revisions, 31 percent of the canal network is still to be built and if one considers the originally planned length, this percentage shoots upto 46 percent. Most of this network is of minor, sub-minor, field channel type without which farmers will not have access to the water. According to SSNNL, the current irrigation potential of SSP stands at 1.42 Mha up to minor level and 1.09 Mha up to sub-minor level, against the planned potential of 1.79 Mha and 1.84 Mha, respectively. In 2013, CWC found the irrigation potential of SSP to be much lower at 0.76 Mha. Unfortunately, the

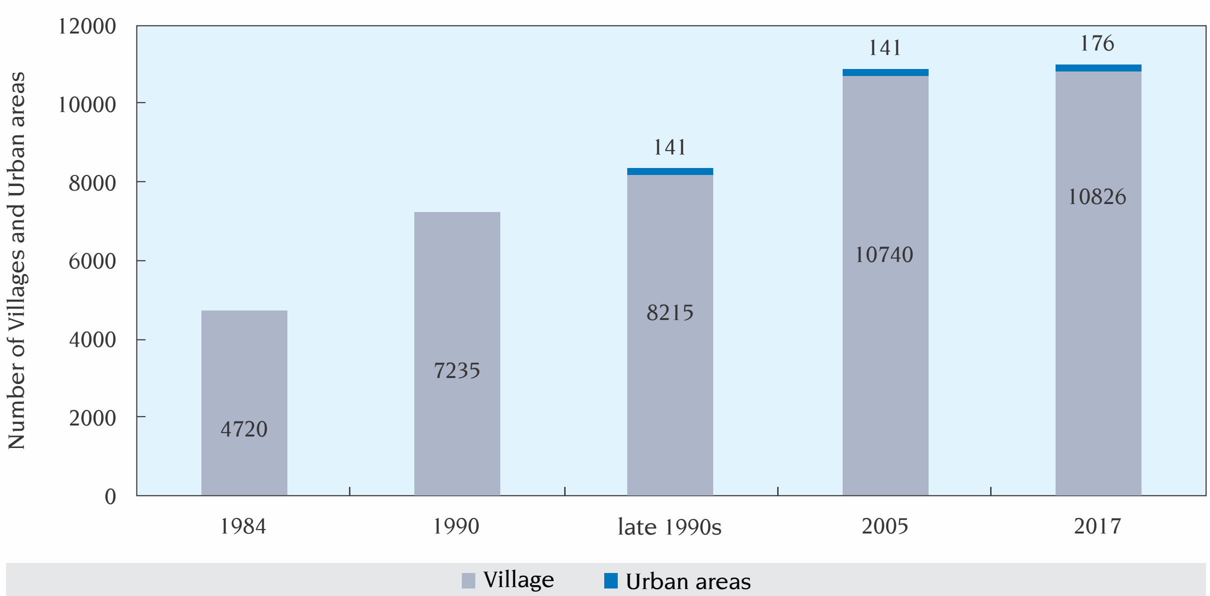
actual area irrigated was only 0.21 M ha, only about 28 percent of the potential (Desai and Sangomla, 2017) and this figure remain unchanged upto 2014-15. Internal review of Narmada Project indicated that actual area under irrigation will increase to 0.33 M ha in 2017-18 and 2018-19. Even CAG report of 2009 points out that " very few areas are being irrigated by the SSP as against the network that has been completed because the agencies have not followed the vertical integration approach which calls for simultaneous construction of the canal network along with the increase in dam height". There can be several reasons for this, but the oft cited is the reluctance on the part of the farmers to part with the land to construct the tertiary network in their small agricultural fields.

Also, during the planning of the project, it was assumed that a large part of the water distribution networks in village areas would be constructed by water user associations (WUAs). By 2006, about 1186 WUAs were registered but only 10 percent of them were active. Moreover, none of them constructed any distribution systems. Hence, farmers ultimately became dependent on diesel pumps to lift water from the main canal. This system thus became heavily influenced by local power relations since access to water became dependent on ownership of pumps and pipes. According to a report by TISS in 2008, "As much as 54% of the command area (26,525 ha out of 57,919 ha) in Gujarat is irrigated by lifting canal water by diesel pumps."

Drinking Water: Drinking water was included in the project's goals much later after its conception but it became an important point of argument for the construction of the dam to counter any controversy surrounding the project.

Number of villages which were promised Narmada water from the projects has been increased significantly over time. In 1979, no villages were promised drinking water from the project. But by 1984, the number was 4720. It was continuously increasing after that. By 1990, the number of villages went up to 7235. By late 1990s, 8215 villages, 135 towns and 6 municipal corporations were promised Narmada water. In 2005, the numbers further increased to 9633 villages and 139 towns in Gujarat and 1107 villages and 2 towns in Rajasthan. By latest estimates (June 2017), the project is proposed to supply drinking water to 30 million people (by 2021) in 9490 villages and 173 urban centers in Gujarat. In Rajasthan, it is supposed to supply water in 1336 villages and 3 towns (almost 4.58 million people) (Fig. 65).

Figure 65: Increasing number of villages and urban areas to be benefitted with drinking water from SSP



Source: TISS (2008)

However, as mentioned in TISS Report (2008), "T*hree performance appraisals carried out by the Comptroller and Auditor General* (CAG) *in* 2003, 2005 *and* 2006 *revealed that both in terms of capacity utilization and villages covered, the performance vis-à-vis drinking water supply from the* SSP *in the districts surveyed has remained at only* 29–33% *of the actual potential*." Furthermore, the report observed that realization of drinking water potential was inadequate even when the dam height was nearing completion.

Power Generation: The installed capacity (River Bed Power House and Canal Head Power House combined) is 1450 Mega Watt (MW). The TISS 2008 report found that the generation of power was not consistent with dam height. According to the report, "…the increase of the dam height from 110.64 m to 121.92 m attributed to 1500–1700 MU of surplus of which only 550 MU was attributable to increased height."

By latest estimates, upto 2017-18, the total power generation has been 41362.3 Million Units (MU).

2.5.1.3 *Financial Cost of SSP: Original Estimation vis-à-vis Cost Over Runs*

In 1983, the first economic appraisal was done for SSP. The estimated cost was Rs. 4887 crore in 1980-81 prices. In 1985, the World Bank estimated the project cost at Rs. 13640 crore. In 1988, Government of Gujarat estimated the cost at Rs. 6406.04 crore at 1986-87 prices. The last one was approved by the Planning Commission. However, due to time over run by decades, the cost also got inflated. Report of the "Working Group on Water Resources for the 11th Five Year Plan" mentioned that the estimated cost of the project has gone up to Rs. 45673 crores. A cost estimate at 2008-09 said that the cost could be Rs. 39240.44 crore[28].

The estimated costs at different period of time are shown in the following graph (Fig. 66).

2.5.1.4 *Current Status*

In the past, the project has been in the center of a lot of controversy. The project is ongoing for almost 6 decades and is still not completed. It became a part of AIBP Programme in 1996-97. But the situation had not improved much after that as well. It became one of the 99 priority projects in 2016 which were to be funded by the Long Term Irrigation Fund (LTIF) through NABARD.

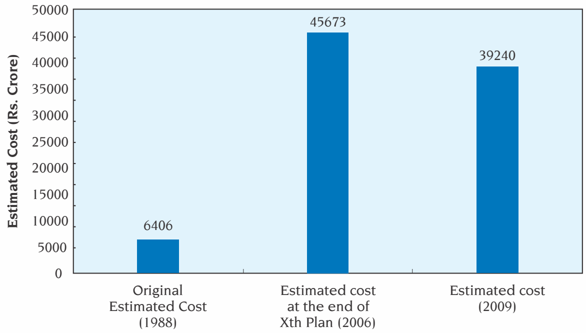
After that, the pace of construction of the project has indeed increased. Rs. 27029.368 crore of expenditure is already done. Against that, the overall physical progress has been 84 percent till the last week of November 2018. The main canal progress is 98 percent while the distributary canal progress is 94 percent. Almost 60 percent of command area development through field channels is also done.

It was originally a priority 3 project, i.e., it was supposed to be completed by December 2019. At the current pace, we can be hopeful that it will be completed within the stipulated time period (complete with field channels to ensure water to the end user). In fact, it might be one of the few prioritized projects which could be completed within the targeted time.

The IPC-IPU gap problem, however, is still prevailing in case of this project. While upto June 2017, 1.4 Mha of 1.8 Mha targeted potential had already been created, the maximum potential utilized upto the same time was much less- only 628 thousand ha. Proper steps should be taken towards bridging this gap through faster field channel creation and ensuring active participation of large number of WUAs.

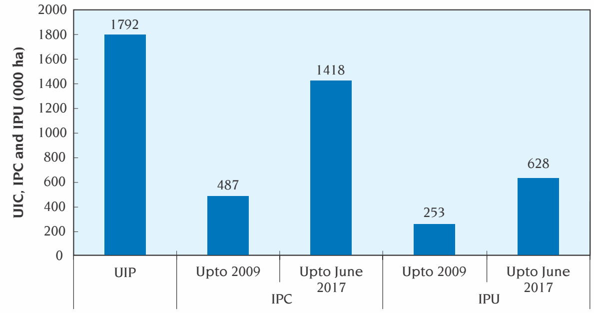
[28] From http://cwc.gov.in/regionaloffices/ntbo/Sardar%20sarovar-status/status%20note_SSP-31-07-2015.pdf accessed on 20.11.2018

Figure 66: Estimated costs (Rs. crore) of SSP at different points of time



Source: Constructed using the data in TISS 2008, GoI 2006, CWC

Figure 67: UIP, IPC and IPU of SSP



Source: http://www.sardarsarovardam.org/fileman/Uploads/Water-Resources-Ready-Recknor.pdf; Socio-Economic review of Gujarat 2017-18

2.5.1.5 *Continuation of the Conundrum, and Some Possible Solutions*

Creation and utilization of the potential in the SSP has remained extremely slow upto 2009 (Fig. 67)

In 50 years of the ongoing work (1961 to 2009) only 27 per cent of the planned potential was created and 52 per cent of the created potential and 14 per cent of the planned potential was utilized.

The present status of completion of the irrigation network of SSP in Gujarat is given in Table 9.

Table 9: Status of completion of different components of SSP in Gujarat

Type of canal	Total length in km	Completed length in km upto Feb., 2018	Per cent completion
Main canal	458	458	100
Branch canal	2731	2604	95.3
Distributaries	4569	4206	92.1
Minors	15670	12912	82.4
Sub-minors	48320	32051	66.3
Total	**71748**	**52231**	**72.8**

Now the project has a culturable command area of 11.52 lakh ha against the initially planned CCA of 17.92 lakh ha which is only 63 per cent of the planned as the remaining area has either urbanized or put to different uses and is as such decommissioned. The main reason is reluctance on the part of the farmers to provide land for construction of the surface irrigation infrastructure though other factors like more time needed for construction, low water use efficiency, inequitable distribution, and damages due to flooding, salinity and waterlogging are also offered. Most farmers along the constructed network and even few kilometers away continue to use the water through direct lifting of water through pumps and conveyance through plastic pipes.

As per the own admission of SSNNL in 2018, the mammoth task of constructing 38,000 km length of sub-minors and field channels is pending to achieve the last mile connectivity. As other

measures of constructing the surface channels have not been successful, the government has now decided to provide option of 'Under Ground Pipe Line (UGPL)' to the farmers with the potential advantages of land and water savings (10-20 per cent), quick construction, integration of field channels with sub-minors, minimum seepage and waterlogging, and assured supply to the tail enders. Farmers need to pay only 2.5 per cent of the cost and enter into an agreement with the implementing agency and will still have the option to select open channel or UGPL. Between January 2015 (launch of the scheme) and February 2018, the following accomplishments have been made:

- Length of UGPL completed: 21,841 km
- New command area developed/ regulated: 7.8 lakh ha
- Beneficiary farmers : > 6 lakh
- Tri-partite agreements: 18,700 Chaks
- Cost incurred: 3,100 crore (~ Rs. 44,300/ha) - The average cost of the OFD works under CAD&WM program of the Ministry is Rs. 22,000/ ha; about 50 per cent of the UGPL cost. Considering the higher efficiency and long-term benefits, this may still be reasonable.

2.5.2 Indira Sagar Irrigation Project, Madhya Pradesh

Indira Sagar is another project on river Narmada. The project is situated at Narmada Nagar, Mundi in the Khandwa district of Madhya Pradesh. The foundation stone of the project was laid by former Prime Minister of India, Indira Gandhi on 23 October 1983. Irrigation and hydropower generation are the main goals of this multipurpose project. Culturable Command Area (CCA) of the project is 1.23 lakh ha with UIP of 1.69 lakh ha.

The project was approved by the Planning Commission in 1989. It is a concrete gravity dam. The dam will be 654 m long and 91.4 m high above the deepest foundation level. It will also consist of a 495 meter long central spillway to pass a design flood (SPF) through 20 radial crest gates. There will be a surface power house on the right bank to house 8 units of 125MW each, with conventional turbines and a left bank flow lined canal (commanding a net irrigable area of 0.99 lakh ha) which would be 249 km long.

2.5.2.1 *Estimated Project Benefits*

i. The districts in Madhya Pradesh that will be benefitted from the project are West Nimar, East Nimar and Barwani.

ii. Upon completion, the project will have the storage capacity of 9750 MCM which would be the largest in India.

iii. It will be used in power generation (installed capacity of 1000 MW), irrigation water and 74 MCM of it will be supplied for industrial and domestic needs.

iv. Due to its upstream position, it is supposed to supply regulated water to Omkareshwar and Maheshwar projects situated downstream for irrigation and power generation.

2.5.2.2 *Cost Estimates over Time*

The original Project proposal was considered by the Advisory Committee of MoWR in the 42nd meeting held on 11 January1989 and was accepted for Rs 1993.67 crore at 1988 prices. This is including the cost of Unit-II of canal for Rs. 541.98 crore and Unit - III power house for Rs 619.37 crore. Like all other major irrigation projects in India, this also got delayed and it has also seen cost over runs of about 64 per cent upto 2012 (Fig. 68) and shall further increase substantially.

2.5.2.3 *Current* Status

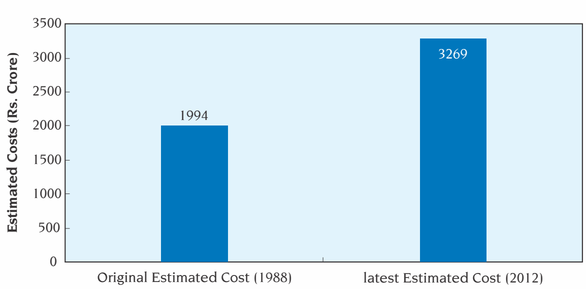
Indira Sagar project has five phases: Phase I and II: 0 km to 142 km ; Phase III: 143 km to 206 km; Phase IV: 206 km to 243 km; Phase V: Khargone Lift Canal system. Different phases were included in AIBP in different time period. While Phases I and II were included in AIBP back in 1996-97, Phases III, IV and V found them in AIBP in 2007-08, 2008-09 and 2014-15, respectively. Even after its inclusion in AIBP, the work was not progressing at the desired pace. Upto 2012, irrigation potential of only 41,727 ha was created as against the UIP of 1.69 lakh ha (24.7 per cent). In 2016, along with some other projects, Indira Sagar (all its phases) was also included in the list of 99 priority projects. Targeted IP of Phase I and II were 62.2 thousand ha. The same for Phases III, IV and V were 20.7 thousand ha, 19.6 thousand ha and 33.14 thousand ha respectively. Together, all the phases of Indira Sagar are estimated to create additional potential of 1.36 lakh ha after completion.

However, priority levels of different phases of the project differed. While Phase I, II and V were under Priority I (were to be completed in 2016-17), Phase III was under priority 2 (was to be completed by March 2018) and Phase IV was under priority III (to be completed by December 2019).

Cost of the AIBP components of the project in 2012 was estimated at Rs. 3200.38 crore (combining all phases) of which Rs. 3037.5 crore is already spent upto November 2018. Against that expenditure, irrigation potential created up until November 2018 through this project is 1.16 lakh ha[29]. According to the AIBP dashboard, Phases I, II and V have been completed by June 2018. However, that is not clear from the progress data provided in the dashboard itself. Whereas, the physical progress of main canal and distributary canals for Phases I and II are more than 99 percent, the same for Phase IV are 85 percent and 88 percent respectively. Distributary canal progress for Phases III and IV are 88 percent and 83 percent, respectively.

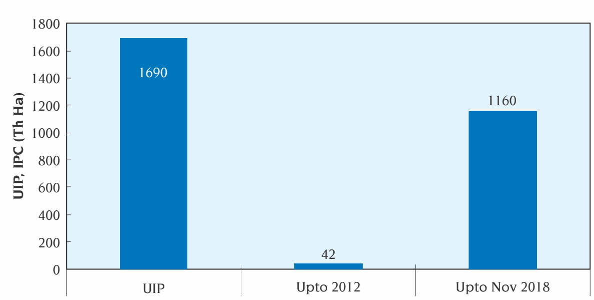
Going only by the main canal and distributary canal progress, we can say that the potential creation has obviously been sped up under the second prioritization. But it is to be kept in mind that, creating potential does not necessarily mean access of irrigation water to the beneficiaries. For that, construction of field channels is necessary. Unfortunately, unlike in SSP, we cannot be hopeful that within stipulated timeline, intended beneficiaries will have access to irrigation water for the field channel construction in this case is lagging behind. According to the CAD&WM Dashboard, only 23.4 percent of field channel CCA for Phases I and II is constructed.

Figure 68: Estimated Costs of Indira Sagar Project (All Phases Taken Together)



Source: India-WRIS, AIBP Dashboard

Figure 69: UIP and IPC for Indira Sagar Project



Source: India-WRIS, AIBP Dashboard

29 Of which, Phase I and II has 59.4 Th. Ha, Phase III has 16.7 Th. Ha, Phase IV has 8.5 Th. Ha and Phase V has 32 Th. Ha.

2.5.3 *Gosikhurd Irrigation Project, Maharashtra*

The Godavari is India's second longest river after the Ganga. The Gosikhurd project is one of the important major irrigation projects in Godavari Basin. Gosikhurd irrigation project is situated on the river Wainganga in Maharashtra's Bhandara district. The project was launched in the year 1984 by the former Prime Minister Rajiv Gandhi. It was declared as 'National Irrigation Project' by the government of India. The project envisages constructing a 10452.1 m long earthen dam maximum height of which would be 22.5 m and 903.9 m long concrete dam with a central spillway which would have a maximum height of 28.37 m. The gated "ogee-shaped" central spillway would be 773.9 m long. It will have 65 m long non-overflow blocks on both sides. It would also have 33 radial gates.

2.5.3.1 *Estimated Project Benefits*

Unlike Sardar Sarovar Project and Indira Sagar Project discussed above, Gosikhurd is not a multipurpose project. It is mainly an irrigation project. The annual irrigation potential of the project is estimated at 2.5 lakh ha in an Irrigable Command Area (ICA) of 1.9 Lakh ha. Of this 1.9 lakh ha:

- I. 58,422 ha ICA is from four Lift Irrigation Schemes (LIS) - Tekepar, Ambhora, Mokhabardi and Nerla (Paghora).
- ii. 30,459 ha ICA is from 22.93 km long Left Bank Canal
- iii. 48,759 ha ICA is from 99 km long Right Bank Canal; and
- iv. Additional 52,360 ha ICA is from Renovation of existing Asolamendha Tank in Chandrapur district to store surplus water of monsoon from the Gosikhurd reservoir

The Culturable Command Area or CCA of the project is 2 lakh ha. The beneficiary districts of the projects are Bhandara, Nagpur and Chandrapur. The project is estimated to provide an annual irrigation to an area of 89,856 ha in Bhandara district; 19,481 ha in Nagpur district and 1,41,463 ha in Chandrapur district.

2.5.3.2 *Cost Estimates over Time*

The project was inaugurated in 1984 but it was first accepted by the Technical Advisory Committee (TAC) of Central Water Commission in 1988. Financial cost estimate for the project was Rs. 461.19 crore at 1981-82 prices. This was subsequently approved by the central Planning Commission in 1995. However, delays in construction caused substantial increase in the project costs. In 2008, TAC estimated the cost to be Rs. 7,777.85 crore at 2007-08 prices which was subsequently approved by the central Planning Commission. As per the AIBP dashboard, the latest estimated cost stands at Rs. 18,494.57 crore (increase of more than 40 times the original cost).

Figure 70 depicts increase in estimated costs for the project.

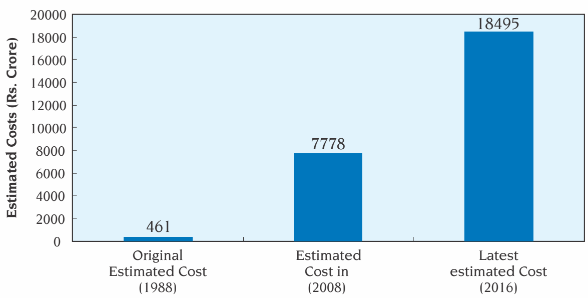
2.5.3.3 *Current Status*

Gosikhurd was included in AIBP in 2008-09 and declared as National Irrigation Project in 2009. By that time, after 25 years of inauguration and 14 years of approval by the Planning Commission, 19,719 ha or only 7.8 percent of irrigation potential was created. In 2016-17, it was included in the 99 priority projects to be completed within December 2019. This project came under Priority 3, or, the target was to complete this project by December 2019.

According to the updates in AIBP Dashboard by November 2018 end, the progress in the main canal is 76.5 percent and distributary canal is 37.9 percent of the original target. The latest estimated cost of AIBP component was Rs. 12770.09 crore of which Rs. 6533.15 crore is spent.

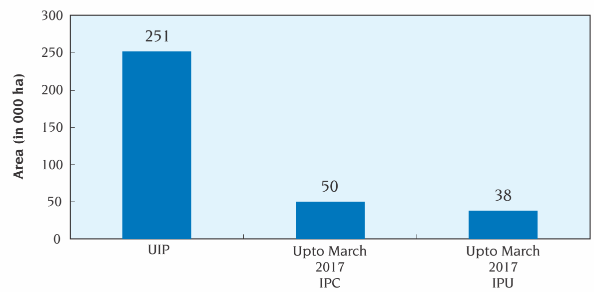
Unfortunately, in the CAD&WM Dashboard, no data is available for the construction update of field channels under this project. So, even if it is mentioned in AIBP dashboard that 74.5 thousand ha of irrigation potential has been created, it is unclear that how much of the created potential is actually being used by the targeted beneficiaries. In a recent performance audit report by CAG (January 2018), it was mentioned that 0.5 lakh ha of potential has been created and 0.38 lakh ha of that created potential was being utilized. So, there is considerably large gap (~ 85 per cent) in potential creation and utilization in case of the project. So it is a case of double whammy, the cost is increased by more than 40 times and still the irrigation potential utilized is only 15 per cent of the planned IPC.

Figure 70: Estimated cost escalation of Gosikhurd Irrigation Project



Source: India-WRIS, AIBP Dashboard

Figure 71: Potential created vs. utilized in Gosikhurd Irrigation Project



Source: CAG (2018)

When the project was started, around 91 villages and around more than 100,000 people were supposed to be affected. The project has been delayed by the irregularities in rehabilitation of affected people and environmental clearances. In its almost 34 years of existence, Gosikhurd has seen protests by the project oustees for the delay in rehabilitation. To make sure that people are benefitted from the project the way it intended, it is imperative to increase the speed of the work to complete not only the main canal but also the field channels properly. Ensuring proper rehabilitation of affected population in a timely manner should also be a priority.

2.5.4 *Krishna-Koyna Major Lift Irrigation Project, Maharashtra*

The Krishna River is the fourth-biggest river in India in terms of water inflows and river basin area - after the Ganga, Godavari and Brahmaputra. It originates near Mahabaleshwar in Maharashtra. The Koyana river is a tributary of the Krishna river which originates in Mahabaleshwar and meets Krishna at Karad (in Satara district, Maharashtra) in Pritisangam. The Krishna-Koyana major lift irrigation project is situated in Krishna Basin on Koyana River in Maharashtra. It was launched in the year 1984.

The project aims at construction of two components: Takari and Mhaisal

- Takari part plans to construct head works (like pump house, rising main, delivery chamber and allied works). This part will be used for lifting of water from Satapewadi Barrage on Krishna river near Takari in Sangli district (Stage I to IV)
- Mhaisal part's objective is to construct head works in stage I to VI-A & VI-B.

2.5.4.1 *Estimated Project Benefits*

As the name suggests, Krishna-Koyana Project is also mainly for increasing irrigated area in Maharashtra. The CCA of the project is 1.72 lakh ha and ultimate irrigation potential is 1.21 lakh ha. Of the 1.21 lakh UIP,

- Takari part is supposed to utilize total canal length of 188 km to irrigate 28939 ha area. The riparian places are Kadegaon, Palus, Walvakhanapur and Tasgaon Talukas in Sangli district.
- Mhaisal part is proposed to irrigate 92317 ha area using a 373 km long canal. The places which would be benefitted upon completion are Miraj, Kavthemahankal, Tasgaon and Jat Talukas in Sangli district and Sangola and Mangalwedha talukas in Solapur District.

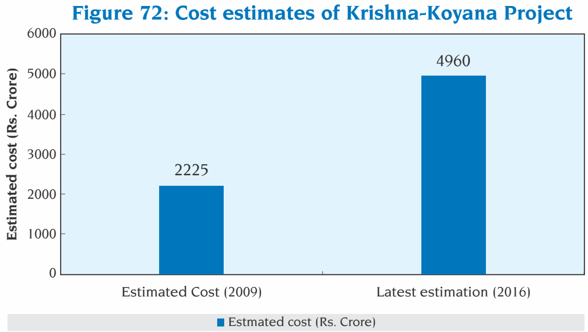
2.5.4.2 *Cost estimates Over Time*

The project was approved by the Planning Commission of India in the year 2009. The cost was estimated at Rs.2224.76 crore at 2005-06 prices. Latest estimated cost of the project as per AIBP Dashboard is Rs. 4959.91 crore of which AIBP component cost is Rs. 2774.9 crore (Fig. 72). Even within a decade of approval, the cost has increased by 2.22 times.

2.5.4.3 *Current Status*

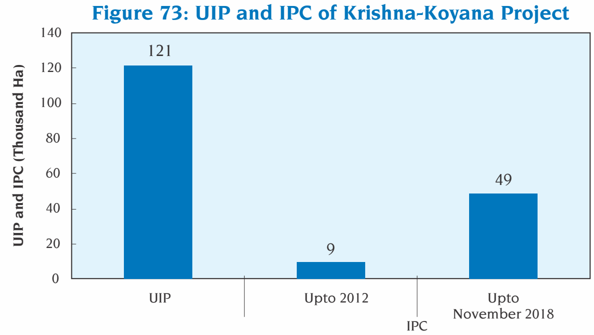
As mentioned earlier, construction work of the project was started in 1984 and it has been included in AIBP during 2009-10. Upto February 2012 irrigation potential of only 9443 hectare was created. It was included in the 99 priority projects in the category priority 3 (to be completed by December 2019). However, till the end of November 2018, the progress of the project is not at all impressive. Although almost 51 percent of the main canal has been constructed according to the AIBP dashboard, distributary canal construction was only at around 14 percent. Although it is being said that 48.5 thousand ha of irrigation potential has been created, since no information on field channel construction is available for the project in the CAD&WM Dashboard, the chance of completing the project within next one year looks bleak. It can be safely assumed that only 14 percent of irrigation project is being utilized. Even under a small Lift Irrigation Project, such a tardy progress should be unacceptable in a drought prone state like Maharashtra where less than 20% cultivated area is under irrigation. Authorities really need to pick up pace to complete the project so that farmers can reap the benefits of additional irrigated land for and provide the much needed succor to the distressed rainfed farmers.

Figure 72: Cost estimates of Krishna-Koyana Project



Source: India-WRIS, AIBP Dashboard

Figure 73: UIP and IPC of Krishna-Koyana Project



Source: India-WRIS, AIBP Dashboard

2.5.5 *Saryu Nahar Pariyojana (Saryu Canal Project), Uttar Pradesh*

Ghaghara River is a major left bank tributary of the Ganges River. Lower part of the Ghaghara river is called Saryu. Saryu Nahar Pariyojana is situated on the Saryu River. Construction work started for this project back in the fifth five year plan. The planning commission of India approved the project in 1998.

2.5.5.1 *Estimated Project Benefits and Costs*

The project has a CCA of 1,200,000 ha and UIP of 1,404,000 ha. Upon completion, the project is supposed to benefit parts of Gorakhpur, Sant Kabir Nagar, Balrampur, Siddharth Nagar, Bahraich, Sitapur, Shrawasti, Maharajganj, Faizabad, Deoria, Basti, Bara Banki, Azamgarh, Ambedkar Nagar and Gonda districts in the eastern Uttar Pradesh.

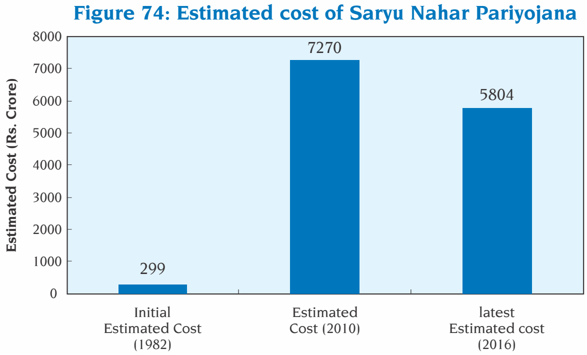
The initial estimated cost for the project was Rs. 299 crore in 1982. According to CAG (2018), it was estimated at Rs. 7270 crore in 2010. According to the latest estimates shown in the AIBP Dashboard, it has risen to Rs. 5803.61 crore – about 20 times the original cost (Fig. 74).

2.5.5.2 *Current Status*

According to the latest performance audit report (January 2018) on national projects by the CAG, 1077 thousand ha potential has been created. However, as CAG observed, due to "mismatch between construction of dam and canal infrastructure, gaps in connectivity and structures and lack of *pari passu* implementation of CAD works" only 276 thousand ha (25.6 per cent) of created potential is being utilized. Evidently, the gap needs to be addressed as soon as possible.

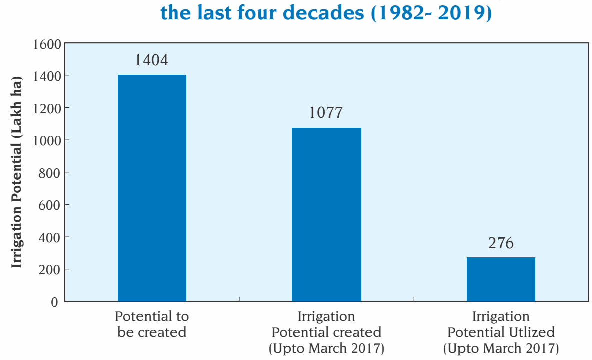
Upto the end of November 2018, Rs. 3038 crore expenditure has been made on the project. As per the AIBP dashboard, the main canal progress is almost 75 percent but the distributary canal progress is only 32 percent. Of the targeted 473 thousand ha under the second prioritization, only 162 thousand ha has been created. However, due to absence of information on field channel creation and the situation of potential utilization mentioned in the CAG report (which shows IPC and IPU of the project upto match 2017), one cannot be too hopeful for completion of this project by its target- that is, December 2019. Fig. 75 shows the gap between irrigation potential created and utilized under Saryu Nahar Pariyojana.

Figure 74: Estimated cost of Saryu Nahar Pariyojana



Source: CAG (2018), AIBP *Dashboard*

Figure 75: Irrigation potential created vs. utilized under Saryu Nahar Pariyojana during the last four decades (1982- 2019)



Source: CAG (2018)

2.5.6 *Polavaram Multi-purpose Irrigation Project*

Polavaram is a multipurpose irrigation project on Godavari River in east Godavari district of Andhra Pradesh. This is not a project under the 99 priority projects, but considered a separate project of importance under AIBP. However, this project is also running for long and created a lot of controversies since estimated benefits as well as associated costs are all very high.

The Polavaram project will be a 45.72 m high, 2.32-km-long dam to make use of water from Godavari River. This is a multipurpose project which on completion expects to have a storage capacity of 551 million cubic meters (MCM) and power generation capacity of 960 MW. It also targets to irrigate 2.91 lakh ha of land through two major canals. The riparian districts would be Krishna, East and West Godavari and Vishakhapatnam.

According to the official estimates, the dam will submerge 276 villages in Andhra Pradesh's Khammam and East and West Godavari districts, Odisha's Malkangiri district, and Chattisgarh's Dantewada district. It was also estimated to cause involuntary displacement of 197,000 tribal people (Reddy 2006, Rao 2006, Rama Mohan 2006). Bondla and Rao (2010) observe that, "Given a choice of constructing or not constructing the Polavaram dam, the tribal people are against the former. But the fundamental question is whether or not they have a choice in the decision: a large majority of them feel that there is no choice and that their view has not been elicited at all so far by the state machinery." Also, as anecdotes suggest, the possible tribal oustees dread going out to live with non-tribal people since they think they would not be welcomed in the new place. Also, the rehabilitation programs are not as efficient and timely in India. This also causes apprehension among the people who are to be displaced. These, along with the sentiment associated with the place of living causes the resistance.

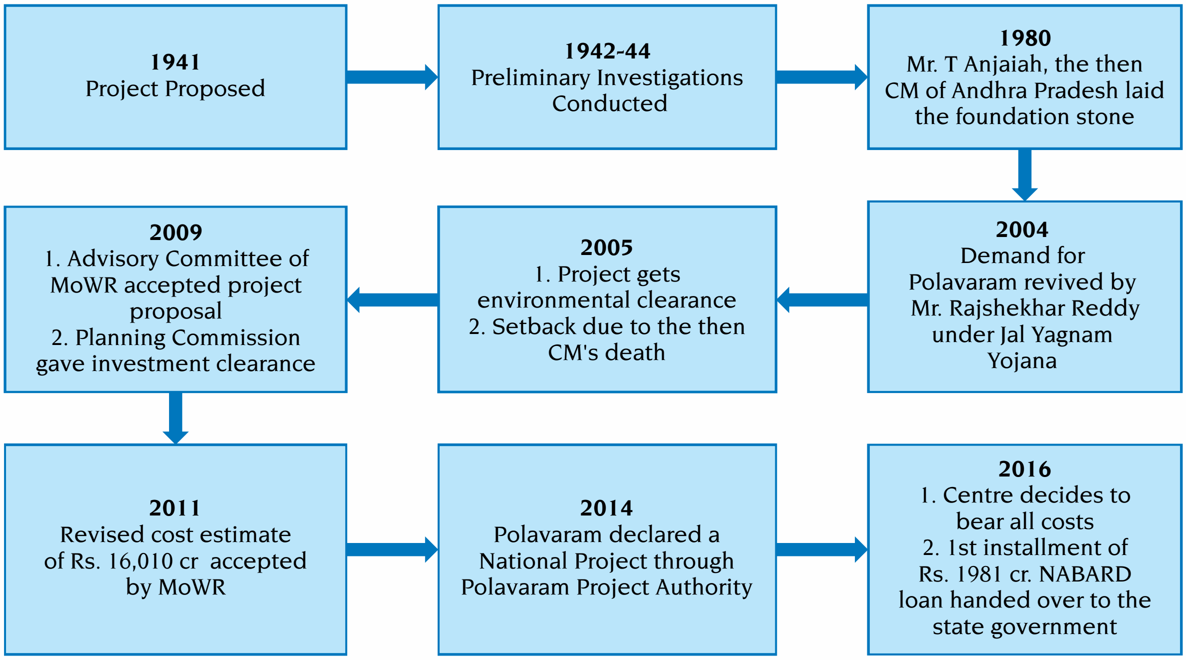
Fig. 76 shows a timeline for important events regarding this project

2.5.6.1 *Cost Estimates over time*

Initial cost estimate of Polavaram project was Rs. 2665 crore in 1982. In 2011, the revised estimate was Rs. 55133 crore. It is mentioned in the January 2018 CAG report that the amount is yet to be approved. According to a press release by the Government in February 2018, the approved cost of the project is Rs. 16010.45 crore at 2010-11 prices including the irrigation component of Rs.12294.40 crore.

Fig. 77 shows the cost estimates for the project over time.

Figure 76: Timeline of Polavaram Multi-purpose Irrigation project

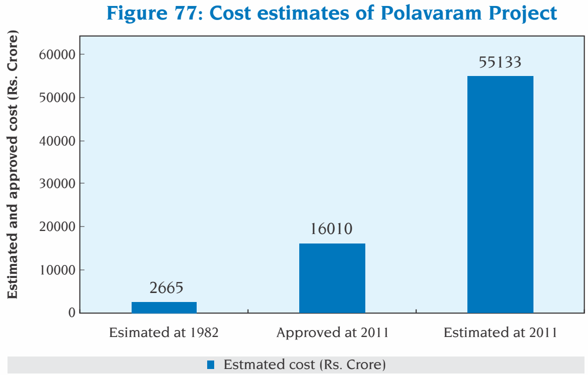


2.5.6.2 *Current Status*

Up until 30th September, 2018, NABARD sanctioned Rs. 6381.54 crore under its Long Term Irrigation Fund (LTIF) for the project and already released Rs. 5814.15 crore. According to the CAG (2018) report, as of March 2017, out of 2.91 lakh ha of UIP, 1.29 lakh ha has been created under this project. Like all the other projects, the IPC-IPU gap story holds true here also. Irrigation potential utilized (1.18 lakh ha) remains lower than potential created through Polavaram Project (Fig. 78). The only solace is that there is only a small gap between the current IPC and current IPU.

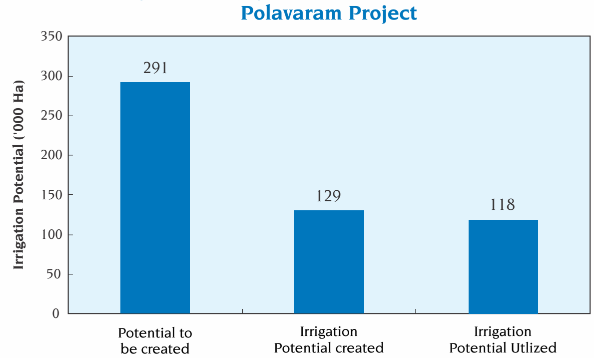
In February 2018, it was notified by Ministry of Water Resources, government of India that the state government is taking all necessary steps to complete Polavaram by 2019. These steps include addressing land acquisition, and restoration & renovation issues, design finalization etc. However, to really achieve this ambitious goal and prevent further cost escalations, construction of field channels should be prioritized. Rehabilitation issues should also be addressed and solved as soon as possible so as to avoid further delay.

Figure 77: Cost estimates of Polavaram Project



Source: CAG (2018), PIB 2018

Figure 78: Target Potential, IPC and IPU for Polavaram Project



Source: CAG Report (2018)

To sum up:

The analysis of the six large projects spread in different parts of the country is summarized under Table 10. In spite of the geographical, hydrological and socio-economic variations of these projects, certain features were discomforting and common

i. ***Prolonged Delays*:** All the projects were inordinately delayed from the date of their inception and even after formal investment approvals by the Technical Appraisals by CWC-MoWR and Planning Commission-GoI. For the analyzed projects the prolonged delays of 9 to 36 years have already happened and even in most optimistic scenario there will be further delays by several years. This should be unacceptable in a country where more than half of the cultivated area is still rain-fed and farmers are in dire stress.

ii. ***High Cost-Overruns*:** In all the six projects there have been excessively high cost over-runs from the initial estimates for which these projects were thoroughly considered and approved. In case one analyses the full costs incurred over time and the potential benefits accrued, the projects shall have very low economic viability. Since the large costs have already been sunk, the government has no option but continue to make fresh investments. The cost over-runs for the six analyzed projects varied from 2.2 times to 40.1 times. It shows that sound and efficient project management systems are perhaps not in place.

iii. ***Low Irrigation Potential Utilization*:** The main issue of concern is that in spite of the prolonged delays and high cost over-runs in completion of the projects, the ultimate benefits achieved through utilization of irrigation potential have remained poor. The utilization of the irrigation potential created of the six projects varied from only 15 to 41percent, except for Indira Sagar which was at 69 percent. This is a double whammy for the poor farmers as they have waited for very long periods and the state exchequer as the state has spent several times more than the initial investment for the proposal.

There is only small solace that for the selected projects, NABARD funding definitely paced up the irrigation potential creation as compared to the previous dismal situation (as per the data available in the dashboards). However, one should be cautious while drawing conclusions from that information since except for SSP either no data is available for command area development (CAD) status or CAD is very low, it is difficult to imagine targeted beneficiaries reaping the benefits of additional potential creation. The recent report of the Comptroller and Accountant General of India (CAG, 2018) has also raised serious concerns about the implementation of National Irrigation Projects (see Box). The analysis clearly indicates that the existing system/ practices and procedures of the Project Conception, Technical and Investment Approval, actual construction of the main works and the field infrastructure for distribution and proper utilization of the water resources is faced with extreme laxity and non-accountability on the part of various players and stakeholders. The existing institutional mechanism for monitoring and evaluation of the project activities and budget utilization and contract management etc. needs a thorough revision and revamping. It needs to be replaced with an efficient, modern, accountable, and a management oriented professional organization which can deliver the expected results and help a large section of the distressed farmers and other domestic and industrial users to have an assured access to the available water resources. Otherwise the country will continue to invest its scarce good money after the large bad money which has already been sunk into the mammoth old on-going irrigation projects or those which may be fresh considerations.

Highlights from CAG Report on National Irrigation Projects under Accelerated Irrigation Benefit Program of India

The CAG report on National Irrigation Projects, tabled in Parliament on July 20, 2018 has revealed that sixteen major multi-purpose irrigation projects, taken up on an expeditious basis about a decade ago, are nowhere near completion, with no work being undertaken in as many as 11 projects despite the focus on improving irrigation facilities in the country.

Out of the 16 projects, identified under the Accelerated Irrigation Benefits Programme (AIBP) in Feb 2008, only five projects (Indira Sagar Project in Madhya Pradesh, Polavaram Project in Andhra Pradesh, Gosikhurd Irrigation Project in Maharashtra, Shahpur Kandi Dam Project in Punjab, Saryu Nahar Pariyojana in Uttar Pradesh and Teesta Barrage Project in West Bengal) with estimated irrigation potential of 25.10 lakh ha were under implementation and even these projects suffer from 8 to 99 per cent shortfall in physical progress. The remaining 11 projects with estimated irrigation potential of 10.48 lakh ha are yet to commence and are at different stages of approval. There is a cost escalation of Rs 50,000 crore and physical progress shortfall of upto 99 per cent in five National Irrigation Projects for the period 2008-17 including Polavaram and Gosikhurd.

The initially estimated cost of the five projects was 3,530 crore, which has now escalated by a whopping 2,341 per cent to 86,172 crore. So far, an expenditure of 13,299 crore has already been incurred on these projects. According to the CAG, the tardy implementation and cost escalation was on account of management failures and deficiencies in terms of non-adherence to the provisions relating to survey and investigations that are essential requirements for preparation of detailed project reports. Administrative delays, poor contract management and lack of monitoring has led to unprecedented cost escalation

- Only 5 out of 16 projects are under implementation, other 11 projects delayed due to various approvals
- Shortfall in Physical Progress of the 5 Projects : 8 to 99 percent
- Total cost escalation for the 5 Projects: ~ Rs. 50,000 crore
- Percent cost escalation: 2,341 per cent

Source: *https://cag.gov.in/content/report-no22-2018-accelerated-irrigation-benefits-programme-ministry-water-resources-river*

Table 10: Summary analysis of the six selected projects being implemented under the AIBP and now financed through NABARD- Long Term Irrigation Fund (LTIF)

Project Name	State	Year of commencement/ (No. of years since inception)	Present Cost Over-run Ratio as Compared to the Original Cost	Year of inclusion in AIBP	Priority	Targeted IP	IPC	Main Canal Progress	Distributary Channel Progress	Field Channel Progress	IPU	Latest Estimated Cost of AIBP Component (works)	Total Expenditure
						000 Ha	000 Ha	%	%	%	%	Rs. Crore	Rs. Crore
Sardar Sarovar	Gujarat	1961/1988 (30 years)	6.12	1996-97	Dec-2019 (Priority III)	1792	1647.148	99.77	95.24	71	35	31522.33	28361
Gosikhurd	Maharashtra	1984/1988 (30 years)	40.11	2008-09	Dec-2019 (Priority III)	250.8	79.38	78.46	39.84	0	15	12770.09	7303
Krishna-Koyana	Maharashtra	1984/ 2009 (9 years)	2.22	2009-10	Dec-2019 (Priority III)	104.17	61.89	57.91	16.59	0	40	2774.9	1249
Indira Sagar I and II (km 0 to km 142)	Madhya Pradesh	1984/1988 (30 years)	1.64	1996-97	June 2018 (Priority I)	62.2	62.2	100.35	100	45.32	69	1608	1613
Indira Sagar III (km. 143 to km. 206)	Madhya Pradesh	1984/1988 (30 years)	--	2007-08	June 2019 (Priority II)	16	16.682	95.02	89.03	17.78	--	890.38	856
Indira Sagar IV (km. 206 to km. 243)	Madhya Pradesh	1984/1988 (30 years)	--	2008-09	December 2019 (Priority III)	27.048	8.5	99.5	86.27	0	--	558.62	499
Indira Sagar V (Khargone Lift)	Madhya Pradesh	1984/1988 (30 years)	--	2014-15	June 2018 (Priority I)	33.14	32	94.75	87.57	0	--	212.12	88
Saryu Nahar	Uttar Pradesh	1982 (36 years)	19.4	2012-13	December 2019 (Priority III)	1312 (473)*	183.8	83.66	32.27	0	20	5803.613	3278
Polavaram	Andhra Pradesh	1980/1982 (36 years)	20.6	2014	National Project	291	129	--	--	NA	41	16010	12683

2.6 Reasons and Some Suggestions for Bridging the IPC-IPU Gap

2.6.1. Reasons for the Widening IPC-IPU Gap

The literature addressing the reasons for gap between irrigation potential created and utilized are limited and fragmented and since groundwater is now established as a pre-eminent source of water for irrigation and domestic uses, the canal irrigation is struggling to maintain its relevance. Some of the important reasons for the rising cumulative gap between IPC and IPU in India are given below:

i. Incongruity in the definitions and understanding of the IPC and IPU

'*Irrigation Potential Created*' by an irrigation scheme is the total gross area proposed to be irrigated under different crops during a year by a scheme. The area proposed to be irrigated under more than one crop during the same year is counted as many times as the number of crops grown and irrigated. This is actually based on the amount of the water resource likely to be annually available in the storage reservoir of the scheme divided by the average annual crop water requirements proposed for the culturable command area. It is a static figure estimated at the time of the scheme planning and generally based on an optimal cropping system and irrigation regime and mostly not revised in view of the field realities.

'*Irrigation Potential Utilized*' on the other hand is the gross area 'actually irrigated' for 'actual cropping system' being adopted by the beneficiary famers. Since, the farmers have just moved from a rain-fed farming system to an irrigated system, and shall try to maximize their benefits after this much sought-after intervention, the large variations from 'an optimal cropping system' and proper irrigation regime are normal. The incongruity is mainly for the reason that whereas 'IPC' is largely resource based and expects optimal crops and irrigation technique, the 'IPU' is mainly area based and calculated for actual crops and actual (mostly less efficient) irrigation regimes followed by the irrigators.

These two approaches need to be reconciled; and the physical figures revised from time-to-time based on the actual field data from the project system and the beneficiary command area.

ii. Lack and inconsistency in the credible data on IPU

Publications of the CWC, Ministry of WR, RD&GR, and MoA &FW and the relevant state departments are the credible sources for the national statistics on irrigation potential created and utilized; and the net/ gross area irrigated by different sources. Additionally, there are research reports/ papers based on remote-sensing based estimations. Unfortunately, there is no co-ordination and synchronization of the data even for the same years, and there is considerable lag between the data availability, its publication and the real time. Data from the MoWR lags behind by several years and the data for IPC has not been updated after 2011-12, though there are some reports available on additional IPU under the 99 AIBP projects. The data from Directorate of Economics & Statistics (DES) of Ministry of Agriculture and Farmers' Welfare (MoA &FW) is slightly update (2013-14) but varies hugely from the IPU data of the MoWR. Whereas, CWC data shows that irrigation potential created by MMI projects in 2007 was 35.01 Mha, the corresponding data by MoA on the gross area irrigated by canals at about 22. 64 Mha was 38 percent lower. Field surveys by MI Census and the NSSO surveys also indicate that canal irrigated area is on the decline in spite of the massive investments. However, research papers based purely on remote sensing show higher coverage under irrigation

(Dheeravath et. al., 2014). The causes for large variations include: (a) reluctance on part of the states to furnish irrigated area data in view of their vested interests in sharing of water, and (b) reporting of large volumes of data with inadequate statistical analysis. There is an urgent need to harmonize the data by different Ministries and share these on common data platforms. India with its huge IT capabilities can surely do this even on real-time basis rather than 5-10 years data lag. There is an urgent need for credible information to understand the true picture of the IPC-IPU gap and then identify its causes to suggest suitable measures to bridge the gap. The need for accurate estimates of irrigated areas is crucial for water use assessments and food security studies and requires high emphasis.

iii. Inordinately long periods for completion of the main system and delay/ deferment in equipping the command area for 'actual access' to the water resource

Multi-purpose irrigation dams and irrigation schemes are marvelous engineering structures which take sometimes more than one or two (or several) decades for its completion. Large amount of the total capital cost is invested in a small area and seems very fascinating. This is followed by construction of the main canals and branch canals. Under typical Indian conditions, the project has already spent several times more than its planned budget and hardly any funds are available for equipping the area to receive the irrigation water, exactly for the same purpose for which the mammoth structures were actually being built. Our analysis for the six selected projects showed that periods of 10 to 36 years have already elapsed and the projects are yet not nearing completion. Moreover, there are well defined rules and practices available for acquiring the land for construction of the large irrigation infrastructure (dam/barrage and main and branch canals) as opposed to the construction of the minors, sub-minors and field channels. As discussed under the Sardar Sarovar Project whereas nearly 100 percent of the dam and main canal have long been completed, there is inordinate delay in completion of the minors and sub-minors and even after 50 years of the life of the Project, only 14 percent of the planned potential was actually utilized. And the main reasons for this glaring IPC-IPU gap were delay in acquisition of the land for equipping the area to receive the irrigation- last mile connectivity. Over these years the socio-economic and the technological options have changed and the farmers are reluctant to provide land for an inefficient open-surface conveyance and distribution system. The farmers preferred either to lift water from the available structures through their private pumps or alternatively government construct an underground pipe line system in consultation with the beneficiary farmers. More or less similar conditions shall be true for most of the other ongoing schemes showing large gaps in IPC and IPU.

iv. Change in cropping systems and the amount of applied irrigation

Once the main and branch canals are completed, but the entire command area is not yet equipped to receive the irrigation water, the system engineers will dump all the available water in the head reaches of the command; forcing farmers to abandon the upland crops and adopt mainly paddy, sugarcane or other water-intensive crops and use up the available water. Later on when even rest of the command is developed, the farmers already enjoying the benefits of canal water irrigation and groundwater recharge resist in changing the cropping system and adoption of precise methods of irrigation application. As a result the command areas shrink, and there is hardly any semblance between 'the initially planned cropping system and optimal delta of irrigation water to be applied' and 'the actual cropping system followed and the amount of water flooded.'

As the irrigation institutions are weak and less developed and local politics and power centers strong, there are little or no chances of enforcing any regulation. This variation in 'planned' and 'actual' is a strong factor for the prevailing IPC-IPU gap.

v. Inefficient public delivery and support systems

Most of the Indian irrigation systems were created during the initial plan periods and have now become old and dilapidated for want of proper maintenance and modern operation rules and structures. The irrigation charges are low and nil in several states and as such hardly generate much revenue. Still, the large irrigation bureaucracy and the created network and the service need regular support and funds to remain operational at the planned level. The casualty in the system is the 'maintenance of the main system and the distribution network.' The deferred maintenance leads to faster degradation and the whole system degenerates into an inefficient infrastructure with much smaller 'actual command area'. Some earlier studies by Vaidyanathan and estimates made by CWC in 2006 reveal that over the years there is sharp decline in the value of service fees and maintenance expenditure. Table 11 below illustrates the deteriorating condition of the canal irrigation in India.

Table 11: Deterioration in the financial indicators for the Major and Medium Irrigation (MMI) Projects in India

Parameter	Vaidyanathan Committee Report, 1992	Central Water Commission 2006
Capital investment in MMI projects (nominal)	Rs. 26,014 crore	Rs. 295,000 crore
Area irrigated by MMI projects, Mha	**25.33**	**18**
Water fees collected as % of capital investment	0.3	0.2
Water fees collected as % of value of crops irrigated	2	1.2
Water fees collected as % of Working Expenses	**20**	**7.9**
Maintenance expenditure as % of working expenditure	38%	34%
Maintenance expenditure as % of capital investment	NA	0.95%

As is evident from the data the area irrigated by canals between 1992 report and 2006 estimates reduced by 29 per cent and water fees collected as percent of working fees decreased by about 60 percent. Irrigation service fee collected by MMI projects was only 1.2 per cent of the value of crops they irrigated and less than 8 percent of the working expenses. As the state governments do not have surplus funds to maintain the system, the maintenance expenditure as percent of capital investment was less than 1 per cent of the capital cost causing deferred and delayed maintenance even in case of serious breaches. The Performance Audit Report of Irrigation Projects of Maharashtra state indicated that “The arrears of water charges for irrigation and non-irrigation purposes increased from Rs. 748.90 crore in March 2008 to Rs. 1,275.31 crore in March 2013 (70.29 per cent).” The Benchmarking Report prepared by the Water Resources Department revealed that in 2009-10, 30 out of 50 major projects and 78 out of 166 medium projects were less than the benchmark. The regulation, division and outlet structures suffer the

most and the large breaches remain unattended. As a result, the average canal conveyance efficiency of main canals in five regions during 2007-11 ranged between 8.68 per cent (Amravati) and 77.24 per cent (Aurangabad)". The Report further remarked that repairs and maintenance to dams and canals were poor due to insufficient allocation of funds or delay in taking up repair works (CAG, 2014).

Generally, irrigation departments sell a small portion of the water at high rates to the domestic and industrial sector to cover the losses, but this tendency overlooks the linkage of irrigation service fees with its collection and accountability for the service. Setting the irrigation service at a reasonable level (as recently done in some states) and its proper collection establishes a critical accountability loop that generates pressure on the irrigation managers to improve service delivery and ensure equitable distribution between head, middle and tail reach farmers (MoWR, 2011).

vi. Participatory irrigation management in the commands

Participatory irrigation management through the farm level Water User Associations (WUAs) was considered a panacea for an efficient water service management at the farm level and was pushed by the donors and accepted by irrigation departments. Through PIM Acts in different states, it was mandatory to establish a WUA at a certain level to be eligible for receiving the canal water. Report of the WG on MMI Project states that by 2011 more than 55,000 WUAs were registered in the country; and over 5 Mha of command area is under WUA management. However, the reality is quite different and most of WUAs are non-functional or just remain on paper due to a number of factors. PIM under government management has shown some success only under exceptionally enlightened and forward looking leadership of irrigation departments as during recent years in Andhra Pradesh, Gujarat and Maharashtra. Huge potential of PIM can be realized by reforming the irrigation system management agencies by making them capable, cooperative, accountable and more supportive. Mukherji et al. (2008) while analyzing 108 cases of PIM in Asia concluded that:

(i) Successful cases of PIM occur under a set of very context specific factors, factors that are either impossible to replicate, or very costly and therefore, impractical to replicate elsewhere.

(ii) PIM should not be treated as the magic potion aimed at curing the irrigation sector of all its ills. Instead, the agencies may explore alternatives to PIM where it has not worked in the first instance. In case of dynamic agrarian economies moving towards high value crops, Public-Private-Partnership may be a viable solution. This has not yet even been seriously tried under public-managed Indian irrigation systems.

(iii) Governments need to re-engage in irrigation management by treating irrigation water as a service delivery issue. This is easier said than done, because governments in low economies afflicted with small and fragmented holdings have the least capacity to provide high quality service.

Working with the irrigation cooperatives/ WUAs and enabling them with improved physical infrastructure and ICT enabled-services can potentially improve the service and thus increase the IPU.

2.6.2. Suggestions for Bridging the IPC-IPU Gap

First we need to realize that the existing irrigation bureaucracy in the states and at the center is an excellent resource for construction and creation of additional irrigation potential, but has limited interest and lacks capability and training in efficient management of the created potential. The system is still somewhat alienated from the farmers and their irrigation needs. Now that the country has already created a large potential, and some more is underway, the irrigation/water resources departments and the ministries can contribute a great deal more to the country's water- and food-security and usher in 'modern irrigation service' in the rural India by shifting the energies and resources away from construction to provide a quality irrigation service. This will require a re-thinking and some re-engineering of the on-going programs and creating innovations which previously were either not considered or were thought as 'too pragmatic'. Following suggestions shall need serious consideration:

I. Accelerate the AIBP

Up to the end of Eighth Plan (1996) there was a great rush in launching new irrigation projects, notwithstanding the completion of the previously commissioned projects. As a result there were 430 MMI and 72 ERM projects with a spillover cost of Rs. 75,690 crore (nominal) pending at various stages with very little forward movement. Taking cognizance, the government launched AIBP to provide Central Loan Assistance (CLA) to the states for timely completion of the on-going and over-stretched projects. Guidelines of AIBP were revised several times to make it more attractive. States took interest in availing the grants but no substantive progress took place for completion of the projects and as a result, even the CLA uptake after 2008-09 slowed down. Performance audit reports of the CAG for the AIBP for individual states and the overall program were very critical in most instances. At all India level , upto 2016 (after 20 years) 58.5 percent of the targeted potential was created , but the recent survey by the CWC itself showed that in 42 surveyed projects the average utilization was only 29 per cent. The Parliamentary Standing Committee in its review remarked that there were frequent changes in the design and scope of AIBP, and slow rate of completion of projects results in time and cost over-runs, and is primarily caused because of diversion of funds, and delay in submission of utilization certificates. CAG made performance audit of the 16 National Irrigation Projects as early as in 2018 and remarked that out of 16 projects, only 5 were under implementation and shortfall in physical progress was 8 to 99 percent, cost escalation in five projects was 2,341 percent; and irrigation potential utilization was only 21 per cent.

The present government took a second prioritization and identified 99 MMI projects, we categorized them under category 'a, b, c and d' (see Section 4.4) all to be completed in about 3.5 years by December, 2019. The Government created a Long Term Irrigation Fund in NABARD with an initial corpus of Rs. 20,000 crore. Total estimated requirement was77, 908 crore with Rs. 31,655 crore as central assistance and Rs. 46,253 crore as state share. Terms of trade were further liberalized as the earlier interest rate of 13 percent was brought down to 6 per cent. Our analysis showed that whereas projects in first two categories (a and b) have a fair chance of completion within the timeline, the chances look bleak for the rest. Even in the most optimistic scenario, around 44 per cent of the total original targeted potential is likely to remain unattained. Data on the utilization of the created potential is still lower and yet under compilation.

So, how can the government and the concerned agencies really 'Accelerate' the AIBP?

a. Funding for an identified project should start flowing only when the major constraints like acquisition of the land for all the structures including the main, branch and distributary channels have been completed with the farmers, railways, NHAI and other line departments. All the components of the scheme should be properly synchronized so that the full completion is achieved around the agreed timeline. Tendering and contract management must evolve on the modern infrastructure management platforms to ensure responsibility and accountability.

b. Incorrect phasing of the project components leads to serious troubles and water will flow and utilized only when it can reach the ultimate beneficiary. Creation of irrigation potential should be recognized only when there are no gaps in the main/ branch canals and all the associated minors and distributaries have been completed. For this the funding agency may also ensure a smooth flow of funds as per the performance and not as a bundle near the end of the financial year.

c. AIBP guidelines and release of funds must stress on the Benefit: Cost Ratio estimated at the beginning of the project and also during construction stage and at the end of the completed project. It must be ensured, possibly through a reputed third party, that B: C ratios for all projects are properly calculated, based on validated and verifiable data and all assumptions relating to costs, revenues, cropping patterns and crafting of local water institutions. This may be true both for tangible and non-tangible benefits and the costs related to project-affected entities (vocal and silent).

d. Integration with command area development- funding of CAD and completion of the activities should be in unison with the main irrigation development. A project may be considered as complete only when corresponding CAD works are also completed.

e. Taking up of regular modernization program for improvement of efficiency by implementing modern technologies of operation and maintenance.

ii. Under Ground Pipe Line (UGPL) Systems and Canal based Micro-Irrigation

Land acquisition for construction of the irrigation networks, especially at the farm level, has been cited as one of the major bottleneck for timely completion of the projects. Whereas there are well-defined rules and procedures and resettlement plans for construction of the dam and the main canals, the same get diluted or are not followed when the land is acquired for the minors and farm channels. Most farmers in India have small holdings and do not want or are not in a position to spare any part of the land especially when they know that irrigation project shall bring large benefits to their small enterprise.

Construction of UGPL for providing the last mile connectivity has several benefits (Shah et al. , 2010) including: (a) achieve utilized potential quickly, at reasonable cost to the government; (b) promote thousands of irrigation cooperatives for long-distance piped water transport distribution; (c) create large number of rural jobs in water distribution;

(d) dramatically raise water use efficiency and spread water from the main system over a large area; (e) enable conjunctive management of groundwater and surface water in groundwater-stressed areas; and (f) establish a new model of irrigation management partnership between farmers and the government.

UGPL have been successfully tried in the sandy and undulating and several other regions in Punjab, some projects in Rajasthan and now in Sardar Sarovar Project in Gujarat. Within a period of 3 years between January, 2015 and February, 2018; significant enhancement in utilisation of the created potential has been made in Gujarat (Fig. 67). For development of 7.8 lakh ha of command area, a UGPL of more than 21,000 km has been laid out at a total cost of 3100 crore and benefitting more than six lakh farmers. This proved to be one of the fastest ways of completing the on-farm works under the CAD. As per the data of the Ministry, during the entire period of XI five Year Plan a total of 20.8 lakh ha was covered under CAD, but with UGPL a command of 6.8 lakh ha was completed in just 15 months under SSP in Gujarat. Cost of UGPL is about two times the average cost of Rs. 22,000/ha with open channels, but the savings in water, land and higher productivity along with quick turnover justify the cost. Several other states have shown interest in adoption of UGPL in their commands. Adoption of UGPL in the suitable commands, especially with lined canals, minors; can be game-changer in quick realization of the potential utilized.

Recently, new technology has helped to integrate the UGPL with micro-irrigation. As an example Ramthal Irrigation Project in Karnataka is based on the unique concept of Integrated Micro Irrigation. Successful commissioning of this project will assume the status of being the largest Micro Irrigation project of its kind in the world for improving water use efficiency in canal command areas through conduit distribution and use of Micro Irrigation Systems. Under this integrated project, water is to be delivered directly using HDPE / PVC piping network to irrigate 30,381 acre command area through Micro Irrigation System by providing pressurized piping network. Similar projects have also been implemented/ under implementation in Maharashtra, Rajasthan and other states.

Important considerations for implementation of such an integrated system are: (i) assured water availability at a shorter interval of 2 to 3 days, (ii) storages at farm level (either in a farm pond or using existing wells), (iii) uninterrupted availability of electric power, (iv) financial support as subsidy towards capital cost of the micro irrigation system, and (v) enforcement at the ground level.

iii. Pick the Low Hanging Cherries First- Target the Underprivileged Geographies

States in the eastern and north-eastern region (eastern Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, West Bengal, Odisha, and Assam) have low irrigation potential created and potential utilized. The states also suffer from low levels of farm power and have to depend upon the costly alternative of diesel fuel and thus economize on irrigation leading to poor agricultural growth and productivity. Fortunately, the region is blessed with abundance of surface and groundwater and just need proper infrastructure to have access to the resource, especially during non-rainy winter and summer season. As per the estimates made in this study, the capital cost of creation and utilisation of MMI in the eastern region is only about one-fourth of the All India averages and the working expenses for operation and maintenance of the systems are only about one-third of the

all India averages. Creation and utilisation of the irrigation potential in the eastern region shall also have the additional advantages of alleviating the fury of floods and reduce the need of using arsenic contaminated groundwater in certain affected pockets of the region.

iv. Make Aggressive Use of ICT, Data Platforms and Project Management Systems

Even after huge investments into the MMI projects in India, the service provision is in complete disarray. There is unequal distribution in the command area making distribution of irrigation water a major concern. There is a huge communication gap as well between the irrigation department, Water User Associations and the farmers, about issues such as time of release of water to the quantity that will be made available to them. There are hardly any mechanisms in place to get feedback from the farmers on whether water is being delivered to them or not. This has led to a complete lack of trust and accountability in the sector and has made farmers lose trust in canal irrigation, and has forced farmers to look for irrigation from other private sources (mainly groundwater) which in turn have increased the cost of cultivation. ICT can be used to build back the lost trust into the system through the development of a water governance system that is farmer friendly and use of improved techniques to improve the communication and accountability of the irrigation department with the farmers (Hiremath et al., 2016). Techniques are now available to assess the water needs of the different parts of the canal command and then synchronize the water delivery as per the crop demand. Weather based information, flow and moisture sensors, and GIS and mobile-based ICT can all be integrated into simple systems where farmer groups can request for water supply and also receive measured allocations. Indian irrigation systems need to be modernized for efficient provision of the service delivery which will cover much large command areas as compared to the existing old, dilapidated and unregulated and unreliable supply system.

At the higher level the irrigation departments and service agencies can measure in real time the extent of area which has been actually irrigated and then generate data systems and data platforms for various characteristics and intelligent decision making. The total ignorance and much delayed data systems based on field surveys need to be replaced with sensor/ remote-sensing based data systems so that there is uniformity in data collection, data sharing and data analysis and interpretation. Most countries even in South East Asia, China and even in Africa are now adopting the improved irrigation data collection, analysis and communication systems for an efficient service and improved irrigation coverage for higher productivity and profitability.

Irrigation management is a dynamic and complex operation in which a fluid resource received in bulk is to be distributed to a large number of small and dispersed users through a properly functioning network with the objective of achieving highest resource-use efficiency and serving all the beneficiaries in the command. Since it deals with living systems, the timeliness is also very important. This can be achieved only through a well-designed Project Management System in which the human and natural resources and the infrastructure function in harmony and with proper responsibility. The department must transform themselves from an old and non-responsive irrigation project to a fully-functional and responsive project management.

All under implementation and future irrigation projects may also put in place a "Concurrent Monitoring System" which shall help to assess quantity, quality and timeliness of the project activities and identify operational constraints to project effectiveness. This will help in controlling overall time delay and cost over-run factors impeding the progress of the project. Recently, Sakthivadivel (2018) has developed a Project Performance Index based on indicators related to physical, financial, CAD work, institutional arrangements and quality control. Such an index can help in evaluating the performance of the schemes at the state and national level and then initiate appropriate remedial measures.

v. Underline the 'Management' in Irrigation Management

Irrigation sector in India has been heavily dominated by the 'creation' and construction approach and over the years have gained good expertise and specialization. But once a resource is created it is of paramount importance that the resource serves the purpose for which it was created in the first place for which a good management is required. Under current scheme of project implementation, focus is more on creation of the potential than utilization of the created potential. Emphasis should be more on utilization of created potential and simultaneous implementation of command area development program. Our present irrigation bureaucracy and mindset does not appreciate this and as such this aspect remains largely neglected. Whenever, a performance or appraisal of the system or grievances of the ultimate beneficiaries are pointed the suggested solution is again 'engineering based'. Most irrigation planners are of the view that the irrigation sector in India is operated under the "Build- Neglect-Rebuild" mode. Innovations in efficient management of the created irrigation potential to realize its intended utilization or even exceed it through modern and efficient management has been absent or very few. First proper infrastructure, conditions, operating rules and regulations may be developed and then the concerned department/ irrigation service agency may be held responsible for under-performance of the system.

vi. Unshackle the Irrigation Sector- Transform it as Public Good Infrastructure

At the time of independence, India received all the public welfare and infrastructure systems- roads, railways, transport, telecom, energy, irrigation etc. which served a purpose and were operated with the objectives of the day. Over the years, public welfare became a priority and heavy investments were made in all these sectors so as to serve the maximum number of the population. However, all these sectors were managed directly by the government and its large bureaucracy. The government then realized that this mode of operation was inefficient and did not serve the aspirations of a large growing population. In due course, the management and ownership of several of these sectors was 'liberalized' and private and public sector undertakings were brought in to improve the performance and service delivery. We cannot still say that most of these sectors like telecom, railways, power, and roads are working under excellent conditions but shall agree that they are striving hard and continually reinventing themselves for improved and larger performance. Unfortunately, it is the irrigation/ water resources sector alone whose performance has much dwindled even in comparison to the colonial era because unlike other sectors it is still under hierarchical bureaucracy and has not

been 'unshackled'. The irony is that the condition is worsening and the gap between the created and utilized potential and the gap on social and economic benefits on these investments is ever widening in spite of the huge post-independence investments in the sector. Inefficiency in canal irrigation sector is also one of the reason for over-dependence and over-exploitation of the privately managed groundwater resource. Over and above, the water resource is also heavily politicized and used as a tool to harness the short-term public sentiments. Irrigation must be managed as an efficient service as it is the first input through which the gains of all the other inputs of improved seeds, fertilizers, mechanization, diversification etc. are realized. Innovative models like creation of efficient and modern irrigation systems, public-private partnership in managing the distribution, bulk-vending to farmer-managed irrigation cooperatives, underground-pipeline based irrigation systems are some of the potential opportunities which need to be seriously considered and implemented- first on large pilots and then on scale.

The government may consider seriously that on the lines (or even better center-state-private-farmer shared partnerships) of NHAI for roads, CEA for electricity, TRAI for telecom and others, it is high time that an independent, modern, well-designed, economically-viable and independent **National Irrigation Authority of India (NIAI)** be created so as to serve the larger interests of the farmers, ensure reasonably good economic and more importantly larger social returns from the huge investments already sunk and new investments proposed to be made under AIBP and other regular irrigation/ water development programs. Its main objective should be to efficiently construct, maintain, operate and manage the major and medium irrigation and flood control projects in active consultation with the states and all the stakeholders so as to deliver maximum benefits in a cost-effective and time-targeted manner.

2.7 Conclusions

In this paper, we have assessed the IPC and IPU gap situation in selected states over the years for both MMI and MI projects. Besides the large inefficiency in the system and poor service delivery to the ultimate beneficiaries, the concepts of IPC and IPU itself need reconsideration and revision in view of the changes in the design and capacities of the main systems, variance with the envisaged and actual cropping systems and the active role of the groundwater in the canal command areas. We have observed that in recent years, most of the states have experienced decrease in gap in case of MI. However, in case of MMI projects, which are funded by the center and the state governments, the IPC-IPU gaps actually have increased. Since there is this gap between IPC and IPU, per hectare cost of creating potential does not reflect the true cost that government is bearing. The cost of potential utilized is considerably higher than the cost of potential creation in many of the states and the former in reality gives us a more accurate estimate of per hectare cost of the project to the government.

It has been almost twenty years since the government has been officially trying to bridge the gap between IPC and IPU by introducing AIBP in 1996-97. But as the reality check indicates, for many MMI projects, even inclusion in AIBP could not improve the speed of completion and bridging the gap. There are a considerable number of projects, Sardar Sarovar being one of them, which

even after almost 20 years of their inclusion in AIBP, were not completed. This necessitated a second prioritization. The present government has singled out 99 projects in 2016 which were to be completed in mission mode by December 2019. We have assessed the current status of all those projects to have an approximate idea about where do we stand after 2.5 years of the second prioritization. As our analysis reveals, it seems very difficult to achieve the ambitious goal of creating 7.6 Mha of irrigation potential within December 2019. It, in fact will be even harder to ensure that majority if not all of the irrigation potential would be utilized since the last mile delivery through distributary or field channel creations have not picked up and continue to be at a very low level.

We then collected information for selected projects to see whether there is increase in the pace of potential creation after the second prioritization when NABARD is funding them through a LTIF created for this purpose. For all the 6 projects considered here, the pace of potential creation has increased, but unfortunately, the speed of command area development is still at either a very low level (Exception: Sardar Sarovar Projects: 60 percent of targeted command area development is done), or there is no information available on the same. This can be due to various reasons including very low priority, poor expertise and capability and funding to the CAD&WM departments at the state level.

Considering our main findings, we propose the following measures to mediate the situation of wasted potential and valuable water resources:

Accelerating AIBP and CAD

It is clear through the analysis that, although the speed of potential creation of the prioritized projects (or at least for the selected ones) have increased compared to earlier situation, the current status of many of them are still enough to raise questions about the achievability of the target potential creation. Also, the status of field channel creation are at such a low level that chance of ensuring water to the targeted beneficiaries by the stipulated timeline is looking bleak. That would eventually add to the already existing gap problem. To avoid making the same mistake again, the speed for command area development also needs to get accelerated immediately. There are some good examples from Madhya Pradesh, Gujarat and Telangana where innovative and concerted efforts made by the respective state governments to rejuvenate the irrigation departments, convergence of irrigation with other social welfare programs, prioritized allocation of funds, incentives, accountability and capacity building of the human resource have paid good dividends.

Underground pipe line and canal based micro irrigation

One of the reasons behind the slow pace of CAD is farmers' unwillingness to give up land for field channel creation. Underground pipe line and canal based micro irrigation system can help to address that problem. Between January 2015 and February 2018, about 21841km of such pipelines are created in SSP ensuring 7.8 lakh hectare of command area and benefitting more than 6 lakh farmers. As mentioned earlier, the average cost of field channel creation is about half than using this system, but keeping in mind the higher efficiency, long term benefits and also chance of bypassing one of the main reasons of delay in CAD, government should consider scaling-up this innovative water-conveyance and conservation technique for the suitable geographies.

First address the underprivileged geographies

Populations are poorer, most of the diesel-based irrigation is costly, irrigation needs are small but critical and cost of irrigation creation is low in the eastern region of India. Creation of irrigation can also reduce rainy season flooding and groundwater contamination. Enhancing irrigation coverage in this region shall also reduce food security pressure from the depleted aquifers of northwestern region. Such a prioritized program is likely to harness quick and cost-effective benefits for the large and under-privileged population.

Make aggressive use of ICT in developing a modern and responsive irrigation system

Absence or lack of communication between the irrigation department and the farmers and other stakeholders is a serious constraint in efficient management of the service. Farmers do not receive an advance information on the schedules and departments do not receive any feedback on the quality of the service and its optimisation. Real time data collection for system monitoring and improvement is also lacking. Efficient use of ICT for developing a modern and responsive irrigation system need to be seriously considerd.

Underline MANAGEMENT in the Irrigation Management

Under current scheme of project implementation, focus is more on creation of the potential than utilization of the created potential. Emphasis should be more on utilization of created potential and simultaneous implementation of command area development program. From the existing "*Build-Neglect-Rebuild*" mode of operation a "*Concurrent Monitoring System*" need to be put in place which will help in controlling overall time delay and cost over-run factors impeding the progress of the irrigation projects at the state and national level.

Unshackle the Irrigation Sector- Transform it as Public Good Infrastructure

Irrigation service like all the other public welfare services of roads, electricity, telecom, railways need to be managed efficiently and professionally, especially when most of the beneficiaries are poor farmers. Whereas, government has introduced professionalism and reasonable efficiency in all the other service sectors, only irrigation has been left behind and still used as a popular political tool *albeit* with high social, economic and environmental costs and low returns and social benefits. It is true that the nature and characteristics of the resource and objectives of providing access to this resource are different from other sectors, but the ultimate objective is to provide maximum benefits to the maximum number of users and also maintain the environmental sustainability and economic viability of the service. Creation of a modern, responsive, efficient and economically viable "*National Irrigation Authority of India*" which will be responsible for construction, maintenance, operations and management of the major and medium irrigation and flood control projects in active consultation and collaboration with the states and other relevant stakeholders needs to be seriously considered to serve the larger interests of the farmers and the state.

Appendix to Part 2

Appendix 1: IPC as a % of UIP and percentage potential utilization in case of MMI in India till 11th Plan- State-wise

Area in Mha

Name of State/UT	Ultimate Irrigation Potential	Potential Creation upto XI Plan	Potential Utilization upto XI Plan	IPC as a % of UIP	IPU as a % of IPC
Andhra Pradesh	5.00	4.80	3.24	96.07	67.54
Assam	0.97	0.46	0.21	47.01	46.26
Bihar	5.22	3.05	1.81	58.48	59.42
Chattisgarh	1.15	1.27	0.95	110.67	74.70
Gujarat	3.00	3.68	1.87	122.64	50.90
Haryana	3.00	2.21	1.89	73.54	85.81
Himachal Pradesh	0.05	0.03	0.01	60.90	27.01
Jammu Kashmir	0.25	0.33	0.18	130.24	55.47
Jharkhand	1.28	0.53	0.25	41.58	46.32
Karnataka	2.50	2.97	2.33	118.63	78.63
Kerala	1.00	0.72	0.59	71.57	82.63
Madhya Pradesh	4.85	2.51	1.17	51.65	46.81
Maharashtra	4.10	4.13	2.31	100.70	56.02
Orissa	3.60	2.15	1.88	59.65	87.49
Punjab	3.00	2.68	2.51	89.48	93.52
Rajasthan	2.75	3.17	2.53	115.17	79.76
TamilNadu	1.50	1.58	1.56	105.22	98.65
Uttar Pradesh	12.15	9.29	7.82	76.42	84.24
Uttranchal	0.35	0.29	0.19	83.52	66.11
West Bengal	2.30	1.90	1.57	82.67	82.76
All-India	**58.47**	**47.97**	**35.01**	**82.05**	**72.97**

Source: Central Water Commission

Appendix 2: IPC as a % of UIP and percentage potential utilization in case of MI in India till 11th Plan- State-wise

Name of State/UT	Ultimate Irrigation Potential	Potential Creation upto XI Plan	Potential Utilization upto XI Plan	IPC as a % of UIP	IPU as a % of IPC
Andhra Pradesh+Telangana	6.26	5.2	4.0	83.2	76.6
Assam	1.9	0.5	0.3	23.8	71.2
Bihar+Jharkhand	6.84	4.6	3.5	67.2	76.1
Gujarat	3.1	5.2	3.7	167.4	71.3
Haryana	1.51	3.0	3.0	200.9	98.9
Jammu & Kashmir	1.11	0.2	0.2	18.8	94.1
Karnataka	3.47	2.9	2.7	83.1	92.1
Kerala	1.68	0.3	0.3	16.5	92.9
Madhya Pradesh+Chattisgarh	11.93	9.5	7.1	79.7	75.1
Maharashtra	4.85	6.7	6.0	138.8	88.6
Orissa	5.2	1.2	0.8	23.9	62.2
Punjab	2.97	7.6	6.3	254.9	83.8
Rajasthan	2.38	7.0	6.1	292.1	88.4
Tamil Nadu	4.03	4.7	3.5	115.6	75.2
Uttar Pradesh+Uttarakhand	18	22.6	17.8	125.6	78.8
West Bengal	4.62	3.0	2.3	65.3	76.2
All-India	**81.43**	**84.9**	**68.7**	**104.3**	**80.9**

Source: CWC 2015 *and calculations from* MI Census Surveys

Appendix 3: State-wise and year-wise CLA released for AIBP

Name of States	CLA released upto 2004-05	Grant released (Amount in Rs. Crore)												Cumulative CLA/Grant released upto March 16
		2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	
Andhra Pradesh	312.9	8.4	161.7	169.8	100.0	264.7	337.5	22.8	0.0	0.0	0.0	0.0	0.0	1377.8
Assam	98.1	0.1	12.6	0.0	15.2	83.3	12.0	49.5	47.0	0.0	0.0	89.2	107.9	514.8
Bihar	454.9	11.2	16.2	3.2	58.7	74.9	77.9	23.4	0.0	0.0	0.0	0.0	41.5	761.9
Chhattisgarh	267.3	0.9	7.7	0.0	37.4	55.5	44.9	29.5	22.3	15.5	37.5	0.0	0.0	518.5
Goa	130.9	0.2	0.0	1.9	32.5	39.2	20.3	20.0	20.3	8.0	0.0	0.0	0.0	273.2
Gujarat	4107.2	45.8	339.6	121.9	585.7	258.6	6.1	361.4	0.0	1285.9	607.6	1033.9	128.0	8881.7
Haryana	78.0	3.3	6.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.5
Himachal Pradesh	60.1	1.6	16.1	2.2	70.5	81.8	52.9	11.1	82.6	0.0	0.0	0.0	0.0	378.9
Jammu & Kashmir	77.0	6.6	24.8	18.3	94.0	95.3	13.7	47.3	61.7	12.7	13.9	14.2	34.3	513.7
Jharkhand	77.8	6.4	5.0	1.3	9.2	3.7	0.0	11.2	335.5	515.7	0.0	0.0	281.6	1247.6
Karnataka	2269.0	81.5	154.8	160.4	368.9	454.1	742.9	537.1	452.2	207.4	200.1	150.8	208.2	5987.4
Kerala	123.7	14.8	31.2	16.7	0.0	4.7	0.0	10.0	0.0	0.0	0.0	0.0	0.0	201.1
Madhya Pradesh	1866.7	155.0	187.2	204.6	305.4	425.1	506.4	421.2	273.6	613.4	314.4	96.0	188.2	5557.1
Maharashtra	973.9	158.8	268.0	466.9	1108.2	1817.1	1459.0	1749.2	1122.7	840.2	279.5	32.4	307.8	10583.6
Manipur	102.9	10.4	70.3	138.1	54.2	182.1	0.0	209.5	0.0	375.0	0.0	82.7	142.4	1367.5
Meghalaya	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
Orissa	873.2	7.3	148.0	133.1	668.2	744.6	728.0	563.8	615.0	14.8	0.0	20.0	173.8	4689.7
Punjab	415.5	0.0	26.3	0.0	13.5	9.5	22.1	140.5	43.6	0.0	0.0	0.0	1.1	672.0
Rajasthan	1386.9	105.9	90.3	11.6	156.5	178.6	143.4	41.9	3.4	0.0	0.0	9.5	45.4	2173.5
Tamilnadu	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0
Telangana	617.7	17.9	149.7	646.6	887.7	358.8	963.3	0.0	256.1	0.0	0.0	65.3	112.5	4075.7
Tripura	30.9	2.7	16.2	0.9	0.0	22.7	4.9	48.0	0.0	0.0	0.0	0.0	0.0	126.3
Uttar Pradesh	1337.3	42.3	108.1	81.9	150.7	315.5	238.1	432.7	279.8	144.6	595.7	308.0	555.0	4589.8
Uttarakhand	574.2	10.5	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	609.8
West Bengal	166.1	4.0	0.0	6.7	0.8	22.8	0.9	81.0	102.6	0.0	0.0	0.0	0.0	385.0
Total	**16426.2**	**695.3**	**1864.7**	**2189.2**	**4717.5**	**5492.6**	**5374.1**	**4811.2**	**3718.3**	**4033.3**	**2048.7**	**1902.1**	**2327.8**	**55601.0**

Source: Handbook on Water and Related Statistics, CWC, June 2017

Appendix 4: State-wise and year-wise potential created (in Thousand Hectares) under AIBP

Name of States	Potential Created Before AIBP	Potential Target for AIBP	Potential Created under AIBP upto 2003-04	Potential Created under AIBP during												Potential Created under AIBP upto March 16	Percent of targeted Potential Created
				2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16		
Andhra Pradesh	23.4	788.9	45.8	6.5	27.8	18.5	67.7	24.3	9.3	60.9	0.0	13.2	3.8	0.0	32.5	310.3	39.3
Assam	96.23	162.3	42.0	4.1	2.7	2.8	4.5	7.8	10.9	6.2	4.0	0.5	8.0	0.5	0.0	93.8	57.8
Bihar	1430.99	684.65	166.5	60.4	174.7	45.3	6.4	10.0	0.5	0.0	0.0	0.0	3.7	0.0	0.0	467.4	68.3
Chhattisgarh	394.94	213.71	73.5	16.0	11.7	11.9	15.8	18.9	10.2	2.8	9.8	11.8	3.5	2.3	0.6	188.8	88.4
Goa	4.81	23.8	7.7	1.8	0.3	0.4	4.9	1.5	0.5	0.8	0.2	1.3	1.2	0.0	0.0	20.5	85.9
Gujarat	168.21	1830.24	230.8	78.0	34.1	81.8	68.2	20.9	25.7	28.9	21.3	128.2	274.8	162.6	185.9	1341.1	73.3
Haryana	179.53	200.97	90.4	7.9	6.9	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.2	57.3
Himachal Pradesh	0	37.51	1.8	0.5	0.5	3.5	3.3	4.2	4.0	5.0	5.6	3.5	5.6	0.0	0.0	37.5	100.0
Jammu & Kashmir	48.93	105.69	12.1	1.1	1.3	1.2	4.5	4.7	4.6	9.0	10.2	4.6	4.4	0.5	1.0	59.3	56.1
Jharkhand	6.04	293.79	11.6	0.0	0.0	0.5	0.0	0.0	0.5	1.7	0.0	4.3	23.8	0.0	0.0	42.4	14.4
Karnataka	967.15	953.53	275.5	69.2	50.5	76.1	18.8	6.5	32.7	24.7	28.8	8.0	21.3	30.3	88.4	730.7	76.6
Kerala	69.12	57.47	24.4	5.0	0.7	2.7	1.0	0.1	1.6	2.6	7.6	2.0	1.9	0.1	0.5	50.1	87.1
Madhya Pradesh	118.25	1028.5	51.6	50.4	21.1	18.1	79.4	48.9	35.5	89.7	82.6	99.1	90.3	85.2	44.3	796.1	77.4
Maharashtra	827.79	1215.17	136.0	36.0	34.5	67.0	89.4	67.2	70.8	34.8	41.3	26.5	35.9	25.9	22.7	687.9	56.6
Manipur	4	51.99	0.0	0.0	0.0	5.0	5.9	4.1	1.8	4.0	0.1	4.0	1.2	2.6	2.0	30.8	59.2
Meghalaya	0	4.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orissa	216.21	649.86	104.3	15.5	4.2	4.6	14.4	10.7	27.7	36.2	20.3	6.8	11.1	6.4	7.3	269.5	41.5
Punjab	0	337.62	96.0	5.0	18.0	8.2	4.8	27.4	12.9	25.0	0.0	1.0	0.0	0.0	2.9	201.2	59.6
Rajasthan	70.11	1605.16	276.7	59.8	81.2	62.5	129.5	54.0	49.0	396.0	13.0	12.8	11.5	1.8	6.3	1153.9	71.9
Tamilnadu	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Telangana	1105.09	827.94	162.9	7.6	34.7	30.1	25.5	60.7	9.3	8.1	25.2	20.4	56.5	6.3	68.8	516.1	62.3
Tripura	2.18	24.54	3.2	0.5	2.1	3.0	1.7	1.3	4.3	0.5	0.0	0.2	0.0	0.0	0.0	16.8	68.5
Uttar Pradesh	2658.52	3213.88	694.3	93.6	111.3	88.6	75.7	105.2	37.1	175.3	68.0	82.1	50.0	0.0	0.0	1581.1	49.2
Uttarakhand	0	270	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
West Bengal	402.02	551.02	66.7	2.5	5.2	2.3	14.6	4.9	5.3	15.3	25.9	3.3	1.7	0.0	0.0	147.5	26.8
Total	**8793.47**	**15133.04**	**2573.8**	**521.2**	**623.1**	**544.1**	**635.9**	**483.1**	**354.2**	**927.6**	**363.7**	**433.4**	**610.2**	**324.6**	**463.1**	**8857.8**	**58.5**

Source: *Handbook on Water and Related Statistics*, CWC, June 2017

Appendix 5: Status of 99 priority projects till 17.07.2019

Serial Number	Project Name	Priority	Revised priority	Targeted Irrigation Potential ('000 Ha)	Changed targeted potential ('000 Ha)	IPC ('000 Ha)	Main Canal Progress (%)	Distributory canal Progress (%)	Expenditure (Rs. Crore)
Andhra Pradesh									
1	Gundalakamma	2		32.4	32.4	28.42	100.00%	97.58%	571.25
2	Tadipudi LIS	2		83.61	83.61	63.76	89.49%	69.35%	489.51
3	Thotapally	2		48.56	53.31	27.93	96.41%	70.52%	771.93
4	Tarakaram Teerta Sagaram	3		10.00	10.00	0	6.80%		223.88
5	Musurumilli	2		9.16	9.16	9.03	100%	100.01%	153.24
6	Pushkara LIS	2		71.18	71.18	55.91	98%	97.27%	438.56
7	Yerracalva	2		6.96	10.00	6.07	100%	79.83%	58.98
8	Maddigedda (Completed)	1		1.42	1.42	1.42	100%	100%	8.94
	Sub-Total			**263.29**	**271.08**	**192.54**			**2716.28**
Assam									
9	Dhansiri	2	Dec-19	86.37	53.26	53.26	91.24%	79.01%	309.11
10	Champamati	2		25	25.00	23.22	100.00%	100.00%	211.16
11	Borolia	3		13.56	13.56	3.30	81.86%	0%	44.75
	Sub-Total			**124.93**	**91.818**	**79.78**			**565.01**
Bihar									
12	Durgawati	3		23.59	23.59	10.28	96.13%	85.73%	865.60
13	Punpun	3		13.68	13.68	0	39.96%	26.11%	427.84
	Sub-Total			**37.27**	**37.27**	**10.28**			**1293.44**
Chhattisgarh									
14	Maniyari Tank	1		14.52	11.52	11.52	100.00%	100.00%	96.85
15	Kelo	3		22.81	22.81	17.01	83.76%	83.29%	617.70
16	Kharung	1		10.3	10.3	10.3	100%	100%	46.47
	Sub-Total			**47.63**	**44.63**	**38.825**			**761.02**
Goa									
17	Tillari	3		14.52	21.05	11.83	89.85%	72%	888.13
	Sub-Total			**14.52**	**21.05**	**11.83**			**888.13**
Gujarat									
18	Sardar Sarovar	3		1792	1792	1647.15	99.77%	95.24%	28361.37
	Sub-Total			**1792**	**1792**	**1647.15**			**28361.37**

				Jammu and Kashmir					
19	Tral Lift	3		6	6.00	4.44	80.77%		136.03
20	Prakachik Khows Canal	3		2.26	2.26	1.25	78.64%	51.21%	43.71
21	Restoration and Mod. Of Main Ravi Canal	2		50.75	50.75	13.74	100.00%	98.70%	57.73
22	Rajpora Lift	3		2.43	2.43	2.43	100.00%		63.37
	Sub-Total			**61.44**	**61.44**	**21.86**			**300.84**
				Jharkhand					
23	Subarnarekha Multipurpose	3		236.85	236.85	107.326	83.36%	50.82%	5727.48
	Sub-Total			**236.85**	**236.85**	**107.326**			**5727.48**
				Karnataka					
24	Upper Tunga Irrigation Project	3		80.49	80.49	75.80	96.66%	90.91%	1027.05
25	Si Rameswar Irrigation	1		13.8	13.80	13.80	100%	100%	177.30
26	Karanja	3	Jun-19	29.23	29.23	25.83	92.70%	95.92%	324.82
27	Bhima LIS	2		24.29	24.29	24.29	100.04%	100.00%	649.79
28	NLBC System Project (New)	3		105	105	104.63	100%	99.43%	1895.81
	Sub-Total			252.81	252.81	244.34			4074.77
				Kerala					
29	Karapuzha	3		7.36	7.36				
30	Muvattupuzha	3		30.719	30.719	27.708	100%	91.55%	370.65
	Sub-Total			**38.079**	**38.079**	**27.71**			**370.65**
				Madhya Pradesh					
31	Sindh Project Phase II	2		162.1	162.10	162.10	100.00%		1951.71
32	Indira Sagar Project Canal Phase I and II (km 0 to km 142)	2		62.2	62.20	62.20	100.35%	100.00%	1613.49
	Indira Sagar Project Canal Phase III (km 142 to km 206)	3	Jun-19	20.7	16.00	16.68	95.02%	89.03%	855.83
	Omkareshwar Project Canal Phase IV (OSP Lift)	2	Jun-18	54.63	54.63	54.63	100.01%	100.00%	340.21
	Bargi Diversion Project Phase I (km 16 to km 63)	3	Jun-19	21.19	34.12	20.09	99.99%	97.34%	428.71
33	Mahi Project	3	Jun-19	33.75	33.75	26.07	98.21%	93.76%	733.69
34	Barriyarpur LBC	3	Jun-18	43.85	43.85	43.85	100.00%	98.41%	458.65
35	Bansagar Unit 2	3	Jun-18	154.54	154.54	154.54	93.51%	97.20%	1545.72
36	Mahan Project	3	Jun-19	19.74	19.74	16.89	89.56%		406.96
37	Pench Project	3	Jun-19	28.27	28.27	21.27	96.81%	97.28%	1527.67
38	Sagad Project	1		17.06	17.06	17.06	100.00%	100%	189.93
39	Singhpur Project	1		10.2	10.20	10.20	100.00%	99.29%	198.46
40	Sanjay Sagar (Bah) Project	3	Jun-18	17.81	17.81	17.81	75.28%	73.86%	149.55

				Madhya Pradesh					
41	Mahuar Project	1		13.78	13.78	13.78	100.00%		120.29
42	Indira Sagar Project Canal Phase IV (km 206 to km 243)	3		19.6	27.05	8.50	99.50%	86.27%	499.35
	Indira Sagar Project Canal Phase V (Khargone Lift)	2		33.14	33.14	32.00	94.75%	87.57%	88.18
	Omkareshwar Project Canal Phase II (RBC km 9.70 to km 65.50)	3	Jun-19	19.58	19.58	15.80	99.90%	53.73%	345.88
43	Omkareshwar Project Canal Phase III (RBC km 65.50 to km 142)	3	Jun-19	48.59	48.59	40.75	94.07%	94.32%	495.84
	Bargi Diversion Project Phase II (km 63 to km 104)	3	Jun-19	31.9	51.36	41.63	99.47%	93.38%	335.83
44	Bargi Diversion Project Phase III (km 104 to km 154)	3		26	41.78	3.00	70.22%	21.07%	768.25
	Bargi Diversion Project Phase IV (km 154 to km 197)	3		34	51.00	10.00	100%	22.66%	460.03
	Sub-Total			**872.63**	**940.54**	**788.84**			**13514.25**
				Maharashtra					
45	Waghur	3	Jun-19	38.57	38.57	22.032	103.87%	101.84%	1204.92
46	Bawanthadi (IS)	1		27.71	27.71	27.708	99.99%	100.00%	737.60
47	Lower Dudhna	2		44.48	44.48	42.95	108.17%	91.17%	1716.44
48	Tillari	2		6.57	6.57	5.613	100.00%		499.99
49	Lower Wardha	3	Jun-19	63.33	63.33	41.606	99.51%	94.30%	2361.30
50	Lower Panzara	1		6.79	6.79	6.79	99.93%	102.58%	326.22
51	Nandhur Madhmeshwar Ph-II	2		20.5	20.5	20.5			748.67
52	Gosikhurd (NP)	3		250.8	250.8	79.38	78.46%	39.84%	7303.22
53	Upper Pen Ganga	3		44.47	44.47	33.437	91.98%	45.33%	1061.27
54	Bembla	3		52.54	52.54	42.557	86.33%	67.25%	1979.22
55	Tarali	3		14.28	14.276	6.902	63.05%	24.13%	662.42
56	Dhom Balaakwadi	3		18.1	18.1	15.203	93.40%	66.92%	718.74
57	Arjuna	3		5.7	5.704	2.054	95.66%		489.12
58	Upper Kundalika	2		2.8	2.8	2.35	99.64%	99.62%	262.67
59	Aruna	3		9.03	11.705	0	1.47%		1109.64
60	Krishna Koyana Lift	3		104.17	104.17	61.89	57.91%	16.59%	1248.98
61	Gadnadi	3		3.47	3.47	0.946	12.81%	0%	494.09
62	Dongargaon	1		2.77	2.43	2.43	100%	99.99%	50.13
63	Sangola Branch Canal	3		11.29	11.288	7.542	40.93%	36.10%	340.53
64	Khadakpurna	3	Jun-19	23.86	22.464	22.496	91.07%	93.48%	1074.09
65	Warna	1		54.75	12.247	12.247	100%		290.09
66	Morna (Gureghar)	3		3.08	3.075	1.769	20.58%		95.00

Maharashtra									
67	Lower Pedhi	3		17.02	19.3	0	22.88%	15.25%	932.54
68	Wang Project	3		7.07	7.068	5.754			203.15
69	Naradave (Mahammadwadi)	3		12.28	12.282	0.96			245.35
70	Kudali	3		5.33	5.33	0	13.18%		147.61
	Sub-Total			850.76	811.469	465.116			26302.96
Manipur									
71	Thoubal	3		29.45	29.45	17.67	76.48%	55.15%	1397.67
72	Dolaithabi Barrage	3		7.54	7.54	3.29	83.83%	87.48%	454.71
	Sub-Total			36.99	36.99	20.96			1852.37
Odisha									
73	Lower Indra (KBK)	2		35.87	35.87	28.60	100.00%	83.38%	1577.14
74	Upper Indravati (KBK)	1		85.95	85.95	41.79	99.99%		548.52
75	Rukura-Tribal	1		7.65	7.65	6.80	100.01%	96.98%	240.56
76	Subarnarekha	3		119.26	115.26	77.97	99.70%	59.55%	4106.01
77	Anandapur Barr. Ph-I/ Integrated Anandapur Barr.	3		8.88	56.72	0.00	61.68%	1.46%	1302.24
78	RET Irrigation	2		8.5	8.50	8.46	99.99%	100.00%	723.64
79	Kanupur	3		47.74	47.71	0.00	71.73%	10.05%	1628.00
80	Telengiri	2		13.83	13.83	11.82	98.21%	83.38%	1039.87
	Sub-Total			327.68	371.5	175.4			11165.98
Punjab									
81	Kandi Canal Extension (Phase II)	1		23.33	23.33	23.33	100.01%	90.80%	527.05
82	Rahabilitation of 1st Patiala Feeder and Kotla Branch Project	1		68.62	68.62	68.624	95.04%		155.95
	Sub-Total			91.95	91.95	91.954			683.00
Rajasthan									
83	Narmada Canal	2		245.88	245.88	245.81	100.01%	99.61%	2395.55
84	Mod. Of Gang Canal	2		69.69	96.51	96.51	100.00%	100.01%	678.69
	Sub-Total			315.57	342.39	342.32			3074.24
Telangana									
85	J. Chokha Rao LIS	3		249	249.00	105.34	77.94%	53.97%	9828.29
86	Srikomaram Bheem Project	2		9.92	9.92	6.09	87.26%	56.77%	427.67
87	Gollavagu Project	1		3.85	3.85	3.85	92.86%	101.76%	78.95
88	Ralliuvagu Project	1		2.43	2.43	2.43	100%	99.99%	42.56
89	Mathadivagu Project	1		3.44	3.44	3.44	100%		55.54
90	Peddabhagu @ Neelwai Project	2		6.07	6.07	3.24	94.51%	84.34%	164.68
91	Palemvagu Project	2		4.1	4.10	2.09	97.52%	69.94%	196.80
92	Peddabhagu @ Jagannathpur	3		6.07	6.07	0.00	67.67%	9.08%	139.77

Telangana									
93	**SRSP St. II**	**2**		178.07	178.07	133.36	96.67%	92.23%	891.01
94	**Rajiv Bheema L.I. Scheme**	**2**		82.15	82.15	59.82	104.04%	70.95%	2314.25
95	**Indiramma Flood flow Canal**	**3**		40	40.00	1.21	80.55%		4345.30
	Sub-Total			**585.1**	**585.10**	**320.87**			**18484.80**
Uttar Pradesh									
96	**Bansagar canal**	**2**		150.13	150.13	150.13	99.70%	90.97%	3329.67
97	**Arjun Sahayak**	**3**		44.38	44.38	6.00	85.29%	54.77%	1997.79
98	**Madhya Ganga Canal Ph II**	**3**		146.53	146.53	44.00	88.18%	31.91%	1590.34
99	**Saryu Nahar (NP)**	**3**		1312	473.00	183.80	83.66%	32.27%	4107.69
	Sub-Total			**1653.04**	**814.04**	**383.93**			**11025.50**
	Total			**7602.54**	**6841.00**	**4971.06**			**131162.09**

Source: AIBP *Dashboard*

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