



# THE BLUE BARGAIN

Scarcity, Allocation and the Future of Water Resources



Research Report 2025-26

**THE ECONOMICS SOCIETY**  
SHRI RAM COLLEGE OF COMMERCE



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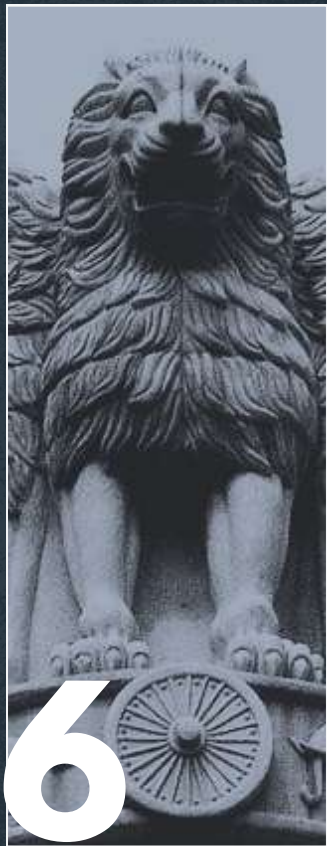
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# Abbreviations

ASCE: American Society of Engineers

ASEAN: Association of Southeast Asian Nations

ASGWA: Assam State Ground Water Authority

CGWB: Central Ground Water Board

CMA: Chennai Metropolitan Area

CWDT: Cauvery Water Disputes Tribunal

DGWMC: District Ground Water Management Council

FCI: Food Corporation of India

IMD: India Meteorological Department

ICWE: International Conference on Water and Environment

PIB: Press Information Bureau

JJM: Jal Jeevan Mission

MRC: Mekong River Commission

NWP: National Water Policy

NBI: Nile River Basin Initiative

OECD: Organisation for Economic Co-operation and Development

PCBs: Pollution Control Boards

# Abbreviations

PDS: Public Distribution System

PWD: Public Works Department

RWRRA: Rajasthan Water Resources Regulatory Authority

EIAs: Environmental Impact Assessments

ELL: Economic Level of Leakage

FRP: Fair and Remunerative Price

IBT: Increasing Block Tariffs

IRP: Integrated Resource Plan

ISRWD: Inter-State River Water Disputes

IWT: Indus Water Treaty

NRW: Non-Revenue Water

PBC: Performance-Based Contracts

PNPCA: Notification, Consultation, and Approval

PPP: Public-Private Partnerships

WFD: Water Framework Directive

WUP: Water Use Permit

GERD: Grand Ethiopian Renaissance Dam

# Abbreviations

GW: Groundwater

GWP: Global Warming Potential

HYV / HYVs: High-Yielding Varieties

MAR: Managed Aquifer Recharge

PAHs: Polycyclic Aromatic Hydrocarbons

PFAS: Polyfluoroalkyl substances

PFOA: Perfluorooctanoic acid

PFOS: Perfluorooctyl sulfonate

RCF: Recycled Fibre

RTI: Reproductive Tract Infections

RWH: Rainwater Harvesting

SWAB: Scientific Wetland with Active Biodigester

SWC: Specific Water Consumption

SWM: Smart Water Management

TDS: Total Dissolved Solids

MSL: Mean Sea Level

ppm: Parts per million



# RESEARCH FRAMEWORK

An overview of water's economic, agricultural, and environmental significance.

# Introduction

Today's world makes it easy to use water by just turning on a tap; however, that ease comes at a cost, with many complex systems for extracting, distributing, and valuing the resource. Water is a major driver of every economy globally.

Water security until now has been assumed to be guaranteed to exist; this assumption is deeply problematic, considering the importance it plays in our everyday lives and the increasing stresses it faces due to constantly growing demand pressures, as well as other challenges. Apart from being fundamental to human existence, water availability also plays a significant role in almost all industrial processes, making unavailability a supply chain risk (e.g., semiconductor chips, wheat).

The report explores how we are transitioning from viewing water as an "infinite" natural resource to treating it as a limited economic resource. We analyse the way historical practices of managing water, including highly developed urban planning in the Indus Valley and very rigid colonial practices, helped create the current system.

We also discuss how our current use of water is exacerbating extremely critical issues because of systemic problems, how the "Tragedy of the Commons" has resulted in moving the world to a vulnerable position with depleting aquifers, and how pollution

in our policies has often been treated as an externality and something that is just a natural consequence of development rather than a serious economic liability.

Access to water is critical to preserve the global economy, which depends on producing food and performing industrial activities. Climate change and population growth will make the dependence on water increasingly vulnerable.

Areas such as Punjab and Haryana (whose aquifers have been drawn dry) will have long-lasting effects because of the economic effects (not only theoretical), which will cause people to relocate and food prices to rise.

The way infrastructure has developed, how we now manage the resource needs new structural solutions to meet 21st-century challenges. Current pricing mechanisms have proven to be counterproductive when it comes to reflecting the scarcity of the resource while at the same time ensuring access.

The current pricing mechanisms and administration systems are unsustainable. Therefore, new pricing models, such as Increasing Block Tariffs and localised governance, are critical to create a sustainable approach to maintaining water as a vital resource.

In this report, an overview of how

water has been managed historically, the major economic drivers of the demand for water, environmental economic principles guiding our understanding of water pollution, and geopolitical factors involved with managing shared rivers in multiple countries are discussed. This report also reviews ways we can develop towards achieving "water security," mainly via better value assessments and cooperation between countries.

# Overview

It was important first to develop an understanding of the history of the management of water as an example of how its evolution transformed from an irreplaceable, shared social resource to an invaluable economic resource. All of these discussions have assisted in providing context to our understanding of modern water governance and the different ways that water contributes to the development of civilisations.

In addition, we attempted to understand why there was a long period where sustainable management of water was missing despite all of the centuries of indigenous engineering.

We accomplished this by reviewing the colonial and early post-colonial water policies to identify how the shift towards centralised, revenue-driven policies disregarded the fragile hydro-ecological equilibrium found in many local ecosystems.

As a result, this has given us an understanding of the historical context of the current sectoral demands for water and the various components that comprise water as an economic input, including its increasing demand in both agricultural and energy production. We will be exploring this re-sourcing of water use in both a qualitative and quantitative manner, with a focus on the increased use of aquifers and the changing technologies associated

with the industrial application of water for cooling and irrigation purposes.

To identify the causes of today's environmental crisis, we try to understand the economic issues related to water. These access-seeking issues include specific examples of the "Tragedy of the Commons" in groundwater extraction; the market failure of pollution as an externality; and the theoretical link between growth and degradation (the Environmental Kuznets Curve). Also, we will look into how, through inefficient pricing and subsidies, we have created systemic waste throughout society.

Once we have an overview of these issues, we will move on to alternatives to manage and value water. Alternatives will include innovative pricing models (Increasing Block Tariffs), initiatives for recycling wastewater, and decentralised governance models.

In each of these cases, we will demonstrate how these alternatives address issues of scarcity and equity while identifying the particular challenges of implementing each alternative.

Finally, we will assess the current challenge facing water in maintaining its neutrality and providing a source of life for us as the world continues to compete on a geopolitical and

regional basis. Water is an international resource and is subject to a number of criticisms relating to its distribution across political borders that preferentially benefit larger nations and/or those with economic power, which makes it difficult to guarantee all people have access to water.

As climate change increasingly limits water availability, we will have to confront questions about our ability to adequately and fairly deliver water to everyone globally, which questions the fundamental purpose of water management as an unbiased system for human and ecological well-being.

# Purpose of Writing

The objective of this study is to look at water management's economic structure, its crucial function in supporting today's world development, and its accelerating crisis during a period of rapid industrialisation and environmental change. Water has been the primary infrastructure for human development across thousands of years, enabling the supply of agricultural, energy, and industrial needs. Yet even given how fundamentally valuable water is, today's systems for managing water supplies have consistently failed to handle the resource properly.

The main reasons for this are well documented: the rapid depletion of groundwater reserves, rising pollution levels and the costs these impose on society, and the growing international tensions surrounding access to and control over shared water sources.

One of the most important contributions of this study is a historical account of how water management evolved from sacred and communal practices into centralised and commoditised systems. Throughout this account, the focus remains on the underlying economic factors that have shaped different management approaches and their contributions to food security and energy production.

The study also examines how water, despite being a renewable resource in

principle, has been consistently mismanaged due to market inefficiencies and outright market failures. The "Tragedy of the Commons" is perhaps the most well-known framework for understanding this problem, and it applies directly to the over-pumping of aquifers and the degradation of shared water bodies. The pollution costs societies bear are almost always far greater than what is actually charged to those responsible.

A particularly telling symptom of this systemic failure is the way water pollution has long been treated as an inconvenience rather than an economic liability. The damage it causes has been externalised onto communities, ecosystems, and future generations rather than being borne by those whose activities caused it in the first place.

This misclassification has allowed the true economic cost of degraded water systems to remain invisible in conventional accounting, and has made corrective action appear more expensive than it really is when weighed against the cost of doing nothing.

This report is therefore built around a re-evaluation of how economic gains and losses are measured in the context of water. More specifically, it argues for the internalisation of the costs of economic activities, meaning that the financial damage caused by pollution, overextraction, and

ecosystem degradation should be properly reflected in the price systems, regulatory frameworks, and governance models that shape how water is used.

This is not a theoretical exercise. Given the current state of global water stress, worsening climate disruption, and mounting geopolitical competition over shared water resources, getting these costs right is a practical and pressing necessity. Without accurate cost internalisation, market signals will keep incentivising overuse and underinvestment in sustainable water infrastructure.

Many governments and economists are already responding to these failures by pursuing governance models that are more equitable and more efficient. Emerging alternative management strategies are reshaping how water services are delivered and how demand is managed. New pricing structures such as Increasing Block Tariffs, alongside wastewater recycling networks and a shift toward decentralised governance, represent a new generation of approaches that prioritise conservation, transparency, and fairness.

This research asks whether these newer approaches are capable of replacing traditional centralised management systems or whether they are better understood as complementary to them. It also asks what lessons can be drawn from these models as the global water sector works toward long-term water security.

Finally, the research considers whether existing water governance can keep pace with an increasingly competitive global environment for water. The combined pressures of inefficient governance, outdated infrastructure, and regional conflict are placing the global water management system under serious strain, contributing to widespread and worsening depletion. Against this backdrop, the research explores the potential for a hybrid model in which traditional delivery systems are integrated with new economic valuation tools and community-based, decentralised participation.

# Methodology

We start the research with an overview of why water transitioned from being a communal resource considered sacred to a very important economic asset. Then we examine the historical systems of water management, from urban drainage of the Indus Valley, to water tariffs under the Mauryan Empire, and finally how these systems changed under colonial rule.

This provides a foundation for creating a consensus around the need to see water as a limited resource, not an unending gift. We provide an overview of the various demands on water in different sectors; in particular showing how agriculture and energy were the primary consumers of water and how early management attempts failed to prevent overall depletion of water.

Next we discuss the evolution of the governance of water. This will include information on the adoption of national policies for water, for example, India's National Water Policy 2012, and how these have continued to evolve over the past several decades.

Additionally, we will provide a summary of the major shifts occurring in how water is used, including technological advances for extracting groundwater and increasing levels of regulatory oversight for industrial discharges and pollution controls.

Next, to be able to discuss the research topic, an examination of the global economic failures of current water management and, therefore, gives the basis for the global shift to another means of conservation to help understand where to look for alternatives. This will include an examination of the nature of the "Tragedy of the Commons" as it relates to aquifers, how this is due to a lack of defined property rights, and its relationship to the long-term sustainability of food and energy security in general.

The analysis also focuses on the Environmental Kuznets Curve (EKC) as a method of understanding the reason for the disparity between how quickly economic growth occurs and how quickly developing countries are able to remediate environmental issues.

Additionally, to address the issues that result from current water management practices, the study provides an analysis of alternative agricultural and industrial practices.

This section will focus on how the various alternatives, such as Increasing Block Tariff (IBT) pricing models and wastewater reclamation, are being successfully used to improve access to water and address inefficiencies, as well as the challenges to the successful implementation of these alternatives.

This leads us to identifying the main issue about water as a global, shared resource, namely, how water is a source of geopolitical and regional stability.

We also explore different aspects of this issue, including interstate conflicts over transboundary river basins such as the Mahanadi River, as well as international tensions caused by large dam projects such as the Grand Ethiopian Renaissance Dam.


Finally, we will explore how both types of conflict negatively affect the reputation of water management as a neutral and cooperative framework for facilitating global peace and development.





# HISTORICAL BACKGROUND

From the Stepwells of the Indus Valley to Modern  
Groundwater Systems.



# TIME

## THE INDIAN SU

**3300  
BCE**



### INDUS VALLEY CIVILISATION



Water was the of the IVC; its water management was the cause of its agricultural surplus, which enabled a population of about 5,000,000 people at its peak.

**320  
BCE**



### MAURYAN EMPIRE

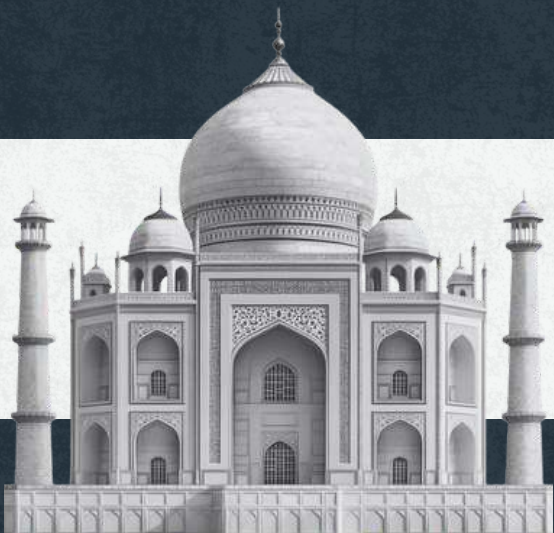


They had an extremely advanced system of water management. Rainfall was measured precisely using rain gauges known as Varshamaan.

**1526**

# LINE

## BCONTINENT



1757



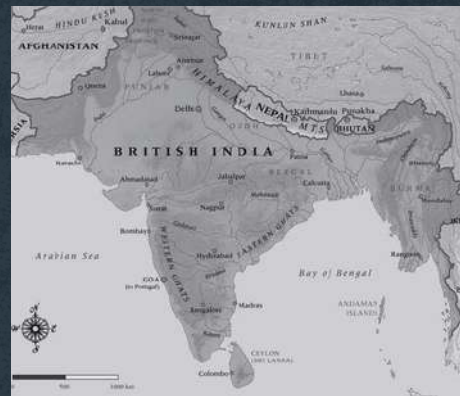
1947

**MUGHAL  
EMPIRE**

**BRITISH  
EMPIRE**



The Mughals built a system of canals, underground networks, wells, reservoirs and garden waterworks to meet their water needs.



Policies reframed water from a social and sacred resource into a commodity and administrative asset, managed for economic and political gain.

# Economic Importance

Water is of enormous importance to our daily living and livelihoods and as probably most people are aware that it is not only the source of life on earth but also a vital element in supporting the sustainable development of many of the world's most important industries, such as artificial intelligence and power generation and many aspects of agriculture, as well as some other agri-based businesses. Water is essential for various forms of human survival, including cooking, drinking, sanitation, and cleaning items by individuals and families, as well as for sanitary systems.

Water is key to irrigation, and therefore, plays an important role in the growth and quality of food. Agriculture uses a large amount of the available water resources on the planet. The agricultural industry uses around 90% of the freshwater extracted in India, with groundwater contributing to 62% of all the water used for irrigation. According to the 2022 UN World Water Development Report by UNESCO.

Currently 70% of global groundwater withdrawals, and even more in arid and semi-arid regions, are used in the agricultural production of food, fibres, livestock and industrial crops, and an estimated 38% of the land equipped for irrigation is serviced by this resource. In order to meet global water and agricultural demands by 2050, including an estimated 50% increase in food, the development of

groundwater could act as a catalyst for improving agricultural productivity and economic growth by increasing the extent of irrigated areas.

The above diagram shows the dependence of irrigation on groundwater, with a majority of the water being extracted for irrigation by all countries. In India, the agricultural industry uses around 90% of the freshwater extracted, with groundwater contributing to 62% of all the water used for irrigation.

In the manufacturing sector, groundwater is used for many different purposes, including the manufacturing, processing, washing, diluting, cooling and transporting of products. Furthermore, groundwater is used by smelting facilities, petroleum refineries, and by industries producing chemical products, food and paper products. Some industrial operations place great reliance on groundwater, whereas others, such as mining, can also cause groundwater displacement or depletion through dewatering into other ecosystems, such as surface water systems. Heavy water-using industries include food, paper, chemicals, refined petroleum, and primary metals.

Ultrapure water is used in the manufacturing of semiconductors used in computers, cell phones, laptops, etc. Semiconductor manufacturing is extremely water-intensive, using an average of 7 litres

of ultrapure water per square centimetre of wafer. This equates to a massive daily consumption for large fabs, with a single plant processing 20,000 wafers per month, potentially using up to 3,000 m<sup>3</sup> of water per day.

Water is also used in cooling systems, which are used to cool down the heat from manufacturing processes and equipment. According to the SUEZ Water Technologies Handbook, the driving force for heat transfer is the temperature difference between the two media, which in most cooling systems is in the range of 10-200°F. Many of the properties of water, including the behaviour of the contaminants it contains, are affected by temperature. As a result, the tendency of a system to corrode, scale, or support microbiological growth is also affected by water temperature.

Despite the digitalisation shift from printed products to soft copies, the paper and pulp industry continues to be one of the largest industries that depend on water resources. Water is involved in nearly 85% of all three stages of paper production, namely, pulp making, pulp processing, and paper/paperboard manufacturing, and their associated activities of cooking, bleaching, and washing. A large quantity of water consumed in this industry is used only for processing, which leads to the generation of large volumes of contaminated wastewater.

Moreover, water is highly used in power generation, primarily in hydropower. Hydropower uses flowing water to generate electricity, providing a sustainable source of energy. In

Apart from these, water is also extremely crucial for sustainable 2022-23, hydropower generated nearly 12.5% of the total power generated in India. In 2024-25, hydropower generated 139780 Million Units (MUs) of electricity.

livelihoods in any economy. Nearly half of the world's workers, approximately 1.5 billion workers, are dependent on water-related sectors for their livelihood. Estimates suggest that 95% of jobs in the agriculture sector, 30% of jobs in the industry sector, and 10% of jobs in the services sector are heavily dependent on water. Additionally, an estimated 5% of jobs in the agriculture sector, 60% of jobs in the industry sector and 30% of jobs in the services sector are moderately dependent on water. It forms the core of an economy's development in the long run. This suggests that water also holds immense economic value and is critical for the growth of a society as a whole. Worldwide, some of the most water-intensive industry sectors employ vast numbers of people: 22 million in food and drink (with 40% women), 20 million in chemical, pharmaceutical, and rubber and tyres, as well as 18 million in electronics (UN Water). Water supply and wastewater facilities operators employ about 80% of the workers in the water industry.

Water pricing becomes very critical to ensure sustainable consumption and efficient use of water resources. Establishing markets, taxes and tariffs can help the economy align demand with supply within sustainable limits. This, in turn, is very important to prevent excessive exploitation and

degradation of water resources. Moreover, there is also a need for the establishment and maintenance of adequate water infrastructure. Without adequate investment, poor water infrastructure threatens economic efficiency and public welfare. Sustainable water infrastructure, including pricing, investment and technological innovation, is necessary to align growing demand and the conservation of water resources for future generations. The Value of Water Campaign and American Society of Engineers (ASCE) examined the economic impacts of fully closing the water infrastructure investment gap in 2020, finding it would take an annual investment of \$109 billion and would result in a transformative gain of \$4.5 trillion to the GDP of the US economy.



# Historical Context



H<sub>2</sub>O (Water), A relatively simple chemical compound of 2 atoms of hydrogen and 1 atom of oxygen, seems extremely ordinary, but it has been the bedrock of human civilisation. From our hunter-gatherer days to the Indus Valley civilisation and even now, in the modern world, water has been the subject of reverence and conflict; it has built and destroyed many civilisations. From the onset of agriculture, humans have been settled near water sources, from the baths of Mohenjo-Daro to the pyramids of ancient Egypt; water has been invaluable, from myth to history.

The Indian subcontinent is no exception; it is nearly impossible to overstate the impact water has had on the region and its history. Here, we dive deep into the history of water through time in the Indian subcontinent.

## **The Indus Valley Civilisation (3300-1300 BCE)**

The Indus Valley Civilisation (IVC) was situated most notably at the banks of its namesake, the Indus River, but it was also supported by a large system of rivers, such as the Ravi River, the now-dry Ghaggar (Old Saraswati River), as well as the Sabarmati and the Bhogawo rivers.

Water was the central resource around which the IVC was built; its water management is widely believed to be the cause of its agricultural surplus, which enabled a population of about 5,000,000 people at its peak.

The civilisation had a large system of public as well as private wells, with most houses having access to a well. This system of wells is considered to be their major source of freshwater for consumption purposes; the great reservoir of Dholavira is proof of a

system of rainwater harvesting in the region.

The IVC also had an extremely advanced agricultural irrigation system. A vast system of canals was utilised to direct water from the Indus and its tributaries to agricultural fields, making farmers less reliant on sporadic rain for farming. This allowed the IVC to have an agricultural surplus, enabling cultural and technological growth of the civilisation.

Cities such as Mohenjo-Daro and Lothal show highly developed drainage systems far ahead of their contemporaries; these cities had vast systems of underground drainage with manholes to facilitate maintenance.

Water also held significant cultural value in the IVC. The great bath of Mohenjo-Daro was a large public bath, which many scholars believe acted as a hub of communal gathering for the people of the city and was also likely used as a place of great religious value, used to perform purification ceremonies.

It is also believed that the ultimate decline of the civilisation was linked to the drying up of the Ghaggar-Hakra River, forcing residents to migrate toward the Gangetic plains.

### **The Mauryan Empire (320-185 BCE)**

The Mauryan Empire is widely considered the first Hydraulic civilisation in India. They had an extremely advanced system of water management. Rainfall was measured

precisely using rain gauges known as Varshamaan. The Arthashastra also provides a detailed account of the distribution of rainfall in various regions of the empire, and a system of forecasting rainfall is also described within the book.

The Ahar-Pyne System, a system of rainwater harvesting, was widely in use throughout the empire. A lot of infrastructure development also took place during this period, various large projects, such as the Sudarsana Dam equipped with spillways, were constructed to store water.

An extensive system of Canals was also in place to provide perennial irrigation throughout the year; in fact, constructing tanks and other reservoirs was considered an act of great religious merit.

A water tariff was also in place, with various rates set for various kinds of irrigation. This serves as proof that by the Mauryan empire, the value of water as an economic resource had been recognised, and an administrative department was established to manage this water effectively.

### **The Mughal Period (1526-1857)**

The Mughals built an extensive system of canals, underground networks, wells, reservoirs and garden waterworks to meet their water needs. This primarily included agriculture and urban supply. A major feature was the qanat system. This system was particularly useful for arid regions. The ancient qanat system can tap alluvial

aquifers at the heads of valleys and conduct the water along underground tunnels by gravity, often over many kilometres. The khooni Bhandara in Burhanpur is a network of wells connected by an underground canal or a huge pipeline made of marble or stone. The system served as a reliable source of water supply in Burhanpur for about 300 years before collapsing in 1977, and serves as a key example of the architectural excellence of the Qanat system.

The Mughals also developed very elaborate Hammams (public bathhouses) and gardens that focused heavily on water usage. The Hammam-e-Lal Qila in Red Fort, Delhi, and the Shahi Hammam in Lahore, Pakistan, are examples of such lavish structures that employed a variety of medieval engineering. The Charbagh layout of the Mughal gardens, which divided the garden by four intersecting water channels, used sophisticated Persian architecture and required an uninterrupted water supply.

Thus, the water workers of the era were of utmost importance. Water-related work encompasses tasks of accessing, carrying, conveying, diverting, irrigating, lifting, and maintaining water systems. It includes floating and boating, which employ the natural work of water for human purposes. These activities involve the design, construction, and maintenance of channels, boats, bunds, fountains, moats, tanks, water-lifting devices, and wells, among others. Administrative texts like the

Ā'in-i Akbarī have detailed information about types of water work and the usage of water in household as well as agricultural activities.

### **The Colonial Era (1757–1947)**

India's water systems underwent numerous changes during the colonial era. Water management during British rule prioritised financial gain over religious or communal values. British policies reframed water from a communal and sacred resource into a commodity and administrative asset, managed primarily for economic and political gain.

The British introduced large-scale irrigation projects across India to facilitate the production of agriculture, which was the dominant source of revenue for the government. One of the most vast and ambitious projects of that time included canal systems such as the Ganges Canal, completed in 1854, and the Upper Bari Doab Canal, which were considered the most extensive irrigation works around the world. The consequences of these undertakings on the local hydrology were immense, as large-scale commercial farming became possible, which was primarily focused on the production of cash crops such as indigo, cotton, and sugarcane, but in most cases, traditional irrigation systems and community tanks were disturbed.

Water management during the colonial era was very much tied to the economic interests of the British Empire. The introduction of water

taxes and irrigation fees was a clear sign that the earlier religious and moral perspective of water being a shared resource had been replaced by one that regarded water as an asset that should generate fiscal returns. Even though British accomplishments in canal construction were remarkable from the engineering viewpoint, they always put imperial revenue before ecological balance or local requirements.

The setting up of modern piped water supply systems was one of the major developments in urban centres, mainly in Bombay, Calcutta, and Madras, with the primary aim of catering to the residential needs of Europeans. These systems gradually transformed to include the Indian populations, making it possible for India to have its own urban water supply network.

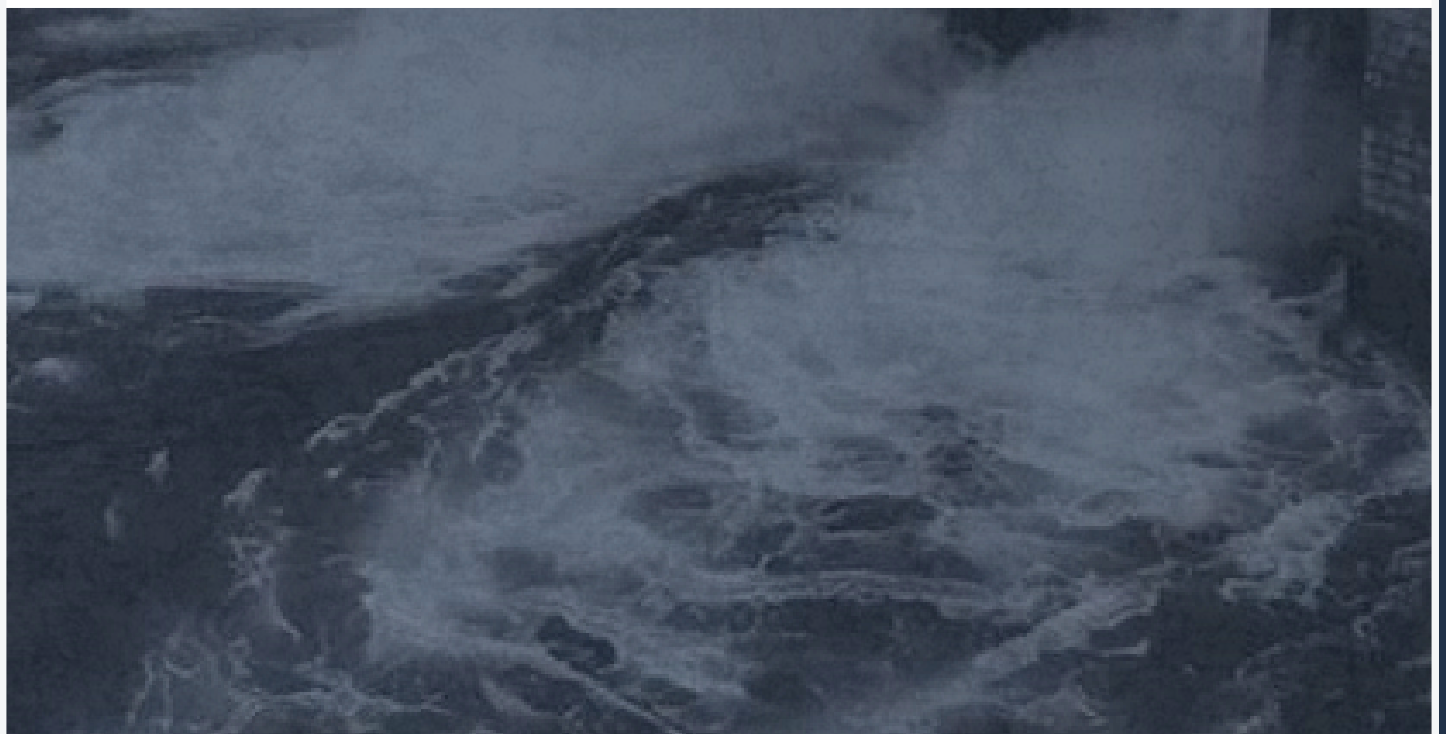
But colonial history also brought disparities in water availability between rich and poor, colonisers and colonised, and rural and urban inhabitants. Cutting of trees on a large scale and excessive irrigation in some areas by the late 19th century caused ecological deterioration and soil salinity, which are still evident today.





# CURRENT USAGE OF WATER

Examining India's growing water demands across agriculture, energy, and urban development.



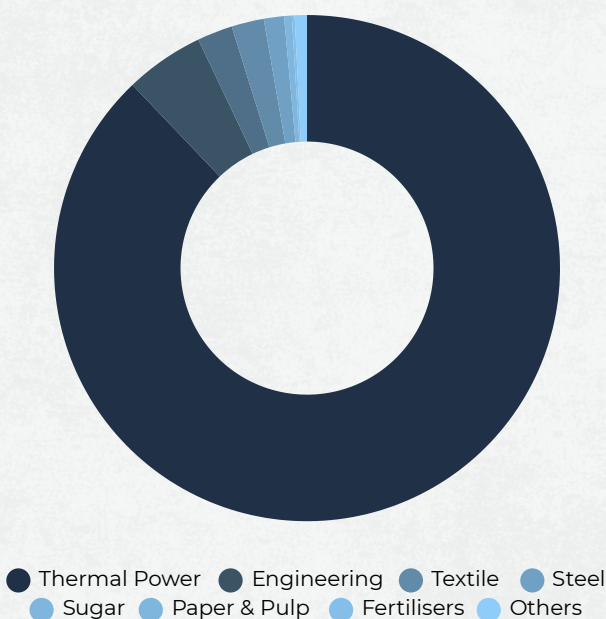
# Industry-Wise Use in India

The agriculture sector is the largest user of water in India, with more than 80% of usable resources being utilised by it. The agriculture sector is responsible for 89-90% of the total groundwater extraction in India. This consumption is driven by water-intensive crops such as paddy and sugarcane. This is followed by the industrial sector at 13%. Industry accounts for roughly 75 billion m<sup>3</sup> of water use annually in India. The major water-intensive industries include the thermal power plants, heavy engineering, textile, pulp & paper, steel, sugar, fertiliser, etc. Thermal power plants are the most water-intensive industry by far, consuming about 88% of the total water resources used by all Industries, other Industries such as steel, pulp, paper, etc., while making up a smaller share of the total water consumption, are still large users of water. Much of this water

usage is unnecessary, caused by the industries in India being less water-efficient compared to global standards.

This section provides an overview of major Indian industries, such as Thermal power plants, textiles, Iron and steel, paper and pulp, & Automobiles, on how they utilise water resources, their total water consumption, and their water efficiency usage. This is done through the lens of the metric “specific water consumption” It is a measure of the amount of water required to produce a unit of output, in industry, agriculture, or domestic use. In other words, it directly links water usage to the functional output, showing how much water is required for each unit produced or performed. The purpose of this analysis is to understand how various industries and their processes contribute to India’s water footprint.

**Water consumption by different industries**



## Thermal Power Plants

Thermal power plants are plants that convert heat energy into electricity through a process called the Rankine cycle. Its motive is to convert thermal energy to mechanical energy with the help of a working fluid (usually water). The process typically involves 4 stages.

### 1. Isentropic Compression

At this stage of the process, the water is pressurised with the help of a feedwater pump. This highly

pressurised water is then pumped into a boiler, where the water (or any other working fluid) being used is highly treated and purified. This is done to prevent any minerals from forming gunk in the boiler or any other part of the process, thereby decreasing its efficiency. The water is pressurised to increase its boiling point, making it possible for the steam carry more energy to the turbine.

## 2. Constant Pressure Heat Addition

After the high-pressure water is in the boiler, heat from the fuel source (Nuclear, Coal, Natural Gas, etc.) is added to the water to boil it, and due to its pressurised nature, it becomes superheated steam, carrying with it large amounts of energy.

## 3. Isentropic Expansion

The superheated steam is passed through the turbine, as it expands and its pressure drops, it starts spinning the turbine. The spinning of the turbine here converts the thermal energy into mechanical energy. This is the stage where power generation happens.

## 4. Constant Pressure Heat Rejection

After the turbine, the “spent steam” (steam which has lost its pressure post the turbine stage) is passed through a condenser, where it comes into contact with chilling coils which are chilled by external water, and is converted back into liquid so the cycle can be started again. This stage is where the vast majority of water consumption takes place, because,

unlike the water inside the system, which is part of a closed loop and is constantly recycled, the water that is used to keep the chilling coils cold is continuously lost, over 80% of the water consumption of a thermal power plant happens at this stage.

Thermal power plants use a multitude of sources, some more efficient than others when it comes to water consumption. Some of these sources include coal, Petroleum, Natural Gas, Nuclear Fission, and biofuels.

More than 80% of India’s Energy needs are met through Thermal Sources.

Thermal energy is the most water-intensive Indian industry, as 87.87% of the total water used in Indian industries is used in thermal power plants. During the six years, i.e., 2011–2017, the power production by coal-fueled thermal power plants in India has increased by 64.82%. Such a condition has led to an enormous increase in the demand for freshwater use in these thermal power plants. Water consumption is significantly higher in coal-based thermal power plants, which use a significant amount of water constantly for cooling purposes, ash handling, steam generation and a variety of other uses, including drinking, coal handling, service water, fire-fighting, etc. The SWC (Specific Water Consumption) for the thermal power plants ranged between about 1.9 m<sup>3</sup> /MW to 6.5 m<sup>3</sup> /MW, representing the water consumption in the range of about 1179 m<sup>3</sup> /h to about 13694 m<sup>3</sup> /h The

efficiency of water utilisation in a thermal power plant is dependent on various factors including the type of cooling system adopted, ash handling practices etc.

The cooling system is the most water-intensive part of the process, and so the water efficiency of a thermal plant is dependent not on the type of fuel used, but instead on the cooling system used.

### **Textile Industry**

The Textile Industry is an extremely important Industry for the Indian Economy. It accounts for about 2.3% of India's GDP, and makes up 13% of our Industrial production and 12% of our exports, exporting about \$34.4 billion worth of apparel in FY 2023-24(9). The textile Industry consumes about 93 million m<sup>3</sup> of water annually globally. Cotton alone, a vital raw material for the textile industry, accounted for about 2.8% of the global water consumption. This is especially concerning for India, for every kg of cotton produced in the country, about 22,500 litres of water is consumed. India is the 2nd largest producer as well as consumer of cotton, producing 5.50 Million Metric tonnes in FY23-24 and is the 1st ranked globally with regards to the acreage dedicated to cotton, with 124.69 Lakh acres being under cotton cultivation. The Indian Textile Industry's cotton to non-cotton fibre usage ratio is 60:40; the global Cotton: Non Cotton fibre ratio is 30:70, so not only are we one of the largest global producers of cotton in the world, producing about 24% of the total global supply, but we also use

more of it in the textiles produced in our country, roughly double the global average, this is worrying for us as a country because we only have access to 4% of the world's freshwater supply, but have 16% of the population, so our water resources are already stretched extremely thin, so thirsty Industries such as textiles and crops such as cotton are significant users our already very limited water resources.

Many of the processes in the textile industry, such as washing of raw material, spinning, bleaching, dyeing, printing, finishing, cooling, etc., require water. Through the application of conservation practices, various industries around the world keep their water consumption below 100m<sup>3</sup> /tonne of cotton. The range of SWC for fabric processing units is lower (about 51.1 – 97.5 m<sup>3</sup> /MT) as compared to integrated industries (cotton) (104.1 – 343.5 m<sup>3</sup> /MT) and integrated industries (woollen) (237.1 m<sup>3</sup> /MT), as they have many more processes. In terms of total water consumption, the observed range varied from 5625 m<sup>3</sup> /day to 5720 m<sup>3</sup> /day in integrated mills (cotton), whereas it varied between 271 m<sup>3</sup> /day and 877 m<sup>3</sup> /day for fabric processing mills, as well as about 3555 m<sup>3</sup> /day for the integrated woollen industry.

### **Iron and Steel Industry**

Ironmaking and steel production are vital industrial processes that involve the transformation of iron ore into molten iron and its subsequent conversion into various grades of steel, supporting diverse sectors worldwide(5). India is the second-

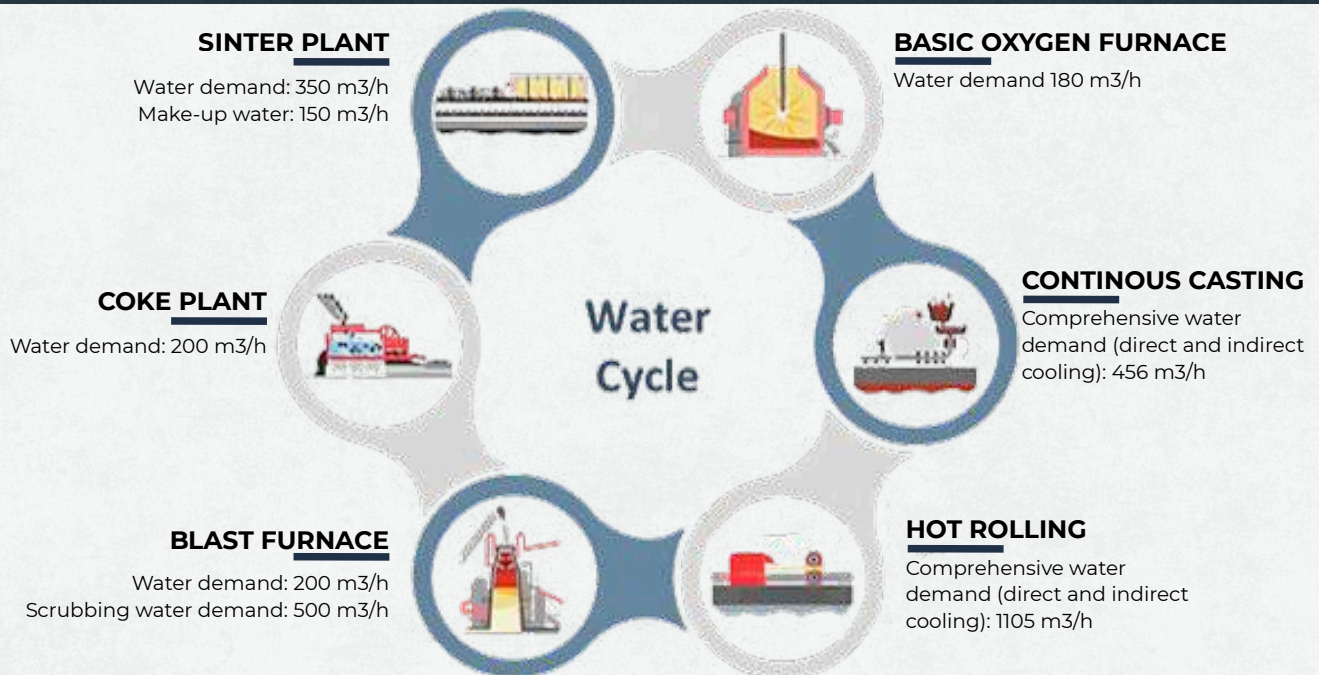
largest producer of steel in the world. Water is needed in the steel plants for activities such as cooling (make-up water to compensate for evaporation and mechanical loss in operations such as quenching, Blast Furnace (BF) shell, continuous casting, and hot rolling), cleaning (BF, basic oxygen furnace (BOF), coke oven, etc.) descaling (hot rolling and continuous casting), chemical and electrochemical treatments (tin-plating and galvanization), and scrubbing (particulate suppression)(5).

lost due to evaporation. Major pollutants include ammonia, cyanides, PAHs, oils and various other contaminants depending on the stage of the process. Cold rolling and scrubbing processes have the least harmful environmental impact.

### Pulp and Paper Industries

Pulp and paper Industries consume a substantial amount of water during nearly all the stages of the production process of paper. The production

## Water requirements for unit operations involved in carbon steel manufacturing



The observed range of water usage in Iron & Steel plants fluctuates based on production, and it ranged between 6874 m<sup>3</sup> /day to 59682 m<sup>3</sup> /day, with Specific Water Consumption (SWC) ranging between 5.3 – 7.7 m<sup>3</sup> /MT for the studied plants. The quantity of wastewater discharge is estimated to be 25–26 m<sup>3</sup>/ton of steel produced, which signifies the quantity of water consumption is not more than 3–4 m<sup>3</sup>/ton, and the rest is

process stages are raw material preparation, pulping, bleaching, washing, paper making and finishing, etc. Pulping and paper-making are the most water-intensive stages of the entire process. RCF ( Recycled fibre) based mills are the most water-efficient technology available to produce paper, consuming in the range of 0 - 25m<sup>3</sup>/tonne, which is considerably lower than the wood-based paper mills, which consume

Type of products in Paper Industry	Volume of Fresh Water (m <sup>3</sup> /t paper)	Volume of Wastewater (m <sup>3</sup> /t paper)
Tissue Paper	5-15	5-12
Offset Paper/Printing	11-60	11-55
Newsprint Paper	18-25	16-23
Wrapping Paper from Recycled Paper	6-32	5-28
Hygienic and Sanitary Paper from Recycled Paper	6-35	5-31

50 -75m<sup>3</sup>/tonne. This is because RCF-based mills do not require pulping.

Currently, 73% of paper is produced from RCF-based mills, 18% is produced from wood-based mills, and the remaining 9% is produced in agro-based mills. The Pulp & Paper industry consumes 2.26% of the total industrial water consumption in India. An industry association reported that the paper industry in the country has reduced water usage by 80% and intends to do so further, owing to investments of US\$3.05 billion (Rs. 25,000 crore) made in environmentally friendly production methods in recent years. Different paper products require different water consumption. The given table illustrates the water requirements of different paper products.

### Automobile Industry

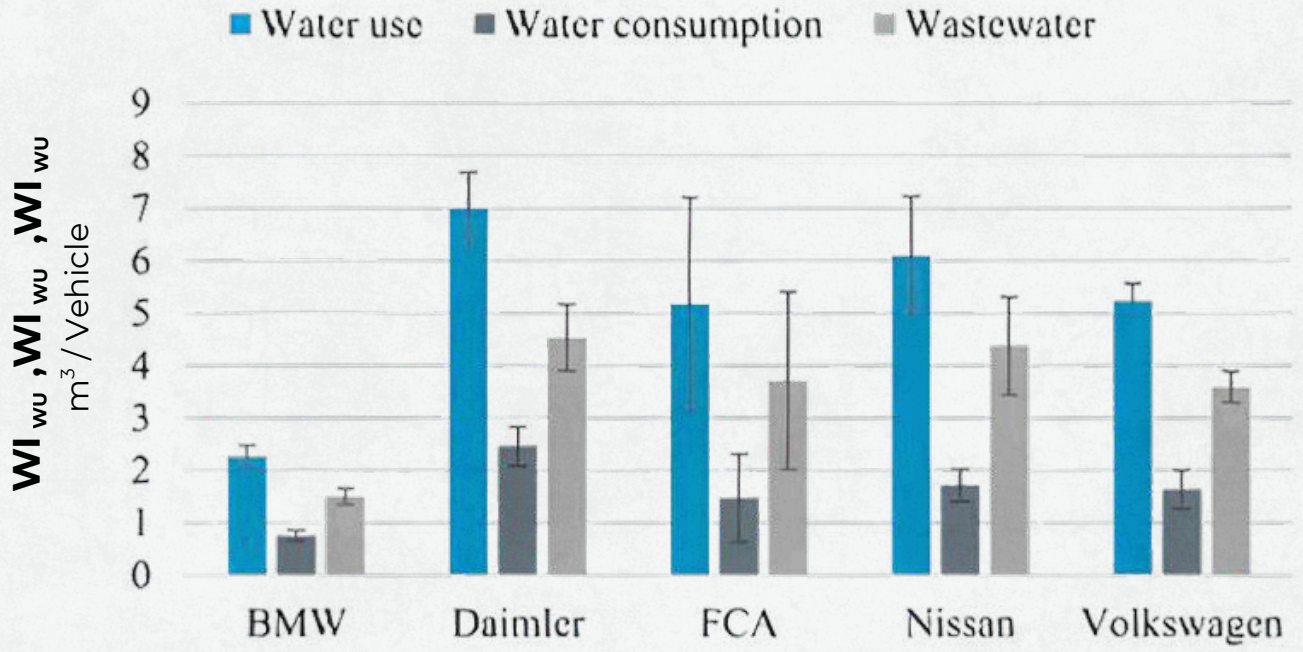
The engineering industry in India makes up 5% of the total industrial water consumption in the country. The automobile sector is the largest part of this engineering industry. The automobile industry in India is the fourth largest in the world and one of the fastest growing around the globe. The water used by the automobile sector can be classified into 2 broad

categories: manufacturing use and non-manufacturing use (water used mainly for electricity generation used in the production process).

Major water-consuming processes in the automobile manufacturing industry include surface treatment and coating, paint spray booths, washing, rinsing, hosing, cooling, air-conditioning systems and boilers. The paint shop is the most water-intensive part of this process. This painting process is primarily for automotive coatings and paints that are water-based products. On top of that, the processing equipment also needs to be cleaned regularly with water. In addition to these direct processes, indirect processes such as electricity production and consumption also consume large amounts of water. estimated average indirect water consumption to be 2.21 m<sup>3</sup> per vehicle. On average, 4.94 m<sup>3</sup> of water and 2.74 MWh of energy are used directly to produce a car. The exact lifespan and division of water usage in a car has conflicting data.

Different car companies manage their water resources with varying efficiency. The following graph illustrates the same.

### Water Efficiency of Different Automobile Companies



# Geographical Distribution



Globally, 1 in 4, or 2.1 billion people, still do not have access to safely managed drinking water. People in least developed countries are more than twice as likely as people in other countries to lack basic drinking water. This shows the extent of inequalities in access to water globally. In 1951, India was a water-rich nation with every citizen having more than 5,200 M of water available annually.

In the last seven decades, the total volume of available water has dropped significantly, reducing it to less than 1500 cubic feet currently; and projected to decrease further to approximately 1200 cubic meters by 2050 which very closely approaches the point at which the country will become classified as having a scarcity of accessible fresh water.

The geographical features of some regions, including those in or near the Himalayas and along the Western

Ghats, receive an adequate supply of fresh water; the elevation and presence of numerous lakes and rivers contributes to those areas receiving a significant amount of rainfall. On the contrary, the western and central India region comparatively does not get enough water.

Now, given the unequal distribution of water within India, it is important to understand how different regions and states with different degrees of water access actually utilise these resources.

## **Water-rich vs Water-scarce Regions:**

Water-rich states like Assam, Arunachal Pradesh, Meghalaya, Kerala, etc. get water annually through rainfall (around 2000-3000 mm, much more than the national average of 1160 mm) and also dense river networks. River systems like the Brahmaputra, Ganga, and Western Ghats basins contribute nearly 60% of nationally

available surface water. Due to the abundance of surface water and rainfall, these states use less than 30% of their groundwater potential. Historically, rainfall has been the dominant mode for irrigation in these states, with minor irrigation projects in use. These states have >1700 cubic m per capita per annum availability of water. Agriculture remains the major consumer (80-85%) of water in these states, followed by domestic use (10-15%) and industrial use (~5%).

Kerala has been a paradox in itself. Paradoxically, Kerala faces water scarcity and a crisis despite being a state known for its water resources, with an average annual rainfall of about 3,000 mm and 44 rivers. The paradox is that the water supply is not enough to meet the demand, although its nature seems to be generic.

A big proportion of the monsoon rain ends up as runoff and goes to the sea. The place has very steep slopes and thin, limited aquifers; hence, the storage of groundwater is very minimal. This results in water shortages during some periods of the year, especially in dry months and in years when monsoons are delayed.

Kasaragod district for instance, suffered a serious depletion of its groundwater due to enlarged borewell drilling coupled with non-recharging. It had a double problem of soil erosion and surface sealing resulting from the area's development. Check dams ('kattas') constructed by villagers and rainwater harvesting are some of the ingenious

interventions that have catered to the relief of some districts. Kerala has problems with frequent hydrological droughts, pollution of one-third of its tested wells and virtually no large-scale conservation. Thus, the basic reason Kerala has trouble accessing water and possibly has health-related issues is based on having access to rain and rivers but having an unreliable means of obtaining it or receiving polluted water for use.

In other states with significant water shortages such as Rajasthan, Gujarat, Maharashtra, etc., the annual rainfall is around 800 mm and the amount of available water per person is less than 1000 cubic metres. The main characteristic of these states is that they rely heavily on groundwater for 90% of their supply, and their groundwater has been compromised through excessive withdrawals.

For example, Gujarat has high chloride levels in its aquifers because of excessive withdrawal and recharge cycles, whereas Punjab has seen its groundwater level drop over one meter per year. Wells are also increasingly going dry in Rajasthan, even though the national annual water recharge increased in the country from 15 BCM in 2017 to 2024.

Gujarat is at the other extreme of the water security spectrum. The scarcity is not only due to a shortage of water, but it is also ingrained in the people's way of life in most parts of Kutch and Saurashtra, which receive less than 500 mm of rain annually and are hit by droughts regularly.

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The shortage has been aggravated by the heavy dependence on monsoon, which is still not reliable, and the indiscriminate extraction of groundwater, which has caused the water level to drop by as much as 70 meters in some districts during the last 30 years. More than 20% of villages are regularly supplied with water tankers for their daily needs and at the same time, aquifer salinisation (the increase of total dissolved solids (TDS) in groundwater, resulting in reduced freshwater quality) is widely prevalent due to coastal intrusion and extraction in the areas which have not been taken care of.

Even though there is still time before the groundwater depletion will render the state without water, Gujarat is facing a paradox of water shortage as a result of it. Urbanisation, industrialisation, and the increase in the area under crops have become the major factors for water demand, and the supply side has been lagging by a long way in spite of the ambitious interventions of the government like the Sardar Sarovar Project and various inter-basin canal systems.

The problem in Gujarat is not only about fresh water but also with climate change, which affects the rain distribution and makes the already

over-exploited resources last longer. The water paradox in Gujarat is that it is the natural limitations of rainfall in some areas and historical overuse of water that keep vulnerable cycles of scarcity existing, even though large engineering solutions are in place.

### **Urban-Rural Consumption**

Water consumption patterns show a huge difference between the consumption patterns in urban and that in rural areas of the country. Agriculture currently uses 89 percent of the surface water and over 92 percent of our underground water resources, leaving limited quantities available for industrial and domestic purposes at the national level. Rapid urbanization and industrial expansion have placed Hyderabad, Delhi, Bengaluru and Chennai in a critical situation with ever-growing pressure for water supply. While rural areas generally have a daily per capita water consumption rate averaging between 135 and 200 litres in metropolitan urban areas, this figure is significantly lower in rural areas across India. Substantial amounts of water used in these major cities are transported from different river basins or, in certain instances, provided by using tankers as temporary supplemental water sources.

Aquifers and monsoons are the major means by which communities in rural India are replenishing their water supplies; however, projects like the Jal Jeevan Mission (JJM) are making water more accessible. By 2025 (SDG Progress Report, 2025), it is estimated that almost all 99.62% of rural homes

will receive clean and safe drinking water via tap connections. The tremendous progress being made to connect all homes to safe drinking water throughout the entire country shows that there is an ongoing depletion of ground water resources; this will negatively impact increasing levels of agricultural production through further intensifying agricultural production practices and continuing to use inefficient irrigation methods, particularly in the Punjab, Haryana, and Maharashtra states of India.

### **Dependence on Monsoon**

India's water mechanism is greatly dependent on the monsoon season, with almost 75% of annual precipitation coming between July and September. The country's water and food security are practically based on the monsoon season. Monsoon-reliant Kharif crops such as rice, maize, pulses, millets, cotton & sugarcane are sown between June-July and account for 55% of the food grains cultivated across India and are dependent on 40%-50% of total unsown lands.

In 2025 an excess of rain at the time of the year helped to stimulate transplanting of paddy in the states of Bihar, Jharkhand, and Chhattisgarh, but created flooding in Punjab, Haryana, Maharashtra, and Rajasthan. Although irrigation continues to grow in use across the entire range of agricultural crops, and 85 districts report having far more than enough irrigated crop yield than they can actually consume, or sell to

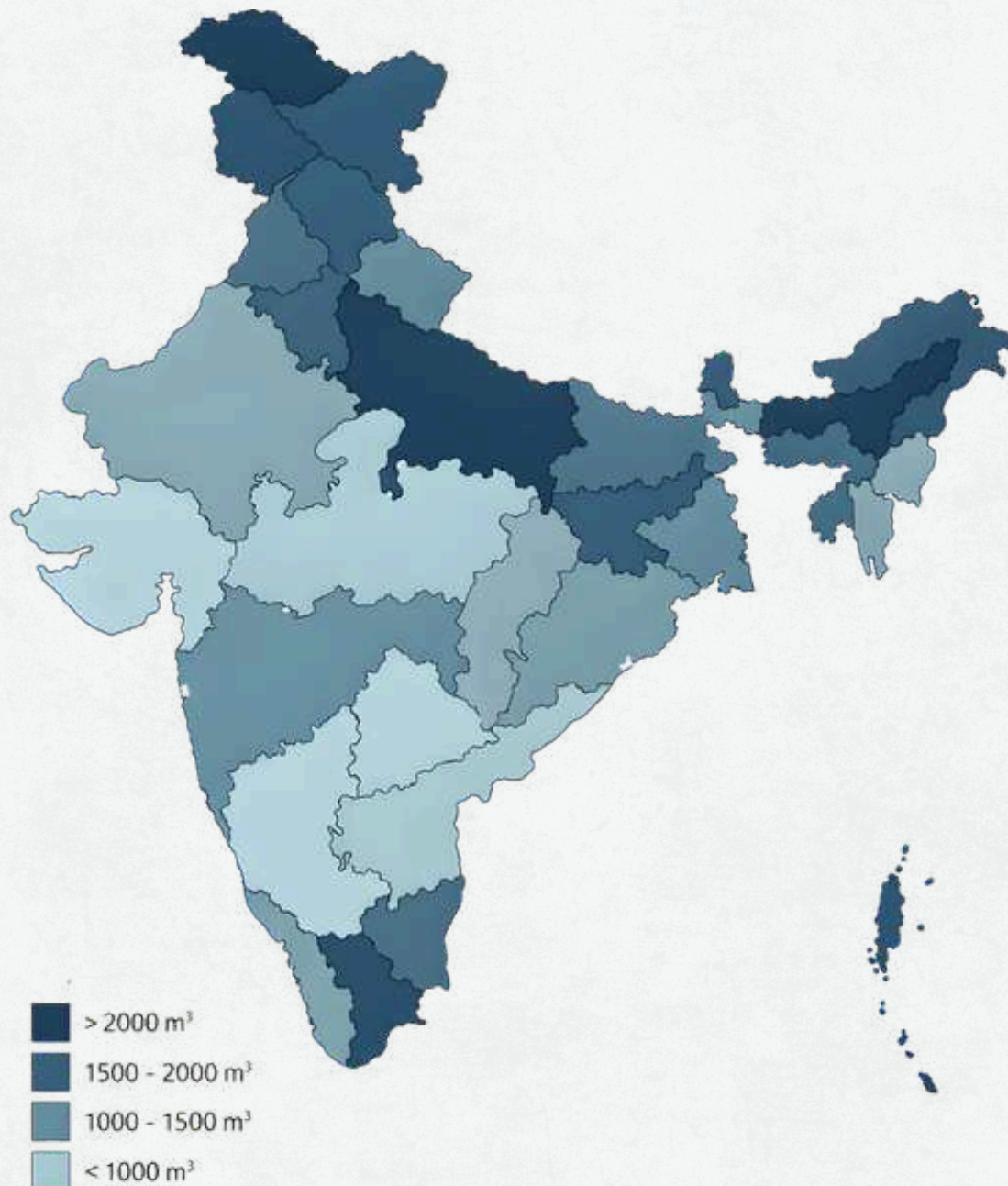
surrounding communities, there are still approximately 130 districts that have insufficient quantity of crops to feed their local strains due to poor irrigation systems. The IMD recently stated that rainfall for the southwest monsoon for the month of December was 108% of the long-period average, with this being the wettest monsoon season for the area in memory.

### **Regional Water Imbalances**

As discussed earlier, there exists a huge water imbalance in India. The Ganga-Brahmaputra-Meghna basin holds nearly 60% of India's surface water resources. On the other hand, the Sabarmati, Cauvery, and Krishna basins, in spite of supporting dense populations, hold less than 5% of the surface water resources. Over 256 districts are over-exploited, where groundwater provides over 60% of irrigation water and 85% of drinking water. One of the major causes of this is that only 30% of the rainwater is captured in reservoirs due to inadequate infrastructure. According to NITI Ayog, by 2030, India's water demand could double its supply, and nearly 40% of the population would not have an adequate water supply.

The 2025 water map for India shows the extent of inequality in water availability in the country. Some areas have little or no or less stress, while some other regions have scarcity in water access.

## Per Capita Water Availability of different States in India



In northern and northwestern areas of India including Punjab, Haryana, Uttar Pradesh, Jammu & Kashmir, Rajasthan, etc., are highly water-scarce. Groundwater in Punjab has been over-extracted; around 172% of the recharge amount has been extracted in the last few years. In Haryana there has been over-extraction of around 133% due to similar reasons. Below are some of the main reasons for this over-extraction: High population density; large

dependence on agriculture (which accounts for about 87% of total annual withdrawal from groundwater); and seasonal river flows that only flow when it rains (rainfall dependent); and thus reliance on monsoons, etc. Per capita availability of water will be reduced to less than 1000 m<sup>3</sup> by 2025 for these northern and northwestern regions.

Similarly, southern regions of India including Tamil Nadu, Karnataka, and Telangana are also very water-scarce. For example, certain districts in Tamil Nadu will have less than 500 m<sup>3</sup> per capita water availability by 2025; and Chennai experienced a 'Day Zero' in 2019 due to lack of rainfall. The main reasons for these are; seasonal rivers resulting in overdependence on groundwater; and the continuing Cauvery River dispute which started in the 19th century and was resolved in 2018. In addition, western regions of India including Gujarat and parts of Madhya Pradesh and part of Maharashtra are also water-scarce areas.

The semi-arid climate, irregular amounts of rainfall, and high irrigation demand are all major reasons for the water scarcity in western India. Groundwater has been over-extracted for agricultural uses as well as for homes in urban areas (such as Mumbai and Pune), which has also contributed to the decrease in the amount of available water in western India.

Assam, Meghalaya, and Mizoram are in the northeast part of India and are not affected by drought. The amount of rainfall these states get is generally well over 2,000 millimetres per year. In addition, they have a large number of year-round flowing rivers. Similar conditions exist in the Himalayan states of Uttarakhand and Himachal Pradesh as well as in the state of Kerala, which also receive a large amount of rain (1,400 mm to 3,100 mm) each year. The Northeast India and Maharashtra, in monthly terms,

have an average of over 1,700 cubic metres per person available for use each month as a total water resource amount.

The average amount of rain falling in India each year is 1170 mm but this is not uniform across the country. For example, major urban areas such as Uttar Pradesh, Bihar and Delhi will have far greater amounts of water related stress than rural areas such as Himachal Pradesh and Arunachal Pradesh. In addition, agricultural production of crops (especially rice, sugarcane and cotton) in Punjab and Haryana will further exacerbate the issues of water availability since these crops require large amounts of water to produce. In addition, the development of industry in both Punjab and Haryana will further add to the number of withdrawals of water, thereby adding to the regional stress of the water resources of the area.

# Policies, Laws & Frameworks

Water is a critical resource to the success of any economy, creating a large part of the overall growth and welfare of the people within an economy. To this effect, it is critical to establish effective water policies to provide access to individuals while avoiding overuse of this resource. In India, there do not appear to be any policies or laws addressing specifically water usage. Nonetheless, the Government of India does have developed a number of policies and regulatory authorities regarding water conservation; we will highlight some examples below.

## **National Water Policy 2012**

The first National Water Policy, developed in 1987, constructed a framework for water resource conservation in India. The policy defines water as 'a basic human need and a valuable national resource.' It outlines an approach for integrated water resource planning, regulating groundwater extraction, encouraging sustainable development of surface and groundwater (among many others) to ensure that all uses of water are within sustainable limits.

The NWP's goals were addressed through The 8th and 9th Five Year Plans of the Planning Commission, which recommended creating significant reforms and restructure of the water sector, including decentralisation of water service delivery to local bodies and the private sector, allowing local bodies to set

water tariffs based on demand, etc.

The NWP 2012 will promote the stewardship of, water related resources through enhancing their conservation, and management. In addition to that, it highlights the need for creating a national water framework and comprehensive legislation relating to the optimal development of the inter-State rivers/river valleys.

Water should be viewed as an economic commodity (after the basic population needs for drinking, food security, sanitation, etc.) in order to promote responsible stewardship and efficient utilisation of this resource. In addition to that, the NWP calls for developing a system to evolve benchmark standards for the various categories of water use, in order to promote efficient use of water resources.

Utilising project financing as a financial tool (through the use of alternative financing mechanisms) to encourage and promote the efficient and productive use of water has also been suggested.

Some modifications to these objectives were made to the NWP in 2020, which primarily focus on conserving water resources, protecting/maintaining water quality and improving government structure (through the creation of a water authorities network.

In addition to proposing the creation of a Water Regulatory Authority and removing major differences between the regulations governing urban versus rural water supply, the Policy suggests that all water resource projects and services should involve the participation of the communities they are intended to serve. As described in the Policy, there are penalties for exceeding sustainable limits on the use of water. However, many people involved in policy and funding processes report a mixed effectiveness of the Policy at the state level due to problems with funding, bureaucracy, and stakeholder involvement. Some participants believe that although the Policy has had success in achieving climate resilience, managing water resources through an integrated approach, and using water efficiently, it mostly acts as an information document without practical, implementable, or timely directions to be followed in either state or national jurisdictions.

### **The Water (Prevention and Control of Pollution) Act, 1974**

The Water (Prevention and Control of Pollution) Act of 1974 is a fundamental piece of legislation regarding the environment in India. The Indian Parliament was the first to enact legislation specifically to control water pollution; the purpose of this Act is to prevent and control pollution and maintain the purity of water. To facilitate compliance, the Act established Pollution Control Boards (PCBs) at the State and Central levels, whose responsibilities include carrying out pollution control

activities, collecting data, educating people on pollution, and using water resources more efficiently. In addition, this Act requires that industries and raw sewage receive permits for discharging into water bodies before they do so. The Boards have the authority to monitor and inspect effluent discharges; to close down operations causing pollution; and to mandate the use and disposal of polluting effluents. Finally, the legislation and Board regulations lead to the abuse of water being managed and controlled using a functional formal system, resulting in a measurable decrease in the levels of pollution in lakes and rivers as a result of the act.

### **State-Level Instruments for Water Law**

#### **Rajasthan**

Rajasthan Water Resources Regulatory Act, 2012: This legislation aims to create equitable, efficient, and sustainable use of water resources within the state of Rajasthan. The Act establishes an independent body - the Rajasthan Water Resources Regulatory Authority ("RWRRA") - to be responsible for regulating how water can be allocated between the different sectors (including irrigation, industrial, and household), as well as to set water tariffs for all users of water (not including drinking water). Bulk water supply, irrigation, and industrial usage will incur fixed charges to advance use of water resources with the greatest amount of efficiency. RWRRA will also monitor the availability, usage, and sustainability of

all water resources in the state.

Rajasthan River Basin and Water Resources Planning Act, 2015: The purpose of this legislation is to establish a framework that will support the management of the state's various water resources, through an overall framework of river basins, sub-basins, and aquifers, and does so in a sustainable and effective manner. The creation of both the State Water Resources Advisory Council and the Rajasthan River Basin and Water Resources Planning Authority are part of this process by providing the authorities needed to oversee the management and allocation of all water resources in the state. Additionally, this legislation promotes the sustainable use of and conservation of all water resources.

### **Assam**

The 2012 Assam Ground Water Control and Regulation Act was enacted to regulate the development and management of groundwater resources in Assam through: limiting the over-extraction and contamination of groundwater, ensuring that groundwater resources are used sustainably and equitably, providing for the establishment of the Assam State Ground Water Authority (ASGWA) to monitor and regulate the use of groundwater in Assam, and provide education to the public about conserving water.

### **Maharashtra**

(The Maharashtra water policy) The Maharashtra water policy (2019), has been created by the government of Maharashtra in response to its diverse climate, frequent flooding, drought, variety of rainfall between 400 mm to 6000 mm per year as 60 % of the people in Maharashtra are dependent upon agriculture, making the governance of water resources of even greater importance for this state. This policy introduces new ways of modernising the management of Maharashtra's weather and water resources, with both floods and droughts being common and will help provide better management of the state's weather and water resources by improving how we use and manage these valuable resources. Additionally, the policy provides an approach to build accountability into the management of water resources by creating a water resource price system that is more transparent and establishes the basis upon which water prices will be established.

### **Gujarat**

Gujarat Domestic Water Supply (Protection) Act, 2019: This law was established "to prohibit unauthorized or excessive withdrawals of water; to prevent the destruction of the water supply infrastructure; and to preserve the water supply system for use in homes by its citizens in Gujarat and other issues associated with or connected to it." The law regulates the entire State of Gujarat and provides for the protection and sustainable management of the water supply for

domestic use. This includes specifying the duties of the authority that has responsibility for maintaining the water supply infrastructure and regulating how that supply is distributed to consumers

### **Uttar Pradesh**

Uttar Pradesh Ground Water (Management and Regulation) Rules, 2020: These regulations were created from the UP GW (Management & Regulation) A 2019 to outline the exact processes to carry out the act, including identifying \*Notified Areas\* (i.e., depletion or degradation of GW) & regulating extraction of GW. The act also outlines parameters for identifying areas that are considered over-exploited & areas with high levels of GW depletion. The regulations define how users can obtain permission from the relevant authorities prior to drilling/using/injecting groundwater at anytime (i.e. industrially, commercially, domestically). The regulations authorize DGWMC's & the State Authority to set limitations on the amount of Water Extracted (e.g. approving WUP's), regulating compliance with those limits, & monitoring those WUP's / Wells. Overall the purpose of this Act is to protect the Quality of GW by defining sensitive areas & controlling pollutants in these sensitive areas.

### **Punjab**

Punjab's Water Resources (Management and Regulation) Act, 2020 provides for an effective management and regulation of the

water resources in Punjab, thus ensuring their judicious, fair and sustainable use and management. The Act establishes the Punjab State Council for Water Management and Development, which approves and modifies the Punjab State Water Policy, the Integrated State Water Plan and related financial assistance recommendations, and issues directions for groundwater extraction structures, surface water optimization, recycling, rainwater harvesting, etc. In summary, the Act enables an efficient use and management of water resources, reduced waste and sustainable development of infrastructure.

### **Meghalaya**

The Meghalaya State Water Policy, 2019, was developed in response to the need for a framework to provide for the sustainable and efficient use of all the water resources of the state, as Meghalaya is the state with the highest average annual rainfall in India. As a result, the Act was developed to provide for the establishment, development and maintenance of water resources in a sustainable manner, with community participation, integrated water resources management, and principles of environmental sustainability, social equity and the 3Rs (reduce, recycle, reuse). With the enactment of this Act, Meghalaya is the first state in India to adopt a comprehensive water policy that focuses on good governance for present and future generations.





# THE ECONOMICS OF WATER

An Analysis of Water Pricing and the Financial Stakes of  
Global Water Security.



# The Cost of Water Scarcity

Due to the integral nature of water in our lives, a lack of freshwater for our needs can have tremendous ripple effects through society. Water is of central importance to our lives, and water scarcity has the potential to cause immense tolls on society. While the economic efficiency lost due to the scarcity of water is an issue of utmost importance, we must also understand the costs that society, and especially the most vulnerable in it, have to bear due to such shortages.

The most vulnerable in society, unfortunately, also have to bear the highest costs of water scarcity. Some of the many social costs of water scarcity are given below.

## **Cycle of Poverty**

**The Poverty Trap:** The scarcity of water ends up trapping a large number of people in a vicious cycle of poverty, as water availability declines, and accessing water becomes increasingly more difficult.

**Loss of Productive Time:** More manhours have to be dedicated to fetching this water, which leads to a wastage of productive energy and time, time and energy which could have been better spent on education or some other economic activity, is instead diverted to fetching water because of the scarcity.

**The Substitution Effect:** also apart from the increased difficulty of

getting access to water, scarcity also forces people to turn to untreated and unsafe sources of water, such as open wells or rivers. This is due to the substitution effect, as safe water gets more expensive (not just in terms of money, but also in terms of the time and effort it takes to access it) makes people substitute it for the cheaper/easier to access sources, even if they carry a higher likelihood of carrying a waterborne disease.

**Health and Financial Impact:** These sources are not treated for common water-borne diseases such as Typhoid or Cholera, which leads to a spike in illness among groups who have to rely on such sources, this further pushes them into poverty, adding healthcare costs (if healthcare is available at all) to their already measly budgets, these costs are often exorbitant for such people, plus the loss of productivity keeps the vicious cycle running in full force.

## **Migration**

Migration as a social cost affects rural agrarian economies the most, when it becomes extremely difficult for a family to survive in a village due to the lower yields in their fields and the increased effort it takes to fetch drinking water, families often end up sending a person from their family (Usually a young male) to an urban center to act as an insurance of sorts in case the crop fails or the yields are lower than expected, so that the

family can survive on the remittances from the city, this leaves families fractured, it forces wives to live without their husbands, it forces children to grow up without their father, and this also leaves the women as the only productive member in their family, this leaves carrying the double burden of having to take care of the work in the field and also take care of the children and the elderly in their family, making it nearly impossible for these women to be able to get any education or learn any skills that can help improve their earning potential making them further dependent on others.

### **Modern Day Slavery**

Due to the migration caused by water scarcity, large swathes of people are forced to move. This water-induced migration can be intra-national or international. When these migrants move to other countries, they are often undocumented. This makes them especially vulnerable to exploitation. How this international migration usually works is that due to the scarcity of water in an area dependent on agriculture, there is a shortage of work available, so in search of jobs, people end up moving to other countries.

To facilitate this distress migration, individuals often resort to hiring unlicensed labour intermediaries (smugglers) to bypass formal borders. These intermediaries charge exorbitant recruitment fees, often upwards of \$5,000. It is extremely rare for a climate-induced displaced farmer, fleeing a total collapse of local

livelihoods due to water scarcity, to possess such capital. Consequently, these intermediaries often collaborate with the informal sector; for instance, a textile mill owner might settle the \$5,000 fee in exchange for the migrant's labour.

This arrangement traps the worker in a state of debt bondage, where they are forced to "work off" the loan under precarious and often horrendous conditions. Because of their undocumented immigration status, the employer holds asymmetric power over the workers related to their ability to work. The employer pays sub-market wage rates; the employees, lacking any recourse, have to work at these rates. Workers' illegal status creates coercion by way of the threat of detaining them or reporting them as undocumented to the authorities. So, the migrant is trapped in a cycle of climate-induced debt bondage, a form of modern-day slavery driven by environmental necessity.

India and China are at the highest risk of water scarcity and modern slavery in the supply chain.

### **Gender Inequality**

"Every step a girl takes to collect water is a step away from learning, play, and safety."

In 7 out of 10 households, the burden of fetching water falls on women. As water availability decreases, they spend more time fetching this water, so girls are unable to participate in education and in productive

economic activity. 200 million hours are spent each day by women worldwide on fetching water; women in India spend 150 million workdays annually on fetching water. Absence of clean toilets with adequate water supply in schools is a major driver behind girls dropping out.

The absence of such facilities in schools is a primary driver behind the school dropout rate among girls.

The impact on boys of the lack of adequate water facilities is significantly lower, exacerbating gender inequality.

As scarcity pushes these women to travel longer distances to fetch water, they are faced with a major security risk. As these women travel further away from their homes and into less secure and more remote regions for collecting water, their security is put at great risk; they are more vulnerable to attacks and abuse.

Lack of access to safe water takes a huge toll on women's health. Women who use unhygienic water and materials are 70% more likely to experience reproductive tract infections (RTIs). 1 million deaths each year are associated with unclean births, and infections account for 11% of maternal deaths. As water availability declines, more and more births will have to be undertaken using unsafe water, which puts women at a greater risk of such infections.

So water scarcity pushes women away from education and economic activity, and into situations where they have to

traverse large distances to fetch water, as well as at greater risk of physical harm and health risks, making women particularly vulnerable to the consequences of water scarcity.

### **Economic Cost**

Water scarcity would have harsh impacts on all spheres of economic life- price, income, employment, growth, as well as high opportunity costs. For example, an opportunity cost related to water scarcity is the cost to women in rural areas. These women spend hours daily searching for available water sources and carrying immense water loads in buckets back to their homes. This time and energy could have been used for a productive economic activity, which would have benefited the women and their families.

### **Employment**

An estimated three out of four jobs that make up the global workforce are either heavily or moderately dependent on water. This means that water shortages and problems of access to water and sanitation could limit economic growth and job creation in the coming decades, according to a UN report(2). The United Nations World Water Development Report, Water and Jobs, also notes that half of the world's workers - 1.5 billion people - are employed in eight water and natural resource-dependent industries(2). Jobs related to water are generally divided into two categories: jobs in industries that use water as a raw material and jobs that are related to

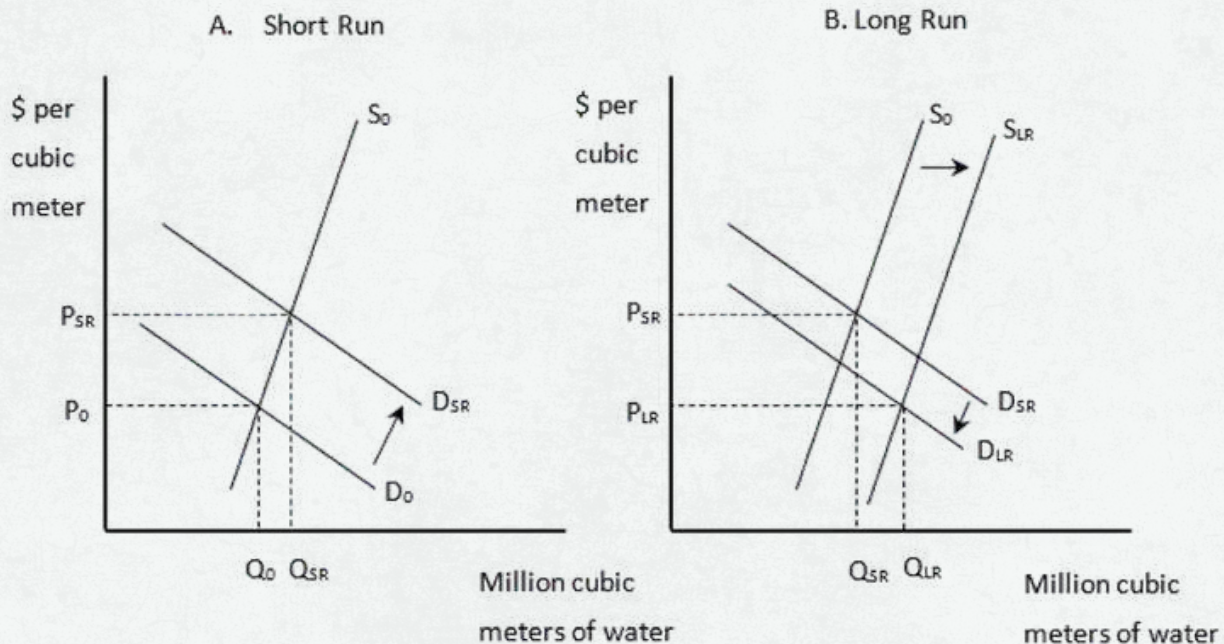
the management of water supply. Water scarcity harshly impacts the first, with adverse effects on industries such as the agricultural, power generation, and textile industries. These constitute a majority of the water-related employment opportunities, and a worsening of the situation would lead to major job losses due to higher costs. Investments in water supply-related projects could help in efficient water management while also creating additional jobs. The U.S. Department of Commerce's Bureau of Economic Analysis found that each job created in the local water and wastewater industry creates 3.68 indirect jobs in the national economy(2). Another study in Latin America found that investing US\$1 billion in expanding the water supply and sanitation network would directly result in 100,000 jobs.

### Income

Water scarcity adversely affects income in all water-related industries due to its adverse effect on the

operational efficiency of the business. While data is conflicting on the exact impact of the same on every individual industry, a World Bank report from 2016 suggested that water scarcity could cost some regions up to 6% percent of their GDP(3). Farming income is particularly affected by water scarcity, as farmers face limitations on available water sources. Farmers whose wells had dried up had their farm income severely affected, and about 25% lower than that of those whose wells were still operational. They cultivated less land, fewer times a year, and with less profitable crops, especially horticultural crops that require assured control of water(4).

While workers in most industries, including farming, try to maintain their income by searching for additional jobs, there is no data that shows they are successful in doing so. This becomes increasingly difficult in regions that have a lack of alternative employment sources.



(A) In the short run, an increase in demand will result in a rise in the price of water.

(B) In the long run, the rise in price would provide incentives for water users to conserve water in the industrial and household sectors. It would also induce investments and innovations that lead to more efficient management of the supply. Water use efficiency thus improves, and scarcity will eventually diminish.

Thus, a price rise is a short-run economic cost of water scarcity.



# Pricing vs Free Access

The free access vs. pricing debate is widely discussed when it comes to water. This is because access to fresh water is considered to be a universal and free human right, but dwindling resources and a burgeoning population are increasing its economic value(1). Water is often seen as a public good, one that is to be covered entirely by the government's expenses, and free and fair access is to be ensured to all citizens. However, it is argued conceptually that, to ensure fair access and optimum utilisation of scarce water, water needs to be priced at a level that covers extraction costs as well as a minimum charge over that.

To understand this argument, we must consider that free access encourages wasteful water usage. Water resources are primarily utilised for agricultural and industrial activities. To provide free water or water at subsidised rates discourages efficient management of water resources as well as the development of technologies that could ensure optimum utilisation. A primary example of this is the farmers of Punjab and Haryana.

Water is provided at heavily subsidised rates to these farmers. This encourages them to grow water-intensive crops as well as enjoy wasteful consumption of the resource. However, this has caused a strain on the already depleting groundwater resources of the states. Theoretically, if

these farmers were to pay a minimum price for the resources (taking into account the cost of extraction and a minimum charge component), they would be encouraged to utilise the resources more efficiently and adopt more resource-friendly techniques.

They may also change their cropping patterns to maintain their income. Thus, a short-term cost to the farmer would result in a long-term benefit to society. But, governments do not generally adopt such policies for fear of political backlash. Such is the situation in many parts of the world. In Spain, for example, farmers typically pay only approximately 3% of the actual value of the water they are using. This has taken an indirect hit on the available water resources due to excessive groundwater depletion. The Axarquía region in southern Spain, a hotspot of avocado and mango production in Europe, underwent an extreme water crisis in 2019–2024.

Since 1992, when water was declared an economic good in the International Conference on Water and the Environment (ICWE) Dublin Principles (ICWE, 1992), the call for higher water prices and for more trade in water has gained widespread support (Saleth, 1997).

An alternative and perhaps more effective step towards the more rational and sustainable use of water in developing countries would be the enforcement of simple allocation

rules, such as per-hectare rations, that would make the scarcity of water immediately obvious. In this view, therefore, restriction rather than higher prices represents a more suitable strategy for farmers in developing nations, as it would “directly force farmers into potentially more efficient water use patterns. Whatever the case may be, it is also important that both these potential solutions be tested at smaller scales before any policy decision is taken.

Household consumption, while only constituting a small percentage of water usage, would also benefit from pricing. While measuring the water consumption of an individual, it is important to take into consideration the total water footprint. This is the total volume of water that is used to produce the commodities, goods and services consumed by that person. A water pricing model would help rationalise total household consumption by encouraging efficient utilisation of face-value water uses, as well as controlling utilisation of water-intensive products.

The right has been guaranteed to everyone in India as a fundamental right under Article 21 (Right to Life) of the Indian Constitution. So any attempts at pricing water must be made while staying cognizant of this fact. While pricing water according to market forces may encourage market efficiency, it also risks the denial of this fundamental right to those who may not have the economic resources to be able to pay for it.

So, any model of pricing water must

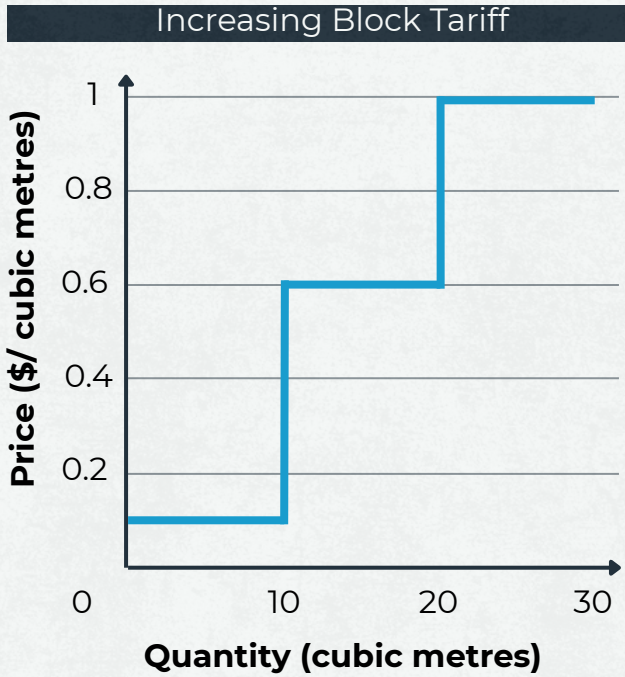
perform the dual role of both incentivising suppliers to increase the supply of water by investing more resources into creating the infrastructure necessary to supply it, while at the same time also ensuring access to at least enough water for everyone to be able to live a reasonable quality of life.

It is necessary to incentivise private players to invest in increasing this supply because there are still 2 billion people in the world who do not have access to safe drinking water. And at the current rate, we will end up falling short of SDG 6, which targets access to water for everyone by 2030.

Some common water pricing models are discussed below.

### **Increasing Block Tariffs**

The increasing block tariff (IBT) model prices water on a volumetric basis; multiple slabs are ascertained based on the volume of water used, and prices are set at an increasing rate. The base slab sets the price of water at an extremely affordable rate. This slab is often a “social” / “lifeline” block; here, the water is priced at a nominal rate or might even be free, and the slab sets the volume of water allowed to be just enough to ensure access to water to ensure survival or a reasonable quality of life.



The second/middle block sets the price of water at a higher rate; here, the price of water is ascertained by charging enough to at least cover the marginal cost of the water as well as the fixed cost, and the highest slab price is the water at the highest rate of all. Here, the price of water covers not

only the marginal cost of the water and the fixed cost of setting up the infrastructure, but also an overuse charge and normal profit for the supplier; in this slab, the consumer can consume as much water as they want, but will have to pay the highest rate.

This model effectively creates a cross-subsidy; here, the richest users pay the highest rate, where they not only cover the cost of their water, but also bear the cost of the subsidised price given to the users who pay the lower costs.

South Africa is an example of a country that uses the IBT model, which raises the rate per Kiloliter of water that needs to be paid, based on the total consumption. The current prices are mentioned in the table below.

Domestic Water Tariff - Conventional Water Meters			
Bands (Kilolitres per month)	2024-25	2025-26	Increase (%)
0-6	Free	Free	-
>6-10	26.20	29.84	13.9%
>10-15	27.35	31.15	13.9%
>15-20	38.34	43.67	13.9%
>20-30	52.99	60.36	13.9%
>30-40	57.95	66.01	13.9%
>40-50	73.12	83.28	13.9%
>50	78.35	89.24	13.9%

## The Dynamic Ramsey Pricing Model

This model tries to price water dynamically, depending on the availability of water at a particular point in time. The model proposes setting prices according to the price elasticity for water at the moment. It mathematically determines the rate to charge users, depending on the availability of the water and the demand, as well as the price elasticity of demand for water at the time. The model sets 2 constraints: 1. The utility provider cannot make a loss, 2. The utility provider can only sell the quantity of water available, and so, this model prices water according to the situation. In the winters, when the water demand is lower, and so the price elasticity of water is higher, the consumer faces a lower tariff, when compared with the summers, when the availability of water is low and the demand is high, this ensures that the utility provider can charge enough of a premium to cover their cost during periods of high demand, and so can ensure consistent availability, even when prices are low. The model aims to maximise welfare while also keeping the utility provider profitable, to keep the model sustainable.

The price is determined as :

$$P = MC + \text{Scarcity Premium} + \text{Ramsey Markup}$$

Here, the markup is intended to represent the price elasticity, and the scarcity premium represents the availability of the water, so the formula enables the recovery of the fixed cost while also maintaining operational profitability of the utility provider.


The Model faces significant drawbacks because, unlike the IBT model, the Ramsey model fails to provide any allowances in the form of a subsidised rate for at least some quantity of water, and so, this model severely lacks in the frontier of providing access to everyone.

While no country currently uses the dynamic Ramsey pricing model in its entirety, the Ivory Coast comes closest, setting higher prices for price-inelastic users, such as industries and in wealthier residential areas. This allows it to be able to keep a very low baseline tariff rate for the poor, ensuring equitable access.

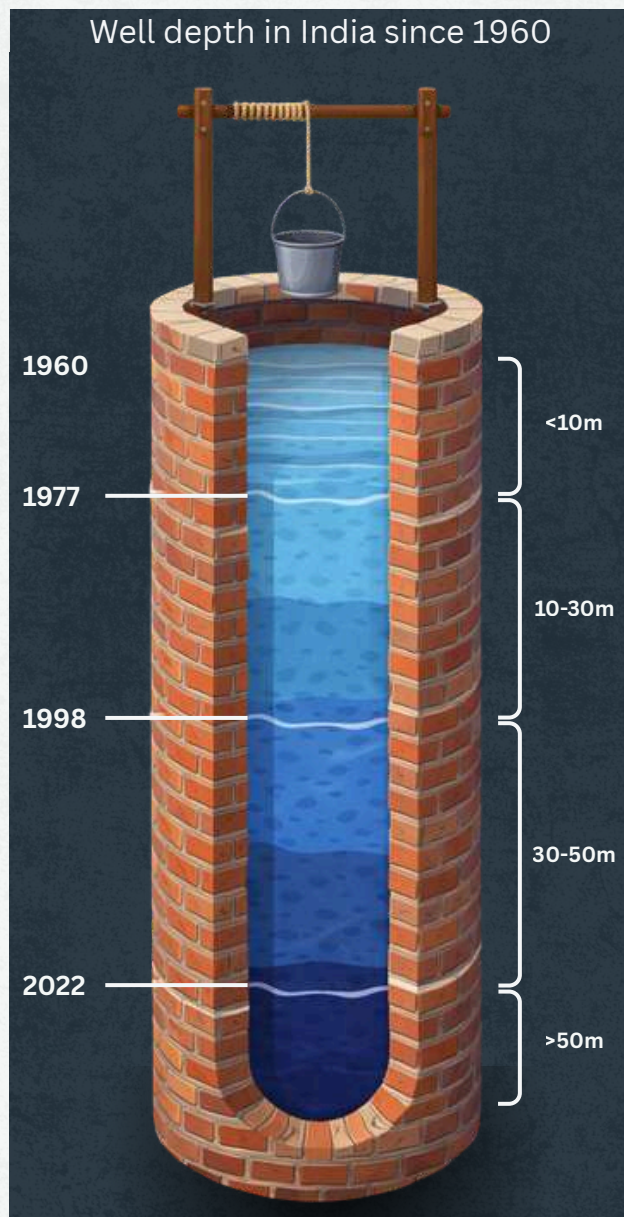


# DEGRADATION & CHALLENGES

Examining the Pollution, Industrial Waste, and  
Overuse Pushing India's Water Systems to the Brink.



# Groundwater Depletion



**Groundwater:** water that is stored under the surface of the earth, usually within the gaps present between rocks and any other space below the surface is referred to as groundwater; it is also called subsurface water.

It is a common-pool resource (resources that are public in nature, where it is not possible/extremely difficult to prevent others from using the resource, but use by one person

reduces the availability of the resource for others).

The groundwater table is the quantity/level of groundwater present at a certain place.

This section seeks to explore why the groundwater table has been continually depleting in India, what the major drivers of this depletion and its consequences.

Groundwater depletion is the significant reduction in the levels of water stored under the surface of the earth over a period of time. This is often caused by human activities like agriculture, urban development, etc. and ultimately leads to water table depletion. This results in wells going dry, poor water quality, land subsidence, etc. Groundwater depletion basically happens when groundwater is extracted at a rate which is higher than the rate at which it is naturally refilled.

Groundwater systems have a finite carrying capacity and a limited recharge rate determined by many factors like climate, geology, and land use. When groundwater extraction exceeds the natural recharge over long periods, the system is pushed beyond a level which is sustainable. This imbalance leads to declining water tables, a reduction in flow to rivers and wetlands, land subsidence, and long-term loss of aquifer storage capacity. In effect, over-pumping

disrupts the natural equilibrium of the aquifer system which can create conditions where water demand surpasses the system's ability to recover, resulting in water scarcity and ecological degradation.

The root cause of this depletion has been the public nature of the resource, because groundwater is a common-pool resource, and so there is very little incentive for any singular individual to actually care about the total quantity of the resource, since they are just one of many users of it. When individuals act only in their own self-interest, despite the potentially negative consequences for others, the result is known as the Tragedy of the Commons. The fundamental cause of the Tragedy of the Commons is that individuals can use a shared resource without having to pay for it, which causes them to ignore the long-term implications of the way they use that resource. Since individuals do not have any negative financial consequences for using a shared resource, they often overuse that resource in order to benefit themselves. This over-exploitation eventually leads to a depletion of the shared resource for all users.

In India, there has been a significant decrease in the amount of groundwater available to meet the needs of the people in the rural and urban areas of the country and in meeting all agricultural needs. India accounts for approximately 25% of all the world's groundwater extraction (approximately 45% of urban water).

Total groundwater recharge of all aquifers in India was approximately 447 billion cubic meters (BC) in 2024, while total groundwater extraction was approximately 246 BC. This indicates that India's stage of groundwater extraction is approximately 60.5%.

According to an annual assessment from the Central Groundwater Board (CGWB), 11% of the groundwater units in India are classified as "over-exploited," and water extraction exceeds groundwater recharge in all of these units. The Punjab and Haryana regions of northwestern India are especially affected by the over-exploitation of groundwater resources. For example, in Punjab, for every 100 BC of water recharged, approximately 164 BC of water is extracted. In Haryana, approximately 136 BC of water is extracted for every 100 BC of recharge. Further, approximately 78% of wells in Punjab are classified as "over-exploited".

According to CGWB, around 20% of the sampled wells contained contaminant levels above the safety limits, with nitrate and fluoride contamination reported in more than half of India's districts. This indicates water quality as an additional issue. About 60% of India's districts experience either a shortage or contaminated or both with respect to groundwater.

## Drivers of Groundwater Table Depletion

### A. The Green Revolution: The Initial Policy Shock

Starting in the 1960s, the 'Green Revolution' has transformed the face of Indian agriculture, having almost quadrupled the foodgrain production, in turn making the country self-sufficient as well as one of the largest exporters of foodgrain in the world(8). However, this agricultural success has not come without a price. Both quantity and quality of water resources in the country have been seriously impacted as a result of the Green Revolution.

India's groundwater resources are under significant strain, with consumption increasing by 500% in the past 50 years, making the country one of the largest users of groundwater globally(3). A major contributor to this issue is the subsidies introduced during the green revolution. These were introduced to encourage farm output by promoting new techniques. Farming incomes have increased, and food security has been ensured (production is 30% more than domestic demand). But there has been a great cost attached, as these crops, including rice and wheat, require a high level of irrigation. Farmers usually depend on groundwater sources for this through personal wells, which has added to the depletion.

Further, the Green Revolution involved the introduction of HYV seeds. These seeds require significantly more

irrigation than natural seeds. The use of High-Yielding Varieties (HYVs) has increased irrigation demands significantly, with 80% of India's freshwater resource currently dedicated to irrigating crops. In Punjab and Haryana, intensive irrigation has created depletion of groundwater tables from both agricultural and domestic use.

Water tables in northern India have dramatically decreased due to overuse of groundwater resources for crop production, this excessive extraction creates a major long-term risk to agricultural viability and water security in northern India. While the nation's average Groundwater Extraction was 60.08% in 2022, an improvement from 63.33% in 2017, Haryana, Punjab, and Rajasthan bucked the trend, exceeding the groundwater extraction by 100% in 2022(8). In Punjab and Haryana, the epicentre of this revolution, groundwater depletion surpasses natural replenishment rates by 65% and 34%, respectively.

Subsidies on electricity have also been a major factor, as farmers are encouraged to use water pumps for groundwater extraction. Free water and power are so politically popular in the economies of farm states that leaders do not suggest a change for fear of not being elected to power.

Starting in the 1960s, the agricultural development model known as the Green Revolution created a state of food security in Indian states where most wheat and rice were produced on the same land for many years. As

part of this agricultural development, large areas of Punjab and Haryana changed their cropping systems from diverse modern agricultural methods to a Wheat-Rice Monoculture System; the geography in that part of India was not suitable for growing rice because of the fact that it has a semi-arid climate.

Three factors were the primary reasons for these changes:

**i) Climate:** The Punjab-Haryana Region Has A Semi-Arid Climate With Sandy/Loamy Soils That Have A High Need For Irrigation. In General, Wheat Grows With Only 4 To 5 Irrigations Compared To Rice 20 To 25 irrigations.

**Soil Type:** Sandy Soils In Northwest India Do Not Retain Water As Well As Clayey Soils In Eastern India. Because Fields Drain Water Quickly In Northern India, Rice Must Be Continuously Flooded To Maintain Their Anaerobic Conditions In Order To Produce The Best Yield.

**Yield Fluctuations:** More Than 80% of India's Water Supplies Have Now Been Diverted to Irrigation, with the Northwest Region being the Most Stressed.

**ii) Policy Support For Farmers:** The MSP And The FCI Are Two Ways That Farmers Are Provided Protection Against Price Risk and Protected from Being Forced to Sell Their Products at a Lower Price Than They Wish To Sell Them.

**MSP:** The MSP Is An Example Of How The Government Protects Farmers

Because The Government Establishes A "Minimum Level" Price For Certain Crop Products. For Example, in 2024-2025, the MSP for Wheat Will Be ₹2,275/per Quintal, Which Will Protect Farmers From Losing Income because There Is No MSP (And, In Some Cases, No Material) For Pulse or Oilseed Products In Both 2024-2025 and beyond.

**FCI/PDS Purchases:** The Food Corporation of India Is Responsible For Purchasing The Amounts Of Grain Needed By The PDS Program. In 2025-2026, the Central Pool of Grains Will Be Approximately 490 lmt of rice, A Great Deal More Than The Required Buffer Norms Of 135 lmt.

**Concentrated Procurement:** Punjab and Haryana provide a disproportionate amount of grain to the Central Pool (i.e., The Government). For Example, In The 2025-2026 Kharif Season, The Government Anticipates that Due To This "Assured Market", That Approximately 116 lmt of Will Be Provided To The Central Pool From Punjab Alone With No Price Risk For The Producer Therefore, It Makes financial Sense For Farmers. despite the ecological cost.

**iii) Infrastructure Expansion:** Canal Irrigation

The government heavily invested in surface water infrastructure to exploit the water-intensive crops produced through the use of HYV seeds.

**Canal Networks:** The construction of irrigation systems, such as the Bhakra Nangal Dam, greatly enhanced the

capacity of the canal irrigation systems of the Northwest region after independence.

**Change in Mandate:** Previously, irrigation policy was solely to benefit farmers through having access to water during years of low rain; however, now farmers have the ability to have a steady supply of water throughout the entire growing season. This allowed rice to be produced in many areas where historically, there would have been no possibility of producing it at all.

Also, due to the increasing demand for agricultural products produced using monoculture, some farmers utilised groundwater; however, aggressive subsidies were available to encourage farmers to use this alternative.

**Free Power Policy:** In 1997, Punjab ceased charging farmers for the use of electricity to pump water from the ground for agricultural purposes. This policy continues today and has effectively eliminated the expense of using electricity to pump water.

**Extraction:** Punjab has an average ratio of 164 units extracted for every 100 units of groundwater recharged, while Haryana has an average ratio of 136 units extracted for each 100 recharged. The power intensity per ha in Punjab is now 1,456 kWh/ha (almost double the national average of 766 kWh/ha).

## B. Cropping Pattern

At the center of the water management problems India faces

today is a fundamental economic failure. The price of water does not represent its true level of scarcity. Ideally, this means that as the supply of water diminishes, the cost of that water should increase. The increased price would act as a signal to consumers to use water more conservatively, adopt more efficient technology, or change to less water-intensive behaviour. However, in practice, agricultural water pricing in India is poorly, if at all, related to the amount of water available.

The majority of irrigation systems in India are based on a flat rate charge, area-based pricing, or implicit subsidies, all of which ignore the seasonal nature of water scarcity, recharge rates of aquifers and the opportunity costs associated with competing uses of water (domestic, industrial, ecological)

As such, the price that most users of water pay for its use is, in most areas, essentially zero. This violates the basic principles of an efficient allocation of a resource, resulting in the inefficient use, misallocation, and ecological degradation of water resources.

Agricultural water use accounts for the majority of freshwater withdrawals in India; however, farmers, particularly those who are irrigators, generally do not pay the true social cost of using water from aquifers. The total social cost of water extraction would include depletion of shared aquifers energy costs associated with pumping and environmental externalities, such as salinisation and loss of ecosystems.

Farmers often do not consider the resource limitations in the area they farm. Rather than thinking about how resources will fit into the larger picture and create wealth, farmers simply think about what the current price of a crop is in the marketplace. This creates a disconnect that creates what economists refer to as a "factor-price distortion", in that both land and water resources are being utilised in ways that look to be profitable when considered privately but are inefficient in their use from a social perspective.

### **Case study: The sugar cane paradox in Marathwada**

Marathwada, positioned in the rain shadow of the Western Ghats and recognised climatically as semi-arid to arid, experiences low average and erratic precipitation, high average rates of evapo-transpiration and high frequency of extreme droughts (multiple years).

Sugarcane, conversely, requires 2000-2500mm of water in a year to grow and is one of the most water-intensive commercial crops grown in India. Thus, from an agro-climatic standpoint, this crop is fundamentally matched to the region.

The continuation of cultivating sugarcane is a result of not following the logic of the environment but through an incentive system established through policies. One of the key factors is the relationship between water and energy.

The electricity that agriculture receives is free or subsidized, which effectively lowers the cost of pumping

water.

Deeply bored wells enable farmers to access groundwater that they would not typically have access to economically.

Energy subsidies effectively convert groundwater from an open access source to a quasi-open access source. The result is an economic environment in which water extraction for agricultural purposes has become effectively "invisible," while the aquifers that supply water for irrigation purposes are quickly being depleted.

The costs of water extraction are not borne directly by the user but instead are absorbed by future farmers, the state (through the provision of power subsidies), and the community at large (through the negative effects on the ecosystem). The amount of institutional support provided to sugarcane as compared to the alternatives (e.g. rice/or wheat) is superior when considering Fair and Remunerative Price (FRP), Guaranteed procurement price gives farmers a cushion against price volatility, Farmers are insulated from market risk, Strong cooperative networks, Sugar mills provide the farmers with sufficient credit, input, and assured access to a market, Political influence provides farmers with bargaining power, Infrastructure Lock-In, Existing mills, canals, and logistics create a path dependency; and, The transitional risk of switching crops is quite high relative to the above-mentioned groups.

On the other hand, other crops that require less water were not guaranteed these same types of buyer commitments (e.g. pulses, oilseeds, and millets), so the financial risk to produce these crops is higher despite the fact that they require less water. The high level of purported profitability associated with producing sugarcane is “illusory.” On average, the water requirement for producing one kilogram of sugar is thousands of litres, but this is not factored into the cost of sugar production.

When the market assigns at least a shadow price to reflect the scarcity of water, the profitability of producing sugarcane will decline materially, and the economic rationality of the choice of crops will be diminished for crops grown in the dry areas of India; less water-intensive crops will receive relatively more comparative advantage.

The groundwater is being pumped out at far greater rates than can be replenished through natural recharge, particularly by way of deep tube wells that are mining ancient fossil aquifers that have formed over many centuries. Large sugarcane producers, who have capital resources to drill expensive wells, dominate the available water supply, while many small farmers and rural residents experience severe water shortages.

The sugar produced in Marathwada is used in other locations, which effectively siphons water out of a drought-prone region and sends it to wetter regions, thus aggravating the local scarcity.

Similar patterns of exploitation can also be found further North in the rice-wheat region of Punjab-Haryana, where, in semi-arid areas, paddy is grown with great reliance on groundwater, the rate of aquifer extraction from tube wells exceeds the rate at which aquifers are being replenished, and the water table is dropping at an alarming rate. This is causing a severe agrarian ecological crisis, characterised by increasingly high costs of energy and supplies. Despite these warning signs, the rice-wheat cycle continues to be a focus for Indian farmers due to: Government Purchase Price (MSP)-based procurement, existing irrigation and milling infrastructure, risk aversion and lack of viable alternatives to rice and wheat, structural lock-in, and Policy Myopia.

In all areas of India, the problem isn't farmer irrationality; it's government-induced lock-in through the following: Government subsidies give farmers incentives for water-intensive crops, existing pricing structures ignore nature's ecological limits, and political economy gives more power to wealthy crop lobbies. If these signals aren't corrected, then neither efficiencies nor conservation messages will work.

The crisis of water use in agriculture is an economic governance failure in India. Until: Water prices reflect the true cost of water, energy subsidies for the extraction of water at a lower-than-market price, and support systems incentivise farmers to grow crops that are not grown in their region. Then water will continue to be

wasted.

Sustainable reform of the Indian water use crisis will require: Rational and volumetric water pricing, separation of electricity subsidies from groundwater extraction, and incentives to grow crops that are aligned with the agro-climatic characteristics in the area.

When price signals reflect scarcity, farmers will make individual decisions aligned with collective necessity.

As aquifers are depleted, the cost farmers must bear to continue extracting water increases exponentially. This is because, as the groundwater level keeps falling, farmers have to continually invest more and more money in better, more powerful technology, which costs a lot of money, and due to its increasing complexity, also requires more maintenance, hence it increases costs in a non-linear manner. To understand this better, we can divide a farmer's costs into fixed cost and variable cost.

Fixed costs are the costs that the farmer will have to undertake regardless of the volume of water he extracts, as the water levels fall lower and lower, farmers have to drill new, deeper wells, which may or may not actually find water, so not only is the farmer subjected to higher capital expenditure, he is also exposed to a higher degree of risk, since he is basically risking the entire cost of the well into whether or not he is actually able to find water.

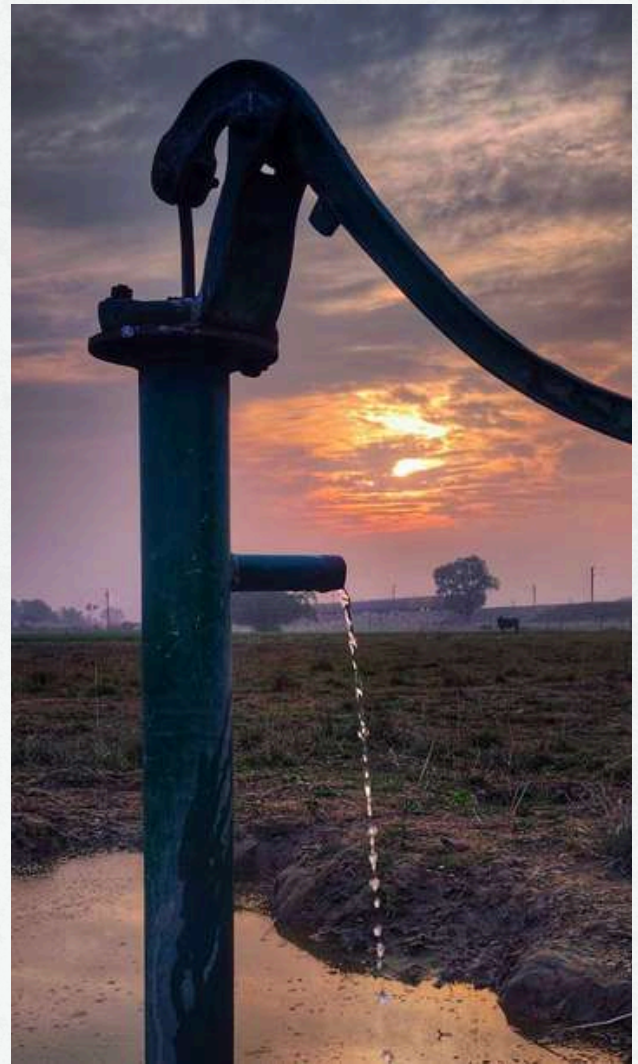
However, even in an area where there is sufficient water for this to not be an

issue, a falling water level still forces farmers to dig deeper, and the cost of digging increases exponentially the deeper it gets so the farmers has to invest significant sums of money to be able to continue extracting the same amount of water, plus because these wells are deeper, the farmer will have to spend money on stronger, more expensive pumps that can actually pump the water to greater heights. So groundwater depletion forces farmers into making substantial non-productive and risky investments, which at best let the farmer maintain their current output.

Because the farmer is now extracting water from deeper wells using more expensive and complex technology, such as stronger pumps, he now has to spend a greater amount of money on his energy bill, which, although it is usually subsidised, the subsidies are often slab-based, so an increased electricity bill may push the farmer into a more expensive slab, plus because the farmer is now using stronger pumps and deeper wells, he will also have to pay higher sums of money on their renovation, and unlike the energy bill, farmers do not get any governmental support for their maintenance bills.

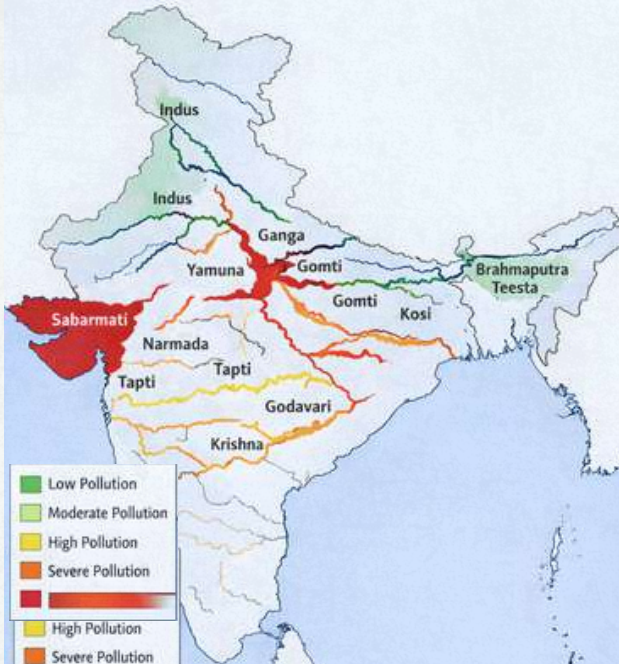
So, a falling groundwater table causes significant financial stress on farmers, plus because farmers have to spend on all this capital expenditure, they will most likely have to turn to debt, often informal sources of debt, leading to another cost for farmers, plus putting them into a more vulnerable position.

Groundwater depletion poses significant long-term systematic risks to food security and economic resilience, especially in regions dependent on groundwater as a primary source of water. As discussed earlier, the Green Revolution has heavily relied on groundwater extraction. This, over time, reduces irrigation facilities in the region and, as a result, the system designed to ensure food security is actually undermining its own sustainability by posing a threat to the food security of those regions. This is because when the groundwater level falls, irrigation becomes difficult over time, and this adversely impacts crop yields and poses threats of food shortages. Moreover, regions dependent on fossil groundwater face economic vulnerability since these are non-renewable sources which are rapidly getting depleted.



# Water Pollution

Pollution levels of different rivers in India



Water Pollution refers to the contamination of water bodies due to the release of chemicals, microorganisms, or other substances into a water body. This deteriorates the quality of the water, making it unsuitable for many uses, including human consumption, and also negatively impacts the rest of the ecosystem.

Water pollution is a negative externality; it is a cost imposed on society at large. Here, the polluter makes society worse off yet pays no price for his actions; this is because of weak implementation in India.

Polluters act this way because they bear no marginal cost by dumping hazardous substances into these water bodies, but they do gain from doing so, as they reduce the expense that they otherwise would have had to

incur on treating this waste.

Unfortunately, the social costs of this dumping are very significant, but since the polluters do not have to bear these costs, they act in what would otherwise seem a fairly irrational way, at least for society as a whole.

This is an example of Market Failure with regard to our water resources. The undervaluation of water resources leads to a lack of sufficient enforcement or insufficient fines, which makes dumping by polluters a rational economic decision. This leads to a decrease in social welfare, and so skewed individual incentives lead to undesirable results such as water pollution.

This lack of enforcement ultimately acts as a subsidy to the polluters, at the cost of society, since it brings their cost of production down at the expense of society.

There are two types of sources of pollution:

**i) Point Source Pollution:** Here, the pollutant originates from a single, easily identifiable source. For example, a large textile factory releasing harmful chemicals into a water body through a pipe, or an oil refinery's effluent pipe.

**ii) Non-Point Source Pollution:** Here, the pollutant originates from sources that are hard to single out and

identify. For example, Nitrogen or other chemicals from thousands of farms running off and being deposited in water bodies, or millions of households improperly disposing of their wastes, leading to substances such as grease or other toxic chemicals getting deposited in water bodies.

### Major Pollutants

In the past century, global water usage has increased six times. The demand for water is increasing twice as fast as the population globally. Rising population and increased industrialisation have resulted in higher requirements for water. This has led to an exploitation of water resources globally, which has increased water pollution on a much larger scale. This has posed serious threats to human as well as aquatic life.

According to the WHO, 748 million people worldwide lack access to safe drinking water, 2.5 billion people lack access to sanitation, and 3900 children die each day due to unhealthy drinking water and related diseases. Almost 80% of all diseases in the world are associated with unsatisfactory water.

Increased diseases and mortality, destruction of biodiversity, etc., can be seen as the consequences of water. The Central Pollution Control Board identified 311 polluted river stretches on 279 rivers in 30 States/ UTs in the country based on the indicator of organic pollution, i.e., Biochemical Oxygen Demand (BOD) (3mg/L).

There are several types of water pollutants, such as the following:

### Organic Pollutants

Organic pollutants may be classified as compounds that contain carbon, hydrogen, nitrogen, and sulfur; from these substances consist of the waste generated from food processing, slaughterhouses, paper, and pulp industries, among others, which results in large quantities of such organic pollutants being released into local bodies of water, resulting in the creation of anaerobic conditions in their respective ecosystems by the removal of large amounts of oxygen from the body of water. Organic pollutants can be subdivided into three distinct categories as follows:

**a. Pesticides:** Pesticides are another category of water pollutants, where they are generally found in large quantities because of incorrect pesticide use during farming operations (i.e., the amount used didn't add up with the need for it) and/or using the wrong pesticide (i.e., mixing two different types). Much of the leftover pesticide can be washed into nearby lakes and rivers and will be collected and taken up by other species of plants or animals; eventually, these same species will pass this chemical off to humans.

**b. Dyes:** Dyes are one of the most commonly used compounds across various industries, but the non-availability of natural dyes has made industries and people more and more dependent on synthetic dyes. However, several industrial processes,

such as sulfonation, nitration, diazotisation, reduction, oxidation, and acidic deposition, lead to the discharge of components of synthetic dyes like chromophore groups, including aromatic structures, nicotine groups, nitrogen-containing groups, etc., into water bodies and reduce light transmission and photosynthesis rates in aquatic plants.

**c. Polyfluoroalkyl:** Polyfluoroalkyl substances (PFAS) are a class of organic compounds that are soluble in water and characterised by long alkyl chains containing multiple fluorine atoms. These substances are used in a variety of industries, including the manufacture of food packaging, waterproof textiles and sprays, etc.

PFAS also contaminate soil and groundwater near specific facilities (e.g., industrial plants where PFAS are manufactured or used to manufacture other items; oil refineries; airports; and during fire-fighting) and are commonly found in the environment.

The two best-known manufacturers of PFAS are Perfluorooctanoic acid (PFOA) and Perfluorooctyl sulfonate (PFOS), which are predominantly hydrophobic/hydrophilic fluorinated compounds. PFAS have subsequently been linked to long-term health issues, such as hypothyroidism and various types of cancer (i.e., liver, testicular and pancreatic adenocarcinoma), asthma-like conditions, and reduced bone mineral density, as well as neurological development related disorders.

## Inorganic Pollutants

Inorganic Pollutants include nutrients like nitrate ( $\text{NO}_3^-$ ), phosphate ( $\text{PO}_4^{3-}$ ), heavy metals, chloride ( $\text{Cl}^-$ ), radioactive isotopes released from mining or nuclear accidents, etc.

These nutrients promote the growth of microbes like blue-green algae (cyanobacteria), which significantly deplete dissolved oxygen and make the water toxic. This is called eutrophication. Nitrate, Nitrogen Dioxide and Ammonia can be the most common inorganic groundwater pollutants.

Excessive use of fertilisers, sewage discharge, water disposal, industrial effluent, etc. can lead to nitrogen-related pollution. Nitrate

concentration of more than 50 milligrams per litre of water can cause health problems in humans and animals.

Another type of inorganic pollutant is heavy metals, which are generally minerals having an atomic number of more than 20 and an elemental density greater than 5 g per cubic centimetre. They get deposited into water bodies as a result of human activities, agriculture, etc. Although some of these metallic ions (such as zinc, copper, and iron) are essential for human health, an increase in their concentration can lead to water pollution and the creation of diseases such as cancer (testicular, uterine, breast, kidney, blood), high blood pressure, thyroid dysfunction, heart disease, mental retardation, and so on.

## Radioactive Pollutants

Radioactive materials get deposited into groundwater through the surface and are discharged by nuclear plants and other industries involving radioactive minerals. These may also get dissolved into drinking water and cause serious health effects such as cancer, radiation sickness and even genetic mutation. During nuclear tests, radioactive dust may encircle the globe at altitudes of 3,000 metres or more, which often comes down to the earth as rain. Eventually, some of the radioactive materials like Strontium 90 either percolate down through the soil into groundwater reservoirs or are carried out into streams and rivers, and either way end up into public water supply.

## Other Pollutants

Other pollutants include pathogens, including bacteria, viruses, fungi, and some parasites, small microorganisms that cause diseases, hormones, pharmaceuticals and personal care products, artificial sweeteners, surfactants, etc. Viruses and bacteria found in industrial wastewater, such as Cryptosporidium, Campylobacter, Salmonella, and Shigella, can lead to diseases like cholera, polio, typhoid, etc.

## Major Sources of Pollutants

### Agriculture

Agriculture constitutes 70% of the total water consumption and is the largest source of non-point pollution of ground and surface water. In order

to increase agricultural productivity, activities like improper use of pesticides and fertilisers often lead to soil erosion, exploitation and degeneration of water sources. Whenever there is precipitation, the fertilisers and pesticides used on crops, along with the waste from livestock, dispose of chemicals, bacteria, and viruses into nearby water bodies. The nutrients in animal waste also cause nutrient pollution, where excess nitrogen and phosphorus seep into water sources.

This is often regarded as the primary threat to global water quality. The rising population is leading to rising demand for agricultural commodities, and farmers are increasingly moving towards non-conventional water sources of marginal quality, including wastewater. Domestic and municipal wastewater present are attractive options because of their high nutrient content, especially when conventional water resources are scarce or lacking. The use of these sources lead to the accumulation of microbiological and chemical pollutants in crops, livestock products and water resources, which ultimately leads to severe health impacts for farm workers as well as the consumers.

### Oil and Shipping

Although major offshore accidental spills are generally regarded as major sources of large-scale water pollution, they account for only 10-15% of the oil that actually escapes into oceans and rivers. Legal and illegal routine discharges constitute almost 35% of the oil that makes it to oceans. Oil

enters into the oceans through various indirect paths, which make it difficult to precisely estimate global oil inputs into the marine environment. It also includes volatile oil constituents, which enter the water after being emitted into the atmosphere during various types of burning processes. This, along with inputs from municipal and industrial effluents and from oil rigs, accounts for another 45%. However, some oil spills can have a very disruptive impact. After the largest oil pollution incident ever recorded up to that time, the Torrey Canyon tanker disaster in 1967, when around 115,000 tonnes of crude oil were spilt on the southern English coast, numerous field studies have been carried out to highlight the impacts of various types of oil on organisms and habitats.

### Households

On average, a person uses about 135 Litres of water daily for domestic purposes like drinking, cooking, bathing, cleaning, etc. 70-80% of this water is discharged, drained out and ultimately poured into rivers, lakes and tanks through municipal drains. Moreover, most of this water receives no treatment before discharge, causing even more harm to the aquatic ecosystem. In Delhi alone, 120 crore litres of water are consumed per day, out of which 96 crore litres is drained into the Yamuna river through 17 big drains. In the same manner, all the 47 towns located on the bank of the river Ganga drain their sewage into it.

### Thermal Plants

Thermal and electric power plants discharge large quantities of hot effluent/water into nearby streams or rivers. Since warm water does not have the same oxygen-holding capacity as cold water, the discharge of thermal waste leads to either death or immigration of fish like black bass, trout and walleyes, etc., which require a minimal oxygen concentration of about 4 ppm. When the temperature of the receiving water is raised, the dissolved oxygen level decreases, and the demand for oxygen increases, anaerobic conditions will set in, resulting in the release of foul gases. Therefore, thermal pollution is considered hazardous for the whole aquatic ecosystem.

### Industrial Waste

It is a known fact that industries like pulp and paper, chemicals, petrochemicals and refining, metal working, food processing, textile, and distillery have a large variety of waste products that are discharged into local water streams, which eventually get poured into rivers. In Delhi, almost 8 lakh tonnes of industrial waste is discharged into river Yamuna. Industrial waste generally contains:

- a. Chlorine, sulfur dioxide, etc., which are considered to be highly poisonous for the aquatic ecosystem
- b. Alkaline wastes, which have high oxygen demand and lead to a reduction in the same in water bodies
- c. Nitrogen, sugar, proteins, etc., which

have very high Biological Oxygen Demand (BOD), are the amount of oxygen consumed by microorganisms to decompose organic matter in water.

d. Hydrocarbons, phenolic compounds and other organic and inorganic sulphur compounds.

**Theoretical Framework:** The Environmental Kuznets Curve (EKC)

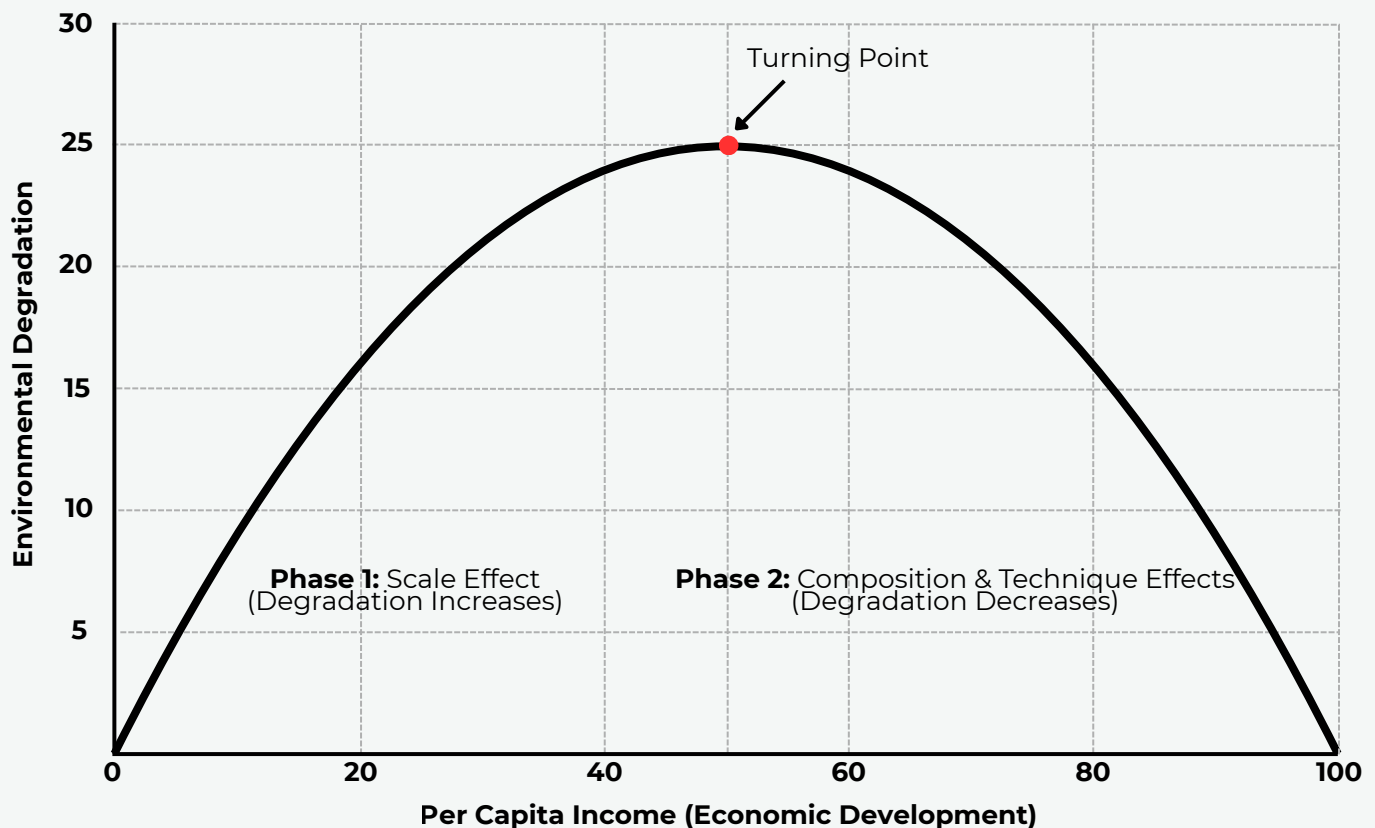
The Environmental Kuznets Curve is a theoretical relationship between various indicators of environmental degradation and Per Capita Income. It suggests that in the initial stages of economic development, pollution emissions increase, thereby increasing environmental degradation. However, in later stages of economic prosperity, ie, when a certain level of per capita income is reached, the trend reverses.

At that stage, further economic growth would lead to economic improvements and potentially reverse the previous harm caused.

The EKC is named after Simon Kuznets, who proposed that income inequality first rises and then falls as economic development proceeds. EKC is primarily supported by the belief that developed countries have a low rate of growth and can focus their efforts and resources on environmental preservation. The pollution conservation efforts can overcome the growth effect. Developing countries may not be able to match conservation efforts with the high rate of growth. Their efforts would be concerted towards achieving economic improvements.

EKC is a general phenomenon and is not always statistically significant or

**The Environment Kuznets Curve**



accurate. Different local pollutants in a developing nation may have different rates of growth. In the modern age of sustainable development, the EKC is not sufficient for analysis due to the pollution control measures taken by the developing countries. Studies of the relationship between per capita emissions and income that attempt to avoid various statistical pitfalls find that per capita emissions of pollutants rise with increasing per capita income when other factors are held constant. However, changes in these other factors may be sufficient to reduce pollution.

A major criticism of the curve is that it assumes that conservation efforts in the later economic stages will compensate for environmental degradation in earlier stages, when this need not be the case. A targeted conservation policy from the beginning is essential to achieve the goal of sustainable development.

The mathematical expression for the curve is as follows:

$$y = a + bx + cx^2 + \epsilon$$

$y$  is the level of environmental damage,  $x$  is the current level of per capita output, and  $\epsilon$  is the unobservable residual.  $A$  is constant, and  $b$  and  $c$ , to be estimated, reflect the influences of income level on environmental quality. In the EKC hypothesis,  $b > 0$  and  $c < 0$ .

### Phases in EKC

**Scale Effect:** If there were no change in the structure or technology of the economy, pure growth in the scale of

the economy would result in a proportional growth in pollution and other environmental impacts. This is called the scale effect. The traditional view that economic development and environmental quality are conflicting goals reflects the scale effect alone. The scale effect indicates the initial stages of EKC before the turning point.

**Turning Point:** This is the point where environmental degradation reaches its maximum and starts to fall thereafter. It reflects the stage at which an economy starts transitioning from the Scale Effect to the Composition and Technique effects. From this point on, the growth in the scale of the economy would be accompanied by a proportionately larger reversal of environmental degradation.

**Composition and Technique Effects:** The Composition and Technique effects are concepts that explain the downward sloping part of the EKC. The Composition effect suggests that the economy starts moving towards more environmentally friendly industries at later stages of development. In particular, the shift is from manufacturing-intensive industries to service-based industries. Technique effect refers to the change in the technique of production, catering to the environment's needs as well as achieving production targets. The improvement in environmental quality resulting from technological advancements, such as the adoption of cleaner technologies or increased energy efficiency, forms the gist of technique effect.

**Water pollution and the EKC:**

The turning point in water EKC is lower than that in air pollution. EKC in America and Europe have turning points of \$13,956 and \$38,221. However, it becomes harder to find turning points in poor countries, as they are currently in the first phase. In addition, water shortages are a major concern in many developing countries around the world.

The underlying relationship between water pollution and economic growth is particularly important as poor countries grow richer. Malaysia, a country that has recently reached a turning point, showed that a 1% income increase led to a 266.27% increase in the water pollution indicator CD and a subsequent 134.05% decrease. The results are in line with the theory of EKC. To get into specifics, in the case of all water pollutants, Cadmium (CD), Arsenic (AS), Biochemical oxygen demand (BOD), the anticipated EKC's are found to exist.

However, the EKC hypothesis is not always efficient. India, for example, has seen variations in pollution levels at different levels of per capita income. The decline in pollution during the process of economic growth has been only temporary, as it tends to rise with further income growth. Population density, livestock population, and literacy are found to have strong effects on the water quality of the rivers of India.

The relevance of the EKC as a method of analysing water pollution thus appears limited. Statistical results appear mixed as the curve holds for certain pollutants and does not do so for others. The same is the case for different regions of the world. The EKC is often a trusted tool for assessing the different pollution problems. However, water pollution is a very complex and dynamic problem. Therefore, the EKC appears to be necessary in its analysis but not sufficient.





# INTERSTATE WATER DISPUTES

Examining the Legal Frameworks, Tribunal Rulings, and Political tensions behind India's Interstate Water Conflicts.



The Blue Bargain

2000



2016



2018



2019



**Chhattisgarh was Born**

Formation of Chhattisgarh; state begins planning dams and barrages, intensifying competition over water use.

**Dispute Formally Erupts**

Dispute formally erupts as Odisha accuses Chhattisgarh of "illegal" barrages and files a complaint under the Inter-State River Water Disputes Act.

**MWDT was Established**

Supreme Court of India directs the Centre to form a tribunal; Mahanadi Water Disputes Tribunal established.

**Formal Adjudication**

Tribunal becomes fully operational, marking the start of formal adjudication of the dispute.

# MAHANADI RIVER WATER DISPUTE

# Mahanadi Water Dispute

The Mahanadi River is 857 km long, originates from Chhattisgarh and flows into the northern part of Odisha. The river supports irrigation and hydropower for 20 of Odisha's 30 districts as well as fisheries. After the construction of the Hirakud Dam by Odisha in the 1950s, the Mahanadi has been used to irrigate 2.35 lakh hectares and generate 347.5 MW of hydropower.

As many as six biodiversity "hotspots" (areas with many kinds of plants and animals) depend on the flow of the Mahanadi, including Bhitarkanika, Chilika Lake, and Tikarpada. The present-day distribution of the Mahanadi River is as follows: 53.9% is located in Chhattisgarh; 45.7% is located in Odisha; the remainder (approximately 0.4%) is located in Madhya Pradesh.

Odisha and Chhattisgarh are engaged in a fairly recent interstate water-sharing dispute regarding the Mahanadi River and its water resources.

The dispute dates back to 1957, when Chhattisgarh was a part of Madhya Pradesh. Earlier, there were no agreements between Chhattisgarh and Odisha over the utilisation of the Mahanadi. Initially, Odisha carried out unregulated use of the water from the Mahanadi. Later on, when Madhya Pradesh opposed this, an agreement was signed between the CMs in 1983 to establish a joint control board.

However, this was never materialised as the states continued using the water in their own way. After 1991, as industrialisation increased in Odisha, more and more water was taken from the river. Mahanadi accounts for around 62% of Odisha's industrial water allocation, which was only 13% a decade ago.

In 2000, when Chhattisgarh became an independent state, the government planned a number of dams to utilise 30% of the Mahanadi's water for industrial use. Now, the construction of these barrages by Chhattisgarh, according to Odisha, is what is affecting the flow of water to the Hirakud dam, on which Odisha relies for water to meet its industrial and agricultural water requirements.

The conflict began in 2016 when the Odisha government alleged that Chhattisgarh had built a number of "illegal" barrages across the Mahanadi and its tributaries, which were "killing" the river and also severely affecting the flow of water to the Hirakud reservoir.

Biju Janata Dal, the ruling party, was set to launch its "Save Mahanadi Campaign" on 16th May, 2018, against the "illegal" construction of barrages by the Chhattisgarh government across the Mahanadi. Four days ahead of the date, Odisha's Water Resources Department declared that it would construct at least 7 barrages across the river. This was a very controversial

declaration since many people opposed it by saying that if the constructions by Chhattisgarh are illegal and harmful, then how can the same be legal and safe in the case of Odisha, while others viewed it as a measure to protect the interests and water requirements of Odisha.

Odisha said that 28+ projects of Chhattisgarh prioritise Industry over Agriculture, causing shortages for 2.35 lakh hectares irrigated by Hirakud and 347.5 MW hydropower. Chhattisgarh, on the other hand, argued that they are entitled to the water of the river Mahanadi due to reasons such as keeping a check on floods, developing their own state, and supporting their farmers through better irrigation facilities.

According to Chhattisgarh, for many years, Odisha has consumed more than its fair allocation of Mahanadi River water, thus preventing Chhattisgarh from having access to the Mahanadi River's resources.

In November 2016, Odisha formally filed a complaint with the Ministry of Water Resources of the Government of India (GoI) (under Section 3 of the Inter-State River Water Disputes (ISRWD) Act of 1956) and requested that the GoI refers their complaint to the Tribunal under Section 4(1) of the Act, which has the task of resolving ongoing interstate water disputes over the Mahanadi and its river basin between Odisha and Chhattisgarh.

Later, after hearing the dispute, on September 25, 2018, the Supreme Court of India issued a directive to the

GoI to establish an independent Mahanadi River Dispute Tribunal to resolve this conflict between the two states. Consequently, the GoI created the Mahanadi River Dispute Tribunal on March 12, 2018. As with all previous interstate river dispute tribunals, the Tribunal's "effective date" is when it became fully operational on December 14, 2019; the Tribunal was not operational from March 2020 until June 2021 because of COVID-19 restrictions.

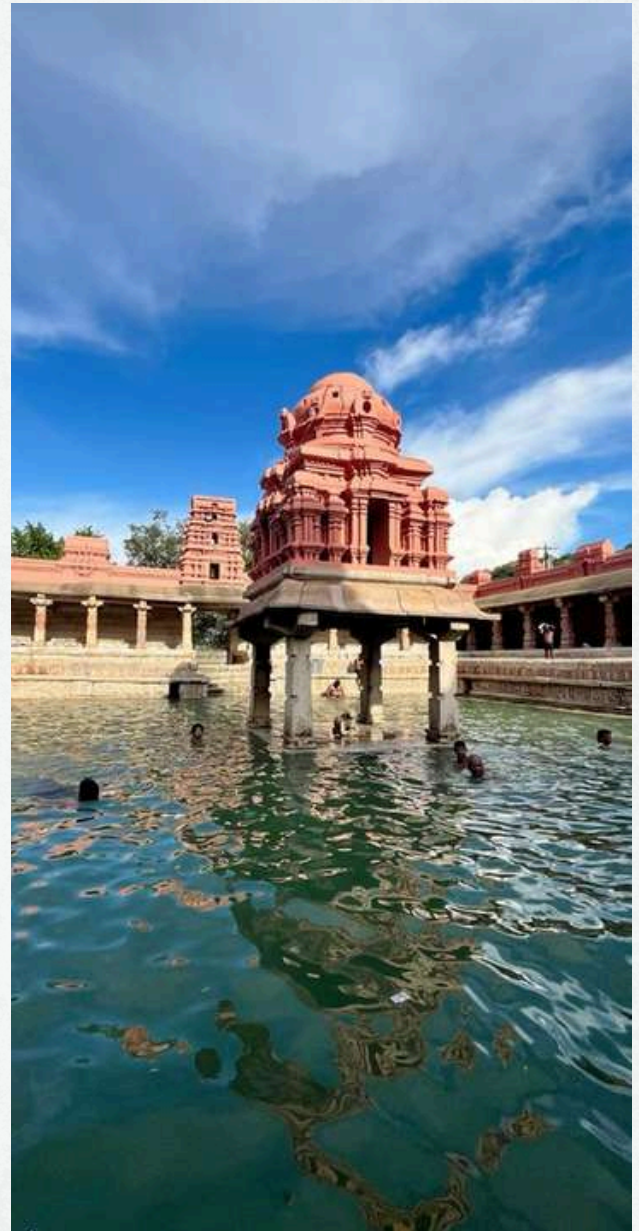
Presently working to get this dispute worked out with the other state through negotiation or by another means of a solution to be reached, although it appears that parties continue to discuss the resolution of the issues.

As per Mr Mukesh Mahaling, Minister of Parliamentary Affairs for the State of Odisha, a joint technical committee (JTC) meeting between Odisha and Chhattisgarh will take place in Raipur to discuss the ongoing process where Odisha and Chhattisgarh are trying to resolve the conflict regarding the sharing of the water from the Mahanadi River. Prior to this JTC meeting, representatives from both states have held meetings throughout the last 4 months regarding reconciling their differences.

In addition to participating in negotiations to settle the matter between the two states, the dispute is being adjudicated by the Mahanadi River Water Disputes Tribunal.

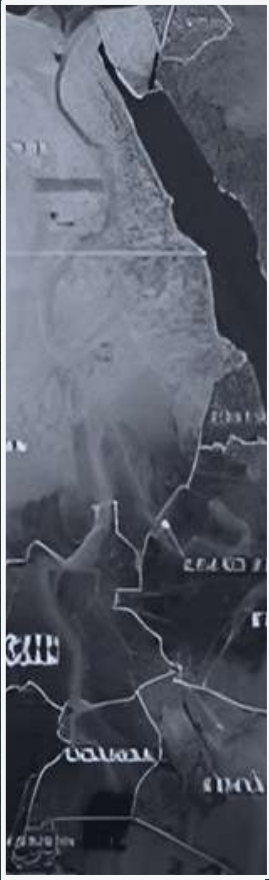
The Mahanadi River Water Disputes Tribunal is scheduled to hold its next

hearing on December 20th of this year. The information and materials received from the JTC meetings will be presented to the Mahanadi River Water Disputes Tribunal for their consideration during the tribunal's proceedings.





1959



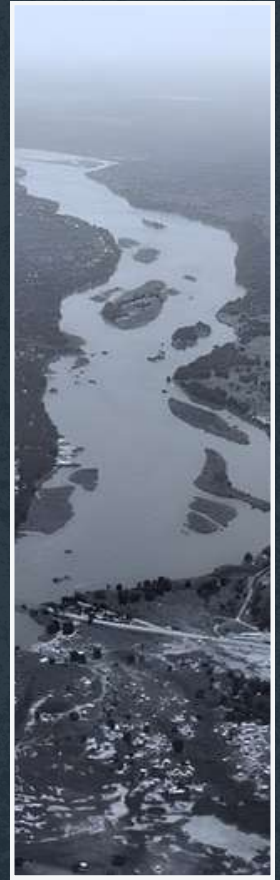
1978



2011



2023



**NWA was Signed**

Signing of the Nile Waters Agreement, granting Egypt and Sudan majority control over Nile waters while excluding Ethiopia.

**Dam Proposed by Ethiopia**

Ethiopia proposes a dam on the Blue Nile; strong opposition from Egypt prevents progress, highlighting early tensions.

**GERD Launched**

Ethiopia launches construction of the Grand Ethiopian Renaissance Dam (GERD), triggering major geopolitical conflict with Egypt and Sudan.

**Escalation of Dispute**

Arab League formally backs Egypt and Sudan, signalling international alignment and rising tensions.

# NILE RIVER WATER DISPUTE

# Nile River Dispute

The Nile is the largest river in the world. At about 6650km, it provides for the water needs of various countries like Egypt, Tanzania, the Democratic Republic of the Congo, Kenya, Uganda, Sudan, Ethiopia and many more. These countries are members of a partnership formed to regulate usage and share benefits of the river, while also maintaining cooperation and avoiding any potential conflicts, that is, the Nile River Basin Initiative (NBI).

The Nile River states' population is estimated to be 400 million, with over half of these residents (250 million) relying on the Nile for daily water supply. The UN estimates that the Nile's population will double by 2050, significantly increasing pressure on the Nile's water flow to sustain a nearly billion-strong population. Currently, 10% (4 million people) of the Nile region's population faces water scarcity.

Colonial times were filled with the creation of many treaties related to the Nile River. These treaties primarily involved the countries dependent on the Nile and the European powers.

For example, the Treaty between Great Britain and Ethiopia, the Agreement between Egypt and Anglo-Egyptian Sudan and many others. A common trend that can be seen in most of these treaties was the unfair treatment of Ethiopia's control of the river. These treaties were often

partial to Egypt and Sudan when talking about the rights to the river.

Egypt and Sudan are part of the Lower Nile Basin countries, which receive very low levels of rainfall. As a result, these regions often face issues with water scarcity. For example, the annual water deficit of Egypt is around seven billion cubic meters(1). Thus, both countries often take advantage of these colonial-era treaties so that they remain water-secure. However, Ethiopia refuses to recognise the treaty's validity due to its clear bias against them and the colonial context.

The tensions between the countries were also seen in 1978 when Ethiopia proposed the construction of a dam on the Blue Nile. However, the Egyptian government vocally protested against the same, and it never materialised.

## **Grand Ethiopian Renaissance Dam (GERD)**

The main reason for conflict in countries dependent on the Nile River has been the construction of the GERD. The countries involved are Ethiopia, Egypt and Sudan. Egypt and Sudan fear that the construction of this dam would adversely affect their water supply as well as undermine their rights over the Nile river as sanctioned by age-old treaties as mentioned above.

An absence of a modern treaty regarding the river usage is perhaps the biggest reason behind this conflict. Treaties like the 1902 Anglo-Ethiopian Treaty, Egypt's 1959 Nile Waters Treaty with Sudan, etc., give Egypt unfair control over the river. According to them, its allocated share is to be 66% of the river, as well as the nation having veto rights on any projects being constructed on the river. Ethiopia was not a signatory to many of these treaties.

The Nile is not only a source of water supply but holds great significance for the Egyptians culturally and historically. On the other hand, GERD will boost Ethiopia's industrialisation, considerably raise the standard of living of millions of Ethiopians, provide water and electricity to 60 per cent of the population currently without it, and provide a large source of income for the nation as it becomes an exporter of power throughout the region. While Egypt views GERD as an existential threat, Ethiopia views it as an existential necessity.

An increase in tension between the Arab nations and the African nations has resulted in conflict over this issue as Egypt receives assistance from Arab nations in the Middle East and Ethiopia receives assistance from the African Union. A summit of the Arab League was held in Saudi Arabia in May 2023, at which time the League adopted a resolution to support Egypt and SUDAN in its dispute with Ethiopia relative to the construction of the dam. With all of this occurring along with rising tension, there is a realistic prospect that the first

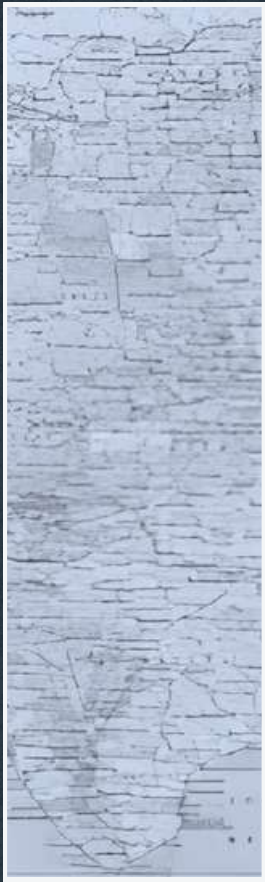
modern-day military confrontation to occur over water could occur.

Another aspect is that there are seventy-three billion cubic meters of water behind GERD, and destroying it would devastate southern Sudan with catastrophic flooding.

The current situation is that GERD has reached its final stages of creation. In view of this, Egypt is pursuing a new agreement that would reestablish its earlier rights and allow it to veto any future projects. However, no consensus has been reached, and no country has been accepted as a trusted mediator (by both) to facilitate the creation of any such agreements.



1924



1990



2007



2018



**Colonial Agreement**

Signing of the Madras-Mysore Agreement, heavily favouring Tamil Nadu and shaping water allocation for 50 years.

**Tribunal Formation**

Supreme Court of India sets up the Cauvery Water Disputes Tribunal (CWDT) after failed negotiations between states.

**Final Award by CWDT**

CWDT delivers its final award, allocating water shares among Karnataka, Tamil Nadu, Kerala, and Puducherry (later notified in 2013).

**Final Verdict by SC**

Supreme Court issues final verdict, slightly increasing Karnataka's share and declaring the river a national asset.

# KAVERI RIVER WATER DISPUTE

# Kaveri River Dispute

The Kaveri is one of India's most significant rivers; it originates from Talakaveri, a spot considered sacred by millions in the Bramhagiri Hills of the Western Ghats, located within the Kodagu(Coorg) district, Karnataka. It is often called the Ganga of the south. The river's total length is about 800 km, and the total area of the Kaveri Basin is roughly 81,115 sq km, which is approximately 2.7% of India's total landmass. It drains into the Bay of Bengal. 66.21% of the basin is agricultural land, and 4.9% of the basin is covered by water bodies.

The Kaveri flows through the states of Karnataka, Kerala, and Tamil Nadu, as well as the Union territory of Puducherry. Its average annual water resource potential is 21,358 million cubic meters, and its utilisable surface water resource is 19,000 million cubic meters. Of the 81,115 kms, 34,273 Sq. Kms lies in Karnataka, 43,856 Sq. Kms. in Tamilnadu, 2,866 Sq.Kms. in Kerala and 160 Sq.Kms in Puducherry.

Crops cover 49.7%(42,469 sq.km) of the basin, trees cover 25.62%(21,873 sq.km) of the basin, and 11.21%(9568 sq.km) of the area is built up(3), various major urban centres like Bengaluru, Mysuru, Tiruchirappalli, Coimbatore as well as smaller cities like, Mandya, Erode, and Salem etc. rely on it for their water consumption needs.

The Kaveri enables year-round agriculture in its basin, since, due to

the river, people do not have to rely on rainfall for irrigation. A variety of very water-intensive crops are grown in the region, such as rice, sugarcane, and other fruits and vegetables.

It also enables the development of various Industries such as textiles due to the readily available water, plus its role as a waterway that plays the pivotal role of being an affordable way to ship goods cannot be understated, making the region attractive to industry.

The Kaveri also holds immense cultural and religious significance, especially in the southern parts of India, where the river is worshipped as goddess Kaveriamma (Mother Kaveri) and is one of the seven sacred rivers of India. It carries with itself many myths, one of the most popular of them being about sage Agastaya and his wife Lopamudra, who used to travel with him within his kamandala (sacred pot).

One day, he dropped the pot, angering Lopamudra, who took the form of the river. Another legend talks about Lord Ganesha, who, disguised as a crow, tipped the sage's pot intentionally to save the region from drought, leading to the river gaining its name from the Tamil words Ka(crow) and viri(to spread). Kaveri Sankranama is a central festival for the locals, who gather in large numbers to celebrate the birth of the river.

The origins of the dispute lie in two colonial-era agreements entered into in 1892 and 1924 between the Madras Presidency and the Kingdom of Mysore. In the 1924 agreement, Mysore and Madras agreed to water-sharing terms which were to be in effect for 50 years (till 1974).

This agreement favoured the Madras Presidency; 75% of the water was allocated to the Madras Presidency (modern-day Tamil Nadu) as well as Pondicherry (Now Puducherry), 23% was allocated to the kingdom of Mysore and the rest to Kerala. During the agreement tenure, Tamil Nadu's Irrigated land area increased significantly from 14,40,000 acres to 25,80,000 acres, while Karnataka's Irrigated area remained stable at about 6,80,000 acres.

After the agreement ended, Karnataka rapidly increased its infrastructure development in the region to use more water for its own agriculture, creating reservoirs (Kabini, Hemavathi, Harangi, Suvarnavathy).

Tamil Nadu argued that this was unfair and that the act violated its prescriptive rights (a legal entitlement to use property, gained through long, unchallenged use), threatening the agricultural yield of the Thanjavur Delta, which had come to heavily rely on the water from the Kaveri, and that any reduction in the water supply would lead to devastating consequences for the local economy and the farmers' income.

Tamil Nadu wanted a review of the 1924 agreement, arguing that this was

an implied/understood term of the agreement, and that the 1924 agreement had acted as the basis for various foundational projects, so a major alteration was not possible, whereas the state of Karnataka wanted a new agreement to be drafted, it considered the previous agreement biased in the favour of Tamil Nadu, they argued for a "fair share" of the resources, and so they advocated for a fresh agreement without the 1924 agreement as its base.

After roughly a decade of being in a regulatory vacuum, in 1983, a society of agriculturists from Tamil Nadu, the "Tamil Nadu Cauvery Neerppasana Vilaiporulgal Vivasayigal Nala Urimai Padhugappu Sangam", filed a writ petition against the government of Karnataka for the developments that they had undertaken along the Kaveri, leading to reduced water availability for these farmers, causing them significant yield losses.

This petition led to the Supreme Court setting up the Cauvery Water Disputes Tribunal (CWDT) in 1990, a three-person tribunal headed by Justice Chittatosh Mookerjee to resolve the issue.

The court did so because it believed the states were not in a position to be able to come to an agreement amongst themselves, noting that 26 negotiations had taken place between the governments of Karnataka and Tamil Nadu during the previous decades, none of which proved fruitful.

In 1991, the tribunal announced a temporary allocation that ordered the release of 205 TMC of water to Tamil Nadu every year, but the Karnataka government found this order unreasonable, and so they passed an ordinance nullifying it. The Supreme Court struck the ordinance down and upheld the tribunal's decision.

In 2007, the CWDT announced its final award. This award was made legally binding and notified in 2013, allocating 270 TMC to the state of Karnataka, 419 TMC to the state of Tamil Nadu, 30 TMC to the state of Kerala, and 7 TMC to the UT of Puducherry. In addition to this, 10 TMC of water was reserved for environmental protection, and 4 TMC of water was appropriated for the inevitable escapage to the sea.

In 2018, the Final Verdict was delivered, the 2007 order was amended, and an extra 14.75 TMC were allotted to Karnataka to act as a water source for Bengaluru, and the Supreme Court also declared the river a national asset, making it clear that no state owns it.

Now the dispute has shifted to water sharing during “distressed years” when the availability of water is lower than in normal years, since a clear formula for determining water allocation during such years was not clearly defined.





# INTERNATIONAL TREATIES

Examining the Global Agreements, Treaties, and Frameworks Governing Shared Water Resources.

1948



1960



2000s-2010s



2025



**Interim Accord**

Signing of the Inter-Dominion Accord, establishing temporary water-sharing post-partition but leaving long-term issues unresolved.

**Treaty Formation**

Indus Waters Treaty is signed with World Bank mediation, formally dividing eastern and western rivers.

**Rising Disputes**

Rising disputes over hydropower projects lead to the use of treaty mechanisms like the Permanent Indus Commission, Neutral Expert, and Court of Arbitration.

**Treaty Suspension**

India suspends the treaty following the Pahalgam attack, marking the first major breakdown of the agreement in over six decades.

# INDUS WATER TREATY

# Indus Water Treaty

The partition of India and Pakistan led to uncertainty between the two countries about the waters of the Indus basin. While most of the rivers sourced from India, they were much more significant to Pakistan as they were a major source of water supply. Pakistan felt insecure about India's potential control over its tributaries originating from the basin.

During the first years of partition, the division of water resources was done by the Inter-Dominion Accord of May 4, 1948, subject to further negotiations. This accord required India to release water through its existing canals to the Pakistani side of the basin. Pakistan was required to give annual payments for the same. However, further negotiations only reached stalemates. Eventually, the World Bank intervened in 1951. After nine long years of negotiations, the Indus Water Treaty came into existence between India and Pakistan on September 19, 1960. It was brokered by the World Bank, which was a signatory to the same.

The treaty involved the allocation of rivers between the countries. The Western Rivers (Indus, Jhelum, Chenab) were given for use to Pakistan, and the Eastern Rivers (Ravi, Beas, Sutlej) were given to India. While the Indus was primarily allocated to Pakistan, it could be used for some domestic uses by India. At the same time, the Treaty allows each country certain uses of the rivers allocated to

the other. The Treaty allows for cooperation and information exchange between the two countries regarding their use of the rivers, through a regulatory mechanism known as the Permanent Indus Commission, which has a Commissioner from each country. The Treaty also sets forth distinct procedures to handle issues which may arise: "questions" are handled by the Commission; "differences" are to be resolved by a Neutral Expert; and "disputes" are to be referred to an ad hoc arbitral tribunal called the "Court of Arbitration."

## Dispute Redressal levels

The permanent Indus Commission established under the IWT is basically a bilateral body that aims for cooperation between India and Pakistan with regard to the water sharing issues. Each country appoints a commissioner who is generally a very experienced engineer. These engineers are required to meet at least once a year for data exchange and to discuss potential hydro-projects. The data to be exchanged includes complex hydrological information and flood data. The neutral expert is the second level, above the commissioners but below the court of arbitration. Solving technical disputes is the duty of the neutral expert.

For serious disputes, the treaty allows the creation of a court of arbitration.

The Court of Arbitration under IWT is supposed to be a neutral, treaty-mandated arbitral tribunal (often formed with the assistance of the World Bank). Disputes involving any interpretation of the treaty and any faulty actions taken by one of the parties are some of the issues that are dealt with by the court.

### **The Current Scenario**

Following the Pahalgam attack in India in 2025 that killed 26 civilians by a supposedly Pakistan-based terror group, India suspended the Indus Water Treaty on 23rd April, 2025, until Pakistan verifiably ended cross-border terrorism support. The step was taken due to security concerns and Pakistan's state-sponsored terrorism. The IWT is one of the world's most "conflict resilient" water sharing agreements, and this suspension marks the end of over 6 decades of endurance by the treaty of various diplomatic breakdowns, full-scale wars and controversies between the two nations, without being objected to by either party.

The suspension also represents India's calls for the modification of the treaty since 2023 due to demographic shifts, climate change, clean energy needs and Pakistan's promotion of cross-border terrorism. Some reports indicate India views the halt as permanent, enabling projects like a canal to divert water to Punjab and Rajasthan, though others describe it as temporary.

Since the suspension, Pakistan has raised India's decision to suspend the

treaty in various international forums and later welcomed the August 2025 decision of the Court of Arbitration, which clarified key provisions of the treaty and emphasised the court's jurisdiction despite India's "unilateral suspension".

For India, this suspension expands options for storage reservoirs, reservoir flushing, and hydropower on western rivers without treaty limits, though immediate water diversion capacity remains limited. Pakistan is at a severe risk since 80% of its agriculture, which contributes to 25% of its GDP, and major cities depend on the Indus waters, exacerbating its water stress. Pakistan has urged the resumption of the treaty post a Hague court supplemental award, though India remains non-committal.

Multiple reports indicate that Pakistan is in a critical state of water emergency, while expressing desperation to resolve this situation. Pakistan had, prior to June 2025, issued multiple letters to France (France signed on the documents referred to herein) and urged Treaty (IWC) revival and participated in all phases of Vienna hearing processes in good faith. Pakistan insisted that the post-Hague award be resumed and that Pakistan is at a disadvantage without the unilateral exit clause of the treaty, and India has excluded jurisdiction by the International Court of Justice.

Four of the letters have been written by Syed Ali Murtaza, Minister of State for Water Resources, to the Ministry of Jal Shakti, and have subsequently

been forwarded to MEA from the Ministry of Jal Shakti. In these letters, Murtaza requests that India reinstate the treaty.

The suspension of the treaty allows India to exceed its limits with respect to storage, reservoir flushing, and, additionally, the planning of hydropower facilities such as Kishanganga II. Further, PM Modi has boldly said, "Blood and water cannot flow together", and some have suggested that he has permanently redirected waters from India to the Punjab-Rajasthan region via canals. However, to date, no bilateral discussions or mediation by the World Bank have advanced as of late 2025, with everything else that is ongoing around the world providing little to no backlash on India during this timeframe.



1995



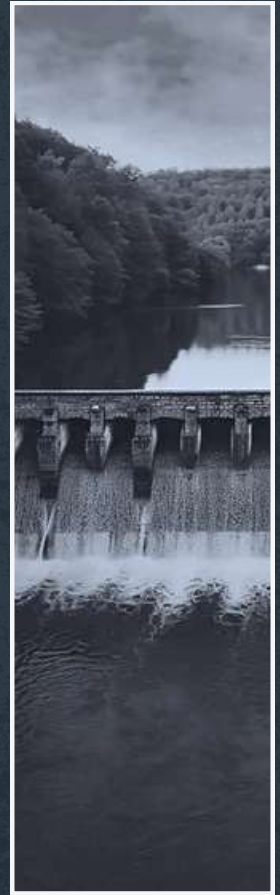
1995



2000s



2010s-Present



**Agreement Signed**

Signing of the Mekong Agreement by Cambodia, Laos, Thailand, and Vietnam to promote sustainable basin management.

**MRC Established**

Creation of the Mekong River Commission as the institutional framework for and governance.

**Process Governance**

Implementation of mechanisms like PNPCA (Notification, Consultation, Approval) for managing projects and ensuring cooperation.

**Ongoing Challenges**

Rising tensions over major dam projects and limitations due to lack of enforcement and absence of upstream countries.

# MEKONG AGREEMENT

# 1995 Mekong Agreement

The foundation of water governance here lies in the 1995 pact signed in Chiang Rai, Thailand, on April 5th, the Agreement on Cooperation for Sustainable Development of the Mekong Basin. Instead of prioritising strict control like during Cold War times, this deal embraced sustainable growth as its main aim. Cambodia, Laos, Thailand, and Vietnam agreed to work together managing water along with linked uses such as farming, transport, fish stocks, electricity production, or handling floods.

Rather than dividing up set amounts of water, a common approach, it centres on processes: how plans must be introduced, reviewed, and then tracked over time. Notably, it covers just the lower part of the basin; countries upstream, China and Myanmar, are not bound by it yet participate through dialogue roles, leaving half the river outside direct oversight.

## Institutional Setup

The Mekong River Commission (MRC). For treaty enforcement, the pact created the Mekong River Commission (MRC), acting as the only regional authority managing the waterway. Instead of multiple agencies, this body uses a three-layer framework meant to link political direction with on-the-ground work. At the highest level sits the Council, made up of ministers, who gather yearly to shape rules or settle key

disputes. Under it comes the Joint Committee, formed by higher-ranking officials (often leading departments) meeting about every six months so they can track how decisions are carried out. The Secretariat, located in Vientiane, Laos, assists these political groups by gathering information, predicting floods, while also building river simulations - this setup aims to base choices on evidence instead of opinions; however, the Council still decides key issues.

## Key Legal Ideas

Articles 5 and 6. At the core of the agreement are Article 5: on fair and balanced use, and Article 6: about keeping flow levels stable; together, they shape how water can be used. Rather than sticking to full national control or veto rights seen in past drafts, Article 5 sets up an adaptable system.

This approach treats tributaries differently from main river channels, also varying by rainy versus dry periods. When it comes to smaller rivers feeding into the larger one, countries usually just have to inform nearby nations before starting projects. Yet for most users, regulations are tighter: shifting water in dry months needs approval beforehand. In addition, Section 6 demands keeping a baseline level of natural flow when levels drop, while also banning surges above normal highs in rainy periods, aiming to

protect the river's seasonal rhythm, essential to Tonle Sap Lake.

The PNPCA method. A key part of the agreement is the PNPCA, Notification, Consultation, and Approval steps. It sets out what countries must do before starting projects such as dams. How nations communicate during planning depends on this process.

In minor cases, often along small rivers, a country just notifies the MRC, sharing basic details about the project's scale. It's a simple permission to proceed. Prior discussion is needed for big projects on the main river, such as Xayaburi or Don Sahong. The country proposing it must go through a strict six-month process. Technical reports, EIAs, along sediment models have to be sent to the MRC. Once submitted, other members examine them while suggesting ways to reduce harm.

Agreement: Applies in limited situations - such as transferring water between basins during dry periods - and demands full agreement among participants. Although the PNPCA promotes openness along with expert evaluation, some argue it fails due to a lack of veto power. When talks conclude without unanimity, the initiating country may still move forward legally, assuming it tried sincerely to respond to feedback.

Dispute settlement and national accountability, Article 7 focuses on stopping or avoiding environmental harm. A country can be held responsible when its activities lead to serious damage affecting another

river-sharing nation's nature or economy. Once such an impact is confirmed, the damaging party must stop the action while discussing financial reparation.

Yet there's no mandatory legal body assigned to uphold these rules. As an alternative, Articles 34–35 describe a conflict-solving process based on negotiation: starting with the MRC Joint Committee, moving up to the Council, then shifting toward direct talks between states if prior steps fail. Depending heavily on mutual agreement instead of enforced rulings marks a core feature of the deal, one shaped by ASEAN's preference for quiet discussions rather than open disputes, but weak nations may still struggle to get fair outcomes under unequal power conditions.





# CASE STUDIES

Unpacking the world's defining water crises.



# Punjab's Groundwater Crisis

As discussed earlier, groundwater is an extremely vital resource of water for drinking, cleaning, irrigation, etc. The Green Revolution brought a transformation in India's agriculture, including Punjab, through the introduction of HYV Seeds and modern farming techniques.

This has resulted in higher productivity but has also led to excess reliance on groundwater for irrigation. Farmers started extracting groundwater at a much higher rate to meet the requirements of water-intensive crops like wheat and rice. This has led to the rapid depletion of the groundwater table in Punjab since about 73% of its irrigation requirement is met from Groundwater.

Between the period of 2000 and 2019, the average GW depletion in Punjab was about 8.91 m, with the highest depletion of about 20.38 m in Barnala district. Farmers continue to grow water-intensive crops such as rice and sugarcane due to the favourable policy regime of free energy and open-ended purchase of these crops at an assured price.

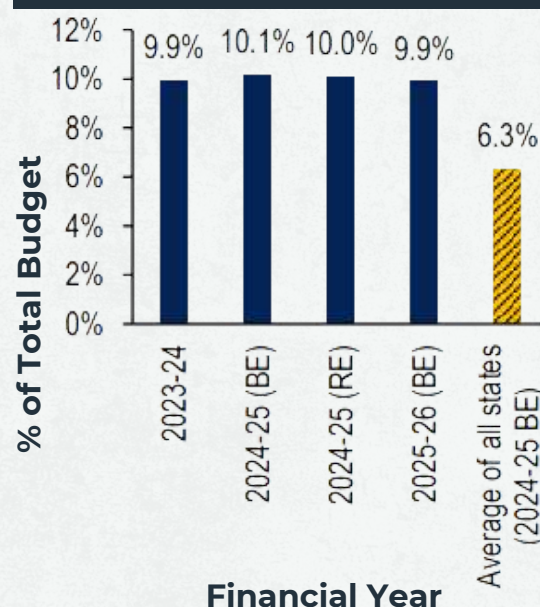
These consume a large amount of water for irrigation, and mainly, rice is the main contributor to the over-exploitation of groundwater and the consequent decline in the GW table in the state.

The area under rice cultivation in Punjab is around 32.46 Lakh Hectares,

which is around 64% of the total geographical area of Punjab, though only about 30% is truly suitable, further leading to water depletion issues despite government efforts for crop diversification. The area has seen massive growth, from less than 0.5 million hectares in 1980 to over 3.2 million hectares now, driven by MSP and irrigation.

Subsidies have also played a major role in increasing overall agriculture in the state. In Punjab, power for agriculture was totally free from 1997 to 2002 and from 2005 onwards. The power subsidy for agriculture amounted to Rs. 4778 crores in 2013–2014. In the 2025-26 Punjab's state budget, Rs. 9992 crores have been allocated towards providing power subsidies to farmers and in total Rs. 14407 crores have been allocated towards agriculture and allied activity, nearly 10% of the state's total budget.

Subsidies in Punjab's state budget



A groundwater resources assessment by the Central Ground Water Board (CGWB) found that most of the districts in Punjab had over-exploited the groundwater levels. In some districts, the groundwater level was marked as critical.

Of Punjab's 153 administrative blocks, 115 have already been classified as overexploited or in the dark zone. Groundwater extraction in Punjab has already reached 150-200 meters in most places in central Punjab. If the depletion continues at the present rate, Punjab's groundwater is expected to drop below 300 meters by 2039. If Punjab goes dry, India's food security would be under a major threat.

As per the State-wise Ground Water Resources of India, 2025, Punjab's total annual groundwater recharge is estimated at 18.60 billion cubic metres (BCM), while the quantity that can be safely extracted each year stands at 16.80 BCM. However, the state is currently extracting about 26.27 BCM annually for irrigation, domestic and industrial use.

Over the last five years, the state's groundwater table dropped at an average annual rate of 0.16 meters. In 2023-24 alone, 28.95 billion cubic meters (BCM) of groundwater was extracted, leaving a massive deficit of 11.32 BCM between recharge and withdrawal. In the last few years groundwater demands for domestic and industrial use show a significant increase of 26%–228%.

Over-extraction of groundwater leads

to soil salinity and reduced fertility. This in turn hampers crop harvest, lower productivity and reduced income. This also leads to increased costs on irrigation. Moreover, an increased agricultural demand leads to decreased availability of water for domestic and industrial uses since agriculture constitutes a major portion of the groundwater usage in Punjab.

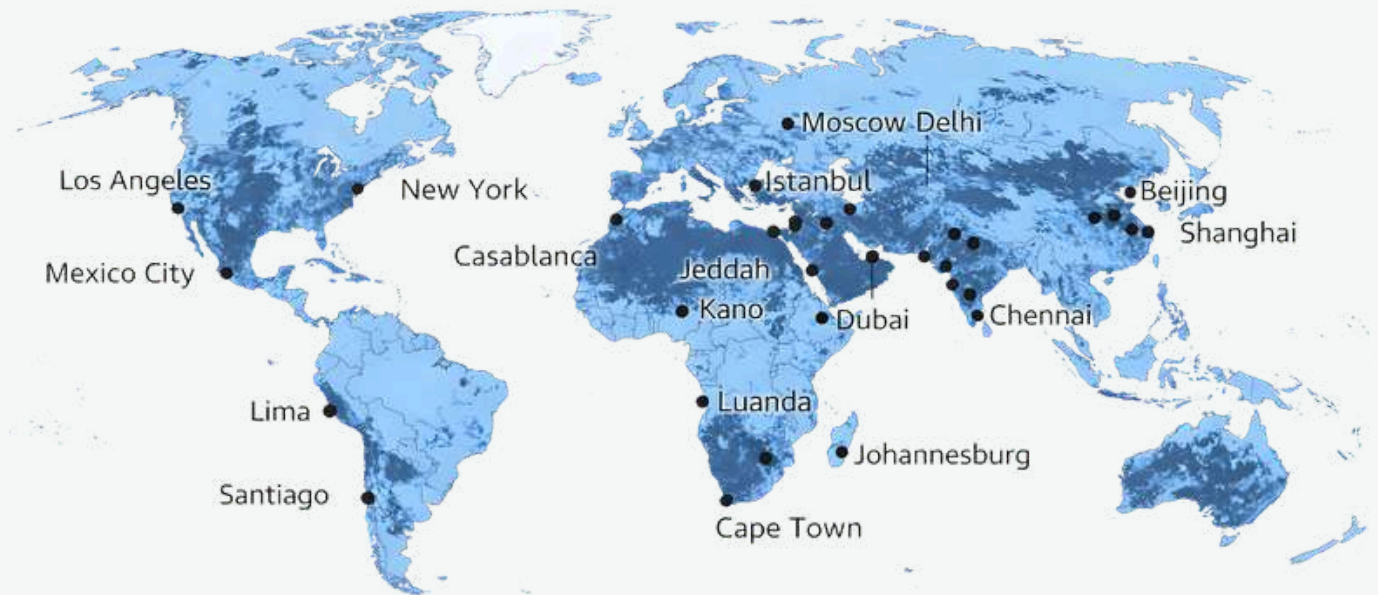
In order to counter this issue, the Punjab State Government rolled out its first 14-point State Groundwater Conservation and Management Plan. It covers around 15.79 Lakh hectares of farmland and focuses on groundwater dependence reduction through micro-irrigation, closed pipeline systems, lift irrigation, check dams, and recharge ponds. It also promotes flood modelling, farmer engagement, and planting bamboo and vetiver for erosion control and water absorption. To further promote the use of surface water, excess water from canals and distributaries will be directed into adjacent ponds.

Water from these ponds will then be delivered to fields using a lift irrigation system, thus expanding the area under surface irrigation. It further proposes storing floodwater from the Ghaggar River for agricultural use. The plan also involves constructing check dams at choke points or drain points in the river to divert water into existing ponds. This water will be treated through treatment plants and nano bubble technology before being transported to agricultural fields.

# Day Zero: Cape Town

## Countries and Cities at the risk of Day Zero

1 = Very Low  5 = Very High



Day Zero refers to a situation where a city is on the verge of running out of freshwater sources and the officials are forced to restrict access. Cape Town was the first city which came close to closing its taps and popularised the term. Many cities have faced Day Zero after Capetown.

Day Zero forces cities to import their water needs and undertake harsh conservation measures. It has a serious impact on health, sanitation, the economy and infrastructure, and the quality of life in general.

Generally, South Africa has a drier atmosphere. Capetown has a different situation however, as it has a more humid and Mediterranean climate. Table mountain traps the moist incoming breezes which leads to rain. This is the primary freshwater source in Capetown.

However rapid population growth, an ongoing drought, and climate change impacts led to the possibility of a Day Zero type situation. While reservoirs in Capetown were largely filled in 2014, the succeeding three years had some of the worst floods that the country had ever seen. According to NASA, the reservoirs stood at 26%.

Due to the huge socioeconomic differences in the population, the scarcity forced the more well off residents to deal with a problem already faced by the poorer lower class residents. These residents, while comprising about 50% of the population of 4.6 million, only utilised about 5% of the total water resources(1). Therefore water conservation habits were prevalent among these groups for a long time.

This was primarily due to a long history of racial segregation introduced by the previously governing Dutch and European powers who also instituted Apartheid in 1948. While black activism and large scale movements led by black leaders led to creation of the new government and fairer laws, racial tensions and inequalities still persist.

Day Zero was initially supposed to be in March 2018. It was then pushed again and again until it was pushed indefinitely due to the successful policies followed by the government.

The prevention of Day Zero is a leading example of the positive impact of government intervention in an adverse situation. Several steps were taken in the lead up to Day Zero. Water theft and fights over water were prevented through patrolling. A check was kept to ensure that vendors do not overprofit from the sale of bottled water(1). Emergency water was stored in military bases. About 200 water stations were situated outside grocery stores gathering areas, with each serving almost 20000 residents.

Residents were requested to reduce their consumption of water to about 50 liters (13 gallons) per day. This was harder for the wealthier groups which were used to overconsumption patterns. Water monitoring systems were put in place to ensure that the daily quotas were taken seriously. A few months later, when the limits were increased, the water conservation habits inculcated by the residents during this period, ensured that the increased limits were not

abused. An online dot system was introduced which helped in tracking the water consumption habits of families. Peer pressure was created as this was a public system and everyone could see the water consumption of other families.

Long-term measures to introduce new freshwater sources, including desalination of soil, were introduced; these were found to be expensive and had a harmful environmental impact.

A primary factor in prevention of Day Zero was also the luck factor involved with the incoming winter rains which helped in avoiding a drastic situation.

As many cities across the globe face a water crisis, the measures taken by Cape Town to avoid a Day Zero provides an excellent example in water scarcity management and crisis aversion.

# Rotterdam vs Chennai

Both Rotterdam and Chennai are cities that represent their situations, and each was included in this Case Study to provide a comparison between them as examples in the way that they manage water resources. Arnold wants to identify successful examples of urban water management at different levels. Rotterdam represents the optimal example of a well-managed city that has successfully managed its water resources. Chennai, on the other hand, is an example of a city that is in the process of trying to meet its water demand and has problems with water supply.

## Rotterdam

The second-largest city in the Netherlands, Rotterdam, is an important entry point into Europe due to over 1 million people living there. Located where the river meets the ocean (North Sea), it has a very good geographical site within a complex system of rivers known as the Rhine-Meuse-Scheldt delta. As a result, the area's geography is very dependent on the balance between land/sea and the average elevation above sea level has been set at zero meters. The highest point in Rotterdam is 21m (69 ft); however, the lowest point (area) is actually roughly 6.7 m below the level of sea; thus, I think your 8m number refers to the below-level part versus the above, since if it were above-level by 8, then Rotterdam would appear much more hilly than it really is!

Due to over 80% being developed on reclaimed land, most part of Rotterdam sits at or below sea level due to risk of flooding; therefore, city is reliant upon world class quality water management systems to keep above water; example - dikes/impressive mechanical storm surge to defend city from both armor plate/rising river discharge, along with several "water basin" which use temporary reservoirs to effectively engineering it away from being built on water.

Of all the water used in Rotterdam, 80% is taken from the river Meuse, 16% from groundwater, and 4% from dune water (5). The water is then collected into the Biesbosch water reservoirs, which can retain enough water supply for about three months. These reservoirs serve two functions: pre-filtering the water as well as storing it (acting as a buffer if there is an emergency) so that the city can have continuous, reliable access to water that meets health standards.

**Treatment:** The water that is collected from the Biesbosch Reservoir goes through a six-step treatment process using Ozonisation and UV tests at three separate treatment facilities: the Berenplaat, the Kraligen and the Baanhoek. Because the treatment facilities are located at one common location, in the event that one of them has an issue or needs maintenance, the other facilities can source production to maintain the least amount of disruption to the water

supply to the city.

The Dune water and groundwater are treated differently because this water is already very clean, because of its passage through sand/ground, and so unlike the river water, it does not require Industrial intervention, and so only has to go through aeration and softening pellets.

**Transmission:** after treatment, the water is transported to the city through its urban distribution network; the total network length is 12,465 Kms. The system is extremely efficient, acting as the global standard for water leakage minimisation, the city has a 24/7 water supply, and was called a global top performer for water leakage minimisation.

The city has 100% meter coverage, and unmetered connections are not allowed. This ensures that the user of the water is paying a fair rate according to their usage. All new connections use a smart water meter, which allows for real-time monitoring of the water supply. This increases the efficiency in the detection of any water leakages.

Water Rates 2026	
Item	Amount
Annual Fixed Charge	€101.05
Variable Rate per cubic metre	€1.320
Tap Water Tax per cubic metre	€0.476

### The Drinking Water Act:

This act is the primary piece of legislation in the Netherlands that deals with various aspects of water in the country. The Drinking Water Act made it mandatory for all the shareholders of a water supply company to be only public authorities (The government, municipal authorities, etc). The purpose of this is to ensure that water is not privatised, clarifying the public nature of water.

Water pricing is based only on cost recovery, so water companies like Evides Waterbedrijf are not allowed to make a profit; all rates are based solely on cost recovery.

Water prices cannot be set by the utility provider alone; they must be approved by the human environment and transport inspectorate.

The act also places a duty of care on all the utility providers, which mandates them to provide 24/7 access to water.

The act also grants all utilities the right to install meters in the user's home to ensure fair billing. It is also required for all the utility providers to share various benchmark data, such as leakages or costs, etc., to set a national benchmark for all the utilities.

### Environment and Planning Act (Omgevingswet):

This legislation makes the municipality of Rotterdam responsible for the collection and treatment of wastewater; it is also responsible for properly managing rainwater by implementing systems like rainwater harvesting. The municipality of

Rotterdam must also manage the groundwater of the city to prevent any infrastructural damage while also ensuring efficient utilisation of the groundwater.

## Chennai

The Eastern Coastal Plain is where Chennai, India, is situated on a flat coastal plain in northeastern Tamil Nadu. Its average height above sea level is approximately 6.7 m (22) and its highest point is 60 m (200). By way of travel, the distances from Chennai to some of the major cities of India are: Delhi - 2184 kilometres (1357 miles) directly south, Mumbai - 1337 kilometres (831 miles) directly SE, and Bangalore - 345 kilometres (214 miles) directly east.

Chennai has two large rivers flowing through it; one is the Oovam River and the other is the Adyar River. They are heavily polluted with residential and industrial waste. The Kosasthalaiyar River flows in the outskirts of Chennai; it also suffers from heavy contamination.

Till about 1870, the people of Chennai were dependent on shallow wells situated in their houses or on public wells and tanks in the neighbourhood to meet their water supply needs. There was no protected water supply at that time, and these sources were not enough to meet the growing needs of the population. Hence, there was a need for the development of an organised water supply system in the city. Accordingly, an organised system of water supply was commenced in 1872, which is the basis of the present-

day water supply structure in Chennai.

In Chennai, the Chennai Municipal Corporation was responsible for the construction, operation and maintenance of the water supply system till August 1978. Later on, it was transferred to the CMWSSB. The major sources of water supply are through the Poondi reservoir, Cholavaram lake and Redhills lake. These are under the control of the State PWD (irrigation). Moreover, the PWD (Ground Water Cell) is responsible for the investigation of groundwater resources within CMA.

Water supply for the city is mainly drawn from the Red Hills Lake located about 6 kilometres from the city. It receives water primarily from the Kosasthalaiyar River, across which a dam was constructed to create a reservoir at Poondi. The anicut constructed downstream at Tamaraipakkam diverts the flow through the upper supply channel to Cholavaram Lake, from where it flows to Redhills Lake and then towards the city.

In the last two decades, Chennai has experienced extreme water conditions due to multiple natural calamities (floods in 2005, 2010, and 2015, droughts in 2003–04 and 2016–18). In 2019, the city reached “Day Zero” or the day when reservoirs had run dry, and no water was left.

In order to protect the city from such extremes, the CMWSSB is working to diversify the water supply through desalination and sewage treatment reuse. They mandated rainwater

harvesting and became the first city in India to reuse 10 per cent of collected wastewater. Between 2015 and 2019, two tertiary treatment plants were established by CMWSSB to supply high-quality treated wastewater via a grid to industries in and around Chennai.

Moreover, due to the flat terrain of the city, the average level of the land in the city is only 2.0m above the Mean Sea Level (MSL), and there is a need for stormwater to prevent flooding, and water stagnation happens in the city during the monsoons. Accordingly, a DPR was prepared for the construction of an integrated stormwater drainage network in the extended areas during 2012.

The Integrated Stormwater Drain was designed across the extended areas of the following four basins: Adyar and Coovum Basin: for a length of 406 km at a cost of Rs. 1387 crores, Kovalam Basin: for a length of 300 km at a cost of Rs. 1332 crores, Kosasthalaiyar Basin: for a length of 769 at a cost of Rs. 3599 crores

The infrastructure responsible for providing Chennai with potable water consists of reservoirs, rivers, groundwater, and desalination plants (CMWSSB).

On January 7th, 2026, the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) issued a notice for residents of Mylapore, Triplicane, Royapettah and surrounding areas about an interim stoppage of piped drinking water service in order to conduct significant

pipeline connection infrastructure work on Mandaveli Ramakrishna Mutt Road. This project is part of a continuing effort to provide robust potable water Distribution Systems throughout the city, indicating that there is much work ahead for Chennai before reaching true potable water security.

According to the seventh schedule of the Indian Constitution, water and allied activities are a part of the state list, so the management of water in Chennai is subject to the laws and regulations of the State of Tamil Nadu.

### **Chennai Metropolitan Water Supply and Sewerage Act, 1978:**

The act provides the Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) with monopoly power over the management of water supply, storage, treatment, and sewage services within the Chennai Metropolitan Area.

### **Chennai Metropolitan Area Groundwater (Regulation) Act, 1987:**

The act prohibits any person from digging a well (open or borewell) within the confines of the Chennai Metropolitan Area without permission from CMWSSB. The act also prohibits the extraction of groundwater for any use other than for domestic consumption without a license.

### **Tamil Nadu Combined Development and Building Rules, 2019:**

These Rules make it mandatory for large residential and commercial,

spaces to have dual plumbing systems to reuse water used for activities such as cleaning clothes or washing hands etc., that is relatively clean and can be safely reused, such water is called “Greywater”.

### **Atal Mission for Rejuvenation and Urban Transformation 2.0:**

The city of Chennai receives funding under this programme from the central government to move to 100% water metering and 20% water recycling. This will help in preventing the wastage of water by placing an economic price on it and by recycling water that can be reused.

### **Environment Protection Act, 1986:**

The Act establishes the polluter pays principle, and gives authorities such as the Tamil Nadu Pollution Control Board the legal grounds to fine polluters, such as industries that release untreated waste into rivers.

The city of Rotterdam is considered one of the best in the world in terms of its water management and infrastructure, while Chennai has faced issues with regard to its water supply and is facing scarcity problems.

This can be primarily due to infrastructural differences. While Rotterdam has world-class infrastructure and high-grade technology in relation to water regulation and management, the infrastructure in Chennai is rapidly ageing. Many of the reforms and upgrades introduced in Chennai were only after the Day Zero crisis. Parts of

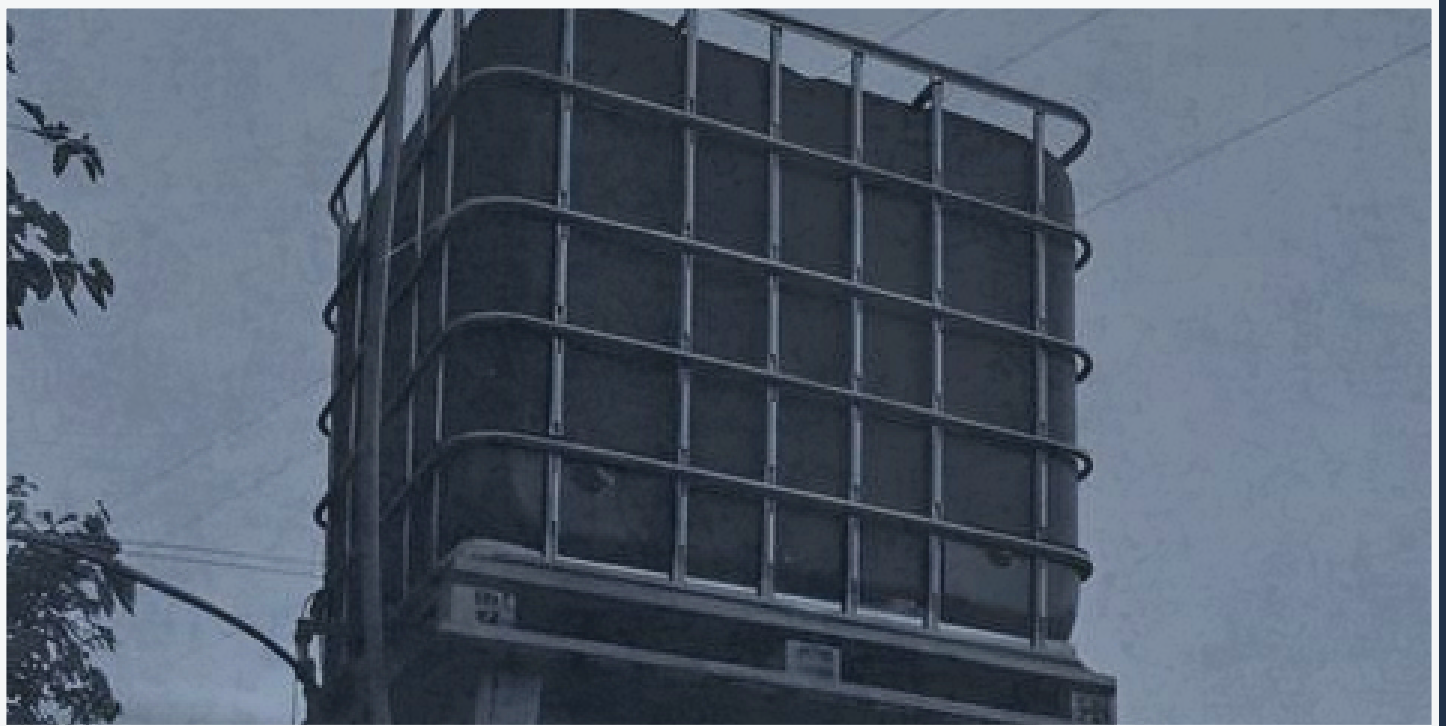
Chennai still primarily rely on the monsoon to meet water needs, while Rotterdam depends on groundwater sources. The city of Rotterdam also has smart technology that regulates demand and supply needs, while Chennai often faces issues with regard to exceeding demand due to leaks and inconsistent supply.

The flood infrastructure is far superior in Rotterdam, while Chennai often faces flooding situations in several areas.

The institutional framework in the cities also has an impact. While Chennai has a centralised authority and limited local networks, Rotterdam has a decentralised network. This allows for stricter surveillance. While Chennai has illegal connections in a few of its local areas, unmetered connections are 100% strictly banned in Rotterdam.

Rotterdam treats water as a public good, and the local authorities are held accountable for failure in the provision of freshwater as well as for any problems in wastewater treatment. This leads to another important point. The quality of water resources is also quite different in the two cities. Rotterdam boasts of safe, clean water, while Chennai has a hard-water issue as well.

Chennai has recently shifted its focus to measures like desalination and harvesting with varying degrees of success. Rotterdam, on the other hand, aims at constant upgradation to ensure water safety as well as meet potential future climate issues.



# WATER STORAGE

Exploring the Systems and Solutions that keep Water Available when it is needed the most.



# Water Storage

Scarcity of freshwater now represents an emerging area of concern across several sectors and has become a key driver of national economic indicators. Water, which was historically considered a low-cost and unlimited resource, is now being recognised as a scarce resource that hurts real GDP growth and investment.

A review of the literature that makes use of a combination of country-specific data from 169 countries confirms this assertion by demonstrating that an increase in water scarcity resulted in a decrease in real GDP growth, as demonstrated through the use of regression analysis.

Regression analysis found that for every 1 percentage point increase in water scarcity, which was defined as a percentage of total freshwater withdrawals compared to total renewable freshwater, economic growth was reduced by 0.08-0.10 percentage points.

The most acute effects of this relationship occurred at the time when a country was experiencing the most limited economic growth.

In addition to reducing GDP growth, increased water scarcity is an important driver of inflation. An increase in the percentage of water withdrawals is correlated with price increases. Therefore, a 1 standard deviation increase in water scarcity may result in an increase in inflation of approximately 2.9%-3.5% per year.

The main channels through which inflation occurs, due to the increased water withdrawals, stem from supply shock effects in food and energy markets. This is particularly true in areas where agriculture, through irrigation, and hydropower generation (through the use of water dams), are affected by cyclical climate events such as El Niño.

Using the information obtained to this point, it can be inferred that improving water management and technological innovation related to water use will have a positive impact on the GDP and inflation rates.

Water storage economics refer to the temporal and spatial allocation of a finite resource to best optimise the differences between natural supply and human desire for this resource. Storing water has a higher economic value than using it for present consumption; therefore, each additional unit of stored water has a "reliability value" associated with it based on its ability to mitigate the future risk of water supply shortages.

As cities' water storage levels decline, the marginal economic value of each unit of stored water increases, because keeping additional water in storage will help, in part, to avoid requiring the use of large amounts of capital to expand the capacity of urban water supply systems (e.g., desalination plants) in the future.

Long-run marginal cost (LRMC) of water supply (a key metric) is the best measure of the cost of providing a utility's future water supply. Typically, the price charged for the use of a certain amount of water is not an accurate representation of the value of that stored water.

While water is scarce, the value of that stored water is largely related to managing droughts and avoiding devastating supply shortages; conversely, while water is readily available, the value of that stored water is primarily concerned with avoiding the costs of building infrastructure to satisfy long-term demands for additional water.

In addition, an opportunity cost associated with financial capital that is not currently invested must also be taken into account, so that when making decisions between current consumption versus the future return from water storage infrastructure, some weight must be given to opportunity cost.

The world is experiencing an increasing "storage gap", or the disparity between the amount of water storage available and the total amount that is needed to meet human water requirements.

The global water storage crisis is due to a combination of biological and physical factors: the loss of natural water storage (glaciers and wetland ecosystems) as a result of climate change and conversion of land from wetland to urban, as well as, the decreasing quantity of available built

water storage infrastructure due to sediment accumulation filling reservoirs faster than the rate of increasing reservoir size.

In the past 50 years, the world's population has increased to 7 billion, creating an increased demand for water storage; however, at the same time, per capita storage has decreased. Approximately 2.97 billion people and more than 55% of the World's food production occur in regions of the World that are anticipated to experience total water storage capacity losses. This loss of storage capacity is part of a systematic trend with the potential to surpass the ability of government entities to provide for public safety and welfare.

Historically, large dams constitute the primary means of water storage throughout the world; 40% of agricultural production through irrigation and 20% of electrical generation on a worldwide basis can be attributed to dams.

However, the narrative surrounding the economics of dams has become increasingly complex due to the magnitude of the externalities related to the environment and society.

The greatest externality incurred due to dams is the effect that climate change has had; The oxygen-depleted, stagnant bottoms of reservoirs often result in a large amount of plant matter decomposing, providing an additional source of greenhouse gases (methane) -- which is 30 times the global warming potential (GWP) of CO<sub>2</sub>.

The social cost of methane varies widely across regions once social and economic inequalities are factored into the calculations; The global mean social cost of methane is estimated to be \$922 per metric ton (ton), but it ranges from \$8,040 per ton for developed nations such as the United States down to \$130 per ton for sub-Saharan Africa.

In addition to the environmental impacts of methane, the human cost of dams is significant. Approximately 80 million people have been displaced as a result of dam projects throughout the world, and many of these people will be economically worse off and/or marginalised as a result.

Finally, the presence of a reservoir may provide a false sense of security and give rise to the so-called "supply-demand cycle", as the increased availability of water has given rise to agriculture and urbanization, which now demand even greater quantities of water and may ultimately negate the original benefits and lead to a "lock-in" effect, leaving this population highly susceptible to drought conditions.

With the recognition of the many limits that exist regarding large-scale surface reservoirs, Managed Aquifer Recharge (MAR) and Aquifer Storage and Recovery (ASR) have rapidly become more popular. ASR is now defined as the process of storing water in an aquifer using wells when water flows or is available from a source where there is more than enough, then recovering (taking from) the stored water whenever it is

needed. The large advantage of ASR has been attributed to its very low capital costs; in many situations, ASR wells can store water at between one-half and one-third of the cost of large-scale surface reservoirs.

Within the agricultural setting in a given area, such as the Lower Namoi district of Australia, it has been demonstrated that aquifer storage is a more cost-effective way of storing water than traditional surface dams.

The levelised cost of aquifer storage through ASR systems was estimated at AUD 192 per megalitre (ML); whereas that for the estimated pond infiltration storage was AUD 264/ML. These storage systems, ASR and RWH, will produce between 6% and 24% greater financial savings than surface storage by virtually eliminating the extremely high evaporation losses associated with open reservoirs.

RWH is another decentralised form of water-storage technology that has a very large impact on the approximately 80% of agricultural land globally that relies on rainwater. In Africa, RWH has the potential to produce a doubling of food production, but has not been adequately prioritised within the majority of national-level water policies.

Urban water bodies such as lakes and ponds are considered to be important natural reserves. Urbanisation has caused significant degradation of these water bodies. Rejuvenating and maintaining the many water bodies in a city is an important strategy for

drought-proofing urban centres.

In New Delhi, the location with the highest groundwater withdrawal rates in India—the Indian Government's project called "The City of Lakes" was started to rejuvenate over 1,000 water bodies within the city.

The Rajokri Lake Rejuvenation project uses a technique called "Scientific Wetland with Active Biodigester" (SWAB), which is a way of treating wastewater that can also be used to restore a dead lake. The use of the SWAB technique enables the treatment of wastewater using much lower-cost materials than traditional chemical and concrete-based treatment options. In addition to reducing waste treatment costs for municipalities, projects such as these also produce a tangible economic return by increasing residential property values and providing social benefits to residents.

Hedonic pricing models indicate that residential property prices in urban centres such as Chandigarh decline as the distance from a water body increases. The evidence shows that, in addition to increasing the aesthetic appeal for urban residents and providing recreational opportunities, desilting traditional water bodies allows them to store millions of litres of water. Increased storage capacity increases the ability of rainwater to percolate into the ground and improve agricultural productivity in the surrounding areas.

The significant amount of funding needed to close the global storage

gap requires an increase in investment under the OECD's three T's (Tariffs, Taxes, and Transfers). Tariffs help guarantee the return of the funds invested in infrastructure, while taxes from government budgets finance the upfront costs of developing this infrastructure, and also help provide funding for projects that benefit society as a whole. PPPs can provide the opportunity for private investment; however, they typically cost more than public financing because PPPs tend to incur greater borrowing costs and transaction costs.

Determining how to consider intangible externalities when evaluating the economics of storage projects is a significant challenge. Shadow pricing is a methodology that allows one to place a monetary value on water based on the risks associated with its scarcity. In one study in Brazil, more than \$40 million was attributed to the shadow price of sediment retention in nature, thus demonstrating the significant economic value of naturally storing sediment.

Modern-day IRPs incorporate the social costs associated with the production of externalities, including the cost of carbon and the value of reduced eutrophication, into the economic evaluations of storage projects, thereby ensuring that the producers of the external environmental costs bear those costs.

# Urban Water Supply

A growing population and rapid population movement to cities both contribute to the sense that urban water is experiencing the converging forces of what is causing climate change, which has increased irregularly. Water is special within the economy. It is a human right, a valuable yet finite resource, and the potential cause of global financial instability, or the threat of it.

As cities become larger (especially in developing nations), traditional methods of providing urban water have been characterised as unable to meet the triple goals of financial sustainability, equity, and long-term environmental sustainability.

The Urban Water Supply is characterised by the Economic Characteristics of a Natural Monopoly. A Natural Monopoly is characterised by industries with high fixed costs for the construction of an infrastructure system based on large capital investments to build reservoirs, treatment facilities, and distribution networks. In this case, one provider can continue to provide services to its customers at a lower average cost than many competing companies can provide services to the same population based on economies of scale. Robust regulation is required, however, to avoid monopolistic pricing and allow utilities to maintain their infrastructure and develop new infrastructure while generating sufficient revenues.

The different components of the water supply industry are:

## **The Theoretical Foundations and Regulatory Paradigms**

Cost recovery is a central focus of modern water economics. Under this principle, the cost of providing a product should be accounted for. However, in the WFD (Water Framework Directive), all Member States are required to account for cost recovery for three different dimensions. The first dimension is financial through capital and investment (C&I) and through operating and maintaining, etc.

The second dimension, as per the WFD, environmental costs incurred by entities that utilise or benefit from the water, known as the Polluter Pays Principle, shall be defined as the cost of damage done to the natural environment through the use of water.

The third dimension is referred to as the resource cost, representing the opportunity cost associated with depleting water resources and losing alternatives. When we look at the total overall cost to society (present consumption) and compare it against what is being paid for by the current user (future consumption), we see a very large discrepancy in the value of this natural resource (time).

Additionally, because of its

classification as a merit good, the economic classification of water is further complicated. In other words, we believe that all individuals in society should have reasonable access to the service regardless of their ability to pay.

An inherent tension exists between people's demands for economic efficiency, usually realised through price signals, and people's demands for social equity. Thus, when water is priced at much less than the total cost of providing and delivering it (the cost incurred by the water provider), then aggregate consumption of water is such that people will continue to use it until their marginal benefit of using it equals zero, even though the marginal costs of providing it are very high.

### **Elasticity and Urban Water Demand**

To implement urban water policies effectively, policymakers need to know how consumers will alter their behaviour in response to changes in both price and income. The primary way to determine this information is by calculating the price elasticity of demand, which shows that there will be a percentage change in the amount of water demanded that results from a 1% change in price. Empirical data show that residential water demand is usually defined as elastic ( $<1.0$ ).

In meta-analyses conducted through different Research Studies, the average price elasticity of residential water demand ranges between  $-0.27$  and  $-0.51$ , showing that there is an incentive for consumers to decrease

water usage when prices increase, but this decrease is not equal in proportion to the price increase.

Many consumers have limited ability to alter their basic indoor water consumption (drinking, cooking, and personal hygiene), which leads to inelastic demands for most of their indoor uses: they cannot substitute for indoor uses with another item because they do not have access/affordability of other necessary items. In other words, the demand for indoor water use is often inelastic because many people cannot afford to purchase substitutes for basic indoor uses.

In contrast, outdoor uses (e.g., landscape irrigation, swimming pool maintenance) tend to be elastic because consumers often have more choices available. Thus, consumers generally will decrease their water usage when prices rise for these non-essential uses of water.

“Demand hardening” is another phenomenon that is associated with the fact that many households have already made easy and inexpensive changes to their water use through the installation of low-flow fixtures.

Thus, these households will increasingly find it more difficult and costly to further reduce their demand for water (i.e. making their demand inelastic) in times of drought or in crisis. Another characteristic of water is that it is considered a normal good; therefore, as household income increases, the consumption of water will also increase.

The reason this happens is that with higher incomes, households tend to have higher standards of living and will have access to more water-dependent items, such as clothing and washing machines, which require the use of water.

The elasticity of income is typically low for water, as a result of the fact that while there will be an increase in water usage as households gain more wealth, the increase will not be proportional to the amount of wealth possessed by the household.

### **Tariff Architecture: Efficiency, Equity, and Sustainability**

The major mechanism by which municipal utilities communicate the value of water to their customers and secure continued financial viability is the structure of municipal water tariffs, which incorporate three often conflicting objectives: the utility's financial independence, society's economic efficiency, and customer equity (fairness).

There are many different tariff models used by municipal water utility systems worldwide. For instance, flat-rate pricing, which finds many utility systems charging a fixed amount for customers regardless of the quantity of water consumed, is a frequently used but economically inefficient option. Flat-rate pricing allows customers to face a zero marginal cost for consuming water, which leads to over-consumption or waste.

In Western Kenya, customers who paid based on the actual volume of

water consumed (volumetric) tended to use much less water (33.2 Litres Per Capita Per Day) than customers who paid on a flat-rate basis (45.8 Litres PCD).

Additionally, flat-rate pricing has created large disparities in water consumption between socio-economic classes, creating cross-subsidisation of low-income customers by wealthier customers, who typically pay for similar amounts of water but use more of it.

The Increasing Block Tariff (IBT) has gained worldwide acceptance due to its tiered structure, wherein the cost of each unit of water increases the more one uses. IBTs are seen by supporters as being "pro-poor" because it is assumed that lower-income residents will consume lower quantities of water than higher-income families and therefore pay less for the first or initial blocks of water.

Unfortunately, the research shows that this is frequently an inaccurate assumption. For instance, in many developing countries, poorer households tend to be larger than the larger-sized households common in more developed countries, share a single water connection with multiple households, as well as utilising a large number of water service providers.

As a result, the average amount of water consumed by a poor household on a monthly basis pushes their monthly consumption into blocks of water priced significantly higher than their counterparts (i.e., their neighbours).

Another alternative to IBT is the use of a Uniform Tariff with Rebate (UTR), which provides all consumers who use water the same price per unit and additionally gives low-income consumers the ability to receive a flat-rate monthly rebate to help offset the additional costs associated with purchasing water.

In this model, all consumers pay the same price, but those consumers classified as low-income will receive an additional benefit in the form of a monthly rebate. The benefits to the consumer remain the same; each household will have a fixed, optimal conservation incentive based upon water use, while still having access to a targeted, non-regressive subsidy for low-income families.

### **Economic Supply-Side and energy/water interdependencies.**

Through Lenders, Efforts to Expand the Amount of Water Offered and Available to Address Global Demand for Urbanised Water Supply—urbanised water supply is a capital-intensive process with long-term life expectancy assets with utilisation rates that may be ending.

A key component for infrastructure management is the need to create a balance between proactive investments and the financial constraints placed on them by the utility rate structure. In addition, the appropriate investment must be made early enough to avoid a situation similar to what has occurred in many urban areas with failures to respond to warnings surrounding an

impending crisis or what has been defined as a "slow onset disaster".

Non-Revenue Water (NRW) is one of the biggest economic challenges for water utilities everywhere. NRW represents the total difference between the quantity of water distributed in the system and the quantity being billed to customers.

NRW is comprised of both physical losses (pipe leakage and breaks) and commercial losses (theft of service, unmetered usage, billing errors). NRW is estimated to be approximately 126 billion cubic meters, and the total annual costs to utilities of NRW globally are approximately \$141 billion.

In order to optimally manage NRW, the Economic Level of Leakage (ELL) must be determined, where the cost for additional efforts to reduce leakage exceeds the benefit of the water saved. In many developing countries, the revenue per unit of water is considerably higher than the variable cost for each water unit produced.

As a result, utilities typically can realise more financial benefits through the recovery of commercial losses (increased revenues) than through the reduction of physical leaks (decreased production costs).

In addition, urban water systems are heavy users of energy. The costs of electric power for producing, distributing, and treating water contribute significantly to the overall operating expense of these utilities, between 5% and 40% of the total operating budget of a utility.

Water and wastewater systems in the United States account for approximately two per cent of the total energy use in the nation and produce over 45 million tons of greenhouse gases each year. Pumps consume approximately 90 per cent of the electrical energy used by these systems.

By improving energy efficiency, the amount of electrical energy consumed by pumping can be reduced by five per cent to twenty-five per cent. This has the potential to create a high return on investment with a payback period of between several months and several years.

As cities continue to deal with the overuse of their natural freshwater supply (i.e., rivers, lakes, etc.), they will likely turn to new technology options - non-conventional water supply technologies - to supplement these supplies (less expensive).

Traditional supply sources remain the least expensive to operate (average USD \$0.10 - 0.50 per cubic metre); however, newer technologies, including the desalination of seawater (USD \$0.50 - 2.50 per cubic metre) and recycling/reclaiming of processed wastewater (USD \$0.30 - 1.15 per cubic metre).

Due to its close proximity to many urban centres, wastewater recycling also allows for reduced costs associated with transporting water over long distances (the average Benefit-Cost Ratio for wastewater recycling available for irrigation applications is 17.02).

Thus, while offering reliability (especially during periods of water shortages), desalinated seawater has a significantly lower BCR than recycled wastewater (average of 4.05) due to higher energy consumption and environmental impacts related to disposal of saline brine.

The introduction of Smart Water Management (SWM) Technologies represents the next generation in technology solutions for the water sector. Smart water meters (AMI) provide continuous monitoring and streaming of usage information and assist the water distribution system with the detection of leaks, forecasting future demand and optimising the distribution system, leading to a 5% to 22% reduction in total annual water use through the installation of smart water meters.

A trial project in Singapore utilising smart meters coupled with an app that incentivised water conservation demonstrated a 5% decrease in daily water use. The cost associated with implementing smart meters ranges from \$350 to \$2,000 per smart meter; however, the average time frame for an investment to provide a payback associated with decreased labour costs and reduced leaks is 2-5 years.

### **Institutional Frameworks and Financial Innovation**

Public-Private Partnerships (PPP) and Performance-Based Contracts (PBC) are two options that have been developed as a way to enhance the performance of utilities.

A Public-Private Partnership is a contract that will last many years, allowing both the public and private sectors to collaborate on delivering water services through the deployment of technology and human resource expertise. PPPs have been successful in providing piped water service to over 24 million people in developing countries since 1991.

Performance-based contracts are specifically designed for NRW reduction. Under a Performance-Based Contract, a private firm is hired to complete a loss reduction program with payments made on the basis of measurable outcomes.

Research indicates that PBCs executed by private companies with specific water loss expertise will achieve 68% greater levels of water loss reduction compared to programs executed solely by the utilities.

An example of a Performance-Based Contract is one that was initiated in Ho Chi Minh City in 2009, which achieved a water savings of 122 million litres per day, for an investment of only \$15 million. In contrast, the cost to produce this same volume of water through new water plants would be \$120 million.

Innovative financing mechanisms such as Blue Bonds are being used to help fill the gap in financing required for SDG #6 (water and sanitation). Blue Bonds are debt securities that are issued by governments or Corporations to fund Marine and Freshwater Projects with long-term sustainability goals. In 2022, BKR

Ambiental in Brazil issued the world's first Blue Bond designed for the Sanitation Sector, at a value of US\$365 Million, with the goal of reducing water waste over 20 years by 25%.

### **Informal Economies**

In many developing urban areas where the public network of piped water fails, the informal Tanker Water Market has emerged as a “supply of last resort”. These informal markets provide an essential service, but they create an enormous cost for the poorest residents.

The price of water from Tankers is between 8 and 24 times higher than from Piped Water.

In Jordan, Tanker Water Markets account for 52% of the total money spent by Households and Businesses on Water, even though they only provide 15% of the total water supply.

“Water-poor” Households (those receiving less than 40 l/d of piped water) spend 16%-20% of their monthly income just on purchasing water from Tankers. In addition, Tanker Water Suppliers take from Ground Water Sources without limit, leading to depletion of Aquifers beyond capacity.





# CONCLUSION

Concluding the Assessment of Water as a Critical Economic Asset.

# Conclusion

While the composition of water is simple, its properties are incredibly complex and it is one of the most necessary and useful resources available for creating the human existence and the economic development we currently experience. The information provided in this report demonstrates that water is more than a basic human or animal need; it is one of the major foundations of our economies because it facilitates the agricultural, industrial, energy, employment, as well as societal well-being.

The role of water reaches well beyond its use in households; it is also a major component in economic systems and has a significant impact on, and therefore will continue to have a significant impact on, the productivity, growth and sustainability of the world's economies.

**Economic Resource Category:** From an economic perspective, the use of water can be described in two broad categories: i.e., consumption goods and factors of production. For example, agriculture is a primary food production sector that relies heavily on water (and specifically groundwater) and provides food security and rural livelihoods. There are also many industries, including textiles, thermal electric generation, iron and steel and pulp and paper, that are dependent on water for cooling, cleaning and manufacturing. The simultaneous role of water as an

economic resource of both consumption and production illustrates its unique duality; it is both an essential core to sustaining life and an integral part of driving the economy. However, the extensive dependency on water creates a level of vulnerability in that an interruption in the availability of water will have a ripple effect across every sector of the economy.

In the past, water has had a defining impact on the rise and fall of civilisations, as seen in the example of the Indus Valley Civilisation, which had developed advanced management systems for water through their wells, drainage systems, and irrigation networks, leading to agricultural surplus and urban growth. There were other historical periods of time like during the Mauryan and Mughal Empires that demonstrated similarly sophisticated systems of governance and infrastructure for water as well. These history lessons illustrate a significant principle: The societies that manage water well are successful while those that do not are unsuccessful. The shift to seeing water as a commodity in the colonial period displaced the previous approach of ecological balance to exploit the economic benefits of water, creating a paradigm that continues to shape today's water management systems.

Today, the issue of water represents many new challenges. There are many contradictions regarding the

availability of water in India; some areas are very rich in water while other areas suffer from extreme water shortages. There are many reasons that have contributed to the disparity of water availability in India such as geographic misallocation of water resources, overreliance on the monsoon to provide seasonal rainfall, and a lack of adequate water supply infrastructure.

The fact that India's per capita water availability has decreased so dramatically, from more than 5,000 m<sup>3</sup> per person in the 1950's to close to the water-scarcity range today, has created an urgent problem. And in some cases, the excessive withdrawal of groundwater to meet agricultural needs has resulted in severe depletion which further reinforces the notion that water is a common-pool resource that is subject to overexploitation.

The impacts of a lack of available fresh water are very broad-reaching. For example, having limited water supply can create lower agricultural production, higher costs to extract and use water, a drop in industrial productivity and job losses. Also, in addition to all these direct impacts, lack of access to water can create large opportunity costs for vulnerable populations, particularly women in rural areas, who will often spend their entire day trying to collect water, a task that, if able to use that time for education or other income-generating activities, would change their economic fortunes. From an overall macroeconomic perspective, a shortage of water will restrict GDP growth, disrupt supply chains and

create increases in price volatility, and thus presents a key barrier to achieving long-term economic growth.

The social impacts of lack of water access are equally important. As explained in this study, lack of access to fresh water can contribute to increased levels of poverty, cause movement of people from where they currently live to other areas and cause increased levels of inequality between men and women. In times of water scarcity, vulnerable populations tend to use untreated water and as a result develop health problems, which, in turn, creates additional medical expenditures and crisis situations. Water-stress migration can also disrupt families and lead to abuses (e.g. various forms of modern bonded slave labour) of individuals during migration. Therefore, it is evident that the social aspects of water scarcity make this an issue of not only an economic or environmental nature, but also of a humanitarian nature that disproportionately impacts the most disadvantaged groups in society.

The report discusses water pollution as a negative externality (classic case of market failure) and mentions how industries and households will discharge pollution into water without having to pay for the full social cost of that pollution; resulting in degraded-quality water, which will pose major threats to human health and nature. Because of the lack of strict enforcement and pricing of discharges into water will be causing an effective subsidy to the polluter and taking away from society to cover

these additional impacts. Therefore, stronger legislation, better monitoring and internalising the environmental costs must be established as part of a solution to the water pollution issue.

In this regard, the policies, laws and regulatory bodies play an important role. India has developed several frameworks such as the National Water Policy and the Water (Prevention Control of Pollution) Act that support sustainable water resources. While these policies have provided a good conceptual basis, their effectiveness in implementation has been limited due to inefficiencies in organisations, lack of funding and lack of coordination between agencies and jurisdictions. Thus, the challenge will be to bridge the gap that exists between the policy and implementation for effective water governance.

The pricing of water is one of the most widely discussed topics in water economics. In the context of pricing water as an economic commodity versus water as a basic human right, the report shows a considerable amount of tension. On one hand, pricing either free or heavily subsidised water encourages over-utilisation and waste, especially in agricultural areas where most of the water is used for growing crops that require large quantities of water but are grown in water-scarce regions. Conversely, if water is only priced on the basis of what the market will bear, the lowest-income people may be excluded from using it. Controlled, regulated pricing structures such as Increasing Block Tariffs provide a

means of combining equitable access with the efficient use of water by charging lower rates for the basic amount of water needed for survival and higher rates for excessive quantities.

The future will likely see an increase in water productivity. The demand for water from every sector continues to grow, and in order for there to be sustainable development, we must increase the efficiency of our use of water. This requires advanced irrigation methods, industrial recycling and re-use of water, investment in technologies that use less water, and consumer behaviour changes. Technological innovations, combined with institutional changes, can potentially revolutionise the way we deal with water-related issues.

To summarise, water connects economic development, social equity and environmental sustainability. Because water affects people and the environment in many ways and in many locations, it is the most important resource for the future of humankind. Water scarcity, pollution of surface and groundwater, and mismanagement of this resource mean that it needs to be addressed immediately through coordinated efforts at the local, national and international levels. Sustainable water management requires a comprehensive approach that combines good pricing arrangements, strong regulations, the use of new technologies, and active community engagement.

Ultimately, how societies manage

their use of water will ultimately determine the future trajectory of society's development. To develop well-designed policies that are efficient and fair, societies must recognise water not just as a natural resource for sustaining life, but also as an economic resource that can be used to generate income, and as a human right that all people should receive. Providing for a sustainable supply of water to future generations should not just be seen as an environmental or economic necessity; it is also the moral obligation of current generations to provide for the sustainable supply of clean, safe, and affordable water to future generations.

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