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Technical Report

Challenges and Opportunities for Catalysing Corporate Water Stewardship: Cauvery Basin

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The CEO Water Mandate, an initiative of the United Nations Global Compact, has partnered with a number of leading global companies to launch an industry-driven, CEO-led initiative, the Water Resilience Coalition. The Coalition aims to preserve the world's freshwater resources through collective action in water-stressed basins and ambitious, quantifiable commitments. As part of this initiative, the Water Resilience Coalition has undertaken analyses to understand the status of water-stressed basins across the world in order to drive water-related collective action among companies with the goal to create positive impact in 100 basins across the world

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The authors conducted this work when they were with the Centre for Social and Environmental Innovation at the Ashoka Trust for Research in Ecology and the Environment (CSEI-ATREE). WELL Labs is now taking it forward in collaboration with ATREE.

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Executive Summary

The Cauvery is a fast-urbanising basin in South India. Some of the major cities in the basin include Bengaluru, Mysore, Coimbatore, Tirupur, and Tiruchirapalli. The river basin is economically important as it has some major manufacturing units, IT industries, and agricultural areas.

This report contributes to a broader effort to mitigate water stress through facilitating corporate water stewardship by the Pacific Coalition, Pacific Institute, and the UNGC CEO Water Mandate via the Water Resilience Coalition. The Water Resilience Coalition's ongoing corporate water stewardship programme is an attempt to catalyse collective action in water-stressed basins toward the most pressing water challenges. The report presents our current understanding of six water challenges in the river basin. Water quality issues and water stress were identified as the main areas of concern. Opportunities to address these water challenges have also been identified.

In the Cauvery basin, the following three challenges were identified:

First, pollution due to the release of untreated sewage and industrial pollution into surface water bodies is a major concern as most sub-basins have low treatment capacity. Insufficient monitoring also results in many water bodies being neglected.

Second, huge amounts of freshwater are being abstracted by the agricultural sector. A major portion of this freshwater is drawn from the groundwater, which increases the level of stress. The lack of groundwater monitoring and regulation systems in the basin worsens the situation. This, in turn, affects the baseflow in many rivers.

Finally, fragmented water governance in the basin results in poor interagency coordination needed to address the links between energy and water, surface and groundwater, water sourcing and wastewater treatment and water services delivery and water source sustainability. The limited availability of platforms for stakeholder participation is another reason that only bureaucrats make management decisions, resulting in top–down approaches to water-related challenges.

Table 1.1: Summary of the major water challenges identified in the Cauvery basin

Water challenge	Major issues identified
WASH	• About 27.3 million people in the basin do not have access to functional tap connections. The primary reasons identified for this

	are inadequate infrastructure, contaminated sources of water, and a lack of coordination between government departments. ● About 12.1 million people in the basin do not use safe sanitation facilities. The primary reasons identified for this are the lack of adequate water sources as well as caste and cultural biases, especially in rural areas.
Water quantity	● All sub-basins are at a medium level of stress except for the Aiyar and Cauvery delta which have a high level of water stress. The basin is about 23.8 billion cubic metres (BCM) of water short every year to remain within safe limits of use. The primary reason for this is the rise in the growth of water-intensive crops in dry regions, leakages in the supply system due to old infrastructure, and the lack of monitoring and regulating systems for groundwater abstraction.
Water quality	● The treatment capacity in the basin is only 11.7% of the total effluents being generated. About 7723 million litres per day (MLD) of wastewater in the basin is not treated. The primary reasons for this are the lack of funds for the maintenance of treatment plants, the low skill level of the maintenance staff, and insufficient data on the amount of sewage being generated, which is necessary to plan for treatment capacity. ● Over 99% of lakes and rivers do not have water within the quality standards; this can damage ecosystem function or human health. The salinity of 86.7% and the nitrate levels of 48.6% of monitoring wells are above the permissible limits. The primary reason for this is inadequate monitoring of water bodies and a lack of sufficient centralised and decentralised treatment facilities.

Opportunities

Based on the assessment of the baseline indicators in the Ganga basin multiple opportunities for collective action were recommended. For solving the issue of water quality, increasing the capacity of treatment of wastewater and treatment of geogenic and industrial contaminants is needed. Nature-based solutions are needed to be installed across the basin to ensure water bodies have good ambient quality. To solve the water quantity issues, assistance needs to be provided to help farmers make sustainable transitions to low water using crops that also earn sufficient income. Recharge in the basin also needs to be increased, particularly of flood waters and potentially treated wastewater.

Chapter 1: Introduction

The Cauvery basin is the fifth-largest river basin in India, covering an area of about 87,300 sq. km. About 42% of the river basin is in Karnataka, 54% in Tamil Nadu, and the rest in Kerala and Puducherry. The river is about 800 km long and has multiple tributaries. Given that the river basin falls within the borders of multiple states, there has been a decades-old inter-state water conflict among the Cauvery basin riparian states. The river basin is divided into 11 sub-basins – Aiyar, Amaravati, Arkavathi, Bhavani, Cauvery Delta, Kabini, middle Cauvery, Noyyal, Shimsha, Thirumanimuthar, and upper Cauvery.

The population in the basin is about 45.6 million, with 51% residing in urban areas and the rest in rural areas (Census 2011). Some of the major economic activities carried out in the basin include agriculture and industries (textile, food, beverages, and transport equipment). Some of the notable companies active in the basin are as follows: Clariant Chemicals Limited, Wipro, Hindustan Coca-Cola Beverages Private Limited, Ultratech Cement, and Tamil Nadu Newsprint and Papers Limited.

Of the total area in the basin, 2% is urban land, 47.4% is used for agriculture, and 24.8% is covered by forests. In recent years, land use in the basin has increasingly tended towards urban and industrial use and the focus of agriculture has shifted from rainfed to plantation crops. These changes have had an impact on the water resources in the basin.

There are multiple water challenges in the basin. Identifying them helps to prioritise the water issues to which businesses can contribute. Using performance metrics and targets, businesses can make basin context–specific efforts that they can align with those of other stakeholders. This report, therefore, maps out the challenges in the basin and opportunities to address them through collective action using six themes: i) WASH, ii) water quantity, iii) water quality, iv) important water-related areas, v) water governance, and vi) water crisis. For each water challenge, there are different basin context metrics. Further, for each basin context metric or indicator used, the state of each sub-basin, challenges, gaps, and opportunities for businesses have been described. Along with this, the current and desired states for each basin context metric have been laid out. An analysis of each sub-basin was conducted using secondary data available on government websites, Geographical Information System (GIS) layers, and a review of the literature.

The Sustainable Development Goals or SDGs were agreed upon by world leaders in the year 2015. The 17 goals aim at creating a better world by the year 2030 by ending poverty, fighting inequality, and addressing the urgency of climate change. The 6th goal focuses on ensuring availability, sustainable management of water and sanitation for all, wastewater and ecosystems, and acknowledging the importance of an enabling environment. Each water challenge was analysed using various targets under this goal as indicators.

Base layers

The basin, sub-basin, stream, and river networks were delineated using the Cartosat DEM version 3 in the ArcGIS software. The district shapefile was downloaded from the Bhuvan-2D archive, compared with secondary data on government websites, and corrected accordingly (e.g. new districts were digitised). The district shapefile was then combined with the secondary data using the GIS tool. Values at the district level were then brought to the sub-basin level using the 'Tabulate Intersection' tool to get weighted averages.

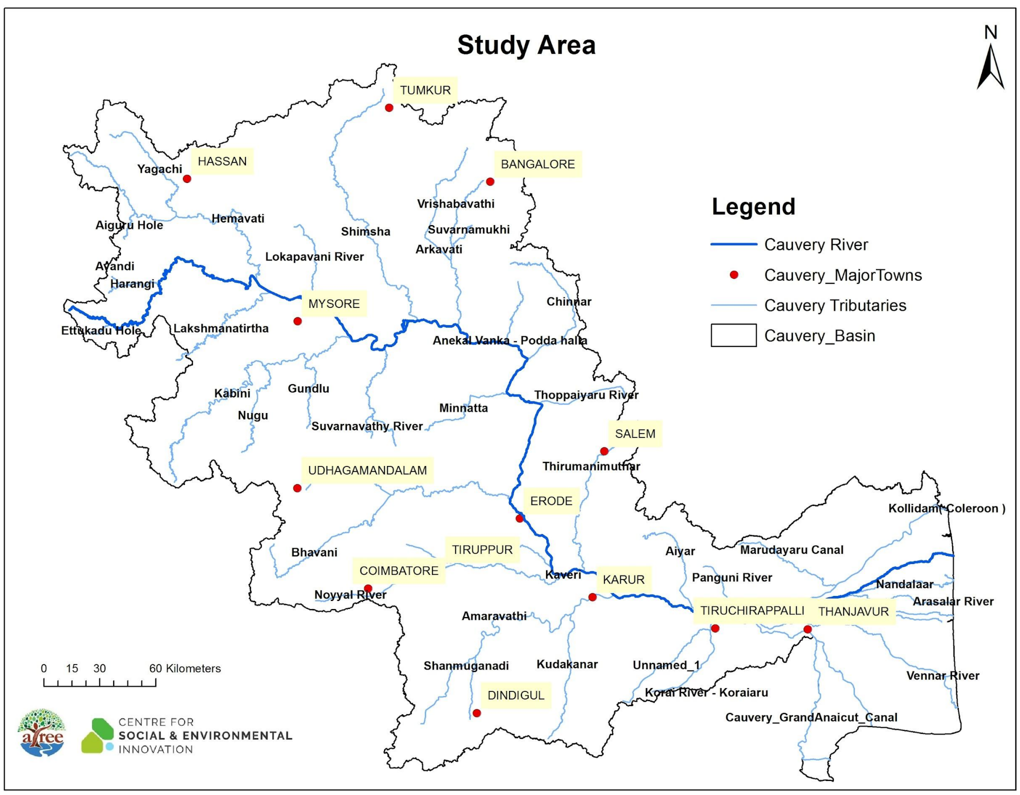

Figure 1.1: Study area map showing the Cauvery basin, Cauvery River, and its tributaries

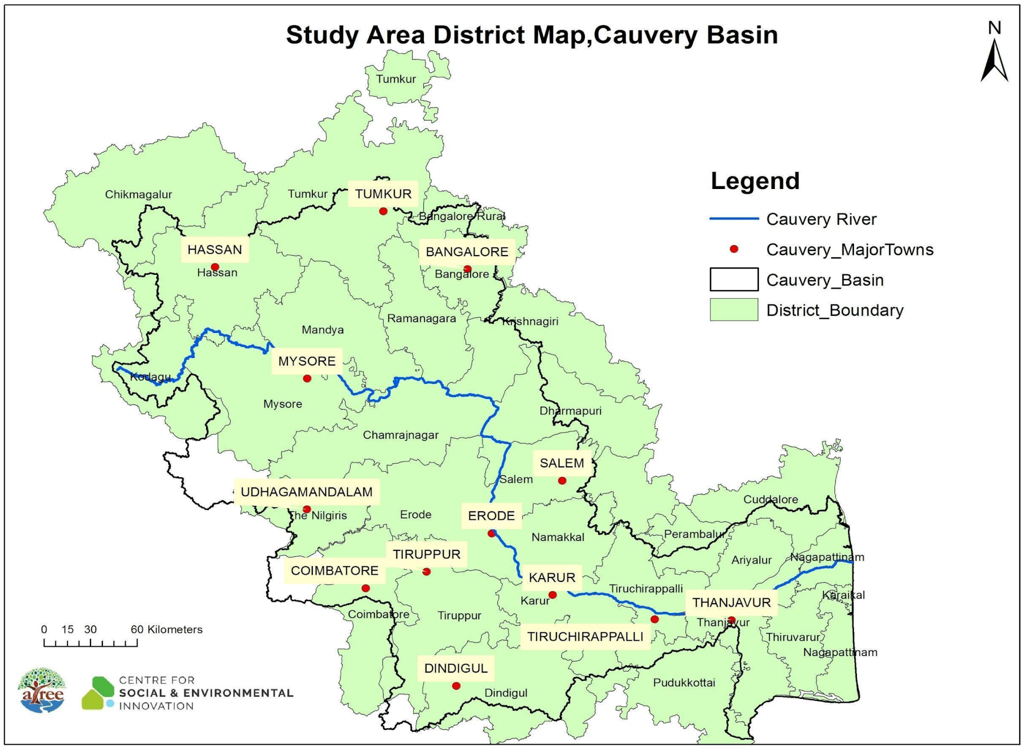

Figure 1.2: Study area map showing the district boundary

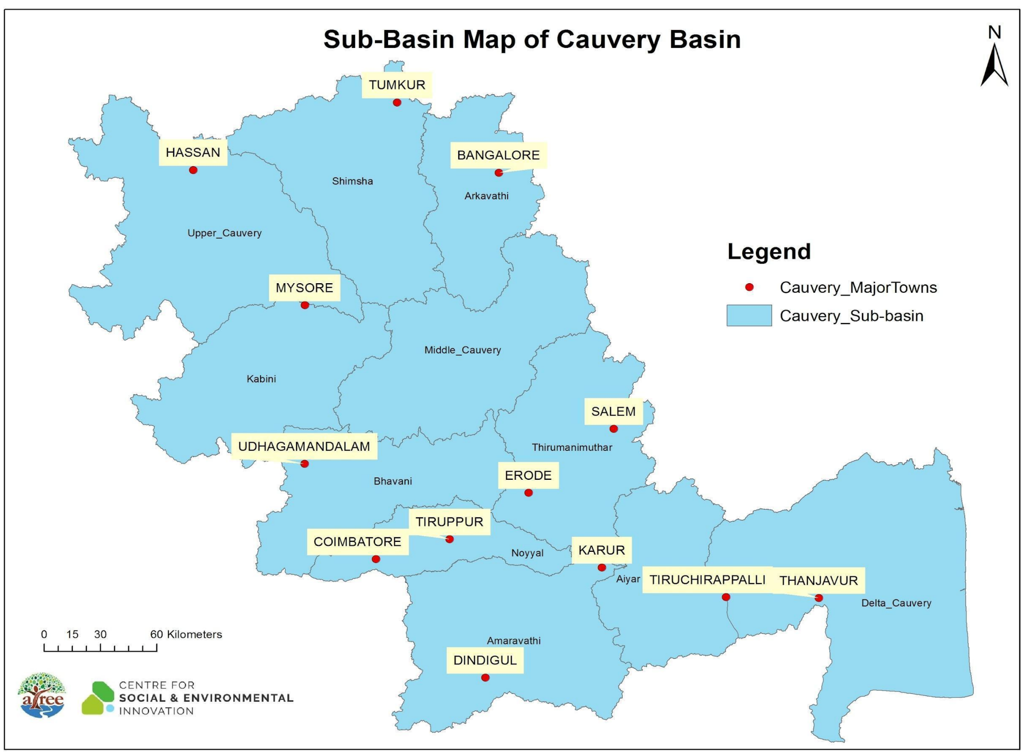

Figure 1.3: Study area map showing the Cauvery sub-basins

Chapter 2: Access to Water, Sanitation and Hygiene

Access to safe drinking water

SDG 6.1 seeks to achieve access for all to safe drinking water. This indicator, therefore, tracks the population that has access to improved drinking water sources including piped water, boreholes or tubewells, protected dugwells, protected springs, rainwater, and packaged or delivered water.

The data on access to functional household tap connections (FHTC) was collected at the district level for all districts in the basin (NJJM, 2022). Using the weighted average method, the values were calculated at the sub-basin level. The percentage of households with functional tap connections was then estimated for each sub-basin.

In the Cauvery basin, 61.6% of households have access to functional tap connections. The Kabini sub-basin has the lowest access, at 45.4%, while the Arkavathi sub-basin has the highest access, at 72.9%. The more urbanised sub-basins have better access to functional household taps.

The Jal Jeevan Mission project by the Government of India aims to provide a functional tap connection with treated water to every rural household for drinking purposes. It aims to ensure access to 55 litres per capita per day (lpcd). Under this mission, which was launched in 2019, the government seeks to enable every household in every village to have an FHTC by 2024 (Ministry of Jalshakti, 2019).

Delays in the implementation are due to a lack of water sources. Most rural areas depend on groundwater from overexploited hard rock aquifers that exhibit sharp seasonal fluctuations – as a source for tap water connections. Even though both the states of Karnataka and Tamil Nadu have made significant progress in increasing access to tap water through multiple schemes, many areas are still affected by declining groundwater levels due to over-pumping and rivers going dry (Kumar, 2019). Most districts in the basin also have contaminated water sources that cannot be used. The contamination has both geogenic and anthropogenic causes (Khambete, 2020).

Some existing gaps in the drinking water sector are as follows:

- There is inadequate infrastructure to raise the service level from 40 to 55 lpcd. There are no source sustainability measures in the form of rainwater harvesting or groundwater recharge structures. Also, grey water management is inadequate, which results in the contamination of water sources.
- Inadequate financial allocation to operations and management leads to the poor upkeep of assets, which ultimately falls into disuse.

- As per the Central Ground Water Board (CGWB), many assessment units are contaminated with nitrate and/or salinity due to both geogenic and anthropogenic causes.
- There is a lack of coordination between the various government departments like water resources, public health engineering, urban development, groundwater, rural development, and rural water supply and sanitation (Ministry of Jalshakti, 2021).

Access to safe sanitation

SDG 6.2 aims to achieve access to sanitation and hygiene for all. This indicator, therefore, tracks the population that has access to improved sanitation facilities including flush/pour flush to the piped sewer system, septic tanks, or pit latrines; and ventilated/improved pit latrines, composting toilets, or pit latrines with slabs.

Data on the number of households with access to toilets (SBM, 2021) and the proportion of the population using safe sanitation services (National Family Health Survey, 2020) was collected at the district level for all districts in the basin. Using the weighted average method, values were calculated at the sub-basin level. Then the following were estimated for each sub-basin: i) the percentage of households with access to individual or community toilets in the region and ii) the percentage of the population living in households that use an improved sanitation facility.

In the Cauvery basin, 100% of households have access to toilets but only 73.4% of the population uses safe sanitation facilities. The Kabini sub-basin has the lowest access, at 63.3%, while the Upper Cauvery sub-basin has the highest access, at 72.9%.

The Swachh Bharat Mission was launched in 2014 with the aim of achieving universal sanitation coverage. The mission has strived to improve the living conditions of people by constructing individual and community toilets and eliminating open defecation (Ministry of Drinking Water and Sanitation, 2014). Complete (100%) coverage of toilets has been possible as the government has created community and public toilets wherever private toilets were impossible to build. Private toilets are difficult to build in many places due to the lack of awareness of the linkage between sanitation and health, the lack of space in which to build toilets in individual houses, and the sheer unaffordability of private toilets, even with external subsidies. While under the mission the government was able to achieve a high level of coverage, most toilets are either not functional or not used. For this reason, the proportion of the population using safe sanitation services has been used to get a better understanding of the on-ground situation.

People in regions with low water availability do not always use safe sanitation services because they prioritise drinking and washing needs over toilets. Many toilets in flood-prone regions become non-functional during seasonal floods. Caste and cultural biases also contribute to the preference for defecating far away, keeping the home pure, and explaining the lack of maintenance of the facilities (Sharma, 2021).

Some existing gaps in the use of safe sanitation services are as follows:

- There are no awareness programmes that address cultural and caste biases.
- There is no reliable source of water.

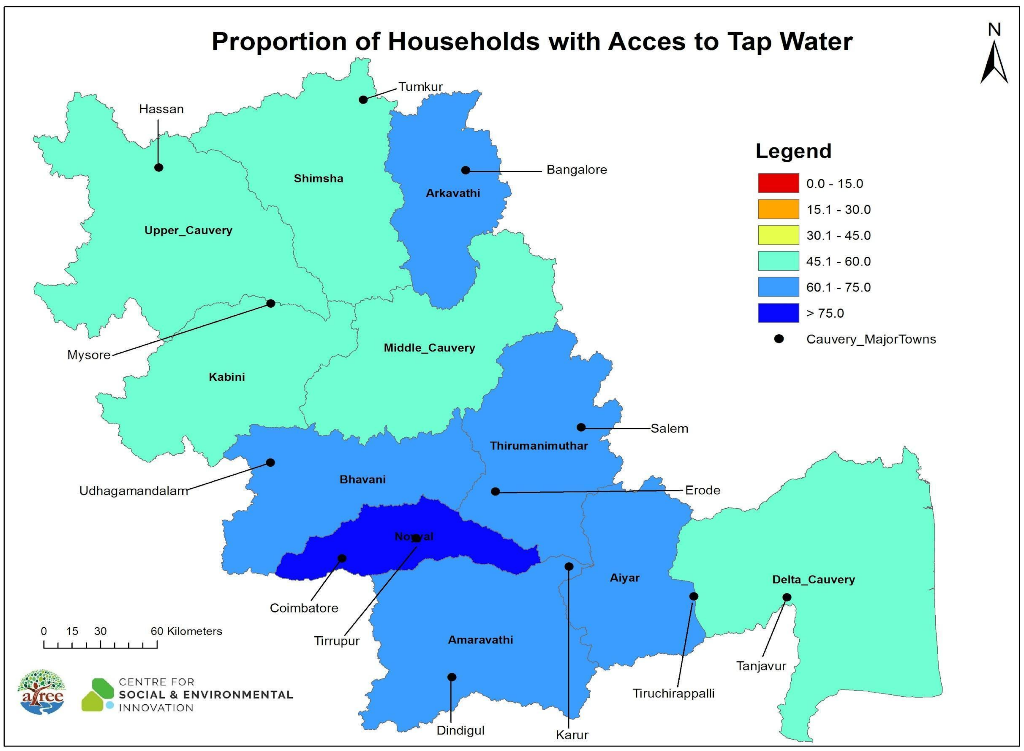

Figure 2.1: Map showing the proportion of households with access to tap water

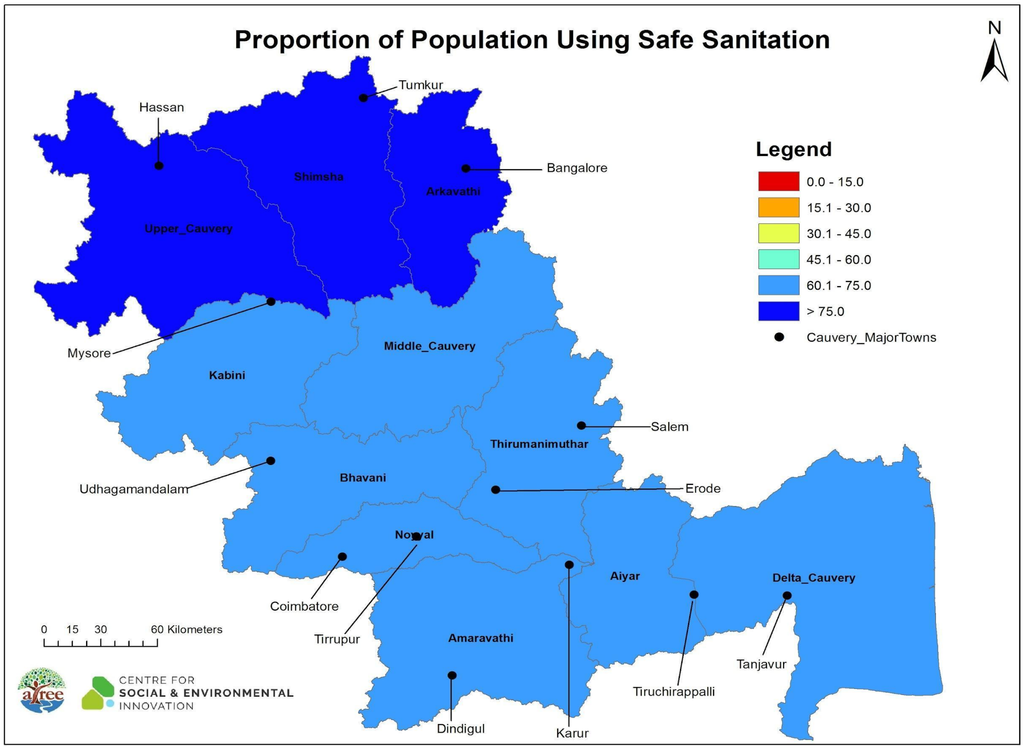

Figure 2.2: Map showing the proportion of the population using safe sanitation

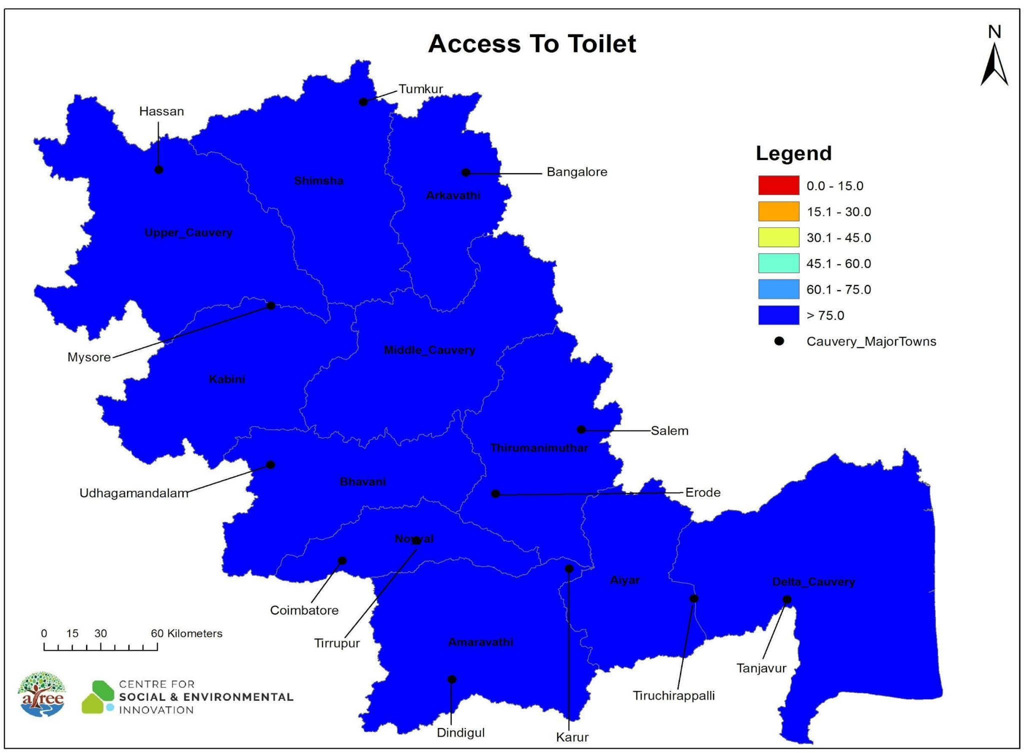

Figure 2.3: Map showing the proportion of households with access to toilets

Table 2.1: Basin Context Metrics- Access to water, sanitation and hygiene

Indicator	Current state	Desired end state
Proportion of the population receiving threshold drinking water services (%)	Around 61.6% of households have access to functional tap connections. About 27.3 million people in the basin still do not have access to functional tap connections.	All (100%) households have access to functional tap connections.
Proportion of the population using safe sanitation (%)	Around 73.4% of the population uses safe sanitation facilities. However, about 12.1 million people in the basin still do not use safe sanitation facilities.	The entire (100%) population uses sanitation services.
Proportion of the population with access to threshold sanitation services (%)	All (100%) households have access to either private or community toilets.	All (100%) households have a water supply and access to functional toilets.

Chapter 3: Water Quantity

Level of water stress

SDG 6.4.2 seeks to ensure sustainable withdrawal and supply of freshwater by tracking how much freshwater is being drawn by all economic activities, and comparing it to the total renewable freshwater resources available.

The amount of water abstracted was estimated for three sectors: agriculture, industry, and domestic. For the agriculture water demand, the data for the area covered under each crop was obtained at the district level. The data for potential evapotranspiration (PET), rainfall (IMD, 2021), and crop coefficient (Kc) was also obtained at the district level. The effective rainfall (ER) table was used to estimate the portion of the rainfall that is necessary to meet crop water needs (Annexure A). The following formulae were then used to estimate the crop water requirement (CWR) and the irrigation water requirement (IWR) for each sub-basin:

CWR = PET × Kc × Area under crop

IWR = CWR – ER

For the domestic water demand the population for each district was obtained. A water demand of 55 lpcd (DDWS, n.d.) and 135 lpcd (CPHEEO, 1999) was assumed for villages and towns, respectively. The domestic water demand for each district was then estimated using the following formula:

Domestic water demand = ((Population in villages × 55) + (Population × 135)) × 365

For industrial water demand, data for the type and number of manufacturing, commercial, and institutional industries in each district was obtained. Data on the number of employees in each establishment was also acquired. The litre per employee per day (lped) coefficient was applied to estimate industrial and commercial water use (R et al., 2021).

Using the weighted average method, the amount of water abstracted by each sector was calculated at the sub-basin level. The sum of the three water demands gave the total water demand of all sectors in the basin.

To estimate the water availability in the basin, the amount of utilisable surface water and groundwater recharge amounts were obtained from government reports(Central Ground Water Board, 2021; Central Water Commission, 2014)

The calculations are done with the assumption that all the water in the basin can be captured for use. The level of water stress was calculated as the proportion of water demand to the total water available after accounting for environmental flows. A threshold of 20% or 40% was used to demarcate medium or high water stress status, respectively (Xu & Wu, 2017).

For total freshwater, the Cauvery Delta and Aiyar sub-basins are at a high level of stress. In terms of surface water abstraction, only four sub-basin are at medium levels to stress. In terms of groundwater abstraction as well, all sub-basins are at a high water stress status due to lack of monitoring and regulation. The presence of hard rock aquifers results in less recharge of water thereby reducing groundwater availability. The total water demand of the agricultural, domestic, and industrial sectors is 65225 million litres per day (MLD). Agricultural water has the highest demand in the basin, requiring around 53625 MLD of freshwater. The domestic sector consumes the second highest amount of freshwater, requiring about 10,766 MLD. Preliminary estimates have shown that the industrial sector in the basin requires about 835 MLD of freshwater.

In many districts in the Cauvery basin, the major crops grown have a high water requirement; the crops include cotton, paddy, coconut, arecanut, banana, and sugarcane. There is rainfed and irrigated agricultural land in the basin, but a significant part is cultivated by irrigation (Directorate of Economics and Statistics, 2018). In the basin, major water consumers among the manufacturing industries are involved in textile, food processing, and beverages. Among the commercial and institutional establishments, which consume about 60% of the water, major sectors include hotels, hospitals, and education institutions (Ministry of Statistics and Programme Implementation, 2013). Most areas in the basin depend on groundwater more than surface water because the temporal and spatial availability of surface water varies. This results in the over-exploitation of groundwater. In all sub-basins, groundwater abstraction exceeds what is available in a year, leading to a year-on-year decline in storage.

Some existing gaps in the efficient use of freshwater are as follows:

- In the irrigation sector, there is no database on agricultural water utilisation. Water efficiency methods like the proper lining of canals, and the use of mulches to save soil moisture, have not been effectively implemented in the basin. The lack of reuse options for irrigated water is another major issue for high freshwater consumption.

- In the domestic sector, water loss is of two types – real and apparent. Real loss includes water lost through leakages in distribution systems, service connections, and storage tanks (including overflow). Apparent loss includes meter and record inaccuracies and unauthorised water use, such as theft and unauthorised connections.

- A lack of efficient cooling technologies, especially in high water demand industries like textile, paper and pulp, and iron and steel, results in the extensive consumption of water. Due to a lack of information, awareness, and motivation, few industries have proactively adopted the available best practices. Improper and irregular water auditing in industries is another reason for inefficient water use (Central Water Commission, 2014).

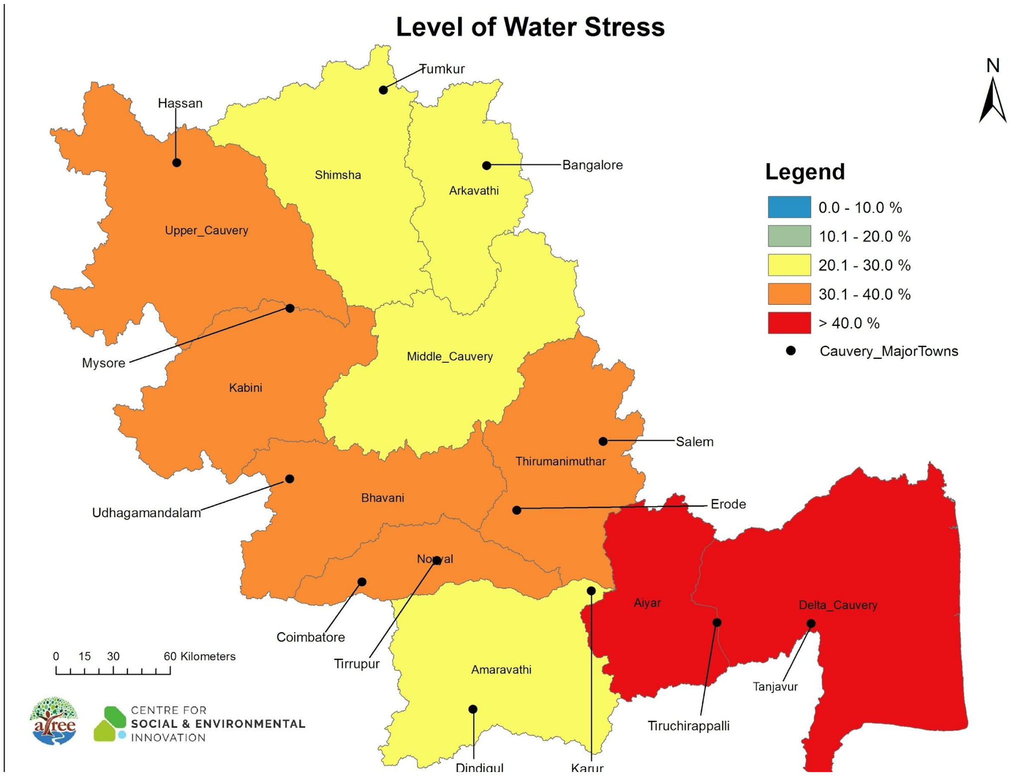

Figure 3.1: Map showing the level of water stress

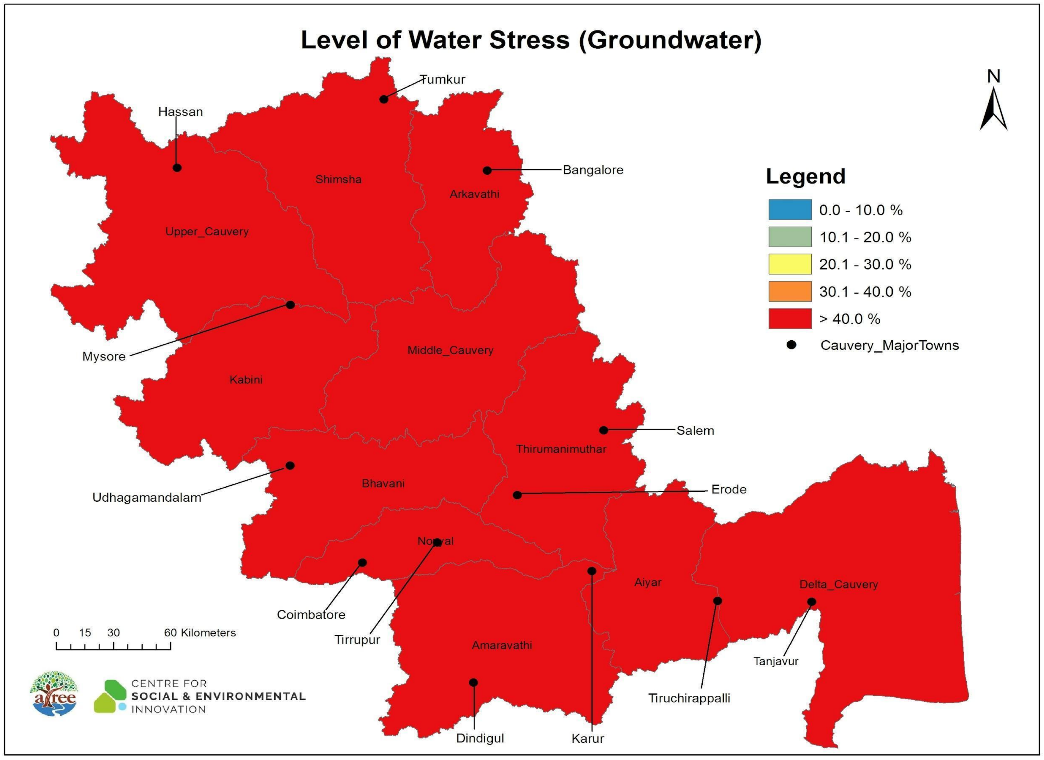

Figure 3.2: Map showing the level of water stress of the groundwater

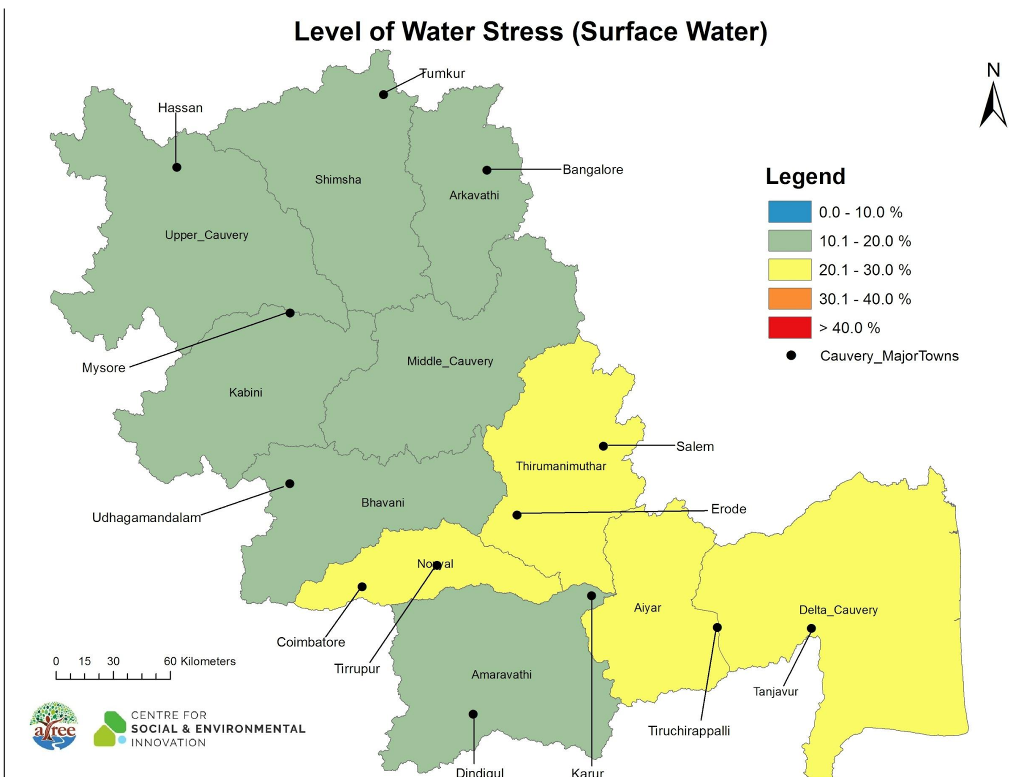

Figure 3.3: Map showing the level of water stress of the surface water

Table 3.1: Basin Context Metrics- Water Quantity

Indicator	Current state	Desired end state
Proportion of unsustainable water withdrawals reduced (%)	All sub-basins are at a medium level of stress except for the Aiyar and Cauvery delta which has a high level of water stress. The basin is about 23 bcm of water short every year to remain within safe limits of use. Groundwater is over-abstracted in all sub-basins. The agricultural sector is a major freshwater user because of the increase in water-intensive crops and leakages from the distribution system. Government subsidies exist for drip irrigation, the practice of which is limited. The zero liquid discharge (ZLD) rule is applicable to dyeing, bleaching units, tanneries, and distilleries. It requires units to recycle and reuse water to the maximum possible extent (90–95%). However, the extent of wastewater recycling practised within these facilities is not known.	1. Less than 20% water stress. 2. Improved water use efficiency for irrigated crops. 3. Improved efficiency in industrial water use through process and technological improvements. Wastewater reuse and recycling wherever feasible or required by the law.

Chapter 4: Water Quality

Treatment of domestic and industrial wastewater

SDG 6.3.1 tracks the percentage of wastewater flows from households, services, and industrial premises that are treated in compliance with national or local standards.

The capacities of all the Sewage Treatment Plants (STPs) and effluent treatment plants (ETPs) in each district were acquired. The water demand of both the domestic and industrial sectors was also obtained. Using the weighted average method, the values were calculated at the sub-basin level. A proportion of the total wastewater generated by the domestic and industrial sectors and the total capacity of the STPs and ETPs were then estimated for each sub-basin.

The amount of effluents generated from the domestic and industrial sectors is 9,448 MLD. Of this, the domestic sector contributes 8,613 MLD of wastewater, and the industrial sector 835 MLD. The existing treatment capacity is around 11.7% of the effluent generation. This shows the dismal state of wastewater treatment, which is a major cause of pollution of water bodies in the basin.

Since states spend huge amounts of money on transferring water from far-off places, they are left with little to invest in sewage treatment. The lack of proper sewage disposal and drainage system is another major factor in why a lot of wastewater is untreated. Many STPs are also not functional due to high maintenance costs. An inadequate power supply also results in the improper functioning of STPs (Dutta, 2017).

Some existing gaps in the wastewater treatment capacity are as follows:

- Union and state governments do not have the funds to bear maintenance costs.
- There is a low level of skill among the maintenance staff.
- The lack of data on the total sewage generated is also a reason why states have not been able to plan for how much capacity is needed for treatment (DTE Staff, 2016).

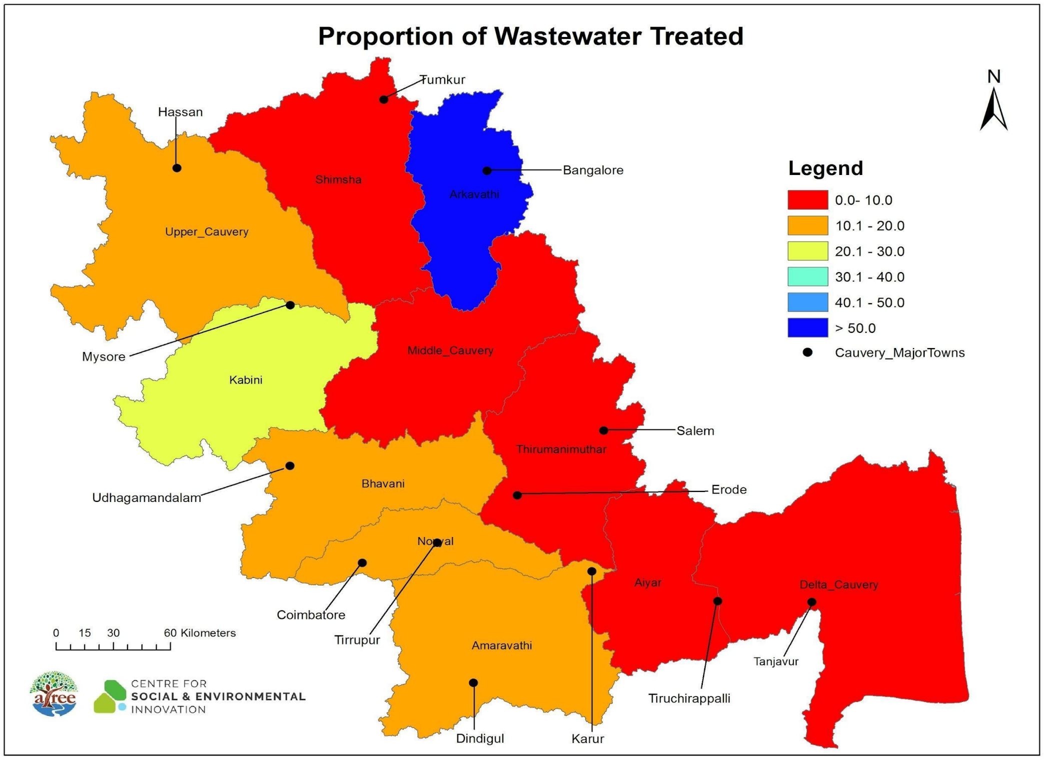

Figure 4.1: Map showing the proportion of wastewater being treated

Water bodies with good ambient water quality

SDG 6.3.2 tracks the percentage of water bodies (rivers, lakes, and groundwater wells) in a country with good ambient water quality. Good water quality according to this indicator is an ambient quality that does not damage ecosystem function or human health. For this indicator, the proportion of lakes, rivers, and groundwater wells with good ambient water was estimated.

The water quality for all lakes, rivers, and groundwater was obtained for different parameters. The water quality of these bodies was then compared with the local water quality standards and SDG targets (Annexure B) to see if they satisfied the standards of good ambient water quality. The percentage of water bodies that meet the good ambient quality standard was estimated for each sub-basin as well. It was found that very little data was available for the water quality of surface water bodies. Among the ones that were reported, it was observed that the overall ambient water quality was bad.

The water quality of the lakes, rivers, and groundwater in the Cauvery basin is sub-par. The lakes in the region are badly affected by the discharge of raw sewage and in some cases even industrial effluents. These discharges make the dissolved oxygen levels in the lakes fluctuate extensively and excess nutrients in the form of nitrates and phosphates create the perfect environment for algal blooms (Jamwal et al., 2021). By causing daily fluctuations in oxygen level they can severely affect the dependent biodiversity like fish and in turn the population dependent on it.

The river system in the basin is slightly better off, as only a handful of stretches of the different tributaries have poor quality water. These parts are primarily downstream from major industrial towns that work with textiles and manufacturing and let out untreated effluents (Sundaram, 2017).

The surface water quality, in general, is also affected by the insufficient water treatment infrastructure in the basin – only around 12% of all the generated wastewater is treated. There need to be significant efforts towards establishing a well-connected framework that addresses the demand for wastewater treatment.

The groundwater in the basin is also of poor quality. The wells are high in salinity and, in some cases, nitrate. In the delta region of the basin, the over-abstraction of groundwater, changes in land use, ingress of seawater into the surface water, and shifts in upstream surface water discharges have resulted in saltwater intrusion from the sea (Central Water Commission, 2011). In areas near the rivers like Noyyal, Bhavani, and Amravati, the groundwater is saline due to high levels of industrial pollution (Sudhakar & Subramani, 2014). In general, regions with high rainfall and good drainage have low salinity problems while in downstream areas the values of salinity exceed their limits. Nitrates in the wells indicate that surface effluents such as domestic waste and agricultural runoff have at some point come in contact with the aquifers (Susiladevi, K, Jayachandran, & Jayanti, 2010).

Some existing barriers to achieving good ambient water quality in water bodies are as follows:

- Data is unavailable for a large number of surface water bodies as they are not monitored.
- The wastewater treatment facilities are inadequate.

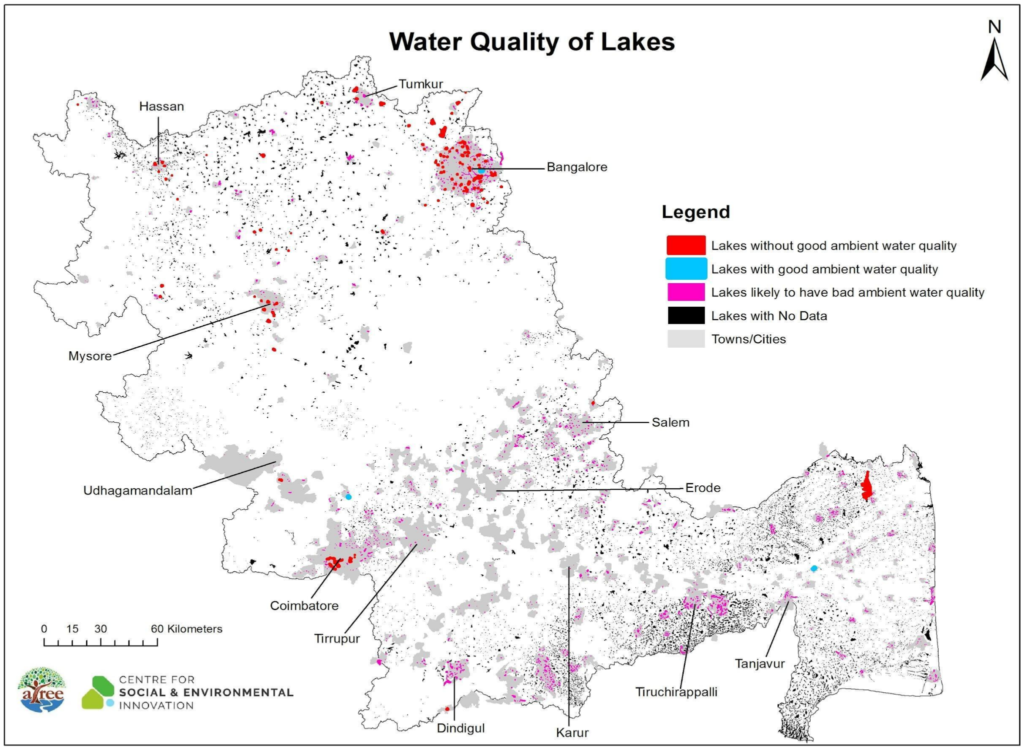

Figure 4.2: Map showing the water quality of lakes

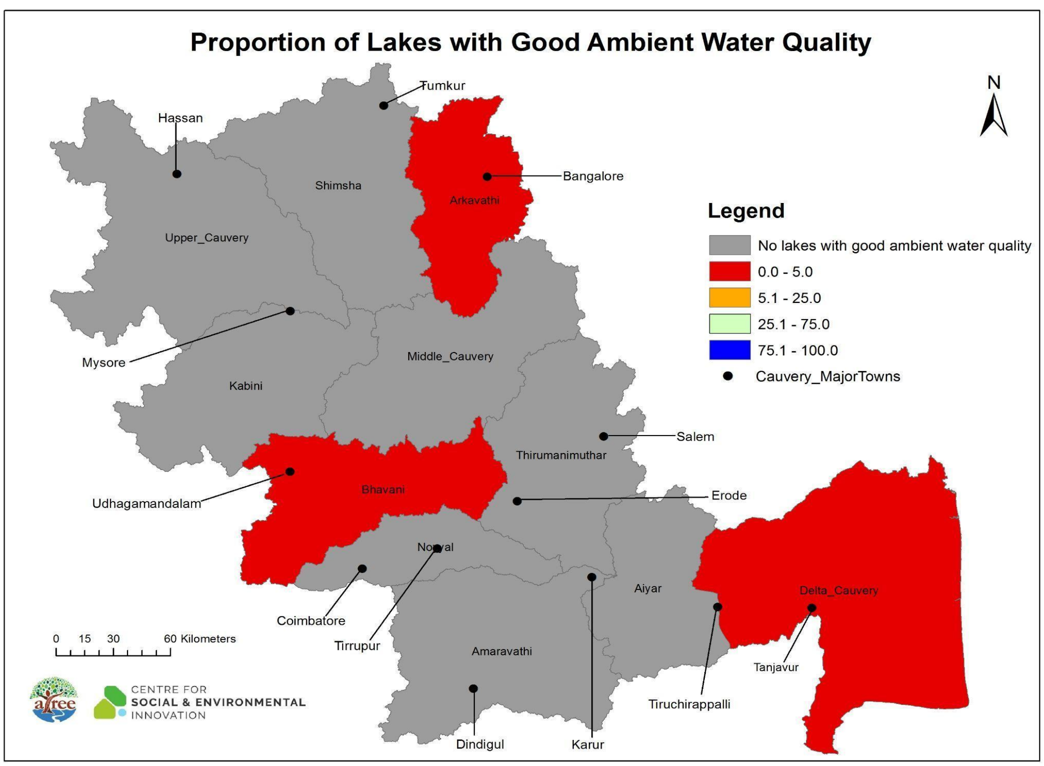

Figure 4.3: Map showing the proportion of lakes with good ambient water quality

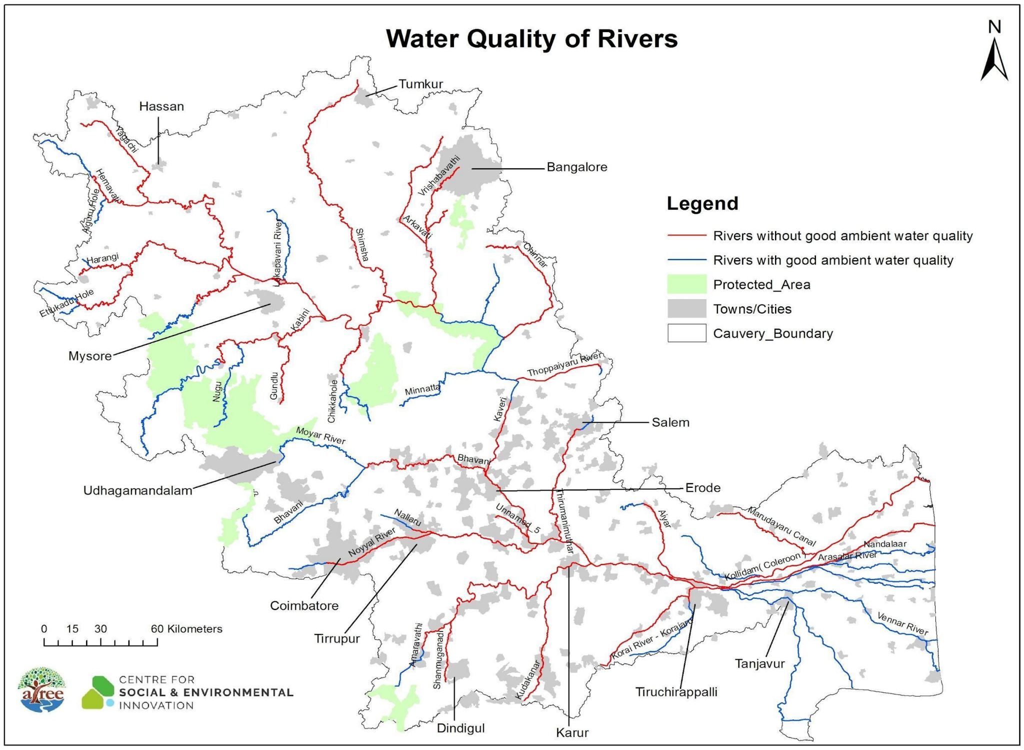

Figure 4.4: Map showing the water quality of rivers

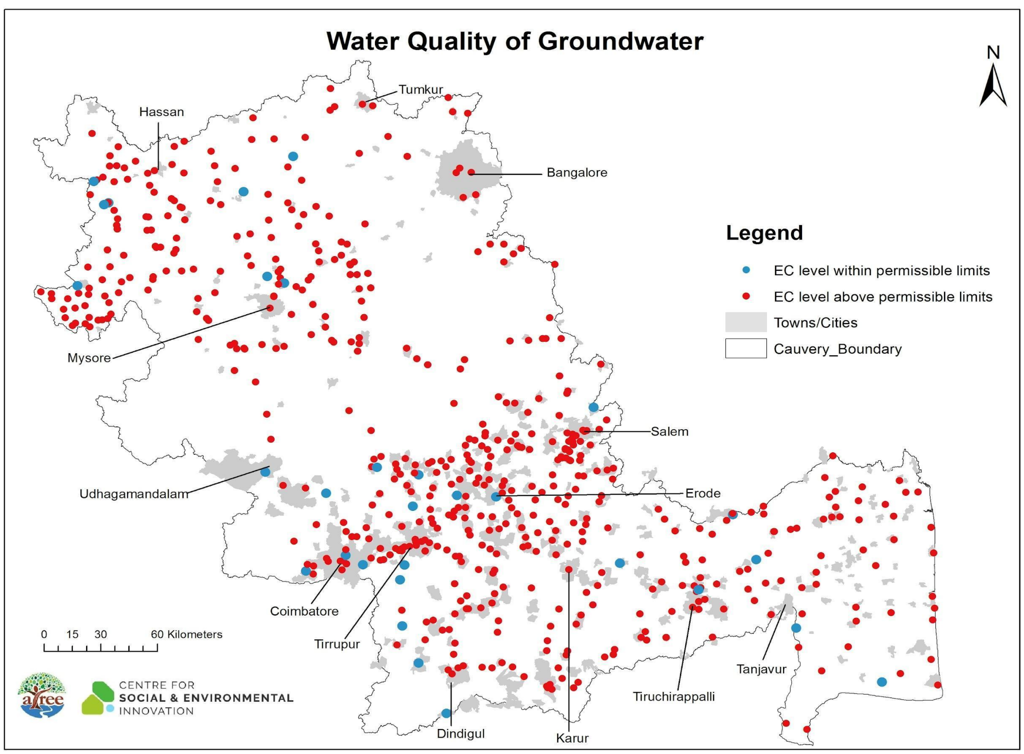

Figure 4.5: Map showing the quality of groundwater – Electrical Conductivity (EC) (SDG)

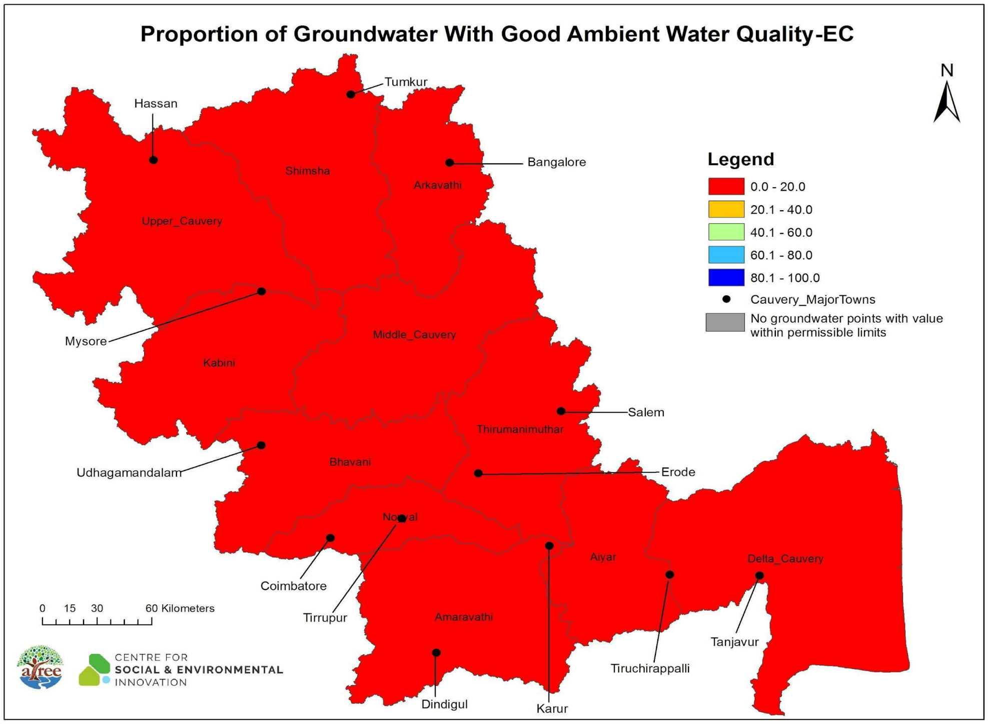

Figure 4.6: Map showing the percentage of groundwater with good ambient water quality – EC (SDG)

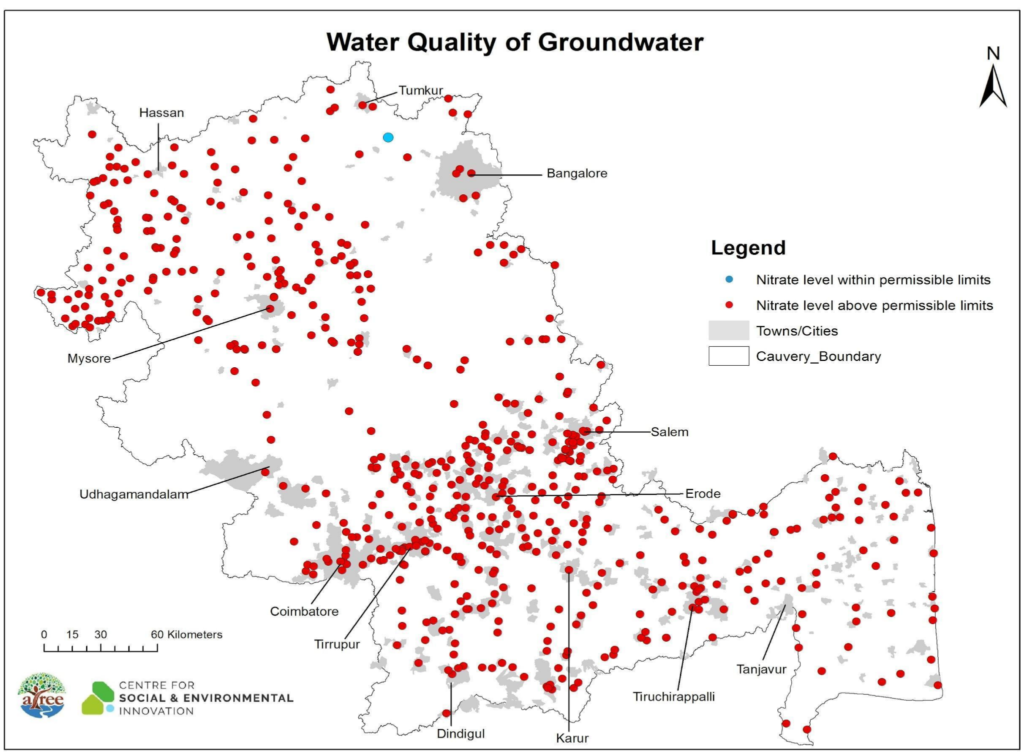

Figure 4.7: Map showing the water quality of groundwater – nitrate (SDG)

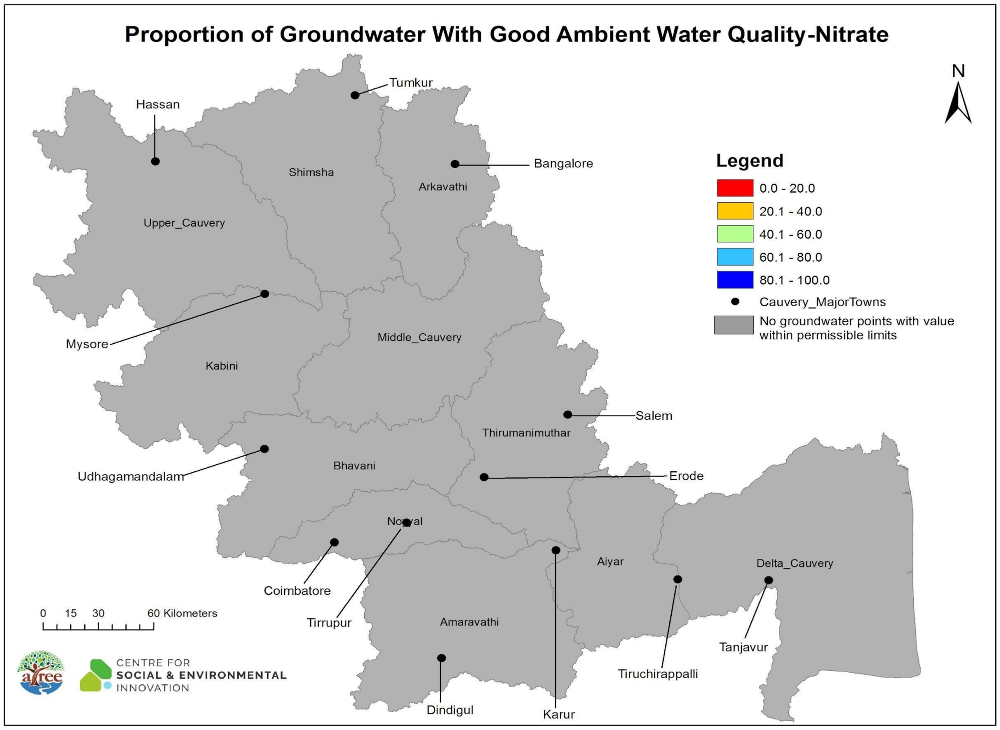

Figure 4.8: Map showing the percentage of groundwater with good ambient water quality – nitrate (SDG)

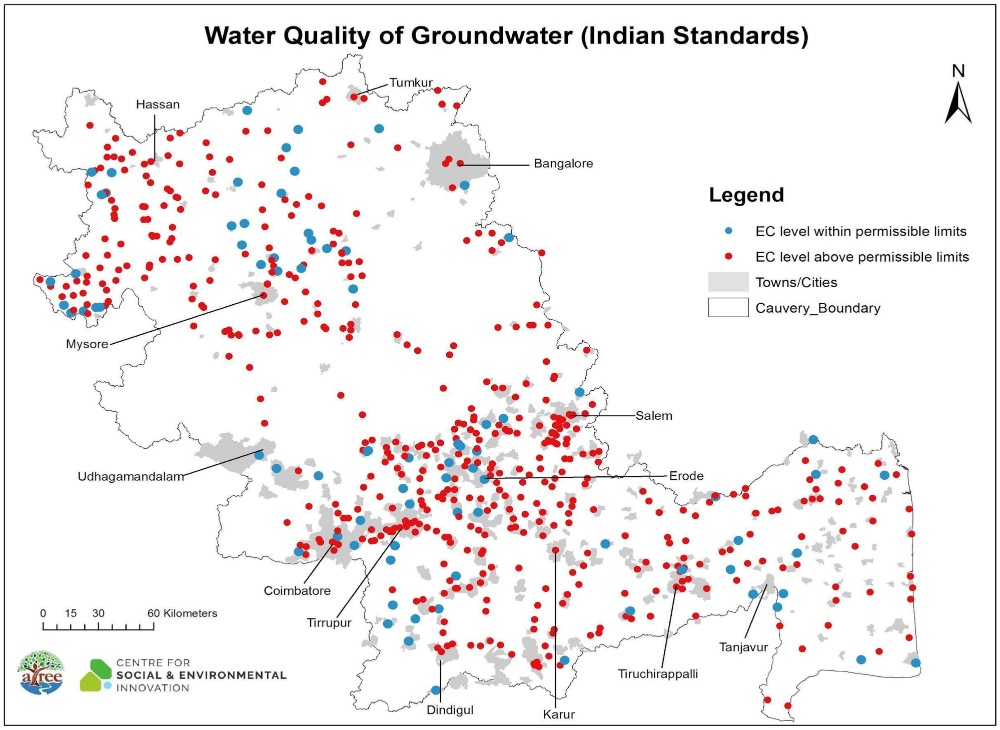

Figure 4.9: Map showing the water quality of groundwater – EC (Indian)

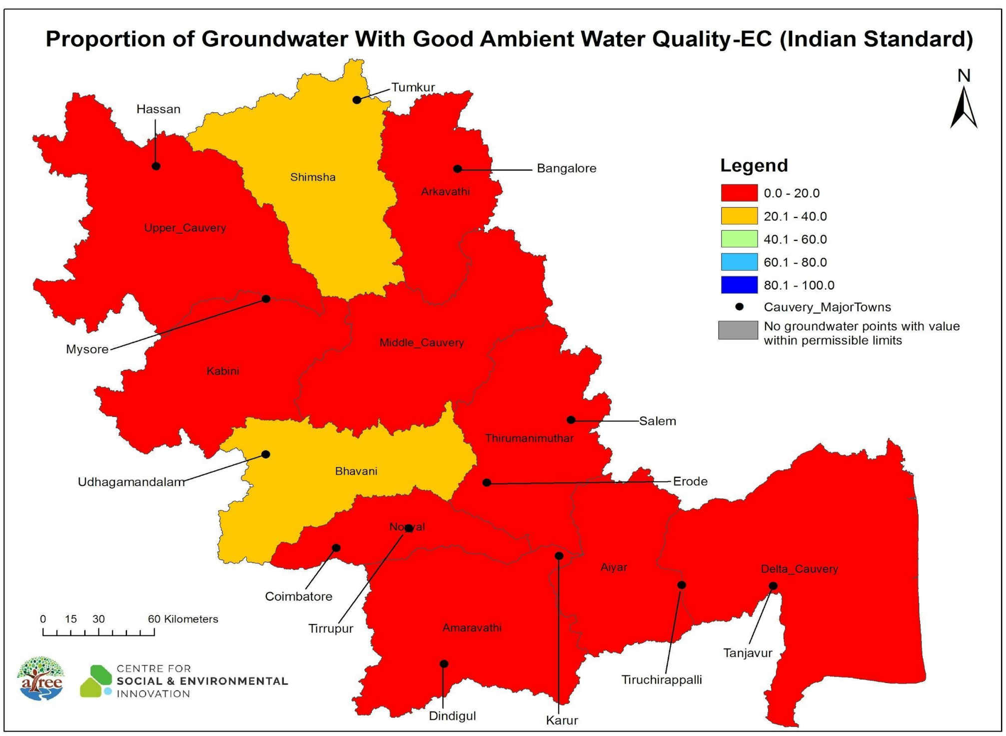

Figure 4.10: Map showing the percentage of groundwater with good ambient water quality – EC (Indian)

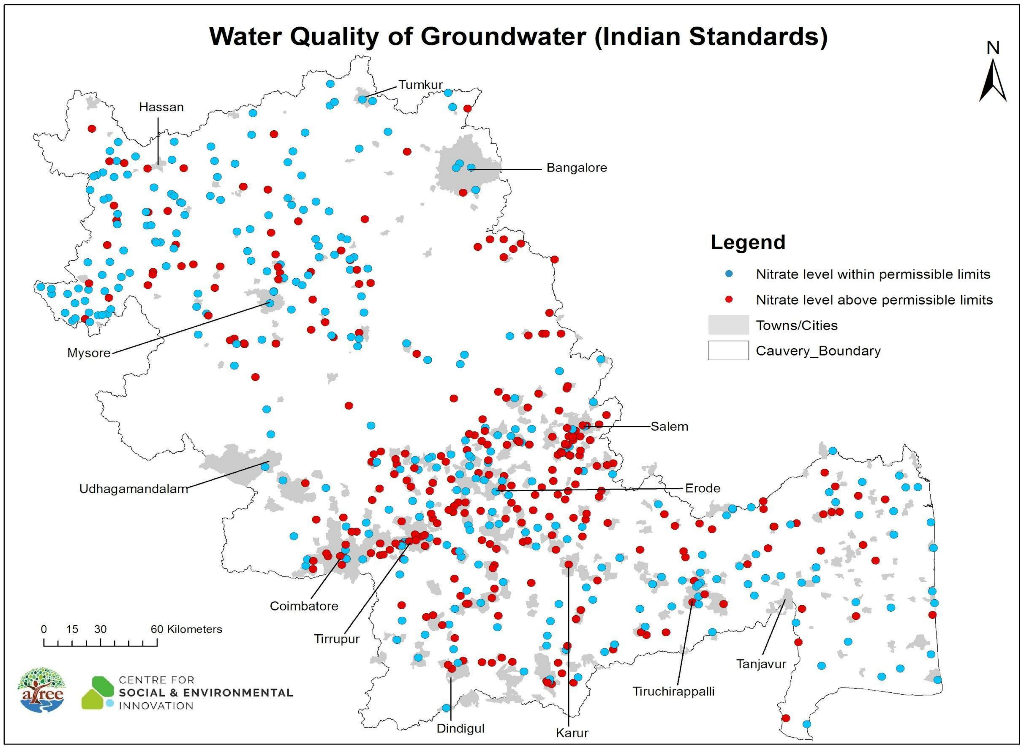

Figure 4.11: Map showing the quality of the groundwater – nitrate (Indian)

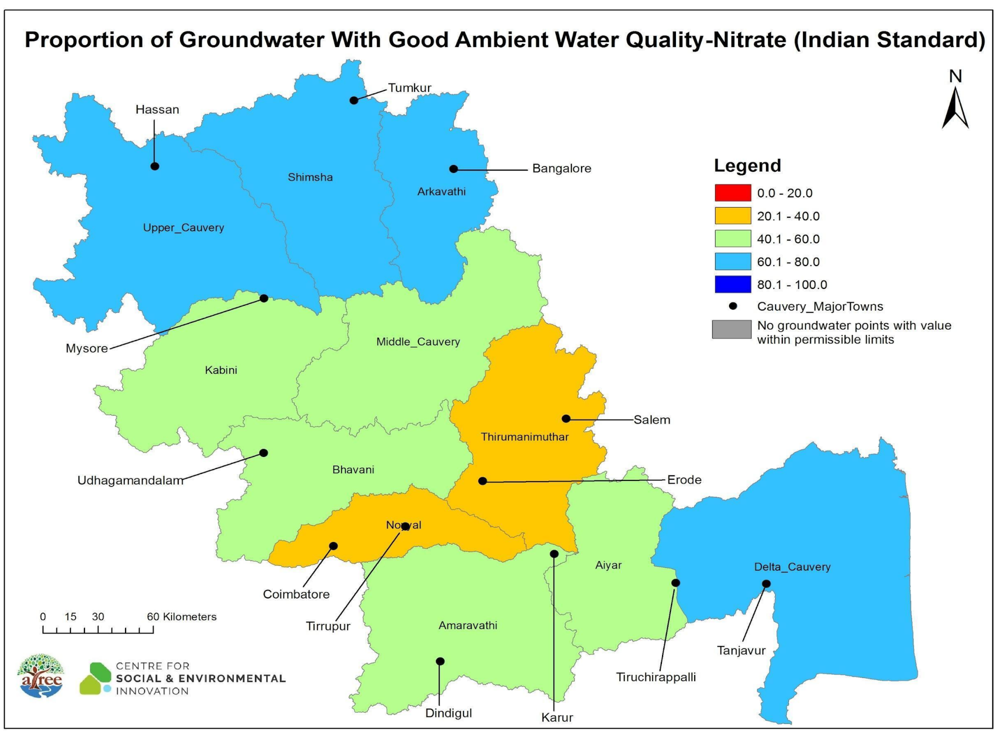

Figure 4.12: Map showing the percentage of groundwater with good ambient water quality – nitrate (Indian)

Table 4.1: Basin Context Metrics- Water Quality

Indicator	Current state	Desired end state
Proportion of excess pollutant removed (%)	Treatment capacity in the basin is only 11.7% of the total effluents being generated. The basin only has the capacity to treat 1108 MLD of the total 8832 MLD of wastewater generated.	1. For urban settlements, 20% reuse and recycling of sewage is the service-level benchmark for Urban Local Bodies (ULBs). 2. Treat 100% of the generated industrial effluents. 3. Reuse within processes wherever possible. 4. Where legally permitted, discharge treated effluents on land/into the water body.
The proportion of lakes with good ambient water (%)	Less than 1% of lakes and rivers have water quality that does not damage ecosystem function or human health. For the rest of the water bodies, Dissolved Oxygen (DO)<9 mg/l, pH<6 or >8, and nitrate>45 mg/l. Around 5% of monitoring wells have salinity within the permissible limit of EC<500 µS/cm but no monitoring wells are within the permissible limit of nitrate<0.25 mg/l (SDG standard). About 13.6% of monitoring wells have salinity within the permissible limit of EC<746 µS/cm and 51.4% of monitoring wells are within the permissible limit of nitrate<0.25 mg/l (Indian standard).	Water bodies must have water quality standards that do not damage ecosystem function or human health. Surface water DO>9 mg/l, pH = 6–8, and nitrate<45 mg/l. Groundwater • Indian standard EC<746 µS/cm and nitrate<45 mg/l. SDG standard, EC<500 µS/cm, and nitrate<0.25 mg/l.

Chapter 5: Important Water-Related Areas

SDG 6.6.1 aims to track changes in water-related ecosystems over time. Remote sensing data is used to determine the changes to surface water bodies, such as lakes, large rivers, flooded wetlands, and reservoirs. For this indicator, Joint Research Centre (JRC) data was used to analyse 20 years of data on the area covered by surface water bodies in the basin.

Water is necessary to sustain ecosystems, both terrestrial and aquatic, in addition to its use for human consumption. Different levels of flow (high, low, flow during the lean season, flood flows, and drought flows) are necessary to protect the biodiversity of aquatic habitats. There is a need to maintain a balance between how much water is abstracted for anthropogenic use and how much should be left to protect aquatic habitats (Anantha, Bhadbhade, & Dharmadhikary, n.d.).

An analysis of the 20 years of data showed that on average there has been an increase in the area under surface water bodies in all sub-basins except Arkavathi, Noyyal, and Shimsha. Excessive groundwater withdrawal and the utilisation of water from borewells for drinking and irrigation have significantly reduced the base flow of streams in many regions. With the rapid increase in the population, especially in urban areas, huge amounts of water are being diverted, for instance to cities like Bengaluru (Vidya, 2018). The Cauvery Water Disputes Tribunal has also allocated 100% of the river water to riparian states and environmental flows. This invariably leads to crises in rain-deficit years (Venkatesh, 2018). There has been an increase in the demand for agricultural water for water-intensive crops such as sugarcane, banana, and paddy in areas like Mandya, Ramanagara, Salem, and the delta region. To meet these demands, just surface water is not sufficient; this has led to extensive extraction of groundwater in the basin. In many urban areas, seasonal water bodies have turned perennial because of the dumping of treated or untreated wastewater into them (BR, 2019).

Some existing barriers to maintaining an adequate quantity of water in surface water bodies are as follows:

- Not exploring alternatives like reusing and recycling wastewater is the reason for such high demands for freshwater.
- There is no monitoring system in place to regulate groundwater extraction (EMPRI, 2017).
- There are no incentives to regulate groundwater extraction.

- Urbanisation and an increase in paved areas have resulted in reduced flow in many lakes in the basin. There is also a lack of understanding of hydrological systems and the connections between water bodies.
- Blockages in stormwater inlets and illegal encroachment also explain why so many lakes are drying up or vanishing (Sarvanan, 2021; Pragatheesh & Jain, 2013).

Table 5.1: Basin Context Metrics- Important water-related areas

Indicator	Current state	Desired end state
Ecosystem services status risk	Many sub-basins have experienced a decrease in the area under surface water due to reduced base flows and blockages in the inlets. The area under surface water has increased in some basins because of the release of treated and untreated effluents into seasonal water bodies, which has turned them into perennials.	1. Adequate quantity and contiguity in flows in the rivers. 2. An adequate quantity of water is maintained in other surface bodies.

Chapter 6: Water Governance

Implementation of integrated water resources management

SDG 6.5.1 aims to track the degree to which integrated water resources management (IWRM) is implemented. This is assessed using four key components of IWRM: enabling environment, institutions and participation, management instruments, and financing. The Cauvery basin got a score of 40 on the assessment. The score indicates a moderate level of implementation of IWRM.

Water is a state issue as per the Indian Constitution – it falls under the control of state governments and there is no dedicated river basin organisation for the management of water resources. Two national laws i.e. the Inter-state River Water Disputes Act, 1956 and River Boards Act, 1956 exist, but they are not strictly based on IWRM (India Code, 1956; Ministry of Water Resources, 1956). There are no basin-level institutional arrangements to monitor the actual operation of an inter-state river water agreement. Since IWRM has not been implemented in any Indian river basin, no revenue has been raised for IWRM elements.

There are no mechanisms to coordinate the planning and management of water resources across sectors that can bring together state institutions and private actors from the agricultural and industrial sectors as well as citizens. The basin also lacks management instruments to regulate and monitor groundwater use. Aquifer management plans have been prepared at the state level but have not yet been implemented. There is also no established organisation for aquifer-level management institutions.

Some existing barriers to implementing IWRM are as follows:

- Stakeholder participation, management instruments, and financing are low or non-existent at the basin level.
- The Tamil Nadu Groundwater Authority and Karnataka Groundwater Authority have been established under the Tamil Nadu Groundwater (Development and Management) Act, 2003, and the Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011, respectively. The latter lays out restrictions and regulations of groundwater in notified areas and specifications of the minimum distance to be maintained between borewells dug for irrigation. In Tamil Nadu, there is no provision for groundwater regulation (IELRC, n.d.). Even though there is a need for industrial and commercial end-users to implement metering under the Water Cess (Prevention and Control of Pollution) Act, 1977, there is no mechanism to monitor groundwater use.

- Stakeholder participation and consultation are low in the context of making water management plans.

Operational arrangement for water cooperation

SDG 6.5.2 tracks any operational arrangement for water cooperation within a river basin. This arrangement can be a bilateral or multilateral treaty, convention, agreement, or other formal arrangements between riparian states that provides a framework for cooperation.

The dispute over the allocation of water from the Cauvery has been going on for years among the states of Karnataka, Kerala, and Tamil Nadu, and the union territory of Puducherry. The Supreme Court of India gave its final verdict in 2018, issuing the Cauvery Water Management Scheme. The Cauvery Water Management Authority and Cauvery Water Regulation Committee were created under this scheme. The main responsibility of the Cauvery Water Management Authority is to secure implementation and compliance with the Supreme Court's order about the storage, apportionment, regulation, and control of Cauvery waters. It also advises the state to improve water use efficiency. This board, which consists mostly of state actors, is the nodal monitoring agency for collating rainfall and inflow data at reservoirs along the river. It is also responsible for allocating water and devising a legal and technical framework for reservoir operation.

There are no schemes concerned with managing water allocation in the basin. There have also been no regular meetings between member states even since the committee was set up. There has been no aquifer management organisation established at the basin level. There are also no effective measures for monitoring groundwater withdrawal (Khandekar & Srinivasan, 2021).

Some existing barriers to implementing operational arrangements for water cooperation in the basin are as follows:

- The judgement for the water allocation was made based on the assumption that dry season inflows remain constant with time. Runoff has been directly equated to the rainfall available and not to reservoir water declines due to evapotranspiration and groundwater extraction. This results in wrong estimates of water availability for allocation across sectors.

- Groundwater is treated as an independent source without consideration for its contribution to base flows.

- No guidance has been given on how water should be allocated when water levels decline due to anthropogenic effects and not rainfall reduction.

Amount of official development assistance received

SDG 6.a.1 tracks the amount of official development assistance (ODA) included in a government-coordinated spending plan. The following are some of the programmes in the Cauvery basin that have received ODA:

1. The objective of the Atal Bhujal Yojana (ABHY) – national groundwater management improvement programme – is to improve the management of groundwater resources in selected states. An amount of USD 450 million (INR 3,000 crore) was granted by the World Bank in 2018, to be used until 2025. Karnataka has been allocated INR 1,200 crore from the total to carry out work in 14 districts. Seven of these districts fall within the Cauvery basin (Ministry of Jalshakti, 2020).

2. The Tamil Nadu Urban Flagship Investment Programme's objective is to develop a priority water supply, sewerage, and drainage infrastructure in at least 10 cities located within strategic industrial corridors of Tamil Nadu. Of these, four cities lie within the Cauvery basin. Of the USD 1,266.40 million required for the project, the Asian Development Bank is providing USD 500 million in assistance between 2018 and 2022 (Asian Development Bank, 2020).

3. The Japan International Cooperation Agency (JICA) has provided support of INR 2,500 crore (USD 400 million) to the water and sanitation sector in Bengaluru. The objective of the project is to provide residents in the Bruhat Bengaluru Mahanagara Palike (BBMP) area, covering 110 villages with a safe and stable water supply and sewerage services by carrying out the construction of a water treatment plant (WTP) and STPs (Japan International Cooperation Agency, 2018).

Participation by local communities

SDG 6.b.1 tracks the level of stakeholder participation in water and sanitation management within a country. There is no multidisciplinary institutional structure and few opportunities to bring non-state actors and water users together to actively participate in the consultation process. Decisions for water management are usually taken by state actors within government agencies, and such processes lack transparency. Public consultations are usually not conducted while taking management decisions. The current scheme has no provision for engagement with experts from multidisciplinary fields as well (Harsha, 2018). However, there are a few platforms that exist.

Karnataka and Tamil Nadu have enacted participatory irrigation management (PIM) acts. Karnataka promulgated an ordinance on 7 June 2000 to amend the existing Karnataka Irrigation Act, 1957. Tamil Nadu enacted the Tamil Nadu Farmers' Management of

Irrigation Systems Act, 2000. This programme included the installation of water users' associations (WUAs) at the local level. The WUAs were set up to manage local irrigation systems.

The Lake Development Authority is an autonomous regulatory, planning, and policy body for the protection, conservation, reclamation, restoration, regeneration, and integrated development of lakes, whether natural or man-made, in Karnataka. This body is mandated to ensure community participation and to raise public awareness through programmes on lake conservation (Department of Ecology and Environment, n.d.).

Under the Jal Jeevan Mission, a programme started by the central government, there is a provision for water groups at the village level (village water and sanitation committee (VWSC)/paani samiti/user group) to plan, implement, manage, operate, and maintain in-village water supply systems (Ministry of Jalshakti, 2021).

The Cauvery family experiment, which was functional between 2003 and 2012, created a platform for farmers, engineers, and subject matter experts to engage in direct dialogue to find shared solutions to improve water efficiency. However, the initiative withered over time due to financial constraints (Khandekar & Srinivasan, 2021).

Some existing barriers to achieving local participation in water and sanitation management are as follows:

- Platforms for stakeholder consultation and engagement are either limited or non-existent.
- Management decisions are made only in consultation with engineers and bureaucrats.

Table 6.1: Basin Context Metrics- Water governance

Indicator	Current state	Desired end state
Implementation of IWRM	There are no basin-level institutional arrangements. There are no management instruments to regulate and monitor groundwater use. The IWRM programme is	1. Effective platforms for inclusive, multi-stakeholder discussions for river basin management. 2. Documentation of water use by sector as well as the total water

	not being implemented.	availability and estimated future requirements.
Transboundary organisation for catchment management	A water regulation committee has been set up for the transboundary management of water, but it is not active. There are no schemes connected to the management of water allocation in the basin.	Operational arrangement for water cooperation with regular, formal communication between riparian states and and exchange of data and information.
Catchment management organisation	Decisions for water management are usually taken by state actors within government agencies; the processes lack transparency. Public consultations are usually not conducted while taking management decisions.	1. A river basin management plan that addresses aspects related to water quality, basin water security, sustainability, crisis preparedness, basin-level governance, and fair water allocations to different user groups. 2. Effective groundwater regulation law. 3. Procedures in law or policy for participation by service users and communities.

Chapter 7: Water Crisis

Disaster reduction strategy

SDG 13.1 tracks the measures that strengthen resilience and adaptive capacity for climate-related hazards and natural disasters in all countries. In India, the Disaster Management Act, 2005 provides for the effective management of disasters. Under this act, the National Disaster Management Authority has been set up; this body lays down all policies and national plans for managing disasters. It also establishes guidelines for states and government departments towards the prevention of disasters. The National Disaster Management Plan, 2016 aligns the national plan with the Sendai Framework for Disaster Risk Reduction 2015–2030. This framework that was adopted at the Third UN World Conference on Disaster Risk Reduction outlines targets and priorities for action to prevent new and reduce existing disaster risks. In addition to this the Tamil Nadu State Disaster Management Authority, Karnataka State Disaster Management Authority, and district disaster management authorities are responsible for coordinating mitigation, preparedness, response, and recovery measures at the local level. Each of these authorities has disaster management plans, in accordance with the Sendai Framework, which lay out the roles and responsibilities of different agencies during a disaster.

Several disaster risk reduction strategies have been adopted at the national and local levels. The following is a list of schemes initiated by the Disaster Management Division:

1. The National Cyclone Risk Mitigation Project (NCRMP) was launched by the Ministry of Home Affairs. It aims to minimise vulnerability to cyclones and make people and infrastructure disaster-resilient. The project costs INR 2,691 crore and is being funded by the central government with assistance from the World Bank (in the form of a loan) and state governments.

2. Infrastructure development for 10 battalions and 10 teams of the National Disaster Response Force (NDRF) scheme was sanctioned to increase the functional efficiency in administration, capacity building, and storage of specialised equipment of NDRF as well as relief stores and resources. The National Disaster Response Reserve (NDRR), India was created to maintain a central inventory of necessary relief equipment for a population of at least 2,50,000 people in the plain areas and store availability for a minimum of 1,50,000 people in hilly areas. The project costs about INR 250 crore.

3. The Aapda Mitra Scheme is a centrally sponsored scheme that focuses on training community volunteers in disaster response in the 30 most flood-prone districts of 25 states in India. It aims to train community volunteers in the skills needed to respond to their community's immediate needs in the aftermath of a disaster.

These skills would enable them to complete basic relief and rescue tasks during emergencies. The project costs around INR 15.47 crore.

4. Strengthening of state disaster management authorities (SDMAs) and district disaster management authorities (DDMAs) was done by the National Disaster Management Authority. It aims to improve the effectiveness of all SDMAs and selected DDMAs and to make them operational by providing dedicated disaster management professionals to facilitate prevention, mitigation, preparedness, and capacity building in the context of threatening situations or disasters. The project costs INR 42.51 crore.

5. The NDRF Academy was set up in Nagpur to establish a dedicated practical training institution for first responders in the event of a disaster. The project costs INR 125.01 crore.

6. The National Emergency Communication Plan (Phase II) aims to set up reliable communication links between decision-makers at various levels and operational response teams at the disaster site. The project costs INR 16.4372 crore (Disaster Management Department, n.d.).

Financial assistance is provided to states through the Calamity Relief Fund (CRF) and National Calamity Contingency Fund (NCCF) for immediate rescue and relief operations. Allocations for state CRFs are made on the recommendation of finance commissions, contributed to by the central and state governments (National Institute of Disaster Management, 2018).

The Central Water Commission (CWC) is responsible for monitoring flood situations in the country during the designated flood periods by observing water levels/discharges along the major rivers in the country. It issues flood forecasts and warnings to the local administration/project authorities/state governments and other central ministries. The Indian Meteorological Department is the nodal agency that provides cyclone warnings in India. District Agriculture Contingency Plans (DACPs) provide guidance to the relevant government departments and farmers on what measures need to be taken during a natural disaster.

The National Remote Sensing Centre has prepared a Flood Vulnerability Index map for the whole country. The map was made by integrating the maximum probable precipitation, runoff potential, and probable maximum runoff layers in the spatial decision support system environment using a multi-criteria evaluation technique (NRSC, n.d.).

The Indian Meteorological Department also uses the standardised precipitation index to monitor droughts. The index is based on long-term precipitation records in a region. The long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean Standard Precipitation Index (SPI) for the location and desired period is zero. Negative values indicate drought conditions and positive values indicate wet conditions (IMD, 2020).

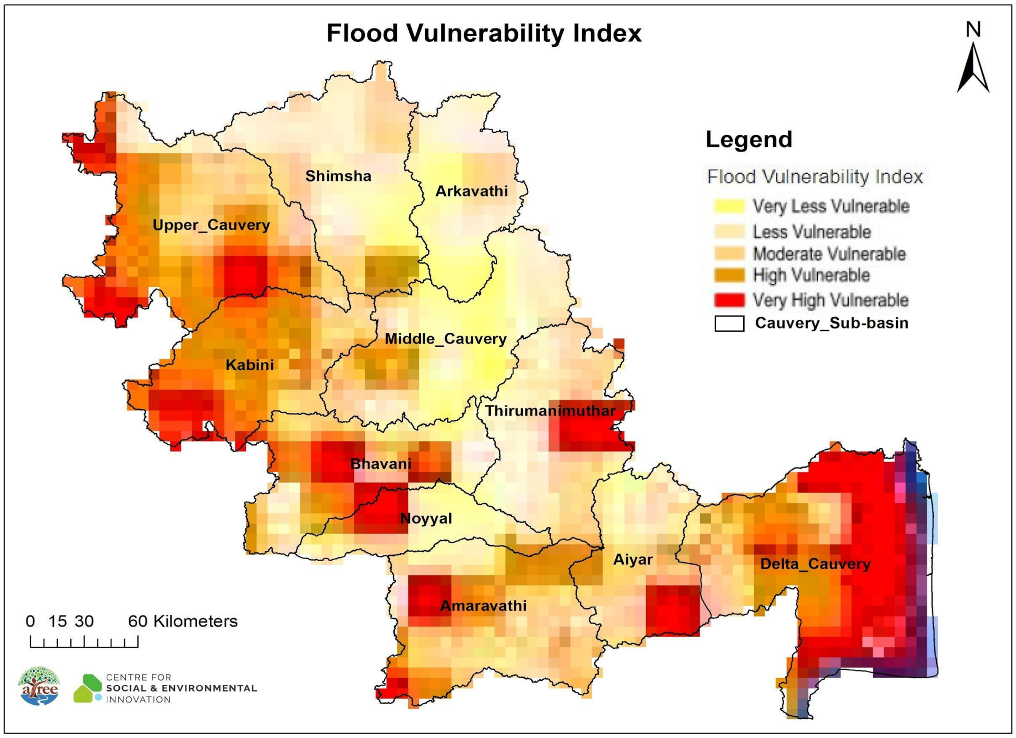

Figure 7.1: Map showing the Flood Vulnerability Index of the Cauvery basin

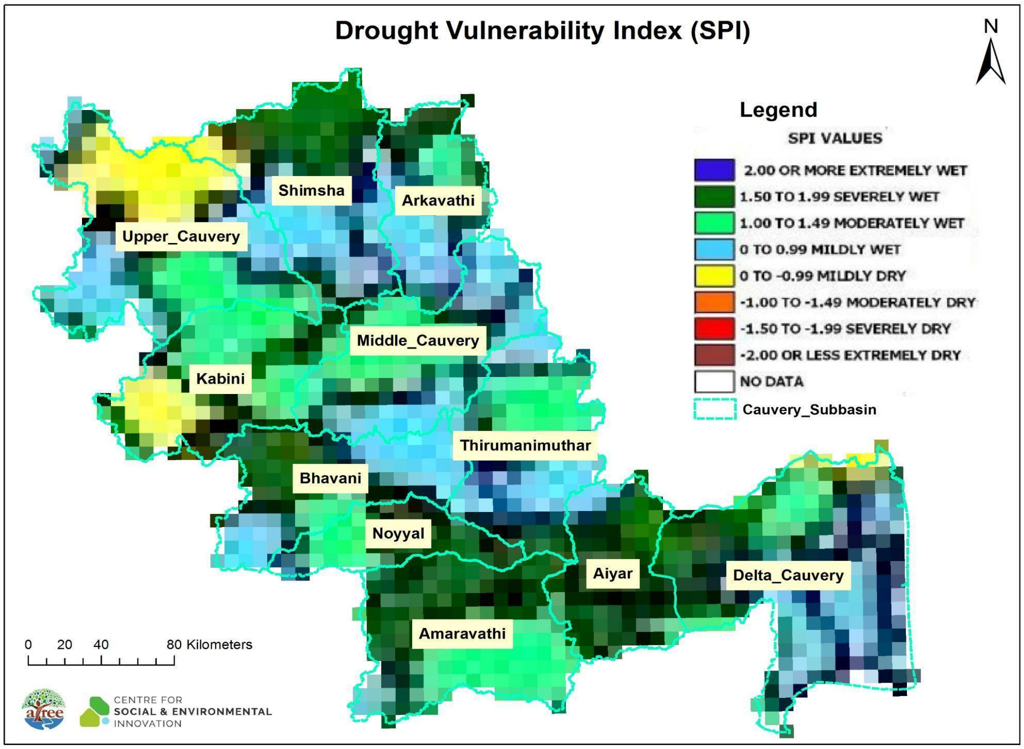

Figure 7.2: Map showing the Drought Vulnerability Index of the Cauvery basin

Table 7.1: Basin Context Metrics- Water crisis

Indicator	Current state	Desired end state
Number of deaths, missing persons, and directly affected persons attributed to disasters per population of 1,00,000	Disaster reduction strategies exist at the national and local levels. There are enough funds allocated for disaster management. There are early warning systems in place.	Strong resilience and adaptive capacity to climate-related hazards and natural disasters in all countries by reducing the number of deaths, missing persons, and directly affected people.
Disaster risk reduction strategy at the	The Disaster Management Act, 2005 provides for the	National disaster risk reduction strategies in line with the Sendai

national level	effective management of disasters.	Framework for Disaster Risk Reduction 2015–2030.
Disaster risk reduction strategy at the local level	In addition to the National Disaster Management Authority, each state has its own state disaster management authorities and district disaster management authorities which are responsible for coordinating mitigation, preparedness, response, and recovery measures at the local level.	Local-level disaster risk reduction strategies in line with the Sendai Framework.
Direct economic loss in relation to the global gross domestic product (GDP), damage to critical infrastructure, and the number of disruptions to basic services, attributed to disasters	There are enough funds allocated for disaster management. Early warning systems are in place.	Low levels of economic loss, relative to the global GDP, as a result of natural disasters.

Chapter 8: Recommendations

Based on our assessment of the baseline indicators in the Cauvery basin, table 8 provides a list of opportunities for collective action.

Table 8: Opportunities for collective action

Indicator	**Severity***	**Current government efforts**	**Opportunities for collective action**		
			Funding	**Training**	**Implementation**
WASH	Low	Jal Jeevan Mission (JJM), Swachh Bharath	• Create innovative financing mechanisms for wastewater. • Provide funds for pump solarisation.	• Create and deploy games and audio-visual aids to train the public in safe sanitation practices.	• Provide drinking water and purification systems in rural areas. • Initiate schemes for source sustainability and protection.
Water quantity	High	National Water Policy 2012, Command Area Development Programme (CADP), Atal Bhujal Yojana,	• Co-create water footprint benchmarks for crops and products that	• Ensure training and capacity building towards implementing	• Stimulate groundwater recharge through treated wastewater injection and

		MGNREGA, JJM, Pradhan Mantri Krishi Sinchayee Yojna (PM-KSY), Tamil Nadu Groundwater (Development and Management) Act, 2003, Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011, Bangalore Water Supply and Sewerage Board (Amendment) Bill, 2021	reflect reasonable levels of water consumption per unit of production. • Fund innovative technologies such as pump solarisation.	modern agriculture and irrigation techniques in local governments/farmer producer organisations (FPOs).	rainwater harvesting. • Establish a repository of model water management plans and solutions, particularly for demand-side management. • Co-develop data and tools to help local governments (towns/gram panchayats) manage water resources better. • Implement watershed management programmes to increase the resilience of watersheds. • Ensure smart and efficient irrigation scheduling and improved soil and crop management.

Water quality	High	Nadanthaai Vaazhi Cauvery Scheme (Tamil Nadu), Water (Prevention and Control of Pollution) Cess Act, 1977, National River Conservation Plan (NRCP) Scheme	• Fund innovative technologies for nature-based solutions.	• Run skill development training programmes for maintenance of treatment facilities.	• Help towns plan and implement sewerage infrastructure. • Provide technical assistance to towns and gram panchayats for accessing government funds. • Pilot wastewater treatment facilities, especially in small towns. • Pilot Natural Biological System (NbS) solutions for treating agricultural runoff, which contaminates water bodies in agricultural areas.
Water governance	Medium	Inter-state River Water Disputes Act, 1956, Cauvery Water Management	• Demonstrate new funding mechanisms, such as water trusts and	• Provide IWRM training to government officials.	• Create and maintain crowdsourced dashboards with quality and quantity

		Scheme, Participatory Irrigation Management, JJM, Tamil Nadu Groundwater (Development and Management) Act, 2003, Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011	drought funds that allow for the reallocation of water between sectors.		data for different water sources. ● Create platforms for stakeholder consultations and engagement, and share knowledge and data on water interventions.
Water crisis	Medium	National Cyclone Risk Mitigation Project (NCRMP), Aapda Mitra Scheme, National Emergency Communication Plan, Calamity Relief Fund	● Fund early warning systems.	● Offer capacity building for early warning systems and better tools for management.	● Ensure the proper maintenance of water bodies, for instance by increasing their storage capacity so that they can act as buffers during drought or flood events.

*Severity levels based on a qualitative assessment of sub-indicators.

Table 9: Existing multi-sector coalitions/partnerships in the water sector

Water challenge	Organisations	Theory of change	Links
WASH	Dhan Foundation, Anna University, ICAR	Initiate a community banking programme to build the capacities of the poor and enable them to meet their needs, such as access to water and sanitation.	http://www.dhan.org/themes/kalanjiam.php
WASH	Arghyam, Swachh Bharat Mission, Public Affairs Foundation, Centre of Gravity	Increase the demand for toilets in rural areas through a behaviour change communication campaign.	https://www.indiawaterportal.org/articles/behaviour-change-communication-sanitation
WASH	Gramalya, Oracle, CAF India	Create WASH committees to impart community awareness and increase the usage of toilets.	https://gramalaya.org/sustainable-sanitation-promotion/
Water quantity	Biome Environmental Trust, Friends of Lake, India Cares Foundation	Dig recharge wells and rejuvenate lakes.	https://biometrust.org/activities-2019-2020/
Water	Indian Institute Technology of	Conduct awareness programmes; desilt and	https://pitchandikulamforest.org/2021/11/12/restoration-of-twin-la

quantity	Madras, Pitchandikulam Forest	restore the lake and channel systems.	ke-siruseri/
Water quantity	Eco Watch, ICRA	Initiate lake restoration.	http://www.ecowatchindia.org/ongoing_programs.html
Water quantity	Biome, Acwadam	• Map existing sources of water. • Develop a groundwater monitoring protocol for each stakeholder. • Implement participatory aquifer mapping.	https://biometrust.org/best-practices-in-participatory-integrated-water-management-at-devanahalli/ https://biometrust.org/participatory-aquifer-mapping-of-upper-ponnaiyar-watershed/
Water quantity	Rainbow Drive, Arghyam	• Conduct performance monitoring of the installed rainwater harvesting systems. • Develop water use monitoring systems.	https://arghyam.org/monitoring-exercise-in-integrated-urban-water-management-iuwm-at-rainbow-drive-layout-bangalore/
Water quantity/quality	World Wide Fund for Nature, Ashoka Trust for Research in Ecology and the	Develop strategies for the restoration of grasslands and to bring back environmental flows.	https://www.wwfindia.org/news_facts/feature_stories/the_song_of_grass_and_water/

	Environment		
Water quantity/quality	CSEI-ATREE, Rainmatter Foundation	Build a digital knowledge commons platform that has environmental data across different categories and analytical tools that provide insights to users.	https://medium.com/centre-for-social-and-environmental-innovation/building-a-knowledge-commons-how-we-got-here-810a8c6d687d

Chapter 9: Limitations

1. For assessing the water stress,

    a. The total water availability(surface and groundwater) is not available at the sub-basin scale both in the literature as well as in the government reports. Thus, our study chose the basin wise water availability and divided it between sub-basins based on the area.

    b. The environmental flow data is not available at the sub-basin scale both in the literature as well as in the government reports. Thus, our study has chosen the total quantity allocated at the basin level in the river basin treaties and then divided it between sub-basins based on their area.

2. For assessing the ambient water quality of surface water bodies, data was unavailable for most of the surface water bodies that fall within the limits of a town/city. For these water bodies it was assumed that they are most likely to have bad ambient water quality given the low treatment capacity in the region.

3. For assessing the water crisis, due to data constraints the analysis had to be done at the state level, making it difficult to understand the severity of the situation at local levels like sub-basin.

4. All the water-related data provided by the government reports are present at the administrative boundary level (like the district of the state). While converting this data to a hydrological boundary could have led to the loss of some finer details.

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Annexure A

Crop water requirement is the amount of water needed to raise a crop. This includes water necessary to meet both consumptive and special needs, such as land preparation, land submergence, leaching, and so on. Effective rainfall refers to the useful or utilisable rainfall. (Figure 8) can be used to estimate the amount of effective rainfall as related to the mean monthly rainfall in the region (FAO, n.d.).

Normal Monthly Rainfall (mm)	Average Monthly Consumptive Use (mm)																					
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550
	Effective Rainfall																					
12.5	7.5	8	8.7	9	9.2	10	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
25	15	16.2	17.5	18	18.5	19.7	20.5	22	24.5	25	25	25	25	25	25	25	25	25	25	25	25	25
37.5	22.5	24	26.2	27.5	28.2	29.2	30.5	33	36.2	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
50	25	32.2	34.5	35.7	36.7	39	40.5	43.7	47	50	50	50	50	50	50	50	50	50	50	50	50	50
62.5	25	39.7	42.5	44.5	46	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
75	25	46.2	49.7	52.7	55	57.5	60.2	63.7	67.5	73.7	75	75	75	75	75	75	75	75	75	75	75	75
87.5	25	50	56.7	60.2	63.7	66	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
100	25	50	63.7	67.7	72	74.2	78.7	83	87.7	95	100	100	100	100	100	100	100	100	100	100	100	100
112.5	25	50	70.5	75	80.2	82.5	87.2	92.7	98	105	111	112	112	112	112	112	112	112	112	112	112	112
125	25	50	75	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125	125	125	125	125	125	125	125	125
137.5	25	50	75	88.7	95.2	98.7	104	111	118	126	132	137	137	137	137	137	137	137	137	137	137	137
150	25	50	75	95.2	102	106	112	120	127	136	143	150	150	150	150	150	150	150	150	150	150	150
162.5	25	50	75	100	109	113	120	128	135	145	153	160	162	162	162	162	162	162	162	162	162	162
175	25	50	75	100	115	120	127	135	143	154	164	170	175	175	175	175	175	175	175	175	175	175
187.5	25	50	75	100	121	126	134	142	151	161	170	179	185	187	187	187	187	187	187	187	187	187
200	25	50	75	100	125	133	140	148	158	168	178	188	196	200	200	200	200	200	200	200	200	200
225	25	50	75	100	125	144	151	160	171	182												
250	25	50	75	100	125	150	161	170	183	194												
275	25	50	75	100	125	150	171	181	194	205												
300	25	50	75	100	125	150	175	190	203	215												
325	25	50	75	100	125	150	175	198	213	224												
350	25	50	75	100	125	150	175	200	220	232												
375	25	50	75	100	125	150	175	200	225	240												
400	25	50	75	100	125	150	175	200	225	247												
425	25	50	75	100	125	150	175	200	225	250												
450	25	50	75	100	125	150	175	200	225	250												

Figure 8: Table to estimate effective rainfall

Annexure B

The Central Pollution Control Board classifies water bodies based on various values of a water quality parameter(CPCB, 2019). For our study, we have used Class D in Table 10 as a criterion to identify surface bodies with good ambient water quality that is suitable for the propagation of wildlife and fisheries.

Table 10: Water quality criteria to classify water bodies into designated best use

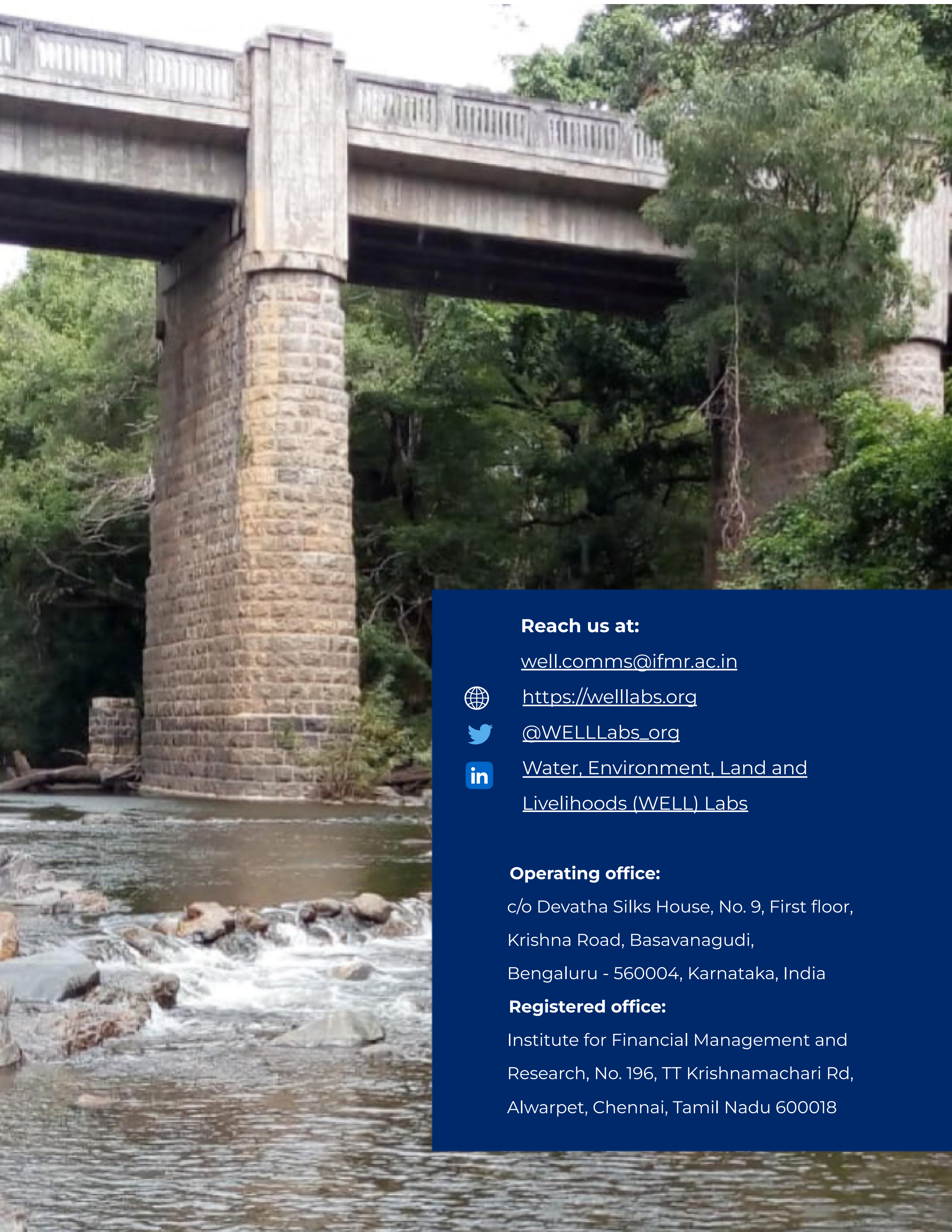
Designated-best-use	Class of water	Criteria
Drinking water source without conventional treatment but after disinfection	A	• Total coliforms organism Most Probable Number/100ml shall be 50 or less • pH between 6.5 and 8.5 • Dissolved oxygen 6mg/l or more • Biochemical oxygen demand over 5 days at 20 °C 2mg/l or less
Outdoor bathing (organised)	B	• Total coliforms organism MPN/100ml shall be 500 or less • pH between 6.5 and 8.5 • Dissolved oxygen 5mg/l or more • Biochemical oxygen demand 5 days 20C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	• Total coliforms organism MPN/100ml shall be 5,000 or less • pH between 6 to 9 • Dissolved oxygen 4mg/l or more • Biochemical oxygen demand 5 days 20C 3mg/l or less

Propagation of wildlife and fisheries	D	• pH between 6.5 to 8.5 • Dissolved oxygen 4mg/l or more • Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	• pH between 6.0 to 8.5 • Electrical conductivity at 25C micromhos/cm max. 2,250 • Sodium absorption ratio max. 26 • Boron max. 2mg/l

The Central Ground Water Board uses the BIS standards to classify the quality of groundwater levels. According to these standards, the nitrate level in the water should be less than or equal to 45 mg/l and the salinity level less than or equal to 746 µS/cm (BIS, 2012). The SDG indicator uses the criteria given in (Figure 9) to classify the ambient water quality (Warner, 2020).

Parameter Group	Parameter	Target type	Rivers	Lakes	Groundwaters
Oxygenation	Dissolved oxygen	range	80 – 120 (% sat)	80 – 120 (% sat)	-
Salinity	Electrical conductivity	upper	500 µS cm^{-1}	500 µS cm^{-1}	500 µS cm^{-1}
Nitrogen	Total Nitrogen	upper	700 µg N l^{-1}	500 µg N l^{-1}	-
	Oxidised nitrogen	upper	250 µg N l^{-1}	250 µg N l^{-1}	250 µg N l^{-1}
Phosphorus	Total phosphorus	upper	20 µg P l^{-1}	10 µg P l^{-1}	-
	Orthophosphate	upper	10 µg P l^{-1}	5 µg P l^{-1}	-
Acidification	pH	range	6 – 9	6 – 9	6 – 9

Figure 9: Water quality criteria by SG to classify water bodies with good ambient water quality that can support wildlife and fisheries.



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