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WATER MANAGEMENT IN THE NOYYAL RIVER BASIN

A SITUATION ANALYSIS

Veena Srinivasan
D. Suresh Kumar
Pennan Chinnasamy
Swati Sulagna
D. Sakthivel
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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CETP	Common Effluent Treatment Plant
CGWB	Central Ground Water Board
COD	Chemical Oxygen Demand
CWC	Central Water Commission
CWDT	Cauvery Water Dispute Tribunal
DO	Dissolved Oxygen
dS/m	Deci-Siemens per Metre
EC	Electrical Conductivity
GoTN	Government of Tamil Nadu
ha	Hectare
IETP	Individual Effluent Treatment Plant
km	Kilometre
LBP	Lower Bhavani Project
LPCD	Litres per Capita per Day
MC	Municipal Corporation
mg/L	Milligrams per Litre
MLD	Million Litres per Day
Mm^3	Million cubic metre
MSE	Madras School of Economics
NRAPA	Noyyal River Ayacutdars Protection Association
NTADCL	New Tirupur Area Development Corporation Limited
PPP	Public-Private Partnership
PWD	Public Works Department
₹	Rupees
₹/ha	Rupees per hectare
sq km	Square Kilometres
TDS	Total Dissolved Solids
TMC	Town Municipal Council
TNAU	Tamil Nadu Agricultural University
TNPCB	Tamil Nadu Pollution Control Board
TP	Town Panchayat
TWAD	Tamil Nadu Water and Drainage Board
ULB	Urban Local Body
VP	Village Panchayat
WRO	Water Resources Organization
ZLD	Zero Liquid Discharge

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1

INTRODUCTION

The Noyyal sub-basin, which is 3510 sq km in area, is part of the Cauvery basin that lies in the state of Tamil Nadu. It is a rapidly urbanizing sub-basin that includes the Class I cities of Coimbatore and Tiruppur as well as 84 smaller urban settlements. Water issues in this basin have been the focus of much public debate and action over the last two decades. Most of the debate, triggered by farmer agitations and court cases, has focused on the question of water pollution; water scarcity and sustainability issues have received relatively little attention. Recent bans on industrial effluent discharge into the Noyyal, as well as changes in water supply infrastructure, watershed development activities, urban demand and agricultural water use have dramatically altered the future of the Noyyal River and merit follow-up studies.

The purpose of this situation analysis is to summarize the current state of knowledge regarding water resources management in the Noyyal sub-basin and identify critical knowledge gaps to inform water-related research in the basin. It is hoped that such an analysis will help those studying or working on water issues in the Noyyal, and also provide useful insights for other urbanizing basins.

1.1
Hydrological and physiographical context

The Noyyal River is a tributary of the Cauvery. It originates in the Vellingiri hills in the western part of Tamil Nadu (Figure 1). The Noyyal has seven major tributaries, all originating from first or second order streams in the foothills of the Nilgiris. It flows through Coimbatore, Tiruppur, Karur and Erode districts before joining the Cauvery River at Kodumudi in Erode district. The natural flow of the Noyyal is seasonal and occurs only during the north-east monsoon months. However, urban domestic and industrial sewage from Coimbatore and return flows from the Lower Bhavani Project (LBP) all drain into the Noyyal; so it experiences perennial flow in some stretches. Occasionally, flash floods occur after heavy rain events.

Rainfall in the basin is highly variable due to the orographic effect of the Western Ghats. The mountains form a 'rain shadow area' (with respect to the south-west monsoon) over the plain, which consequently has a dry climate. The extreme western and upper reaches usually receive more than 3000 mm annually during the south-west monsoon, whereas the major eastern part of the basin receives an annual rainfall of 600 mm, which mostly occurs during the north-east monsoon. Mayilswami (2006) estimated the average rainfall, from 1990 to 2004, to be 634 mm/year after considering 13 rain gauges stationed across the basin.

The climate is generally warm, with temperatures ranging from a maximum of 47°C in April to a low of 13°C in January (Mayilswami 2006: data collected from Meteorology Dept., TNAU). The major rock formations

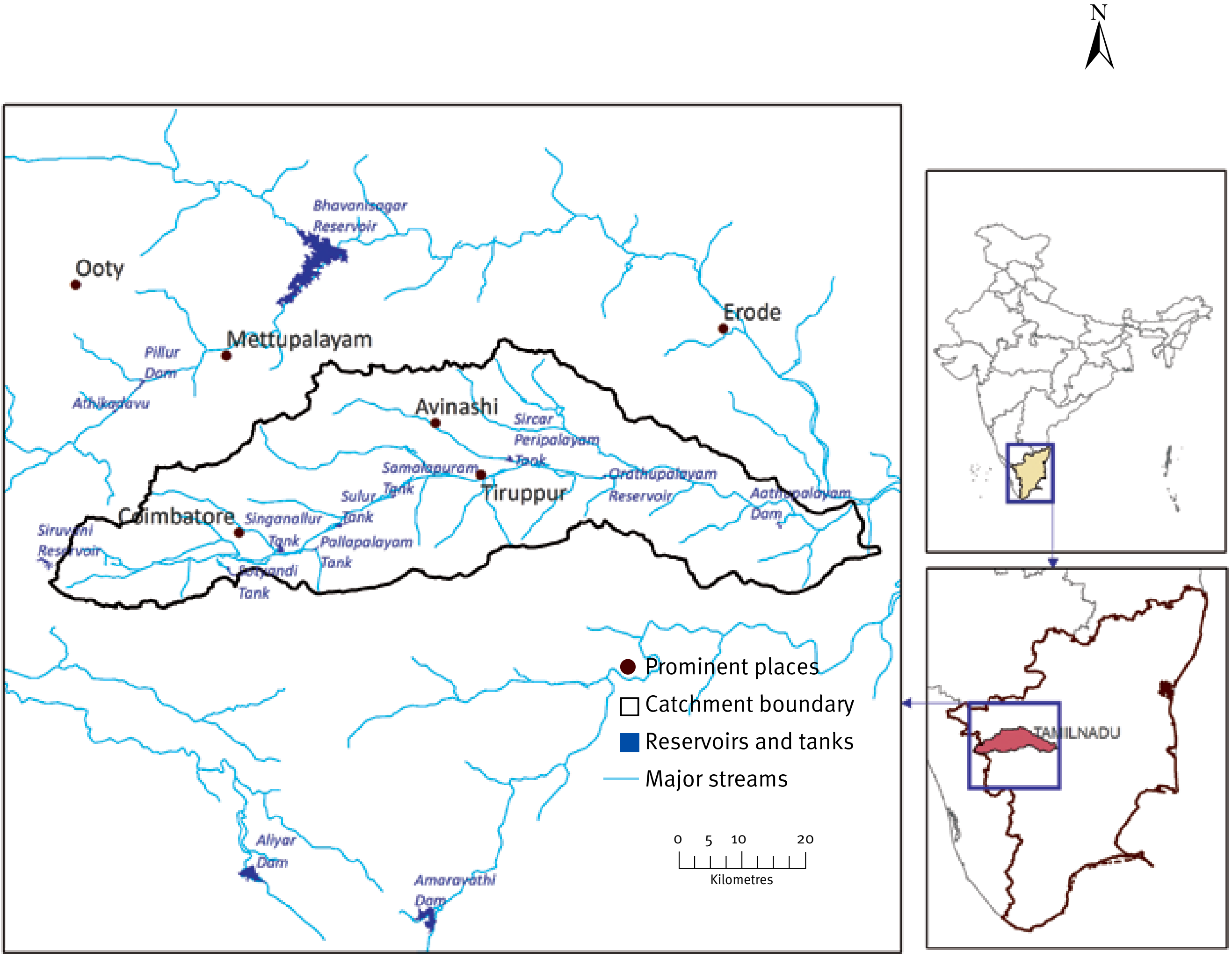

Figure 1: Schematic map of the Noyyal sub-basin (Map prepared by Ecoinformatics Lab, ATREE)

consist of hard rock for the entire basin (Mayilswami 2006), overlain by recent alluvial valley-fill along the river. The major physiographic units consist of upland plateau region with hill ranges, hillocks and undulating plains. The dominant soil types are mostly red sandy and red loamy soils (CGWB 2008a, 2008b).

1.2
Demographic trends

The Noyyal sub-basin is highly urbanized (Figure 2). Of the total population of 42 lakhs in the sub-basin, over 75% resides in 86 urban settlements, with the remaining 25% residing in 243 villages (Census of India, 2011). The major cities in the basin are Coimbatore, with a population of 10.6 lakhs, and Tiruppur with a population of 5.5 lakhs (Census of India, 2011).

Demographic and urbanization trends were obtained by analysing Primary Census Abstracts for all rural and urban centres within the basin for the years 1991, 2001 and 2011. The analysis reveals that the total population in the basin doubled in 20 years, from 19.5 lakhs in 1991 to 42 lakhs in 2011. During this period, urban population quadrupled, from 8 lakhs in 1991 to 33 lakhs in 2011, while rural population in the basin decreased post-2001. This can be attributed to increased migration from rural to urban areas, as well as to immigration by people from other states because of expansion of the industrial and service sectors.

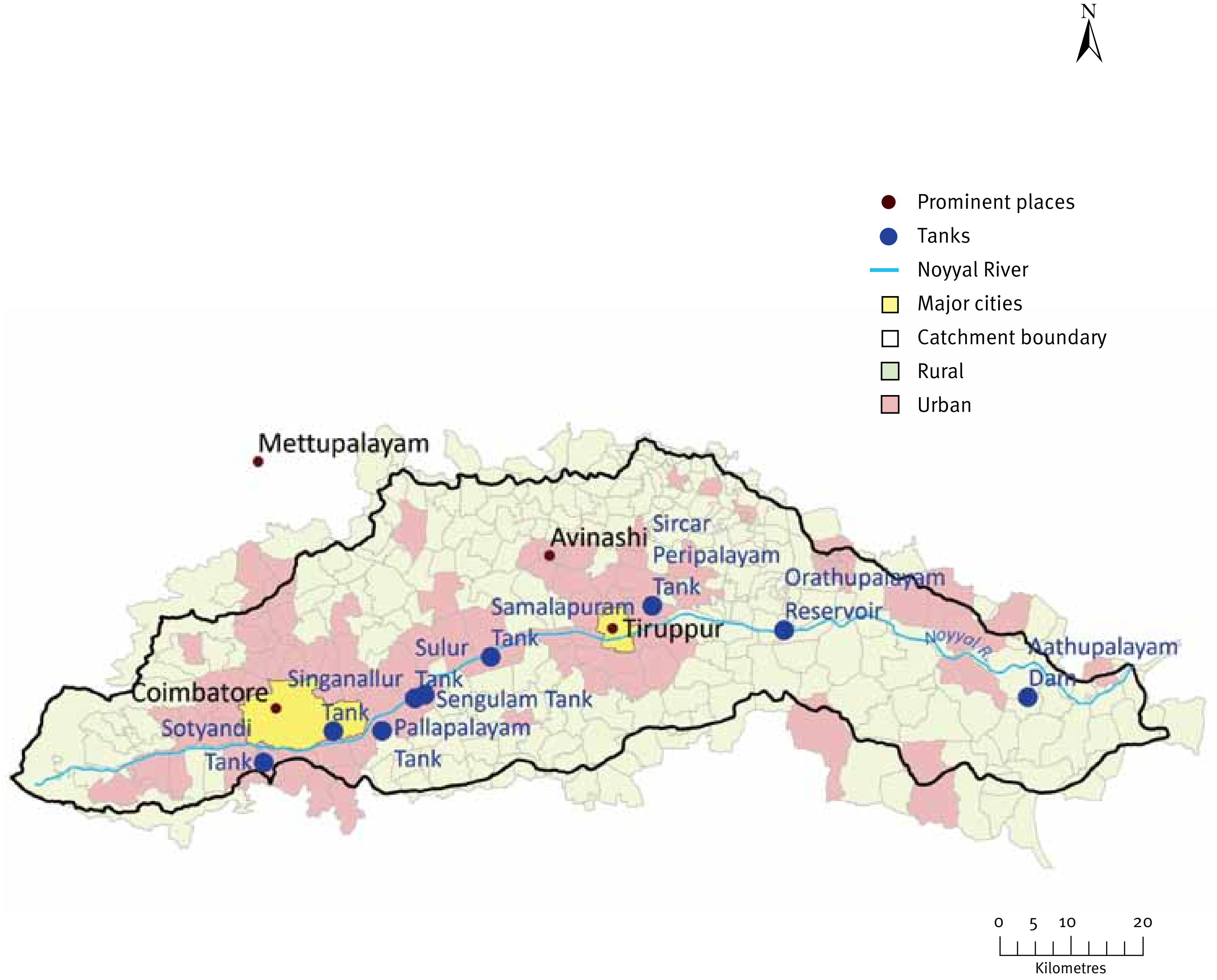

Figure 2: Map of urban and rural settlements in the Noyyal sub-basin (Source: Census of India, Primary Census Abstract, 2011. Map prepared by Ecoinformatics Lab, ATREE.)

1.3
Land use

As a result of heavy urbanization, land use in the basin has moved away from agriculture towards urban and industrial uses, reflecting the changing nature of occupations. An approximate estimate of land use in the basin constructed from block-level data[1] shows that only about 39% of the land in the Noyyal sub-basin is cultivated. About 20% of the land is under habitation, while another 33% is fallow (Figure 3). Our field observations revealed high rates of conversion of land, driven by sky-rocketing land prices, into urban uses, especially into housing layouts, commercial complexes or educational institutions.

Comparing the block-wise cropping patterns between 2007-08 and 2011-12, we found the area under cereal crops reducing from 33% to 22%. Area under fodder crops has increased significantly from 15% to 23% in a period of four years. The other major crops are the oil crops, especially coconut (24%) and spices such as

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[1] *We collected land use data for each of the 21 blocks that overlap with the Noyyal basin, and then scaled down the areas in proportion to the area of the block that lies inside the basin.*

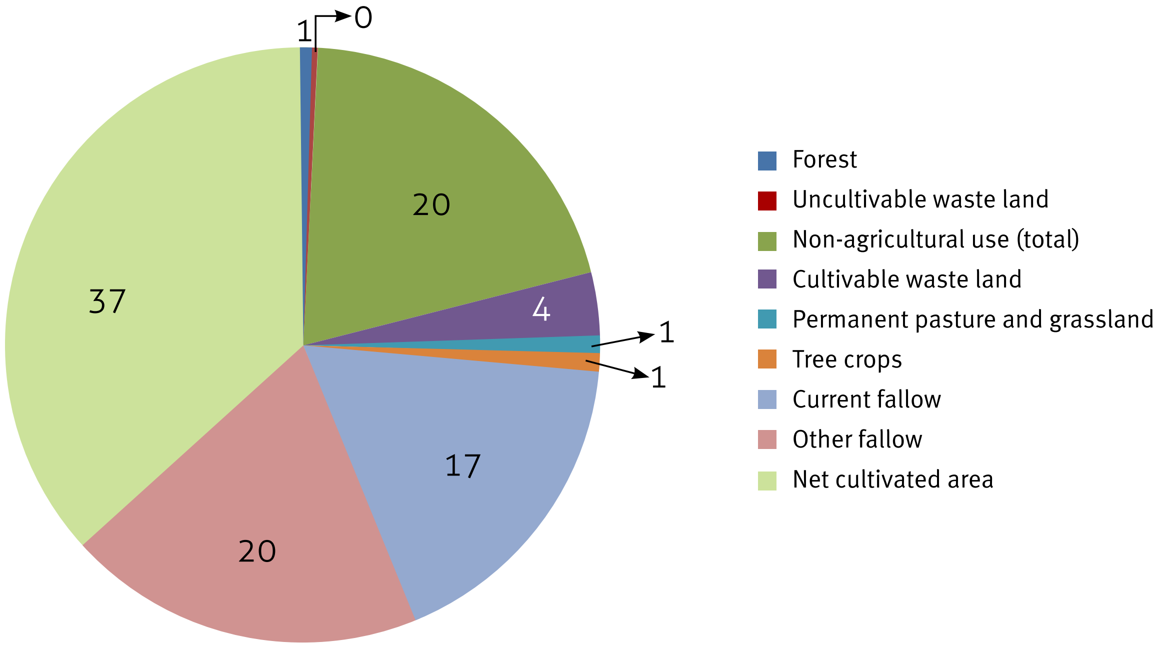

Figure 3: Land use in the Noyyal sub-basin in 2012 (Source: Assistant Director of Statistics for different blocks; figures are in percentages)

turmeric, which have doubled in share of cropping area from 3% to 6%.

1.4
Water provisioning infrastructure

For irrigation, the biggest surface water structure on the Noyyal River is the Orathupalayam dam, constructed in 1992 and located downstream of the Tiruppur industrial area. This dam was originally constructed to store flood waters of the Noyyal and irrigate about 500 acres in Erode district and 10,375 acres in Karur district (the latter via a feeder canal to the Aathupalayam reservoir). However, as the Orathupalayam dam receives most of the industrial effluents from Tiruppur, it became increasingly polluted and is no longer being used as a source of irrigation. In recent years, the water has only been released during high rainfall events when the dam is in danger of being breached and the pollutants are diluted by rainwater.

There are no other major storage structures along the Noyyal. However, the sub-basin is covered with a series of cascading tanks. Along the 179 km length of the Noyyal River, there are a total of 31 tanks and 23 anicuts. Nevertheless, very little area is currently irrigated by surface water from tanks; the tanks primarily function as percolation structures to recharge groundwater. In the lower reaches of the Noyyal sub-basin, a significant fraction (60-77%) of the irrigated area – comprising Chennimalai, Kodumudi, and Modakurichi blocks – is irrigated by canals bringing water from the Lower Bhavani Project.

For meeting domestic water needs, the main infrastructure is in the form of pipelines linking dams and reservoirs outside the basin with mostly urban consumers within the basin. The Siruvani project is a gravity-fed scheme that obtains its water from the Siruvani reservoir in the Nilgiris. The Pillur scheme involves pumping water from the Bhavani basin into the Noyyal basin from the Bhavanisagar dam. Both these schemes supply water to Coimbatore city and some villages en route. The NTADCL project imports 185 MLD of water from the Cauvery River just downstream of where the Bhavani meets the Cauvery, and provides it to industries and domestic users in the city of Tiruppur. Municipalities and Town Panchayats (TPs) that lie en route the different schemes receive water in bulk from TWAD. Some TPs adjacent to larger urban centres receive bulk water supply from the urban centre.

1.5

Institutions of water provisioning and governance

Over the years, the governments (primarily, the state government) have created a number of agencies to address different aspects of water provisioning, sewerage, allocation, as well as monitoring and regulation of quality and depletion. At the same time, the non-governmental sector and the courts have become involved in this sector as well. An overview of the agencies and actors involved in different functions in the Noyyal sub-basin is given in Table 1, and brief descriptions of roles and responsibilities are given in the following subsections.

Tamil Nadu Water and Drainage Board

The Tamil Nadu Water Supply and Drainage Board (TWAD) is the statutory body formed by the Tamil Nadu Water Supply and Drainage Board Act, 1970. It is responsible for the supply of water and sewerage

Table 1: Institutional actors in the water sector in the Noyyal sub-basin

Objective	Sector/Source	Unit/Scale		
		Municipal Corporation	Towns	Villages
Quantity (supply)	Domestic	TWAD, self supply, NTADCL, MC	TWAD, self supply, NTADCL,TP	TWAD, self supply, NTADCL, VP
	Industry	NTADL, TWAD (10%), self supply	NTADL, TWAD, self-supply	Self-supply
	Agriculture	—	—	WRO, Panchayat Union (tanks, wells)
Sewage disposal	Domestic	CMC, TMC	TP, self	VP, self
	Industrial	NTADL, MC	TP, self	VP, self
Water quality	Groundwater	TNPCB*, CGWB* , TWAD*		
	Surface water	TWAD*, TNPCB, WRO	TWAD*, TP	VP
Water sustainability	Groundwater	CGWB, TWAD		
	Surface water	CWC, WRO		
Water allocation	Micro/meso-scale	MC , TWAD	TP , TWAD	VP , TWAD
	Macro-scale	CWDT, state government, WRO, CWC		

*Agencies that only have monitoring power.

For acronyms, please check list of abbreviations on page 04 facilities to the public in all of Tamil Nadu except Chennai, rural and urban areas. One major function of TWAD is bulk water supply and implementation of infrastructure schemes. TWAD sources and allocates water for different uses and users. It is also responsible for water supply planning, conservation of water resources and maintenance of the quality of water for its various uses. Once the schemes are completed, they are handed over to the respective local bodies for maintenance. Schemes of composite nature covering more than one local body are maintained by TWAD Board. Most of the surface water supplied for domestic purposes within the Noyyal sub-basin is sourced from outside the basin. Additionally, TWAD Board has its own borewells, which supplement surface water sources for domestic water supply. The bulk supply of water is initially treated by TWAD and TWAD has a water quality division that repeatedly monitors the quality of water.

New Tirupur Area Development Corporation Ltd.

The New Tirupur Area Development Corporation Limited (NTADCL) was incorporated in 1995. It was promoted by the Government of Tamil Nadu (GoTN) and Infrastructure Leasing and Financial Services Ltd. as a Special Purpose Vehicle to implement the Tiruppur Area Development Programme. NTADCL was mandated, via a concession contract, to develop, construct, operate and maintain a 185 million litre per day (MLD) water supply project and sewerage facility on a Build-Own-Operate-Transfer basis to meet industrial requirements and needs of about 60% of the population in Tiruppur Municipality. The project also needed to provide low-cost sanitation facilities to slum areas in Tiruppur and surrounding villages. The NTADCL project is the first public-private partnership (PPP) water supply and sanitation project in the country and one of the country's largest private investments in urban infrastructure.

NTADCL supplies water to industries, for which it collects water charges from them. NTADCL also supplies bulk water from the project to the Tiruppur Municipal Corporation and TWAD and receives bulk sewage at specific points where the water and sewage are metered. Operation and maintenance of the piped distribution system and underground sewerage systems, tariff setting and revenue collection functions remain with the respective local authorities (Elangovan, NTADCL, pers. comm. 2 September 2013).

Urban Local Bodies: Town Panchayats, Municipalities and Municipal Corporations

Maintenance of the water distribution systems and revenue collection is the responsibility of the respective urban local bodies (ULBs). Coimbatore and Tiruppur Municipal Corporations are responsible for the operation and maintenance of the piped supply and distribution systems within the cities of Coimbatore and Tiruppur, respectively. The TPs and Municipalities perform this function in the smaller towns. They set the tariff, perform revenue collection and maintain the piped supply and sewerage systems. All these ULBs receive bulk water from TWAD for distribution, but in many cases, they also own and operate their own borewells. They are also responsible for sewage treatment and disposal.

Village Panchayats

In case of villages through which a drinking water pipeline passes, TWAD supplies a pre-defined amount in bulk to the Village Panchayat (VP). TWAD has a well-developed system of water supply with a tap for approximately every five households. Peri-urban villages often receive their reserved quota of water from the nearest Municipal Corporation. However, the panchayat remains the main agency for distribution, maintenance and collection of monthly charges. Villages that do not receive TWAD bulk supply are supplied via panchayat borewells financed by state or national schemes. A number of national schemes such as Swajaldhara and National Rural Drinking Water Programme are financing development of drinking water facilities for rural households using a demand-driven and community participation approach. The panchayats plan, implement, operate, maintain and manage all drinking water schemes, for which they cover the operational cost and part of the installation cost.

Water Resources Organization

The Water Resources Organization (WRO, part of the erstwhile Public Works Department) is responsible for executing and maintaining all irrigation projects such as dams, canals, tanks as well as construction of culverts, water harvesting and storage structures, and implementation of water supply in rural areas (see www.wrd.tn.gov.in).

Tamil Nadu Pollution Control Board

Pollution control power rests with the Tamil Nadu Pollution Control Board (TNPCB). The stated objective of TNPCB is *"to control, prevent and abate pollution of streams, wells, land and atmosphere in the state to protect the environment from any degradation by effective monitoring and implementation of pollution control* *legislations."* The listed functions of TNPCB cover all aspects of pollution control, including comprehensive planning, monitoring of groundwater and surface water bodies, inspection of individual and common effluent treatment plants (IETPs and CETPs), setting of standards and ensuring compliance. However, a survey of the literature suggests that most of the substantive action on the Noyyal has progressed through judicial action (court rulings) rather than administrative action on the part of TNPCB.

Madras High Court

Much of the actual change on water quality issues in the Noyyal has occurred through judicial action. Following a Public Interest Litigation filed by the Noyyal River Ayacutdars Protection Association (NRAPA), in 1996, the Court applied the 'Polluter Pays' principle and directed TNPCB to implement the pollution control laws, ensure the setting up of IETPs and CETPs and decide the compensation amounts that polluting dyeing units were liable to pay to farmers .

In 2000, the Government of Tamil Nadu passed a notification that the river water stored at Orathupalayam dam should be cleaned. Following no improvement in quality, the Noyyal River Ayacutdars Protection Association filed a petition that the cleaning should occur within a stipulated time at the government's own expense; alternatively, it suggested, the expenses could be recovered from the dyeing and bleaching units' associations. Further, pollution of the Noyyal River in future should be prevented. While the situation was under dispute, release of water from the Orathupalayam dam was halted. On 22 August 2005, following heavy rains, the dam was drained of more than ten years of stagnant effluents. The exercise flushed over 0.5 million cubic feet of toxic effluents into the Cauvery, and yielded more than 400 tonnes of dead fish and a reservoir bed that was several metres thick with toxic sludge (Anonymous 2005). Repeated appeals by the dyeing and bleaching units, on grounds of the livelihood and foreign exchange benefits of these industries, and the high cost of cleaning the Orathupalayam dam and pollution abatement, failed. The High Court then enforced a pricing mechanism for common effluent treatment plants (CETPs) and in 2009 appointed a Committee to oversee compliance (Chauhan 2009). Eventually, in 2011, the High Court passed an order imposing a Zero Liquid Discharge (ZLD) rule for industries. After the settlement, the High Court delegated all further powers to TNPCB. Currently, all licensing, regulations and enforcement authority rests with TNPCB (Kuttiappan, High Court-appointed environmental consultant, pers. comm. 16 August 2013)

Civil society actors

There are several non-governmental organizations that are actively involved in water issues in the Noyyal. They represent the interests of various stakeholders. Siruthuli, Residents Awareness Association of Coimbatore (RAAC) and Save Coimbatore Wetlands are the prominent environmental ones. They are primarily involved in de-silting, restoration of tanks and artificial recharge schemes. These associations lobby the government for change in water policies and for additional resources. For instance, the Tirupur Exporters Association (TEA) played an important role in negotiating with the Tamil Nadu government to establish NTADCL in order to supply more water to the dyeing industry. Similarly, the Dyers Association was instrumental in generating support among the dyers and mobilizing capital from industries to establish the CETPs (Blomqvist 1996).

1.6

Framework for situation analysis

Our situation analysis attempts to understand the nature of the 'water problem' in the Noyyal sub-basin. However, a 'problem' can only be defined with respect to a normative concern, i.e., a societal objective that is not met. We identify four broad objectives of water resources management that guide our analysis:

1. To ensure that sufficient quantity of safe, affordable water is supplied to domestic, commercial/industrial/institutional (CII) and agricultural users and to determine whether adequate water is left for ecological and environmental purposes.
2. To ensure equitable allocation of water within similar users, and fair allocation between different users/sectors.
3. To maintain sustainability (sufficient water available for future generations) by regulating overdraft and ensuring resilience of water resources to variability in supply.
4. To maintain water quality so as to sustain public health and environmental amenities.

These objectives are identified on the basis of our understanding of the water policy and sector debates in the country (see, e.g., Joy et al. 2004; Lele et al. 2013). To the extent these objectives are not met, there is a problem that needs to be addressed. We summarize from the literature (supplemented by secondary data where available) the magnitude of the problem (shortfall) with respect to each objective, possible causes for the shortfall, and the nature of the response or adaptive measures.

1.7
Roadmap to this report

In the following sections, we describe the 'current situation' in the Noyyal sub-basin with respect to each of the objectives of water management outlined here, as understood from the published literature, expert interviews and some secondary data analysis. In Section 2, we discuss the issues of sufficiency of safe, affordable supply. In Section 3, we discuss issues of fairness of allocation. In Section 4, we discuss whether current levels of consumption are sustainable and resilient. In Section 5, we cover water quality issues. For each issue, we summarize the magnitude and distribution of the problem and then discuss some of the biophysical and socio-economic and institutional determinants. At the end of each section, we highlight the key knowledge gaps that remain to be addressed.

2

SUFFICIENCY OF SAFE AND AFFORDABLE WATER

The first question we address is whether there is sufficient water to meet the current needs of water users in Noyyal sub-basin, which users experience water scarcity, where and when. In trying to understand whether there is sufficient water, there are two considerations. In defining whether users get enough water to meet their present needs, it would be useful to clarify what it means to say that users get 'enough' water to 'meet' their present needs.

First, defining 'enough' is a challenging task. In the case of domestic needs, clear norms exist. TWAD has norms that vary from 40 LPCD in rural areas, to 70 LPCD for towns without an underground sewerage system, to 135 LPCD for large cities, with several categories in between (TWAD Board Order Lr. No. F. HOTC/ AE10/PDC/2008/).

However, no such norms exist for agricultural and industrial water demand. Therefore, it is difficult to define how much water is 'enough' for industrial/ commercial versus agricultural use versus environmental needs. For the purposes of this review, we define sufficiency for non-domestic users loosely, in terms of whether the water supplied is enough to satisfy current demand as perceived by those users (Lele et al. 2013).

Second, it is not clear what 'meeting needs' means. Does it imply that all water needs must be met by public agencies, or is self-supply by citizens acceptable? Must all water needs be met from within the local watershed, or will water from anywhere do? The latter is particularly pertinent to the Noyyal sub-basin. Most of the water supplied to domestic users in the Noyyal sub-basin is imported from the Bhavani basin to the north; a small amount is supplemented from TWAD Board borewells. Similarly, with the exception of the Orathupalayam dam, all surface water irrigation in the Noyyal sub-basin is also reliant on water imported from the Bhavani basin to the north.

At the same time, a significant fraction of the domestic, industrial and agricultural water use is met from local groundwater, which in turn, is recharged by the Noyyal, including various rain-fed tanks that occur along its course, and open drains carrying storm-water. Therefore, we assess water sufficiency considering all sources of water, but we do not distinguish between local and imported water. However, it is unclear if imports can be endlessly increased to meet future growth.

2.1
Domestic water sufficiency

2.1.1
Urban domestic water availability

As described earlier, urban domestic water needs are met from a combination of water imported from sources outside the Noyyal basin and from groundwater. For

Coimbatore, the Siruvani River and the Pillur project on the Bhavani River provide most of the domestic water. For Tiruppur, the Cauvery water supplied by NTADCL is, again, the major source. In the case of other municipalities and TPs, while drinking water is generally sourced from one of these imported water projects, the major portion of domestic water supply is sourced from borewells managed by the ULB. In these cases, imported (potable) water supply alternates with borewell water supply, with the overall frequency of supply generally being once in two days (but variable by season and location). The average outcome in terms of LPCD, as reported by TWAD, is given in Table 2.

The TWAD data in Table 2 suggest that the water supply norms are being mostly met in larger towns and Town Panchayats. However, the data are strangely uniform: 41 of the TPs reportedly receive exactly 70 LPCD. It is not clear whether the LPCD norms can be met so precisely and uniformly across so many urban local bodies. Furthermore, it is also not clear what fraction of the urban supply is actually provided to commercial and industrial users (there is anecdotal evidence that some does). Finally, it is not clear that these levels of supply are actually maintained throughout the year and in drought years. For example, newspaper articles[2] indicate that shortages during the summer and drought years remain a recurring problem.

On the other hand, the LPCD data in Table 2 only refer to water supplied by the TWAD Board. We were unable to find reliable estimates for self-supply from private wells in any of the urban areas, although there is sufficient anecdotal evidence to suggest that many urban users source significant fractions of their water requirements from private wells. This is relevant because, ultimately, the only major users of 'Noyyal water' appear to be those households, farmers and industries that rely on groundwater from within the basin. Whether the groundwater is enough to tide over the needs of the basin water users in drought years when imports fail remains an unanswered question. The sole study on household consumption of water in Coimbatore city was conducted in the 1990s (Bergh and Nordberg 1996). It estimated that majority of households consumed 25-75 LPCD of water. It also showed that although Siruvani water constituted the largest part of the water consumed by Coimbatore residents, groundwater use was significant and varied seasonally, increasing, on average, from 9 LPCD (11% of water use) during non-summer months to 16 LPCD (~21% of water use) during summer months.

Table 2: Water supplied to Municipal Corporations

City/Town	2011 Census population (aggregate)	Sources/schemes	Average LPCD
Coimbatore	10.5 lakhs	Pillur, Siruvani	138
Tiruppur	4 lakhs	Cauvery	100
6 Municipalities	5 lakhs	Various	70
38 Town Panchayats	7.4 lakhs	Various	66
36 Census Towns	5.3 Lakhs	Various	No data

Source: http://www.twadboard.gov.in/twad/map.aspx and Census of India 2011: Primary Census Abstracts

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[2] *http://articles.timesofindia.indiatimes.com/2013-05-07/coimbatore/39089295_1_water-supply-water-tanker-pillur*
http://www.thehindu.com/news/cities/Coimbatore/water-shortage-lack-of-storage-facility-irk-coimbatore-residents/article4183818.ece
http://www.thehindu.com/news/cities/Coimbatore/two-zones-in-coimbatore-reel-under-water-shortage/article438585.ece

2.1.2
Rural domestic water sufficiency

In the case of domestic water supply in villages, the supply comes largely from groundwater managed by the Gram Panchayats, with some augmentation with imports from the Bhavani basin. Data from the National Rural Drinking Water Programme website provide some indication of the extent to which domestic water supply norms are met in rural areas of the basin. These village-wise data suggest that in most villages, groundwater supply is above 30 LPCD, and about half of these receive nearly 40 LPCD. Again, the variation in LPCD values seems surprisingly small. Whether this uniformity is a reflection of the efficient functioning of TWAD Board or poor data reporting can only be established via independent household surveys in the field.

2.1.3
Coping with and adaptation to water scarcity in the domestic sector

Water from 'drinking water schemes' such as the Siruvani and Pillur projects is usually insufficient to meet all domestic water needs. Based on our field visits over summer, we found that drinking water is supplied to many neighbourhoods only once in every 7-10 days. To make up for the deficit, municipal corporations and TWAD supply borewell water on alternate days. This ensures that users get sufficient water, albeit some of it is of a poorer quality (to be used for non-drinking purposes). The same tap provides drinking water as well as domestic water and the lineman informs the residents of the type of water that would be provided on a given day. Community cohesiveness then comes into play in informally spreading the word. In our field visits, we found households to be well-informed regarding the type of water (borewell water or Siruvani drinking water) that would be supplied on a given day. Adapting to this situation, households store drinking water separately. In newly constructed houses, there are two separate storage tanks, one for drinking water and another for other domestic uses.

From our field visits, we found that the quantity supplied declines during the summer months. However, again, we were unable to locate studies documenting the extent of this seasonal scarcity.

2.2
Industrial water sufficiency

Industrial water use comprises one of the biggest end uses of water in the basin, especially in certain locations. Of these, the textile (dyeing and bleaching in particular) industry in Tiruppur is one of the biggest water users. Water availability is one of the major limiting factors for these industries because good quality of water is needed for textile dyeing and bleaching. The rapid growth of these industries after economic liberalization in 1990s depleted the local sources of water. Water was then brought in by tankers from a 50 km radius around the Tiruppur industrial cluster, eventually leading to the groundwater also getting depleted. This led to a conflict between farmers and industrialists (Janakarajan 1999). However, the flourishing economy of the dyeing and bleaching industry meant that the government was unwilling to clamp down on the industry's over-extraction.

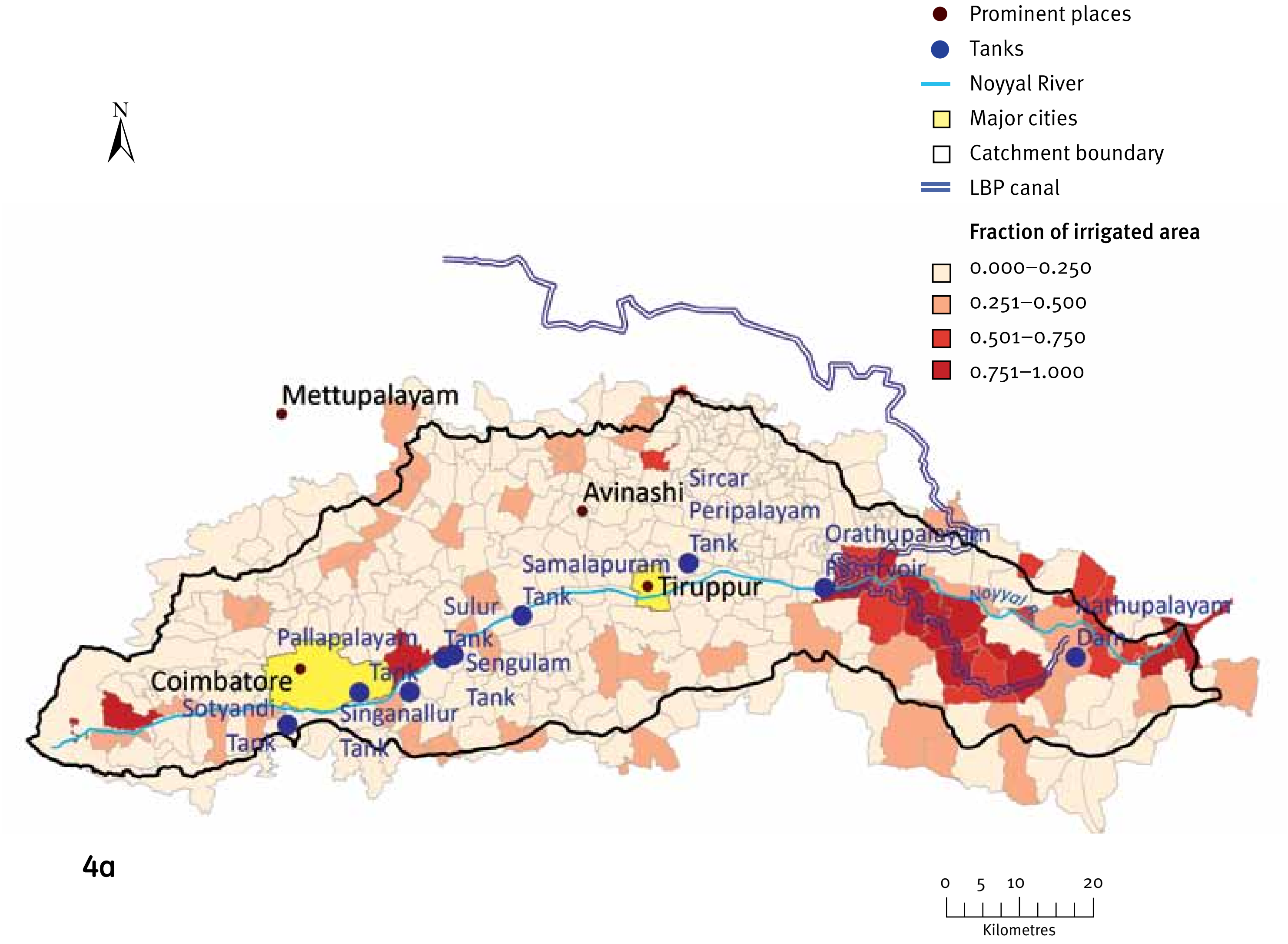
Eventually, a proposal was made by the government to divert water from the Cauvery (just downstream of the Bhavani-Cauvery confluence) to Tiruppur for use by the industry. In 2005, the government established the NTADCL to provide the infrastructure facilities to Tiruppur via a PPP arrangement. Under the project, facilities were constructed to extract, treat and supply 185 million litres of water per day (MLD), which would gradually be increased to 250 MLD. Since the time it was commissioned, in 2005, water is being supplied to the dyeing and bleaching industries and domestic consumers in and around Tiruppur (Elangovan, NTADCL, pers. comm.).

However, there has been a sharp drop in industrial demand for water due to several independent factors. While water availability to industry was addressed by NTADCL, the problem of industrial effluents was not, as we shall describe in section 5. The ZLD regulation ordered by the Madras High Court has raised costs for many industries because of the high costs of setting up and operating an IETP that has reverse osmosis. Those who are able to operate such plants, however, recycle their own water, thereby reducing their demand for water. Furthermore, competition from other countries and the global financial crisis has resulted in weak demand for garment exports. As a result, in the last few years over 50% of the small-scale textile units in the Tiruppur area have shut down (the total number declining from 800 to 400 units). Industrial demand for water has gone down from 60 MLD in 2005 to 20 MLD in 2012 (Elangovan, NTADCL, pers. comm.) Thus, it could be said that industrial water is in over-supply rather than insufficient.

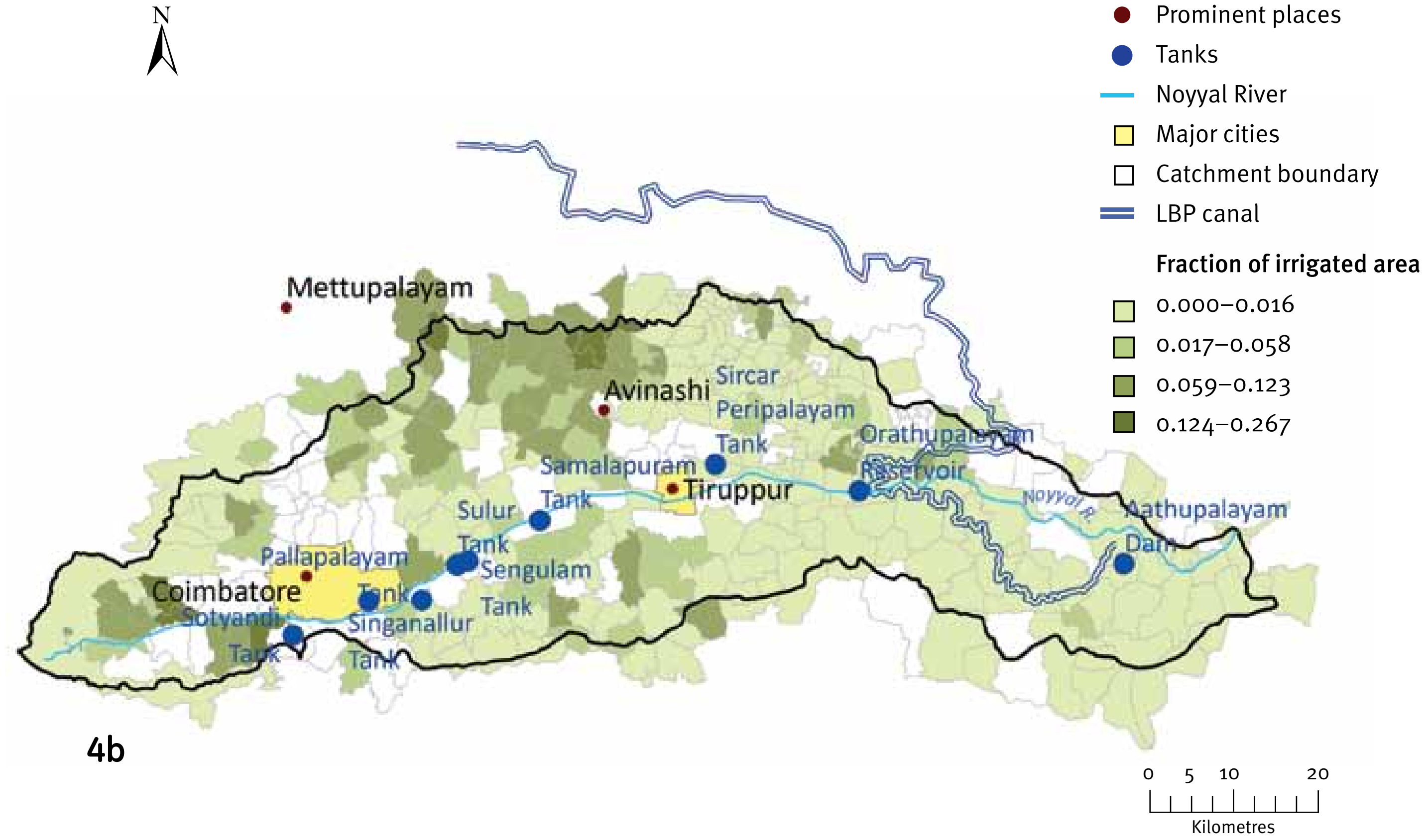
2.3
Agricultural water sufficiency

In contrast to the domestic and industrial sectors, water for agricultural purposes appears to have become somewhat scarcer over time. However, the situation varies across the basin and is also complicated by a number of factors.

Initially, before the 1990s, as irrigation shifted from tank irrigation to open wells and then to borewells, irrigated area probably expanded. Tank irrigation has all but disappeared today (Census 2001 village amenities data). The only surface irrigation project set up within the basin (the Orathupalayam dam) collapsed because of industrial pollution (see section 5). The Lower Bhavani irrigation project brings water from the Bhavani basin and irrigates the eastern end of the valley, both directly and because its unlined canal recharges the shallow aquifer and enables open well irrigation (see Figure 4c). Open well irrigation also exists in a few pockets in and around Coimbatore, where the groundwater is locally recharged because of heavy inflows of sewage into tanks. Borewells are the predominant source of irrigation in the rest (central and western portions) of the basin in the Noyyal sub-basin (Figure 4b).



4a



4b

4c

Figure 4 a, b, c: Fraction of cultivated area irrigated by all sources, only borewells and only open wells (Source: Census of India, 2001. Maps prepared by Ecoinformatics Lab, ATREE)

Several studies have documented the intense pressure on groundwater resources in the Noyyal sub-basin (Palanisami et al. 2008; Suresh Kumar and Palanisami 2011). These studies have documented quantitative data as well as farmer perceptions on agricultural water scarcity. These studies indicate that in agricultural areas away from the Noyyal River and tanks, groundwater levels have dropped below 800 ft. in places. Closer to the Noyyal River and in urbanized areas, the situation appears to be better.

The Central Ground Water Board (CGWB) maps support the idea that groundwater is over-exploited in the upper parts of the Noyyal sub-basin (see Figure 5). Downstream of Coimbatore and Tiruppur, the problem of over-exploitation disappears. We believe that this is in part because groundwater gets recharged by wastewater flows emanating from Coimbatore and Tiruppur, and in part because of recharge from canal irrigation from the Lower Bhavani Project.

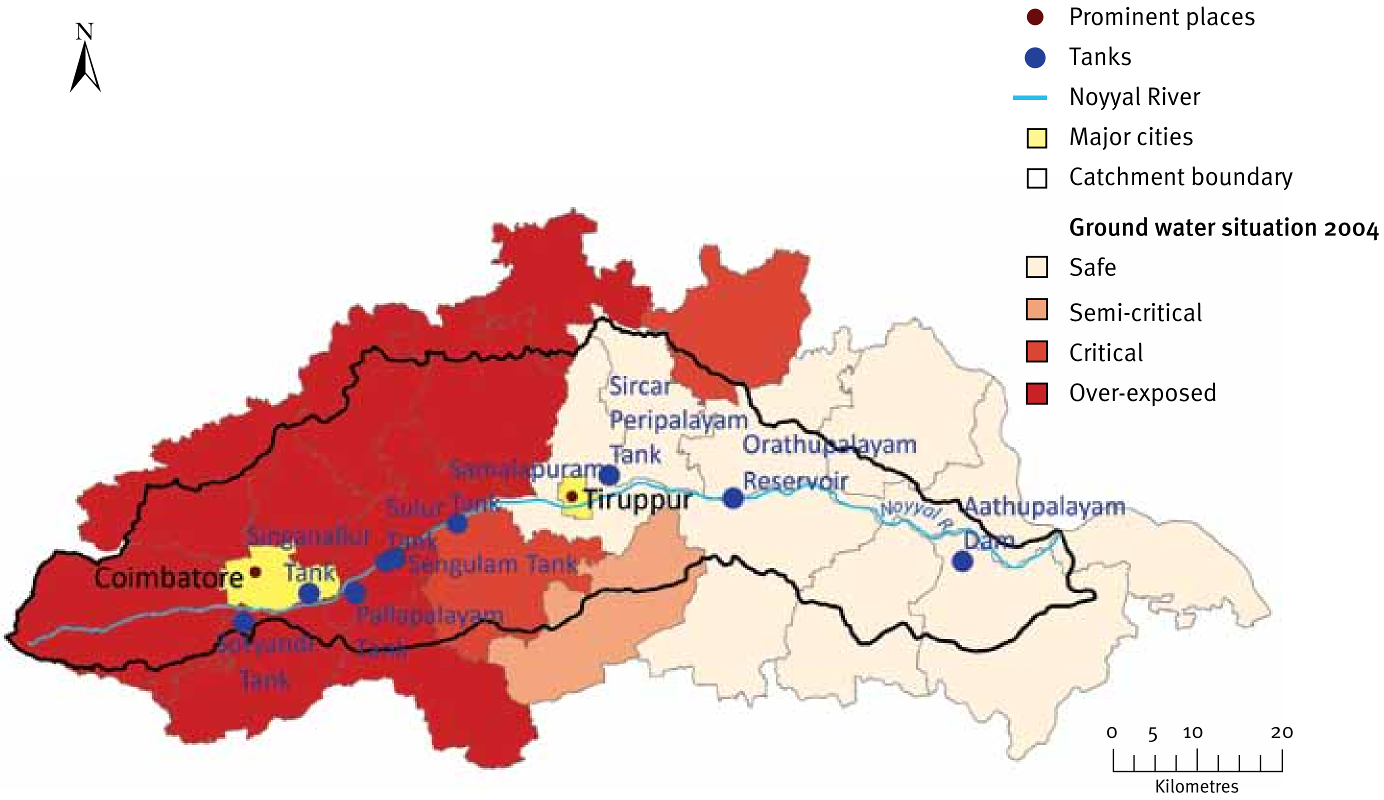


Figure 5: Groundwater criticality status map as of 2004 (Source: CGWB online data . Map prepared by Ecoinformatics Lab, ATREE.)

At the farm scale, falling groundwater levels manifest as well failures. Farm-level surveys provide evidence of this. One study conducted in Coimbatore district, Palanisami et al. (2008) shows that the average area irrigated per well has declined over the years, both, under open wells and borewells: an indication of declining groundwater availability. In many villages, the average number of wells owned by a farmer has ranged from three to six borewells and one open well. The average well failure rate was 47% for open wells and 9% for borewells (Palanisami et al. 2008). This study estimated the cost of failed wells in Coimbatore district alone at ₹ 55 crores. The study also found that competitive deepening of wells was worsening the situation. Based on field visits and discussions with the farmers, the authors found that new borewells with a depth exceeding 250 m were causing shallower wells in the vicinity to dry up, forcing those farmers, in turn, to deepen their wells.

This lack of availability of water for irrigation has imposed significant costs on farmers. Suresh Kumar and Palanisami (2011) have documented evidence of groundwater depletion on wells and the costs associated with this (Table 3). Although farmers made investments in protective irrigation in all blocks, they invested approximately ₹ 7,000/ha more in wells, electric motors and storage tanks in over-exploited versus safe blocks.

Table 3: Coping investments in ₹/ha (% of total investment in brackets)

Particulars	Over-exploited blocks	Critical blocks	Semi-critical blocks	Safe blocks
Investment on wells	18,827 (71%)	15,756 (67%)	13,325 (67%)	13,226 (69%)
Investment on electric motors	7,141 (27%)	7,055 (30%)	6,307 (31%)	5,451 (29%)
Investment on storage tanks	628 (2%)	565 (2%)	357 (2%)	346 (2%)
Total investment on irrigation structures	26,596 (100%)	23,376 (100%)	19,989 (100%)	19,023 (100%)

Source: Suresh Kumar and Palanisami 2011

Despite this evidence, assessing the extent of agricultural water scarcity is complicated for two reasons. First, agriculture as a whole is declining in the Noyyal sub-basin due to urbanization. The workforce has become more non-agricultural and land use has also shifted to non-agricultural uses due to demand for housing and industrial estates. Therefore, it is not possible to deduce the extent of water scarcity based on declines in agricultural output or cultivated area. Moreover, given that groundwater use is unregulated and electricity is free, many farmers do not face absolute water scarcity (except in the increasing coping cost mentioned above). Farmers are essentially able to 'postpone' scarcity by drilling deeper into the aquifer.

Second, it is not clear if the water availability is getting better or worse. The secondary data show signs of a recovery following recent imports from the Bhavani basin. Specifically, data for 1991 and 2001 indicate a decline in both cultivated and irrigated areas. But data for 2007 and 2011 show that, while cultivated area has continued to decline, irrigated area has actually increased (Figure 6). The decline in total cultivated area may be related more to the demand of land for other uses.

When we spatially mapped the irrigated and non-irrigated fractions, we found that almost all the decline in irrigation in the 1990s occurred around the Tiruppur area. The villages that experienced the steepest declines in irrigation, were also some of the villages that suffered from conflicts between farmers and industries due to sale of tanker water to the garment industry in the 1990s (Janakarajan 1999). After the creation of NTADCL in 2005, tanker water sales ceased and irrigated agriculture picked up again. Block-wise data show a significant increase in irrigated area in the blocks in and around Tiruppur from 2007-2011.

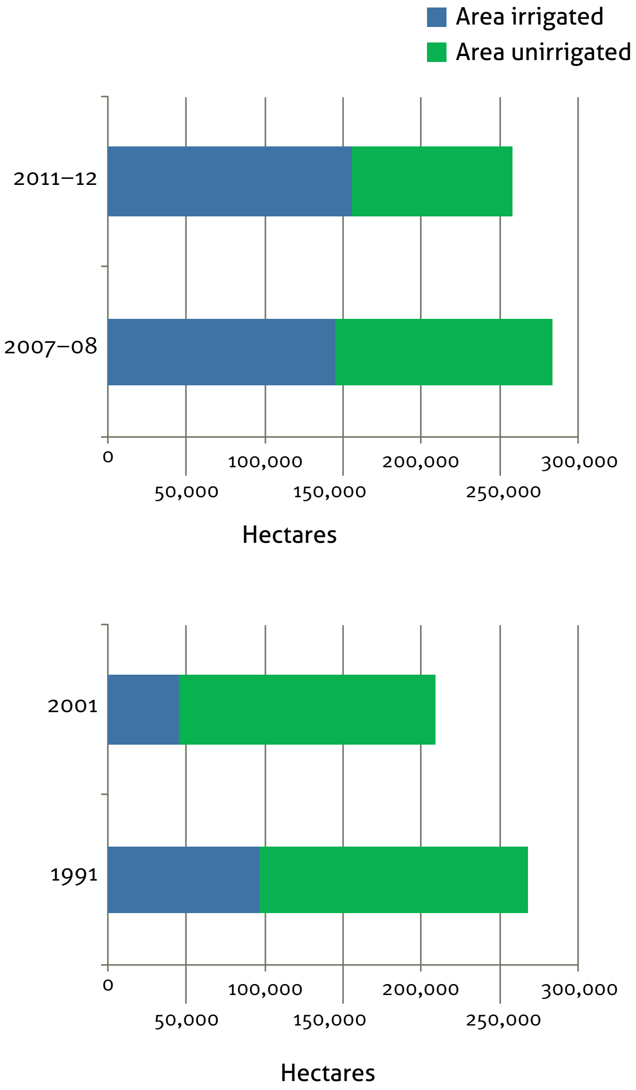


Figure 6: Trends in irrigated area (1991-2001 data are from the Village Amenities Tables of the respective Censuses; 2007-2011 data are from block-level 'G-Returns' from the Department of Economics and Statistics, GoTN)

Overall, published literature does indicate that agricultural water scarcity is a problem in pockets, and in many interior areas, farmers are suffering from borewell failures and repeated investments in water abstraction structures. However, it is also clear that this situation is not uniform throughout the basin. Urbanization of land and availability of water formerly allocated to industry (due to a decline in the textile industry and creation of NTADCL) has eased agricultural water scarcity in some pockets.

2.3.1
Coping with agricultural water scarcity

Farmers have had several responses to decreases in agricultural water quantity and quality. First, there has been an expansion of drip irrigation. It is not entirely clear if the expansion in drip irrigation is a private coping response because there has been a major move to promote drip irrigation by government and agricultural extension agencies with the help of subsidies. Moreover, the impacts of drip irrigation are also mixed. Suresh Kumar and Palanisami (2011) show that drip irrigation has generated significant benefits in terms of resource savings: cost of cultivation, crop yields and overall farm profitability. However, drip irrigation has also resulted in expansion of irrigated area, suggesting that the decline in water used per acre may be offset by increases in irrigated area. This happens in regions where there is scope for expansion of crop area. When land was limited, expansion of drip irrigation resulted in water saving.

Second, there has been a gradual shift of irrigation sources from surface water sources to open wells and in the last three decades, to borewells. This has been augmented by the construction of on-farm storage structures, which help the farmers to store water from low-yielding wells and irrigate when needed. Water is pumped from very deep borewells when electricity is available and stored in these tanks, and then used for irrigation (Suresh Kumar and Palanisami 2011). In this context, water scarcity may be characterized as water being unavailable when needed rather than absolute scarcity – a phenomenon that arises from the combination of electricity shortages and poor yields.

Third, there has been considerable emphasis on watershed development and drought-proofing work by the Tamil Nadu government. Of the 19331 micro-watersheds in Tamil Nadu, a quarter underwent soil and water conservation activities by 2009 (Palanisami and Suresh Kumar 2010). Overall, watershed development activities have been shown to have positive impacts in improving soil moisture, raising water tables and contributing to livelihood security. In one meta-analysis of watershed development activities, the overall impact of watershed development projects was assessed; the benefit cost ratio was in the range of 1.27 to 2.3 (Palanisami and Suresh Kumar 2010). Although it is not clear what fraction of land within the Noyyal basin has been treated under watershed development, it is clear that watershed development is likely to have ameliorated some of the decline in water tables in the basin and its consequent impacts.

2.3.2
Adequacy of water for environmental amenities

Anecdotal evidence suggests that water available for environmental amenities such as wetlands and aquatic biota has declined over the last few decades. The Noyyal River that was flowing regularly during the monsoon now experiences very little flow, and several of the smaller tanks are dry. Although the impacts of deteriorating water quality have been extensively examined, there appears to be no study on the impacts of low flows on aquatic communities (Senthilnathan 2005). However, it is clear that public efforts to rejuvenate urban water bodies are at least partly motivated by a desire to restore and preserve aquatic ecosystems, both for their existence value and because they provide higher quality of life to residents living around the water bodies.

2.4
Summary and knowledge gaps

At this stage, it is not clear that domestic water scarcity is acute in the basin. On the contrary, due to their ability to set up water imports from the Bhavani basin, the authorities have managed to meet the sharply rising urban water demand, and also supplement rural domestic water supply – even if this is not entirely successful during drought years. Overall, our impression is that TWAD Board has been able to ensure a minimum quantity of both high-quality drinking water and lower-quality borewell water to all households. Anecdotal evidence from newspapers and field visits indicate that water scarcity is a problem in some periods. However, there are no recent independent household surveys characterizing water scarcity, coping or groundwater dependence in the Noyyal basin.

Similarly, the importing of water for Tiruppur industries from the Cauvery under NTADCL, combined with the decline in the dyeing-bleaching industry itself has meant that from a situation of severe conflict between farmers and industry over water extraction, the industrial sector (especially in Tiruppur) is experiencing surplus water availability.

The agricultural situation is more complex. While water scarcity and competition from industry are a problem in some pockets, there have been many other factors that are causing farmers to move out of agriculture: in particular, labour scarcity for farm work and high returns from converting land to urban layouts. Nevertheless, agricultural sector water availability remains precariously poised. On the other hand, there is a clear shortage of water for environmental amenities.

2.4.1
Knowledge gaps

The above review indicates the following key knowledge gaps:

- In the domestic sector, while on an average, scarcity may not be a problem, it is not clear how much scarcity is experienced during the summer season or during drought years. Further, the estimation of adequacy or scarcity needs to be done after including self-supply from private borewells or purchased water.
- In the agricultural sector, there was an urgent need to resolve the inconsistency in different stakeholders' views on water scarcity. Deep groundwater levels (below 800 feet), failing borewells and severe water scarcity reported by farmers, and observed anecdotally from our field visits, are not borne out by published data from CGWB and TWAD on groundwater levels. This requires further investigation.

3

SUSTAINABILITY AND RESILIENCE OF SUPPLY

In the previous section, we examined the issue of whether current water availability is adequate to meet current needs. However, current use affects future availability also, particularly in the case of groundwater. Moreover, variations in year-to-year availability (of rainfall and surface water) are high and therefore resilience against drought years also needs to be considered. Thus, both sustainability of average use under average conditions and resilience against major droughts are of concern. There is also a question of whether pollution levels affect usability of water.

There are various sources of data and several studies that have looked at these issues, particularly regarding the sustainability of groundwater use. These include government reports and data (CGWB 2008a) as well as academic hydrological modelling studies (Mayilswami 2006; Saravanan et al. 2011). Upon reviewing these datasets and this literature, we find some points of consensus but also several points of disagreement or ambiguity. We then identify knowledge gaps where more investigation is required.

3.1

Areas of consensus in previous groundwater studies

The objective of these studies varies from estimating the water balance (Mayilswami 2006) to identifying potential recharge zones (Saravanan et al. 2011) or tracing the impacts of pollution (Ljungberg and Qvist 2004). Although, the studies do not directly address the question of whether current levels of groundwater extraction are sustainable or resilient, they nevertheless do provide several useful insights.

First, tanks are clearly functioning as recharge structures. Ljungberg and Qvist (2004) conducted a pilot study in the Sulur watershed, located in the Noyyal sub-basin, to assess the influence of pollutants in the Sulur tank on local groundwater quality. Their field observations indicated that tanks are polluted due to pollution in the main river channel but also act as recharging structures for local groundwater resources.

Second, watershed development activities have resulted in recharge of groundwater. For instance, Palanisami and Kumar (2004) enumerate the impacts of watershed development activities in two watersheds, viz., Kattampatti and Kodangipalayam. The watershed development activities undertaken included construction of check dams, percolation ponds, etc.

The study showed about 10% average increase in groundwater availability in treated villages compared to untreated ones. However, this increase benefitted those farmers who had wells in the proximity of watershed treatment structures.

3.2
Points of divergence and ambiguity

Several points of confusion nevertheless remain, because the results of the studies are not consistent. The crucial questions are: whether groundwater levels are rising or declining, whether this trend exists even after rainfall variation is factored out, whether the changes are driven by changes in pumping for irrigation or pumping for industries or by water imports, and whether these changes are affecting river flows. Here, we find inconsistencies between current studies, published datasets, perceptions of water users that we encountered during reconnaissance visits, and water-level data we collected on our own during these field visits with regards to trends in groundwater levels. Further, we find incomplete information or understanding of the hydrology to answer some of the causal questions. Due to this, we could not make a conclusive assessment of whether the groundwater situation in the Noyyal sub-basin is indeed deteriorating or improving.

3.2.1
Are groundwater levels improving or declining?

Different studies and reports appear to reach slightly different conclusions about the long-term prospects of groundwater in the Noyyal basin. CGWB has 41 monitoring wells across the basin. The CGWB annual groundwater level data (http://gis2.nic.in/cgwb/) for selected wells (Figure 7) show an increase in groundwater levels from 2005 to 2011 (Figure 8). CGWB also favourably revised its estimates of the stage of groundwater development in at least three blocks in the Noyyal basin – Sulur, Sultanpet and Avinashi – from Over-exploited to Semi-critical/Critical over the period 2004 to 2011. However, there appears to be a contradiction in the CGWB data in that groundwater levels rose sharply in all blocks including 'over-exploited' blocks such as Annur. We were unable to reconcile the reasons for this but it does suggest that a critical look into the methodology of the Stage of Groundwater Development is needed.

In contrast, other studies (e.g., Mayilswami 2006a) show that the groundwater levels initially decreased from 1995 to 2002, but then rose again till 2005 (see Figure 9).

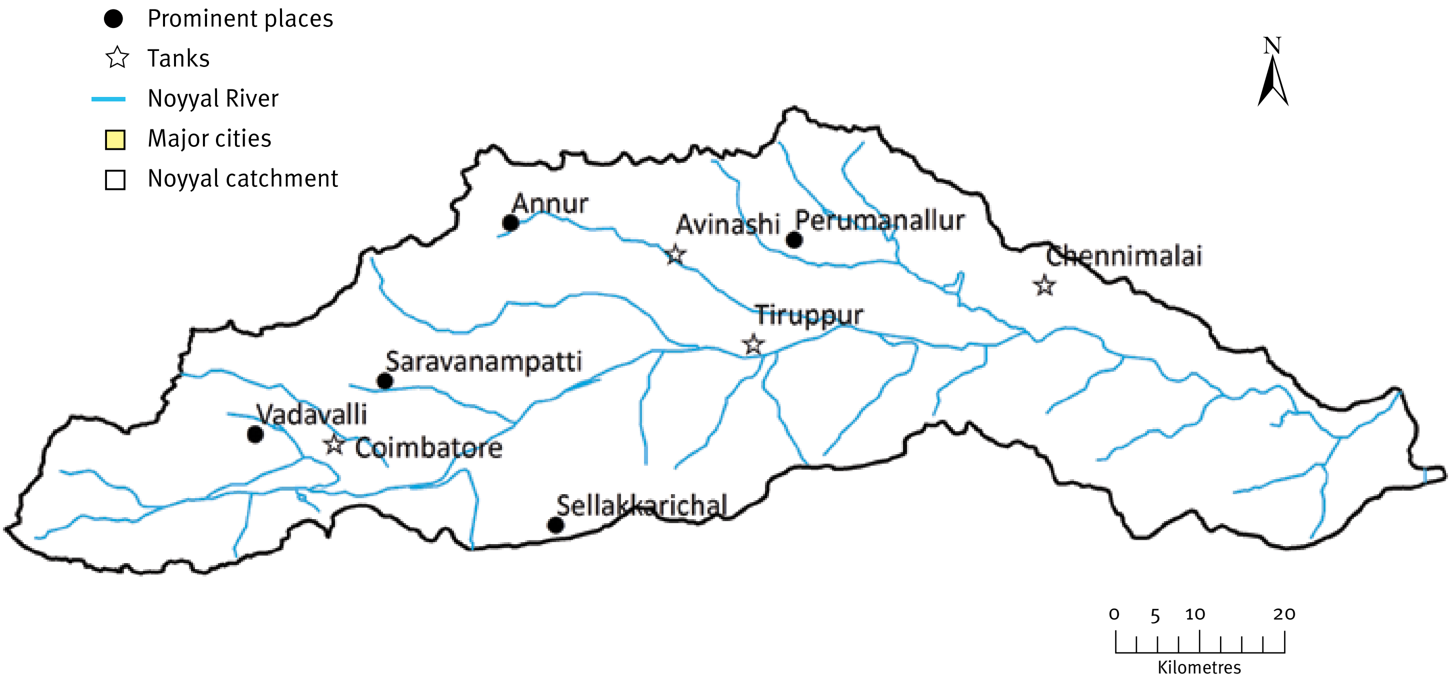
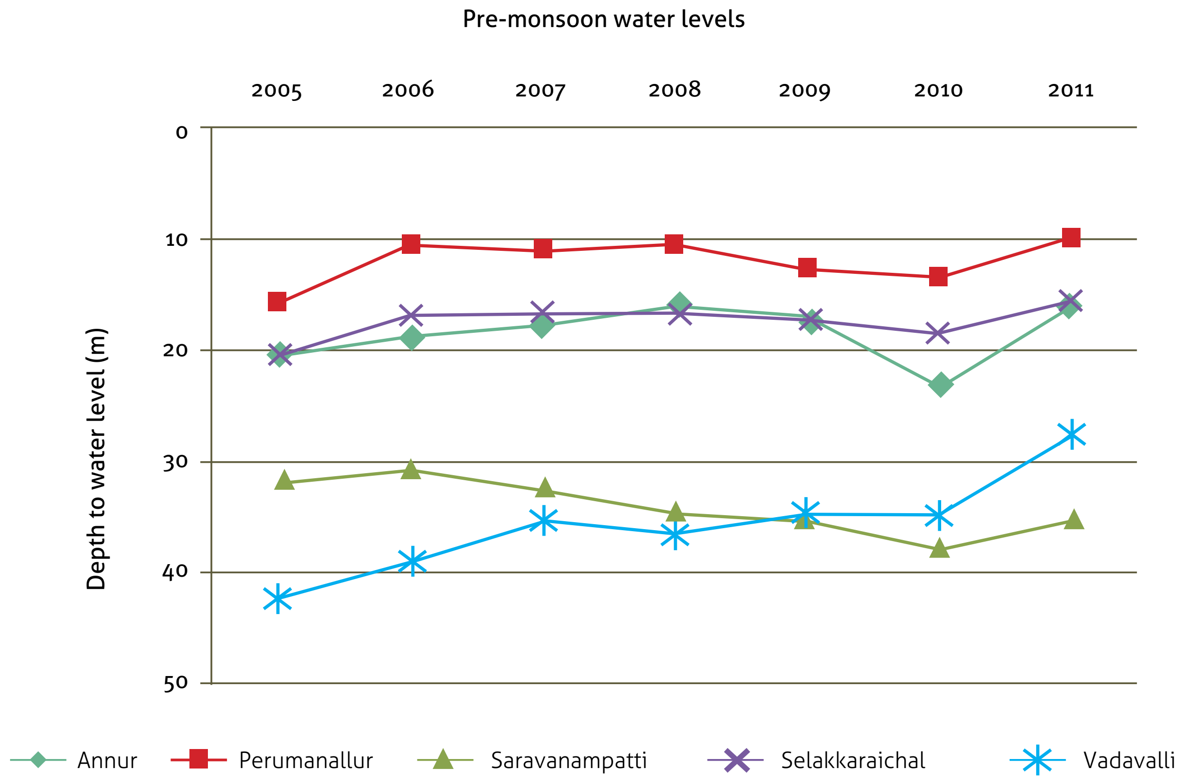


Figure 7: Location of CGWB wells used for analysis (Source: http://gis2.nic.in/cgwb/; locations are approximate, based on village names)



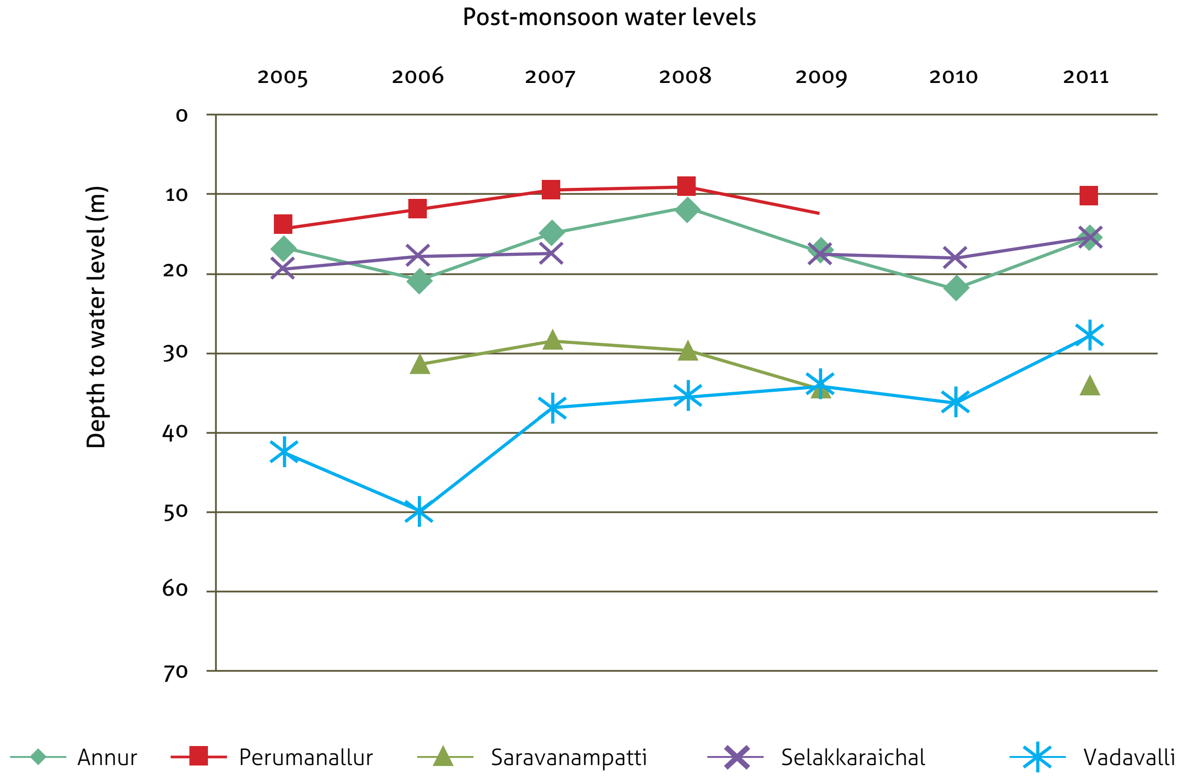


Figure 8: Groundwater levels in CGWB monitoring wells from 2005 to 2012 (pre- and post-monsoon)

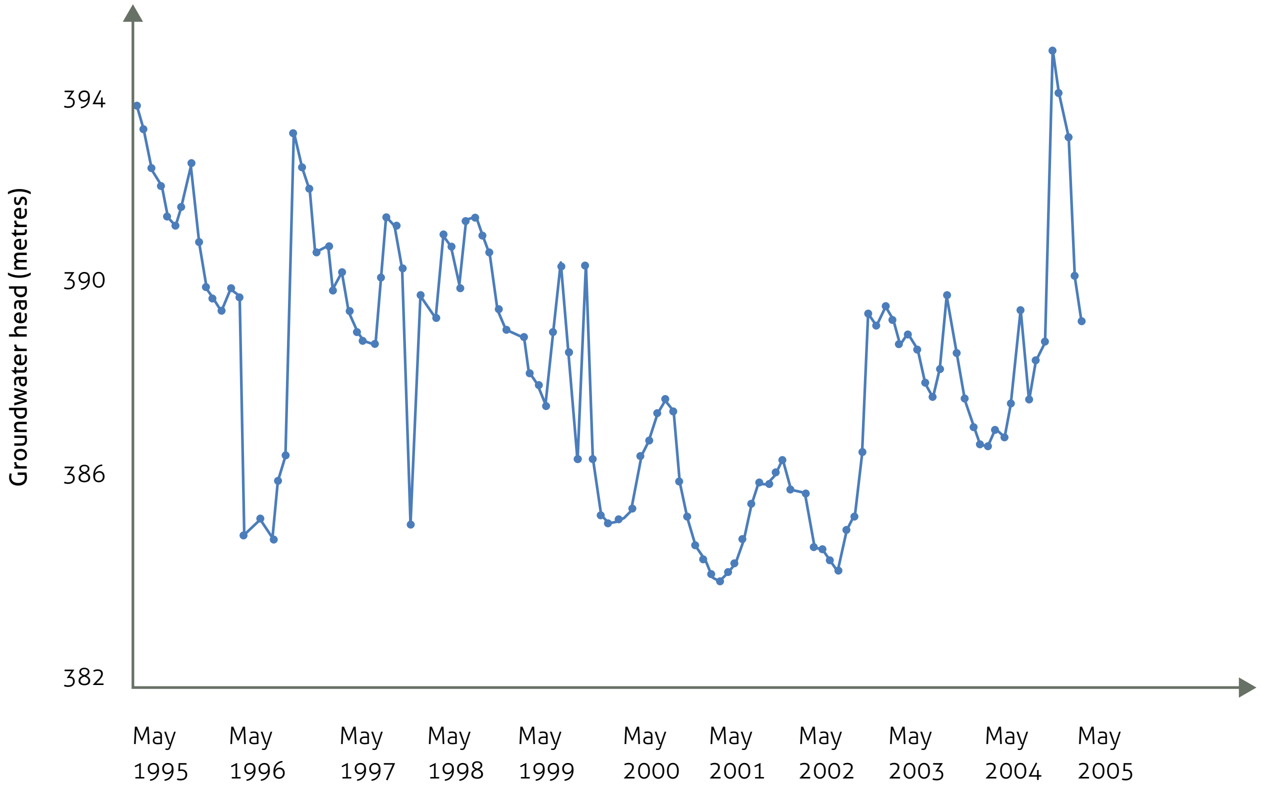


Figure 9: Monthly average groundwater levels in NG-13 (Kallapalayam). From Mayilswami, 2006 (axes redrawn)

Similarly, detailed farmer surveys in sample villages by agricultural economists have indicated that farmers perceive a clear decline in well water levels. For instance, a study by Suresh Kumar (2012) indicates that farmers perceive significant declines in water levels (Table 4). Moreover, there has been a significant investment in coping with groundwater declines. This suggests that there are at least pockets of groundwater depletion.

Table 4: Reported decline in groundwater in Kalampalayam Village

Particulars	Kalampalayam	
	Past	At present
Open wells	18.5 m	Most open wells are dry
Borewells	150 m	245-305 m

Source: Suresh Kumar, unpublished source

Is it possible to reconcile these apparently divergent trends? The Mayilswami (2006) study covers a different time period from the trends in CGWB data. The longer term TWAD Board record suggests that both may be true. TWAD Board, along with the WRO, also has 30 monitoring wells across the basin. These data show a decline in water levels between 1997 and 2003, an improvement after 2003 till 2005, and then a slight decline in post-monsoon groundwater levels between 2005 and 2010 (Figure 10). Overlaying approximate rainfall data (district averages), it seems plausible that the historic heavy rains of 2005 explain the major improvement (an almost 20 m rise) in groundwater levels between 2003 and 2005. After 2005, groundwater levels, especially pre-monsoon, began to slowly decrease again, where again, rainfall may be playing a role.

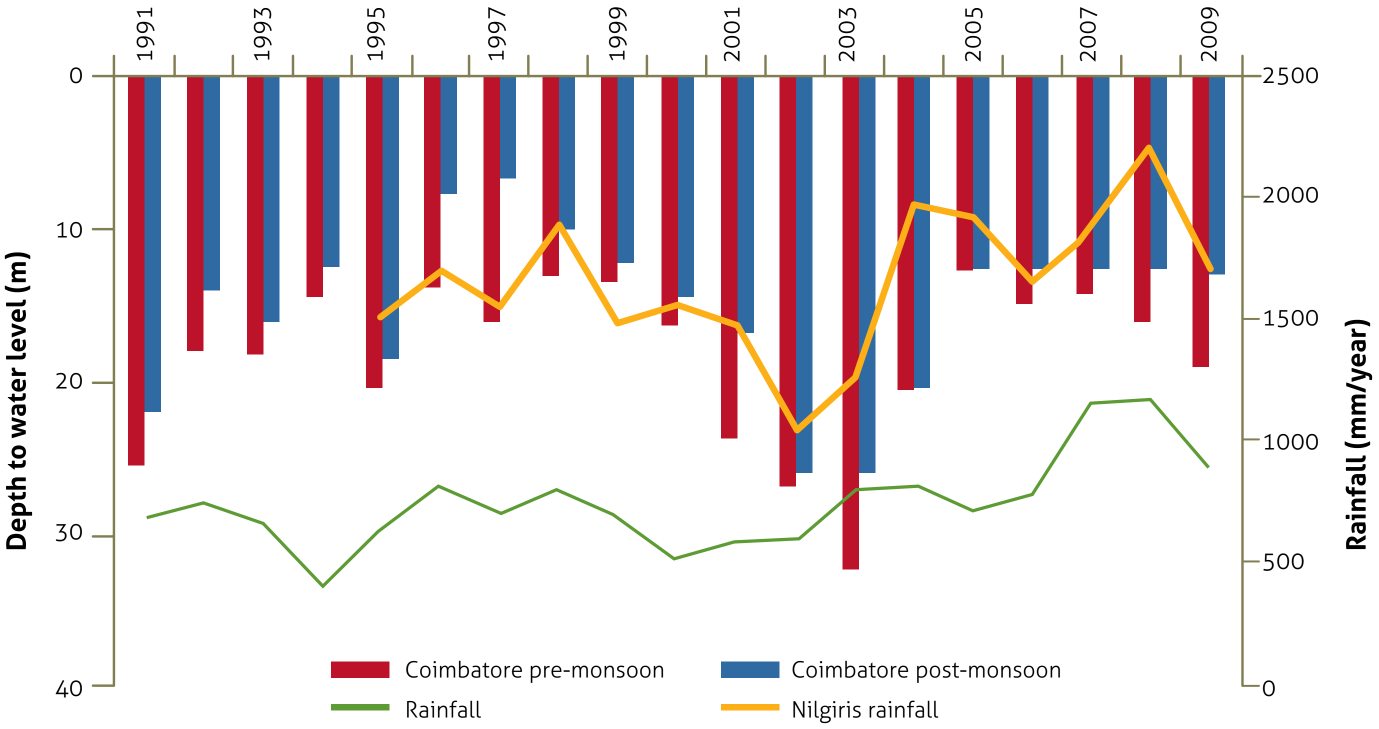


Figure 10: Average annual groundwater levels in Coimbatore district from TWAD data. The solid line refers to the district averages in rainfall for Coimbatore (green) and Nilgiris (orange), respectively.

As part of our reconnaissance visits to the field, we tried to reconcile these different views. Part of the problem may be because the different data sets may be measuring different entities. All of the TWAD Board wells are shallow wells, while CGWB monitored both shallow and deep wells. We measured groundwater levels across the basin using a water level meter (during field visits in January 2013 to August 2013), and plotted the same on a map of the basin (Figure 11). We found that evidence of much deeper water levels than is apparent from the CGWB and TWAD data.

3.2.2
Are shallow and deep aquifers connected?

Some scholars argued that the difference in the water levels between shallow and deep aquifers is largely insignificant, suggesting that the two, shallow and deep, aquifers are hydraulically connected (Mayilswami 2006). However, our own field measurements (Figure 11) suggest that differences in heads between shallow and deep aquifers persist for at least a few months of the year. Our field data reveal that there is not much groundwater level difference between shallow and deep wells along the main channel of the Noyyal and near major tanks containing water. However, the static groundwater levels are much deeper (150-700 feet) when we move away from the main channels of the Noyyal, its tributaries and tanks. This suggests that the river itself plays an important role in groundwater recharge. The lower groundwater tables away from the main channel and tanks may be due to less groundwater recharge from the surface water sources.

Heavy pumping from deep borewells in rural areas may account for the persistence of a 'head difference' between shallow and deep borewells. In other words, water is being pumped from the deep aquifer creating a drop in head even when there is some water available in the shallow aquifer, as is observable from the circled points in Figure 11. At these points, the circle (shallow GW level) and triangle (deep GW level) are adjacent to each other but have different values. However, as distance from the recharge structures increases, the head difference between deep and bore wells becomes more pronounced .

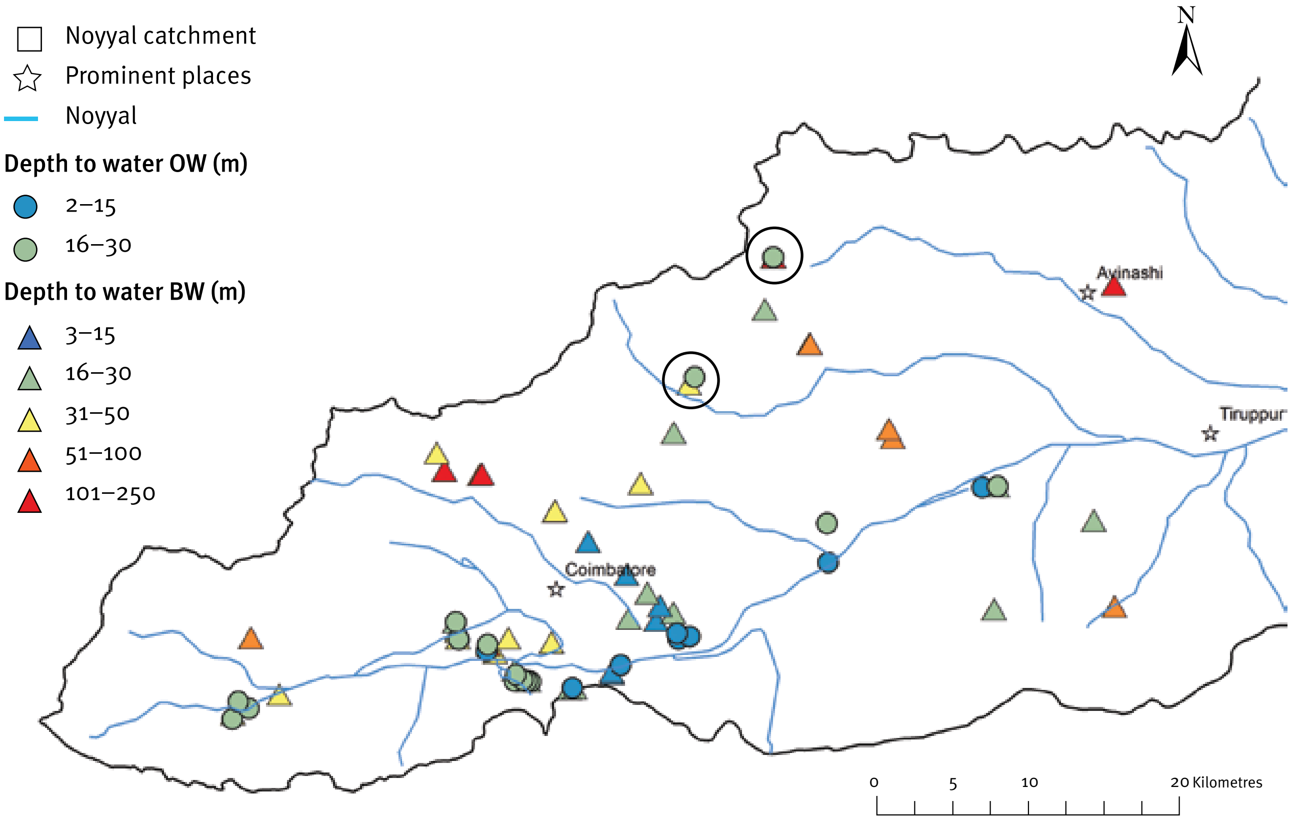


Figure 11: Depth to groundwater level: measurements during field visits from January to August 2013

3.2.3
Groundwater-surface water interactions and vulnerability

Our field observations showed that there is a high degree of correlation between groundwater levels and stream water levels in the Noyyal. Even if groundwater levels are stable, we may still want to know (a) how stable this situation is or how vulnerable to drought it is, and (b) whether this stability is coming at the cost of surface water, i.e., by converting the Noyyal from a gaining river (a river that is augmented by base-flow from the aquifer and hence flows for several months after the rains) into a losing river (a river that recharges the aquifer, thereby drying up quickly and not flowing).

To understand the extent of stability or vulnerability to future scenarios, it is necessary to know the difference between recharge (from surface and from river) and the extraction. Although a few studies have examined groundwater-river interactions, the available research on these aspects is incomplete. Ljungberg and Qvist (2004) used a groundwater model to understand the interaction between sewage contamination of tanks and pollutant transport via groundwater flow. Their results suggest that water is being pulled from the Noyyal into the aquifer. As intensive pumping is inducing recharge into the aquifer from the Noyyal, under the prevailing groundwater pumping conditions, there will never be a situation where the Noyyal flow becomes perennial. In contrast, the shape and direction of the water level contours in Mayilswami (2006) suggest that the Noyyal is a gaining stream and it is being recharged by groundwater.

3.2.4
How much groundwater is being extracted?

Surprisingly, we did not find any empirical literature for any part of the basin, which estimates sector-wise groundwater extraction rates triangulated against cropping patterns, well density, etc. Previous groundwater studies either used fixed estimates of groundwater extraction or simply estimated net recharge (extraction-recharge) based on the difference in water levels method. As the studies did not link the magnitude of groundwater pumping due to domestic/industry/agricultural activity, the studies do not help understand how changes in groundwater extraction or recharge rates might influence groundwater flow paths or sustainability of the aquifer system.

3.2.5
Do water imports play a significant role in groundwater recharge?

Regarding recharge rates, Saravanan et al. (2011) and Mayilswami (2006) derive estimates of recharge rates from detailed groundwater models, but their estimate rates of 20-25% of rainfall are significantly higher than comparable estimates for other hard rock areas. For instance, the value assumed by CGWB (1998) for hard-rock aquifer is 12%. Marechal (2006) provide an estimate of 13-19% for the Maheswaram watershed in Andhra Pradesh, which has a similar hydrogeological environment to the Noyyal sub-basin. It is possible that this difference is due to the fact that these studies have not incorporated the possible impacts of imports from the Bhavani. A back-of-the-envelope calculation suggests that leakage from pipelines and sewers could be significant, at least in pockets.

3.3
Summary and knowledge gaps

Despite the plethora of studies on groundwater issues in the Noyyal basin, several knowledge gaps and, indeed, contradictions remain. First, there remains considerable uncertainty on the absolute levels and trends in groundwater levels. While the CGWB and TWAD data suggest that groundwater levels have been rising or constant in recent years (i.e., 2011), these do not appear to tally with the fact that many blocks continue to be classified as over-exploited and that their status did not change between 2004 and 2011. Not surprisingly, perhaps, at a recent workshop conducted at TNAU, farmers disputed government claims that groundwater levels were rising. Their own perception is that groundwater levels are declining. The farmers allege that the methods used by CGWB and the State GW agencies are faulty. Better understanding of groundwater level trends and the reasons for divergence between farmer perceptions and published data is urgently needed.

Second, even though many studies have used groundwater models to predict groundwater flow regimes in the basin, due to the paucity in quality evapotranspiration estimates, groundwater pumping rates, inter-basin water transfer from the Bhavani basin and finer scale aquifer boundary mapping, the applications of the results to policy formulations are limited. Some of the missing gaps include:

- No study has included estimates of stream flow/ stream head, which is a major component in groundwater modelling. We were unable to ascertain the extent to which the Noyyal recharges or is fed by the shallow groundwater.
- There are virtually no estimates of groundwater pumping by households, industry and agriculture. Existing extraction estimates are either circular (using past water level changes to estimate extraction and using extraction again to predict future water levels) or not triangulated independently (e.g. comparing groundwater extraction data from electricity board data, farmer surveys and evapotranspiration estimates).
- Most groundwater analyses completely failed to account for inflows into the Noyyal sub-basin from the Bhavani. Given the magnitude of urban and industrial water imports, it is likely that water imports and pipeline leakage is a significant influence on Noyyal sub-basin groundwater. Similarly, there are anecdotal reports that wells along the LBP are recharged when water is released in the channels. The contribution of imported water to groundwater recharge in the Noyyal sub-basin appears to have been underestimated or missed out.
- Most studies did not include the pumping of water from borewells by households and agencies in their analysis. Much of this water is also returned to the river (in the form of sewage) and contributes to recharge.
- Overall, the models were weak on groundwater and surface water connectivity. Whether the Noyyal discharges to the groundwater, or is recharged by the local groundwater, or both, in different sections, remains unclear.
- The TWAD Board declares the presence of 924 check dams across the four districts that constitute the sub-basin. However, there has not been any comprehensive study of the usefulness/hindrances due to these dams and what role they play in redistributing water resources.
- Although patterns of contamination of groundwater due to polluted surface waters has been studied in many reports (TNAU), there has not been any modelling done to understand the source, movement and fate of the pollutants, or potential groundwater pollution by illegal dumping of dye effluents.

4

EQUITABLE AND FAIR ALLOCATION OF AVAILABLE WATER

The third dimension on which the water situation may be assessed is the fairness of water allocation. Unfortunately, there are no objective or broadly accepted criteria for us to judge how water ought to be allocated across users/uses. We therefore talk about quantitative equity only when it comes to allocations within a particular sector or user group. On the other hand, allocation between sectors or user groups, such as domestic versus industrial versus agriculture, or upstream versus downstream, is judged in terms of fairness. Since there is no clear criterion for fairness, we examine the fairness in the process of allocation (Lele et al. 2013).

4.1

Equity within the domestic sector

Within the domestic sector, it is appropriate to consider if different sub-populations receive 'equitable supply' in terms of litres per capita per day (LPCD). Although the distribution system seems to be equitable, there exist differences in amount of water supplied even within the same city. Bergh and Nordberg (1996) showed that there were significant differences in amount of water supplied within Coimbatore city. The central part of the city and Pudur were better supplied with Siruvani water than suburban areas such as Kurichi. However, the absence of any recent study on water consumption prevents us from providing a detailed picture of the present situation.

During our field visits, we did not come across pockets of extreme water scarcity, although there was variability across neighbourhoods and cutbacks in water supply during dry periods. In the summer of 2013, most households interviewed reported receiving water once every 7-10 days, supplemented by groundwater from TWAD Board municipal borewells. There is inequity between how different income-class households use water. The richer households use more than double the amount of water than the lower income households while the very low-income households are actually paying the highest prices for water (Bergh and Nordberg, 1996). However, there have been no recent studies on domestic water use and we had to rely on analysis of secondary data in order to understand the current situation.

In evaluating if water supply is equitable, we looked at variability in supply across towns. TWAD Board data indicate that water supply norms were not being met for most of the TPs (Norm: 70/90 LPCD without and with underground sewerage system) or municipalities (Norm: 90/135 LPCD without and with underground sewerage system) as shown in Figure 12.

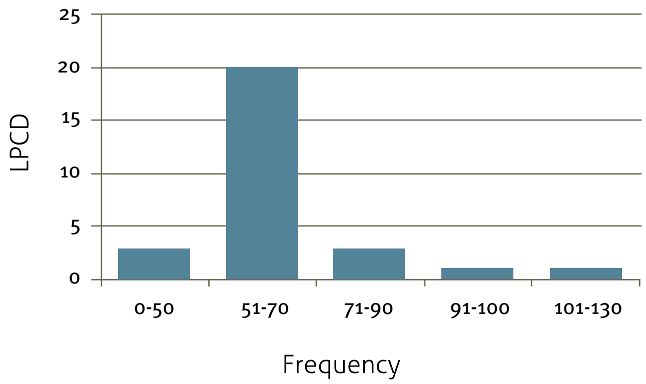


Figure 12: Pattern of water availability across Town Panchayats in the Noyyal sub-basin
(Source: http://www.twadboard.gov.in)

There is, however, a larger question of whether such 'structural inequity' between TPs, Municipalities and Municipal Corporations is justifiable, or whether they simply perpetuate a privileging of wealthier populations in cities. How these engineering standards have evolved and whether they are appropriate is a question that needs further investigation.

4.2
Equity within the agricultural sector

Groundwater is the main irrigation source (except in the Lower Bhavani Project command area). Therefore, access to irrigation water is determined by access to groundwater, inherently benefitting the wealthier farmers (who can afford to drill borewells). Palanisami et al. (2008) show that small and marginal farmers typically have only one borewell and pump only for 4 hours in a day compared to large farmers who have four to six borewells and can pump simultaneously from two to three wells. Moreover, energy costs are proportionately higher for marginal and small farms compared to large farms because the latter enjoy economies of scale.

4.3
Fairness across users/sectors

There is significant competition for water in the Noyyal at specific locations and periods. However, it is hard to assess if the allocation of water across users is 'fair' for several reasons. Since, the major part of the public supply in the Noyyal is imported, in effect, the inter-sectoral conflicts over water in the Noyyal play out elsewhere, particularly in the Bhavani basin. Different agencies also supply water to domestic and industrial users from different sources, so the priorities are hard to establish. Moreover, water is supplied through a network of surface-water-based public supply and groundwater-based private supply. Wealthier households, farmers and larger industries draw the most water. However, because groundwater-surface water connections are poorly understood, it is difficult to understand who is impacted and how.

At present, TWAD, the main bulk supply agency, only has the right to take water from the water sources as needed. The rivers themselves are managed by PWD for the people. TWAD cannot manage the resource or build storage infrastructure; it only has the authority to build water supply and transmission systems and to carry out treatment before supplying the water to local governing bodies. Most of TWAD's water is supplied for domestic water use in Coimbatore, small towns and rural areas. About 10% of the public supply goes to commercial and institutional entities (Lannerstad and Molden, 2009). In addition, a small amount is sold to industries at a higher tariff. TWAD Board engineers claim that they have maintained a steady amount of domestic water supply to Coimbatore for many years. This statement was not, however, consistent with our field observations during the summer of 2013, when residents complained about the decreased frequency of Siruvani supply, although they acknowledged it was temporary. In contrast, industries in Tiruppur are supplied by the NTADCL from the Cauvery, so it is hard to establish priorities over domestic supply. Downstream farmers in the Cauvery delta may be suffering from NTADCL's extraction but we did not find papers discussing this. However, NTADCL argues that the withdrawals by NTADCL constitute a mere 1-2% of the flow of the Cauvery at the abstraction point.

Moreover, most irrigation, rural water supply and industrial water use is groundwater-based, the question of equitable allocation of groundwater often stems from the conflicts between users of the same aquifer, e.g., farmers with shallow wells versus farmers with deep wells and farmers with shallow wells versus environmental flows in the Noyyal and so on (Lannerstad and Molden, 2009). Although many groundwater models provide evidence for a link between shallow groundwater and the Noyyal River, it is not clear where the river feeds groundwater and where it is the other way around.

4.4
Fairness between upstream and downstream users

Over time, drinking water diversions and the small-scale river, canal and groundwater pumping have contributed to double counting of the water available in the basin. We did not find analysis of upstream-downstream conflicts along the Noyyal, but this issue has been studied in the Bhavani basin: where more water is abstracted upstream, less flows downstream (Lannerstad and Molden, 2009). Despite a high variability in flow at the Lower Bhavani Project reservoir site, there is a discernible decline in inflows to the LBP reservoir: by about 500 Mm^3 over the last decade, amounting to a reduction of about 25% of the inflow (Lannerstad, 2009). This is due to the cumulative effect of abstractions in the upper part of the basin: the 104 Mm^3 of drinking water transfers to Coimbatore and Tiruppur cities, and evaporation of about 50 Mm^3. There was no discernible long-term trend in rainfall over the same period.

LBP farmers who constitute the ‘downstream users’ have the lowest priority. PWD records show that as soon as the inflow to the LBP reservoir is less than 1,500 Mm3/year, the LBP farmers lose one or both seasons of canal water releases. In effect, in the absence of a formalized water rights system, the LBP farmers, both in the Noyyal watershed and elsewhere, have to bear the brunt whenever inflow to the LBP reservoir is not enough to meet all downstream needs.

4.5
Summary and knowledge gaps

- There are no systematic household surveys that quantify urban water use in the urban and rural areas of the Noyyal basin.
- At a conceptual level, there is little debate and clarity on what constitutes fair or unfair allocation across sectors, or between upstream and downstream users. There is no formal system of water rights, and the National Water Policy gives priority to domestic needs without clarifying what agriculture or industry might be entitled to. Thus, the development of a water rights structure is, in itself, a major need at this juncture.
- The lack of knowledge about the relationship between upstream groundwater pumping and changing inflows into tanks or rivers downstream remains a major knowledge gap. There are no studies that evaluate trade-offs between the direct use and aesthetic functions of urban water bodies.
- The absence of disaggregated information on water supply within villages and city wards means that there is limited understanding (beyond individual case studies) of the extent of variation in water availability to domestic users.

5

WATER QUALITY TO SUSTAIN PUBLIC HEALTH AND ENVIRONMENTAL AMENITIES

Since the mid-1990s, water quality and the impact of industrial pollution have been the most debated aspect of water resource management in the Noyyal basin. The intense debate and public interest in water quality issues in the Noyyal have generated vast literature – including government-commissioned, academic and non-governmental – on the types and distribution of contaminants in the region.

However, as described in Section 1, the series of court cases that sparked this debate have culminated in the High Court passing a ZLD order in 2011. Due to this, and other factors mentioned earlier, by 2013 almost half the textile units in Tiruppur have either shut down or relocated, and the remaining are either recycling their effluents themselves (using IETPs) or through CETPs (Sakthivel, Tiruppur Exporters Association, pers. comm.). However, there are no studies on water quality in the post-2011 period. We therefore use the available studies to summarize the pre-2011 situation in terms of water quality and its impact on various sectors, discuss adaptation and other responses that have emerged, and indicate what might be the current situation using anecdotal information. It may be noted that the 2011 ZLD order only pertains to industrial effluents and influences only surface water quality, if implemented.

5.1
Water quality in the Noyyal

5.1.1
Surface water quality

The water quality of Noyyal River has been found to be highly polluted (Geetha et al. 2008; Raja and Venkatesan 2010; Chitradevi and Sridhar 2011; Sellamuthu et al. 2011). High levels of biological oxygen demand (BOD), chemical oxygen demand (COD), faecal coliform, faecal streptococcus and total dissolved solids (TDS) were observed in the surface water samples from the Noyyal River. High TDS levels in the river water indicated the discharge of treated and untreated industrial effluent, as well as disposal of partially treated sludge along the banks of the river.

The surface water along the Noyyal River has been classified into four zones (Figure 13): Zone 1: Vellingiri Hills to Perur tank, Zone 2: Perur tank to Samalapuram tank, Zone 3: Samalapuram to Orathupalayam dam, and Zone 4 Orathupalayam to Kodumudi (downstream of Orathupalayam reservoir up to confluence with Cauvery) (Madras School of Economics 2002). This classification remains useful even in the post-2011 context.

Zone 1 is the least polluted as it is upstream of most of the urban areas, although urban expansion during the last decade (after the MSE study) has introduced some biological contamination here too (Usharani et al. 2010).

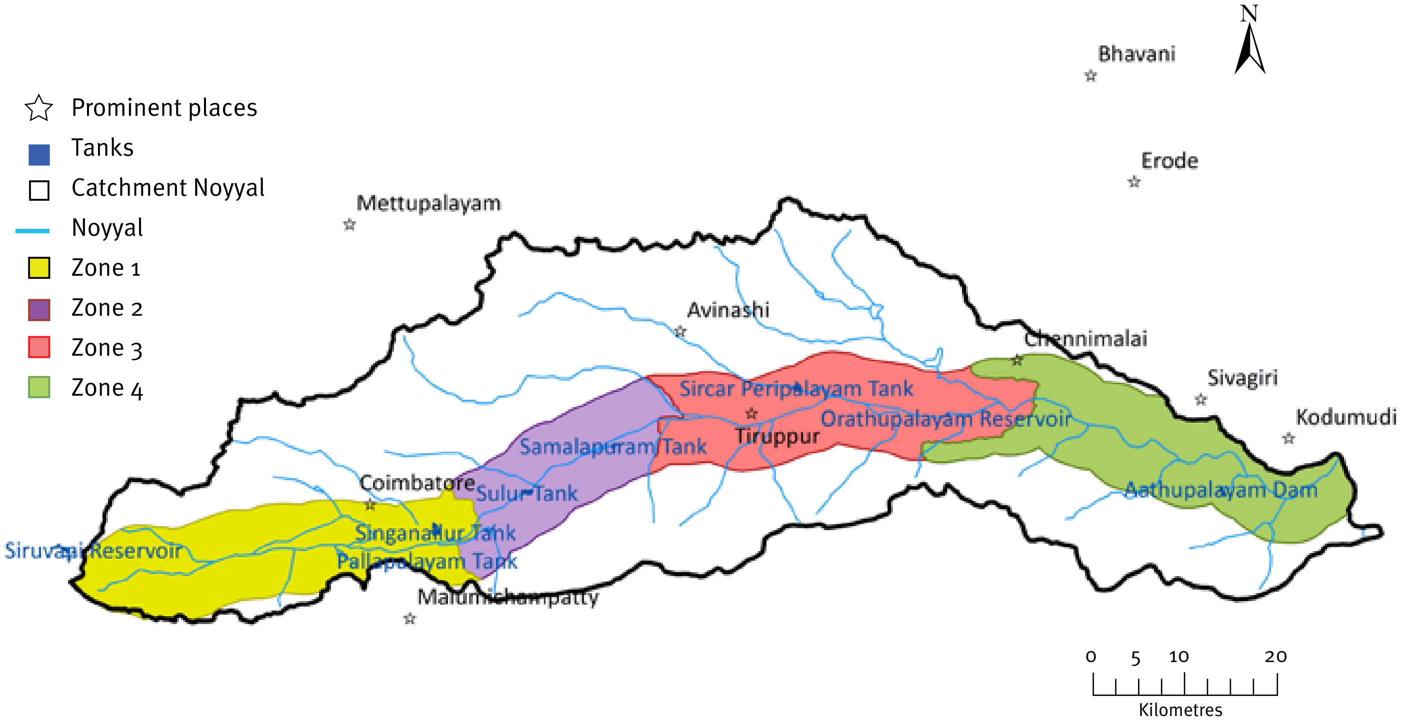


Figure 13: Surface water zones along the main Noyyal River (Source: Madras School of Economics 2002)

Zone 2 is affected mostly by Coimbatore's domestic sewage combined with a little industrial pollution. Zone 3 is affected mainly by industrial pollution. Zone 4 is not affected as much because of dilution of inflows from the Lower Bhavani Project and the trapping of effluents at Orathupalayam dam.

5.1.2
Groundwater quality

Various studies have been carried out to evaluate the quality of the groundwater resources in the Noyyal sub-basin (Geetha et al. 2008; Raja and Venkatesan 2010; Chitradevi and Sridhar 2011; Sellamuthu et al. 2011). Most of the studies rely on relatively easy-to-measure parameters such as TDS, electrical conductivity (EC), dissolved oxygen (DO), sulphates, chlorides, nitrates, magnesium, calcium, sodium and potassium. The studies vary in their sampling strategies, sample sizes and locations, and reach somewhat different conclusions. Nevertheless, the studies show the existence of high contamination pockets in groundwater.

In Tiruppur district, the groundwater wells located near the river had high TDS as compared to the groundwater samples located far from the river. Ion balance, piper diagram and Gibbs diagram analysis were carried out to confirm the source, impact and process of groundwater chemistry. It was found that the levels of chloride and sodium ions were strongly correlated with TDS as compared to the bicarbonate and calcium ions, indicating that sodium and chloride are introduced into the aquifer from external sources (Sellamuthu et al. 2011). The studies clearly show that anthropogenic activity dominates the change in chemical composition of groundwater in Noyyal basin (Chitradevi and Sridhar 2011).

Sellamuthu et al. (2011) studied the impact on industrial effluents on quality of groundwater used for irrigation. The groundwater samples were collected from open wells, borewells and dug-cum-borewells in the Noyyal river basin covering the urban and industrial stretch of Tiruppur. The EC of groundwater samples ranged from 0.41 to 15.95 dS/m. Groundwater samples were dominated by sodium, among the cations, and chloride, among the anions. Heavy metals such as iron, nickel, cobalt and manganese were also detected in selected groundwater samples. In another study, Srinivasamoorthy et al. (2009) attempted to identify the extent of groundwater pollution in the matrix of the Tiruppur aquifer using electrical imaging techniques. Their imaging surveys in Valipalayam, Pethichettipuram, Palayakadu and Chellapuram indicate that the shallow aquifer is highly contaminated and unfit for domestic use.

Rajashekariah (2011) indicates that the Noyyal River Ayacutdars Protection Association have found groundwater pollution extending up to 3 km on either side of the Noyyal River. Furn (2004) found that in the soil irrigated with polluted Noyyal water (e.g. Orthupalayam and Thittampalayam), sodium content was eight times greater than that in neighbouring non-irrigated fields (e.g. Pudur and Ramalingapuram).

5.1.3
Linkages between groundwater and surface water quality

Overall, few studies have addressed processes of contaminant transport and existing studies are confusing. For instance, the Ljungberg and Qvist (2004) study of the pollutants from the Sulur Lake, which receives Sulur town's sewage, found that the contaminated sewage is transported by groundwater flow and captured by local pumping wells. However, the study further found that groundwater quality is actually worse than the Noyyal surface water. This suggests that the surface water pollution is not the only reason for poor groundwater quality. Some other illegal pollution discharge directly to groundwater may also be occurring. Thus, the results were not conclusive.

5.2
Impacts of poor water quality in the Noyyal watershed

Several studies have analysed the impacts of deteriorating water quality in the Noyyal. They cover the impact on the agricultural and livestock sector, on human health and ecosystem health. Some studies have attempted to estimate these impacts in economic terms, some in physical terms.

5.2.1
Impacts on agriculture and livestock

High TDS, EC and sodium absorption ratio in groundwater impact the soil fertility, which in turn impacts agricultural productivity. Chemical analysis and sodium absorption ratios indicated that the long-term application of groundwater will impact the infiltration capacity of soil and thus will have negative impact on crop yield (Madras School of Economics 2002; Soil Survey and Land Use Organisation 2002; Furn 2004; Rajashekariah 2011). In addition to this, agricultural costs are likely to increase as regular tilling and addition of gypsum would be required to improve the infiltration capacity of soil.

Several studies have documented the impacts of using polluted Noyyal water for irrigation. Excess salinity in soil water, due to application of effluent polluted surface water, can decrease water available to plants and cause plant stress. The polluted water, when applied to fields, increases the electrical conductivity. Moreover, acidic effluents make the soil acidic and unfit for traditional crops (e.g. rice, turmeric and sugarcane are replaced by sorghum and coconut) (Soil Survey and Land Use Organisation 2002; Senthilnathan 2005). A farmer survey conducted by Furn (2004), noted that the seeds watered with polluted Noyyal water did not germinate, imposing losses on farmers. With increased effluent loading, the soil became white, porous and fragile, rendering it unfit for agriculture. Currently, salt-tolerant sorghum and coconut are mostly grown in areas affected by Noyyal water seepage. The survey also noted that the farmers along the LBP canal further downstream did not observe these negative effects despite their proximity to the Noyyal River, due to the dilution effect. However, the water quality of these areas during no-flow periods in LBP canals needs to be studied to isolate the effect of Noyyal water pollution.

Senthilnathan (2005) used a combination of questionnaire and personal interviews to assess farmers' perception of agricultural loss. The farmers were selected from Thondamuthur, Madukkarai, Sulur, Palladam, Tiruppur, Chennimalai, Kangayam, Kodumudi and K. Paramathi to represent upper, middle and lower reaches of the Noyyal River basin. The study reported a drastic reduction in the span of ten years, in surface water irrigated area – a 74% drop – which was mostly attributed to failures in rainfall and effluent pollution, while well-irrigated area decreased by 6% due to low water yield. About 92% of farmers ranked failure in monsoon as the most limiting factor to their agricultural productivity. Water pollution, due to effluent discharge, was ranked as the second biggest problem for agricultural productivity; Noyyal pollution ranked first in the 'anthropogenic factors' affecting productivity loss. Sand mining (not well-studied) and encroachments along the river course were perceived as a problem by 27% of the farmers.

Another very detailed study by Madras School of Economics (2002) (hereafter MSE) assessed the impact of polluted Noyyal water on agriculture, in the area between Coimbatore and Orthupalyam dam, in economic terms. Following a pilot study of 13 villages, MSE conducted farm-level studies in three villages, namely Kathankanni, Semmangulipalayam and Kuppam. The studies showed evidence of shifts in cropping patterns due to contamination of groundwater. The farmers in Kathankanni village shifted from paddy, sugarcane, and banana to cholam and cotton. However, the yields declined as the soils absorbed the contaminants. The decline in average value of the output per acre was estimated to be ₹ 12,237 for cotton and ₹ 3,403 for cholam. Semmangulipalayam village was affected initially; however, the water supply from LBP has diluted the effects of the Noyyal water pollution. On the other hand, Kuppam village totally depends on rainfall for agriculture and was less affected.

The valuation of crop damage due to pollution was conducted in all the villages. Using the results from the study and survey, MSE worked out the damage cost for the Noyyal basin due to the increased alkalinity and salinity of agricultural lands (either by direct application of Noyyal surface water or by the use of polluted groundwater) in three different ways. While the estimated cost of soil reclamation was ₹ 38 crores, the estimated damage based on loss in capitalized value of agricultural productivity was ₹ 234 crores, and if calculated in terms of decline in land value, it was ₹ 286 crores. In extreme cases, as a consequence of such losses and continued poor water quality, many farmers and agricultural labourers have quit agriculture, while a few have left the basin in search of alternative livelihoods (Furn 2004; Senthilnathan 2005; Rajashekariah 2011).

In summary, the effluent discharge in the Noyyal has caused socio-economic stress by reducing agricultural productivity and fish stock, leading to the relocation of many farmers and/or resulting in occupational change (Madras School of Economics 2002; Furn 2004; Senthilnathan 2005; Saravanan 2007).

The MSE (2002) report also documents the impact of water pollution on livestock. Livestock rearing was traditionally a subsidiary occupation in rural areas. However, since the water quality has deteriorated, livestock rearing has declined. The livestock were not drinking the polluted water. In areas where the livestock were dependent on polluted water, MSE's primary survey revealed that many calves were born without hair and suffered high mortality rates.

5.2.2
Impacts on human health

Several studies have documented the adverse impacts of consumption of polluted water and contact with polluted water in the Noyyal. Govindarajalu (2003) conducted a study to evaluate the impact of polluted water on human health in rural areas of Noyyal basin. For this purpose, 31 villages and 600 households were selected. The villagers were mostly farmers and daily wage labourers who worked in the farms. Problems such as skin allergy, respiratory infections, gastritis, general allergy and ulcer were found to be common in villagers. The maximum number of cases reported was related to water-borne diseases and it was medically accepted that the polluted water had significant influence on these diseases.

Furn (2004) conducted interviews with the locals living near Noyyal and noted the presence of skin diseases and allergic diseases in people bathing with well, dam or river water. Most locals also reported hair loss when bathing in polluted surface water. The study points to the urgent need to set up healthcare programmes specific to the affected areas along the Noyyal. Rajan (2012), in an article entitled 'Water of infertility', reports on how the polluted Noyyal water has turned the land, animals and people (in chronological order) barren. Due to the increase in infertility cases, the number of new fertility clinics is growing every day in Tiruppur, Erode, Karur and Coimbatore. The hospitals in the worst affected districts, Erode and Tiruppur, report an increase in infertility treatments for people dwelling near the Noyyal. The doctors report a 67% decrease in sperm count (from 120 million to 40 million) from men living downstream of the polluting industries and effluent discharge. Dr. S. Dhanabagiyam, a well-known specialist in in vitro fertilization (IVF), conducted an independent survey to assess the level of infertility in the area. She noted that a staggering number, 30 to 40 couples per day, visit the infertility clinics and claimed that 80% of impotency cases were related to contact with water pollution. According to Rajan (2012), Dr. S. Dhanabagiyam found that the water pollution resulted in decrease in male sperm count, while in females, it created ovarian complications and hormonal changes, leading to loss of oestrogen and abortions. The farmers are slowly realizing that the water pollution has finally 'caught' up to the humans, after decreasing the field productivity, followed by decreasing farm animal productivity.

Senthilnathan (2005) documents the health status of households within the Noyyal sub-basin using morbidity data from public health centres. Acute diarrhoeal disease, tonsillitis, sinusitis and other water-borne diseases were commonly noted across the basin, and were attributed to contact with polluted water in the Noyyal and contaminated groundwater. Mostly people who bathed, fished and lived close to the Noyyal reported these problems. The study also noted the presence of bronchial asthma; other respiratory tract disorders were very common in the basin. Especially in Puluvapatti, Boomalur and Nambiampalayam, 40% of patients complained of respiratory tract problems. The respiratory-related problems were due to the fact that many effluent water treatment units were disposing off the salts along the banks of the river. According to the local people, the salts, after drying, become airborne, resulting in an increase in breathing-related diseases near the dumping fields. Recent news articles suggest that a solution to the sludge disposal problem is being negotiated. (Anonymous, 2013)[3]

5.2.3
Impacts on ecosystem services

Several field studies have analysed the impacts of water quality on aquatic life along the course of the Noyyal and in tanks/wetlands (Chandra et al. 2010, Nishash et al. 2010). Although the lakes in Coimbatore continue to support large bird and fish populations (Guptha et al. 2011, Reginald et al. 2007), there is strong evidence of declining ecosystem health in at least two ways. First, because of the high nutrient loads, several of the tanks are affected by eutrophication and the future of these wetlands and the biodiversity they support is threatened. Several tanks are overgrown with vegetation. This, along with encroachments and silt, blocks the channels, hampers flow and prevents recreational uses of the tanks, such as boating, which is practised in Singanallur and Sulur tanks (AFPRO n.d.). Second, decomposing aquatic vegetation and organic matter in the streams and tanks depletes the oxygen, killing the fish. Senthilnathan (2005) has documented the impact of pollution on fish catch in tanks in the Noyyal sub-basin area, and estimated total losses to fisheries at ₹ 3 crores. Simultaneously, industrial pollution is possibly affecting fish health (Govindaraju et al. 2010).

5.3
Responses to poor water quality

5.3.1
Adaptation responses by farmers

Studies suggested that farmers, even uneducated ones, recognise and adapt to the poor water quality. There is some evidence that with rise in groundwater EC concentration, farmers shift cropping patterns (MSE, 2002) from less salt-tolerant crops (such as banana, coconut, etc.) to more salt-tolerant crops (curry leaf, tobacco, etc.). Traditional crops such as paddy and cereals are virtually absent (Mukherjee and Nelliyat, 2007).

5.3.2
Adaptation responses by drinking water agencies and households

The MSE study also analysed the increased treatment costs imposed by poor quality water. They found that much higher investments in treating drinking water were made by water supply agencies in the polluted Zones 2 and 3 of the Noyyal sub-basin (Madras School of Economics 2002)(Figure 14).

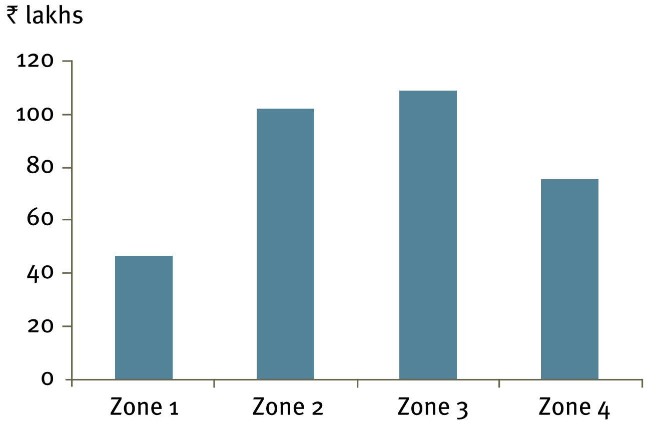


Figure 14: Amount spent on drinking water investments by zone (Source data: Madras School of Economics, 2002)

5.3.3
Institutional responses

The main institutional response to the problem of pollution came from the judicial system, which responded to the public interest petitions by mandating effluent treatment plants (individual and common). The Tamil Nadu Pollution Control Board is in charge of testing the effluents from the CETPs which were put in place in 2008. However, a report by an Environmental Consultant in 2009 found that although the CETPs executed by the Tamil Nadu Water Investment Corporation Ltd. were fully operational, from an environmental perspective, they were disastrous because the 'Reject Management System' was completely bypassed (Kuttiappan, pers. comm.). The CETP was able to separate out the good water or 'the permeate' from the bad water or 'the reject', but then failed to develop a safe disposal system for the reject. The reject from all the CETPs was simply being dumped locally. The TNPCB apparently was silent on this issue, as the practice continued for more than a year. In effect,

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[3] *http://www.thehindubusinessline.com/industry-and-economy/tn-govt-nod-for-landfill-in-tirupur-for-disposal-of-hazardous-waste/article4610908.ece.*

the entire pollutant load was being released back into the Noyyal in 2009, and the expensive CETP performed no real pollution-reduction function at all. To what extent this issue has been rectified today is unclear. During our field visits, we found sites where the sludge was being dewatered and dumped in various places. However, local residents had now begun to complain of asthma as the toxic sludge dried up and was blown by the wind. It appears that the government has not sanctioned an official dumping site.

A study by Nishadh et al. (2010), which assessed the functional efficiency of 11 IETPs and one CETP in Tiruppur found that many of the ETPs were not functioning as proposed, and their discharges were not compliant with CPCB norms. Interestingly, some ETPs had negative efficiency (i.e. quality of outflow was worse than inflow) for TDS, sulphates and BOD/COD. The authors suggest that the plants are not inspected frequently enough to ensure compliance.

Figure 15: Oil contamination observed in borewell in 2013

It is still likely that the closure of many textile units has reduced the pollution load in the Noyyal after 2011. However, there is also increasing concern that some textile units have shifted to interior areas, usually farmlands, and that they may be disposing the effluents locally in various ways. One method is to dump the effluents on their own or neighbouring lands and hope that the effluents get assimilated through percolation, seepage and evaporation. One study (Mukherjee and Nelliyat 2007), which sampled several wells, shows that there has been an observable deterioration in groundwater quality. Pre-monsoon heavy metal concentrations exceeded permissible limits, although post-monsoon levels were acceptable. Our field visits and conversations with farmers suggest that dumping effluents into abandoned borewells might be an approach that some industries are adopting. For instance, in one well, our white water-level-tape came out black (see Figure 15). It has not been possible, based on currently available information, to map out the location and existence of contaminant plumes created by either past or present leaching/disposal of effluents into groundwater.

5.4
Summary and knowledge gaps

The vast body of literature on water quality issues in the Noyyal clearly highlights the serious nature of the water quality problems. However, there are still a few knowledge gaps. First, much of the literature pre-dates the passage of the Zero Liquid Discharge ruling. The direct and indirect impacts of the ZLD Law remain to be seen.

Second, most of the studies have attempted mapping exercises and assessments of whether the water quality is suitable for domestic or irrigation use. Very little is known about the processes governing the exchange of contaminants between surface water and groundwater. Groundwater, in particular, is a hidden resource. Past and present contaminant plumes have not been mapped. There is anecdotal evidence that industries might be meeting the ZLD requirement by dumping effluents into borewells. So there is a real danger that existing contaminated hotspots may spread and impact human health.

Finally, much of the focus has been on industrial effluents. However, untreated domestic sewage also poses a major water quality challenge in the Noyyal sub-basin and merits attention. The impact of raw sewage discharges on human health (e.g. nitrate contamination) and environmental amenities (e.g. lake eutrophication) has not been studied.

6

SUMMARY AND CONCLUSIONS

We have attempted to review and summarise the current state of knowledge on water issues in the Noyyal sub-basin. We defined water 'problem' using a four-dimensional framework of water scarcity, fairness, sustainability and water quality.

We find that there are significant issues on all fronts. Water scarcity is not immediately apparent to many domestic users because they are primarily dependent on inter-basin imports from the Bhavani basin to the north. However, anecdotal evidence suggests that there is also considerable dependence on local groundwater, which may be depleting. Industrial water scarcity has not been a problem, at least in the Tiruppur region, after the commissioning of NTADCL. However, water scarcity for agriculture remains a big problem due to declining groundwater levels, except in the small region served by the LBP canal. Distribution among users and between sectors is not always fair and transparent. With regards to sustainability, it is not clear from the literature if long-term water sustainability is a problem in the Noyyal sub-basin, although again, discussions with farmers suggest that groundwater is depleting. Finally, water quality remains a major issue; the Noyyal, for the most part, acts like a drain for sewage and industrial effluents, making it not only unusable for any human activities but also highly detrimental to aquatic and other biota.

Coupled to this somewhat fuzzy picture regarding nature and magnitude of the problems, the literature on the causes of these problems or the adequacy of response is limited. Anecdotal evidence suggests that enforcement of pollution laws remains an issue. Meanwhile, sewage discharge from Coimbatore and many other urban settlements is increasing rapidly, although no systematic estimates of their contribution to pollution are available. Increasing water demand from a rapidly growing and urbanizing population continues to be addressed through increased water imports, but it is not clear what impacts these imports may be having in the source basin, or how long it will be politically feasible to continue this policy. The absence of recent studies of actual groundwater extraction by different sectors makes it difficult to estimate who is contributing how much to groundwater depletion.

In the past, rapid growth of water-demanding and water-polluting industries precipitated water conflicts and a grave river pollution crisis, which after decades of debate, research, litigation and action, have been ameliorated to an extent. Future problems may be more insidious but multi-dimensional, including groundwater depletion and urban domestic pollution, and may trigger different forms of inter- and intra-sectoral conflict. If such a situation is to be averted, we believe that an integrated effort at understanding this multi-dimensional water question is essential, requiring close collaboration between researchers, state agencies and civil society actors.

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