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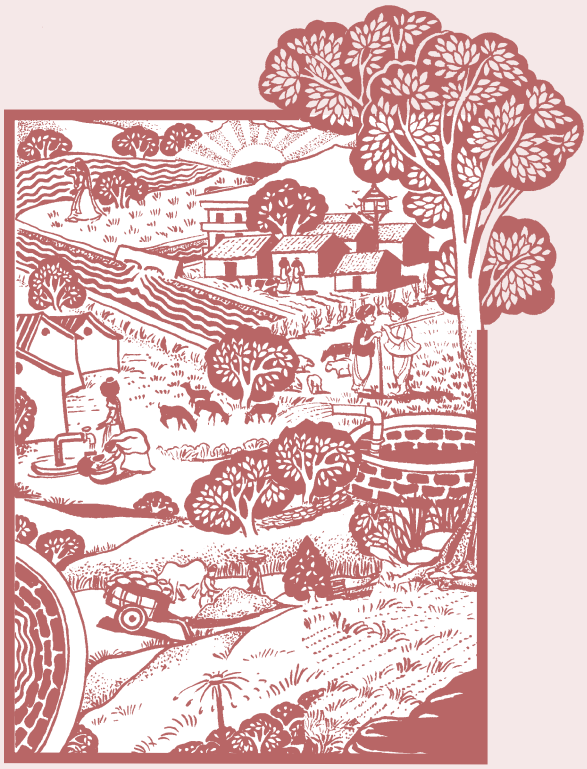

IWMI-TATA
Water Policy Program

Water Policy Research

HIGHLIGHT

Wastewater Irrigation in Gujarat

An Exploratory Study

Wastewater irrigation is commonplace in peri-urban areas of Gujarat as elsewhere in India. The treatment facilities in Gujarat for sewage are highly insufficient and sewage generation is increasingly polluting the streams, lakes and water bodies, where untreated sewage is disposed. In such a scenario, wastewater use in agriculture is an opportunity to address irrigation needs and to minimize pollution. While environmental and health concerns related to wastewater use in agriculture are acknowledged, it is equally important to recognize its contribution to agriculture as a resource. The main questions that emerge are: What is the extent and magnitude of the agricultural economy in influenced through wastewater irrigation peri-urban areas? What factors drive the use of wastewater for irrigation? Are there models of wastewater treatment with direct economic returns from wastewater use in irrigation? An exploratory study was undertaken with the support of IWMI-TATA Program for wastewater irrigation in the state of Gujarat.

This Highlight summarizes the use of wastewater around the major cities of Gujarat for agriculture based on the findings of the exploratory study.

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Wastewater Irrigation in Gujarat: An Exploratory Study[1]

Research highlight based on a report with the same title[2]

Introduction

The management of urban wastewater in India today poses serious challenges in the face of rapid urbanization. The treatment facilities in Gujarat, as elsewhere in India, for sewage are highly insufficient and untreated sewage is rapidly polluting the streams, sea creeks, and water bodies, where it is disposed. Concurrently, it has been observed that wastewater irrigation is commonplace in peri-urban areas of Gujarat. Instances from field visits support the growing use of wastewater for irrigation due to scarcity of fresh water sources for irrigation. The wastewater has become an important resource for agriculture, especially for increasingly urbanized and water scarce states like Gujarat.

While cognizance of concerns related to negative impact on health and environment is taken, the significant use of wastewater for irrigation generating economic benefits to farmers also needs to be recognized. However, currently there is a lack of enough systematic information on the subject, particularly on the extent and magnitude of wastewater's contribution to agricultural economy. Moreover, there is no standard methodology developed to estimate the wastewater use for agriculture.

Wastewater scenario in India and Gujarat

As per Central Pollution Control Board (CPCB) rules, a city or town's municipality or Water Authority (WAs) is responsible for collecting and treating 100 percent of the sewage generated within its jurisdiction. At present, a majority of the WAs in the country neither have the installed capacity nor the collection networks to undertake sewage recycling. A 2010 Centre for Science and Environment (CSE) report puts installed treatment capacity at only 19 per cent of total sewage generation and even this limited capacity reportedly runs at 72 percent utilization (CSE 2010). A 2007 CPCB sample survey of existing Sewage Treatment Plants (STPs) classified the performance of only 10 per cent as 'good' with 54 per cent falling into the 'poor' and 'very poor' categories (CPCB 2009). The CSE also brought out 'Excreta Matters' as their 7th Citizens' Report on the state of India's Environment in the year 2012 (CSE 2012). This study captures the water supply, water generation, water treatment and ultimately, wastewater disposal in urban areas across the nation. The findings are that the water, which is supplied to cities, are demand based and the official records under represent actual supply. This under represented water supply does not have sewage collection network or sufficient treatment systems of sewage.

With a population of over 60 million inhabitants, Gujarat is one of the most urbanized states of India. The urban population of Gujarat is 43 per cent in the year 2011 rising from 37 per cent in the year 2001. The state comprises 167 urban local bodies (ULBs), the service providers of water and sanitation services in urban Gujarat. The growing urban population has meant increased water supply and consequently, increased sewage generation during the previous decade. Although there are proposals to set up STPs along with conventional sewerage systems in all the class A, B, C cities and municipal corporations, as of now the treatment facilities remain far below the required capacity.

The report of the Comptroller and Auditor General of India for Gujarat (year ending March 2011) mentions, “out of 167 ULBs, 158 (93 percent) ULBs have no facility for treatment of sewage. These ULBs discharge untreated sewages in to lakes (9 ULBs), groundwater (18 ULBs), open land (46 ULBs), rivers (40 ULBs), natural drains (26

[1]This IWMI-Tata Highlight is based on research carried out under the IWMI-Tata Program (ITP). It is not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or its funding partners - IWMI, Colombo and Sir Ratan Tata Trust (SRTT), Mumbai.

[2]This paper is available on request from p.reghu@cgiar.org

ULBs) and sea creek (9 ULBs). 8 ULBs divert sewage water for irrigation, while for the remaining 5 ULBs, the position is un-ascertainable".

The use of wastewater for farming in Gujarat is a useful means of supporting livelihoods of farmers and is also a major way of disposing sewage. Thus, application of wastewater for agricultural purpose assumes a higher significance in the current scenario.

Significance and objectives of the study

In this backdrop, the impact of wastewater irrigation on agriculture is worth assessing. To estimate the contribution of wastewater to agricultural economy, Gujarat was taken as a case due to adequate knowledge of the state. Additionally, since most of Gujarat is water scarce, the probability of wastewater irrigation is considered to be significant.

The objective for this study therefore is to estimate the scale of wastewater irrigation in Gujarat. The health and environmental impacts of wastewater irrigation can be studied subsequently.

The specific objectives of this study are:

- To draw attention towards wastewater as a resource and accord it the importance it deserves with growing scarcity and pollution of water;
- To use this exploration to confirm wastewater's use for irrigation and estimate the magnitude of its contribution to agriculture in Gujarat.

Key issues related to use of wastewater

Farming with wastewater for irrigation is known as 'sewage farming' among farmers. Although it results in lots of benefits, there are also growing concerns about health and environmental risks. The people at risk are the users (farmers), consumers of wastewater irrigated produce and populace in the vicinity, which might suffer negative impacts owing to groundwater contamination and evolution of habitats for mosquitoes and other disease vectors. The breeding of mosquitoes and other disease vectors is more widespread in crops irrigated by wastewater as compared with breeding of the same in freshwater irrigated crops like paddy and sugarcane.

The research report by the Winrock Foundation (2005) mentions the main health risks associated with wastewater use for irrigation. These include transmission of intestinal infections to agricultural workers working on wastewater irrigated fields and to consumers of wastewater irrigated produce due to worms and transmission of faecal bacterial diseases, like diarrhea, dysentery, typhoid and cholera. There are documented instances of users suffering from acute skin and gastric disorders. Furthermore, untreated wastewater carrying chemicals is held primarily responsible for the deterioration in water quality and contamination of lakes, rivers and groundwater aquifers. It is also reported in the same report that the soil quality is deteriorated with the use of wastewater for irrigation.

Despite issues related to use of wastewater, there are some benefits of using wastewater identified, which include:

- It helps in conserving fresh water.
- It is a low-cost method of municipal wastewater disposal.
- It is comparatively inexpensive to irrigate crops with wastewater when compared with cost incurred for irrigating with groundwater from deep bore wells, or lifting with diesel pumps from canals.
- It helps in reducing pollution of rivers and other water bodies.
- It helps in conserving nutrients, thereby reducing the need for artificial fertilizers, increases crop yields, crop density and provides a reliable water supply to farmers even during lean season for water availability.

Methodology for Estimating the Magnitude of Agriculture Irrigated with Wastewater

As the objective of this study is to capture bulk of the wastewater use in Gujarat, the peri-urban areas of municipal corporations were studied. This was done since maximum water supply gets generated, supplied and used in the municipal corporations and consequently, there is a logical assumption that maximum sewage generation also comes from these corporations.

Furthermore, from the secondary data, the municipal corporations with a reasonable coverage of underground connections were selected for study. Out of eight municipal corporations, Jamnagar and Junagadh were discarded. Jamnagar has only 14 percent coverage of underground sewage system and Junagadh has none. Additionally, Bhuj was also taken as a case of wastewater irrigation. Bhuj assumes importance because Kutch, where it is located is a highly water scarce area with low sources of irrigation.

During the reconnaissance visits in the sampled cities, it was also found that the STPs have become just aggregators of sewage, parts of which are treated, parts are passed through the treatment plants and parts are bypassed into the disposal area. This disposal area also receives untreated sewage coming directly from a network of open drains (nallahs). The sewage passing through these nallahs within the city limits was not taken into

account for this study, since no agriculture is practiced within the city.

A transect walk along the path of sewage flow was undertaken and the villages were marked on the map. Subsequently, using remote sensing and Geographic Information System (GIS), land use classification was done to compute the area under crop in Rabi season. The GIS of Rabi season was taken since this season is best to estimate the use of irrigation.

The field visit process comprised Participatory Rural Appraisals (PRAs), which were conducted in all the selected cities with the irrigated areas worked out from the maps. This was to estimate the wastewater-irrigated areas out of total irrigated areas in selected villages.

Subsequently, the major cropping patterns were ascertained through PRAs and the expenses incurred and receipts received from these crops were calculated. This was undertaken to arrive at the cost-benefit ratio of wastewater irrigated agriculture.

Key Findings

1. Most wastewater irrigation in Gujarat occurs along rivers that flow through cities. Most of these rivers are already dammed and therefore, do not have much flow of their own beyond the dam during most part of the year. They are extensively used as conveyance channels for wastewater. Farmers along the river use this wastewater for irrigation.
2. STPs are used as aggregation points for sewage in cities from where it is passed out and disposed in rivers or seeps into the groundwater. Often agricultural use is downstream from these locations at the periphery of cities.
3. The reliability of wastewater supply, its nutrient value and almost no cost to access it make it an appealing proposition for the farmers. However, the main attraction remains the reliable availability of it. This is true for all the cities except for water abundant coastal cities like Surat.
4. When farmers find that the wastewater they can access has too many chemicals, beyond the tolerance limits of crops, they do not use it any further for irrigation.
5. The wastewater use is recognized by the Government of Gujarat (GoG) and water charges are being collected at the same rates as applicable for lifting water from notified rivers. In the cities of Rajkot and Bhavnagar, the municipal corporations collect charges for water from farmers. These charges are collected till the treated water is disposed into the river. Once the treatment facilities are dysfunctional, the charges are not collected. It is common to find non-functional treatment facilities in municipal corporations.
6. The GoG also collects charges for treated wastewater conveyed through a pipeline for disposal. A case in point is the charges collected for wastewater generated by Gandhinagar city. The treated wastewater in the city of Gandhinagar is conveyed through an underground pipeline, around 22km in length. It is intercepted at many places by the farmers along the way and the irrigation department charges for this use as per prescribed rates of water lifting from a notified river.
7. Farmers not only use wastewater but even compete for it for its assured availability and nutrient value. However initiation into using wastewater is due to reliable availability. Auctions are held annually in villages of Kutch district to bid for it and use it for irrigation. In the villages of Anadpur (Yaksh), Mota Dhavda and Sanyara, it is auctioned annually at Rs. 5000 to Rs.11000. The land irrigated with wastewater in these villages is 2 ha, 5.5 ha and 4.5 ha respectively.
8. One of the major problems with wastewater treatment methods in cities is that none of the used technologies have direct economic returns. However, few villages of Kutch have operational models with economic returns. As stated in the above point, selling treated water in these villages generates revenue. However, the expenses towards operation and maintenance of these treatment systems are much lower than the revenue generated. The treatment plant is required to be cleaned every alternate year. It uses no electricity and there are no other costs involved
9. The higher nutrient in the wastewater not only increases the agricultural produce, but also the other outgrowth like weeds also comes up profusely. The farmers of the Ruva village in the vicinity of Bhavnagar and the farmers growing fruit crops in the villages around Ahmedabad felt that if micro irrigation is used the weeds would grow lesser. The other issue reported by few farmers in vicinity of Ahmedabad and Vadodara using wastewater for irrigation reported of compacting and formation of crust on topsoil.
10. Use of wastewater irrigation is not only recognized by the GoG but also by farmers' cooperatives. There are cooperatives formed to access the wastewater for year-round irrigation in peri-urban Rajkot, Bhavnagar and Ahmedabad. All of them have been operating for 40 to 70 years. The first STP and collection network in Gujarat was set up in Bhavnagar in 1940, where such a

cooperative was formed at that time for wastewater irrigation.

11. With increasing demand for freshwater in cities, there have been trade-offs between farmers and the cities for availing fresh water in exchange for wastewater. There exists an MoU, which was signed between the farmers of a wastewater cooperative in Rajkot and the Rajkot Municipal Corporation since around 1970 according to which farmers are not allowed to lift water from Lalpari Lake for irrigation to allow supply to Rajkot city. In exchange, wastewater is supplied to the farmers by the Corporation. This MOU is operational even today.
12. In Bhavnagar, it was found that the villages would have preferred the city's only STP location in such a place, which would have enabled irrigation of a larger area using the wastewater. Currently, limited use of this water is made as it reaches sea unutilized. In Gandhinagar also it was found that earlier the water was disposed in the water body of Gota village. This has changed now and wastewater is being used by about nine villages for irrigation.
13. It is also learnt that many cities (Table 1) are selling treated and untreated wastewater for use in agriculture. However, details of all these cities are yet to be found.

Extent of Wastewater Irrigation

There are some studies on developing a methodology to measure the extent of wastewater irrigation. For developing framework for global assessment of extent of wastewater use, Scott *et al.* (2004) used secondary sources and nationally aggregated assessments. Bhamoriya (2002) used a basic inventory of wastewater use with rapid rural appraisals to compute the areas irrigated with wastewater in the city of Vadodara and triangulated the information with focused group discussions and in-depth interviews.

In this exploratory study, use of GIS was made to arrive at an estimation of irrigated areas and then ground verification of these areas was done through transect walks and discussions with farmers' groups. To estimate the extent of wastewater irrigation in the vicinity of each city, firstly, the STPs were marked on a GIS image. During the field visit, the wastewater flow was tracked based on the potential wastewater using villages from the GIS image. After the transect walk, the actual villages using wastewater were confirmed and additionally, the irrigated areas in those villages were computed for the Rabi crop by classifying the image for various land uses like habitat, irrigated land, open land and water bodies. While classifying for irrigated areas the assumption being that if in Rabi there is agriculture, it must have some form of irrigation. Once the total irrigated areas of the villages were known, PRAs were conducted in each of these

Table 1 Urban local bodies charging for use of untreated/treated wastewater

Class of the city	Name of the city	No. of members (where cooperatives exist)	Period of wastewater charges collection	Water Charges
Class C	Balasinor	--	--	--
Municipal Corporation	Bhavnagar	162	Collection from 1994 to 1998	Rs. 750 per ha (Rs.120 per bigha)
Municipal Corporation	Gandhinagar	Around 200	On-going since 1982	Per season per ha of land depending on the crop
Class A	Nadiad	--	--	--
Class D	Oad	--	--	--
Class B	Palitana	--	--	--
Class A	Patan	--	--	--
Municipal Corporation	Rajkot	210	Towards pumping cost from 1962 to 2004	Rs. 2500 per ha (Rs. 1000 per acre)
Municipal Corporation	Rajkot	108	Towards pumping cost since1962-present	Rs. 3000 per ha (Rs. 1200 per acre)
Class B	Visnagar	--	--	--

Source: *Authors' discussions with municipal officers in various cities*

villages to arrive at percentage of irrigated areas using wastewater for the crops. The cropping patterns were also ascertained in PRAs. The land under each crop in each village was determined in focus group discussions. The information sought was for the last year's crops. In the same focus group discussions, agricultural receipts and expenses towards external labour, seeds, fertilizers, pesticides and energy costs were also found for each crop in that village or a set of villages in the surroundings, where not much variance was found. These costs were extrapolated to calculate approximate figures mentioned in Table 2 and Table 4.

The extent of wastewater use in agriculture is represented in Figures 2-7

As part of the study, the use of wastewater, agricultural yields of crops irrigated through wastewater, expenses and profits were estimated. Table 2 provides data on agricultural yields and profits with wastewater irrigation.

The extent of wastewater use in a village with access to it depends on following factors:

1. The availability of irrigation water: The villages on the periphery of Surat city have abundant irrigation water available through Ukai Kakarapar irrigation scheme. They do not need to irrigate with wastewater, which would result in higher costs for lifting it. However, few fields, where wastewater is accessible and canal water does not reach, it is used for irrigation. Largely, this is disposal from Bhesan and Ichhapur STPs.
2. Availability and quality of groundwater: There are places, where groundwater is available at economically prohibitive depths or is too saline for agricultural use. These places use wastewater for irrigation. In the peripheral villages of Vadodara, the groundwater is saline in most part of the villages. In some pockets, fresh water is available at reasonable depths. If the wastewater is not accessible in such pockets, freshwater is being used, which are few. Hence, in the peripheral villages of Vadodara, 65 percent of the total irrigated area is irrigated by wastewater.
3. Load of industrial effluent in wastewater: Villages of Vinzol, Ropada and Gamadi in the vicinity of Vinzol STP in Ahmedabad receive significant quantity of wastewater. Groundwater is also available at a depth of 800 feet and more. Due to such depths, using groundwater becomes expensive because diesel is used for pumping. In such circumstances, wastewater use is the obvious choice, which flows next to the farms. But, it was surprising to find that wastewater is not being used here as it is loaded with industrial effluents and is acidic in nature. This causes severe damage to crops and is therefore, not used.
4. Salinity in surface and groundwater deemed unfit for irrigation: Khari River in Nagor village in the periphery of Bhuj city has only saline water. The groundwater there is also saline. As no other source is

Table 2 Extent of wastewater use for irrigation in peripheral villages of major cities of Gujarat

Sr. No.	Cities whose surrounding villages use wastewater for irrigation	No. of villages availing wastewater for irrigation (including the city itself)	Net irrigated area (in ha)	Wastewater irrigated net area (in ha)	Percentage of wastewater irrigated area
1	Ahmedabad	45	21086	9450	45
2	Bhavnagar	1	391	195	50
3	Bhuj	2	619	248	40
4	Gandhinagar	7	2251	769	34
5	Rajkot	16	6921	3252	47
6	Surat	4	745	70	9
7	Vadodara	19	6001	3875	65
	Total	94	38014	17,859	47

Source: *Field work, 2012*

available, the farmers are happy to receive wastewater from Bhuj city for last three years and use it for irrigation. Cultivation in Rabi has started with this water on the lands, which were fallow prior to the receipt of wastewater from Bhuj. Earlier, the wastewater of Bhuj was disposed in two ponds within the city limits. As the sewage generation grew, the capacities of these ponds were found to be insufficient. Thus, sewage started getting passed to the Khari River. Khariwas a dry river and had flowing water only during intense monsoons. Now, it has perennial flowing sewage water. It is interesting to note that the sowing of crops in Nagor village is dependent on water supply to Bhuj. If there is a cut in water supply, then crops requiring less water are cultivated.

Ruva village on the periphery of Bhavnagar city also has only saline groundwater as the source for irrigation. The farmers there have been irrigating their land with wastewater since last 70 years ever since the inception of first STP of Gujarat in Bhavnagar city.

5. Reliability of supply: Chitrasar, Ambaliyara and Sathal and few other villages near Ahmedabad having canal water coming from Fatehpura canal. But, the supplies from it are limited and not available in critical period of irrigation. As the farmers also have access to wastewater, they use it for irrigating their crops.
6. Nutrient value: The wastewater for irrigation is preferred due to its nutrient value. This was found in the villages near Gandhinagar, which use wastewater for irrigation despite the availability of groundwater and Narmada canal water (drawn illegally only in those instances where wastewater is far from the fields) mainly due to the presence of nutrients in it. In the villages near Rajkot also, wastewater is preferred over groundwater for its nutrient value.

Table 3 Receipts from agricultural produce irrigated with in peripheral villages of major cities of Gujarat

Sr. No.	Crop	Receipts per ha of produce (in Rs. '1000)	Expenses per Ha (in Rs. '1000)	Yield in Quintal/ Ha	Average Yield In Freshwater Irrigated Produce Quintal/Ha	Period
1	Alfa Alfa sown in kharif	187	60	600	300	9 Months
2	Rabi to Summer Alfa Alfa	112	30	400	250	6 Months
3	Kharif Juwar Fodder	100	25	1200	800	3.5 Months
4	Rabi Juwar/Maize Fodder	93	15	1000	500	3.5 Months
5	Bottle Gourd (Lauki/Dudhi)	152	30	500	300	12 Months
6	Summer Green Leafy Vagetable (Tandaliya)	130	30	130	---	3 Months
7	Mint	450	120	250	---	12 Months
8	Rose	140	120	---	---	12 Months
9	Kharif Cauli flower	100	20	250	100	2 Months
10	Rabi Cauli Flower	100	30	250	100	2.5 to 3 Months
11	BT Cotton	210	80	30	20	12 Months
12	Rabi Wheat	112	25	40	25	3 Months
13	Castor	117	40	15	8	8 Months
14	Kharif Groundnut	91	25	25	20	4 Months
15	Kahrif Paddy	122	30	40	25	3 Months
16	Summer Groundnut	110	40	22	---	4 Months
17	Summer Paddy	142	40	40	25	3 Months

Source:*Field work, 2012*

Evidences Reinforcing Significance Of Wastewater Irrigation For Farmers

1. During the field visits, it was found that the yield in the wastewater irrigated fields located within the city of Ahmedabad and Rajkot is far higher than for crops produced with freshwater irrigation due to its high nutrient values. Some receipts from these yields are shown below in Table 3. This is mainly based on discussions with two groups of members of co-operatives in the vicinity of Ahmedabad and Rajkot cities using wastewater for irrigation. The expenses incurred for labour intensive crops like alfa-alfa, BT cotton and paddy are about 40 per cent of the receipts. The expenses mentioned do not account for family labour and land rent. However, high value crops like flowers and vegetables have profitability about 75 percent of the receipts. There is lesser risk with these crops, as market fluctuations largely do not impact these crops, which are required by the residents of the city on a daily basis.
2. The villages of Kutch such as Anandpar (Yaksh), Mota Dhavda and Snayara have opted for wastewater irrigation for its nutrient value despite having groundwater available to them.
3. Jaspar village on the west of SG Highway Gandhinagar convinced the Gandhinagar Municipal Corporation to retain the pipeline with a dead end to enable them to continue farming using wastewater.
4. A 2.5 km of canal was constructed by 'Miroli Piyat Sahakari Mandali' in 2006 in Miroli village near Ahmedabad at a cost of Rs. 34 lakhs[3] borne by the farmers to bring wastewater from Sabarmati River.
5. Farmers in Bedi village of Rajkot claim that the yield of wheat grown using wastewater is almost double of the yield of wheat grown using other sources of irrigation in Gujarat. This is based on anecdotal accounts of the farmers, with whom group discussions were conducted. The average yields reported by farmers of this village in group discussions were 80 quintal per hectare. With freshwater irrigation, the average 'good' yields are from Junagadh district, which is about 45 quintal per hectare.

Agricultural receipts and net profit with wastewater irrigation

The section below provides the explanation of the Table 4 on receipts and profits emerging from wastewater irrigation.

1. Based on the estimation of wastewater use of irrigation in the villages for this study, it was found that Rs. 184.69 crore of receipts are generated annually. Out of this, Rs. 108.65 crore is the cash profit, which amounts

Table 4 Annual agricultural receipts and net profits of wastewater irrigated crop in peripheral villages of major cities of Gujarat

Sr. No.	Cities whose surrounding villages use wastewater for irrigation	Wastewater irrigated gross area (in ha)	Agriculture receipts (in Rs. crores)	Cash profit (in Rs. crores)	Percentage of net profit
1	Ahmedabad	13346	83.7	50.77	61
2	Bhavnagar	293	1.8	1.24	69
3	Bhuj	371	20.7	6.3	30
4	Gandhinagar	1834	8.79	5.62	64
5	Rajkot	5453	35.3	25	71
6	Surat	146	1.08	0.85	79
7	Vadodara	5748	33.32	18.78	56
	Total	27191	184.69	108.56	59

Source: *Field work, 2012*

[3]One lakh = 0.1 million
[4]One crore = 10 million

to 59 percent. It is to be mentioned here that the cost of renting the land and family labor have not been accounted for in this study.

2. The cash profit is substantial as high value crop like vegetables and flowers can be grown and supplied to the cities almost everyday. The transportation cost is minimal as these areas are very near the city centers.
3. The peripheral villages of Rajkot and Bhavnagar maximize on profits as they are using wastewater for irrigation since many years. They recognize the amount and quality of the nutrients present in the wastewater and make proper application. There is a risk of wastewater stagnation in the scenario of its availability in abundance due to over irrigation. This can damage the crops if the soil is not well drained. However, these villages have well drained soils and hence, crop growth is good. This is especially true for BT cotton.
4. The villages near Surat show maximum profits amongst all other villages in the vicinity of other cities due to sugarcane farming. Moreover, the paddy productivity is very high in this area as compared to paddy productivity in villages near Ahmedabad and Gandhinagar fetching farmers' higher profits. Summer paddy is cultivated in some of the villages, which has higher profitability.
5. In the villages near Ahmedabad and Vadodara, the discharged sewage is contaminated with industrial effluents, which reduces the yield. Therefore, this mixed wastewater is assumed to be lower in nutrients. Also, both Ahmedabad and Vadodara are highly industrialized and hence, labor availability is very limited. This causes a spike in labor costs. In addition, the soil productivity of Vaododara is poorer that has a direct bearing on the cash profits.
6. It is only the second year that most of the villages of Gandhinagar are using wastewater. They still apply fertilizers. Over the years, it is expected that their profit margins would increase further with reduced application of fertilizers.
7. The farmers of Nagor village near Bhuj city have to lift wastewater from Khari River, which is deep. The wastewater is carried upto 5 km. There are no electrical connections for pumping this water and diesel pumps are used which results in high-energy costs. This is the only area where diesel pumps of 16 hp and 20 hp are commonly used by individual farmers.

Salient features of cropping patterns

The cropping patterns in almost all the villages using wastewater exhibit that the land use is maximized for cropping throughout the year with assured supply of it for irrigation. The farms are kept fallow only for a small period to enable drying up and preparation for sowing in monsoon. The ratio of net area irrigated to gross area irrigated with wastewater ranges from 1.4 to 2.4, indicating that the fields are at least sown more than once and sometimes three times. In addition, the crop density especially, for fodder crops increases when irrigated with wastewater.

In absence of chilling facilities and cold storages, high value crops like vegetable, flowers and milk must be produced as close to the consumers as possible. Therefore, the peri-urban areas of the cities are ideal for producing such crops. The distance to reach the markets also reduces considerably for the crops grown in these areas. Hence, these areas are very important producers and suppliers for daily needs of the adjoining cities. Further, fodder cultivation and thus milk production is suited to wastewater irrigation as the fodder crops are more tolerant to cosmetic and other chemicals of the domestic sewage. It is observed that the areas near the cities have seen proliferation of farms growing fodder, flowers and vegetables for fulfilling the need of the cities. As one goes further, other crops like BT cotton, castor, groundnut, paddy and wheat are grown.

Conclusions

The key factors driving increasing use of wastewater are three fold.

First set of driving factors is based on limited availability of freshwater. There is no access to canal water; groundwater is saline; water table has gone very deep and/or diesel costs are too high.

The second, and more recent driver of wastewater irrigation expansion is rapid urbanization which has resulted in competition between irrigation needs and municipal demand with priority being given to the later. There is ever-growing sewage generation and its use for irrigation turns out to be a convenient way for cities to dispose off this otherwise unmanageable sewage.

The third set of driving factors for expansion in wastewater irrigation is related to farmers' convictions. Many farmers irrigate with wastewater despite having the

option of freshwater irrigation because they are convinced that wastewater is: (a) more reliable and accessible throughout the year; (b) cheaper to lift; and/or (c) more profitable because of its nutrient value leading to higher yields and savings in fertilizer input costs.

Farmers' Suggestions for Wastewater Irrigation

1. As in the city of Rajkot and in villages of Kutch, it is felt that it is often cheaper and more reliable for farmers to meet non-potable water demand like irrigation water demand through sewage treated water than by pumping freshwater from deep aquifers. Even if the cost differentials exist, this may be still preferred to preserve freshwater for meeting potable water demands. Since municipal bodies are required to treat their sewage anyway, selling treated sewage at full or partial treatment costs can help them realize a sizeable revenue stream. This is particularly important when in Gujarat many ULBs are in the process of installing treatment facilities. 74 cities have approved underground drainage network for their respective cities and once the network is done, the treatment facilities proposed will be taken up soon. The parameter of the use of disposal for these proposals may be considered appropriately to overcome one of the major problems with wastewater treatment methods that they do not have direct economic returns.
2. A critical factor in wastewater irrigation is that untreated and partially treated water is being applied to land. Its impact needs to be studied especially, on soil quality and groundwater aquifers, where it gets leached. The small holders of land did not have any aversion towards using sewage water for irrigation. They claimed that it does not cause any harm to soil quality as the flow in river naturally cleanses the water and in addition, it is rich in nutrients. On the other hand, large landowners felt that the use of this water may harden the soils due to detergent and other chemicals present in it. They preferred mixing it with freshwater from ground prior to its application. Most of the large landowners did not farm themselves but gave it for sharecropping. Sharecroppers used wastewater without any hesitation.
3. The other limitation of wastewater use in irrigation is that the wastewater treatment plants are located in land, where irrigation is not needed. This calls for some decentralization and a careful site specific assessment for use of wastewater for productive purposes as done in the case of Gandhinagar wastewater disposal.
4. The amount and quality of the nutrients present in the wastewater have to be ascertained by technical experts and farmers in order to guarantee proper application. It needs to be discussed by experts, farmers and extension support may be required for making this knowledge available.
5. Currently, conventional irrigation techniques of either flood or furrow irrigation are used to irrigate with wastewater. Micro irrigation technology is not suitable for using wastewater. Hence, suitable irrigation technique needs to be explored. Similarly, it is observed that in most places, the cropping patterns have not changed much except that they have become dense and intense. Water and nutrient availability calls for suitable changes in cropping patterns too and a need for further exploration.

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Figure 1 Villages Around City of Ahmedabad Using Wastewater for Irrigation

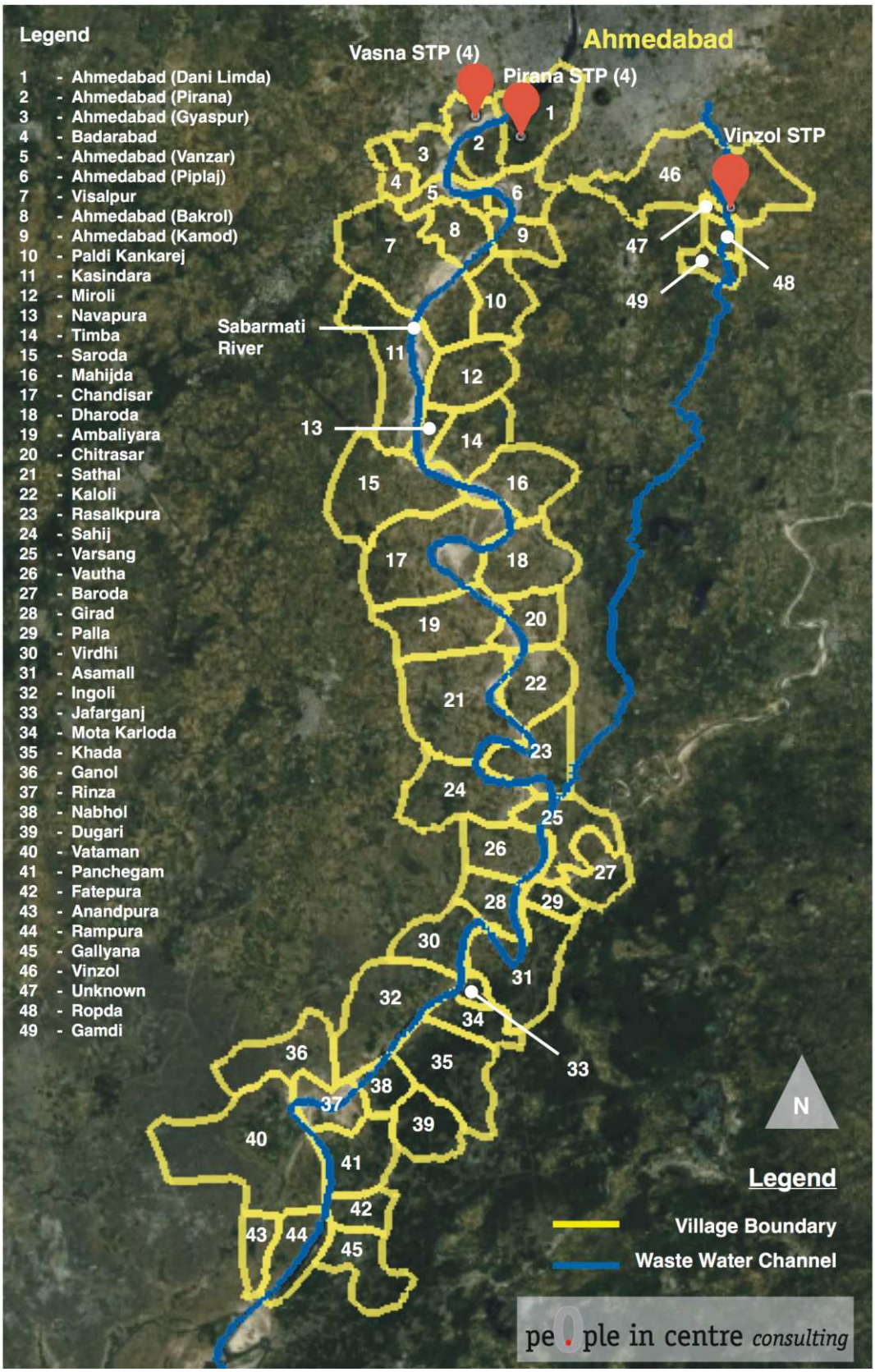


Figure 2 Villages Around City of Bhavnagar Using Wastewater for Irrigation

Figure 3 Villages Around City of Bhuj Using Wastewater for Irrigation

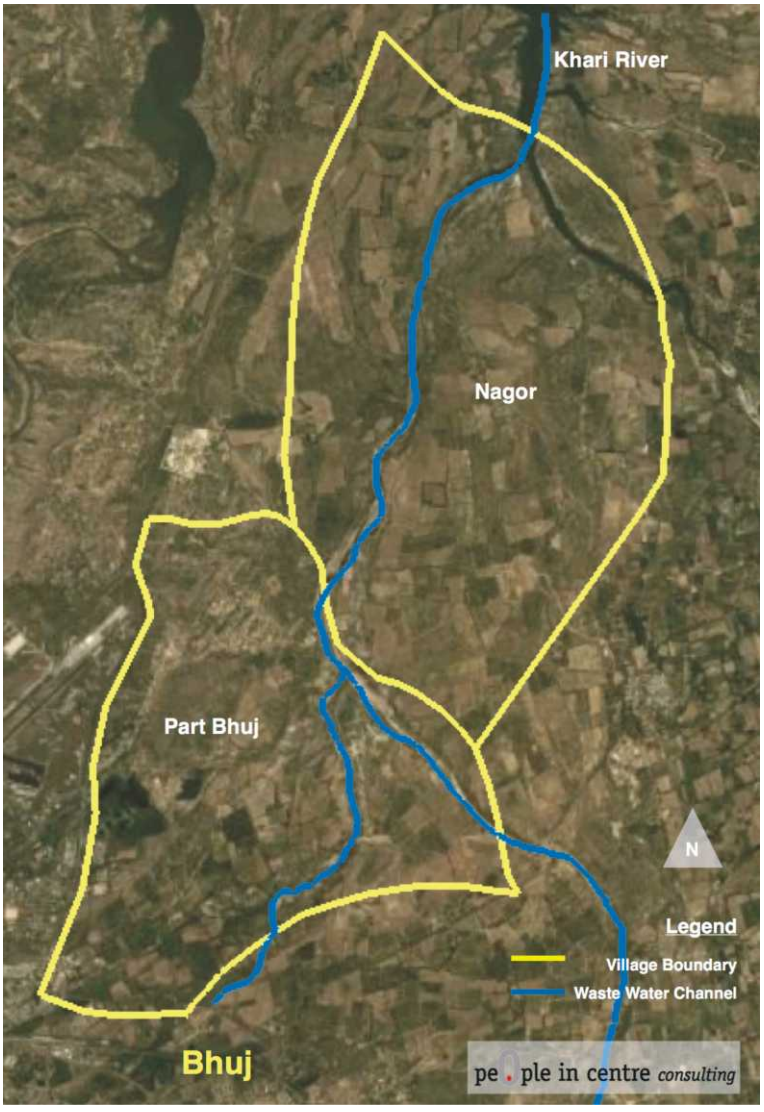


Figure 4 Villages Around City of Gandhinagar Using Wastewater for Irrigation

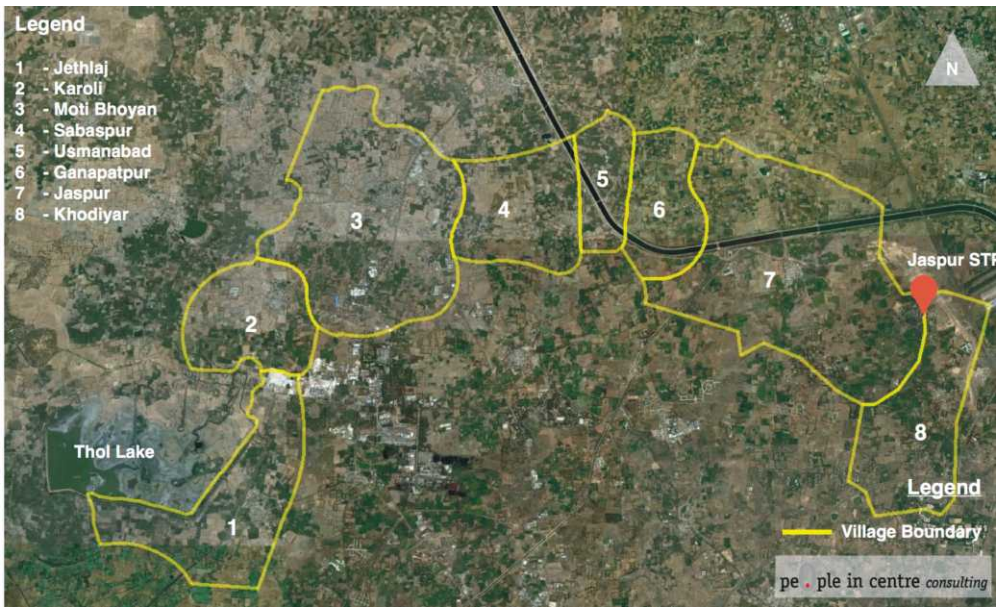


Figure 5 Villages Around City of Rajkot Using Wastewater for Irrigation

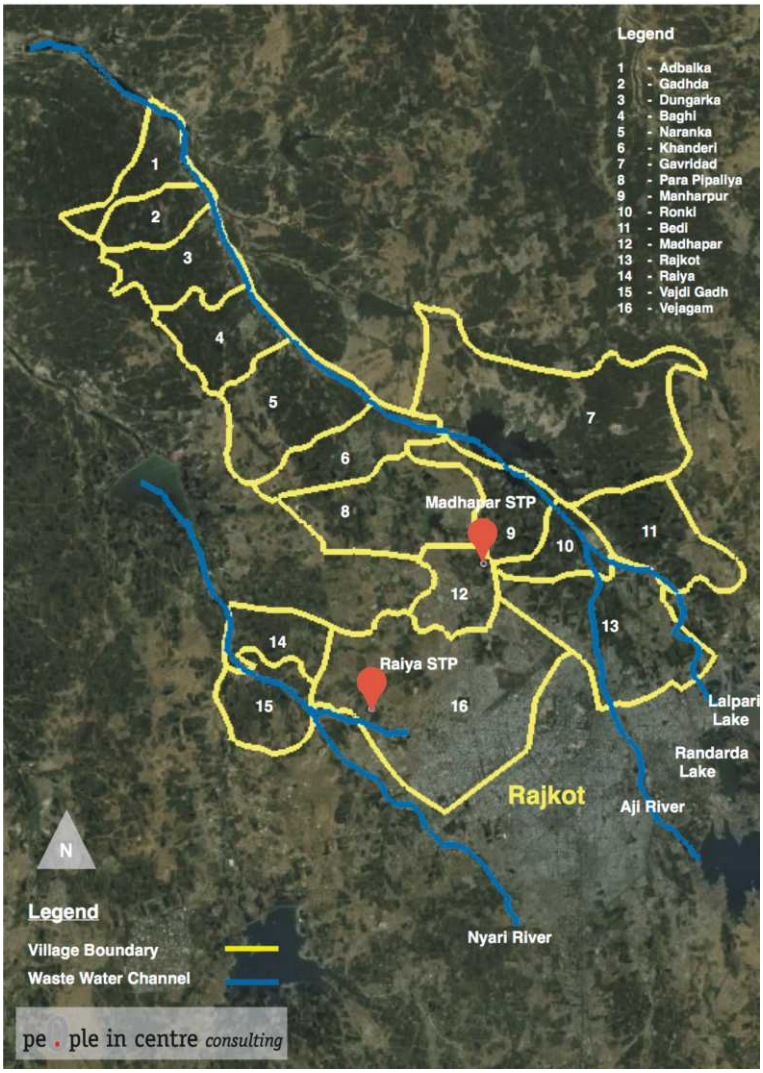


Figure 6 Villages Around City of Surat Using Wastewater for Irrigation

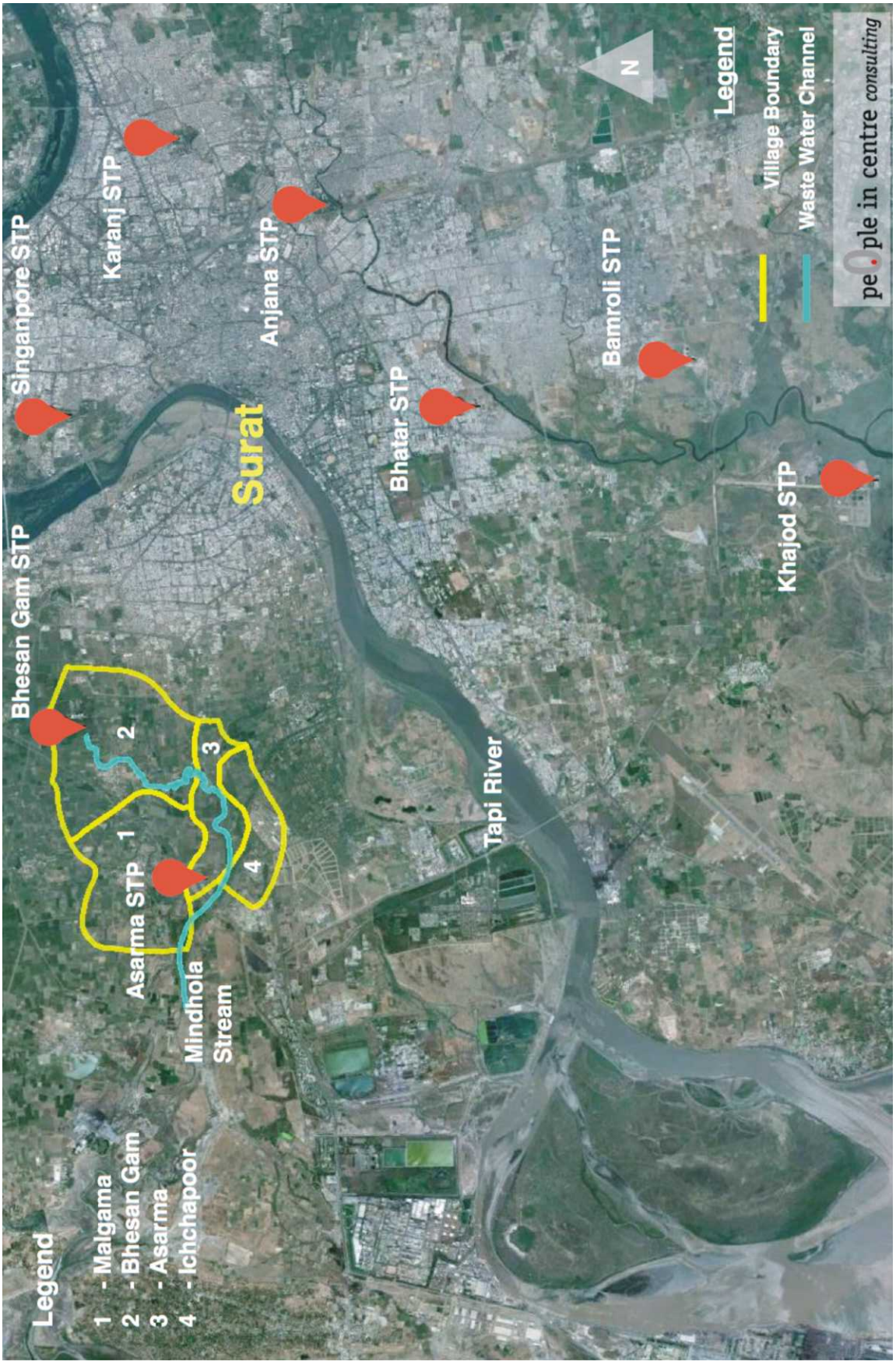
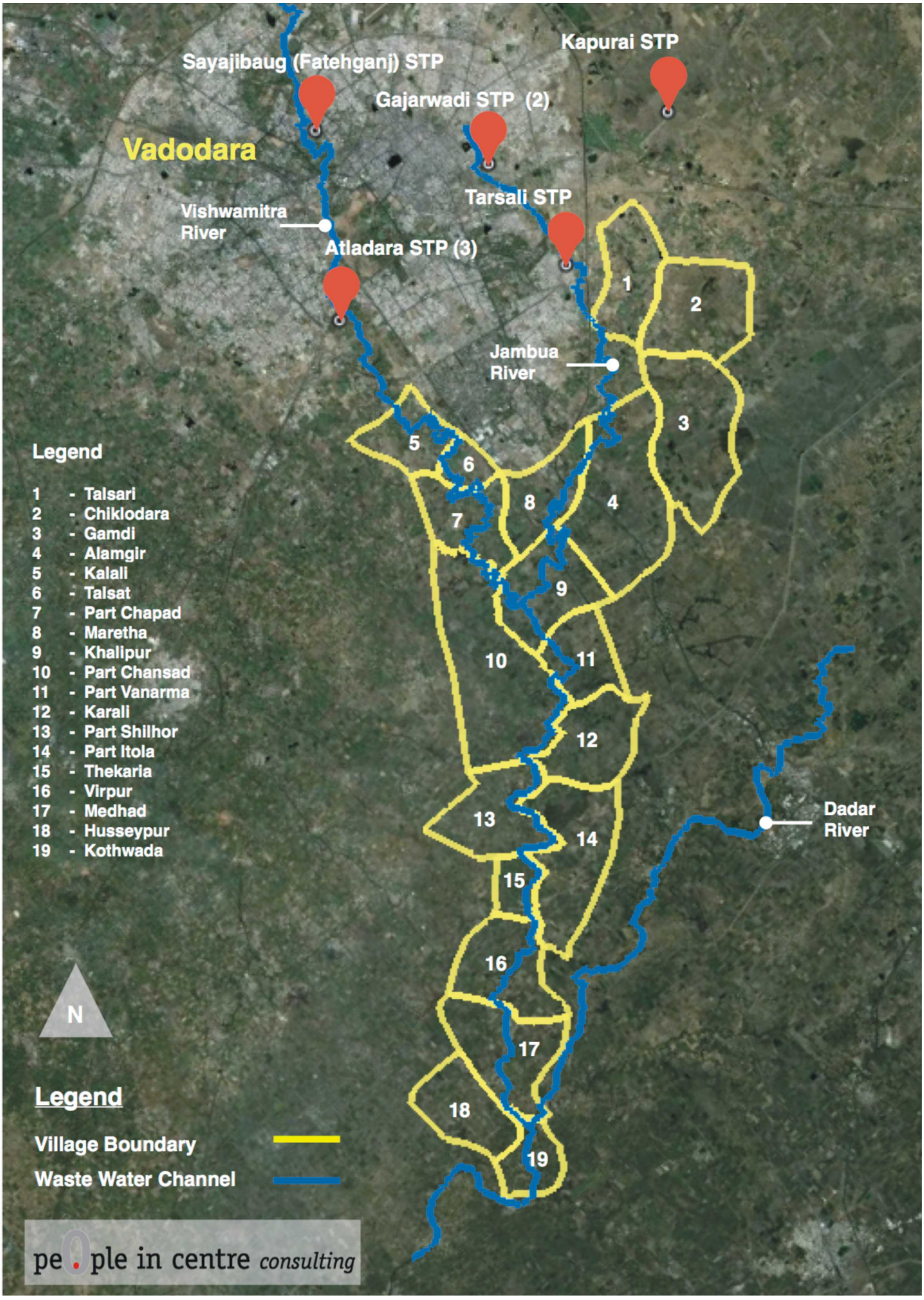
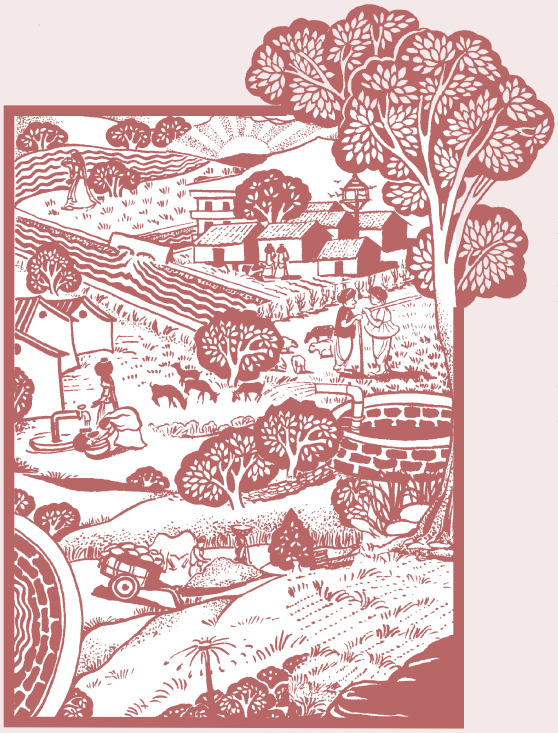


Figure 7 Villages Around City of Vadodara Using Wastewater for Irrigation





About the IWMI-Tata Program and Water Policy Highlights

The IWMI-Tata Water Policy Program (ITP) was launched in 2000 as a co-equal partnership between the International Water Management Institute (IWMI), Colombo and Sir Ratan Tata Trust (SRTT), Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Through this program, IWMI collaborates with a range of partners across India to identify, analyze and document relevant water-management approaches and current practices. These practices are assessed and synthesized for maximum policy impact in the series on Water Policy Highlights and IWMI-Tata Comments.

Water Policy Highlights are pre-publication discussion papers developed primarily as the basis for discussion during ITP's Annual Partners' Meet. The research underlying these Highlights was funded with support from IWMI, Colombo and SRTT, Mumbai. However, the Highlights are not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or either of its funding partners.

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